Lower Colorado River Multi-Species Conservation Program

Balancing Resource Use and Conservation

Yellow-billed Cuckoo Distribution, Abundance, and Habitat Use on the Lower Colorado River and Tributaries, 2010 Annual Report

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August 2011

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Lower Colorado River Multi-Species Conservation Program

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Executive Summary

This report details the third year of a five-year project to assess yellow-billed cuckoo (*Coccyzus americanus*) populations within the lower Colorado River Basin. Western cuckoo numbers declined rapidly in the mid-twentieth century due to extensive loss of available habitat. The Lower Colorado River Multi-Species Conservation Program (LCR MSCP) was created to assist in the recovery of several threatened and near-threatened populations, including cuckoos, by creating, protecting, and maintaining wildlife habitat within the lower Colorado River Basin. Cuckoos are one of twenty-six Focal Species included in the MSCP, which aims to create over 3,278 hectares of habitat over a fifty-year period. Our project objectives are to (1) conduct comprehensive, repeatable yellow-billed cuckoo surveys in all potentially suitable habitat types within the MSCP boundary, (2) determine breeding habitat selection and preferences in the study area, and (3) evaluate the effectiveness of the current breeding season survey methodology, refining it to use over the term of the MSCP.

In 2010 we surveyed forty-six sites (Chapter 1), resulting in 272 detections. We estimated these to represent a maximum of 56 potential breeding pairs (twenty-two confirmed), a 30% increase from our 2008 and 2009 maximum estimates. Lower Colorado River restoration sites continued to increase in detections, occupancy, and confirmed breeding. Survey detection probability averaged 58.4% but varied over the season, and was highest between June and July (78%) and lowest in August (27%).

During the 2010 season we resighted four cuckoos banded in 2009 (2010 resight rate 31%), which added two natal dispersal and two breeding dispersal records to our first

cuckoo natal dispersal record in 2009. We also captured twenty-seven adults, radio-tracking twenty-three of them (Chapter 2). Many cuckoos were transient, passing though the restoration sites early in the season, and spending an average of about eight days at a site before departing. The average home range estimate of 19 birds radio-tracked at MSCP restoration sites was 21.7 ±10.4 ha.

We found 17 nests in the study area in 2010, over twice the number of nests found in 2009. Seven nests were at Bill Williams River National Wildlife Refuge (NWR), six at Cibola Valley Conservation Area (CVCA), two at Palo Verde Ecological Reserve (PVER), and one each at Havasu NWR and Cibola NWR. We also confirmed breeding for the first time at Havasu NWR (Beal Restoration), PVER Phase 3, CVCA Phase 2, and Cibola NWR Nature Trail. Breeding was confirmed again at Bill Williams River NWR, PVER Phase 2, and CVCA Phase 1 (Chapter 3).

We analyzed vegetation data collected for this project from 2006-2010. Our results showed that yellow-billed cuckoos prefer large patches of habitat with high densities of native large and small trees. We also found that small native trees and dense canopy cover were important to cuckoo nest site selection (Chapter 4). Increased tamarisk (*Tamarix* spp.) density was negatively associated with cuckoo occupancy and nest placement. Ground cover was also important in several models, which may be an indirect consequence of canopy cover or increased arthropod prey abundance. Additionally, microclimate (temperature and relative humidity) data loggers were placed at 139 locations during the 2010 breeding season. We found nest locations to be cooler and more humid than available habitat, which concurs with what we have found in previous years (Chapter 5).

We continued in 2010 to explore the relationship between cicadas and yellow-billed cuckoos, again finding a close coupling of cicada emergence with peak cuckoo nesting and fledging (Chapter 6). To explore the paucity of cicadas at restoration sites, we added an in-depth analysis of cicada abundance and environmental factors (Chapter 7), finding strong positive correlations between cicadas and native large tree density, and strong negative correlations between cicadas and soil moisture and marsh vegetation. These results may have implications for irrigation regimes and fine scale topography at restoration sites. Our main results and management recommendations are summarized in Chapter 8.

Introduction and Project Background

Lower Colorado River Multi-Species Conservation Program

The Lower Colorado River Multi-Species Conservation Program (LCR MSCP) is a coordinated, comprehensive, long-term, multi-agency effort, with goals including habitat conservation, recovering threatened and endangered species, and preventing the listing of additional species (LCR MSCP 2004a). The MSCP covers areas within the historical floodplain of the Colorado River from Lake Mead to the United States-Mexico Southerly International Boundary, a distance of about 400 river miles (LCR MSCP 2004a). Developed between 1996 and early 2005, the LCR MSCP includes the creation of more than 3,278 hectares (ha) (8,100 acres, ac) of riparian, marsh, and backwater habitat for six listed species and 21 other species native to the lower Colorado River, including at least 1,639 ha (4,050 ac) of habitat for the riparian obligate yellow-billed cuckoo (LCR MSCP 2004a).

Yellow-billed Cuckoo Biology and History

Western cuckoo populations have declined dramatically over the last 100 years due to extensive loss of available habitat (Gaines and Laymon 1984, Halterman et al. 2001, Hughes 1999, Laymon and Halterman 1987). Mearns (1907) estimated approximately 160,000-200,000 ha (400,000-500,000 ac) of densely wooded alluvial floodplain between Fort Mohave and Yuma (Grinnell 1914). By 1980, only 32,678 ha (80,749 ac) of riparian woodland remained in the lower Colorado River Valley (Hunter et al. 1988). Currently, approximately 50,990 ha (126,000 ac) of woody riparian vegetation is estimated to occur within the LCR MSCP boundary, of which 18% is native (LCR MSCP 2004b).

The taxonomic status of eastern and western cuckoo populations is unclear; some researchers support two distinct subspecies (Ridgeway 1887, Franzreb and Laymon 1993,

Pruett et al. 2001), while others find no basis for separation (Banks 1988, Fleischer 2001, Farrell 2006). In 2001 the United States Fish and Wildlife Service (USFWS) determined that western yellow-billed cuckoos represent a Distinct Population Segment (DPS), and they became a candidate for listing (USFWS 2001). In 2002 the listing was determined to be warranted but precluded by higher priority listing actions (due to resource limitations) (USFWS 2002). The yellow-billed cuckoo is listed as endangered in California (CDFG 1978), a species of special concern in Arizona (AGFD 1988), and a sensitive species on US Forest Service lands within Arizona and New Mexico (USDA 1988).

Cuckoos begin arriving in Arizona and California in late May (Bent 1940, Hughes 1999). Nesting activities usually take place between late June and late July, but can begin as early as late May and continue to late September (Hughes 1999). Nests take one to two days to build, and are often at the edge of openings (Hamilton and Hamilton 1965). Incubation begins as soon as the first egg is laid, and lasts 9-11 days (Hughes 1999). Clutch size averages just over two eggs and may be as high as four (Laymon et al. 1997). Young hatch asynchronously and are fed large food items such as katydids, tree frogs, large caterpillars, lizards, mantids, and cicadas (Laymon et al. 1997, Halterman 2009). After fledging at five to seven days, young may be dependent on adults for at least three weeks (Laymon and Halterman 1985).

Suitable breeding habitat within the range of western cuckoos primarily consists of riparian forests and associated bottomlands dominated by native vegetation. The two primary nest tree species are Goodding's willow (*Salix gooddingii*) and Fremont cottonwood (*Populus fremontii*). Other species are also used, including mesquite (*Prosopis spp.*) and tamarisk (Halterman et al. 2001).

While variations exist in plant species composition and structure across their western range, cuckoo presence has been shown to be correlated with patch size (Halterman 1991). In a meta-analysis of edge-effect studies, cuckoos demonstrated an avoidance of small patches (Parker et al. 2005). Cuckoos were estimated to require 10-40 ha of habitat on the Sacramento River in California (Gaines 1974, Laymon 1980). Mean home range (95% kernel density) estimates of radio-tracked cuckoos averaged 38.6 ha on the San Pedro River in Arizona (n=23, Halterman 2009), 56.3 ha on the Rio Grande, NM (n=10, Sechrist et al. 2009), and 21.6 ha on LCR MSCP restoration sites (n=6, McNeil et al. 2010).

Chapter 1. SURVEYS, SITE OCCUPANCY, AND DETECTION PROBABILITY

Introduction

Long-term monitoring programs focus on the status and trends of species distribution, and can effectively document a species' annual state and changes in their condition through time (LaRoe et. al. 1995). Through repeated surveys, the annual status of populations can be assessed by examining within-season distribution, occupancy, and abundance patterns, both spatial and temporal, across the landscape. The analysis of multi-year datasets can reveal emergent trends in a number of population parameters, including fluctuations and response to environmental changes such as habitat restoration or creation. Western yellow-billed cuckoos have a limited distribution, significantly diminished from their historical extent (Gaines and Laymon 1984, Laymon and Halterman 1987, Hughes 1999, Halterman et al. 2001). The best conservation practices for cuckoos will involve ongoing status and trend assessments for their adaptive management. These

assessments enable us to meet our research goals and determine the success of LCR MSCP restoration efforts. They may also provide an early warning of pending problems which then allows for informed and preemptive remedial actions. Timely actions are often more successful than responses delayed until problems are critical, such as when a species becomes endangered (LaRoe et al. 1995).

In 2010, we continued long-term monitoring of yellow-billed cuckoos within the LCR MSCP boundary. Through repeated surveys and follow-up efforts, we determined site occupancy and estimated the number of breeding pairs in the study area. The analyses are predominantly stratified by site type, natural vs. restoration, to maximize our power to detect cuckoo responses to restoration. While surveys designed to monitor a species can uncover patterns of distribution, the mechanisms behind these patterns are often better discerned through supplemental research (such as nest observations, radio telemetry, and habitat analyses) described in Chapters 2-6 of this report.

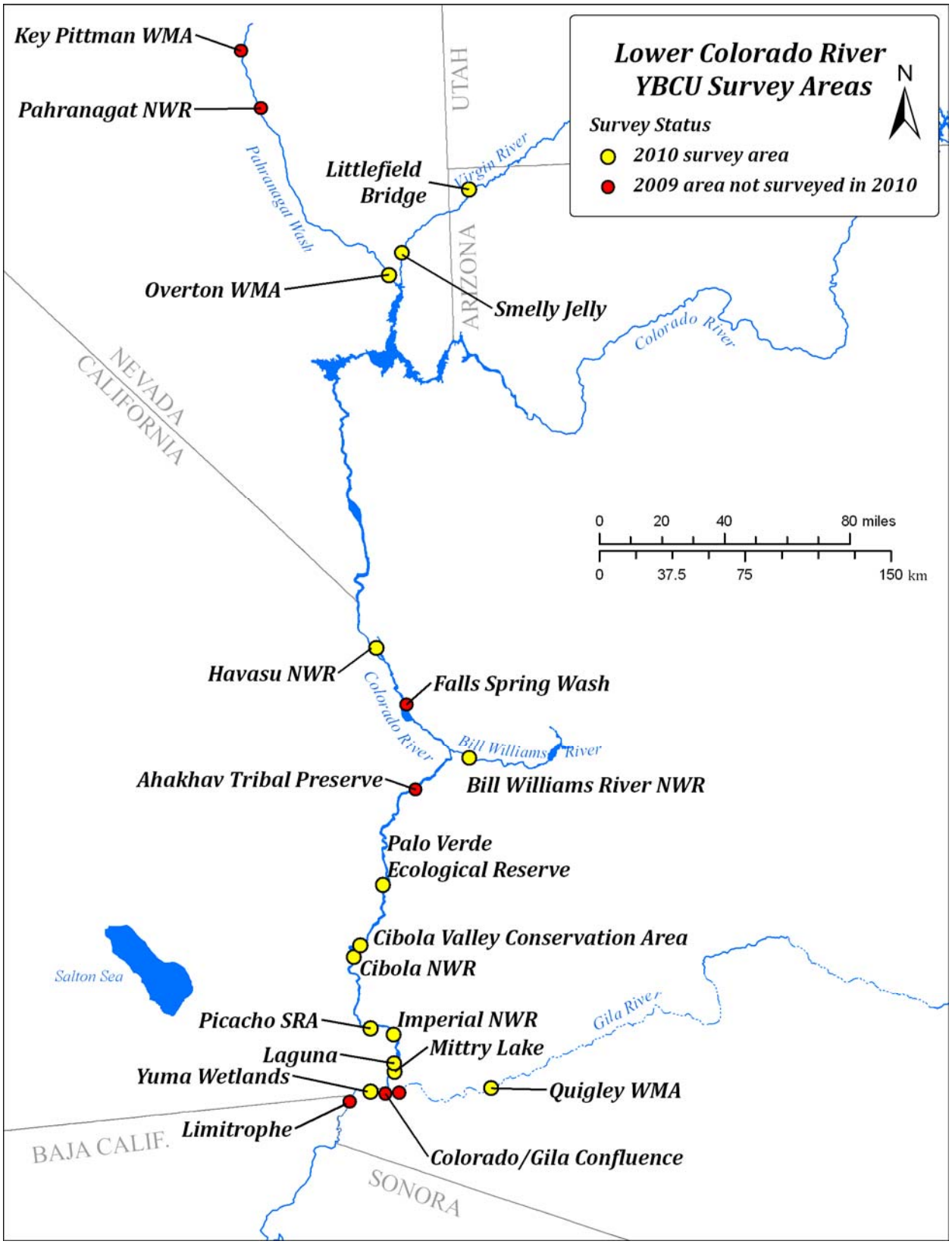
Methods

Study Area and Survey Site Selection

We conducted yellow-billed cuckoo surveys within potentially suitable habitat along a 400 river-mile stretch of the LCR and tributaries. A habitat patch was defined as an area of potentially suitable habitat 2 ha (4.9 ac) or greater in extent, that was separated from another patch of potentially suitable habitat by at least 300 meters (m). A survey site was defined as part of a patch, an entire patch, or a collection of patches of potentially suitable habitat treated as one site. Sites were selected based on past cuckoo detections, patch size, plant species composition, and habitat structure. All sites were delineated by walking the boundaries with a GPS unit. Where site boundaries were inaccessible (such as areas of Bill

Williams River National Wildlife Refuge (NWR), boundaries were estimated in ArcGIS 9.3 using geo-referenced 2004 aerial photography. Each site's size (ha) was estimated using ArcGIS 9.3. A description of all sites is presented in Appendix A.

Forty-six sites were surveyed in 2010 (Map 1-1, Table 1-1, Appendix A), twenty-one restoration sites and twenty-five sites classified as natural. We added four new survey sites, and dropped eighteen sites previously surveyed in 2009 primarily due to lack of sufficient habitat, and also to focus our efforts at more suitable sites. Subsets of dropped sites will be surveyed again in 2011 and 2012.



Map 1-1. Lower Colorado River yellow-billed cuckoo study area, 2010.

Table 1-1. Yellow-billed cuckoo surveys sites, LCR 2010.

Site Name	Site Code	Drainage	Geographic region	Size (ha)	Site Type
Littlefield Bridge	LITBR	Virgin	North	19.9	Natural
Smelly Jelly	SMJE	Virgin	North	18.7	Natural
Wilson Pond	OVRWP	Muddy	North	0.7	Natural
Overton Wildlife	OVRW	Muddy	North	10.1	Natural
Topock Platform	HAVTPR	Lower Colorado	North	9.3	Restored
Pintail Slough	HAVPS	Lower Colorado	North	11.7	Restored
North Dike	HAVND	Lower Colorado	North	5.1	Restored
Havasu Levee Road	HAVLR	Lower Colorado	North	3.2	Natural
Lost Lake	HAVLL	Lower Colorado	North	4.0	Natural
Glory Hole	HAVGH	Lower Colorado	North	13.2	Natural
Beal Restoration	HAVBR	Lower Colorado	North	21.3	Restored
Cave Wash	BWCW	Bill Williams	Central	88.1	Natural
Cottonwood Patch	BWCP	Bill Williams	Central	38.1	Natural
Honeycomb Bend	BWHB	Bill Williams	Central	29.6	Natural
Mineral Wash	BWMW	Bill Williams	Central	49.8	Natural
Esquerra Ranch	BWER	Bill Williams	Central	40.2	Natural
Cougar Point	BWPT	Bill Williams	Central	43.1	Natural
Gibraltar Rock	BWGR	Bill Williams	Central	66.5	Natural
Kohen Ranch	BWKR	Bill Williams	Central	37.1	Natural
Sandy Wash	BWSW	Bill Williams	Central	50.9	Natural
Fox Wash	BWFW	Bill Williams	Central	62.5	Natural
Borrow Pit	BWBP	Bill Williams	Central	33.6	Natural
Cross River	BWCR	Bill Williams	Central	30.2	Natural
Mosquito Flats	BWMF	Bill Williams	Central	37.1	Natural
North Burn	BWNB	Bill Williams	Central	30.0	Natural
Middle Delta	BWMD	Bill Williams	Central	25.2	Natural
Bill Williams Marsh	BWMA	Bill Williams	Central	19.7	Natural
PVER Phase 1	PVER1	Lower Colorado	Central/Blythe	8.3	Restored
PVER Phase 2	PVER2	Lower Colorado	Central/Blythe	24.2	Restored
PVER Phase 3	PVER3	Lower Colorado	Central/Blythe	19.8	Restored
PVER Phase 4	PVER4	Lower Colorado	Central/Blythe	35.8	Restored
CVCA Phase 1	CVCA1	Lower Colorado	Central/Blythe	34.8	Restored
CVCA Phase 2	CVCA2	Lower Colorado	Central/Blythe	24.7	Restored
CVCA Phase 3	CVCA3	Lower Colorado	Central/Blythe	37.0	Restored
Cibola North	CIBNTH	Lower Colorado	Central/Blythe	8.6	Restored
Cibola Nature Trail	CIBCNT	Lower Colorado	Central/Blythe	62.3	Restored
Cibola Eucalyptus	CIBEUC	Lower Colorado	Central/Blythe	29.4	Restored
Cibola Island South	CIBSTH	Lower Colorado	Central/Blythe	126.8	Restored
Picacho SRA	PICSRA	Lower Colorado	South/Yuma	14.8	Restored
Imperial South	IMPSTH	Lower Colorado	South/Yuma	13.0	Restored
Laguna 2	LAG2	Lower Colorado	South/Yuma	3.9	Natural
Laguna 3	LAG3	Lower Colorado	South/Yuma	3.8	Natural
Mittry Lake/Pratt	MLPR	Lower Colorado	South/Yuma	14.0	Restored
Quigley WMA	GRQP	Gila	South/Yuma	10.6	Restored
Yuma East Wetlands	YUEW	Lower Colorado	South/Yuma	9.0	Restored
Yuma West Wetlands	YUWW	Lower Colorado	South/Yuma	24.3	Restored

Surveys

We conducted yellow-billed cuckoo surveys following Halterman et al. (2008) once per survey period (Table 1-2) at each site, spaced 12 to 20 days apart. Four surveys were completed at most sites. In addition, many sites were surveyed a fifth time to assess late breeding season occupancy and detection probability estimates; some sites were deemed vacant and not surveyed a fifth time. Fifth surveys were conducted at most sites where cuckoos were detected during the fourth survey.

Table 1-2. Survey period dates.

Survey Period	Dates
1	June 15 to June 30
2	July 1 to July 14
3	July 15 to July 31
4	Aug 1 to Aug 14
5	Aug 15 to Aug 31

We surveyed along point transects on foot or by kayak, between sunrise and 10:30, or until temperatures exceeded 40° C (104° F). Each site contained one or more survey transects with survey points spaced 100 m apart, and transects spaced approximately 200 m apart. The point-transects primarily traversed through the habitat patches. However, some transects ran along riparian habitat edges or adjacent roads to take advantage of greater visual detectability from these locations or because the interior of the habitat was inaccessible. Survey points were located using Garmin GPS units. We recorded the location, date, start time, temperature, humidity, cicada abundance, habitat type, and structure at each survey point. Survey information was recorded using standardized forms.

Yellow-billed cuckoos are inherently secretive and call infrequently (Hamilton and Hamilton 1965). To elicit a response from cuckoos and increase our detection rate call-playbacks were used (Johnson et al. 1981, Gaines and Laymon 1984, Halterman et al. 2008). Upon arriving to a survey point, surveyors listened and watched for cuckoos for one minute. If no cuckoos were detected, surveyors used an MP3 player and handheld speaker

to broadcast a five-second yellow-billed cuckoo contact call (the 'kowlp' call) (Hughes 1999) once per minute for five minutes. Five seconds of calling was followed by 55 seconds of active observation and listening. If a cuckoo was detected the point call-playbacks were discontinued immediately and all pertinent data was recorded (see below). Following a detection, surveyors progressed along the point transect 300 m from the cuckoo's estimated location. This was done to avoid additional disturbance and duplicate detections of the same bird. When surveys were conducted by more than one person, if a cuckoo was detected one person went on to complete the survey while another remained and attempted to determine breeding status.

For each detection, the surveyor recorded the true bearing and estimated distance from the surveyor to the cuckoo, time of detection, response type, behavior, vocalizations, vegetation type, presence of other cuckoos, interactions, and the presence and/or color combination of leg bands. Any observed breeding evidence was also recorded, including carrying food or nesting material, copulation, the presence of a juvenile, or a nest.

An individual cuckoo visually observed or heard during a survey was recorded as a survey detection. We counted individual cuckoos detected more than once during a single survey as one survey detection. Cuckoos located >300 m apart during a single survey were counted as separate individuals and therefore separate survey detections. Cuckoos encountered any time other than during a survey were classified as non-survey or incidental detections. Information collected for incidental detections was the same as that collected for survey detections.

We entered survey data into an MS Access 2007 database. Locations and details of all survey points were incorporated into an ESRI ArcGIS 9.3 geodatabase, using DNRGarmin v5.03 (Minnesota Department of Natural Resources 2001), MS Access, and ArcGIS 9.3 software. Estimated distance/bearing lines were stored in the geodatabase and overlaid with geo-referenced 2004 aerial photographs of the LCR. We created survey detection maps for all sites, with the distance/bearing of cuckoo detections represented by an arrow. We used these maps to assess survey detections and update the number of individuals detected during a survey if necessary (e.g. if two separate detections indicated the same area, they were changed to a single detection). We projected all geospatial data to the North American Datum of 1983 (NAD83), Universal Transverse Mercator (UTM) Zone 11 projection.

Breeding Status

Yellow-billed cuckoos' furtive nature and infrequent calling coupled with large home ranges and short nesting period make them challenging to study (Laymon et al. 1997, Hamilton and Hamilton 1965, Halterman 2009). When surveyors are seen, cuckoos often display avoidance behavior or avoid moving (Hamilton and Hamilton 1965, SSRS personal observations). To add to these difficulties, cuckoos are on their breeding grounds for only a short time. Compared to other North American breeding migrants, cuckoos arrive relatively late (most in June). They have the shortest nesting cycle among birds, a minimum of 16 days between egg and fledging (Payne 2005). Most birds begin their fall migration south by late August (Bent 1940, Hughes 1999). On top of these difficulties, telemetry observations from 2009 and 2010 indicate that many of the cuckoos we detect are transitory and do not stay long at our sites (McNeil et al. 2010, Chapter 2). Taken

together these behaviors make monitoring cuckoos and assessing their breeding status difficult. Overall, relatively few cuckoo nests are found and as a result, we have developed alternate methods for estimating cuckoo breeding status.

Observations of transient birds indicate that detections from only one survey period may not be a good indicator of site occupancy; cuckoos may use a site one survey period, but not the next. Therefore, we deemed sites occupied if cuckoo detections occurred in any two survey periods (and at least 12 days apart). All detections were assessed by location (using ArcGIS 9.3), observed behaviors, and detection dates. These detections were then used to categorize breeding probability in each detection area as *possible*, *probable*, or *confirmed*. Two or more detections in an area at least 12 days apart warranted a *possible breeding pair* (POS). POS cuckoos observed carrying food, traveling as a pair, or exchanging vocalizations were considered a *probable breeding pair* (PRB). Breeding was only *confirmed* (COB) when a copulation, stick carry, nest, or fledgling was observed. Estimates of breeding status utilized all detections, including incidental, survey, and follow-up. Follow-up visits included nest searching, mist netting, telemetry, and other site visits. During the field season POS and PRB observations were followed-up whenever possible to confirm their breeding status. Overall, we find these breeding guidelines useful for estimating population size. However, on some occasions extensive follow-up visits on POS and PRB birds yielded no breeding evidence and so exceptions to these guidelines were sometimes made and documented. Using the POS, PRB, and COB classifications, we calculated the minimum and maximum pair estimates. The minimum number of cuckoo pairs is the number of confirmed breeding pairs (the most conservative estimate). The maximum pair estimate is the sum of POS, PRB, and COB breeding pairs. We use the term

"pairs" to indicate the adults associated with a single nest. Cuckoos utilize multiple breeding systems, including polyandry (Halterman 2009), and a breeding pair may be accompanied by a third adult.

Detection Probability and Occupancy

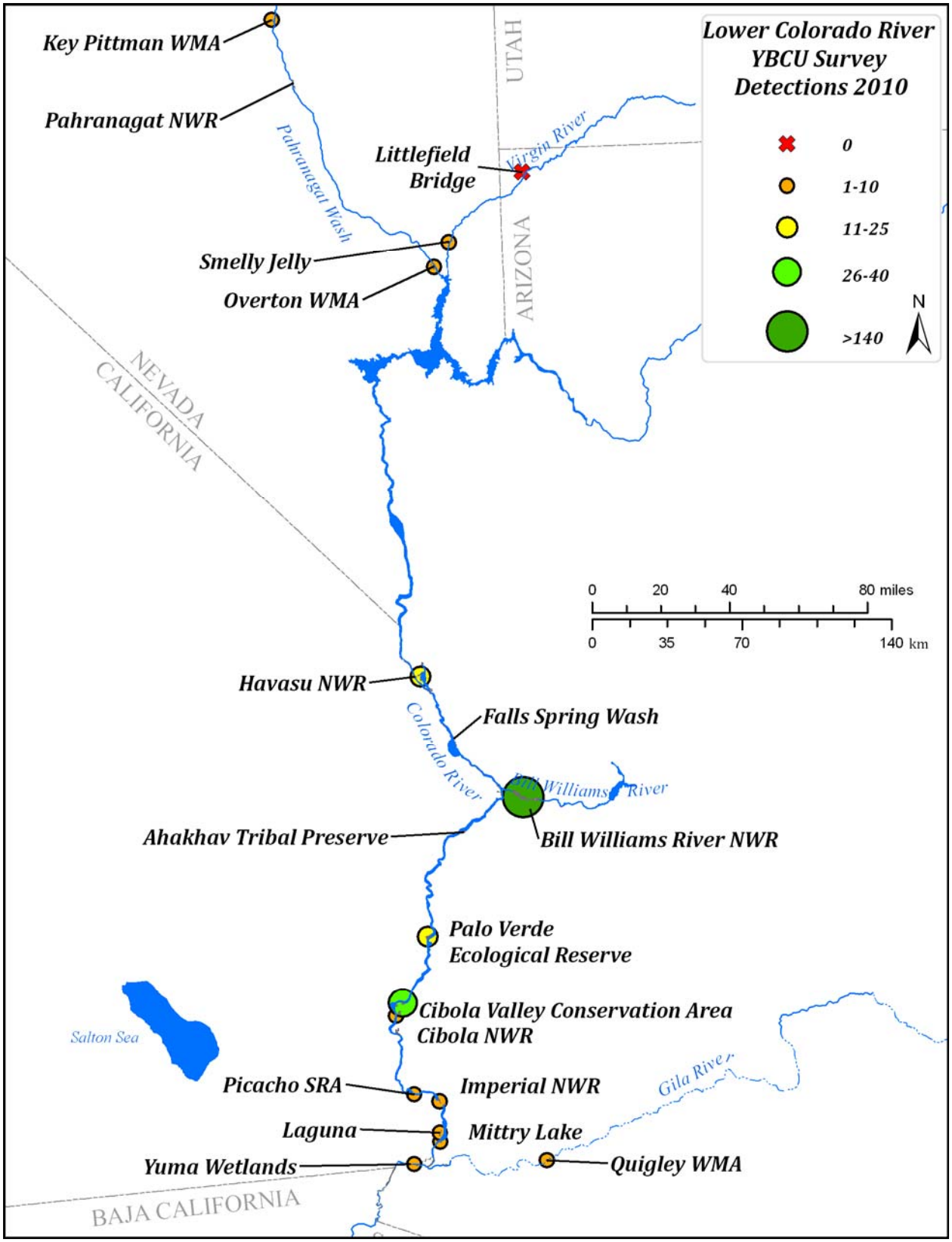
We incorporated detection probability into our occupancy analyses to avoid classifying a site as unoccupied when presented with the possibility that a cuckoo was present, but remained undetected. MacKenzie et al. (2006) illustrates how "naïve occupancy estimates", derived from survey results using only the observed proportion of sites occupied and not incorporating a probability of detection, will often underestimate the true site occupancy. The probability of detecting a species can be estimated from repeated surveys of a site (MacKenzie et al. 2002). Across multiple visits, the repeated or intermittent detection of a species is used to generate a detection probability estimate. This estimate can then be used to calculate a site occupancy probability which accounts for individuals present, but not detected. We calculated detection probability and occupancy estimates using the software program Presence v3.1 (Hines 2006) from the presence or absence of cuckoos recorded on each site survey visit. We calculated detection probability and site occupancy estimates for restoration and natural sites separately to uncover potential differences in detection probability or occupancy between the two site types. We also examined the possibility of latitudinal differences in cuckoo migration timing by stratifying the data by north and south, and calculating detection probabilities for the Bill Williams River NWR and sites further north vs. sites south of the Bill Williams River NWR.

Cuckoos disperse from sites during all survey periods (Chapter 2). This movement indicates that site populations are open and adds uncertainty to the interpretation of

detection probability estimates. Under open conditions, the estimate is a combination of two confounding components: (1) the probability that the species was present in the sampling unit, and (2) the probability that a species was detected, given that it was present (MacKenzie et al. 2002). Furthermore, changes in the detection probability between survey periods may not necessarily reflect a change in cuckoo behavior (e.g. from vociferous one survey period to secretive the next), because there is the possibility that the cuckoo may have left the study site. In closed populations, the detection probability is simply interpreted as the probability that a species was detected given that it was present, and allows for more tangible inferences when temporal changes occur.

Results

Across five survey periods between June 15 and August 31, we conducted 207 surveys at forty-six sites, resulting in 272 detections of yellow-billed cuckoos (Map 1-2, Tables 1-3 to 1-6). The detections per survey period were as follows: first period 69, second period 85, third period 71, fourth period 38, and fifth period 9. Half of all survey detections were at Bill Williams River NWR; the Cibola Valley (CVCA and Cibola NWR) also had a relatively high number of detections.



Map 1-2. Yellow-billed cuckoo survey detections, all survey periods, LCR 2010.

Table 1-3. 2010 LCR YBCU survey detection results and breeding status for sites north of the Bill Williams River NWR.

Site	Site Code	Cuckoos Detected Per Survey Period					Total Survey Detections	Occupied[1]	Possible Breeding [2]	Probable Breeding [3]	Confirmed Breeding [4]	Min Pairs[5]	Max Pairs[6]
		1	2	3	4	5							
Smelly Jelly	SMJE	1[7]	0	0	0		1	0	0	0	0	0	0
Wilson Pond	OVRWP	1	1	0	0		2	1	1	0	0	0	1
Overton Wildlife	OVRW	0	1	0	0		1	0	0	0	0	0	0
Littlefield Bridge	LITBR	0	0				0	0	0	0	0	0	0
Topock Platform	HAVTPR	3	1	1	1	0	6	1	1	0	0	0	1
Pintail Slough	HAVPS	0	1	3	0	0	4	1	0	1	0	0	1
North Dike	HAVND	0	1	1	0	0	2	1	1	0	0	0	1
Havasu Levee Road	HAVLR	0	0	0	0		0	0	0	0	0	0	0
Lost Lake	HAVLL	1[7]	0	0	0		1	0	0	0	0	0	0
Glory Hole	HAVGH	0	0	0	0		0	0	0	0	0	0	0
Beal Restoration	HAVBR	1	3	3	2	0	9	1	0	0	1	1	1
Total		7	8	8	3	0	26	5	3	1	1	1	5
Observed Occupancy								45.45%					

[1]Occupancy based on YBCU detections on two or more survey periods.
[2] Possible breeding pair = ≥2 detections in an area ≥12 days apart
[3] Probable breeding pair = possible breeding pair + food carry or traveling as a pair or vocalization exchanges.
[4] Confirmed breeding pair = copulation, stick carry, nest or fledgling.
[5] Maximum YBCU pair = possible breeding pairs + probable breeding pairs + confirmed breeding pairs
[6] Minimum YBCU pair = confirmed breeding pairs
[7] Reported by SWCA.

Table 1-4. 2010 LCR YBCU survey detection results and breeding status for Bill Williams River NWR sites.

Site	Site Code	Cuckoos Detected Per Survey Period					Total Survey Detections	Occupied[1]	Possible Breeding [2]	Probable Breeding [3]	Confirmed Breeding [4]	Min Pairs[5]	Max Pairs[6]
		1	2	3	4	5							
Cave Wash	BWCW	7	3	5	5	0	20	1	3	0	1	1	4
Cottonwood Patch	BWCP	4	3	2	3	1	13	1	1	0	1	1	2
Honeycomb Bend	BWHB	3	5	2	2	1	13	1	2	0	3	3	5
Mineral Wash	BWMW	6	4	4	2		16	1	1	0	2	2	3
Esquerra Ranch	BWER	1	3	0	0		4	0[7]	0	0	0	0	0
Cougar Point	BWPT	5	5	4	5	2	21	1	0	0	3	3	3
Gibraltar Rock	BWGR	1	3	2	0		6	1	1	0	0	0	1
Kohen Ranch	BWKR	1	1	2	3	0	7	1	2	0	1	1	3
Sandy Wash	BWSW	1	4	3	0		8	1	2	0	1	1	3
Fox Wash	BWFW	1	1	1	0		3	1	0	0	0	0	0
Borrow Pit	BWBP	0	2	1	2	0	5	1	1	0	0	0	1
Cross River	BWCR	3	3	1	1		8	1	2	0	0	0	2
Mosquito Flats	BWMF	2	6	1	1	1	11	1	2	0	0	0	2
North Burn	BWNB	2	0	0	0		2	0	0	0	0	0	0
Middle Delta	BWMD	0	1	2	0	0	3	1	2	0	0	0	2
Bill Williams Marsh	BWMA	2	0	0	0	0	2	0	0	0	0	0	0
Total		39	44	30	24	5	142	13	19	0	12	12	31
Observed Occupancy								81.25%					

[1]Occupancy based on YBCU detections on two or more survey periods.
[2] Possible breeding pair = ≥2 detections in an area ≥12 days apart
[3] Probable breeding pair = possible breeding pair + food carry or traveling as a pair or vocalization exchange.
[4] Confirmed breeding pair = copulation, stick carry, nest or fledgling.
[5] Maximum YBCU pair = possible breeding pair + probable breeding pair
[6] Minimum YBCU pair = confirmed breeding pair
[7] All detections but one were at the site's borders and heavily overlapped a breeding territory or YBCU detections in adjacent sites.

Table 1-5. 2010 LCR YBCU survey detection results and breeding status for Blythe area sites.

Site	Site Code	Cuckoos Detected Per Survey Period					Total Survey Detections	Occupied[1]	Possible Breeding [2]	Probable Breeding [3]	Confirmed Breeding [4]	Min Pairs	Max Pairs
		1	2	3	4	5							
Cibola Nature Trail	CIBCNT	3	5	3	2	0	13	1	2	0	1	1	3
Cibola Eucalyptus	CIBEUC	1	0	1	0	1	3	1	0	0	0	0	0
Cibola North Restoration	CIBNTH	1	0	0	0	0	1	0	0	0	0	0	0
Cibola South Restoration	CIBSTH	1	4	1	0	0	6	1	1	0	0	0	1
CVCA Phase 1	CVCA1	0	7	7	4	1	19	1	0	0	3	3	3
CVCA Phase 2	CVCA2	0	3	5	3	2	13	1	0	0	3	3	3
CVCA Phase 3	CVCA3	1	3	2	0	0	6	1	1	0	0	0	1
PVER Phase 1	PVER1	0	0	2	0	0	2	0	0	0	0	0	0
PVER Phase 2	PVER2	2	2	4	0	0	8	1	1	0	1	1	2
PVER Phase 3	PVER3	2	4	1	0	0	7	1	1	0	1	1	2
PVER Phase 4	PVER4	0		2[7]	2	0	4	1	0	1	0	0	1
Total		11	28	26	11	4	82	9	6	1	9	9	16
Observed Occupancy								81.82%					

[1]Occupancy based on YBCU detections on two or more survey periods.
[2] Possible breeding pair = ≥2 detections in an area ≥12 days apart
[3] Probable breeding pair = possible breeding pair + food carry or traveling as a pair or vocalization exchange.
[4] Confirmed breeding pair = copulation, stick carry, nest or fledgling.
[5] Maximum YBCU pair = possible breeding pair + probable breeding pair
[6] Minimum YBCU pair = confirmed breeding pair
[7] Non-survey detections

Table 1-6. 2010 LCR YBCU survey detection results and breeding status for Yuma area sites.

Site	Site Code	Cuckoos Detected Per Survey Period				Total Survey Detections	Occupied[1]	Possible Breeding [2]	Probable Breeding [3]	Confirmed Breeding [4]	Min Pairs	Max Pairs
		1	2	3	4							
Picacho SRA	PICSRA	5	1	3	0	9	1	0	1	0	0	1
Imperial South Restoration	IMPSTH	0	1	2	0	3	1	1	0	0	0	1
Laguna 2	LAG2	0	0	0	0	0	0	0	0	0	0	0
Laguna 3	LAG3	1	0	0	0	1	0	0	0	0	0	0
Mittry Lake/Pratt Restoration	MLPR	2	2	0	0	4	1	1	0	0	0	1
Quigley WMA	GRQP	2	1	0	0	3	1	1	0	0	0	1
Yuma East Wetlands	YUEW	1	0	0	0	1	0	0	0	0	0	0
Yuma West Wetlands City Park	YUWW	1	0	0	0	1	0	0	0	0	0	0
Total		12	5	5	0	22	4	3	1	0	0	4
Observed Occupancy							50%					

[1] Occupancy based on YBCU detections on two or more survey periods.
[2] Possible breeding pair = ≥2 detections in an area ≥12 days apart
[3] Probable breeding pair = possible breeding pair + food carry or traveling as a pair or vocalization exchange.
[4] Confirmed breeding pair = copulation, stick carry, nest or fledgling.
[5] Maximum YBCU pair = possible breeding pair + probable breeding pair
[6] Minimum YBCU pair = confirmed breeding pair

Survey Detection Probability

Detection probabilities remained fairly constant across sites in June and July at 74% – 78%, but then steadily declined in August to 37% and then 27% (Figure 1-1, Table 1-7). Stratified by site type, detection probabilities at natural sites exceeded those at restoration sites and both showed a dramatic decrease in August, with restoration sites experiencing the lowest August detection probabilities (Table 1-7). Northern site detection probabilities exceeded those at southern sites during all but the last survey period (Table 1-8). At southern sites, cuckoo detections peaked in the first survey period and declined thereafter. In contrast, at northern sites cuckoo detections peaked later, in the second survey period, followed by a more gradual decline. However, the overlapping confidence intervals indicate that the disparity was not statistically different.

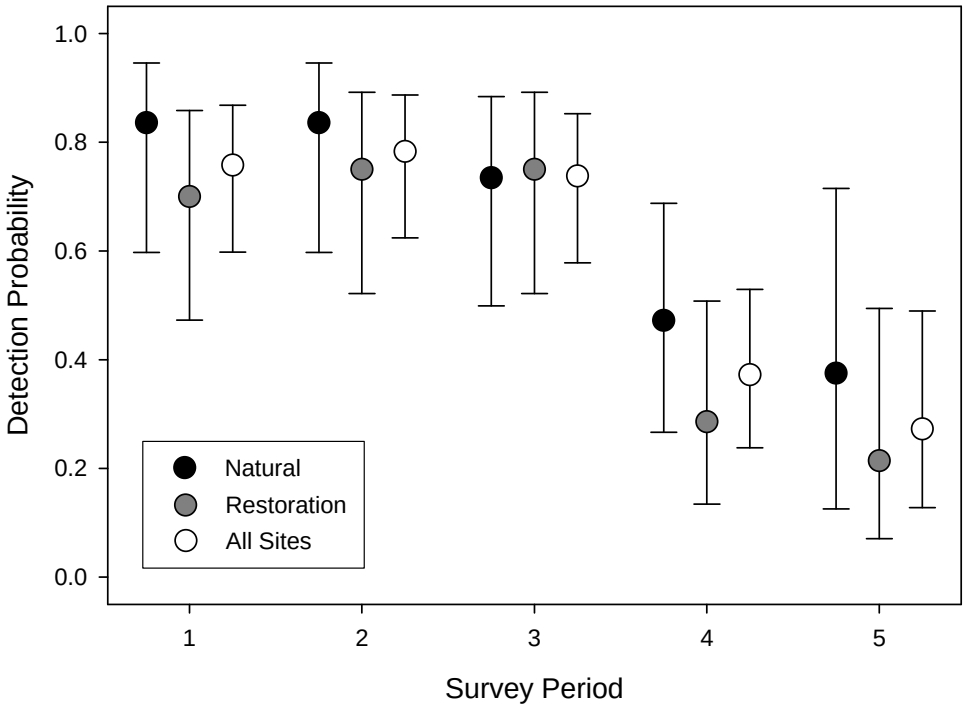


Figure 1-1. Yellow-billed cuckoo 2010 detection probabilities with 95% confidence intervals for natural, restoration and all sites.

Table 1-7. Detection Probability estimates with 95% confidence intervals (CI) by survey period for restoration, natural and all sites. Data is displayed in figure 1-1.

Survey period	Detection Probability Estimates					
	Restoration (CI)		Natural (CI)		All Sites (CI)	
1	0.700	(0.473 - 0.859)	0.836	(0.597 - 0.946)	0.758	(0.598 - 0.868)
2	0.750	(0.525 - 0.892)	0.836	(0.597 - 0.946)	0.783	(0.624 - 0.887)
3	0.750	(0.522 - 0.892)	0.734	(0.499 - 0.885)	0.738	(0.578 - 0.852)
4	0.286	(0.134 - 0.508)	0.472	(0.267 - 0.688)	0.372	(0.238 - 0.529)
5	0.214	(0.071 - 0.494)	0.375	(0.125 - 0.715)	0.273	(0.128 - 0.489)

Table 1-8. Detection probability estimates with 95% confidence intervals (CI) by survey period for all sites south of Bill Williams NWR compared to the Bill Williams sites and north sites.

Survey period	Detection Probability Estimates					
	South (CI)		North (CI)		All Sites (CI)	
1	0.742	(0.482 - 0.899)	0.768	(0.550 - 0.900)	0.758	(0.598 - 0.868)
2	0.628	(0.383 - 0.821)	0.904	(0.687 - 0.976)	0.783	(0.624 - 0.887)
3	0.628	(0.383 - 0.821)	0.817	(0.601 - 0.930)	0.738	(0.578 - 0.853)
4	0.216	(0.083 - 0.456)	0.500	(0.302 - 0.697)	0.372	(0.238 - 0.529)
5	0.300	(0.100 - 0.624)	0.250	(0.083 - 0.552)	0.272	(0.128 - 0.489)

Site Occupancy

Cuckoo occupancy at restoration sites exceeded that at natural sites in both the early and late breeding season (Table 1-9). Occupancy at all sites dramatically decreased in August. At centrally located study sites (Blythe area and Bill Williams River NWR sites), occupancy exceeded 80% (Tables 1-4, 1-5), but was at or below 50% at northern and southern study sites (Tables 1-3, 1-6). Restoration site occupancy (80%) exceeded that at natural sites (68%). The average occupancy across all sites was 74%. By August site occupancy at restoration (48%) and natural sites (38%) declined by approximately 40% compared to the observed rates in June and July (Table 1-9).

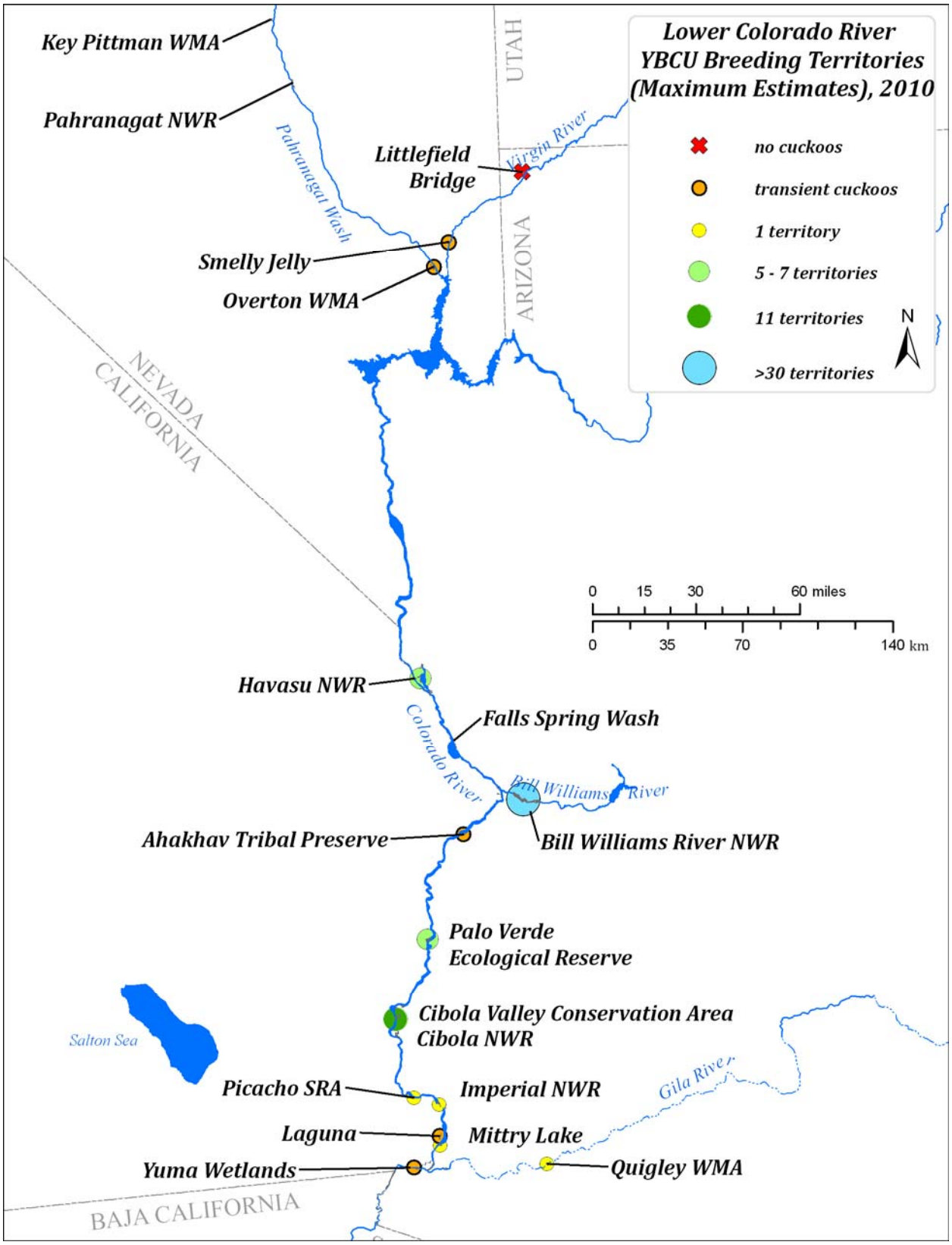
Table 1-9. Occupancy estimates with standard errors (SE) for restoration, natural and all sites grouped by periods 1-3 and 4-5.

Survey Period	Occupancy Estimates					
	Restoration (SE)		Natural (SE)		All Sites (SE)	
1-3	0.802	(0.0897)	0.683	(0.0937)	0.737	(0.0663)
4,5	0.484	(0.2278)	0.375	(0.0988)	0.444	(0.1264)

Breeding Evidence

Based on the timing, location and persistence of all detections, we estimated between 22 and 56 breeding pairs of cuckoos to occur within the LCR MSCP region (Map 1-3), including 31 possible, 3 probable, and 22 confirmed breeding pairs (Tables 1-3 to 1-6). We confirmed breeding at Havasu NWR in 2010 (2 POS, 1 PRB, 1 COB, Table 1-3). The Beal Restoration area contained the first and only confirmed breeding at the Refuge, with one nest and three individual yellow-billed cuckoos observed (one radio-tracked). Pintail Slough (1 PRB) also contained three cuckoos (two radio-tracked), but no breeding activity was observed. We detected cuckoos at the Topock Platform site during four surveys, but repeated follow-up visits after each survey yielded no additional sightings of these secretive birds. Further north, the Overton, NV area sites yielded one POS (Table 1-3).

The majority of confirmed breeding and possible pairs were at the Bill Williams River NWR (12 COB, 19 POS, Table 1-4). Breeding was confirmed at Cave Wash (1 pair), Cottonwood Patch (1 pair), Honeycomb Bend (3 pairs), Mineral Wash (2 pairs), Cougar Point (3 pairs), Kohen Ranch (1 pair), and Sandy Wash (1 pair).



Map 1-3. Yellow-billed cuckoo breeding territories (maximum pair estimates), LCR 2010.

In the Blythe area, breeding was confirmed at PVER, CVCA, and Cibola NWR (Table 1-5). PVER Phases 2 and 3 had 1 confirmed breeding pair each, while Phase 4 had suspected breeding activity (PVER3: 1 POS, 1 COB; PVER4: 1 PRB). CVCA Phases 1 and 2 supported three confirmed breeding pairs each. Phase 3 held one possible breeding pair. Other Cibola area sites with breeding activity included Cibola Nature Trail (1 nest) and Cibola Island South (1 POS). Breeding activity in the Yuma area included one probable breeding pair at Picacho State Recreation Area (SRA), and one possible breeding pair each at Imperial NWR, Mittry Lake, and Quigley WMA (Table 1-6).

Discussion

Yellow-billed cuckoo detection probabilities in 2010 were similar to those in 2009 (McNeil et al. 2010), with peak detections occurring in July followed by steep declines in August. However, disparate patterns emerged between northern and southern sites. The detection probabilities at southern sites showed a pattern of decline. Systematic declines in detection probabilities indicate that emigration from sites was not balanced by additional immigration (MacKenzie et al. 2006), i.e. the number of birds leaving a site exceeded the number remaining and arriving. It appears that in June and possibly into July the southern sites were used as migratory stopover locations for cuckoos en route to their eventual breeding grounds.

The transient behavior suggested from our detection probabilities is supported by the movements observed using radio telemetry. These results, most of which were recorded at sites south of the Bill Williams River, revealed that cuckoos dispersed during all survey periods (Chapter 2). Forty-four percent of cuckoos radio-tracked between June

15 and June 31 left during or shortly after the survey period of capture. Large scale transient behavior was also observed at the end of the breeding season. The onset of cuckoo dispersal for fall migration usually begins at the end of August (Hughes 1999). However, we noted declines in detection probabilities and corresponding occupancy estimates indicating dispersal was well under way starting in early August. Eighty percent of our radio-tracked birds left their sites prior to August 15 (Chapter 2). Fall dispersal appeared to begin weeks earlier than what is generally reported. These results indicate that August surveys along the LCR should not be the sole determinant for estimation of site occupancy, and the highest levels of site use and occupancy occur in July.

The 2010 cuckoo site occupancy rates exceeded those from 2009 (restoration sites 53%, natural sites 63%, all sites 59%, McNeil et al. 2010). The increase in restoration site occupancy (80%) is especially noteworthy and is a result of cuckoos newly occupying several sites in 2010 including Pintail Slough and North Dike at Havasu NWR; CVCA Phase 2; PVER Phases 3 and 4, and Mittry Lake/Pratt Restoration. The proportion of natural sites occupied increased slightly from 2009 to 2010.

Data gathered from our surveys provides essential information we used to assess yellow-billed cuckoo breeding and occupancy status. Cuckoo breeding activity increased at four of the five regions within the study area (Bill Williams River NWR, Havasu NWR, Blythe area, and Yuma area). Occupancy at Overton sites remained unchanged from 2009. In general, we saw increases in restoration site occupancy and breeding activity from 2009. Bill Williams River sites again overshadowed restoration sites by supporting the majority of confirmed breeding and estimated pairs. Overall, the emergent distribution pattern

showed increases in occupancy coupled with increases in minimum and maximum breeding pair estimates at restoration areas and throughout the LCR. Additional details of cuckoo occupancy and breeding evidence are described in Chapter 3 and Appendix B.

Chapter 2. MIST NETTING, COLOR BANDING, AND TELEMETRY

Introduction

Mist netting and banding are valuable supplements to visual and auditory surveys, and can improve estimates of populations and pairs at a site when combined with regular site visits (Dunn and Ralph 2004). Critical information only available from birds in the hand includes morphology, molt, age, parasite load, physiological state, and genetics (Dunn and Ralph 2004). Banding also enables the identification of individuals during future encounters, and provides information on key traits such as longevity, mating systems, site fidelity, migration, within-season movements, natal and breeding dispersal, and population demography. Even though the banding of almost 11,000 yellow-billed cuckoos across North America from 1955 to 2004 resulted in just 26 recorded reencounters (USGS 2000), the information to be gained from large-scale banding efforts still makes it a worthwhile pursuit. Through the 2009 recapture of one of five nestlings banded on the LCR in 2008, we obtained the first yellow-billed cuckoo natal dispersal record (McNeil et al. 2010). Additionally, radio-tracking cuckoos during the breeding season can reveal information difficult to determine by banding alone, including home range, breeding status, and within-season behaviors and movements (e.g. Halterman 2009, Sechrist et al. 2009, McNeil et al. 2010). In this chapter we report our 2010 banding and radio tracking results.

Methods

Mist Netting

We captured adult cuckoos between mid-June and mid-August. First we located a responsive cuckoo by broadcasting recorded conspecific vocalizations; if a cuckoo was observed flying towards the broadcast, we assessed the area for suitable net lanes, then used a target mist net technique modified from Sogge et al. (2001): three or four stacked (totaling 7.8 to 10.4 m high) mist nets ranging from 9 to 18 m in length were attached between two canopy poles placed in a vegetation gap of similar canopy height. We then broadcast a variety of recorded vocalizations from speakers placed on either side of the net to lure in cuckoos. We recorded information during each attempt, including temperature, number of cuckoos in the area, and which vocalizations elicited a response. Capture efforts typically began around dawn. If no cuckoos displayed interest after approximately 45 minutes, we moved the set-up to another location. We ceased our attempts when temperatures reached 40° C (104° F). In addition, we attempted to resight previously banded cuckoos throughout the season by attempting to observe with binoculars the legs of all detected cuckoos.

Color Banding

We banded all captured cuckoos with a gold anodized Federal metal band and three Darvic color bands forming a unique color combination. Non-target birds captured were immediately released without banding. We used a stopped wing rule to measure wing and tail. Tarsus, bill length and bill width were measured with calipers. Birds were weighed using either a 100 g Pesola® scale or 400 g Acculab digital scale. Blood was extracted by brachial or femoral vein puncture and placed on PermaCode™ cards and/or in buffer for

genetic analysis. Blood cards were sent to HealthGene for DNA sexing. We recorded other morphological data such as molt, feather wear, cloacal protuberance (CP), brood patch, and orbital ring color. Birds were tentatively sexed behaviorally or morphologically (pending DNA-sexing) as follows: nesting birds observed incubating at night were assumed to be males (Potter 1980, Halterman 2009); birds observed incubating only during the day were assumed females; some males were sexed by the presence of a large CP (Pyle 1997); and birds observed giving the 'coo' vocalization were likely female (Wilson 2000, Payne 2005, Halterman 2009) (whether the coo vocalization is also given by male yellow-billed cuckoos is still unresolved and requires more data from known-sex birds, though all three DNA-sexed females we captured in 2009 were observed cooing).

Nestlings were banded at 3-5 days when reachable (i.e. nests less than 7 m high and accessible by ladder). Each chick was banded with a Federal metal leg band and between zero and two Darvic color bands. A stopped wing rule was used to measure wing and tail. Tarsus, bill length and bill width were measured with calipers. Birds were weighed using either a 30 g Pesola® scale or 400 g Acculab digital scale. Blood samples were extracted from either a radial or femoral vein puncture and stored in buffer or on a PermaCode™ card for future genetic analysis.

Telemetry

We equipped a subset of captured adults with Holohil BD-2 transmitters (Holohil LTD) weighing between 1.7 and 1.8 grams, broadcasting at 151-152 MHz, and operational for 8 to 16 weeks. Transmitters were tied or stitched near the base of the two central rectrices with dental floss and secured with a small drop of cyanoacrylate (following Bray and Corner 1972, Pitts 1995, Woolnough et al. 2004). We used two types of telemetry

receivers (Wildlife Materials TRX48S and Communications Specialists Model R1000) and two types of directional antennae (AF Antronics model F151-3FB and Communications Specialists RA-150 Folded Yagi) to monitor the marked birds. Vocalizations, intra-specific interactions, movements, behaviors, and habitat characteristics were recorded for each location. Observers attempted to sight the bird once every 30 to 60 minutes to record behavioral data and habitat use. At sites with high vegetation density, more frequent visual observation may excessively disturb the cuckoos. If an observer thought that their presence was disturbing the bird, they moved away from the bird and used biangulation or triangulation to estimate the bird's location (Springer 1979). If a bird's signal was no longer detected at its capture site, we regularly searched for the bird by foot or vehicle at other project sites for the remainder of the season.

We imported telemetry points into ArcGIS 9.3 and used Hawth's Analysis Tools (Beyer 2004) to calculate home ranges for each cuckoo. Three home range estimates were calculated: minimum convex polygons (MCP), and 50% and 95% kernel density estimators (KDE, Silverman 1986). MCP and 95% KDE estimates are commonly used to represent an animal's home range, while the 50% KDE describes an animal's core range (Laver and Kelly 2008). MCPs are obtained by connecting all outer data points to form a convex hull (following Mohr 1947). While popular due to its simplicity, MCP is extremely sensitive to data outliers, often over-estimating the animal's true home range (Worton 1995, Burgman and Fox 2003). KDEs determine the probability of locating the bird in an area at any given time, and are less biased towards outliers (Seaman and Powell 1996).

Results

Mist Netting

We made 57 mist netting attempts over 37 days in 2010, resulting in the capture of 27 adults (Table 2-1). The mean capture rate in 2010 was 41% per attempt. Nets were open an average of 52 minutes per attempt. The average capture took approximately 30 minutes, although some birds were captured in less than 2 minutes. Temperatures during attempts ranged from 18° C to 36° C with an average of 26° C. Details of all capture attempts can be found in Appendix C.

Table 2-1. Yellow-billed cuckoo capture attempts by area, 2010.

Area	#Attempts	#Captures	Capture rate
Havasu NWR	9	3	33%
Bill Williams River NWR	10	3	30%
PVER	9	6	67%
CVCA	18	12	67%
Cibola NWR	10	5	50%
Imperial NWR	1	0	0%
Total	57	29	41%

Color Banding

We banded 25 adult birds, recaptured two previously banded birds, and resighted two other banded birds in 2010 (Table 2-2). We also banded 24 hatch-year birds in 2010 (Table 2-3). All recaptures and resights were of birds previously banded in 2009, giving a resight rate of 31% (4 of 14 banded in 2009). Through these returns we added four new dispersal records (two natal and two breeding) in 2010 (Table 2-4).

Table 2-2. Adult yellow-billed cuckoos captured or resighted on LCR, 2010.

Site Code	Date	Bird ID	Status[1]	Band#	Bands[2]	Sex	How Sexed[3]	Age[4]	Breeding Evidence[5]	Days Tracked	Min Days at Site[6]
Havasu Pintail Slough	7/10	PC	N	121213765	AgW-YBl	U		AHY	-	10	14
Havasu Pintail Slough	7/14	TB	N	121213767	AgG-BkO	U		AHY	-	7	10
Havasu Beal	6/23	LB	N	121213750	GAg-WG	F	DI, VC	AHY	Nest	15	34
Bill Williams Cave Wash	6/20	PP	S	121213745	BkO-WAg	U		SY	Nest	-	42
BW Cottonwood Patch	6/19	GZ	N	121213762	WAg-RW	U		AHY	-	0	1
BW Cottonwood Patch	7/04	AF	N	121213764	BlW-RAg	M	CP	AHY	Cop	8	34
BW Cottonwood Patch	7/13	CA	S	121213729	RY-GAg	F	DNA, VC	ASY	Cop	-	1
BW Mineral Wash	6/28	RAL	N	121213763	RAg-RG	M	CP	AHY	Nest	4	36
PVER2	7/01	LL	N	121213748	GAg-WR	U		AHY	-	2	3
PVER2	7/01	PD	N	121213741	YAg-RBl	U		AHY	-	6	7
PVER3	7/07	AA	N	121213752	BlAg-RG	M	NI	AHY	Nest	15	42
PVER3	7/30	LG	N	121213782	BkR-OAg	U		AHY	Nest	-	17
PVER4	7/28	MBS	N	121213778	WBl-Rag	M	CP	AHY	-	14	21
PVER4	8/12	LIB	N	121213790	RY-YAg	U		AHY	FC	-	17
CVCA1	6/23	BA	N	121213743	RW-BkAg	F	VC	AHY	Nest	9	34
CVCA1	6/23, 7/25	LJ	R,R	121213733	WAg-WO	M	CP, NI	ASY	Nest	23	35
CVCA1	6/24	YB	N	121213746	BlO-Wag	U		AHY	-	9	10
CVCA1	6/24, 8/13	TGB	N,R	121213742	BkW-Wag	F	VC, DI	AHY	Nest	38	60
CVCA2	7/25	PQ	N	121213776	RG-BlAg	U		AHY	-	16	16
CVCA2	7/31	SJR	R	121213737	RAg-GW	M	CP, NI	SY	Nest	17	31
CVCA2	7/31	TA	N	121213783	BlAg-OBk	U		AHY	Flg	9	35
CVCA2	8/05	FZ	N	121213787	OAg-OY	M	NI	AHY	Nest	-	17
CVCA3	7/08	GO	N	121213753	GAg-RBl	U		AHY	-	4	4
CVCA3	7/08	GG	N	121213754	WO-YAg	M	CP	AHY	-	0	1
Cibola Nature Trail	6/19	RP	N	121213740	WAg-BlO	U		AHY	-	9	14
Cibola Nature Trail	7/05	KW	N	121213751	WR-BlAg	M	CP	AHY	-	6	11
Cibola Nature Trail	7/11	KS	N	121213755	YAg-OW	M	NI	AHY	Nest	-	24
Cibola Island South	6/17	WFF	N	121213736	GW-Gag	F	VC	AHY	-	8	11
Cibola Island South	7/03	PM	N	121213749	OBl-BlAg	M	CP	AHY	-	11	16

1.Status: N=new band, R=recapture of bird banded in 2009, S=resight of bird banded in 2009. 2.Colors: Ag=Anodized gold Federal band. Darvic colors: Bk=Black, Bl=Blue, G=Green, O=Orange, R=Red, W=White , Y=Yellow. 3.Birds tentatively sexed by: NI=nocturnal incubation, DI=diurnal incubation, VC=coo vocalization, CP=cloacal protuberance. 4.Age: AHY=after hatch year, SY=second year, ASY=after second year. 5.Breeding evidence: Cop=copulation, FC=food carry, Flg=observed with fledgling. 6. Minimum number of days the bird was detected on site before the signal was lost.

Table 2-3. Hatch-year yellow-billed cuckoos banded on LCR, 2010.

Site	Nestling ID (Parent)	Date	Band #	Band Combination
Havasu Beal	N1-1 (LB)	07/25	121213768	Ag-
BW Honeycomb Bend	N1-1 (PP)	08/01	121213766	Ag-(G/O)
BW Honeycomb Bend	N2-1(RA)	08/01	121213769	Ag-Bl (O/G)
BW Honeycomb Bend	N2-2(RA)	08/01	121213770	Ag-(O/G)
BW Cougar Point	N3-1	08/06	121213774	Ag-(G/O)
BW Cougar Point	N3-2	08/06	121213773	Ag-(G/O)
BW Sandy Wash	N1-1	08/02	121213771	Ag-(G/O)
BW Sandy Wash	N1-2	08/02	121213772	(G/O)-Ag
CVCA1	N1- 1	07/18	121213758	W-Ag
CVCA1	N1-2	07/18	121213759	W-Ag
CVCA1	N1-3	07/18	121213760	W-Ag
CVCA1	N2-1 (BA)	07/24	121213761	W-Ag
CVCA1	N3-1 (SJR)	08/14	121213792	Lg-Ag
CVCA1	N3-2 (SJR)	08/14	121213793	Lg-Ag
CVCA1	N3-3 (SJR)	08/14	121213794	Lg-Ag
CVCA2	N2-1 (TGB)	08/09	121213788	Lg-Ag
CVCA2	N2-2 (TGB)	08/09	121213789	Lg-Ag
CVCA2	N3-1 (FZ)	08/03	121213784	W-Ag
CVCA2	N3-2 (FZ)	08/03	121213785	W-Ag
CVCA2	N3-3 (FZ)	08/03	121213786	-Ag
PVER2	N1-1 (AA)	07/15	121213756	-Ag
PVER2	N1-2 (AA)	07/15	121213757	-Ag
PVER3	N1-1 (LG)	07/29	121213779	Lg-Ag
PVER3	N1-2 (LG)	07/29	121213781	Lg-Ag

Band Combination: Ag=Anodized gold (Federal metal band). Darvic colors: Bk=Black, Bl=Blue, G=Green, Lg=light green, O=Orange, R=Red, W=White, Y=Yellow.

Table 2-4. Yellow-billed cuckoo resights and recaptures, LCR 2009-2010.

YBCU ID	Site banded	Sex (how)[1]	Date banded	Age when banded	Resight Date	Recap Date	Resight Site	Distance moved	Dispersal type
PM	CIBSTH	M(CP)	7/03/10	AHY	7/08		CVCA1	13 km	within season
LJ	CVCA1	M(CP)	7/11/09	AHY	6/22	6/23/10	CVCA1	0 m	breeding
SJR	CVCA1	M(CP)	7/29/09	HY	7/30	7/31/10	CVCA1	135 m	natal
PP	BWHB	U	8/30/09	HY	8/01		BWCW	30 m	natal
CA	CRIT	F(DNA)	6/30/09	AHY	7/13		BWCP	37 km	breeding
ODY	CVCA1	F(VC)	7/15/08	HY		8/03/09	PVER2	33 km	natal

1. How sexed: CP= by cloacal protuberance, DNA=by blood DNA, VC=by coo vocalization.

Telemetry

We fitted 23 of the 27 adults with transmitters and followed each between 0 and 38 days for a total of 250 days (an average of 11 days per bird) (Figure 2-1). Departure of birds from sites was steady throughout the season. Birds leaving sites in the first half of the season (<July 23) stayed 0 - 16 days (average 8.25 days, n=12) with no breeding evidence.

Confirmed breeders spent significantly more days at sites (average 36.3 days) than birds that left before breeding was confirmed (9.7 days, Table 2-5). The greatest recorded within-season distances moved were 13 km (Cibola South to CVCA) and 6 km (Mineral Wash to 6 km upstream). The average home range size of 19 birds radio tracked at restoration sites was 21.7 ±10.4 ha (95% kde, Table 2-6), very similar to our 2009 result of 21.6 ±8.8 ha (n=6), McNeil et al. 2010).

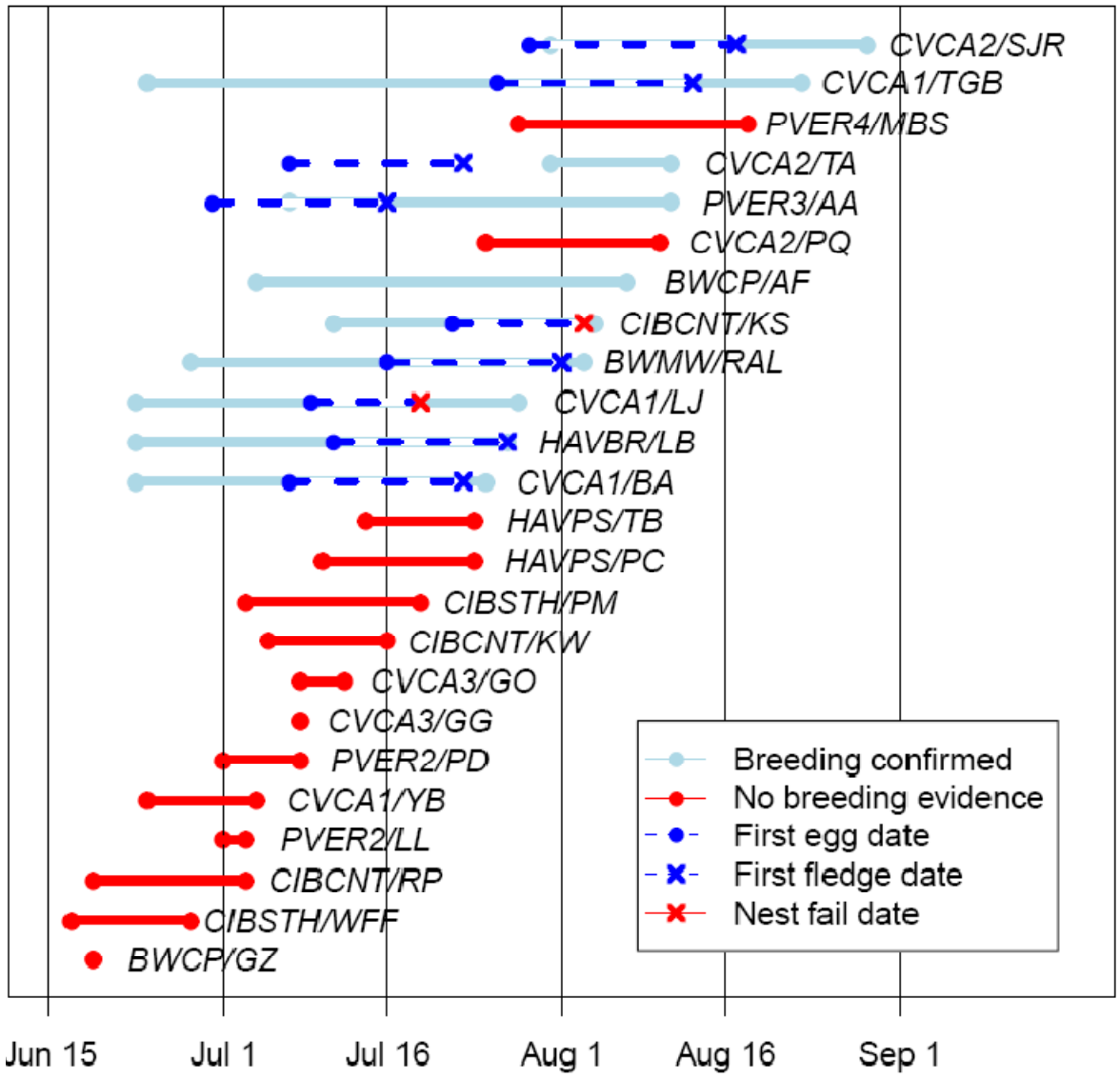


Figure 2-1. Capture, last known presence and nesting dates of banded yellow-billed cuckoos, LCR 2010. First circle represents date of capture, last circle represent date bird last detected at site. Birds are ordered by last known date at site to show the regular departure of birds throughout the season.

Table 2-5. Mean number of days at site for breeding and non-breeding yellow-billed cuckoos, LCR 2010.

		Days at site	
Status	n	Range	mean
Early departure (<July 23)	12	0 - 16	8.25
No breeding confirmed	14	0 - 21	9.7
Later departure (≥July 23)	12	16 - 60	33.3
Confirmed breeding	10	24 - 60	36.3

Two birds dropped their transmitters on site (BA and SJR, both at CVCA1). The rest departed with transmitters still attached. Most missing birds were never relocated despite intensive searching. However, we temporarily relocated two missing birds. One (RAL) was found at a nest 2.5 km from its Mineral Wash capture location 20 days after we lost the signal. The other (PM) was captured at Cibola Island on July 3 but was missing by July 5. The signal was then picked up 3 days later at CVCA1, 13 km to the north, where he spent 11 days before leaving. PM was observed interacting with other cuckoos at that site, including being chased from CVCA1 to CVCA2 by another cuckoo who was giving unusual high-pitched "kuks". This occurred in an active breeding territory in which the nest (BA's, CVCA1 nest 2) was two days into incubation (estimated from known nest fledge date). PM was seen later that day following a cooing bird and in the presence of four other cuckoos. On July 12, several cuckoos were heard knocking, possibly directed at PM. PM was observed near at least one other cuckoo until July 19, the last day the signal was located.

Table 2-6. Home range estimates of yellow-billed cuckoos radio-tracked at LCR restoration sites, 2010.

Site	Site area (ha)	YBCU ID	#days data	# points	Sex	Mated/nesting status	MCP (ha)	95% KDE (ha)	90% KDE (ha)	50% KDE (ha)
Havasu Pintail Slough	12	PC	10	48	U	Unknown	67.3[1]	22.9	15.2	3
Havasu Pintail Slough	12	TB	7	30	U	Unknown	8.6	17.1	11.7	3.9
Havasu Beal	21.3	LB	15	108	F	Nesting	8.9	12	8.3	2.1
PVER 2+3	40.5	LL	2	15	U	Unknown	5	12.3	9.2	2.5
PVER 2+3	40.5	PD	6	47	U	Unknown	23.9	26.2	21.3	6.7
PVER 2+3	40.5	AA	15	119	M	Nesting	28.5	23.3	17.9	3.6
PVER 4	35.8	MBS	14	118	U	Unknown	58	28.7	22.4	5
CVCA 1+2	60	LJ	23	234	M	Nesting+post-nesting	53.5	44.2	35.1	9.9
CVCA 1+2	60	BA	9	103	F	Prenesting	16.8	17.7	13.8	4.9
CVCA 1+2	60	YB	9	107	U	Unknown	41.2	40.2	30.7	8.7
CVCA 1+2	60	TGB	38	536	F	Pre-nesting+nesting	32.6	26.2	19.5	4.4
CVCA 1+2	60	PM	11	136	M	Unknown	360.9[2]	17.6	14.4	3.7
CVCA 1+2	60	PQ	16	132	M	Unknown	15.5	19.8	15.2	4.4
CVCA 1+2	60	SJR	17	147	M	Nesting	13	13.9	9.5	1.7
CVCA 1+2	60	TA	9	144	U	Post-nesting	12.3	16.6	13.3	4
CVCA 3	37.3	GO	4	19	U	Unknown	12	15	11.8	2.5
Cibola Nature Trail	61.1	RP	9	137	U	Unknown	5.5	10.2	7.6	1.9
Cibola Nature Trail	61.1	KW	6	102	U	Unknown	3.5	8	5.5	1.4
Cibola Island South	66.6	WFF	8	225	M	Unknown	48.3	39.5	29.7	6.9
Mean (± SD)	41.8		12	132			42.9 ± 79.5	21.7 ± 10.4	16.4 ± 8.3	4.3 ± 2.3

MCP=minimum convex polygon, KDE=kernel density estimate. 1. Large MCP due to two outliers. 2. Large MCP due to points at Cibola Island (capture location) and CVCA (site last observed, 13 km north of Cibola Island).

Discussion

In 2010, we resighted two birds banded as nestlings in 2009 who returned to nest at their natal sites (one male sexed by CP, one unknown sex). We resighted two birds banded as adults, one (male by CP and nocturnal incubation) captured in the same net lane and the other (female by DNA and coo vocalization) resighted 37 km to the north. The sexes of some of these birds are still unconfirmed, however in addition to the natal dispersal distance of 33 km (female by coo) obtained in 2009, our limited data suggests that cuckoo natal and breeding dispersal may be sex-biased, with females on average dispersing further distances than the more philopatric (site-faithful) males. Female-biased dispersal is found in most bird species (Greenwood 1980). The reduced life spans of dispersers due to increased predation risk (Yoder et al. 2004, Brown et al. 2008) may explain the skewed sex ratios found in many wild bird populations (30% more males on average, Donald 2007). Natal dispersal is among the least understood, yet most important aspects of population biology and evolution (Penteriani and Delgado 2009), and is vital for inbreeding avoidance and maintenance of genetic diversity (Greenwood 1980, Wheelwright et al. 2006). As it can be impacted by habitat fragmentation and isolation, even in species capable of flying great distances (Martin et al. 2006, Martín et al. 2008, Ortego et al. 2008), dispersal in populations occurring in patchy environments such as western riparian systems is crucial for long-term population viability.

Over half the birds we tracked left their sites within two weeks, before breeding could be confirmed. We do not know whether these birds were attempting to breed or still migrating. Non-breeding birds are often transient and stay at a site only long enough to replenish nutrients or investigate breeding possibilities (Chernetsov 2006). Nur and

Geupel (1993) found their constant-effort mist nets caught more non-breeding (floaters) than breeding wrentits, although breeders were more likely to be recaptured than floaters. Studies of other mobile species have successfully employed aerial radio-tracking to monitor far-ranging individuals (e.g. Whitehouse and Steven 1977, Rogers et al. 1996, Romano et al. 2007, Imlay et al. 2010). Another useful tracking technique employs fixed base receiving stations placed at strategic locations (along the LCR corridor, for example), with each station recording a signal's presence as an individual passes by (e.g. McQuillen and Brewer 1997). While potentially costly, the addition to our project of either of these large-scale tracking methods may reveal the subsequent movements and final breeding destinations of transient birds.

We observed a recently-arrived cuckoo being chased out of an active breeding territory by another cuckoo who was giving unique high-pitched kuks. This was likely an aggressive territorial display directed at the newcomer to the site. Hamilton and Hamilton (1965) also observed a cuckoo aggressively supplanting another on the San Pedro River. Few territorial displays have been recorded for cuckoos, and they are often described as non- or loosely territorial (e.g. Laymon 1998). Our observations, along with those of other researchers (e.g. Hamilton and Hamilton 1965) suggest that nesting cuckoos are likely territorial, but due to a combination of low numbers, dense vegetation, and furtiveness, these displays are rarely observed.

In 2009, we began using canopy mist nets (3 to 4 stacked nets instead of 1 or 2). We have continued to improve our netting techniques and were able to triple our capture rate in 2010 with less relative effort compared to 2009. We also increased the number of

banding teams enabling greater site coverage. These efforts combined with intensive nest-searching and nestling banding contributed to four new natal and breeding dispersal records, and 25 adult and 24 hatch year birds banded in 2010. If our relatively high resight rate (31% in 2010) continues, our understanding of dispersal and site fidelity will significantly increase over the next two years of this project. To improve our capture rate in 2011, we will begin our capture efforts earlier in the season and increase our target netting attempts. We plan to band a significant proportion of the LCR yellow-billed cuckoo population, and resight these birds during current and future seasons to increase our understanding of cuckoo population dynamics in the region.

Chapter 3. NEST SEARCHING AND MONITORING

Introduction

Long-term declines in populations of Neotropical migratory birds, including yellow-billed cuckoos, have led to increased interest in monitoring and management (Martin and Guepel 1993). Understanding demographic processes such as reproductive success, survival of young and adults, and recruitment of young into the breeding population are critical to monitoring and managing landbird populations (Nur and Guepel 1993). To measure these demographic processes in the LCR yellow-billed cuckoo population, we intensively searched for and monitored nests and recorded all potential breeding evidence, concentrating our efforts at the Bill Williams River (BWR) NWR and LCR MSCP restoration sites.

Methods

We used a number of techniques to search for nests. The first occurred during surveys, when all detected cuckoos were located visually if possible, and vegetation in the vicinity was examined (following Martin and Geupel 1993). Cuckoos may respond from the nest to broadcast survey calls, and if they are close enough to the surveyor the nest can be located. The second technique takes advantage of the fact that nesting pairs share incubation duties (Potter 1980). Soon after sunrise the female replaces the male on the nest; both often vocalize during the exchange. Additionally, some individuals call prior to arriving at the nest to feed young. One or more researchers waited before dawn in the area of a suspected nest. Biangulation or triangulation was then used to locate the calling bird. A third technique involved following localized activity or behavioral clues (e.g. food carries, stick carries). Efforts were directed into that area until a nest was located. Systematic searches were also performed, concentrating on edge and structural transition habitats. Additionally, we used radio telemetry to locate nests (Chapter 2). We distinguished used cuckoo nests from similar stick nests of other species (such as doves) by the presence of bluish egg fragments remaining in or directly below the nest.

When a nest was located, a GPS location was recorded approximately 10 m from the nest. A more accurate reading was taken after nesting activity ceased. We recorded nest site characteristics such as nest tree species and height, nest height, stage, and the banded status of adults if known. Nestlings were banded at 3-5 days when reachable; see Chapter 2 for banding details.

We monitored nests every 2-5 days, using telescoping mirror poles to check nest contents. Nest contents and any observed behaviors were recorded. Nests were judged successful if at least one young fledged, or if a cuckoo (adult or juvenile) was detected in the vicinity of the nest within two days of the estimated fledge date. Young cuckoos leave the nest before they can fly, climbing or hopping out onto nearby branches where they may remain in close proximity to the nest for several days. They continue to receive parental care for at least two weeks (Laymon 1998) to 3-4 weeks (Halterman 1991) after fledging. Following nest failure, adult cuckoos were found to move over 400 m to re-nest compared to an average of 131 m moved following successful nests (Halterman 2009). Nests were considered failed if they were found damaged or destroyed, with large egg shell fragments or remains, or empty before the earliest possible fledge date with no observed parental activity nearby. Nests were considered deserted if intact eggs were found and no parental activity was observed for two days.

We used a Fuhrman Diversified black-and-white time lapse video camera system to monitor only one nest located at Cibola Valley Conservation Area. We placed the camera at the nest containing nestlings to reduce the risk of nest desertion (more likely during incubation). The system comprised a small video camera with both daytime and nighttime visibility. We secured the camera to a branch by a series of adjustable clamps placed approximately 1 m from the nest. The camera was connected by a cable to a VCR unit, which was placed 18 m away from the nest to prevent further nest site disturbance. The system was powered by a 12 volt battery, which along with the VCR tape we changed every 24 hours, the amount of time recorded by each tape. We camouflaged the camera, cable, VCR and battery with vegetation and tarps. After camera installation the nest was

observed through the attached VCR monitor until an adult was observed returning to the nest. If an adult had failed to return to the nest within one hour, we would have removed the camera and observed from a distance until we saw an adult returning to the nest. We reviewed all tapes and recorded key activities such as food items delivered and fledging times.

Results

We found 17 nests at five locations during the 2010 breeding season (Table 3-1), seven at Bill Williams River NWR, six at CVCA, two at PVER, and one each at Havasu NWR and Cibola NWR. We confirmed a total of 22 breeding territories (nests, fledglings, or copulations) and estimated a maximum of 56 possible pairs based on the timing and duration of detections at all sites (Appendix B). We found nests at four restoration sites for the first time (Beal, PVER Phase 3, CVCA Phase 2, and Cibola Nature Trail). Of the nests found, the earliest was initiated at PVER (June 30) and the latest at CVCA (July 29). Nesting activity peaked during the second half of July (Figure 3-1).

Table 3-1. Yellow-billed cuckoo nests found on the LCR, 2010.

Nest ID	Date Found	Date 1st Egg	Adult ID[1]	# Eggs	# Banded	Nest Fate[2]	Tree Species	Nest Height (m)	Tree Height (m)
HAVBR-N1	20-Jul	10-Jul	LB	1	1	S(1)	POFR	5	10
BWHB-N1	17-Jul	15-Jul	PP	2	1	S(2)	TASP	3.2	5.5
BWHB-N2	19-Jul	16-Jul	RAL	2	2	S(2)	TASP	4.6	7.5
BWHB-N3	17-Jul	16-Jul	U	2+	0	S(2+)	TASP	3.8	5.8
BWMW-N1	4-Aug	14-Jul	U	1+	0	S(1+)	SAGO	2.5	4.5
BWPT-N1	27-Jul	13-Jul	U	2	0	S(2)	POFR	3	8
BWPT-N2	31-Jul	21-Jul	U	2	2	S(2)	POFR	4.5	8
BWSW-N1	30-Jul	19-Jul	U	2	2	S(2)	TASP	5.7	8.7
PVER2-N1	13-Jul	30-Jun	AA	2	2	S(2)	SAGO	3	8
PVER3-N1	15-Jul	15-Jul	LG	2	2	S(2)	POFR	1.6	7
CVCA1-N1	18-Jul	2-Jul	U	3	3	S(3)	TASP	4.8	8.7
CVCA1-N2	22-Jul	7-Jul	BA/TA	2	1	S(2)	POFR	3	6
CVCA1-N3	2-Aug	29-Jul	SJR	3	3	S(3)	POFR	7	12
CVCA2-N1	12-Jul	9-Jul	LJ	2	0	F	POFR	4	8
CVCA2-N2	28-Jul	26-Jul	TGB	2	2	S(2)	POFR	4	7
CVCA2-N3	2-Aug	22-Jul	FZ	3	3	S(3)	SAGO	4	7
CIBCNT-N1	27-Jul	22-Jul	KS	3	0	F	BASAL	4	5
Total (average)	(23-Jul)	(15-Jul)		36(2.2)	24	S31+		(4.0)	(7.5)

1. ID of banded adults if known (see Chapter 2). 2. F=failed (depredated), S=Successful (fledged at least 1 young).

Nest success (the proportion of nests fledging at least one young) was 88%, with all but two successful and at least 31 young fledged. Nest success was verified by seeing or hearing at least one fledgling in the nest area (3 nests), seeing an adult in the nest area after the nest became empty (2 nests), or detecting both fledglings and adults in the nest area (10 nests) all within two days of the estimated fledge date.

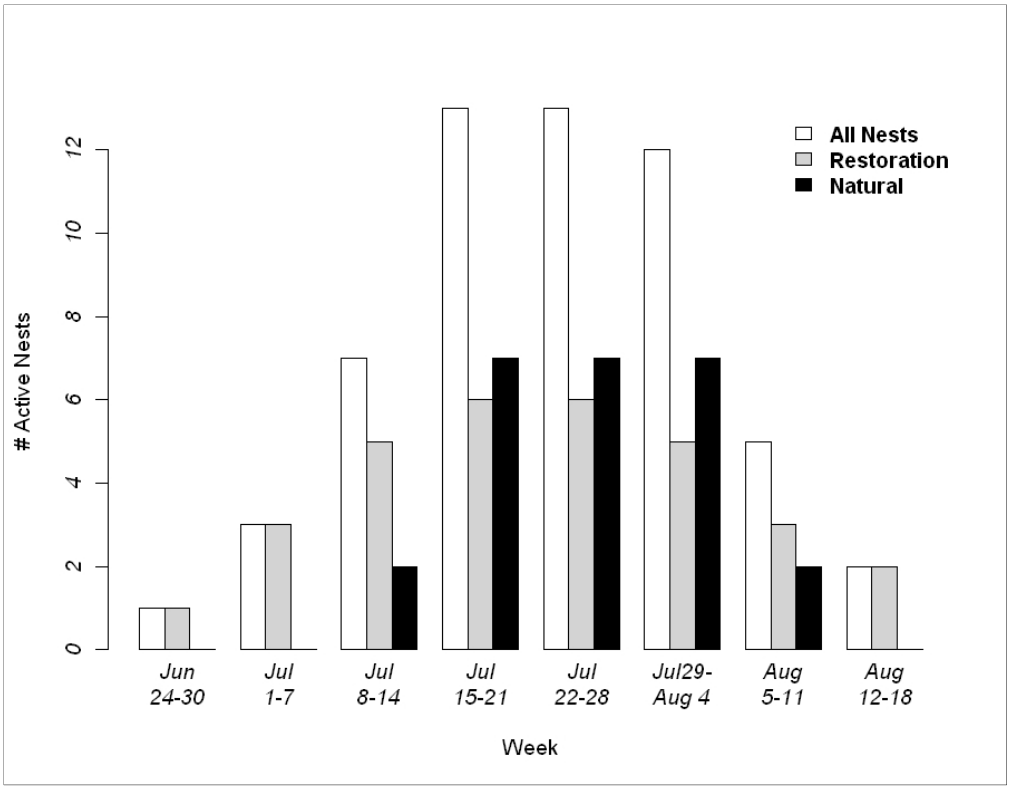


Figure 3-1. Number of active nests (all sites, restoration sites, and natural sites) during each week of the breeding season, LCR 2010.

Most restoration site nests (6 of 10) were in cottonwoods, while most found at Bill Williams River NWR (4 of 7) were in tamarisks (Figure 3-2). Canopy cover above all nests averaged 89.6%. One nest at CVCA1 was in a lone tamarisk, surrounded on three sides by densely planted coyote willows and a road on the remaining side. All other nests in tamarisk were at the Bill Williams River. Honeycomb Bend had three tamarisk nests, two with a Goodding's willow/cottonwood high canopy overstory, a third located in a tamarisk stand immediately surrounding the nest with 25% ground water cover. The Sandy Wash nest was located in a seep willow (*Baccharis salicifolia*)/tamarisk mix, with tamarisk the dominant overstory. All tamarisk nest trees had diameters at breast height (DBH) from 7 to 13 cm and heights from 5.8 to 8.7 m. Tamarisk stem DBH within 11.3 m of nests averaged higher at Bill Williams River nests (3.8 cm) compared to other nests (2.1 cm).

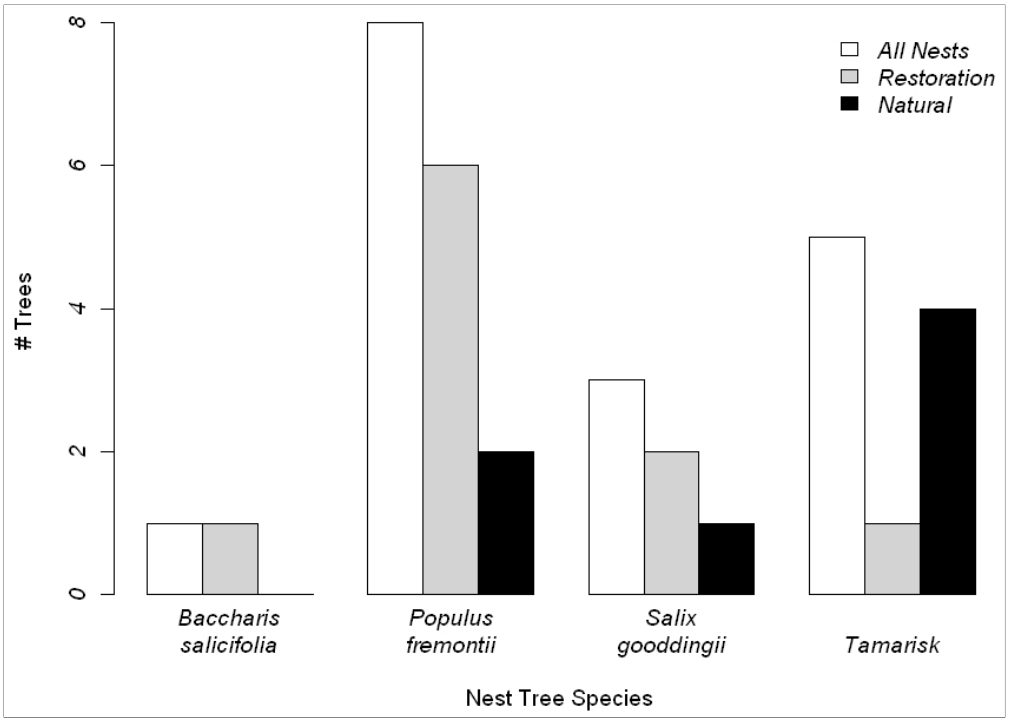


Figure 3-2. Nest tree species for 17 yellow-billed cuckoo nests (all sites, restoration sites, natural sites), LCR 2010.

The majority of shrubs (0-2.5 cm DBH) within 5 m of Bill Williams River nests were tamarisk or arrowweed, while coyote willow was the dominant shrub at restoration nests driven by nest placement near edges of dense coyote willow plantings. The majority of small trees within a 5-m radius of Bill Williams River nests were tamarisk, followed by an equal number of Goodding's willow and cottonwood. Coyote willow was the dominant small tree at restoration nests followed by equal amounts of tamarisk and Goodding's willow. Cottonwood was the only large tree recorded in restoration site nest plots. The most common large trees within an 11.3-m radius of Bill Williams River nests were Goodding's willow followed by tamarisk and cottonwood.

Northern Nests

The Havasu NWR (Beal Restoration) nest was the first confirmed yellow-billed cuckoo breeding within the Refuge. The nest contained a single egg when found on July 20.

We returned four days later and found the nest badly damaged, which we attributed to high winds the night before. We found a live chick on the ground, which we placed in an inactive dove nest to replace the damaged cuckoo nest. Dove nests resemble cuckoo nests in appearance and both are flimsily constructed of twigs. This was then placed on top of the original damaged nest to raise the chick above the ground, which was under threat of flood-irrigation. No adults were observed coming to the nest, although they were observed in the area and gave alarm calls while we were present. The next day (July 25) the nest was revisited and the chick was again found on the ground. We estimated its age was four days based on weight (37 g), wing, and tail lengths (Halterman 2009). The chick was slightly muddy on the belly and one leg but it appeared healthy and defecated when picked up (an indication it had recently been fed). After a few minutes an adult appeared and gave alarm calls; a second bird was also heard nearby. We left the chick on the ground as it appeared to be receiving parental care. Two days later (July 27) we revisited the nest site, and saw an adult with a cicada in its mouth. The chick was not relocated, but cuckoo fledglings are difficult to find due to their cryptic coloration, lack of movement, and silence when frightened or disturbed. The nest area was visited on July 29 and although the chick was not seen again, we believe it successfully fledged based on juvenile calls heard on this day, and an adult seen flying with a caterpillar in its mouth on August 5, most likely feeding the juvenile.

Bill Williams River NWR Nests

Seven nests were found at Bill Williams River NWR, including three at Honeycomb Bend, two at Cougar Point, and one each at Mineral Wash and Sandy Wash. An adult (PP) at BWHB-N1 was banded as a juvenile in 2009, returning in 2010 to nest approximately 30 m

from its natal nest. The adult male (RA) at BWHB-N2 was radio-marked in July but subsequently disappeared. On August 1 he was re-sighted at the nest during nestling banding. He was again sighted flying to and from the nest area after the nest was found empty.

Soon after an adult at Mineral Wash was observed feeding a fledgling, a nest (BWMW-N1) was located nearby, identified by broken blue egg fragments. Two nests were found at Cougar Point. BWPT-N1 was found on July 27 with two nestlings and when revisited on July 29 both had fledged. BWPT-N2 was found following a nest exchange. It contained one egg and one nestling. A single nest containing two nestlings was found at Sandy Wash following eight days of searching. All found Bill Williams River nests were successful, fledging at least 13 young.

Southern Nests

Palo Verde Ecological Reserve

Two nests were found at PVER, one each in Phases 2 and 3. Both nests were successful and fledged two young each. Assuming one egg is laid per day, the Phase 3 nest was found on the day the first egg was laid, so exact incubation and nestling periods are known. The nest was found on July 15 with one egg. It was checked the following morning and contained two eggs. No further eggs were laid. The first egg hatched on July 25, after 10 full days. The second egg hatched the following day, also after 10 full days. The chicks were banded on July 29 (days 4 and 3). The oldest fledged on July 31, after six full days. The other chick fledged the following day. Thus the incubation and nestling periods for this nest were ten and six days respectively.

Cibola Valley Conservation Area

Six nests were found at CVCA, three each in Phases 1 and 2 (a contiguous habitat patch), though no more than three nests were active here at any one time. Five nests were successful and fledged a total of 13 young (12 banded). The female at CVCA1-N2 was banded on June 23 (BA) and tracked for a week before dropping her transmitter (see Chapter 2). She continued to be resighted in the area and was eventually seen attending a nest three weeks after transmitter loss. She was then observed feeding a fledgling incapable of flight within 30 m of the nest on July 25, two days after the nest fledged. Additionally, a bird captured on July 31 340 m from this nest (TA) was observed feeding a banded juvenile approximately 400 m from the nest on August 4, 12 days after fledging.

The male at CVCA1-N3 was banded as a nestling in 2009 at this site (SJR), returning to nest approximately 135 m from his natal nest. The nest was the last found in 2010 (initiated July 29, fledged August 18). These cuckoos were still at the site at the beginning of dove hunting season (September 1).

The male at CVCA2 -N1 was also banded in 2009 (as an adult - LJ). In 2010 he was recaptured at the same net lane as in 2009, and fitted with a radio transmitter. Nineteen days later (July 12) he was followed to a nest which contained two eggs. The first egg hatched around July 17. When we checked the nest on July 19 it had been depredated; one intact egg and some small egg fragments remained. A gopher snake was found in a tree close to the nest during a vegetation survey on September 2.

Nest Video Camera

Nest three at CVCA2 was found with three nestlings on August 2 and a time lapse video camera was installed on August 3. The adults were observed feeding large insects to the nestlings (including katydids, large moths, butterflies, cicadas, and praying mantids), although the video quality was too poor to identify most food items. Two adults were observed in near-constant attendance at this nest, shading the nest during the heat of the day and brooding overnight. During this stage, the two largest nestlings received the majority of the food, many times sitting on the younger nestling and almost pushing it out of the nest on several occasions. The oldest two fledged early on August 6 (approximately 6 and 5 days old). The parents continued to feed the remaining nestling, which appeared reluctant to leave the nest. The parents dangled food above and away from the nest apparently enticing the nestling to leave. The chick fledged on the afternoon of August 8 (approximately 7 days old).

Cibola NWR

One nest was found on Cibola NWR, the first confirmed breeding at the Cibola Nature Trail restoration site. When found on July 27 the nest contained three eggs. An adult banded (but not radio-tracked) on July 11 (KS) was identified attending the nest. On August 1, two nestlings and one egg were observed. Birds were heard calling in the area during the August 2 survey, and during MAPS banding on August 3 (Allen Calvert, Reclamation, pers. comm.). On August 4, the area was quiet; no cuckoos were detected in the area and nest failure was suspected. A Cooper's hawk was noted at the Nature Trail on this day, also two cuckoos (possibly this pair) were observed near KS's banding location approximately 960 m west of the Nature Trail. The following day we mirrored the nest

which was empty apart from several large broken egg fragments and a large piece of egg membrane. We speculate the nest was depredated shortly after the third egg hatched.

The Nature Trail nest was the first we have found in a shrub (seep willow). The seep willow was large (over 4.2 m high) with a DBH of 4.9 cm, and situated below a low overhanging screwbean mesquite. The nest was unusual in appearance as it was well-constructed, circular, and comprised mostly of screwbean mesquite twigs (Photo 3-1). More typical cuckoo nests are loosely built (resembling a dove nest, Photo 3-2).

Photo 3-1 (left). Cibola Nature Trail nest in a large seep willow, built from screwbean mesquite twigs. Photo 3-2 (right). More typical cuckoo nest constructed with willow twigs at PVER2, 2010.

Discussion

We found over twice as many nests on the LCR in 2010 as in 2009. Although this increase may be due to greater observer effort and experience, confirmed breeding events also doubled from 2009 to 2010, and potential pair estimates also increased considerably. The higher numbers are likely partially due to a significant increase in the amount of available breeding habitat provided by LCR MSCP restoration sites. For example, in 2009 we verified (through telemetry) two nesting pairs at CVCA1; one of these territories spilled over into CVCA2 which was only occasionally used for foraging. In 2010 the maturation of

CVCA2 vegetation increased the amount of available breeding habitat from approximately 35 to 60 ha, and the number of confirmed breeding territories tripled.

Nest success was high at both natural and restored sites. High nest success (exceeding 70%) has been observed in other western cuckoo studies (Laymon et al. 1997, Halterman 2000, Halterman 2009). Cuckoos appear to experience higher average nest success than other open-cup nesters who typically have nest success rates of 46% (Nice 1957), as well as other birds in this region, e.g. southwestern willow flycatchers (*Empidonax traillii extimus*) averaged 45% nest success from 2003-2007 (McLeod et al. 2008). Higher cuckoo nest success compared to open-cup-nesting passerines may in part be explained by the absence of brown-headed cowbird (*Molothrus ater*) parasitism of cuckoo nests. A number of potential factors make cuckoos unsuitable cowbird hosts, including a shorter host incubation period (McMaster and Sealy 1998), faster host nestling growth rates (Friedmann 1963), larger host nestling or egg size (Friedmann 1963, Strausberger and Ashley 1997), low host abundance (Freeman et al. 1990), effective host defense (Strausberger and Ashley 1997), and unsuitable host adult-to-chick feeding mechanisms (Friedmann 1963, Strausberger and Ashley 1997).

We found most nests in cottonwoods and tamarisks this year. Tamarisk was the most common nest tree at Bill Williams River NWR, although they all occurred within a cottonwood/willow-dominated canopy. At CVCA, a planted site with very little tamarisk, one pair nested in a single tamarisk growing at the edge of a dense coyote willow plantation. Whereas tamarisk has invaded most historic riparian areas within the LCR, it is

also a suitable nest substrate when occurring in low densities within a native-dominated ecosystem, and appears to provide ideal nest habitat structure.

Adult cuckoos with recently fledged young were still at CVCA when dove hunting season began on September 1. The use of breeding sites by hunters may impair re-nesting attempts or cause birds to leave sites prematurely (Klien et al. 1995, Wingfield et al. 1997). Gill et al. (2001) noted that from a conservation perspective, human disturbance of wildlife is only important if survival or fecundity are impacted (causing population declines). As of 2010, there were no reported cases where disturbance from hunting was known to have reduced the reproduction or survival rate of any population or species (USFWS 2010), although there is little known about the direct impact of hunting disturbance on birds at the population level (Madsen and Fox 1995). Dove hunting at these restoration sites has unknown impacts on site fidelity (see Chapter 2 discussion on dispersal and philopatry), additional within-season nesting attempts, or juvenile survival. We therefore recommend delaying hunting at these sites until at least mid September.

At Picacho SRA, a pair was located on several occasions between mid-June and mid-July, although breeding was not confirmed. During the last week of July, a construction project began at the site involving heavy machinery (Sue Barney, California State Parks, pers. comm.). After this, cuckoos were no longer detected at the site. Though we cannot establish cause and effect, low-frequency construction noise may have impacted the birds. Noise has the potential to mask vocal signals (e.g. mating songs, begging calls of young, alarm calls), potentially affecting communication and ultimately reproduction (Bowles 1995). Goodwin (2009) found noise to be the single best predictor of yellow-billed cuckoo

occupancy within otherwise suitable habitat, with 35-55% lower occupancy rates in noisy compared to quiet areas. Previous studies have found that birds may adapt to man-made noises by singing louder or varying their frequency (Slabbekoorn and Peet 2003, Brumm 2004, Wood and Yezerinac 2006). Yellow-billed cuckoos have both a low and narrow range of vocalization frequencies (average below 3 KHz, Goodwin 2009), and are not likely able to increase their amplitude nor vary their frequency. Declines have been found in other species in response to traffic noises (Reijnen and Foppen 1995, Reijnen et al. 1995, Reijnen et al. 1997). We recommend delaying noise-intensive activities at occupied sites until at least mid-September to reduce the likelihood of breeding impacts.

Chapter 4. HABITAT AND OCCUPANCY ANALYSIS 2006-2010

Introduction

The riparian forests of the Southwest were historically part of a dynamic ecosystem, dependent on periodic flooding to alter the community to earlier successional stages (Warner and Hendrix 1985). The ever-changing vegetation provided habitat for many species including the endangered least Bell's vireo, southwestern willow flycatcher, and western yellow-billed cuckoo (Bell 1997). However, modern river regulation and anthropogenic development across the Southwest has altered the natural hydrologic cycle and led to the loss of riparian vegetation turnover and variety in its successional stages. In addition to the loss of successional diversity, changes to hydrologic regimes have induced shifts in plant distributions (Scott et al. 1997) and changed riparian plant community composition (Nilsson et al. 1997). These changes have drastically reduced the amount of

available riparian habitat resulting in an extensive range reduction and population decline for western yellow-billed cuckoos (Hughes 1999).

In an effort to restore riparian habitat, revegetation has taken place on the lower Colorado River floodplain (most recently under the LCR MSCP). Studies have demonstrated that vegetative species composition and structure are important components of avian habitat selection within riparian habitats of the Southwest (Anderson and Ohmart 1977, Rice et al. 1984). A better understanding of the important components of suitable habitat will facilitate restoration efforts in creating optimal habitat for yellow-billed cuckoos.

Research on yellow-billed cuckoo distribution and habitat use on the lower Colorado River was initiated in 2005 by the USGS Colorado Plateau Field Station under the LCR MSCP (Johnson et al. 2006). In 2006, the study expanded to include additional sites further north, extensive cuckoo surveys, and collection of vegetation data at most survey sites (Johnson et al. 2007, 2008). In 2008 the Southern Sierra Research Station (SSRS) was contracted to continue cuckoo research under the LCR MSCP (Halterman et al. 2009). In this chapter, we analyze vegetation data collected during the 2006-2010 field seasons at two spatial scales: site-level analysis (areas ranging from 0.7 to 126.8 ha; see Chapter 1 for site definition and selection), and plot-level analysis (circular areas of 11.3 m radius, 0.04 ha). Plots were delineated following the BBIRD Field Protocol (Martin et al. 1997) at random points within sites and at nest locations. At a larger scale, sites were referred to as occupied or unoccupied during the season, while on a smaller scale, plots were considered either used or unused (available). We aimed to address two primary goals: to expand our

understanding of the factors influencing habitat selection by cuckoos and to help refine methods for future vegetation data collection. We addressed these goals by examining the following: (1) how habitat characteristics at occupied sites differ from those at unoccupied sites; (2) how habitat characteristics at used vegetation plots (hereafter referred to as plots) differ from available habitat within occupied sites; (3) how habitat characteristics at nest plots differ from available habitat within occupied sites; and (4) how vegetation characteristics at restored sites differ from natural sites.

We hypothesized that cuckoo habitat selection would be strongly influenced by the availability of foraging habitat at the site and plot level. At both spatial scales, we expected a positive association with native vegetation, especially native trees, and a negative association with increased tamarisk density. Cuckoos are primarily foliage-gleaning insectivores and are known to prefer native vegetation over non-native vegetation (Gaines and Laymon 1984, Hunter et al. 1988, Laymon and Halterman 1989). Cicadas are an important yellow-billed cuckoo prey component in the LCR region (Rosenberg et al. 1982, McNeil et al. 2010) and are typically found in riparian areas with large native trees and dense vegetation (Glinski and Ohmart 1984, Smith et al. 2006).

From previous research, we also predicted that increased site size (area) (Halterman 1991), a multilayered canopy (Halterman 1991), and increased canopy height and cover (Laymon 1980) would be strong influences on cuckoo site occupancy. At the smaller (plot) scale we expected cuckoo habitat selection to be weighted around features associated with prey availability. We predicted that a multi-layered canopy and increased canopy height and cover would be strong influences on cuckoo plot use when compared to

available habitat within occupied sites. Detailed observations of cuckoo foraging behavior found that most attempts at prey capture occurred at heights greater than 3 m in dense canopy (Laymon et al. 1997), although they have been observed foraging below this height in grassy orchards (Laymon 1980).

Laymon (1980) found that nests were typically placed in deciduous riparian forests amongst dense foliage. Cuckoo nests in the Kern River Valley were found in locations with increased canopy cover and willow densities when compared to random locations (Laymon et al. 1997). We hypothesized that nest locations would be associated with increased canopy cover, native tree density, and structural diversity compared to available habitat. We also expected nest locations to be closer to water (Gaines 1974) compared to random locations within occupied sites. We assessed the influence of habitat characteristics on selection by cuckoos at sites, plots, and nests to test our hypotheses, and used our results to develop suggestions for adaptive habitat management strategies.

Methods

Vegetation Plot Selection

The majority of plots were sampled during the 2006-2009 field seasons. Plots were also placed at the locations of 39 cuckoo nests found between 2007 and 2010 (no nests were found in 2006). A total of 670 plots were sampled during the five years of the study. Plot placement methodology varied somewhat between years (Table 4-1). We assumed that each year's plots were representative of the available habitat, and that the differing plot placement methods did not bias the data in any way that would significantly affect the results of our analysis.

At the larger spatial scale, sites were considered to be occupied if a cuckoo was detected during at least two survey periods during the season; otherwise they were considered unoccupied during that year. At a smaller scale, a plot was considered to be used if a cuckoo detection occurred within 50 m of the plot center. We assumed that vegetation characteristics of the sampled plot were representative of the habitat in which the cuckoo was residing prior to a survey playback. For the plot and nest level analyses, we included only vegetation plots from occupied sites to examine differences in cuckoo use versus available habitat within occupied sites.

Table 4-1. LCR vegetation plot placement methods, 2006-2009.

Year	Plot placement method	Source
2006	"The survey region was stratified north to south from the Grand Canyon to the United States/Mexican International border, and 11 areas were selected from the total list based on the presence of cuckoos (in 2005) and/or the feasibility of placing the microclimate data loggers that were co-located with the vegetation sampling locations. Within study areas, vegetation sampling plots were located in both occupied and unoccupied survey sites. Within sites, vegetation plots were centered on microclimate sampling locations that were selected in two ways: (1) At occupied sites, vegetation sampling locations included the estimated coordinates of cuckoo detection locations and one or more GIS-generated random points. (2) At unoccupied sites, locations included one or more random UTM coordinates generated from orthorectified aerial photographs of sites. In cases where random UTM locations were inaccessible or located in inappropriate habitat such as marsh, an alternate was selected by choosing a random compass bearing and a random distance to a new location. If the random distance could not be reached, the plot was established at the first patch of riparian vegetation along that compass bearing."	Johnson et al. 2007
2007	"The entire survey region was stratified north to south from the Grand Canyon to the United States/Mexican International border. […] in 2007 […] we continued our vegetation sampling at the locations [sites] pre-established in our protocol [...] To identify sampling points we used orthorectified aerial photographs for each study site to identify habitat boundaries. We then created a numbered list of Geographic Information System (GIS)-generated random locations (Universal Transverse Mercator [UTM] coordinates) for each site. Sampling locations [plots] were assigned to these random UTM coordinates. These points were then located in the field using a handheld Global Positioning System (GPS) unit and, in cases where random UTM locations were inaccessible or located in inappropriate habitat, such as marsh, an alternate random location was selected by choosing the next point on the list for that site."	Johnson et al. 2008
2008	"Habitat characterization plots were established throughout the study region. Sampling plots were spaced approximately 300 m apart along established survey routes within potentially suitable habitat. Individual plot centers were located at a randomly selected distance (0-50 m) in one of two randomly chosen directions perpendicular to the survey route from a known survey point. If this direction placed the survey plot in unsuitable habitat (such as upland scrub vegetation) the plot was established in the opposite direction."	Halterman et al. 2009
2009	"Habitat characterization plots were established throughout the study region. One project objective was to determine microclimate differences between occupied and unoccupied cuckoo habitat. Because only minor microclimate differences have been found between occupied and unoccupied plots in previous years, a new method was used to place the [plots]. Using detection data from the previous 3 years (2006-2008), areas both occupied and unoccupied for each of the past 3 years were determined using ArcGIS 9.3, and [plots] were placed at the centers of these areas."	McNeil et al. 2010

Vegetation Sampling Design

The original sampling design was selected to characterize riparian habitat at the site-level scale (Johnson et al. 2007, 2008) and was derived from the BBIRD Field Protocol (Martin et al. 1997). This point-based sampling method was chosen to provide a general

and appropriately scaled habitat characterization to guide riparian restoration efforts along the lower Colorado River. Habitat variables were selected based on the current understanding of cuckoo habitat use and physical features considered most important in characterizing breeding cuckoo habitat. Variables were selected to provide data on vegetation composition and structure, the numbers and identities of plant species present in a plot, and the relative abundance or importance of riparian woody species.

Sampling design and collection methods varied somewhat between years. The data were therefore standardized for analysis (Table 4-2). In 2006, each plot had 4 subplots; in 2007 the subplots were dropped (Johnson et al. 2008), and beginning in 2008 SSRS followed the 2007 vegetation sampling methods (Halterman et al. 2009). The 2006 and 2007 dataset contained many vegetation plots in close proximity to each other. To control for effects of plot non-independence, we averaged vegetation data from plots within 50 m of each other for the 2006 and 2007 dataset.

Table 4-2. Differences in vegetation data collection methods or definitions 2006-2010 and how addressed.

Issue	Year	Collection/Sampling Method	How Addressed
Definition of plot use	2006-2007	All plots within occupied sites were considered to be used	Plot use was recalculated for all plots (2006-2009), which were considered to be used if a cuckoo detection was recorded within 50 m of the plot center during that season
	2008	Plots were considered used if a cuckoo detection occurred within 150 m of the plot center during at least two survey periods	
	2009	Plots were considered used if at least one cuckoo detection occurred within 50 m of the plot center	
Spatially-dependent plots	2006	Each vegetation plot had four subplots close to one another	Vegetation data for plots that were located within 50 m of one another were averaged for each year's data (2006, 2007)
	2007	Subplots were dropped beginning in 2007, but some 2007 vegetation plots were located close to one another	
Small trees counted within different sized areas	2006	Small trees counted in the larger (11.3 m-radius) circle	Small tree stem counts for each species were divided by the area of the circle in which they were counted (i.e. 11.3 m radius or 401.15 m^2 for 2006, 5 m radius or 78.54 m^2 for all other years)
	2007-2010	Small trees counted in the smaller (5 m-radius) circle	
Distance to Water incomplete data set	2006, 2007	Not collected for all plots, water included river or large water body only (M. Johnson pers. comm.)	Distance to water not included in full dataset analyses, additional analysis performed on subset of data that included both distance to water (any standing water) and percent high canopy cover
	2008, 2010	Collected for all plots, water included any standing water	
	2009	Not collected for all plots, water included any standing water	
High Canopy Cover incomplete dataset	2007	High Canopy Cover not recorded	High canopy cover not included in full dataset analyses, additional analysis performed on subset of data that included both distance to water and high canopy cover
	All other years	High Canopy Cover recorded for all plots	
Nest data Collection and analysis	2006	No nests located	Additional analysis performed comparing nest plots to non-nest plots within occupied sites. Year was excluded from the analysis (as this would bias the results).
	2007, 2008, 2009	Vegetation data collected at all nest locations and also at vegetation plots in available habitat	
	2010	Vegetation data collected at all nest locations to increase sample size, but no data collected at vegetation plots in available habitat	

For all years (2006-2010), plots consisted of two circles centered on the same point: a 5-m-radius circle nested within an 11.3-m-radius circle. The inner circle was used to determine ground cover estimates and counts of small trees (except 2006, Table 4-2),

shrubs, and saplings. The larger circle was used to describe canopy layers and counts of large trees and snags.

The detailed methods for vegetation data collection are found in Appendix D. Vegetation variables collected are summarized in Table 4-3. Three general categories of vegetation data were collected: structural characteristics of the habitat (canopy height, cover, composition); ground cover characteristics (ground cover, litter depth); and plant species composition and abundance. Tree densities were derived from stem count data by dividing the total number of stems of a given species by the area of the plot. These categories were then grouped for analyses: native small tree density, native large tree density, small tree density, large tree density, tamarisk density, shrub/sapling density (native and non-native), *Populus fremontii* density, and *Salix gooddingii* density. A total of 31 habitat variables were included in the analyses (Appendix E).

Some variables considered important to cuckoos were not collected in all years (Table 4-2). We believed distance to water (the closest water source, perennial or permanent), recorded for all plots only in 2008, may be relatively important to cuckoos (Hughes 1999). We explored the importance of this variable in cuckoo plot use and nest occurrence with a subset of the data. Percent high canopy cover, not recorded in 2007, was also thought to be important (Laymon and Halterman 1985) and was included in these separate subset analyses.

Table 4-3. Vegetation parameters collected 2006-2010.

Parameter	2006	2007	2008	2009	2010[1]
Location Information	X	X	X	X	X
Main Canopy Co-dominant Species		X	X	X	X
Distance to Water[2]	X	X	X	X	X
Aspect and Slope	X	X	X	X	X
Total Canopy (all canopy layers, any height): Average Ht/Dominant Species/Cover (Densiometer Reading)	X	X	X	X	X
High Canopy (above 5 m): Average Ht/Dominant Species/Cover (Visual Estimate)	X[3]	X[4]	X	X	X
Main Canopy (layer that provides the most shade): Average Ht/Dominant Species/Cover (Visual Estimate)	X	X	X	X	X
Sub-Canopy: Average Ht/Dominant Species/Cover (Visual Estimate)		X	X	X	X
Shrub or Sapling: Average Ht/ Dominant Species/Cover (Visual Estimate)		X	X	X	X
Nearest Live Shrub in each quadrant: Species/Distance/Height/Crown Width	X	X	X	X	X
Nearest Live Tree in each quadrant: Species/Distance/Height/DBH/Crown Width/Canopy Cover	X	X	X	X	X
Nearest Snag: Species/Distance/Height/DBH	X	X			
Litter Depth: Average of 12 readings within 5 m plot	X		X	X	X
Percent Ground Cover (sum to 100%): Grass/Leaf Litter/Downed Logs/Bare Ground/Standing Water/All Green/Shrub/Forb/Sedge/Marsh Vegetation/Brush	X	X	X	X	X
Shrub or Sapling: Species/Number <2.5 cm DBH/Number 2.5-8 cm DBH	X	X	X	X	X
Small Trees: Species/Number <8 cm DBH/Number 8-23 cm DBH	X[5]	X	X	X	X
Large Trees: Species/Number 23-38 cm DBH/Number >38 cm DBH	X	X	X	X	X
Snags: Species/Number >8 cm and <12 cm DBH/Number >12 cm DBH	X	X	X	X	X

[1]Data also recorded for 2010 nests to increase the sample size for nest selection analysis.
[2]In 2006 and 2007 water included rivers and large water bodies only (M. Johnson pers. comm.). In 2008-2010, water included any standing water.
[3]In 2006 Average canopy height was not recorded for the High Canopy.
[4] In 2007 Canopy cover was not recorded for the High Canopy.
[5]In 2006 small trees were counted in the larger 11.3-m circle. In 2007-10 they were counted in the 5-m circle only.

Data Analysis

We used data from 2006-2010 to examine relationships between the habitat characteristics of yellow-billed cuckoo occupied sites, used plots (within occupied sites), and nest plots (within occupied sites) compared to available habitat. We analyzed the vegetation data using two separate statistical techniques: (1) Principal Coordinate Analysis (PCoA) and (2) multiple logistic regression.

For our initial data exploration, we performed PCoA to examine the relationships between vegetation variables and site occupancy, plot use, and nest placement, as well as

site type (restoration or natural). The object of PCoA is to reduce a dataset containing many (often correlated) variables to a smaller number of composite variables that explain the variation in a multivariate dataset (Gotelii and Ellison 2004). We removed categorical data (such as 'high canopy dominant species') prior to the analyses; these variables are not conducive to ordination techniques such as PCoA (Gotelli and Ellison 2004). We performed our PCoA on Bray Curtis dissimilarity matrices derived from vegetation data because it is most effective for continuous numerical data (Gotelli and Ellison 2004). We graphed the output data to visually inspect the results. Vegetation plots similar in their data composition will be closer together when plotted on a graph. Output from the PCoA (which represents the original dataset) can be used for visual inspection as well as further analyses.

PCoA is recommended for ordination applications in which the goal is to preserve the original multivariate distances between observations in reduced (ordination) space (Gotelli and Ellison 2004). PCoA creates a principal coordinate (PCO1) that passes through the center of a multi-dimensional dataset, and minimizes the squared distance from each point to that coordinate (i.e. explains the most variation). The second coordinate (PCO2) must also pass through the center, but it must be completely uncorrelated (i.e. orthogonal) to PCO1. Additional coordinates are created until all of the variation in the dataset is explained. Typically, the higher order coordinates (greater than third order) account for only negligible variation in the dataset. The output generated by PCoA are in the form of numeric scores which are referred to as points, one for each sample. Significant PCoA coordinates' points are visually inspected with a bi-plot.

We reduced habitat variables by performing three independent PCoAs and then examined the output for the relationships of interest (site occupancy, plot use, and nest occurrence) to determine differences in vegetation characteristics for each relationship. For each of the three PCoAs we also examined habitat differences between site types (restoration or natural). Significant principal coordinates were indicated by an eigenvalue greater than one (McCune and Grace 2002). We performed non-parametric Wilcoxon rank-sum t-tests (due to non-normal data distributions) on the output data from each significant principal coordinate (α=0.05). This test allowed us to determine if there were statistically significant differences for each relationship of interest: (1) site occupancy versus non-occupancy; (2) plot use versus available habitat; (3) nest occurrence versus available habitat; and (4) restoration versus natural sites. When the Wilcoxon rank-sum tests indicated significance, we correlated principal coordinate output data and original predictor variables (vegetation data) to infer the habitat variables responsible for the differences. Stronger correlations ($|r| > 0.50$) indicated a stronger association with that end of the respective axis.

In addition to PCoA, we performed separate multiple logistic regressions to explore hypotheses of cuckoo site occupancy, plot use, and nest selection. We checked for multicollinearity between habitat variables and excluded variables from the same model if they had a variance inflation factor greater than five in any model (Belsle et al. 1980). We used an information theoretic approach (Burnham and Anderson 2002) to model the data. Model ranking and selection was done using Akaike's information criterion (AIC_c) for small sample sizes. Burnham and Anderson (2002) advise the use of AIC_c (instead of AIC) when the sample size divided by the number of variables is less than 40, as was the case. For

each model we calculated the log likelihood (log ($\mathcal{L}$)), number of parameters (K), AIC_c values, the relative AIC_c difference (Δ_i, the AIC_c difference between each model compared to the top model with the lowest AIC_c), and the relative Akaike weights (ω_i). Models were selected using the Δ_i values, which are used to quantify the uncertainty associated with model selection and to determine the likelihood of the model given the data (Burnham and Anderson 2002). Models with Δ_i of less than 2 were considered to have substantial support, those with Δ_i between 2 and 7 considerably less support, and those with Δ_i greater than 10 to have no support (Burnham and Anderson 2002).

We used multi-model inference to obtain accurate estimates of model parameters from competing models by averaging models with a Δ_i <2 (Burnham and Anderson 2002). Model-averaged multiple logistic regression estimates and odds ratios were calculated using Akaike weights for the weighted model average (Burnham and Anderson 2002). The final averaged models contain the most important variables. We used the sample variances from each model in conjunction with the model's Akaike weight to calculate unconditional standard errors (the standard error terms are not conditional upon any one model). We calculated the relative importance of each variable in the set of top competing models by summing the Akaike weights from all the models in the set where the variable occurred (Burnham and Anderson 2002). We also calculated the independent contribution of each predictor variable to the total explained variance of the averaged model through hierarchical partitioning (MacNally 2002). Hierarchical partitioning isolates the amount of variance attributed to each predictor variable independent of any joint contribution, while the AIC_c relative importance is a measure of the variable's importance in explaining the data in the averaged model.

In our sampling design of use versus availability, model averaged logistic regression results yield a logistic discriminate function that can be used to identify those habitat characteristics most strongly correlated with habitat use based on a comparison of observed use versus random available plots (Keating and Cherry 2004). The odds ratio is used to understand the influence of predictor variables on occupancy and use versus availability (Keating and Cherry 2004). An odds ratio greater than 1 indicates a positive relationship and an odds ratio less than 1 signifies a negative relationship (Ott and Longnecker 2001). Strong relationships are indicated by odds ratios with 95% confidence intervals that do not contain 1 (Ott and Longnecker 2001). Prior to our analyses we verified that the assumptions of all statistical tests had been met. We used the R statistical package 2.11.1 for all data analyses (R Development Core Team 2010).

RESULTS

Site Occupancy

Principal Coordinate Analysis

The first (two principal coordinates (PCO1 and PCO2) were significant in summarizing the variation in the data at the site level (Figure 4-1). PCO1 explained 21.6% of variation in the data and PCO2 explained an additional 12.6% of variation for a cumulative 34.2% variation explained. Plots on restoration sites were different from those on natural sites for both PCO1 ($W = 29573; P = 0.014$) and PCO2 ($W = 13464; P < 0.001$). Occupied sites and unoccupied sites were also different for PCO2 ($W = 41567; P < 0.001$), but not for PCO1.

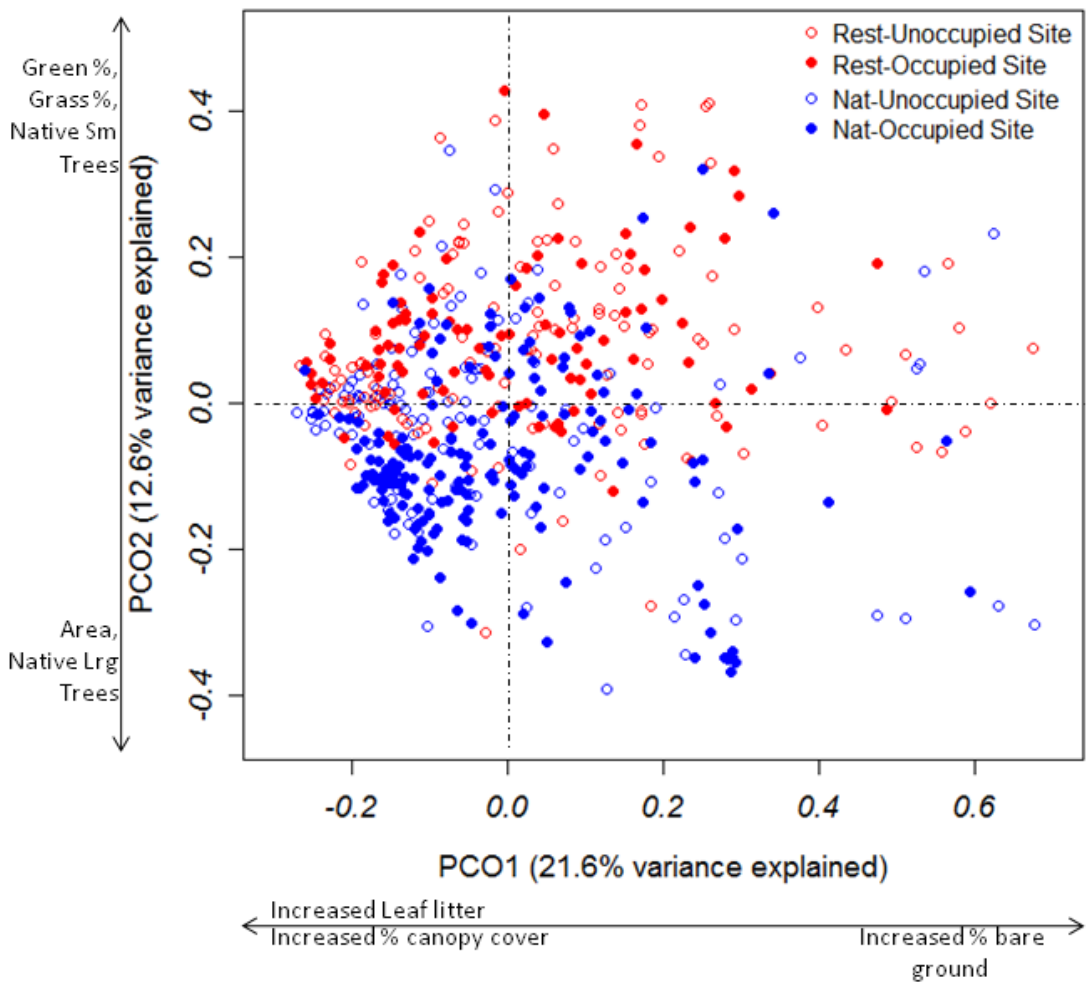


Figure 4-1. Principal Coordinate Analysis for vegetation data 2007-2009 depicting vegetation plots located at restoration sites (all red circles, n=224) and natural sites (all blue circles, n=302).

Plots in occupied natural sites (solid blue circles, n=178) and occupied restoration sites (solid red circles, n=94) are also shown. Plots on restoration sites were different than those on natural sites for both PCO1 (W = 29573; *P* = 0.014) and PCO2 (W = 13464; *P* <0.001). Occupied sites were also different than unoccupied sites for PCO2 (W = 41567; *P* <0.001), but not for PCO1. Increased canopy cover and leaf litter were the main influences on the negative end of the PCO1 axis while increased bare ground was associated with the positive end. For PCO2, increased grass cover, green cover, and native small tree densities were associated with the positive end of the axis, while site size and native large tree density was associated with the negative end.

The first coordinate (PCO1) represented the habitat variables in the dataset showing differences between restoration and natural sites (W = 29573, P = 0.014). Natural sites had increased total canopy cover (all canopy layers); *r = 0.697, P <0.001*), main canopy cover (layer that provides the most shade); *r = 0.697, P <0.001*), and leaf litter (*r =*

0.791, P <0.001) compared to restoration sites. In contrast, restoration sites had more bare ground (*r = 0.771, P <0.001*).

The second coordinate (PCO2) explained less variation in the dataset (12.6%) and these variables are of lesser strength than those associated with PCO1. PCO2 represented the habitat variables in the dataset that had the most influence on site occupancy (W = 41567, *P <0.001*) and site type (W = *13464, P <0.001*). Overall, occupied sites were larger (*r = 0.642, P <0.001*), with higher densities of native large trees (*r = 0.106, P = 0.015*, Figure 4-1). This coordinate also showed vegetation differences between restoration and natural sites. Restoration sites had greater native small tree densities, green ground cover (*r = 0.583, P <0.001*), and grass cover (*r = 0.601, P <0.001*), while natural sites were larger (*r = 0.642, P <0.001*) with more native large trees (*r = 0.106, P = 0.015*).

Multiple Logistic Regression Analysis

Five models with considerable support elucidated cuckoo occupancy at the site level (Table 4-4). These models were averaged (Burnham and Anderson 2002), resulting in an averaged model containing eleven explanatory variables (Table 4-5). The amount of variance explained and the relative importance of these eleven variables are displayed in Table 4-6.

Table 4-4. Results of AIC-based model selection for yellow-billed cuckoo site occupancy. A * indicates the model had considerable support (Δ_i <2) and was used in the averaged model.

Number	Model	K	-log likelihood	AIC_c	Δ_i	w_i
1	AR + NLT + TCC + TC + FP + MC + LP + SHP	8	-295.546	609.44	0.00*	0.21158
2	AR + NLT + TCC + TC + FP + MC + LP + SHP + TD	9	-294.683	609.79	0.35*	0.17751
3	AR + NLT + TCC + TC + MC + FP + SHP + YS	8	-294.701	609.83	0.39*	0.17421
4	AR + NLT + NST + TCC + TC + MC + FP + LP + SHP	9	-295.212	610.85	1.41*	0.10446
5	AR + NLT + TCC + TC + MC + FP + SHP	7	-297.311	610.90	1.46*	0.10195
6	AR + TCC + TC + FP + SHP	5	-300.202	612.57	3.13	0.04433
7	AR + NLT + TCC + TC + FP + SHP	6	-299.248	612.71	3.27	0.04123
8	AR + STD + TCC + TC + MC + FP + SHP	7	-298.416	613.11	3.67	0.03379
9	AR + SAD + TCC + TC + SHP + FP	6	-299.477	613.17	3.73	0.03277
10	AR + PD + TCC + TC + SHP + FP	6	-300.016	614.25	4.81	0.01913
11	AR + PD + TCC + TC + SAD + FP + TD + SHP	8	-298.914	614.74	5.30	0.01494
12	AR + TCC + TC + MC + FP + SSD	6	-302.306	614.83	5.39	0.01430
13	AR + NLT + CC + TC + MC + SSD + FP	7	-298.914	615.06	5.62	0.01277
14	AR + SSD + TCC + TC + FP	5	-302.189	615.52	6.08	0.01011
15	AR + NLT + TCC + TC + MC + NSSD + FP	7	-300.499	617.28	7.83	0.00421
16	AR + NLT + TCC + TC + MC + TD + FP	7	-300.390	618.15	8.71	0.00272
17	AR + TD + TCC + TC + SAD + FP	6	-302.090	619.51	10.07	0.00138
18	AR + TCC + TC + FP	4	-304.803	619.72	10.28	0.00124
19	AR + NLT + PD + TCC + TC + TD + FP	7	-302.644	621.56	12.12	0.00049
20	AR + TD + SHP + NLT + FP	5	-309.713	630.24	20.80	0.00001
21	AR + TCC + TC	3	-313.990	636.06	26.62	0.00000
22	AR + TCC	2	-319.886	645.82	36.38	0.00000
23	NLT	1	-356.931	718.85	109.41	0.00000
24	TCC	1	-358.803	721.63	112.19	0.00000
25	STD	1	-363.301	730.63	121.18	0.00000

Abbreviations:.AR = Area, FP = Forb Percent, LP = Percent Leaf Litter, MC = Main Canopy Average Height, NSSD = Native Shrub/Sapling Density, NLT = Native Large Tree Density, PD = *P. fremontii* Density, SAD = *S. gooddingii* Density, SHP = Percent Low Shrub Cover, SSD = Shrub/Sapling Density, STD = Small Tree Density, TCC = Percent Total Canopy Cover, TC = Total Canopy Height, TD = Tamarix Density. All abbreviations are in Appendix E.

Table 4-5. Model averaged results for important vegetation characteristics of occupied versus unoccupied yellow-billed cuckoo sites (N=429) from top models (Δ_i <2.00). The odds ratio is used to understand the influence of variables on occupied sites compared to unoccupied sites. An odds ratio greater than 1 indicates a positive relationship with site occupancy, while an odds ratio less than 1 signifies a negative relationship with site occupancy. In the averaged model the vegetation variables with the strongest associations (indicated by a *) have confidence intervals that do not include 1.

Vegetation Variable	Odds Ratio	95% Confidence Interval for Odds Ratio	Association with Site Occupancy	Estimate	Unconditional Standard Error
Native Large Tree Density	1.297	(0.96, 1.76)	+	0.26	0.156
Total Canopy Average Height	1.090	(1.03, 1.15)*	+	0.09	0.029
Percent Forb Cover	1.041	(1.01, 1.07)*	+	0.04	0.014
Area	1.031	(1.02, 1.04)*	+	0.03	0.004
Year Sampled	1.029	(0.93, 1.14)	+	0.03	0.053
Native Small Tree Density	1.016	(0.94, 1.10)	+	0.02	0.038
Percent Total Canopy Cover	1.014	(1.01, 1.02)*	+	0.01	0.004
Percent Leaf Litter	0.994	(0.99, 1.00)	-	-0.01	0.004
Tamarisk Density	0.980	(0.91, 1.06)	-	-0.02	0.039
Percent Low Shrub Cover	0.966	(0.94, 0.99)*	-	-0.03	0.013
Main Canopy Average Height	0.926	(0.86, 1.00)	-	-0.08	0.039

*indicates a strong association.

Table 4-6. Hierarchical Partitioning of the amount of variance explained and the relative importance of parameters in the averaged model (Δi <2) for occupied versus unoccupied sites. Hierarchical partitioning isolates the amount of variance attributed to each predictor variable independent of any joint contribution, while the AIC_c Relative Importance is a measure of the variable's importance in explaining the data in the averaged model. Parameters with higher numbers in the left column independently explain more variance in the model than those with lower numbers and parameters with higher numbers in the right column are of overall greater importance in the averaged model.

Variable	% Variance Explained	AIC_c Relative Importance
Area	35.85	1.00
Total Canopy Average Height	12.18	1.00
Percent Forb Cover	10.67	1.00
Percent Low Shrub Cover	10.47	1.00
Percent Total Canopy Cover	10.10	1.00
Native Large Tree Density	7.22	1.00
Year Sampled	4.48	0.23
Main Canopy Average Height	4.17	1.00
Tamarisk Density	2.41	0.23
Native Small Tree Density	1.28	0.14
Percent Leaf Litter	1.17	0.87

The averaged model showed that sites with higher densities of native large and small trees were more likely to be occupied by cuckoos. Increases in site size, total canopy cover, average total canopy height, and forb cover were also associated with cuckoo site

occupancy. Increases in tamarisk density, low-shrub cover, and average main canopy height were negatively associated with cuckoo site occupancy.

To investigate the differences in area between occupied and unoccupied sites, we performed nonparametric t-tests (i.e. Wilcoxon rank-sum tests) due to non-normal data distributions. Occupied sites were significantly larger in size than unoccupied sites ($W = 272, P < 0.001$), with occupied sites having a median size of 49.8 ± 29.4 ha (n = 272) compared to 10.6 ± 6.4 ha (n = 254) for unoccupied sites.

<u>*Plot Use*</u>

Principal Coordinate Analysis

In the exploratory analysis, the first (PCO1) and second (PCO2) principal coordinates were significant in explaining differences between used and unused plots within occupied sites. PCO1 explained 20.7% of variation in the data and PCO2 explained an additional 15.3%, for a cumulative 36.0% of total variation explained. Plots on occupied restoration sites were different than those on occupied natural sites for both PCO1 ($W = 6000; P < 0.001$) and PCO2 ($W = 14393; P < 0.001$). We saw similar trends as in the site occupancy analysis whereby occupied natural sites had increased total canopy cover ($r = 0.568, P < 0.001$), main canopy cover ($r = 0.598, P < 0.001$), native large trees ($r = 0.218, P < 0.001$), and leaf litter ($r = 0.886, P < 0.001$), and less bare ground ($r = 0.508, P < 0.001$) than occupied restoration sites. Occupied restoration sites had higher native small tree densities ($r = 0.132, P = 0.032$) and green ground cover ($r = 0.824, P < 0.001$), forbs ($r = 0.537, P < 0.001$), and grass cover ($r = 0.609, P < 0.001$). We did not explore this analysis further because no principal coordinates showed any differences between used and unused plots within occupied sites.

Multiple Logistic Regression Analysis

Five models showed considerable support for predicting cuckoo habitat use versus availability within occupied sites at the plot level (models 1 to 5, Table 4-7). The averaged model contained seven explanatory variables (Table 4-8). The variables that best explained plot use independently of other variables were shrub/sapling density, total canopy average height, and forb cover. While still important, leaf litter, low-shrub cover, grass cover, and year sampled were weaker predictors of habitat use (Table 4-9). Increases in total canopy average height, low-shrub cover, and forb cover all increased the likelihood of cuckoo plot use within occupied sites. Increases in shrub/sapling density, leaf litter, and grass cover had negative associations with plot use (Table 4-8).

Table 4-7. Results of AIC-based model selection for yellow-billed cuckoo plot use versus availability within occupied sites. A * indicates the model had considerable support (Δ_i <2) and was used in the average model.

Number	Model	K	-log likelihood	AIC_c	Δ_i	w_i
1	FP + SSD + TC + GP + LP + SHP + YS	7	-166.727	350.00	0.00*	0.16591
2	FP + SSD + TC + SHP	4	-170.063	350.35	0.35*	0.13937
3	FP + SSD + TC + GP + LP + SHP	6	-168.121	350.67	0.67*	0.11895
4	FP + SSD + TC + GP + SHP	5	-169.429	351.17	1.17*	0.09224
5	FP + SSD + TC + LP + SHP	5	-169.522	351.36	1.36*	0.08408
6	FP + SSD + TC + PD + GP + LP + SHP + YS	8	-166.713	352.12	2.11	0.05771
7	SSD + TC + SHP	3	-172.104	352.36	2.36	0.05110
8	FP + SSD + PD + TC + SHP	5	-170.061	352.44	2.44	0.04907
9	FP + SSD + TD + TC + SHP	5	-170.061	352.44	2.44	0.04903
10	FP + SSD + TC + LP + SHP + NST	6	-169.342	353.11	3.11	0.03510
11	FP + SSD + SHP + NST + TCC + YS	6	-169.412	353.25	3.25	0.03272
12	FP + SSD + SHP + NST + TC + LP + YS	7	-168.547	353.64	3.64	0.02687
13	FP + SSD + PD + TC + LP + SHP + YS	7	-168.579	353.71	3.70	0.02603
14	FP + SSD + TC	3	-172.986	354.12	4.12	0.02116
15	FP + SSD + TC + LP + YS	5	-171.104	354.53	4.52	0.01729
16	FP + SSD	2	-174.732	355.55	5.55	0.01034
17	FP + SAD + TC + LP	4	-173.068	356.36	6.36	0.00690
18	FP + TC + LP + YS	4	-173.341	356.91	6.91	0.00525
19	FP + SAD + TC + LP + YS	5	-172.513	357.34	7.34	0.00422
20	FP + SAD + LP	3	-174.811	357.77	7.77	0.00341
21	FP + SAD	2	-175.891	357.87	7.87	0.00324

Abbreviations: FP = Percent Forb Cover, GP = Percent Grass Cover, LP = Percent Leaf Litter, NST = Native Small Tree Density, PD = *P. fremontii* Density, SAD = *S. gooddingii* Density, SHP = Percent Low Shrub Cover, SSD = Shrub/Sapling Density, TC = Total Canopy Average Height, TCC = Percent Total Canopy Cover, TD = Tamarisk Density, YS = Year Sampled.

Table 4-8. Model averaged results for important vegetation characteristics of yellow-billed cuckoo occupied versus available plots (N=271) from top models (Δ_i <2.00). The odds ratio is used to understand the influence of variables on used plots compared to unused plots. An odds ratio greater than 1 indicates a positive relationship with plot use, while an odds ratio less than 1 signifies a negative relationship with plot use. An odds ratio of 1 implies that the event is equally likely in both groups. In the average model the vegetation variables with the strongest associations (indicated by a *) have confidence intervals that do not include 1.

Vegetation Variable	Odds Ratio	95% Confidence Interval	Association with Plot Use	Estimate	Unconditional Standard Error
Year Sampled	1.069	(0.83, 1.33)	+	0.066	0.111
Percent Low Shrub Cover	1.061	(1.01, 1.12)*	+	0.059	0.027
Total Canopy Average Height	1.039	(1.00, 1.08)	+	0.039	0.018
Percent Forb Cover	1.018	(1.00, 1.08)	+	0.018	0.009
Percent Leaf Litter Cover	0.996	(0.99, 1.01)	-	-0.005	0.005
Percent Grass Cover	0.992	(0.97, 1.01)	-	-0.008	0.009
Shrub/Sapling Density	0.666	(0.48, 0.93)*	-	-0.406	0.172

*indicates a strong association.

Table 4-9. Hierarchical partitioning the amount of variance explained and the relative importance of parameters in the averaged model (Δi <2) for plot use versus availability within occupied sites. Variables with higher AIC_c are more important to the model than those with lower numbers. Hierarchical partitioning isolates the amount of variance attributed to each predictor variable independent of any joint contribution, while the AIC_c Relative Importance is a measure of the variable's importance in explaining the data in the averaged model. Parameters with higher numbers in the left column independently explain more variance in the model than those with lower numbers and parameters with higher numbers in the right column are of overall greater importance in the averaged model.

Variable	% Variance Explained	AIC_c Relative Importance
Shrub/Sapling Density	29.41	1.00
Total Canopy Average Height	16.73	1.00
Percent Forb Cover	15.27	1.00
Percent Leaf Litter Cover	11.33	0.61
Percent Low Shrub Cover	10.91	1.00
Year Sampled	8.69	0.28
Percent Grass Cover	7.66	0.63

Nest Occurrence

Principal Coordinate Analysis

The first (PCO1) and second (PCO2) principal coordinates were significant in explaining nest occurrence versus availability within occupied sites (Figure 4-2). PCO1 explained 22.4% of variation in the data and PCO2 explained 17.7% of the variation in the data with a cumulative 40.1% variation explained. There were differences between nest plots and randomly selected plots for PCO1 ($W = 3576$; $P = 0.032$) and PCO2 ($W = 2822$; $P < 0.001$). There were also differences between restoration and natural sites for PCO1 ($W = 10768$; $P < 0.001$) and PCO2 ($W = 4371$; $P < 0.001$).

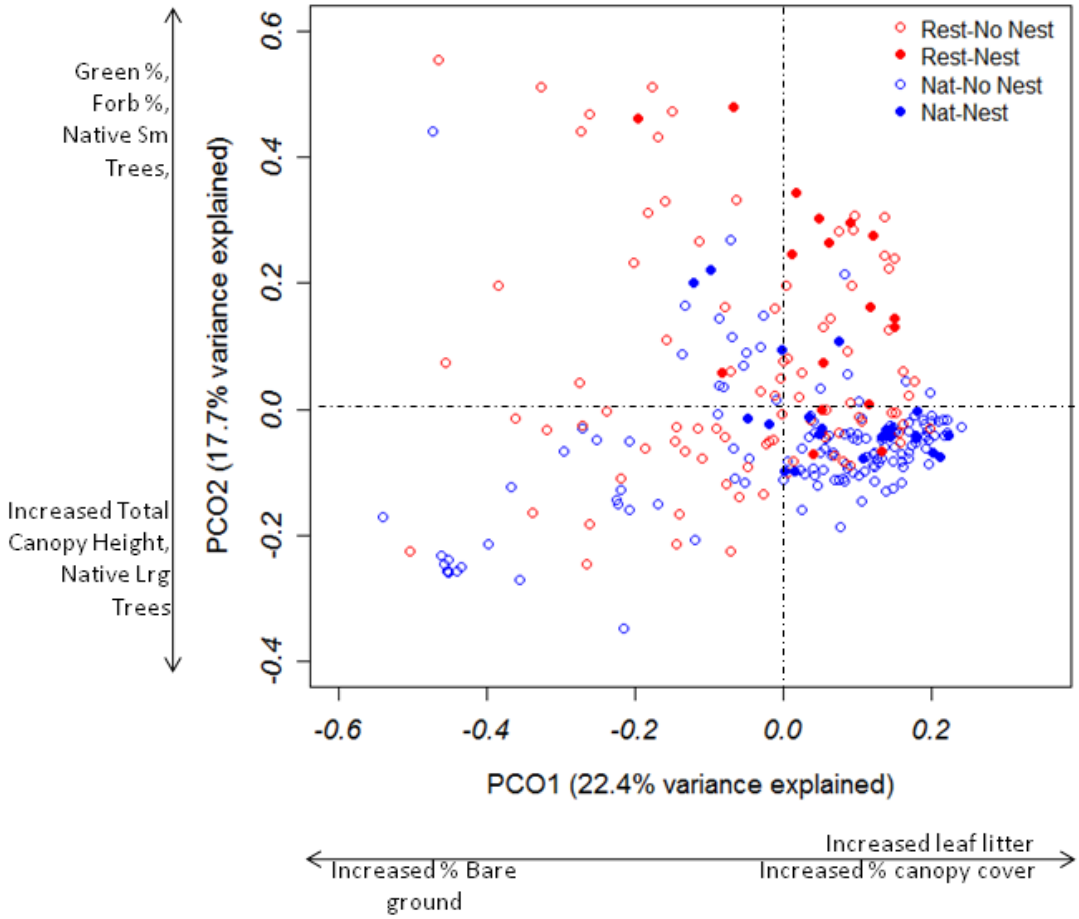


Figure 4-2. Principal Coordinate Analysis for vegetation data 2007-2010 depicting vegetation plots located at occupied restoration (red circles) and natural sites (blue circles).

Plots at nests on natural sites (solid blue circles, n=21) and restoration sites (solid red circles, n=18) are also shown. Nest and non-nest plots were different for both PCO1 (*W = 3576; P = 0.032*) and PCO2 (*W = 2822 ; P <0.001*). Plots on occupied restoration sites and occupied natural sites were also different for both PCO1 (*W = 10768; P <0.001*) and PCO1 (*W = 4371; P <0.001*). Increased canopy cover and leaf litter were the main influences on the positive end of the PCO1 axis while increased bare ground was associated with the negative end. For PCO2, increased native small tree density and green ground cover and forbs were associated with the positive end of the axis, while increased total canopy height and native large tree density were associated with the negative end of PCO2.

The first coordinate (PCO1) represented the habitat variables in the dataset that had the most influence on both nest site selection and site type within occupied sites. PC01 (22.4% variation explained) revealed that the primary influences were indicators of vegetation structure. Nest plots had higher leaf litter (*r = 0.868, P <0.001*) and total canopy cover (*r = 0.730, P <0.001*), and less bare ground (*r = 0.476, P <0.001*) than non-nest plots.

The second coordinate (PCO2) explained less variation in the dataset (17.7%). PC02 suggested that nest plots had higher green ground cover (includes grasses, low shrubs, forbs, and marsh vegetation) ($r = 0.867, P < 0.001$), forb cover ($r = 0.630, P < 0.001$), and native small tree density ($r = 0.199, P = 0.001$) than non-nest plots (Figure 4-2). The results also showed vegetation differences between restoration and natural sites for both principal coordinates. PCO1 indicated that occupied natural sites had higher leaf litter and total canopy cover than occupied restoration sites. PCO2 showed that occupied natural sites also had greater average canopy heights ($r = 0.366, P < 0.001$) and native large tree densities ($r = 0.270, P < 0.001$) than occupied restoration sites. PCO2 also showed that restoration sites, as well as nest plots at restoration sites, had more green and forb ground cover.

To test the differences in green and forb ground cover between nests and available habitat at occupied restoration and natural sites, we grouped the original data by site type and performed individual logistic regression analyses. After testing for multicollinearity between these variables, we found green ground cover and forb cover to be correlated ($r_{262} = 0.70, P < 0.001$); we therefore performed separate analyses for each variable. At occupied restoration sites, nest plots contained greater forb cover ($Z_{106} = 2.326; P = 0.020$) and green ground cover ($Z_{106} = 1.964; P = 0.049$) compared to available plots. At occupied natural sites, nest plots showed a mild increase in green ground cover ($Z_{154} = 1.82; P = 0.069$), but not forb cover ($Z_{154} = 1.429; P = 0.153$) when compared to available plots.

Multiple Logistic Regression Analysis

We performed two separate multiple logistic regression analyses for nest site selection. The first analysis employed the full dataset from 2007-2010 (no nests were

found in 2006). The second analysis was performed on a subset of the data (2008-2010) and only that data which included distance to water and percent high canopy cover. For the 2007-2010 nest analysis, eight models provided considerable support for predicting cuckoo nest placement (models 1 to 8, Table 4-10). The averaged model retained nine explanatory variables (Table 4-11). Of these, the most important were native small tree density, total canopy cover, and total canopy average height; these three variables also explained the most variance in the data (Table 4-12).

Table 4-10. Results of AIC-based model selection for predicting yellow-billed cuckoo nest placement. A * indicates the model had considerable support (Δ_i <2) and was used in the averaged model.

Number	Model	K	-log likelihood	AIC_c	Δ_i	w_i
1	TCC + TC + MCC + TD + NST	5	-74.385	161.10	0.00*	0.18169
2	TCC + TC + NST	3	-76.614	161.38	0.29*	0.15747
3	TCC + TC + MCC + TD + NST + BP	6	73.517	161.47	0.37*	0.13100
4	TCC + GNP + TC + TD + NST	5	74.810	161.95	0.85*	0.10326
5	TCC + FP + TC + MCC + NST	5	-74.927	162.18	1.08*	0.10563
6	TCC + GNP + TC + MCC + TD + NST	6	-73.889	162.22	1.12*	0.10383
7	TCC + TC + MCC + NST	4	-75.796	163.06	1.97*	0.06801
8	TCC + TC + MCC + TD + NST + NLT	6	-74.327	163.09	1.99*	0.06702
9	TCC + TC + NST + NLT	4	-76.535	163.30	2.21	0.06032
10	TCC + GNP + TC + MC + NST	5	-75.796	163.92	2.82	0.04431
11	TCC + FP + TC + NST + NLT	5	-75.881	164.09	2.99	0.04073
12	FP + TCC + GNP + TC + MC + NST	6	-75.720	165.88	4.78	0.01664
13	TCC + GNP + TD + NST	4	-78.041	166.31	5.22	0.01338
14	TCC + GNP + NST	3	-79.099	166.35	5.26	0.01312
15	TCC + NST	2	-80.508	167.11	6.01	0.00899
16	NST	1	-87.516	179.08	17.98	0.00002
17	TCC + TC	2	-97.757	201.61	40.51	0.00000
18	TCC	1	-101.886	207.82	46.72	0.00000
19	SAD	1	-106.275	216.60	55.50	0.00000
20	TC	1	-107.898	219.84	58.75	0.00000

Abbreviations: BP = Percent Bare Ground, FP = Percent Forb Cover, GNP = Percent Green Ground Cover, MC = Main Canopy Average Height, MCC = Percent Main Canopy Cover, NLT = Native Large Tree Density, NST = Native Small Tree Density, SAD = *S. gooddingii* Density, TC = Total Canopy Average Height, TCC = Percent Total Canopy Cover, TD = Tamarisk Density.

Table 4-11. Model-averaged results for important vegetation characteristics of nest (n=39) versus non-nest plots (n= 225) within occupied yellow-billed cuckoo sites. The odds ratio is used to understand the influence of variables on nest plots compared to non-nest plots. An odds ratio greater than 1 indicates a positive relationship with nest plots, while an odds ratio less than 1 signifies a negative relationship with nest plots. An odds ratio of 1 implies that the event is equally likely in both plot types. In the averaged model the vegetation variables with the strongest associations (indicated by a *) have confidence intervals that do not include 1.

Vegetation Variable	Odds Ratio	95% Confidence Interval	Association with Nests	Estimate	Unconditional Standard Error
Native Small Tree Density	1.458	(1.24, 1.71)*	+	0.377	0.080
Percent Total Canopy Cover	1.053	(1.02, 1.08)*	+	0.051	0.014
Native Large Tree Density	1.007	(0.95, 1.06)	+	0.007	0.028
Percent Green Ground Cover	1.003	(0.99, 1.01)	+	0.003	0.005
Percent Bare Ground	0.997	(0.99, 1.01)	-	-0.003	0.005
Main Canopy Average Height	0.996	(0.98, 1.02)	-	-0.004	0.010
Percent Main Canopy Cover	0.993	(0.98, 1.01)	-	-0.007	0.009
Total Canopy Average Height	0.902	(0.83, 0.98)*	-	-0.103	0.043
Tamarisk Density	0.631	(0.22, 1.81)	-	-0.461	0.539

*indicates a strong association

Table 4-12. Relative importance of parameters in each averaged model (Δ_i <2) for the nest-level. Hierarchical partitioning isolates the amount of variance attributed to each predictor variable independent of any joint contribution, while the AIC_c Relative Importance is a measure of the variable's importance in explaining the data in the averaged model. Parameters with higher numbers in the left column independently explain more variance in the model than those with lower numbers and parameters with higher numbers in the right column are of overall greater importance in the averaged model.

Variable	Variance Explained	AIC_c Relative Importance
Native Small Tree Density	56.17	1.00
Percent Total Canopy Cover	23.30	1.00
Total Canopy Average Height	5.46	1.00
Percent Green Ground Cover	4.03	0.34
Tamarisk Density	3.12	0.65
Percent Bare Ground	2.96	0.16
Main Canopy Average Height	2.49	0.07
Percent Main Canopy Cover	1.37	0.64
Native Large Tree Density	1.10	0.07

Native small tree (8-23 cm DBH) density, native large tree (>23 cm DBH) density, total canopy cover, and green ground cover were positively associated with cuckoo nest placement (Table 4-12). Increases in tamarisk density, total canopy average height, main canopy cover, main canopy average height, and bare ground were negatively associated with nest placement.

For the subset analysis, both distance to water and high canopy cover were in the competing top models. Six models provided considerable support for predicting the presence of a cuckoo nest (models 1-8, Table 4-13). The averaged models retained nine explanatory variables (Table 4-14). Of these variables, native small tree density, high canopy cover, and total canopy cover were the most important; these three variables also explained the most variance in the data (Table 4-15).

Table 4-13. Results of AIC-based model selection on a subset of the data containing distance to water and percent high canopy cover for predicting yellow-billed cuckoo nest placement. A * indicates the model had considerable support (Δ_i <2) and was used in the averaged model.

Number	Model	K	-log likelihood	AIC_c	Δ_i	w_i
1	DW + TCC + HCC + MC + TD + NST + MCC	7	-26.416	70.06	0.00*	0.14734
2	DW + HCC + TCC + MCC + NST	7	-28.901	70.51	0.45*	0.11787
3	TCC + HCC + MC + TD + NST	6	-28.936	70.58	0.52*	0.11389
4	HCC + TC + MCC + TD + NST	6	-28.964	70.63	0.57*	0.11074
5	DW + HCC + TCC + MCC + TD + NST	8	-27.983	70.92	0.85*	0.09618
6	HCC + TCC + MCC + NST	5	-30.212	70.92	0.86*	0.09581
7	DW + HCC + TCC + TC + MCC + TD + NST	4	-27.475	72.18	2.12	0.05108
8	DW + TCC + HCC + MC + BP + TD + NST	4	-27.482	72.20	2.13	0.05073
9	DW + HCC + TCC + HCC + MC + BP + TD + NST	5	-28.699	72.35	2.29	0.04699
10	TCC + HCC + MC + BP + TD + NST	3	-28.829	72.61	2.54	0.04128
11	DW + PD + TCC + HCC + MC + BP + TD + NST	6	-26.641	72.84	2.77	0.03684
12	HCC + TCC + MCC + NST + NLT	5	-30.133	72.97	2.91	0.03440
13	HCC + TCC + NST	3	-31.382	73.26	3.20	0.02973
14	HCC + MCC + TD + NST	1	-32.558	73.45	3.38	0.02712

Abbreviations: BP = Percent Bare Ground, DW = Distance to Water, FP = Percent Forbs, GNP = Percent Green Ground Cover, MC = Main Canopy Average Height, MCC = Percent Main Canopy Cover, NLT = Native Large Tree Density, NST = Native Small Tree Density, SAD = *S. gooddingii* Density, TC = Total Canopy Average Height, TCC = Percent Total Canopy Cover, TD = Tamarisk Density.

Table 4-14. Model-averaged results for important vegetation characteristics of nest plots (N=17) versus non-nest plots (N=109) on a subset of the data (N=126) containing Distance to Water and Percent High Canopy Cover. The odds ratio is used to understand the influence of variables on nest plots compared to non-nest plots. An odds ratio greater than 1 indicates a positive relationship with nest plots, while an odds ratio less than 1 signifies a negative relationship with nest plots. An odds ratio of 1 implies the event is equally likely in both plot types. The variables with the strongest associations (indicated by a *) have confidence intervals that do not include 1.

Vegetation Variable	Odds Ratio	95% Confidence Interval	Association with nest sites	Estimate	Unconditional Standard Error
Native Small Tree Density	1.451	(1.104, 1.904)*	+	0.372	0.139
Percent Total Canopy	1.068	(1.014, 1.125)*	+	0.066	0.026
Percent High Canopy Cover	1.048	(1.012, 1.085)*	+	0.047	0.018
Distance to Water	0.999	(0.996, 1.002)	-	-0.001	0.002
Percent Main Canopy Cover	0.972	(0.932, 1.015)	-	-0.028	0.22
Main Canopy Average Height	0.910	(0.696, 1.190)	-	-0.094	0.137
Tamarisk Density	0.313	(0.028, 3.490)	-	-1.160	1.230

*indicates a strong association.

Table 4-15. Relative importance of parameters in each averaged model (Δ_i <2) on a subset of the data containing Distance to Water and Percent High Canopy Cover at the nest level. Hierarchical partitioning isolates the amount of variance attributed to each predictor variable independent of any joint contribution, while the AIC_c relative importance is a measure of the variable's importance in explaining the data in the averaged model. Parameters with higher numbers in the left column independently explain more variance in the model than those with lower numbers and parameters with higher numbers in the right column are of overall greater importance in the averaged model.

Variable	Variance Explained	AIC_c Relative Importance
Native Small Tree Density	31.56	1.00
Percent High Canopy Cover	27.70	1.00
Percent Total Canopy Cover	18.01	1.00
Distance to Water	12.55	0.53
Main Canopy Average Height	3.90	0.38
Tamarisk Density	3.67	0.69
Percent Main Canopy Cover	2.60	0.83

Even with a limited dataset, high canopy cover was positively associated with cuckoo nest placement. Also, as the distance to water increased, the probability of a cuckoo placing a nest at that location decreased. Similar to the analysis of the full dataset, native small tree density and total canopy cover had positive associations with cuckoo nest placement. Increases in tamarisk density, main canopy average height, and main canopy percent cover were negatively associated with cuckoo nest placement (Table 4-15).

Discussion

The extensive revegetation efforts on the historical lower Colorado River floodplain has thus far created successful yellow-billed cuckoo breeding habitat. Compared to natural sites, the restoration sites are overall in an earlier successional stage; however, there was overlap in vegetation characteristics. Over future years, we expect to see this overlap increase, with restoration sites having increased native large tree densities, canopy cover, tree heights, and leaf litter, and less bare ground.

Site Occupancy

Over the past five years, potentially suitable habitat ranging in size from 0.7 to 126.8 ha has been surveyed within the LCR MSCP boundary. Our results indicate that area (site size) was extremely important to cuckoos and was a strong predictor of cuckoo site occupancy. We found the median size of occupied sites (49.8 ha) to be almost five times as large as unoccupied sites (10.6 ha). The positive relationship between habitat size and occupancy has been previously documented for western yellow-billed cuckoos. Similar to our results, Laymon and Halterman (1989) concluded that willow/cottonwood habitat <15 ha in extent and <100 m in width were unsuitable, sites 20-40 ha and 100-200 m wide were marginal, sites 41-80 ha and wider than 200 m were suitable, and sites >80 ha and wider than 600 m were optimal in a study done in California.

After increased area, several tree-related habitat variables were found to be important predictors of cuckoo site occupancy, including increased total canopy average height and cover. Cuckoo foraging behavior in dense canopy at heights greater than 3 m has been documented previously in California riparian habitat (Laymon et al. 1997); these

results concur with that preference. Higher densities of native large trees, and to a lesser extent, native small trees positively influenced site occupancy. Paradoxically, increased main canopy (layer providing the most shade) average height was negatively associated with cuckoo site occupancy while total canopy (all canopy layers) average height was positively associated with site occupancy. This may indicate that at the site level, cuckoos prefer more native large trees than native small trees, but also suggests that cuckoos use smaller trees (likely for nest placement). It seems they prefer a structurally diverse habitat of both native large and small trees. Mixed-height habitat stands would be similar to the historical riparian habitat where frequent spring flooding created patches of small native trees including Fremont cottonwood and Goodding's willow (Stromberg 2001). Creation of this type of mosaic habitat is already part of the goals of the LCR MSCP (LCR MSCP 2004a).

As expected, cuckoo site occupancy decreased with increased tamarisk density. Conversely, cuckoos in New Mexico have used tamarisk habitat where temperatures are lower than on the LCR, but these were not monotypic stands (Livingston and Schemnitz 1996). Overall, the preference for native trees was expected and concurs with multiple other studies that show cuckoos prefer to inhabit cottonwood-willow riparian forests (Laymon 1980, Gaines and Laymon 1984, Girvetz and Greco 2009).

At the ground level, increased forb cover was positively associated with cuckoo site occupancy. This result may be due to irrigated restoration sites causing increased forb cover (particularly alfalfa). This low vegetation may also provide an indirect source of food, i.e. a breeding and/or feeding ground for insect prey. Yellow-billed cuckoos at restoration sites forage on prey other than cicadas (Chapter 3) and the grasses and forbs at

restoration sites could be a partial source of this alternative prey (directly or indirectly). Yellow-billed cuckoos feed on a variety of prey including large macroinvertebrates such as caterpillars, katydids, grasshoppers, crickets, and mantids (Laymon 1980, Halterman 2009, Chapter 3) which can be found in this type of habitat (Borror et al. 1989). Additional macroinvertebrate sampling in grasses and forbs would explore this hypothesis and assess whether ground cover is important for cuckoo site occupancy.

The response of vegetation to river regulation depends on the interaction of species-specific life history strategies and flow regime characteristics (Mortenson and Weisberg 2010). Dewatered streams in arid regions decrease obligate floodplain species that depend on shallow water tables or perennial stream flows, while upland species that grow on drier portions of the floodplain may be unaffected or expand into areas once occupied by riparian obligates (Stromberg et al. 1996). Increased low-shrub cover (the percentage of ground covered by woody perennial plants that are below 50 cm tall) at unoccupied sites may reflect a drier plant community that has resulted from stream regulation.

Historically, river floodplains along the lower Colorado River experienced periodic flooding from increased influxes of water due to snow melt in early spring and monsoons in late summer (Webb et al. 2007). Increased leaf litter may be another indication of river floodplains that are not subject to annual flood pulses (Ellis et al. 1999). This may be particularly true in arid systems, where a lack of moisture throughout most of the year inhibits decomposition by decreasing microbial activity on the soil surface (Facelli and Pickett 1991). Our results indicate that although leaf litter was negatively associated with

cuckoo site occupancy, it was not a strong association and may be a factor of other site-level attributes.

Overall, cuckoos appear to select sites based on increased native large and small tree densities, total canopy average height, canopy cover, and site size. Cuckoos have been detected more often in the latter years of the study and appear to be responding positively to habitat creation.

Plot Use

The plot-level and the site-level analyses exhibited similar trends. We found a positive association between cuckoo plot use and increased total canopy average height. The selection for increased canopy height may be a measure of foraging habitat preference (Laymon et al. 1997). Used plots showed few significant differences in overstory vegetation compared to available plots within occupied sites, but did show different understory characteristics. Increases in forb cover increased the likelihood of cuckoo plot use; again, the low vegetation may provide an indirect source of prey.

Although site occupancy can be assessed accurately with our data, we suspect that our finer scale analyses of plot use may be less precise; mainly because when playing a call back, it is typical for a cuckoo to be drawn toward the surveyor from up to 100 m away (Halterman 2009). Since our used plots only represent locations where a cuckoo was detected within 50 m, the inclusion of playback detection locations to analyze cuckoo plot use could lead to specious results. Findings from a study in the Kern River Valley showed that cuckoos attracted by a playback behaved in a biased manner, and therefore did not reflect their true habitat use (Laymon and Halterman 1985). The assumption that

vegetation characteristics are the same on the sampled plot as that which the cuckoo was residing may therefore not be valid. Consequently, we view these results with some skepticism. A more appropriate method to address the question of how cuckoos are selecting habitat at the plot level may be habitat use observations through radio telemetry paired with random available habitat sampling.

Nest Placement

Yellow-billed cuckoo nests have primarily been found in locations with specific vegetation structures when compared to available habitat. Increased native small tree density was the strongest predictor of cuckoo nest placement, especially at restoration sites. Increased native large tree density also increased the likelihood of nest placement; however this relationship was weaker. Native large trees may be important because they provide canopy cover, a seed source, and foraging areas (Laymon and Halterman 1985). Decreases in total and main canopy average height were associated with cuckoo nests and likely reflect the preference for small trees over larger trees as suitable nesting habitat, but may also be because we tend to find nests located at lower heights easier. Similar nesting results have been observed along the South Fork Kern River in California where optimal nesting sites tended to have a mean canopy height of 7-10 m, while sites 10-15 m high were chosen less frequently (Laymon et al. 1997).

Additionally, increased cover at all canopy levels had strong positive relationships with cuckoo nest placement. This result was expected and has been documented previously. In California, cuckoos chose nest locations characterized by greater canopy closure and higher foliage volume (Laymon et al. 1997). Increased cover from dense foliage is important for concealing and protecting the nest from predators (Laymon 1980).

Increased cover over the nest will also shade the nest, keeping it cooler and increase nestling survival (Rangel-Salazar et al. 2008). Our results also show that decreases in main canopy cover increased nest placement probability. This suggests that cuckoos are placing nests in locations with increased canopy cover at all canopy levels, but the main canopy cover does not need to be great. It may indicate that cuckoos prefer nest locations in areas with structural diversity. For example, stands of mixed-age trees, or areas near edges may display these characteristics. Parker et al. (2005) found yellow-billed cuckoos to have an affinity for edges, while Hamilton and Hamilton (1965) often found cuckoo nests at the edge of openings.

Increased tamarisk density resulted in a negative response in nest site selection from 2007-2010, yet tamarisk was also the most common natural site nest tree in 2010 (Chapter 3). However, these nest trees were found within a mosaic of native trees. Tamarisk thrives where spring floods and water flows have declined, the water table has become too deep, and soils are too salty for mesic native vegetation to survive (Shafroth et al. 2005). Establishment of native trees (cottonwood-willow forests) requires floods which create areas for germination, keep the seedlings moist, and protect them from subsequent burial and prolonged inundation (Scott et al. 1997, Tallent-Halsell and Walker 2002). Tamarisk has superior salt tolerance, is equivalent to native species in growth and water use characteristics, and inferior in flood tolerance (Vandersande et al. 2001). This suggests that tamarisk would possess less of a competitive advantage over native floodplain plant communities under a more natural hydrologic regime (Vandersande et al. 2001). We suspect that dense monotypic stands of tamarisk are unsuitable nesting habitat, but at low

densities where small patches are found within a mosaic of native floodplain vegetation, tamarisk is not a deterrent for cuckoo nest site selection.

Nest locations tended to be closer to water, with increased high canopy cover than available habitat within occupied sites. These results concur with other studies on cuckoo nest site selection (Gaines 1974, Gaines and Laymon 1984). Cuckoos may prefer these as nest sites because of lower temperatures and increased humidity found in this type of microhabitat (Chapter 5).

At restoration sites, increased green ground and forb cover were associated with nests while at natural sites, nest locations were not associated with increased forb abundance, but still exhibited a weak association with green ground cover. The stands of young trees which provide preferred nest locations for cuckoos are likely associated with forbs and green ground cover. The low vegetation may be providing an indirect source of food and/or indicate a more preferred microclimate since these types of vegetation thrive in moist conditions (Stromberg et al. 1993). In the South Fork Kern River Valley, Laymon et al. (1997) also found increased forb cover at cuckoo nests compared to available habitat. To explore these results further, additional macroinvertebrate sampling and observations in grasses and forbs would be required. Overall, the results show that yellow-billed cuckoos are selecting nest locations based on high densities of native small trees and increased cover at all canopy layers; they may be secondarily selecting for high grass and forb cover.

Management Considerations

Our results support the current understanding that yellow-billed cuckoos depend on large patches of habitat, native large tree overstory for foraging, and dense canopy cover

for nesting (Laymon and Halterman 1991). We also found that increased densities of small native trees were important to cuckoo nest placement. Our strongest results along with management recommendations are presented in Table 4-16.

Table 4-16. Strongest factors associated with cuckoo site occupancy and nest placement.

Vegetation Variable	Important for:	Association	Recommended Management Action
Area	Site Occupancy	+	Increase
Year	Site Occupancy	+	None – indicates a positive response to restoration
Leaf Litter	Site Occupancy	-	None
Low Shrub Cover	Site Occupancy	-	Increase moisture at dry sites
Total Canopy Average Height	Site Occupancy/ Nest Placement	+/-	Create varied habitat
Main Canopy Average Height	Site Occupancy/ Nest Placement	-/-	Create varied habitat
Forb Cover	Site Occupancy/ Nest Placement		Increase moisture at dry sites
Tamarisk Density	Site Occupancy/ Nest Placement	-/-	Decrease monotypic stands
Native Small Tree Density	Site Occupancy/ Nest Placement	+	Increase
Total Canopy Cover	Site Occupancy/ Nest Placement	+/+	Increase
Main Canopy Cover	Nest Placement	-	Create varied habitat
Green Ground Cover	Nest Placement	+	Increase moisture at dry sites
Bare Ground	Nest Placement	-	None
High Canopy Cover	Nest Placement	+	Increase

Disruption of seasonal flood patterns and channelization typically create homogenous groves of mature cottonwoods and willows (Stromberg 2001). These areas may be suitable for foraging by cuckoos, but provide neither the dense canopy cover nor native small tree densities preferred for nest placement. A heterogeneous mixture of mature and young stands of native trees would fulfill both the foraging and nesting requirements of the yellow-billed cuckoo. Currently, restoration sites are characterized by high native small tree densities which appear to be preferred nest locations. If the trees are encouraged to grow, but not to reproduce, in the future these sites may contain native large

trees only, which may not provide favorable nesting habitat. Optimal management practices should aim to provide riparian habitats that continue to provide both mature large trees and dense patches of small trees.

Although restoring historical flow regimes may not be practical, river restoration projects should use knowledge of native and non-native species' life history strategies (Mortenson and Weisberg 2010) to reinstate or mimic water conditions as close to natural as possible. Tamarisk and other low shrubs are more tolerant of low soil moisture than cottonwood and willow, but most depend on moist substrate for seed germination and establishment and therefore typically dominate areas with relatively infrequent surface flow and deep groundwater (Lite and Stromberg 2005, Busch and Smith 1995. For example, non-seasonal flood releases late in the growing season (August) may cause mortality of cottonwood seedlings, while encouraging tamarisk seed dispersal and germination (Warren and Turner 1975). In damper conditions at the right time, cottonwood seedlings can decrease the growth and survival of tamarisk seedlings through competition (Sher and Marshall 2003). A more naturalized water regime with flooding at appropriate times (mimicking peak spring floods) will benefit established native species, and favor natural regeneration of native tree species. This strategy would ensure the creation of other habitat characteristics that will benefit cuckoos including increased canopy cover, the creation of varied habitat, and increased native small and large tree densities.

Chapter 5. MICROCLIMATE

Introduction

Microclimate can affect a species' foraging and nesting decisions, and can be a determinant of habitat suitability. Birds may respond to microclimate changes directly or indirectly depending on specific habitat preferences and life history traits (Champlin et al. 2009). For example, in extreme environments birds may shift habitat use in regards to microclimate factors for physiologic comfort (Champlin et al. 2009) or prey availability (Wachob 1996, Wilson 2005). In the southwestern United States, Walsberg (1986) documented that Phainopepla (*Phainopepla nitens*) shifted to cooler microclimates to balance thermoregulatory demands during the summer months. Additionally, the importance of microclimate to nesting birds has been documented for several species (D'Alba et al. 2009, Hoekman et al. 2009, Robertson 2009). These studies found that temperature and/or humidity differences can affect reproductive outcomes. However, few studies have specifically addressed avian nest site selection due to differences in microclimate in extreme desert riparian habitats, where temperature and humidity likely have a strong influence on reproductive success.

In 2009, our results showed that yellow-billed cuckoo nest sites exhibited lower temperatures and higher relative humidity than available habitat within occupied sites (McNeil et al. 2010). We also found that occupied sites had higher diurnal and nocturnal humidity than unoccupied sites, while used plots had slightly lower diurnal temperatures than available plots (McNeil et al. 2010). However, we saw that microclimate varied along

a latitudinal gradient (becoming hotter and drier from north to south, McNeil et al. 2010) which likely affected some of our results. To further our understanding of microclimate influences on yellow-billed cuckoo distribution on the lower Colorado River, we continued to monitor microclimate in 2010 at the site, plot, and nest level, and controlled for latitudinal differences in the analysis.

Methods

We used one model of Thermocron iButton® (Embedded Data Systems LLC) to measure temperature (DS1921G), and another model (DS1923) to measure both temperature and relative humidity (RH) at sites during the 2010 breeding season. We programmed and uploaded data from IButtons® (hereafter called data loggers) using a dual iButton® receptor interface cable and high speed USB interface adapter (SK-IB-R Connectivity Kit made by Embedded Data Systems LLC) and One Wire Viewer© software (Maxim Integrated Products). The data loggers were set to record temperature and RH once each hour, on the hour. They were also synchronized and programmed to record temperature to the nearest 0.5° Celsius (C) and to 0.6% RH.

A stainless steel wire was glued to each data logger with epoxy before it was suspended from a 5.1 cm x 5.1 cm x 1 cm plastic container which provided shade. The containers were painted light beige and suspended with wire 2 m above the ground in a shaded area at the center of microclimate monitoring plots. Data loggers were deployed at sampling plots between 15 June and 13 July. Additional data loggers were placed at nests within a few days of discovery. We took care to conceal the data loggers and to minimize disturbance to nesting birds. Nests were found between mid-July and early August, so this

data set covers less time than the rest of the loggers. Data loggers were retrieved between mid-August and mid-September.

We averaged hourly data from each data logger to estimate diurnal (05:00:01-19:00:00) and nocturnal (19:00:01-05:00:00) means for each day. We used these averages to determine differences between occupied and unoccupied sites. We only used data from occupied sites to assess differences in microclimate at the plot and nest level. For the nest analysis, we truncated the data to between the second week of July and the first week of August, when nests were active.

Microclimate Plot Selection

Microclimate monitoring plots were established throughout the study region. Areas of both occupied and unoccupied habitat for 2006-2008 were determined using ArcGIS 9.3 and detection/non-detection data from the past three years. Microclimate data loggers were placed at the centers of these areas in 2009 (McNeil et al. 2010) and 2010. Logger placement was stratified by occupancy status (occupied or unoccupied) and site type (restoration site or natural). Microclimate data loggers were placed at 139 plots within 42 sites.

Microclimate plot use was determined at the end of the season based on the current year's detections. A microclimate plot (hereafter referred to as plot) was considered used if a cuckoo was detected during the season within 50 m of the plot center. This distance was chosen to separate plots with spatially dependent (proximally close) detections from those with no dependent detections, while ensuring a sufficient number of used plots for

analyses. For site occupancy status, we considered a site to be occupied if a cuckoo was detected during at least two survey periods and at least 12 days apart.

Data Analysis

We examined relationships between microclimate of occupied and unoccupied sites, used and unused plots (within occupied sites), and nest sites compared to microclimate of available habitat (within occupied sites). We also analyzed the relationship between microclimate variables and site type (restoration or natural). For the plot level analysis, we only included diurnal data because this is when we observed cuckoo use on the plots. We used logistic regression mixed-effects models to analyze temperature and humidity because of our repeated measures dataset. We also incorporated latitude (UTM Northing) into our models to account for latitudinal variation across sites (McNeil et al. 2010). We used odds ratios to understand the influence of microclimate on use versus availability (For details see Chapter 4). An odds ratio greater than 1 indicates a positive relationship and an odds ratio less than 1 signifies a negative relationship (Ott and Longnecker 2001). We performed separate analyses for nocturnal and diurnal RH and temperature because of multicollinearity amongst these four variables. Additionally, we employed Pearson's correlation coefficient to examine relationships between microclimate and total canopy cover (spherical densiometer readings: see Appendix D). The dataset for this last analysis used plot averages and was truncated to include only those plots from which temperature, RH, and canopy cover readings were available. We also performed a paired t-test comparing the average difference between nest and available habitat at the same site to control for temporal and latitudinal variation. We used the R statistical package 2.11.1 for all data analyses (R Development Core Team 2010).

Results

Temperature and humidity data loggers were placed at 139 locations within 42 sites; 26 loggers recorded temperature only. Eight loggers failed to record data or were lost. Microclimate averages are displayed in Figure 5-1 and Figure 5-1. Both temperature and humidity showed temporal variation (Figure 5-1). Temperatures peaked once in early July, then again in mid-August, while RH peaked in mid-August. Diurnal temperatures were negatively correlated to canopy cover ($r_{121} = -0.357, P < 0.001$), while diurnal RH was not correlated to canopy cover ($r_{96} = 0.245, P = 0.881$). Canopy cover was negatively correlated to nocturnal temperature ($r_{121} = -0.245, P = 0.015$), but not nocturnal humidity ($r_{96} = 0.270, P = 0.788$). As expected, temperature and RH were highly negatively correlated both diurnally ($r_{96} = -0.942, P < 0.001$) and nocturnally ($r_{96} = -0.900, P < 0.001$).

Table 5-1. Average and standard deviation for microclimate at restoration and natural sites, occupied sites and available habitat sites, used and available plots, and nests versus available plots.

	Temperature (°C)		Humidity (%RH)	
Status[1]	Diurnal	Nocturnal	Diurnal	Nocturnal
Restoration Site	33.80 ± 2.97 (n=53)	27.37 ± 3.96 (n=53)	41.55 ± 13.32 (n=51)	52.80 ± 15.56 (n=51)
Natural Site	31.67 ± 2.91 (n=62)	26.28 ± 4.10 (n=62)	50.64 ± 13.66 (n=44)	61.26 ± 16.35 (n=44)
Occupied Site	32.70 ± 3.11 (n=27)	26.81 ± 4.04 (n=27)	45.91 ± 14.66 (n=25)	56.86 ± 16.75 (n=25)
Unoccupied Site	32.53 ± 3.20 (n=13)	26.72 ± 4.20 (n=13)	44.63 ± 11.93 (n=12)	55.61 ± 15.10 (n=12)
Used Plot	33.11 ± 3.08 (n=64)	26.88 ± 4.03 (n=64)	43.76 ± 14.40 (n=53)	55.33 ± 16.33 (n=53)
Unused Plot	31.81 ± 2.98 (n=30)	26.66 ± 4.06 (n=30)	50.84 ± 14.06 (n=24)	60.38 ± 17.16 (n=24)
Nest Plot	30.11 ± 2.82 (n=17)	24.31 ± 3.45 (n=17)	61.81 ± 8.71 (n=10)	75.59 ± 10.33 (n=10)
Non-nest Plot	32.67 ± 3.12 (n=94)	26.81 ± 4.04 (n=94)	45.91 ± 14.66 (n=77)	56.86 ± 16.75 (n=77)

[1]Status: Site means were calculated by first averaging all plots within each site, then averaging the occupied and unoccupied sites. Site type means were also calculated this way. Plot data and nest averages were calculated by averaging all temperatures recorded from each data logger and were based on data from occupied sites. All averages do not take latitude into account.

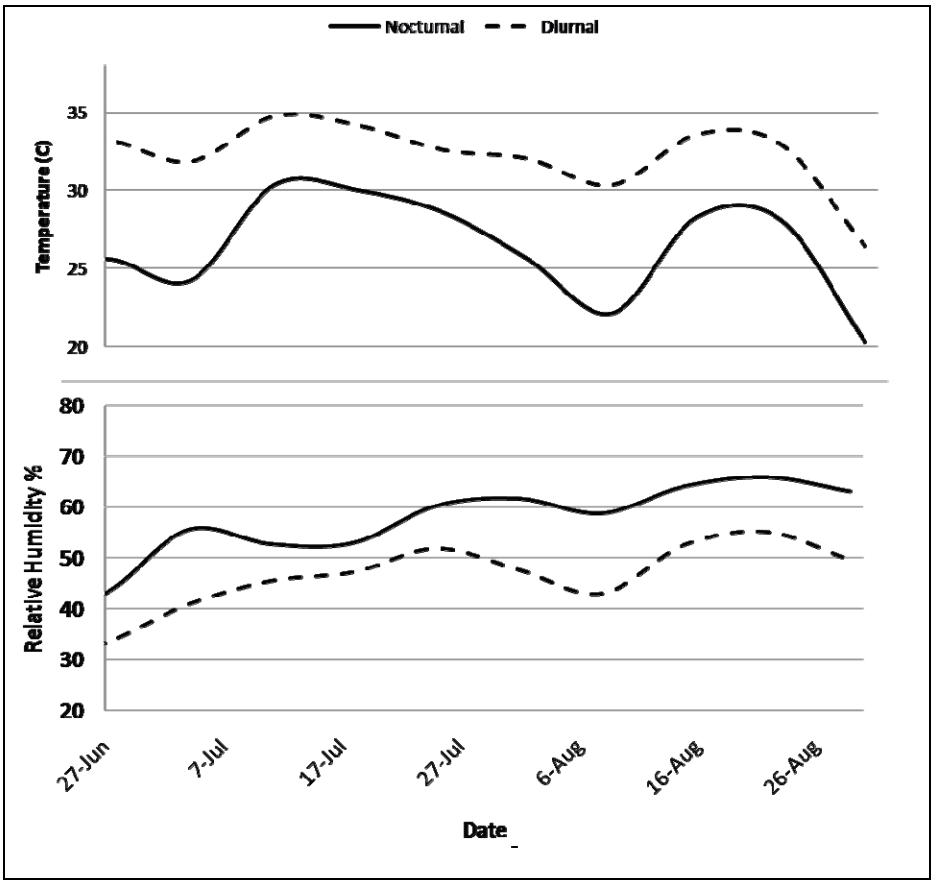


Figure 5-1. Average diurnal and nocturnal temperature (°C) and relative humidity (%) averaged by week during the 2010 survey season. Averages do not take latitude into account.

We found no differences between site types (restoration or natural, Table 5-2) or between occupied and unoccupied sites for diurnal and nocturnal temperatures or RH (Table 5-3). Within occupied sites, we also found no differences between used and unused plots for diurnal temperature or RH (Table 5-4).

Table 5-2. Site type (restoration versus natural) results of logistic regression mixed-effects models for diurnal and nocturnal temperature and humidity, LCR 2010. No significant results (P <0.05).

Microclimate Variable	Odds Ratio	Estimate	Standard Error	P-Value
Diurnal Temperature	1.276	0.244	3.024	0.936
Nocturnal Temperature	0.988	-0.012	1.939	0.995
Diurnal Relative Humidity	1.021	0.021	0.678	0.956
Nocturnal Relative Humidity	0.967	-0.033	0.699	0.962

Table 5-3. Site Occupancy results of logistic regression mixed-effects models for diurnal and nocturnal temperature and humidity. No significant results (P <0.05).

Microclimate Variable	Odds Ratio	Estimate	Standard Error	P-Value
Site Diurnal Temperature	0.960	-0.041	2.616	0.987
Site Nocturnal Temperature	0.988	-0.012	1.939	0.995
Site Diurnal Relative Humidity	1.021	0.021	0.740	0.978
Site Nocturnal Relative Humidity	1.016	0.016	0.544	0.976

Table 5-4. Plot use results of logistic regression mixed-effects models for diurnal and nocturnal temperature and humidity, LCR 2010. No significant results (P <0.05).

Microclimate Variable	Odds Ratio	Estimate	Standard Error	P-Value
Plot Diurnal Temperature	0.999	-0.001	0.016	0.970
Plot Diurnal Relative Humidity	1.002	0.002	0.004	0.658

Similar to our results from 2009, we found that microclimate was different at nests compared to available habitat (Figure 5-2, Figure 5-3). These differences were significant when controlling for latitude and repeated measurements (Table 5-5). Nest sites were more likely to be located at plots with lower diurnal and nocturnal temperatures. Correspondingly, nest plots were also more likely to have higher diurnal and nocturnal RH. The paired t-test showed the same results (Table 5-6), however the mean difference estimates should not be interpreted directly because of the small sample sizes and large standard deviations.

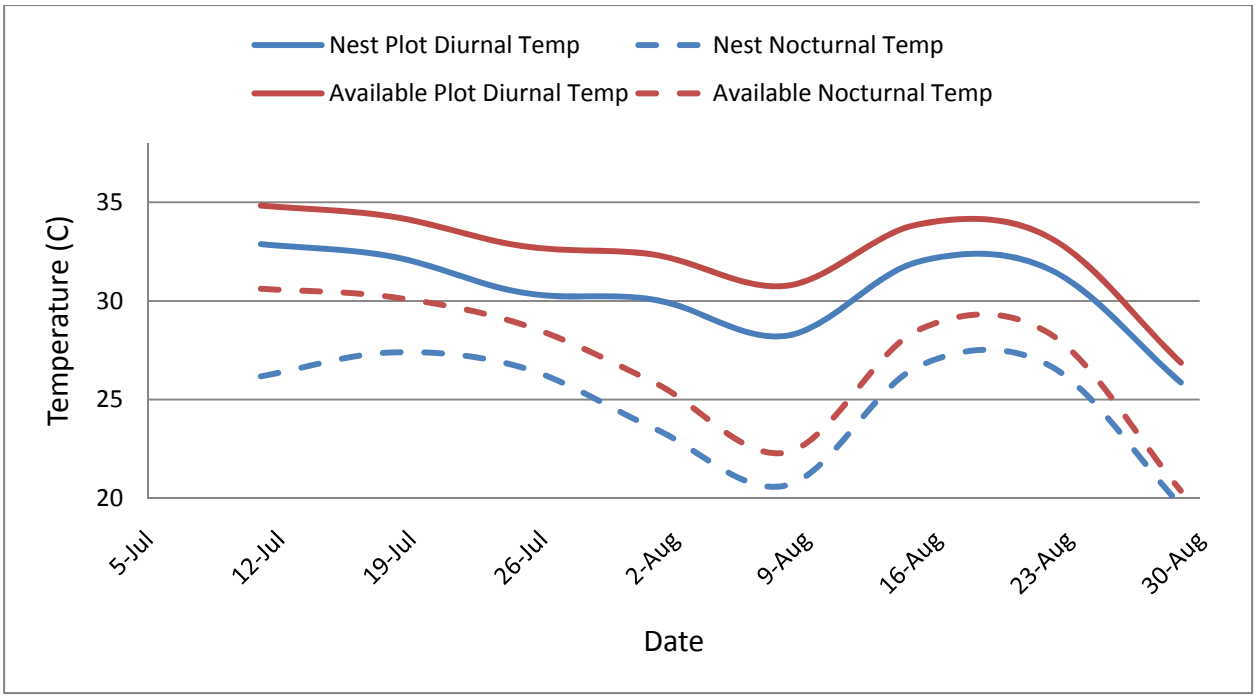


Figure 5-2. Average diurnal and nocturnal temperature (°C) at nest plots versus available plots (occupied sites only) during the 2010 survey season.

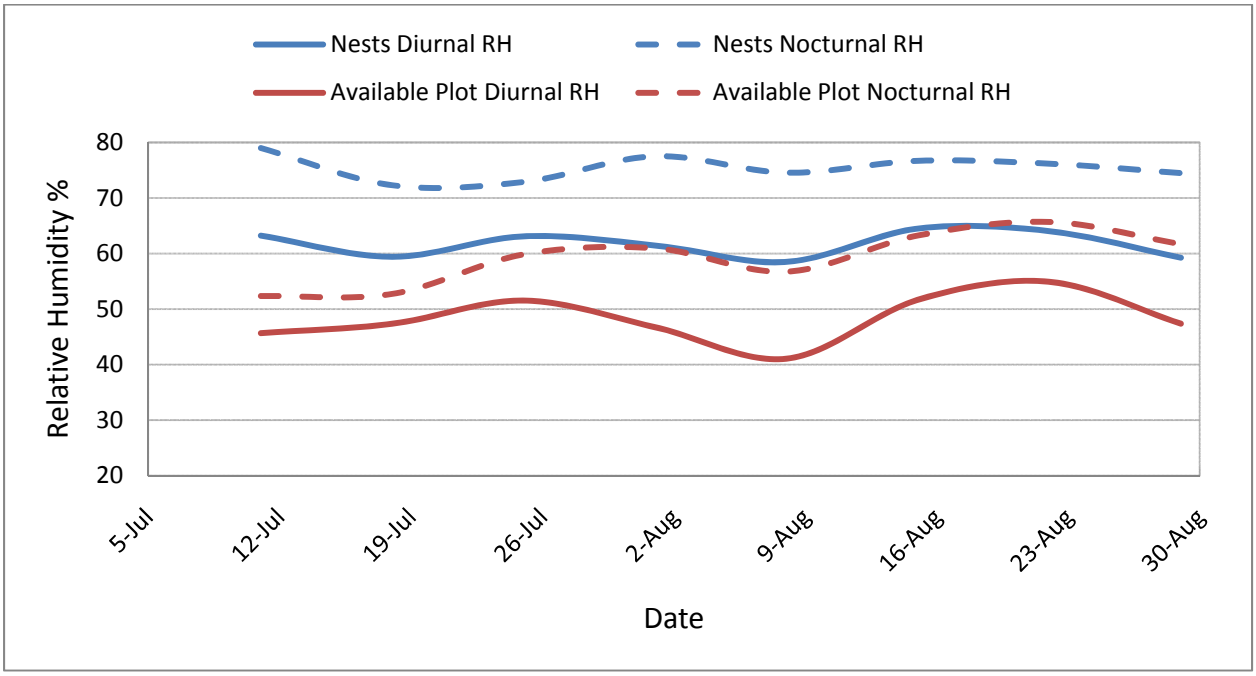


Figure 5-3. Average diurnal and nocturnal relative humidity (%) at nest plots versus available plots (occupied sites only) during the 2010 survey season.

Table 5-5. Nest placement logistic regression mixed-effects models for diurnal and nocturnal temperature and humidity. The odds ratio is used to understand the difference in nest plots compared to available habitat for temperature and humidity. An odds ratio greater than 1 indicates a positive relationship with occupied sites, while an odds ratio less than 1 signifies a negative relationship with occupied site.

Microclimate Variable	Odds Ratio	Estimate	Standard Error	P-Value
Nest Diurnal Temperature	0.839	-0.175	0.019	<0.001
Nest Nocturnal Temperature	0.890	-0.117	0.015	<0.001
Nest Diurnal Relative Humidity	1.082	0.079	0.008	<0.001
Nest Nocturnal Relative Humidity	1.089	0.085	0.008	<0.001

Table 5-6. Mean differences, standard deviation, and paired t-test results for microclimate at paired nest plots versus available habitat within occupied sites.

	Temperature Difference (^{o}C)		Humidity Difference (%RH)	
Comparison	Diurnal	Nocturnal	Diurnal	Nocturnal
Nest plot vs. available	- 1.63 ± 1.33 (N=17) t_{16} = -5.08, P <0.001	-1.75 ± 0.97 (N=17) t_{16} = -7.46, P <0.001	11.36 ± 7.97 (N=10) t_{9} = 4.51, P <0.001	13.71 ± 2.89 (N=10) t_{9} = 7.45, P <0.001

Discussion

We found no significant differences in humidity or temperature (diurnal or nocturnal) between occupied and unoccupied sites, or between natural and restored sites when we controlled for latitude. The lack of association between site occupancy and microclimate may be an indication that cuckoos are not selecting larger-scale areas (i.e. sites) based on temperature and humidity alone. Our sites may also exhibit analogous microclimate characteristics because they are all located in potentially suitable cuckoo habitat within cottonwood-willow riparian vegetation on the LCR. We also found no differences in temperature or diurnal humidity between used and unused plots within occupied sites. Similar to the plot use analysis of vegetation characteristics (Chapter 4) we view the plot level results with some skepticism. A more appropriate way to address microclimate effects on cuckoo plot selection may be through habitat use observations through radio telemetry paired with random non-use habitat sampling.

On the other hand, nest sites represent a specific kind of habitat selection at the plot scale and our results strongly suggest that cuckoos are selecting cooler, more humid locations for nest placement. Likewise, there is evidence from numerous avian studies that microclimate plays a role in nest site selection (Beissinger et al. 2005, Rhodes et al. 2009, Roberston 2009). During the early stages of offspring development, microclimate must be regulated in the nest because embryos are unable to regulate their own temperature. Most species maintain eggs at temperatures of 32-35˚C regardless of habitat, incubation strategy, or body size (Webb 1987, Williams 1996). Typical lethal limits have been found to be at extremes, with a lower limit of 25-27˚C and an upper limit of 43-44˚C. Breeding birds found in the desert southwest are exposed to these types of extreme environmental conditions (often exceeding 43˚C in July) during nesting. Therefore, greater canopy cover and dense vegetation at the nest site (Chapter 4) is likely needed to provide a more suitable microclimate for nest incubation and rearing young. On the lower Colorado River in Arizona, southwestern willow flycatchers choose more humid nest sites and cooler mean temperatures than available habitat (McLeod et al. 2008). Our results are similar in that cuckoos are also selecting nest sites at cooler and more humid locations which may improve nest success. Although microclimate cannot be manipulated directly, providing a site with suitable nesting microclimates can be achieved indirectly through changes in vegetation characteristics and possibly soil moisture (McLeod et al. 2008). Ensuring that restoration sites have areas of dense canopy and high humidity may ensure the availability of suitable nesting locations for yellow-billed cuckoos.

Chapter 6. CICADA – YELLOW-BILLED CUCKOO OCCUPANCY

Introduction

The mechanisms behind species distributions and habitat selection have been debated for decades (MacArthur and Wilson 1967, Connor and Simberloff 1979, Ricklefs 1987). While there is much still to learn we know that resource availability, in particular food availability factors highly in affecting the distribution of all species (MacArthur and MacArthur 1961, Cody 1981). Knowledge of a species' food resources is invaluable to conservation biologists; it is a vital yardstick to understand a species current habitat use and future use under a changing environment (Visser 2006). Research in the LCR region has uncovered cursory relationships between yellow-billed cuckoos and Apache cicadas (*Diceroprocta apache*) (Rosenberg et al. 1982, McNeil et al. 2010). Rosenberg et al. (1982) found indirect evidence that cuckoo fledging is timed to the temporal peak in cicada abundance, and research conducted by SSRS revealed relationships between cicada abundance and the number of cuckoo survey detections and estimated pairs at a site (McNeil et al. 2010). However, these cuckoo-cicada relationships are apparent at natural areas only and have not yet developed at LCR restoration sites.

Restoration site cicada abundances in 2009 were considerably less than those at natural areas and were not related to cuckoo abundance or detections (McNeil et al. 2010). To further our understanding of the relationships observed in 2009 and those observed by Rosenberg et al. (1982), we conducted analyses to assess the relationship between cicadas and cuckoo abundance and site occupancy. We also compared 2009 and 2010 cicada abundances to detect possible changes in our survey areas.

Methods

We measured cicada activity and abundance by two methods: (1) live cicada counts were recorded during cuckoo surveys at every survey point to measure cicada activity at the survey time and estimate temporal cicada abundance, and (2) cicada exoskeletons (exuviae) were counted at the end of the field season at habitat sampling plots to estimate cicada abundance (following Dybas and Davis 1962). We then developed a linear model to determine the correlation between the two cicada metrics.

Live Cicada Counts

We recorded an index of the estimated cicada abundance at each survey point. Observations were made prior to playing survey broadcast calls and we counted all cicadas observed on vegetation, flying as the surveyor approached the survey point, and those heard calling in the area around the survey point. Cicada counts were indexed as follows: 0 = 0 cicadas, 1 = 1 cicada, 2 = 2-5 cicadas, 3 = 6-10 cicadas, 4 = 11-19 cicadas, and 5 = 20+ cicadas. We compared average cicada index data between occupied and unoccupied sites, and between natural and restored sites using t-tests and repeated-measures regression analyses. Prior to analysis, we tested all data for normality using Shapiro-Wilk tests. We also assessed the relationship between cicada index values and cuckoo fledging dates. Yellow-billed cuckoo egg-hatching and fledging occur asynchronously (Hughes 1999). We used the date the first chick fledged from each nest for our analyses.

Exuviae Counts

To estimate cicada abundance, we counted cicada exuviae (the exoskeletons left clinging to vegetation when nymphs eclose into adults) between late August and early September concurrent with vegetation sampling at established sampling plots. Counts

were made within five 1x1 m sampling grids at each vegetation plot. The first grid was centered at the plot center with the sides of the grid oriented with the cardinal directions. The remaining four grids were placed at the nearest vertical vegetation that was more than five m from the center of the sampling plot, in each of the four quadrants. Observers spent as much time as needed (no less than three minutes), to thoroughly search each of the five sampling grid locations. The five counts were averaged for each plot for analysis. Each site's plots were also averaged to generate a site-average cicada abundance to compare cicada abundance across sites.

We compared the cicada exuviae counts between occupied and unoccupied plots, and between natural and restoration plots to assess the relationship between cicadas and cuckoo habitat occupancy. Plot occupancy was determined in ArcGIS 9.3 using all 2010 yellow-billed cuckoo detections. A plot was considered occupied if a cuckoo was detected within 50 m of the plot center. Non-parametric Wilcoxon rank-sum tests were used to assess differences between plots due to the non-normal distribution of exuviae counts. For regression analyses the count data were log-transformed to achieve an appropriate normal distribution to meet statistical test assumptions. All analyses were performed using R statistical package 2.11.1 (R Development Core Team 2010).

Results

Comparison of Methods (Live Cicada and Exuviae Counts)

Site mean exuviae count and mean live cicada index were closely related ($r^2 = 0.20$, *P = 0.003; Site mean exuviae count = 0.8555 + 7.6230 (Site mean cicada index)*). However, two outliers with high leverage appeared to influence the results. Removal of these two outliers significantly strengthened the relationship between mean exuviae count and mean

cicada index ($r^2 = 0.54$, $P < 0.00001$, *Site mean exuviae count = -0.841 + 7.169 (Site mean cicada index)*) (Figure 6-1) and also provided normality in the test residuals ($W = 0.946$; $P > 0.05$).

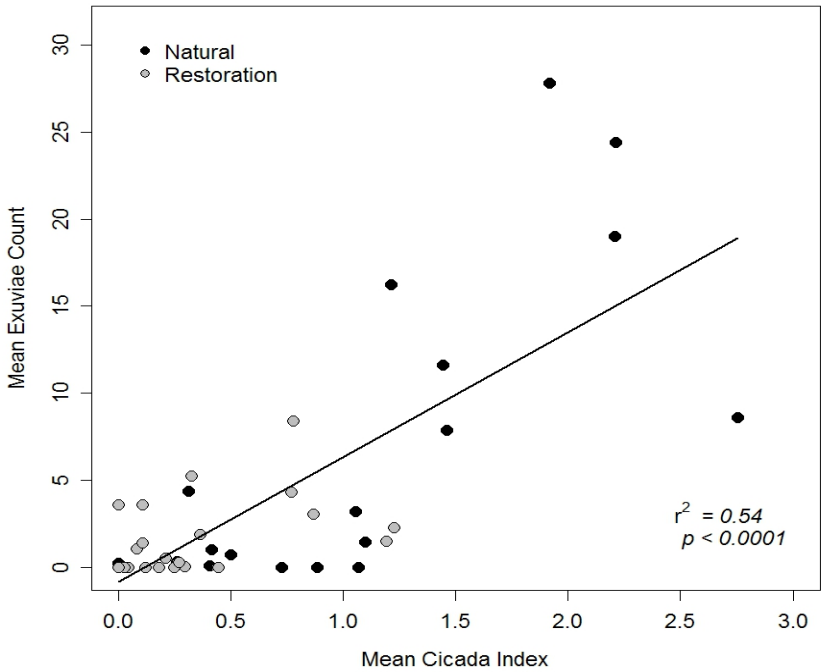


Figure 6-1. Mean cicada Index relative to Mean Exuviae Count. Mean site live cicada index was strongly related to site mean exuviae count.

Live Cicada Counts

Mean cicada index was greater at natural area sites (1.17 ± 0.14 SE, n = 25) compared to restored areas (0.73 ± 0.07 SE, n = 22), ($t_{41.25} = 2.55$; $P = 0.014$). Similarly, across the study area, the average mean cicada index at occupied sites (1.10 ± 0.11 SE, n = 33) was greater than at unoccupied sites (*0*.64 ± 0.14 SE, n = 14), ($t_{30.66} = -2.65$; $P = 0.012$). At natural sites, occupied site mean cicada index (1.46 ± 0.15 SE, n= 16) was greater than at unoccupied sites (0.65 ± 0.18 SE, n = 9) ($t_{17.76} = -3.34$; $P = 0.004$). However, within restored areas we found no differences in average cicada indices between occupied (0.76 ± 0.11 SE, n = 17) and unoccupied sites (0.61. ± 0.20, SE, n=5) ($t_{6.91} = -0.65$; $P = 0.54$).

Using a linear mixed-effects model for repeated measures data, we found that natural and restoration live cicada index trends changed differently through time (t_{140} = -2.19; P = 0.031, Figure 6-2). Observed or estimated nest initiation occurred in mid-July at natural-site nests; eggs hatched primarily during the latter half of July (Figure 6-2) (nesting details described in Chapter 3). Cuckoo nestling activity overlapped with a period of increasing cicada activity. The fledgling stage coincided with the period of maximum cicada abundance which suggests a timed response to this resource peak. The restoration site cicada index trend followed that observed at natural sites (Figure 6-2). However, cicada activity was shorter in overall duration and notably less intense. Observed fledge dates at restoration sites were widely dispersed, spanning early July to early August.

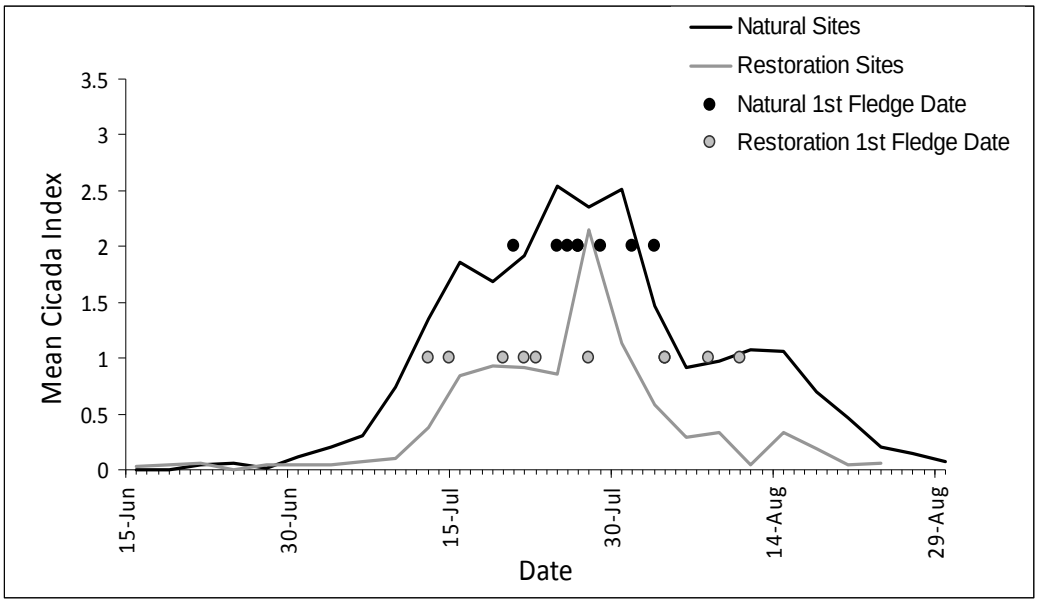


Figure 6-2. Cicada activity and nesting dates at natural and restoration sites.

Temporal trends in cicada activity were similar between natural (black lines) and restoration sites (gray lines), but changed differently through time (P = 0.031). Cuckoo fledge dates are closely tied to peak cicada activity at natural sites (black circles), but not at restoration sites (gray circles).

Exuviae Counts

Cicada exuviae were counted at 131 plots, 70 natural and 61 restoration plots. In total, cuckoos used 64.1% (n=84) of the plots. At natural areas, cuckoos used 44.3% (n=31) of the 70 plots. At restoration sites 86.9% (n=53) of the 61 were deemed to be used by cuckoos. In 2010, site-average exuviae abundance was significantly greater at natural area sites (mean = 10.5 ± 3.33 SE, median = 3.2, range = 0.0 – 57.8) compared to restoration sites (mean = 1.77 ± 0.49 SE, median = 1.07, range = 0.0 – 8.4, W = 294; P = 0.03, Figure 6-3). The 2010 natural site cicada exuviae average was similar to the 2009 natural site cicada exuviae average (mean = 11.6 ± 3.3 SE, median = 1.3, range = 0.0 - 64.8). The restoration site cicada averages of 2010 were similar to those found in 2009 (mean = 2.2 ± 0.62 SE, median = 1, range = 0.0 – 11.1).

At natural areas, cicada exuviae counts at occupied sites (mean = 15.7 ± 4.41 SE, median = 10.1, range = 0.3 – 57.8) exceeded those at unoccupied sites (mean = 0.25 ± 0.20 SE, median = 0, range = 0.0 – 1.45) (W = 3; P = 0.0001) (Figure 6-4). At restoration sites, we found no difference in exuviae counts between occupied (mean = 1.34 ± 0.41 SE, median = 0.8, range = 0.0 – 5.24) and unoccupied sites (mean = 3.12 ± 1.55 SE, median = 3.6, range = 0.0 – 8.4), (W = 49; P = 0.48) (Figure 6-4).

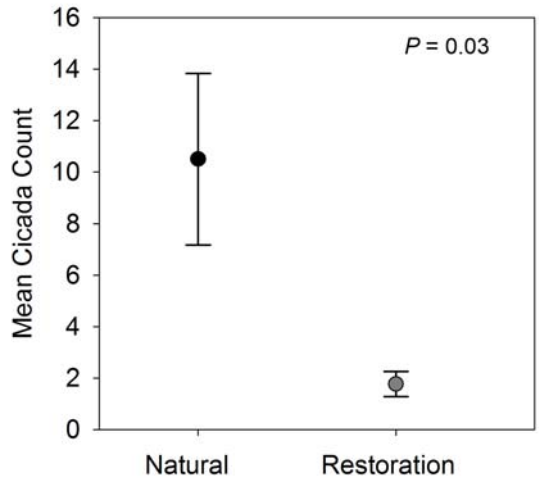


Figure 6-3. Mean cicada counts at natural areas (black circle) exceeded those at restoration areas (gray circle) (SE are shown).

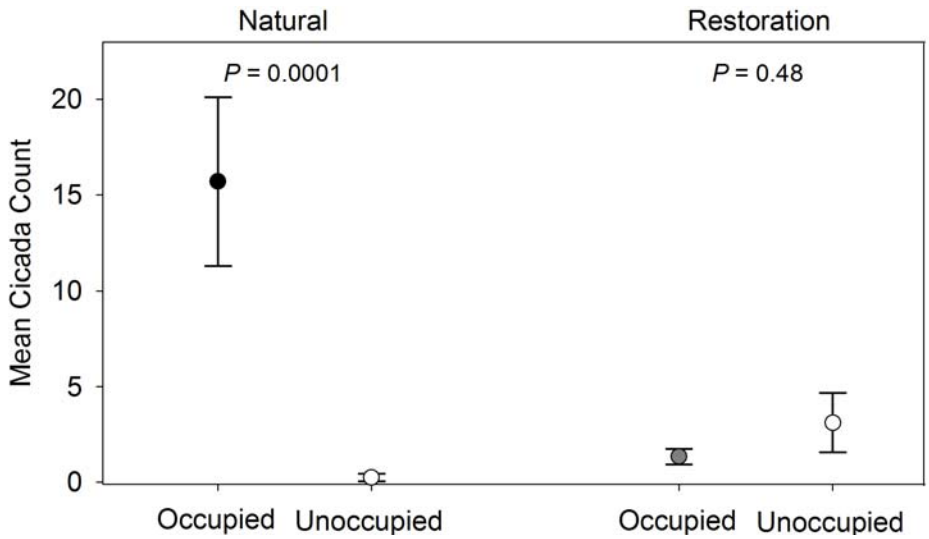


Figure 6-4. At natural areas (left) mean cicada count at occupied sites (black circle) exceeded those at unoccupied sites (white circle). At restoration areas (right) the mean cicada count did not differ between occupied (gray circle) and unoccupied (white circle) sites (SE bars shown).

In comparing plot use, at natural sites cicada exuviae abundance was similar at used plots (mean = 12.54 ± 2.55 SE, median = 8.4, range = 0.0 – 57.8) and used plots (mean = 10.5 ± 2.86 SE, median = 1.4, range = 0.0 – 83.6) (*W = 776, P = 0.101*). The removal of two outliers resulted in greater natural site cicada exuviae abundance at used plots (statistics as above) compared to unused plots (mean = 7.38 ± 1.86 SE, median = 1.2, range = 0.0 – 36.8) (*W = 408, P = 0.041*, Figure 6-5). At restoration sites we failed to detect a difference between cicada exuviae abundance between occupied (mean = 1.65 ± 0.47 SE, median= 0.0, range = 0.0 – 20.2) and unoccupied plots (mean = 2.13 ± 1.01 SE, median= 1.0, range = 0.0 – 8.4) (*W = 141.5; P = 0.1133*). We also found no difference in exuviae abundance between nest plots and non-nest plots at either natural or restoration sites ($P > 0.33$).

The estimated number of cuckoo pairs at natural sites (*1.24 ± 0.30 SE, n = 25*) was similar to the estimate at restoration sites (*1.09 ± 0.21 SE, n = 22*) ($t_{41.8} = 0.4127$; $P = 0.682$).

The relationship between estimated pairs and logged average exuviae counts was found to be statistically significant (*Number of cuckoo pairs = 0.8482 + 0.4406 (log mean exuviae*); $r^2 = 0.17$; $P = 0.008$). We also examined two similar models: one including an extra predictor variable of site type (restoration or natural); the other including an extra predictor of site type and an interaction term between site type and exuviae count. However, in these two models the logged average exuviae predictor variable remained statistically significant while the additional predictor variables were not. This indicates that a site's number of cuckoo pairs was not related to the site type (restoration or natural) or to an interaction between site type and cicada abundance. If the lack of cicadas at restoration sites negatively affected cuckoos the interaction term should have been significant. As expected, at natural sites the relationship between the number of cuckoo pairs and average exuviae count was found to be statistically significant (*number of cuckoo pairs = 0.6748 + 0.5724(log mean exuviae count)*; $r^2 = 0.26$; $P = 0.017$). At restoration sites we found no relationship between the number of cuckoo pairs and average exuviae count ($P = 0.77$, Figure 6-5).

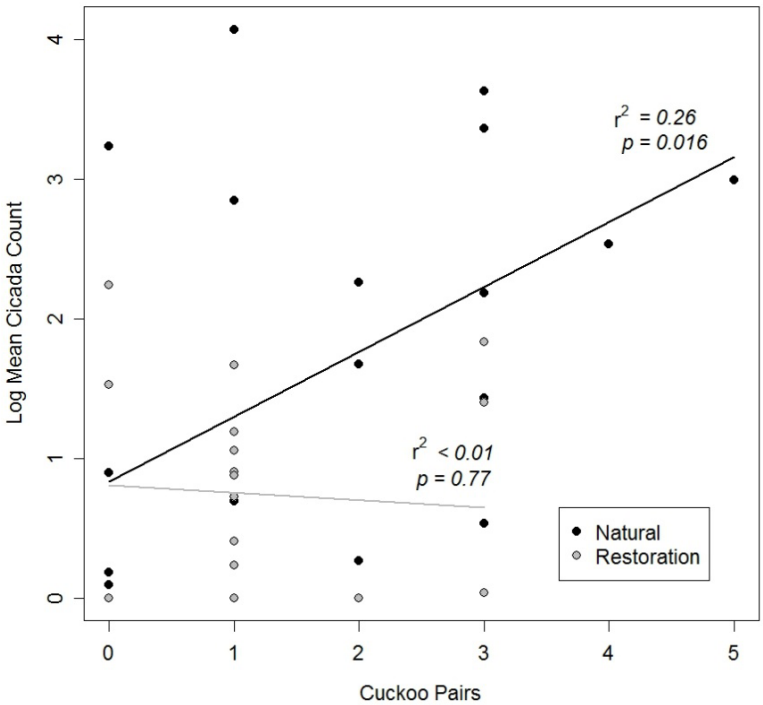


Figure 6-5. At natural sites (black) the number of cuckoo pairs was significantly related to cicada exuviae abundance while at restoration sites (gray) they were not. The number of displayed cuckoo pairs includes all possible, probable or confirmed breeding.

Discussion

Cicada abundance indices in 2010 were similar to those in 2009 at both natural and restoration areas. Yellow-billed cuckoos displayed a strong relationship with cicadas at natural sites. In contrast, no relationship was detected at restoration sites. Cuckoo site occupancy, plot occupancy, and breeding activity at natural sites were all positively related to cicada abundance and activity. Similar relationships have been noted in the past, though with less strength of evidence or detail; Rosenberg et al. (1982) noted that cuckoo breeding and the cicada peak both occur in July; McNeil et al. (2010) showed positive relationships between natural site cicada exuviae abundance and cuckoo detections and pair estimates.

Apache cicadas are present at restoration sites and display a similar though weaker abundance and activity trend as that found at natural sites. The significantly lower cicada abundance at restoration sites did not negatively affect cuckoo site occupancy, and the

estimated number of cuckoo pairs per site was comparable to natural sites. The dearth of cicadas may have affected cuckoo breeding phenology as nesting activity is now decoupled from their historical primary food resource in this area. Despite this phenological shift, cuckoo fecundity in restoration areas relative to natural areas does not appear compromised. Restoration site cuckoos are clearly foraging on alternative prey items; aside from cicadas they have been observed foraging on mantids, orthopterans, and lepidopterans (Rosenberg et al. 1982, Chapter 3). Overall, the lower numbers of cicadas at these sites do not appear to be detrimental to yellow-billed cuckoo productivity in these areas. Cuckoos show incredible plasticity in what they consume and adjust to outbreaks of native and non-native insects (Yard 2004, Koenig and Liebhold 2005, Barber et al. 2008). However, the reduced cicada abundances indicate that the ecological processes operating at restoration sites have not yet been restored to levels found at natural sites along the LCR. Rosenberg et al. (1982) found the Bill Williams River NWR cicada population to be a non-limiting resource for the avian community and concluded that the average daily cicada abundance was up to an order of magnitude greater than the caloric needs of the thirteen birds studied. The effects of cicadas on community structure and function may be quite large (Anderson 1987, Anderson 1994). The impacts of not having this unlimited resource for the avian community at restoration sites are unknown.

Future Research

The cicada data we recorded at survey points and vegetation plots should continue; it is easy to collect and provides vital baseline data. Most importantly, this data will be used to determine if the restoration site cicada abundance and activity increasingly align with natural site trends in following years. The final two seasons of this study provide an

opportunity to expand on what we have learned about cuckoo food resources. We show that cuckoo site occupancy, plot occupancy, and breeding phenology are strongly related to cicadas and believe it to be an important component of habitat restoration. Understanding the relationships between a species and its food resources is an integral measurement in managing the health of current and future populations.

The cuckoo prey base, especially at restoration sites, should be examined more closely. There are several ways to do this. Nest monitoring using high-resolution, color video cameras would help identify the items fed to nestlings in addition to the wealth of knowledge they would provide on cuckoo nesting behavior. This type of monitoring has a high cost and time investment and the number of cameras would be limited. To get the most useful data from using this technique, the observations should be weighted toward restoration site nests.

In addition to surveying the food fed to chicks, it would be prudent to learn more about prey availability at restoration and natural sites. A variety of successful methods have been developed to sample arboreal insects, including malaise, window, sticky and light traps (Chapman and Kinghorn 1955, Canaday 1987, Darling and Packer 1988, Johnson 2000). However, using traps for the collection of the large arthropods may be difficult as cuckoos will forage in high forest canopy and placing a subset of traps at these heights would be problematic. Sweep nets are the standard method for insect sampling, but have previously yielded mixed results. Another option is to conduct auditory insect surveys along line and point transects using passive listening similar to bird, bat, and frog surveys, identifying insects by species-specific calls (Diwalker et al. 2007).

Chapter 7. CICADA HABITAT ANALYSIS

Introduction

Apache cicadas (*Diceroprocta apache*) reside in Sonoran Desert riparian areas where they spend most of their life in the nymph stage as below-ground herbivores for two or three years. In their final life stage, they emerge from the soil and eclose into a winged adult for a brief 2-3 month summer breeding season. After mating, adult females deposit eggs in small stems of woody vegetation (Andersen 1994). Upon hatching, the 2-mm cicada nymphs fall to the soil and burrow down to the plant's roots. Not traveling far underground, they remain in the upper 30 cm of soil excavating subterranean burrows and feeding on the xylem found in plant roots (Glinski and Ohmart 1984, Andersen 1987). Upon nearing the adult breeding stage, the nymphs tunnel to the surface, climb nearby vegetation up to 1.5 m above ground, and emerge from their exoskeleton (exuviae) into adults (Andersen 1987). Their exuviae is left behind clinging to vegetation, slowly decaying over time. In Arizona, adult numbers peak in July and drop to near zero by late August (Rosenberg et al. 1982, Glinski and Ohmart 1984). Adult cicadas lack defenses, are easily captured, and readily consumed (Koenig and Liebhold 2005). During large outbreaks, predators are quickly satiated and do not impact the cicada population's reproductive success, though predators are able to eradicate small populations (Lloyd and Dybas 1966b, Koenig and Liebhold 2005). At the Bill Williams River NWR, the annual semelparous breeding event saturates the local avian predator population, yellow-billed cuckoos included, and offers a near-limitless food resource (Rosenberg et al. 1982). Their

importance to the desert riparian community has led to their suggested designation as a keystone species (Andersen 1994).

In natural areas on the LCR, cicadas have been deemed important for yellow-billed cuckoos which tightly couple their nesting activities with the summer peak in cicada abundance (Rosenberg et al. 1982, Chapter 6). Newer habitat restoration sites have far fewer cicadas compared to natural sites (Halterman et al. 2009, McNeil et al. 2010, Chapter 6), for unknown reasons. To further explore the relationship between cicadas and habitat characteristics, we generated four non-exclusive hypotheses which focused on the habitat differences between natural and restored sites.

The Apache cicada life span exceeds most arthropods. Longer generation times lead to slower population growth. As a result, initial cicada population growth might be relatively slow at newly suitable habitat with young vegetation. Second, cicada population growth could be slowed by suboptimal subsoil habitat conditions (Glinski and Ohmart 1984), such as those generated from altered hydrologic regimes compared to natural sites. Third, fragmentation, patch size, and distance from source populations may affect dispersal ability and colonization of new sites (Cook et al. 2001, Maleque et al. 2006). These factors may considerably delay the full colonization of restored areas (McNeil et al. 2010). Lastly, cicada population growth is density-dependent with increased reproductive success at higher cicada densities (Lloyd and Dybas 1966b, Karban 1982). At natural sites, the sheer abundance of cicadas prevents the species from being over-exploited as a food resource (Karban 1982, Glinski and Ohmart 1984). However, at restoration sites, the low cicada

abundances may not prevent this from occurring and predators may be able to suppress cicada population growth.

All but the last hypothesis can be explored using LCR vegetation data from 2008 and 2009 collected for cuckoo habitat analyses. While this data was not collected with the intent to apply it to cicada analyses, data of this nature has been used to examine Apache cicada habitat relationships (Glinski and Ohmart 1984, Ellingson and Andersen 2002). Most of our variables are vegetation measurements and as such our models may not fully explain the observed cicada abundance patterns. A dearth of subsoil habitat variables in the dataset will prohibit exploration of the complete breadth of utilized cicada habitat.

Based on our hypotheses, we supposed that the following predictor variables would be most important to Apache cicadas: percent soil moisture, percent marsh vegetation, native large tree density, Fremont cottonwood (*Populus fremontii*) density, Goodding's willow (*Salix gooddingii*) density, mesquite (*Prosopis spp.*) density, site area, site type (restoration or natural), and year sampled. We hypothesized that cicadas would exhibit a negative relationship to high water content in the soil and considered soil moisture to be a fluctuating measure of water content (it could vary by week or month dependent upon flooding and irrigation schedules) and the abundance of marsh vegetation to be indicative of a more stable and long-term water-saturated substrate. We anticipated a positive relationship with all native large tree predictor variables. We also expected a positive relationship between site area and cicada abundance. We included site type to account for unknown and unmeasured habitat characteristics which may negatively affect cicada abundance at restoration sites. We included year to account for temporal differences.

Methods

Data Collection

These analyses relied on the vegetation dataset prepared for the 2006-2009 cuckoo habitat analysis (see Chapter 4 for vegetation collection methods). Twenty-four vegetation variables were explored for this analysis. To estimate cicada abundance, we counted cicada exuviae in late August and early September concurrent with vegetation sampling at established vegetation plots (see Chapter 6 for exuviae sampling methods).

Data Analysis

We used an information theoretic approach (Burnham and Anderson 2002) to model the data using Akaike's information criterion (AIC). Prior to our analyses we verified statistical assumptions were met (following Osborne et al. 2002). We inspected the dataset for multicollinearity, and removed highly correlated data pairs with an inflation factor greater than six from models (Belsle et al. 1980). Using a set of 24 habitat predictor variables, we modeled 35 variable subsets using multiple regressions with mean plot exuviae abundance as the response variable. We recursively removed non-significant predictor variables ($P > 0.05$) in each model and then reanalyzed each model. This resulted in duplicate models and reduced our final set of models to twenty-four. For each model, we calculated the log likelihood ($\log(\mathcal{L})$), number of parameters (K), AIC values, the relative AIC difference between each model and the top model with the lowest AIC (Δ_i), and the relative Akaike weights (ω_i). Models were ranked using AIC values (Burnham and Anderson 2002) and their relative strength assessed by their Δ_i. Models with Δ_i between 0-2 were considered to have substantial support in explaining the data, Δ_i = 3-7 had less support, and models with Δ_i greater than 10 had virtually no support for explaining the variation

observed in the data. Akaike weights (ω_i) were calculated for each model to represent the strength of evidence of the particular model as the best model out of the set of models considered. Because no single model was clearly superior ($\omega_{max} > 0.9$), an average model was calculated using the Akaike weights to weight the model coefficients (Burnham and Anderson 2002). Inference was then based on the entire set of models. Because variables may vary in their overall importance in multi-model inference we calculated the relative importance for each variable by summing the individual model Akaike weights (ω_i) across all models which contained the respective variable (Burnham and Anderson 2002). The summed weights offer a relative measure of importance of a predictive variable and the more important variables will contain a larger Akaike weight sum ($\sum\omega_i$). We also used hierarchical partitioning (HP) to determine the individual contribution of each predictor variable in explaining the response variable, independent of the other variables (MacNally 2000, 2002). HP and relative AIC variable rankings may differ because of how and why they are calculated. Akaike weights are derived from the AIC measure of model parsimony determined from the inclusion of variables most important in explaining the data. In contrast, HP measures the independent contribution of each variable to the response variable and does not take into account possible joint contributions between variables (MacNally 2000, Burnham and Anderson 2002, MacNally 2002). All analyses were performed using R statistical package 2.11.1 (R Development Core Team 2010).

Results

Cicadas were counted at 123 plots in 2008 and at 128 plots in 2009. Twenty-four models remained after the removal of non-significant variables. After ranking our set of candidate models by their AIC values from best to worst (Table 7-1), model 1 came out on

top with the lowest AIC value and highest ω_i (0.65). It was the only model with considerable support as the best model. Models 2-8 offered less support in explaining the dataset and models 9 and 10 earned very little support. The extremely small ω_i 's for models 11-24 indicated no support for these models. No model was clearly superior ($\omega_i > 0.9$) indicating that an average model would be most appropriate to describe the variation observed in the dataset. Models with Δ_i of 10 or less were included for model averaging.

Table 7-1. Results of AIC-based model selection for cicada abundance.

Number	Model	log($\mathcal{L}$)	*K*	AIC	Δ_i	ω_i
1	AR + MV + NLT + ST + SM + YS	-993.07	6	2002.1	0	0.65042
2	MV + NLT + ST + SM + YS	-996.03	5	2006.1	4.0	0.08803
3	AR + MV + NLT + ST + SM	-996.34	5	2006.7	4.6	0.06521
4	AR + MV + NLT + ST + YS	-996.52	5	2007.0	4.9	0.05613
5	AR + NLT + ST + SM + YS	-996.63	5	2007.3	5.2	0.04831
6	MV + NLT + ST + SM	-998.42	4	2008.8	6.7	0.02282
7	AR + MV + NLT + ST	-998.56	4	2009.1	7.0	0.01964
8	AR + MV + ST + SM + YS	-997.63	5	2009.3	7.2	0.01777
9	NLT + ST + SM + YS	-999.33	4	2010.7	8.6	0.00883
10	AR + NLT + ST + SM	-999.40	4	2010.8	8.7	0.00839
11	MV + ST + SM + YS	-1000.16	4	2012.3	10.2	0.00397
12	NLT + ST + SM	-1001.34	3	2012.7	10.6	0.00325
13	AR + MV + ST + YS	-1000.80	4	2013.6	11.5	0.00207
14	AR +ST + SM + YS	-1000.90	4	2013.8	11.7	0.00187
15	MV + NLT + ST	-1002.03	3	2014.1	12.0	0.00161
16	MV + NLT + ST + YS	-1001.06	4	2014.1	12.0	0.00161
17	SM + ST	-1006.52	2	2021.0	18.9	0.00005
18	ST + NLT	-1007.91	2	2023.8	21.7	0.00001
19	NLT + AR + MV + YS	-1006.54	4	2025.1	23.0	0.00001
20	ST	-1011.79	1	2029.6	27.5	<0.00001
21	MV + NLT	-1018.75	2	2045.5	43.4	<0.00001
22	NLT	-1021.27	1	2048.5	46.4	<0.00001
23	SM	-1022.63	1	2051.3	49.2	<0.00001
24	MV	-1024.68	1	2055.4	53.3	<0.00001

Maximized log-likelihood log($\mathcal{L}$), number of predictor variables (K), AIC, AIC differences (Δ_i), and Akaike weights (ω_i) are shown. AR = area, MV = marsh vegetation, NLT = native large tree density, ST = site type, SM = soil moisture and YS = year sampled.

Model-averaged regression coefficients were calculated using ω_i for the weighted model average (Burnham and Anderson 2002). Unconditional standard errors (the standard error terms are not conditional upon any one model) were calculated using the

sample variances from each model in conjunction with the model's ω_i. The averaged model retained six statistically significant explanatory variables (P <0.017).

To test initial hypotheses, we attributed two site level characteristics to our plots, 'area' and 'site type' to assess their importance. Both were found significant in explaining cicada abundance. We found positive relationships between cicada abundance and area, native large tree density, and year sampled; and negative relationships between cicada abundance and percent marsh vegetation, soil moisture, and restoration site type (Table 7-2). The amount of variance explained by each of these predictor variables is given in Table 7-3. Litter depth showed a mild negative relationship to cicada abundance (P = 0.106), but was not statistically significant and dropped from the analysis. The following variables were also examined but showed no relationship to cicada abundance: percent bare ground, percent leaf litter, native small tree density, Fremont cottonwood density, Goodding's willow density, mesquite density, total percent cover, total canopy cover average height, high percent canopy cover, high canopy cover average height, percent main canopy cover, main canopy cover average height, percent water, tamarisk (*Tamarix spp.*) density, large tamarisk density, small tamarisk density, and tamarisk sapling density.

Table 7-2. Variables contained in the averaged model with their coefficients and unconditional standard errors.

Variable	Coefficient	Unconditional Standard Error
Site Type	-9.010	1.960
Area	0.066	0.039
Native Large Tree Density	11.90	4.330
Soil Moisture	-0.073	0.036
Percent Marsh Vegetation	-0.252	0.117
Year Sampled	3.780	2.150

Table 7-3. Hierarchical measurement of the independent contribution of each predictor variable to the response variable (cicada abundance).

Variable	Variance Explained	AIC Relative Ranking
Site Type	39.62	1
Area	19.37	5
Native Large Tree Density	15.68	2
Soil Moisture	11.43	3
Marsh Vegetation Percent	8.55	6
Year Sampled	5.35	4

The AIC relative importance ranking is an overall measure of the variable's importance in explaining the data.

Discussion

To better understand yellow-billed cuckoo food resources we explored both vegetative and subterranean habitat features that may influence Apache cicada habitat suitability. We revealed several familiar and two previously undocumented habitat variables (percent soil moisture, percent marsh vegetation) related to cicada abundance. Two vastly different habitats are important to the cicada, the terrestrial and subterranean, and the explored habitat variables are relevant to both adult and nymph habitat use.

The positive association between cicadas and native large tree density could be relevant to both adult and nymph cicadas and suggests a preference for mature stands of native vegetation over the invasive tamarisk prevalent in this region. Native large trees may be preferred by adult females as oviposit sites (Glinski and Ohmart 1984) and may also provide suitable subterranean nymph habitat with more expansive and mature root systems available as a food resource. Trees aggregated into this habitat variable exceeded 23 cm DBH and included Fremont cottonwood, Goodding's willow, honey mesquite (*P. glandulosa)*, and screwbean mesquite (*P. pubescens*). In a desert riparian environment similar to the Bill Williams River, Smith et al. (2006) found that cicadas (*Tibicen dealbatus*) on the Rio Grande in New Mexico were positively associated with percent cover of Rio

Grande cottonwood (*P. deltoides*). Ellingson and Andersen (2002) found that cicadas on the Bill Williams River were positively associated with percent cover Goodding's willow (they measured too few cottonwood and mesquite trees at their plots to include in their analyses). In contrast, in examining non-native vegetation Ellingson and Andersen's (2002) results are nuanced in that they found no relation between cicadas and tamarisk at the plot level, but a negative relationship emerged as the tamarisk stand size increased in area. At the plot level, we measured four different tamarisk parameters, and like Ellingson and Andersen we did not find any to be related to cicada abundance. In our study, the lack of an individual relationship with Fremont cottonwood, Goodding's willow or mesquite trees suggests a lack of a preference for these trees individually. However, these large trees were not found in great abundance on our plots and it is possible that a relationship was not observed because we had too little data.

Cicadas spend the majority of their lives underground. Therefore, subterranean habitat quality (and other ecologic factors such as predation and competition) will be highly influential for cicada survival (Lloyd and Dybas 1966a). Soil compaction, texture, moisture and temperature affect fossorial insect survival rates (Glinski and Ohmart 1984, Andersen 1987). Similarly, drought and flooding may have significant effects on below-ground herbivores, though temporary flooding does not reduce survivorship in some below-ground invertebrate species (Andersen 1987). Our observed negative relationships between cicada abundance and both soil moisture and marsh vegetation can be interpreted in two nonexclusive ways. Adult female cicadas may show an avoidance to oviposit eggs in vegetation over wet ground or open water. Alternatively, cicada nymph survival may decrease with increased soil moisture. Without further research, causation cannot be

determined, but either way it appears that high soil moisture negatively affects cicada abundance. Marsh vegetation is an interesting negative correlate. Directly interpreted, cicadas may avoid egg placement in marsh vegetation over areas containing water as the newly hatched larvae would not survive in their attempt to burrow underground. Indirectly, the variable acts as a measure of the water table depth and the presence of standing water, long after visible signs of water have gone. At many sites, the amount of surface water diminishes through the summer, whereas the presence of marsh vegetation is indicative of a high water table and seasonal standing water long after its disappearance by late summer when the vegetation plots were sampled.

Soil compaction has not yet been researched to our knowledge, though Ellingson and Andersen (2002) found no affect of soil texture on cicada abundance at the Bill Williams River NWR. Ellingson and Andersen (2002) also examined leaf litter cover as it may play a role in affecting soil habitat conditions, and also found no relationship between leaf litter and cicada abundance. However, we noticed a weak negative relationship between cicada abundance and litter depth. Increasing litter depth may promote high soil moisture or impede newly hatched larvae from reaching the soil.

We found our two site-level variables to be our most important predictors of cicada density indicating that factors dictating cicada abundance are operating at more than the plot scale. The positive relationship between area and cicada abundance indicates that the overall size of the habitat patch plays an important role in cicada abundance. Intuitively, larger habitat patches should support more cicadas (Rosenzweig 1995) and natural sites are generally much larger and have more habitat area compared to restoration sites.

Related to area affects, we initially hypothesized that habitat fragmentation and distance to source populations could be contributing to the low cicada abundances at restoration sites. Our analyses did not address these factors, but the literature indicates that cicadas have low dispersal ability. Karban (1981) observed that *Magicicada* cicada females rarely dispersed farther than 50 m, males even less. The low dispersal ability of cicadas may inhibit their movement to distant habitat fragments across an inhospitable matrix (Ricketts 2001).

Cicadas showed a negative relationship to restoration sites, a variable we included to account for the unknown and unmeasured ecological processes operating at natural and restoration sites. The effects of area and site type on cicadas may be related to the cicada's density-dependent reproductive success, where the rate of population increase is relative to the number of cicadas present. Cicada population growth at restoration sites may be kept below the threshold needed to achieve large cicada populations due to the relatively small habitat areas and disparate ecological pressures (i.e. predators may be heavily impacting cicada growth at restoration sites, but are swamped at natural sites). Observations dating back to the early 1900s have noted that avian predators are able to annihilate small cicada populations (Lloyd and Dybas 1966b, Koenig and Liebhold 2005).

Adult cicada abundance is patchy and concentrated at chorus centers (Karban 1981), but cicada nymph abundance is related to where females choose to lay their eggs. Females disperse to oviposit their eggs to avoid strong competition for food and increase the survival prospects of nymphs (Lloyd and White 1976, White and Lloyd 1979). They tend to oviposit along forest edges and other sunlit locations where root-shoot ratios are

high (Karban 1981). The exuviae counts adequately measure cicada abundance (Glinski and Ohmart 1984, Andersen 1994). However, the location of the exuviae reflects female oviposit site selection and nymph habitat quality more than the terrestrial habitat selected by breeding adults. As a result, it is not surprising that our measures of cicada abundance are not related to data we collect such as percent canopy cover which might be more relevant to adult cicada preferences.

Efforts to restore sites to the ecological equivalent of remaining intact natural areas should aim to establish cicada populations to comparable levels. Current practices tend to over-irrigate restoration plots (Hartwell et al. 2010). In light of our results, we recommend setting aside some areas that will not be intensively irrigated, or mimic natural historic flooding events under which Apache cicadas evolved. Other possibilities include the increased use of berms, as we have incidentally observed higher adult cicada emergence on restoration site berms compared to adjacent ground, and these may provide additional subterranean nymph habitat. Alternatively the positive relationship between cicadas and native large trees suggests that time may be a factor and cicada populations will increase as the sites mature.

Chapter 8. SUMMARY OF RESULTS AND MANAGEMENT RECOMMENDATIONS

Some of these recommendations are already being implemented.

- Area is a strong predictor of yellow-billed cuckoo site occupancy. We found the median size of occupied sites (almost 50 ha) to be almost five times as large as unoccupied sites. We also found the average home range size of cuckoos radio-tracked on restoration

sites was almost 22 ha, matching our 2009 estimate. Creating large areas of habitat will increase cuckoo abundances and may also increase cicada densities.

- Creating multi-structured habitats by establishing native small trees spaced randomly apart and encouraging large native tree growth will increase preferred nesting and foraging areas for cuckoos as well as possibly increase cicada abundances.
- Simulating natural flood regimes with flooding at appropriate times (mimicking peak spring floods) will benefit established native species, and favor natural regeneration of native over non-native species. This strategy would also ensure the creation of other habitat characteristics that will benefit cuckoos, including increased canopy cover, the creation of varied habitat, and increased native small and large tree densities.
- Yellow-billed cuckoos select nest sites at cooler and more humid locations which may improve nest success. Although microclimate cannot be manipulated directly, providing a site with suitable nesting microclimates can be achieved indirectly through changes in vegetation characteristics and possibly soil moisture. Ensuring that restoration sites have areas of dense canopy and high humidity may ensure the availability of suitable nesting locations for yellow-billed cuckoos.
- Adult cuckoos with recently fledged young were still at CVCA when dove hunting season began on September 1. As it is unknown what impacts hunting may have on breeding success, we recommend delaying hunting at high-occupancy sites such as CVCA until at least mid September. Additionally, as sustained low-frequency noise (such as heavy machinery) has been found to negatively impact yellow-billed cuckoo occupancy (Goodwin 2009), we recommend delaying noise-intensive projects at

occupied sites (as was the case at Picacho SRA this year) until well after the breeding season.

- We have continued to improve our netting techniques and were able to triple our capture rate in 2010 with less relative effort compared to 2009. These efforts, combined with intensive nest-searching and nestling banding (in 2009) contributed to four new natal and breeding dispersal records, and 25 adult and 24 hatch year birds banded in 2010. If our relatively high resight rate (31% in 2010) continues, our understanding of cuckoo dispersal and site fidelity within the LCR will significantly increase over the next two years of this project.
- We saw increases in restoration site occupancy and breeding activity from 2009. Breeding activity increased in 2010 at four of the five regions within the study area (Bill Williams River NWR, Havasu NWR, Blythe area, and Yuma area). Occupancy at Overton sites remained unchanged from 2009. Bill Williams River sites again overshadowed restoration sites by supporting the majority of confirmed breeding and estimated pairs. Overall, the emergent distribution pattern showed increases in occupancy coupled with increases in minimum and maximum breeding pair estimates at restoration areas and throughout the LCR.

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LITERATURE CITED

Andersen, D. C. 1987. Below-ground herbivory in natural communities: a review emphasizing fossorial animals. Quarterly Review of Biology 62:261-286.

Andersen, D. C. 1994. Are cicadas (*Diceroprocta apache*) both a" keystone" and a" critical-link" species in lower Colorado River riparian communities? Southwestern Naturalist 39:26-33.

Anderson, B. W., and R. D. Ohmart. 1977. Vegetation structure and bird use in the lower Colorado River Valley. Pages 23-33 *in* R.R. Johnson and D.A. Jones, editors: Importance, preservation, and management of riparian habitat. USDA Forest Service General Technical Report RM-43, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

Arizona Game and Fish Department. 1988. Page 17 *in* Threatened native wildlife in Arizona.

Banks, R. C. 1988. Geographic variation in the yellow-billed cuckoo. Condor 90:473-477.

Barber, N. A., Marquis, R. J., and Tori, W. P. 2008. Invasive prey impacts abundance and distribution of native predators. Ecology 89: 2678–2683.

Bell, G. P. 1997. Ecology and management of *Arundo donax*, and approaches to riparian habitat restoration in Southern California. Pages 103-113 *in* Brock, J. H., M. Wade, P. Pysek, and D. Green, editors: Plant invasions: studies from North American and Europe. Blackhuys Publishers, Leiden, The Netherlands.

Belsle, D. A., E. Kuh, and R. E. Welsch. 1980. Regression diagnostics: Identifying influential data and sources of collinearity. John Wiley and Sons, New York, New York, USA.

Borror, D. J., C. A. Triplehorn, and N. F. Johnson. 1989. An introduction to the study of insects. Sixth edition. Thomson Brooks/Cole, Belmont, California, USA.

Bent, A. C. 1940. Life histories of North American cuckoos, goatsuckers, hummingbirds, and their allies. United States National Museum Bulletin No. 167, Washington, D.C.

Beissinger, S. R., M .I. Cook, and W. J. Arendt. 2005. The shelf life of bird eggs: testing egg viability using a tropical climate gradient. Ecology 86:2164–2175.

Beyer, H. L. 2004. Hawth's Analysis Tools for ArcGIS. Available at http://www.spatialecology.com/htools

Bowles, A. E. 1995. Responses of wildlife to noise. Pages 109-156 *in* R. Knight and K. Gutzwiller editors: Wildlife and recreationists: Coexistence through management and research. Island Press, Washington, D.C., USA.

Bray, O. E., and G. W. Corner. 1972. A tail clip for attaching transmitters to birds. Journal of Wildlife Management 36: 640-642.

Brown, C. R., M. B. Brown, and K. R. Brazeal. 2008. Familiarity with breeding habitat improves daily survival in colonial cliff swallows. Animal Behaviour 76:1201-1210.

Brumm, H. 2004. The impact of environmental noise on song amplitude in a territorial bird. Journal of Animal Ecology 73:434-440.

Burgman, M. A., and Fox J. C. 2003. Bias in species range estimates from minimum convex polygons: implications for conservation and options for improved planning. Animal Conservation 6: 19-28.

Burnham, K. P. and D. R. Anderson. 2002. Model Selection and Multimodel Inference: A practical information-theoretic approach . Second edition. Springer-Verlag, New York Inc., New York, NY., USA.

Busch, D. E., and S. D. Smith. 1995. Mechanisms associated with decline of woody species in riparian ecosystems of the southwestern U.S. Ecological Monographs 65: 347-370.

Canaday, C. L. 1987. Comparison of insect fauna captured in six different trap types in a Douglas-fir forest. Canadian Entomologist 119: 1101-1108.

California Department of Fish and Game. 1978. At the crossroads, 1978: A report on California's endangered and rare fish and wildlife. Calif. Dept. of Fish and Game, Nongame Wildlife Investigations rep., Project. E-W-2, Job IV-1.

Champlin, T. B., J. C. Kilgo, M. L. Gumpertz, and C. E. Moorman. 2009. Avian response to microclimate in canopy gaps in a bottomland hardwood forest. Southeastern Naturalist 8: 107-120.

Chapman, J. A., and J. M. Kinghorn. 1955. Window flight traps for insects. Canadian Entomologist 87: 46-47.

Chernetsov, N. 2006. Habitat selection by nocturnal passerine migrants en route: mechanisms and results. Journal of Ornithology 147:185–191.

Cody, M. L. 1981. Habitat selection in birds: the roles of vegetation structure, competitors, and productivity. BioScience 31:107-113.

Connor, E. F., and D. Simberloff. 1979. The assembly of species communities: chance or competition? Ecology 60:1132-1140.

Cook, W. M., R. D. Holt, and J. Yao. 2001. Spatial variability in oviposition damage by periodical cicadas in a fragmented landscape. Oecologia 127:51-61.

D'Alba, L., P. Monaghan, and R. G. Nager. 2009. Thermal benefits of nest shelter for incubating female eiders. Journal of Thermal Biology 34: 93–99.

Darling, D. C., and L. Packer. 1988. Effectiveness of Malaise traps in collecting Hymenoptera: The influence of trap design, mesh size, and location. Canadian Entomologist 120:787-796.

Diwalker, S., M. Jain, and R. Balakrishnan. 2007. Psychoacoustic sampling as a reliable, non-invasive method to monitor orthopteran species diversity in tropical forests. Biodiversity Conservation 16:4081-4093.

Donald, P. F. 2007. Adult sex ratios in wild bird populations. Ibis 149:671–692.

Dunn, E. H., and C. J. Ralph. 2004. Use of mist nets as a tool for bird population monitoring. Studies in Avian Biology 29:1–6.

Dybas, H. S., and D. D. Davis. 1962. A population census of seventeen-year periodical cicadas (Homoptera: *Cicadidae: Magicicada*). Ecology 43: 432-444.

Ellingson, A. R., and D. C. Andersen. 2002. Spatial correlations of *Diceroprocta* apache and its host plants: evidence for a negative impact from Tamarix invasion. Ecological Entomology 27: 16-24.

Ellis, L. M. M. C. Molles, Jr, and C. S. Crawford. 1999. Influence of experimental flooding on litter dynamics in a Rio Grande riparian forest, New Mexico. Restoration Ecology 7:193-204.

Facelli, J. M., and S. T. Pickett. 1991. Plant litter: its dynamics and effects on plant community structure. The Botanical Review 57:1-32.

Farrell, L. L. 2006. Subspecies status of the western yellow-billed cuckoo (Cuculidae: *Coccyzus americanus occidentalis*): Using cytochrome B to elucidate the enigma. Thesis, Lakehead University, Canada.

Fleischer R. C. 2001. Taxonomic and evolutionarily significant unit (ESU) status of western yellow-billed cuckoos (*Coccyzus americanus*). Report to the USGS and USFWS.

Franzreb, K.E., and S.A. Laymon. 1993. A reassessment of the taxonomic status of the yellow-billed cuckoo. Western Birds 24:17-28.

Freeman, S., D. F. Gori, and S. Rohwer. 1990. Red-winged blackbirds and brown-headed cowbirds: some aspects of a host-parasite relationship. The Condor 92: 336-340.

Friedmann, H. 1963. Host relations of the parasitic cowbirds. U.S. Natl. Mus. Bull. 233.

Gaines, D. 1974. A new look at the nesting riparian avifauna of the Sacramento Valley, California. Western Birds 5:61-80.

Gaines, D., and S. A. Laymon. 1984. Decline, status and preservation of the yellow-billed cuckoo in California. Western Birds 15:49-80.

Gill, J. A., K. Norris, and W. J. Sutherland. 2001. Why behavioral responses may not reflect the population consequences of human disturbance. Biological Conservation 97:265-268.

Girvetz, E. H., and S. E. Greco. 2009. Multi-scale predictive habitat suitability modeling based on hierarchically delineated patches: an example of yellow-billed cuckoos nesting in riparian forests, California, USA. Landscape Ecology 24:1315-1329.

Glinski, R. L., and R. D. Ohmart. 1984. Factors of reproduction and population densities in the Apache cicada (*Diceroprocta apache*). The Southwestern Naturalist 29:73-79.

Goodwin, S. E. 2009. Patch landscape, and soundscape effects on the forest bird community in the National Parks of the National Capital Region. Thesis, University of Delaware, Newark, USA.

Gotelli, N. J., and A. M. Ellison. 2004. A primer of ecological statistics. Sinauer Associates Inc., Saunderland, MA., USA.

Greenwood, P. J. 1980. Mating systems, philopatry and dispersal in birds and mammals. Animal Behavior 28:1140-1162.

Grinnell, J. 1914. An account of the mammals and birds of the lower Colorado Valley, with special reference to the distributional problems presented. University of California Publications. Zoology 12:97-110.

Halterman, M. D. 1991. Distribution and habitat use of the Yellow-billed cuckoo (*Coccyzus americanus occidentalis*) on the Sacramento River, California, 1987-1990. Thesis, California State University, Chico, USA.

Halterman, M. D. 2000. Population status of the Yellow-Billed Cuckoo at the Bill Williams River NWR, Alamo Dam, Arizona, and Southern Nevada: Summer 2000. Report to the Bureau of Reclamation, Lower Colorado River Division.

Halterman, M. D. 2009. Sexual dimorphism, detection probability, home range, and parental care in the Yellow-billed Cuckoo. Dissertation, University of Nevada, Reno, USA.

Halterman, M. D., D. S. Gilmer, S. A. Laymon, and G. A. Falxa. 2001. Status of the yellow-billed cuckoo in California: 1999-2000. Report to the USGS-BRD Dixon Field Station, 6924 Tremont Rd, Dixon, CA 95620.

Halterman, M. D., M. J. Johnson, and J. A. Holmes. 2008. Western yellow-billed cuckoo natural history summary and survey methodology. Unpublished draft report, Southern Sierra Research Station, P.O. Box 1316, Weldon, CA 93283.

Hamilton, W. J. III, and M. E. Hamilton. 1965. Breeding characteristics of yellow-billed cuckoos in Arizona. Proceedings of the California Academy of Sciences. Fourth Series 32:405-432.

Hartwell, S., K. Morino, P. L. Nagler, and E. P. Glenn. 2010. On the irrigation requirements of cottonwood (*Populus fremontii* and *Populus deltoides* var. *wislizenii*) and willow (*Salix gooddingii*) grown in a desert environment. Journal of Arid Environments 74:667-674.

Hines, J. E. 2006. PRESENCE. Software to estimate patch occupancy and related parameters. USGS-PWRC. http://www.mbr-pwrc.usgs.gov/software/presence.html.

Hoekman, S, I. Ball, and T. Fondell. 2002. Grassland birds orient nests relative to nearby vegetation. Wilson Bulletin 114:450-456.

Hughes, J. M. 1999. Yellow-billed cuckoo (*Coccyzus americanus*). No 148 *in* A. Poole and F. Gill, editors. The Birds of North America, Inc. Philadelphia, PA. USA.

Hunter, W. C., R. D. Ohmart, and B. W. Anderson. 1988. Use of exotic saltcedar (*Tamarix chinensis*) by birds in arid riparian systems. Condor 90:113-123.

Imlay, T. I., J. F. Crowley, A. M. Argue, J. C. Steiner, D. R. Norris, and B. J. M. Stutchbury. 2010. Survival, dispersal and early migration movements of captive-bred juvenile eastern loggerhead shrikes (*Lanius ludovicianus migrans*). Biological Conservation 143:2578-2582.

Johnson, M. D. 2000. Evaluation of an arthropod sampling technique for measuring food availability for forest insectivorous birds. Journal of Field Ornithology 71:88-109.

Johnson, R. R., B. T. Brown, L. T. Haight, and J. M. Simpson. 1981. Playback recordings as a special avian censusing technique. Pages 69-75 *in* C. J. Ralph, and J. M Scott, editors: Estimating numbers of terrestrial birds. Studies in Avian Biology. Allen Press Inc., Lawrence, KS, USA.

Johnson, M .J., J.A. Holmes, C. Calvo, I. Samuels, S. Krantz, and M. K. Sogge. 2007. Cuckoo distribution, abundance, and habitat use along the lower Colorado and tributaries, 2006 annual report: U.S. Geological Survey Open-File Report 2007-1097.

Johnson, M. J., J. A. Holmes, R. Weber, and M. Dionne. 2006. Yellow-billed cuckoo distribution, abundance and habitat use along the lower Colorado and Gila Rivers in La Paz and Yuma Counties, 2005. Report submitted to Arizona Game and Fish Heritage Program, Bureau of Land Management, Bureau of Reclamation, and Northern Arizona University, Flagstaff.

Johnson, M. J., S .L. Durst, C. M. Calvo, L. Stewart, M. K. Sogge, G. Bland, and T. Arundel. 2008. Yellow-billed cuckoo distribution, abundance, and habitat use along the lower Colorado River and its tributaries, 2007 Annual report: U.S. Geological Survey Open-File Report 2008-1177.

Karban, R. 1981. Flight and dispersal of periodical cicadas. Oecologia 49:385-390.

Karban, R. 1982. Increased reproductive success at high densities and predator satiation for periodical cicadas. Ecology 63:321-328.

Keating, K.A. and S. Cherry. 2004. Use and interpretation of logistic regression in habitat selection studies. Journal of Wildlife Management 68:774-789.

Klein, M. L., S. R. Humphrey, and H. F. Percival. 1995. Effects of eco-tourism on distribution of waterbirds in a wildlife refuge. Conservation Biology 9:1454-1465.

Koenig, W. D., and A. M. Liebhold. 2005. Effects of periodical cicada emergences on abundance and synchrony of avian populations. Ecology 86:1873-1882.

LaRoe, E. T., G. S. Farris, C. E. Puckett, P. D. Doran, and M. J. Mac. 1995. Our living resources: a report to the nation on the distribution, abundance, and health of US plants, animals, and ecosystems. U.S. Department Interior, National Biological Service, Washington, D.C.

Laver, P. N., and M. J. Kelly. 2008. A critical review of home range studies. Journal of Wildlife Management 72: 290-298.

Laymon, S.A. 1980. Feeding and nesting behavior of the yellow-billed cuckoo in the Sacramento Valley. California Dept. of Fish and Game, Wildlife Management Branch, Sacramento, CA, Administrative Report 80:2.

Laymon, S. A. 1998. Yellow-billed cuckoo (*Coccycus americanus*). In The Riparian Bird Conservation Plan: a strategy for reversing the decline of riparian-associated birds in California. California Partners in Flight. http://www.prbo.org/calpif/htmldocs/riparian_v-2.html

Laymon, S. A., and M. D. Halterman. 1985. Yellow-billed cuckoos in the Kern River Valley: 1985 population, habitat use, and management recommendations. Report to the Nature Conservancy. Sacramento, CA.

Laymon, S. A. and M. D. Halterman. 1987. Can the western subspecies of the yellow-billed cuckoo be saved from extinction? Western Birds 18:19-25.

Laymon, S. A., and M. D. Halterman. 1989. A proposed habitat management plan for yellow-billed cuckoos in California. USDA Forest Service Gen. Tech. Rep. PSW-110 p 272-277.

Laymon, S. A., P. L. Williams, and M. D. Halterman. 1997. Breeding status of the Yellow-billed cuckoo in the South Fork Kern River Valley, Kern County, California: Summary report 1985-1996. Prepared for USDA Forest Service, Sequoia National Forest, Cannell Meadow Ranger District.

Lite, S. J., and J.C. Stromberg. 2005. Surface water and ground-water thresholds for maintaining Populus-Salix forests, San Pedro River, Arizona. Biological Conservation 125:153-167.

Livingston, M.F., and S.D. Schemnitz. 1996. Summer bird/vegetation associations in tamarisk and native habitat along the Pecos River, southeastern New Mexico. Pages 171-180 in USDA General Technical Report RM-GTR-272. USDA Forest Service, Rocky Mountain Research Station, Fort Collins, Colorado

Lloyd, M., and H. S. Dybas. 1966a. The periodical cicada problem. I. Population Ecology. Evolution 20:133-149.

Lloyd, M., and H. S. Dybas. 1966b. The periodical cicada problem. II. Evolution. Evolution 20:466-505.

Lloyd, M., and J. A. White. 1976. On the oviposition habits of 13-year versus 17-year periodical cicadas of the same species. Journal of the New York Entomological Society 84:148-155.

Lower Colorado River Multi-Species Conservation Program. 2004a. Lower Colorado River Multi-Species Conservation Program, Volume II: Habitat Conservation Plan. Final December 17 (J&S 00450.00.). Sacramento California.

Lower Colorado River Multi-Species Conservation Program. 2004b. Lower Colorado River Multi-Species Conservation Program, Volume III: Biological Assessment. Final December 17. (J&S 00450.00.) Sacramento, CA.

MacArthur, R. H., and J. W. MacArthur. 1961. On bird species diversity. Ecology 42:594-598.

MacArthur, R. H., and E. O. Wilson. 1967. The theory of island biogeography. Princeton University Press, Princeton, NJ, USA.

MacKenzie, D. I., J. D. Nichols, G. B. Lachman, S. Droege, J. A. Royle, and C. A. Langtimm. 2002. Estimating site occupancy rates when detection probabilities are less than one. Ecology 83: 2248-2255.

MacKenzie, D. I., J. D. Nichols, J. A. Royle, K. H. Pollock, L. L. Baily, and J. E. Hines. 2006. Occupancy estimation and modeling: inferring patterns and dynamics of species occurrence. Academic Press, Burlington, MA, USA.

MacNally, R. 2000. Regression and model-building in conservation biology, biogeography and ecology: the distinction between–and reconciliation of–'predictive'and 'explanatory'models. Biodiversity and Conservation 9:655-671.

MacNally, R. 2002. Multiple regression and inference in ecology and conservation biology: further comments on identifying important predictor variables. Biodiversity and Conservation 11:1397-1401.

Madsen, J., and A. D. Fox. 1995. Impacts of hunting disturbance on waterbirds – a review. Wildlife Biology 1:193-207.

Maleque, M. A., Ishii, H., and Maeto, K. 2006. The use of arthropods as indicators of ecosystem integrity in forest management. Journal of Forestry 104:113-117.

Martín, C. A., J. C. Alonso, J. A. Alonso, C. Palacín, M. Magaña, and B. Martín. 2008. Natal dispersal in great bustards: the effect of sex, local population size and spatial isolation. Journal of Animal Ecology 77:326–334.

Martin, J., J. D. Nichols, W. M. Kitchens, and J. E. Hines. 2006. Multiscale patterns of movement in fragmented landscapes and consequences on demography of the snail kite in Florida. Journal of Animal Ecology 75:527-539.

Martin, T. E., C. R. Paine, C. J. Conway, W. M. Hochachka, P. Allen, and W. Jenkins. 1997. BBIRD Field Protocol. Montana Cooperative Wildlife Research Unit, University of Montana, Missoula, Montana.

Martin, T. E., and G. R. Geupel. 1993. Nest-monitoring plots: methods for locating nests and monitoring success. Journal of Field Ornithology 64:507-519.

McCune, B., and J. B. Grace. 2002. Analysis of Ecological Communities. MjM Software Design, Gleneden Beach, Oregon.

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 Bureau of Reclamation, Boulder City, NV by SWCA Environmental Consultants, Flagstaff, AZ.

McMaster, D. G., and S. G. Sealy. 1998. Short incubation periods of brown-headed cowbirds: how do cowbird eggs hatch before yellow warbler eggs? The Condor 100: 102-111.

McNeil, S. E., M. D. Halterman, E. T. Rose, and D. Tracy. 2010. Yellow-billed cuckoo distribution, abundance and habitat use on the lower Colorado River and tributaries, 2009. Annual report to the U.S. Bureau of Reclamation, Multi-Species Conservation Program, Boulder City NV, by Southern Sierra Research Station.

McQuillen, H. L. Jr., and L. W. Brewer. 1997. Use of a prototype automated radio telemetry system to monitor avian survival and bird use of agricultural fields. USGS forum on wildlife telemetry: innovations, evaluations, and research needs. Snowmass Village, Colorado.

Mearns, E.A. 1907. Mammals of the Mexican boundary of the United States: a descriptive catalogue of the species of mammals occurring in that region; with a general summary of the natural history, and a list of trees. U.S. National Museum Bulletin No. 56.

Minnesota Department of Natural Resources. 2001. DNRGarmin GPS Application, version 5.1.2600. http://www.dnr.state.mn.us/mis/gis/tools/arcview/extensions/DNRGarmin/DNRGarmin.html.

Mohr, C. O. 1947. Table of equivalent populations of North American small mammals. American Midland Naturalist 37:223-249.

Mortenson, S.G., and P.J. Weisberg. 2010. Does river regulation increase the dominance of invasive woody species in riparian landscapes? Global Ecology and Biogeography 19:562-574.

Nice, M. M. 1957. Nesting Success in altricial birds. Auk 74:305-321.

Nilsson, C., R. Jansson, and U. Zinko. 1997. Long-term response of river-margin vegetation to water-level regulation. Science 276:798-800

Nur, N., and G. Geupel. 1993. Evaluating mist-netting, nest-searching and other methods of monitoring demographic processes in landbird populations. Pages 237 -244 *in* D.M. Finch & P.W. Stangel editors: Status and management of neotropical migratory birds. USDA Forest Service Publication GTR RM-229.

Ortego, J. O., J. M. Aparicio, P. J. Cordero, and G. Calabuig. 2008. Individual genetic diversity correlates with the size and spatial isolation of natal colonies in a bird metapopulation. Proceedings of the Royal Society. Biological Sciences 275:2039-2047.

Osborne, J., and E. Waters. 2002. Four assumptions of multiple regression that researchers should always test. Practical Assessment, Research & Evaluation 8:2.

Ott, R.L., and M. Longnecker. 2001. An introduction to statistical methods and data analysis, Fifth Edition. Wadsworth Group, Pacific Groove, CA, USA.

Parker, T. H., B. M. Stansberry, C. D. Becker, and P. S. Gipson. 2005. Edge and area effects on the occurrence of migrant forest songbirds. Conservation Biology 19:1157-1167.

Payne, R. B. 2005. The Cuckoos. Oxford University Press. Oxford, UK.

Penteriani, V., and M. M. Delgado. 2009. Thoughts on natal dispersal. Journal of Raptor Research 43: 90-98.

Pitts, T. D. 1995. A tail-mounted radio transmitter for Eastern Bluebirds. North American Bird Bander 20:106-110.

Potter, E. F. 1980. Notes on nesting yellow-billed cuckoos. Journal of Field Ornithology 51:17-28.

Pruett, C. L., D. D. Gibson, and K. Winker. 2001. Molecular 'cuckoo clock' suggests listing of western yellow-billed cuckoos may be warranted. Wilson Bulletin 113:228-231.

Pyle, P. 1997. Identification guide to North American birds. Part I. Slate Creek Press, Bolinas, CA., USA.

R Development Core Team. 2010. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Rangel-Salazar J. L., K. Martin, P. Marshall, and R. W. Elner. 2008. Influence of habitat variation, nest-site selection, and parental behavior on breeding success of Ruddy-Capped Nightingale Thrushes (*Catharus Frantzii*) in Chiapas, Mexico. Auk 125:358-367.

Reijnen, R., and R. Foppen. 1995. The effects of car traffic on breeding bird populations in woodland. Influence of population-size on the reduction of density close to a highway. Journal of Applied Ecology 32:481-491.

Reijnen, R., R. Foppen, and H. Meeuwsen. 1996. The effects of traffic on the density of breeding birds in Dutch agricultural grasslands. Biological Conservation 75:255-260.

Reijnen, R., R. Foppen, and G. Veenbaas. 1997. Disturbance by traffic of breeding birds: Evaluation of the effect and considerations in planning and managing road corridors. Biodiversity and Conservation 6:567-581.

Rice, J., R. D. Ohmart, and B. W. Anderson. 1984. Habitat selection attributes of an avian community: a discriminate analysis investigation. Ecological Monographs 53:263-290.

Rhodes, B., C. O'Donnell, and I. Jamieson. 2009. Microclimate of natural cavity nests and its implications for a threatened secondary-cavity-nesting passerine of New Zealand, the South Island Saddleback. Condor 111:462-469.

Ricketts, T. H. 2001. The matrix matters: effective isolation in fragmented landscapes. American Naturalist 158:87-99.

Ricklefs, R. E. 1987. Community diversity: relative roles of local and regional processes. Science 235: 167.

Ridgeway, R. 1887. A manual of North American birds. Lippincott, Philadelphia.

Robertson, B.A. 2009. Nest site selection in a postfire landscape: Do parents make tradeoffs between microclimate and predation risk? Auk 126:500-510.

Rodgers, A. R., R. S. Rempel, and K. F. Abraham. 1996. A GPS-based telemetry system. Wildlife Society Bulletin 24:559-566.

Romano, M. D., J. F. Piatt, and H. R. Carter. 2007. First successful radio-telemetry study of Kittlitz's Murrelet— Problems and potential, in Piatt, J. F., and S.M. Gende, editors: Proceedings of the Fourth Glacier Bay Science Symposium October 26–28, 2004: U.S. Geological Survey Scientific Investigations Report 2007-5047.

Rosenberg, K. V., R. D. Ohmart, and B. W. Anderson. 1982. Community organization of riparian breeding birds: response to an annual resource peak. Auk 99:260-274.

Rosenzweig, M. L. 1995. Species diversity in space and time. Cambridge University Press, Cambridge, UK.

Sechrist, J., V. Johanson, and D. Ahlers, 2009. Western yellow-billed cuckoo radio telemetry study results, Middle Rio Grande, New Mexico 2007-2008. U.S.D.I. Bureau of Reclamation, Technical Services Center, Fisheries and Wildlife Resources Group, Denver, Colorado.

Seaman, D. E., and R. A. Powell, 1996. An evaluation of the accuracy of kernel density estimators for home range analysis. Ecology 77:2075-2085.

Scott, M .L., G. T. Auble, and J. M. Friedman. 1997. Flood dependency of cottonwood establishment along the Missouri River, Montana. Ecological Applications 7:677-690.

Shafroth, P.B., J.R. Cleverly, T.L. Dudley, J.P. Taylor, C. Van Riper III, E.P. Weeks, and J.N. Stuart. 2005. Control of *Tamarix* in the western United States: implications for water salvage, wildlife use, and riparian restoration. Journal of Arid Environments 49:17-34.

Sher, A. A., and D. L. Marshall. 2003. Competition between native and exotic floodplain tree species across water regimes and soil textures. American Journal of Botany 90:413-422.

Silverman, B. W. 1986. Density estimation for statistics and data analysis. Chapman and Hall, London, UK.

Slabbekoorn, H., and M. Peet. 2003. Ecology: Birds sing at a higher pitch in urban noise - great tits hit the high notes to ensure that their mating calls are heard above the city's din. Nature 424:267-267.

Smith D. M., J. F. Kelly, and D. M. Finch. 2006. Cicada mergence in Southwestern riparian forest: influences of wildfire and vegetation composition. Ecological Applications 16:1608-1618.

Sogge, M. K., J. C. Owen, E. H. Paxton, S. M. Landgridge, and T. J. Koronkiewicz. 2001. A targeted mist net capture technique for the Willow Flycatcher. Western Birds 32:167-172.

Springer, J. T. 1979. Some sources of bias and sampling error in radio triangulation. Journal of Wildlife Management 43:926–935.

Strausberger, B. M., and M. V. Ashley. 1997. Community-wide patterns of parasitism of a host "generalist" brood-parasitic cowbird. Oecologia 112: 254-262.

Stromberg, J. C. 2001. Restoration of riparian vegetation in the south-western United States: importance of flow regimes and fluvial dynamism. Journal of Arid Environments 49:17-34.

Stromberg, J. C., B. D. Richter, D. T. Patten, and L. G. Wolden. 1993. Response of a Sonoran riparian forest to a 10-year return flood. Great Basin Naturalist *53:118-130.*

Stromberg, J. C., R. Tiller, and B. D. Richter. 1996. Effects of groundwater decline on riparian vegetation of semiarid regions: The San Pedro, Arizona. Ecological Applications 6:113-131.

Tallent-Halsell, N. G. and L. R. Walker. 2002. Responses of *Salix gooddingii* and *Tamarix ramosissima* to flooding. The Society of Wetland Scientists: 22:776-785.

USDA Forest Service Region 3. 1988. Regional Forester's sensitive species list.

U. S. Geological Survey, Biological Resources Division, Patuxent Wildlife Research Center. 2000. Brief history of bird banding. Bird Banding Laboratory, The North American Bird Banding Program. (http://www.pwrc.usgs.gov/bbl/homepage/history.htm) Accessed Oct 2010.

U. S. Fish and Wildlife Service. 2001. Endangered and threatened wildlife and plants; 12-month finding for a petition to list the yellow-billed cuckoo (*Coccyzus americanus*) in the western continental United States. Federal Register 66(143): 38611-38626.

U. S. Fish and Wildlife Service. 2002. Yellow-billed cuckoo candidate listing on Endangered Species List. Federal Register 67(114).

U. S. Fish and Wildlife Service. 2010. Issuance of annual regulations permitting the hunting of migratory bird species draft environmental impact statement. fws.gov/migratorybirds/ NewReportsPublications/Hunting/SEIS 7 June b 2010.pdf. Accessed 2 Dec 2010.

Vandersande, M. W., E. P. Glenn, and J. L. Walworth. Tolerance of five riparian plants from the lower Colorado River to salinity drought and inundation. Journal of Arid Environments 49:147-159.

Visser, M. E., J. M. Holleman, and L. P. Gienapp. 2006. Shifts in caterpillar biomass phenology due to climate change and its impact on the breeding biology of an insectivorous bird. Oecologia 147:164-172.

Wachob, D. 1996. The effect of thermal microclimate on foraging site selection by wintering Mountain Chickadees. Condor 98:114-122.

Walsberg, G. E. 1996. Thermal consequences of roost-site selection: the relative importance of three modes of heat conservation. The Auk 103:1-7.

Warren, D. K., and R. M. Turner. 1975. Saltcedar (*Tamarix chinensis*) seed production, seedling establishment, and response to inundation. Journal of the Arizona Academy of Science 10:135-144.

Warner, R. E., and K. M. Hendrix. 1985. Riparian resources of the Central Valley and California Desert. California Department of Fish & Game, Resources Agency, Sacramento, CA.

Webb, D. R. 1987. Thermal tolerance of avian embryos: a review. Condor 89: 874-898.

Webb, R. H., S. A. Leake, and R. M. Turner. 2007. The ribbon of green: change in riparian vegetation in the Southwestern United States. The University of Arizona Press, Tucson, AZ, USA.

Wheelwright, N. T., C. R. Freeman-Gallant, and R. A. Mauck. 2006. Asymmetrical incest avoidance in the choice of social and genetic mates. Animal Behaviour 71: 631–639.

White, J. A., and M. Lloyd. 1979. 17-year cicadas emerging after 18 years: a new brood? Evolution 33: 1193-1199.

Whitehouse, S., and D. Steven. 1977. A technique for aerial radio tracking. Journal of Wildlife Management 41: 771-775.

Williams, J. B. 1996. Energetics of avian incubation. Pages 375-416 *in* C. Carey (ed.). Avian energetic and nutritional ecology. Chapman Hall, New York.

Wilson, J. 2000. Additional observations on precopulatory behavior of yellow-billed cuckoos. The Southwestern Naturalist 45: 535-536.

Wilson, A., R. Fuller, C. Day, and G. Smith. 2005. Nightingales *Luscinia megarhynchos* in scrub habitats in the southern fens of East Anglia, England: associations with soil type and vegetation structure. Ibis 147:498-511.

Wingfield, J. C., K. Hunt, C. Bruener, K. Dunlap, G. S. Fowler, L. Freed, and J. Lepson. 1997. Environmental stress, field endocrinology and conservation biology *in* J. R. Clemmons and

R. Bucholz editors: Behavioral approaches to conservation in the wild. London Cambridge University Press, UK.

Wood, W. E., and S. M. Yezerinac. 2006. Song sparrow (*Melospiza melodia*) song varies with urban noise. Auk 123:650-659.

Woolnough, A. P., W. E. Kirkpatrick, T. J. Lowe, and K. Rose. 2004. Comparison of three techniques for the attachment of radio transmitters to European Starlings. Journal of Field Ornithology 75:330-336.

Worton, B. J. 1995. A convex hull-based estimator of home-range size. Biometrics 51:1206-1215.

Yard, H. K., C. Van Riper III, B. T. Brown, and M. J. Kearsley. 2004. Diets of insectivorous birds along the Colorado River in Grand Canyon, Arizona. Condor 106:106-115.

Yoder, J. M., E. A. Marschall, and D. A. Swanson. 2004. The cost of dispersal: predation as a function of movement and site familiarity in ruffed grouse. Behavioral Ecology 15:469–476.

Zar, J. H. 1999. Biostatistical Analysis, Fourth Edition. Prentice Hall, Englewood Cliffs, NJ, USA.

Appendix A. Yellow-billed cuckoo Survey Site Descriptions.

LITTLEFIELD BRIDGE

Mohave County, AZ (Beaver Wash)

Beaver Wash crosses county Hwy 91 approximately 1.2 km north of Interstate 15 at Littlefield Bridge, in the town of Littlefield. The floodplain of Beaver Wash consists of structurally diverse native dominated riparian vegetation from its confluence with the Virgin River, upstream for more than 2 km. One site was surveyed at Littlefield Bridge during the 2010 breeding season.

Littlefield Bridge (LITBR) ELEVATION 565 M, 19.9 HA

Continuous native-dominated riparian habitat upstream of Littlefield Bridge was surveyed during the 2010 season. Extensive recruitment of young cottonwoods and willows was evident, while mature cottonwoods lined the edges of, and were interspersed within the floodplain at this site. Water was present at this site throughout the breeding season. Beaver Wash is used for off-road recreation. Adjacent upland use includes a golf course, residential and commercial areas, as well as grazing along the NE border of the riparian habitat. No cuckoos were detected in 2010 (Table 1-3).

MORMON MESA

Clark County, NV (Virgin River Drainage)

The Virgin River runs through a wide floodplain upstream of Lake Mead on the west side of the Mormon mesa. The floodplain consist of a variety of habitat types dominated by tamarisk (*Tamarix spp.*), with intermittent Goodding's willow and cattail (*Typha* sp.) marshes.

SMELLY JELLY (SMJE) ELEVATION 380 M, 18.7 HA

The site is dominated by mature tamarisk 4-5 m tall with scattered small Goodding's willow stands averaging between 4 and 7 m tall. Much of the tamarisk is dense with over 90% canopy cover. Standing water and deep mud persisted in much of the area for the duration of our surveys. We detected a cuckoo here in a tall Goodding's willow stand during the first survey period (Table 1-3). No subsequent detections were observed at this site in 2010.

OVERTON WILDLIFE MANAGEMENT AREA

Clark County, NV (Muddy River Drainage)

Overton Wildlife Management Area (WMA) lies in the Moapa Valley about 3.2 km south of Overton on SR 169. The WMA consists of 7,145.5 ha (17,657 ac) of Mojave desert upland and riparian floodplain where the Muddy River flows into the Overton arm of Lake Mead. Nevada Department of Wildlife (NDOW) manages this area as wildlife habitat. Within the floodplain, 66 ha (165 ac) of agricultural crops including barley (*Hordeum vulgare*) and alfalfa (*Medicago sp.)* are grown to enhance habitat for migrating and wintering waterfowl. Most riparian habitat not managed for waterfowl has been invaded by tamarisk. There are small patches with remnant Goodding's willow overstory and tamarisk understory along the main channel of the Muddy River. Cottonwoods line the perimeter of the agricultural fields. Two sites within the WMA were surveyed during the 2010 breeding season.

Overton Wildlife (OVRW) ELEVATION 365 M, 10.1 HA

The survey route follows a line of young cottonwoods between an access road and fallow fields, continuing along the floodplain of the Muddy River. Dominant trees are Goodding's willow, which lines the main channel, and tamarisk providing a dense understory. Young cottonwoods are also scattered through the site. Several fields to the west are dry during the cuckoo breeding season and flooded in the winter to provide waterfowl habitat. Upstream to the north, east, and south, patches of young tamarisk line the main fork of the Muddy River. Adjacent to the riparian vegetation are creosote bush-dominated Mojave Desert uplands. One cuckoo was detected during the 2010 surveys (Table 1-3).

Wilson Pond (OVRWP) ELEVATION 365 M, 0.7 HA

This survey route circles Wilson Pond along an overgrown dirt road. The pond and riparian vegetation (cottonwood, Goodding's willow, tamarisk, seep willow, and sedges (*Carex* spp.), dominate the interior of the survey route. Away from the pond the road is bordered by a thin stand of intermittent cottonwood and willow with abundant seep willow and tamarisk. Further out the habitat is dominated by tamarisk. Single cuckoo detections were recorded during the second and third survey periods each. No additional cuckoo detections were made during later surveys or follow-up visits (Table 1-3).

HAVASU NATIONAL WILDLIFE REFUGE

Mohave County, AZ (Colorado River Drainage)

Havasu National Wildlife Refuge was established in 1941 and encompasses over 30 river miles of the Colorado River and adjacent land from Needles, California to Lake Havasu City, Arizona. Yellow-billed cuckoo habitat within the Refuge is almost entirely within the Topock Marsh area, a historic river meander east of the main river channel currently managed as wildlife habitat. Water levels are increased in the early spring to benefit southwestern willow flycatchers and gradually lowered during the fall. Seven sites were surveyed here in 2010, including one new area (Lost Lake). Four of the seven sites are restoration sites. Two sites are on the north end of the marsh, separated by 350 m (Pintail Slough, North Dike); the rest are 5 to 9 km to the southwest, between the main channel of the Colorado River and Topock Marsh (Havasu Levee Road, Topock Platform, Glory Hole, Beal, Lost Lake).

Pintail Slough (HAVPS) ELEVATION 140 M, 11.7 HA

This site consists of a narrow stand of mature cottonwoods (50-60 cm DBH) lining the slough, a restored field 250 m to the south, and another stand 300 m southeast. The slough is lined with cattails and the surrounding understory is a mix of tamarisk, arrowweed (*Pluchea sericea*) and quailbush (*Atriplex lentiformis*). The southeast habitat is dominated by cottonwoods which established naturally following flooding of nearby wintering waterfowl habitat (Pers. comm. Jack Allen, Refuge biologist). The southern planted field has a sparse overstory of cottonwoods and a dense ground cover of Johnson grass (*Sorghum halapense*). Water was present at the site intermittently through the season. A system of access roads intersects the site. Three cuckoos were detected at this

site in 2010 (Table 1-3). Two of these cuckoos were captured and tracked using radio telemetry. No nesting activity or breeding behaviors were observed. Dove hunting was observed in the area, starting in early September.

North Dike (HAVND) ELEVATION 140 M, 5.1 HA

This is a mature restoration site along the north dike of Topock Marsh. The patch has an overstory of Fremont cottonwood and Goodding's willow and an understory of seep willow and honey mesquite (*Prosopis glandulosa*). An agricultural field borders the site to the north. The site is surrounded by access roads, with a cement-lined irrigation canal along the western edge. To the south and west is a historic floodplain dominated by mesquite and tamarisk. There was hunting activity here late in the field season. Single cuckoo detections were made during two survey periods at this site in 2010 (Table 1-3).

Havasu Levee Road (HAVLR) ELEVATION 143 M, 3.2 HA

This site is composed of a narrow strip of remnant riparian habitat between the levee road and the Colorado River, 350 m northwest of Topock Platform. This small patch of mixed native habitat has a sparse overstory of Goodding's willow, tamarisk, and mesquite. The main canopy ranges from 4-6 m high and has an average canopy cover of about 20%. Arrowweed and seep willow provide a dense understory 1-3 m high. The Colorado River to the west experiences heavy motorized boat traffic. No cuckoos were detected at this site in 2010 (Table 1-3).

Glory Hole (HAVGH) ELEVATION 139M, 13.2 HA

This mixed native site is on an island bounded by channels along the eastern shore of Topock Marsh. Suitable cuckoo habitat includes a mosaic of willow and tamarisk patches interspersed with marsh vegetation. The overstory covers less than 10% of the site while the understory is dominated by dense tamarisk. No cuckoos were detected during surveys in 2010 (Table 1-2).

Topock Platform (HAVTPR) ELEVATION 141 M, 9.3 HA

The Topock Platform site includes 8.8 ha (21.7 ac) of restored native habitat, located next to fields flooded in winter for waterfowl habitat. Three distinct areas make up this site. The section adjacent to the public access parking and Topock Platform consists of six-year-old Fremont cottonwoods and Goodding's willow with tall (8-14 m) and dense canopy cover. This area was planted as a nursery site for other restoration efforts. The understory is open, with about 20% cover of 1-5 m-high screwbean mesquite (*Prosopis pubescens*), Goodding's willow and Fremont cottonwood. To the east is a stand of shorter and more sparsely planted young cottonwoods and willows. Along the southern edge is a small stand of dense mesquites. Bermuda grass (*Cynodon sp.*) dominates the ground cover throughout the site. The landscape to the south and east is dominated by extensive stands of quailbush, arrowweed and dense tamarisk with a few remnant willows and mesquites. In 2010 cuckoos were detected during surveys one through four (Table 1-3). Follow-up visits made after each survey yielded no further detections.

Beal Restoration (HAVBR) ELEVATION 137 M, 21.3 HA

Beal Restoration lies approximately 3 km south of Topock Platform, between Beal Lake and Topock Marsh. This site consists of a mosaic of native trees planted in the historic floodplain of the Colorado River. The survey route follows suitable habitat within the site. Approximately 21.3 ha of the 43.4 ha planted from 2003 to 2005 as part of Phases 1 and 2 (LCR MSCP 2006a) were surveyed for cuckoos in 2010. Nearly 5 ha of Fremont cottonwood and 4 ha of mixed Goodding's willow and mesquite were planted. The remaining area is relatively open with a sparse native overstory and an understory of arrowweed, screwbean mesquite and coyote willow. The overstory ranges from 3-7 m high, with approximately 10% canopy closure. The understory vegetation ranges from 1-3 m, and covers about 40% of the area. Multiple access roads cross the site and define the perimeter. There is year-round water in an irrigation ditch bordering the southeastern edge of the site. This ditch connects Beal Lake on the southwest with Topock Marsh to the northeast. We detected 3 individual cuckoos during surveys in 2010 (Table 1-3). From extensive mist-netting, telemetry and follow-up efforts we located one nest (see Chapter 3).

Lost Lake (HAVLL) ELEVATION 137 M, 4 HA

The site boarders the Lost Lake and consists of a narrow band of cottonwood trees with an understory dominated by tamarisk. The overstory averages 5 m high. The site is surrounded by tamarisk and arrowweed on three sides. Marsh vegetation dominates the northwest side. In 2010 one cuckoo was detected (Table 1-3).

Bill Williams River National Wildlife Refuge

Mohave and Yuma Counties, AZ (Bill Williams River Drainage)

Bill Williams River NWR was established in 1941 and is located 14.3 km south of Lake Havasu City, AZ. It consists of 2,430 ha (6,000 ac) of Bill Williams River drainage managed by USFWS to protect the largest remaining natural riparian habitat in the lower Colorado River Valley. this Refuge extends from Lake Havasu upstream on the Bill Williams River for 16 km, and contains the most extensive and productive yellow-billed cuckoo habitat in the LCR watershed. Portions of the Bill Williams River have perennial surface water. The managed hydrologic regime enables overbank flooding necessary for natural regeneration of native vegetation and persistence of cottonwood-willow forest. Releases from Alamo Dam during the winter of 2005 resulted in natural regeneration of large areas of riparian habitat. Sixteen routes within the BWR NWR, covering over 680 ha (1680 ac) of potential cuckoo habitat were surveyed in 2010. They are described upstream (east) to downstream (west).

<u>Cave Wash (BWCW)</u> ELEVATION 175 M, 88.1 HA

This site is in the floodplain of the Bill Williams River at the eastern edge of the Refuge. This section of the Refuge consists of a broad riparian area with both historic and recently formed river channels. There are extensive areas of dense tamarisk although the vegetation is predominately native. Water is seasonally present in some side channels, and perennial in the main channel. The main channel is lined with young cottonwood, willow, and tamarisk averaging 8 m high, with dense marsh vegetation in the main channel. The survey route follows two old river channels. There were 20 survey detections in 2010, representing one confirmed and three possible breeding pairs (Table 1-4).

Cottonwood Patch (BWCP) ELEVATION 180 M, 38.1 HA

This site in the floodplain of the Bill Williams River at the eastern end of the Refuge, adjacent to Planet Ranch and currently owned and managed by the City of Scottsdale, AZ. The site is dominated by dense patches of cottonwoods established following flooding in 2005, surrounded by large open areas. Ground cover is predominantly Bermuda grass. The survey route winds through the widest parts of the habitat. The soil is sandy gravel, with intermittent water flow through river meanders. The upland side is composed of old agricultural fields, and the route is separated from the main stream of the Bill Williams River by a 200-400-m open sandy wash with scattered tall cottonwoods. There were thirteen survey detections in 2010 and a maximum of two breeding pairs (one confirmed and one possible breeding pair, Table 1-4).

Honeycomb Bend (BWHB) ELEVATION 170 M, 29.6 HA

This route follows the Bill Williams River, connecting with Cave Wash to the east and Mineral Wash to the west. Tall cottonwoods and willows with a dense understory of willow, arrowweed, and tamarisk dominate the multi-structured habitat. The river is perennial, and multiple beaver dams have created ponds lined with dense willows, cattails, and tamarisk. The riparian area is restricted by surrounding cliffs as the river passes through a narrows. There is intermittent overbank flooding at the site, and little ground cover. There were 13 survey detections in 2010, representing three confirmed breeding pairs (nests), and two possible breeding pairs (Table 1-4).

Mineral Wash (BWMW) ELEVATION 165 M, 49.8 HA

This route is located between the Honeycomb Bend and Esquerra Ranch sites. It is a linear route following the river channel from a restricted canyon bordered by cliffs to a more open floodplain. The river is lined with bands of tall dense willows, large cottonwoods, and an understory of willows, tamarisk, arrowweed and mesquite. Extensive marsh vegetation and cattails line the river channel. The route is bordered by old agricultural fields. The surrounding Sonoran Desert vegetation includes saguaros and creosote bush. Perennial water flows through the site, while seasonal flooding occurs during winter and summer rains. A public access road follows Mineral Wash, and there is some recreational activity where the road terminates at the river. There were 16 survey detections in 2010, representing two confirmed and one possible breeding pair (Table 1-4).

Esquerra Ranch (BWER) ELEVATION 165 M, 40.2 HA

This site is the eastern section of the 2008 Big Bend route which was split in 2009 to increase coverage of the habitat, and lies between Mineral Wash and Cougar Point routes. The new route name was chosen after consulting with Refuge personnel, who do not use the name "Big Bend". The route begins at the intersection of Mineral Wash Road and the Bill Williams River. The route makes a loop downstream along the current river channel to a river bend (also known as Cougar Point), then upstream along an old (pre-2005) river channel. Both channels contain perennial water and are lined with cottonwoods, willows and a dense understory of tamarisk and arrowweed. The route is bounded by a steep cliff on the southwest and a broad dry upland area (the former Esquerra Ranch) to the northeast. Within the survey site there was one survey detection in 2010, but no evidence

of breeding (Table 1-4). At the edges of the site we had additional cuckoo detections, but these extensively overlapped a breeding territory or cuckoo detections in adjacent sites and were not attributed to the Esquerra Ranch site.

Cougar Point (BWPT) ELEVATION 165 M, 43.1 HA

This site is the western section of the pre-2009 Big Bend route, and lies between the Esquerra Ranch and Gibraltar Rock routes. The route follows a river bend (Cougar Point). The northernmost part runs through an area of extensive forest which regenerated following 2005 flooding. The southern part skirts older forest along the main river channel, composed of cottonwoods, willows, and a dense understory of tamarisk and arrowweed. Several meanders contain perennial water. There were 21 survey detections in 2010, and three confirmed breeding pairs (Table 1-4).

Kohen Ranch (BWKR) ELEVATION 145 M, 37.1 HA

This site was modified and expanded from the 2009 Kohen Cliff site. It covers areas of natural regeneration which occurred following prolonged flooding during 2005-2006. The route begins at the historic Kohen Ranch and heads northeast following the northern edge of the riparian and paralleling the Gibraltar Rock route. The route passes through mature cottonwood-willow forest as well as a mix of park-like vegetation, with a high cottonwood overstory and Bermuda grass ground cover. There is a 2009 FWS mesquite restoration site on the edge of this route, which may be included in future surveys. The Bill Williams River was flowing through the site at the start of the field season, but by August there was only water in the eastern section of the Refuge. There were seven survey detections in 2010, representing one confirmed and one possible breeding pair (Table 1-4).

Gibraltar Rock (BWGR) ELEVATION 145 M, 66.5 HA

This site is located between the Cougar Point and Sandy Wash sites, following an old road and river channel. Water was present early in the season but the main channel was completely dry by mid-July. The eastern part of the route parallels the main river channel, passing through dense high-canopy cottonwood/willow, dense stands of mesquite, and scattered open cottonwood/mesquite. The western half of the route is drier, with small patches of large native trees and a dense understory of tamarisk. The route passes through a gap in the cliffs. West of this gap, the floodplain widens and is dominated by tamarisk. This site experiences winter flooding. Recreational use (hiking) is present but light. There were six survey detections in 2010, representing one possible breeding pair (Table 1-4).

Sandy Wash (BWSW) ELEVATION 145 M, 50.9 HA

This route connects with Gibraltar Rock to the southeast and Fox Wash to the northwest. This section of the Refuge gradually widens into a floodplain laced with dry river channels. The route makes a loop around the eastern end of the broad floodplain, following an old road and river channel. The site is structurally diverse, with an overstory of tall cottonwoods and willows with a tamarisk-dominated understory on the southern edge, mature tamarisk in the central part, and tall dense native-dominated cottonwood /willow to the east. There was standing water along the old river channel at the eastern part of the site during the field season, but the rest was dry. Hikers and researchers frequently use this easily accessible route. There were eight survey detections in 2010, representing two possible and one confirmed breeding pair (Table 1-4).

Fox Wash (BWFW) ELEVATION 140 M, 62.5 HA

This route lies north of Sandy Wash, along the main channel of the Bill Williams River, and ends in a wide floodplain to the west. Scattered dense bands of tall cottonwoods and willows line the main channel. Narrower and more open native vegetation line several of the older channels. The interior is open with patches of scrubby tamarisk, while narrow patches of marsh vegetation surround remnant pools along the main channel. Mature cottonwood and mesquite are interspersed throughout the site. There were three survey detections in 2010 and no evidence of breeding activity (Table 1-4).

Borrow Pit (BWBP) ELEVATION 140 M, 33.6 HA

This route was created in 2009 and follows a new trail along an old river channel paralleling the west end access road, and incorporates part of the former Mosquito Flats route. The survey is conducted from an old river channel and bluffs overlooking the habitat. It connects Cross River to the west and Sandy Wash to the east. The habitat along the southern half of the route contains mature riparian cottonwood/willow forest with a dense tamarisk understory. The northern half includes occasional dense stands of tall cottonwoods and willows and extensive dense tamarisk. There were small ponds of standing water present on the site until mid-July. There were five survey detections in 2010, representing one possible breeding pair (Table 1-4).

Cross River (BWCR) ELEVATION 140 M, 30.2 HA

This route was established in 2009 and bisects the Bill Williams River delta approximately 1 km upstream from Lake Havasu. It connects Borrow Pit to the south and North Burn to

the north. This site is primarily composed of extensive tall cottonwoods and willows with a mixed native and dense tamarisk understory. There are also smaller patches of younger cottonwood-willow forest and occasional monotypic patches of dense tamarisk. There are multiple old meandering river channels within the site. This site is bordered both upstream and downstream by contiguous riparian habitat. There were seven survey detections in 2010, representing two possible breeding pairs (Table 1-4).

Mosquito Flats (BWMF) ELEVATION 140 M, 37.1 HA

This route was significantly modified in 2010. The eastern section which is surveyed from bluffs overlooking the riparian habitat, skirting along the edge of the riparian was ceded to the Bill Williams Marsh route for logistical reasons. The riparian habitat at the western end of the refuge spreads out into a wide floodplain. The 2008 route followed the southern edge of the habitat, but in 2009 the route was moved to follow a new trail accessing more of the dense cottonwood/willow forest with occasional stands of tamarisk and scattered mesquite in the interior of the site. Both the 2008 exterior and 2009 interior routes were surveyed in 2010. There is light visitor use in the summer, and some vehicle traffic on the main road to the south. Although there was no standing water on vegetation plots, the water table appears to be high here, and there were several standing ponds and water-filled side channels on or near the route. There were eleven survey detections in 2010, representing two possible breeding pairs (Table 1-4).

North Burn (BWNB) ELEVATION 133 M, 30 HA

The route begins at the northern branch of the Bill Williams River slough and continues along that channel. The overstory ranges from 8-18 m high and provides around 70%

cover, while the understory is 2-8 m, providing around 75% cover. The route encompasses two distinct habitat types. The eastern third of the site is a mixed native forest, with a mature willow/cottonwood overstory. The western two thirds of the site are dominated by tamarisk. The area burned in 2005, and is regenerating with tamarisk and quailbush. The site is surrounded by tamarisk-dominated floodplain and Sonoran Desert upland habitat to the north and east. The area to the south and west has more native-dominated habitat extending up the river. Standing water was observed until the middle of the breeding season. There were two survey detections in 2010 and no breeding activity (Table 1-4).

Middle Delta (BWMD) ELEVATION 135 M, 25.2 HA

This site was added in 2009, and traverses an extensive patch of mature, mixed exotic vegetation extending upstream from the Bill Williams River delta between the Bill Williams Marsh and North Burn sites. It also connects to Cross River. The eastern (upstream) end of the route has extensive patches of mature cottonwood overstory with an open understory. To the west, the overstory consists of patches of mature willow, which become sparse closer to Lake Havasu. The understory is dominated by dense tamarisk. Although no water was found within the site this season, the western end of the site is bordered by two forks of the Bill Williams River delta. There were three survey detections in 2010, with two possible breeding pairs (Table 1-4).

Bill Williams Marsh (BWMA) ELEVATION 133 M, 19.7 HA

This route is surveyed by kayak, and provides access to habitat within the broad western floodplain. The route follows the main channel of the Bill Williams River, which floods seasonally from upstream waters, and is periodically inundated by fluctuating lake levels.

The riparian habitat consists of cottonwood/willow with a dense understory of tamarisk. The shore is lined with cattails. There is regular boating and fishing activity at this site. There were two survey detections in 2010 and no breeding activity at this site (Table 1-3). The 2009 Saguaro Slot (BWSS) route paralleled this route from the xeric uplands and covers the same area, so the two sites were merged into one in 2010. Two cuckoos were detected during the first survey only (Table 1-4).

PALO VERDE ECOLOGICAL RESERVE

Riverside County, CA

Palo Verde Ecological Reserve (PVER) is located 12 km north of Blythe, CA. The 547 ha (1351 ac) site was acquired by the State of California in 2004. Restoration activities are a joint effort by Reclamation and the California Department of Fish and Game (CDFG), and are outlined in the Palo Verde Ecological Reserve Restoration Development Plan Overview (LCR MSCP 2006b). Phases 1, 2, and 3 were fully surveyed in 2010, while Phase 4 received late-season surveys due to observed cuckoo activity.

Palo Verde Ecological Reserve Phase 1 (PVER1) ELEVATION 86 M, 8.3 HA

Phase 1 of PVER was planted in 2006. In 2010 the cottonwood and willow overstory was 3-10 m tall, providing about 90% canopy cover. Groundcover is predominately alfalfa. The site is bordered by dirt access roads used to conduct the surveys. Agricultural fields border the site to the north and east. There were two survey detection at this site in 2010, and no evidence of breeding (Table 1-5).

Palo Verde Ecological Reserve Phase 2 (PVER2) ELEVATION 86 M, 24.2 HA

PVER2 was planted in 2007 and first surveyed in 2009. The site consists of Goodding's willow, coyote willow and Fremont cottonwood plantings. These trees now range in height from 3 to 10 m with approximately 70% canopy cover. The plantings were designed to maximize the amount of edge between Goodding's willow and coyote willow, considered to be preferred habitat for the southwestern willow flycatcher (LCR MSCP 2006b). A Northern Arizona University research area is less densely planted with a variety of genetic plant material. There were eight survey detections in 2010, one confirmed (nest) and another possible breeding pair (Table 1-5).

Palo Verde Ecological Reserve Phase 3 (PVER3) ELEVATION 86 M, 35 HA

Phase 3 was planted with cottonwood and willow strips for southwestern willow flycatcher habitat in 2008. The species composition and density was planted to mimic a natural riparian landscape when fully mature. Phase 3 was first fully surveyed for cuckoos in 2009. There were seven detections in 2010, representing one confirmed (nest) and one possible breeding pair (Table 1-5).

Palo Verde Ecological Reserve Phase 4 (PVER4) ELEVATION 86 M, 43 HA

Phase 4 was planted with cottonwood and willow strips in 2009. This site will be managed for the southwestern willow flycatcher (LCR MSCP 2006b). In 2010 the site was not surveyed until mid-season when activity was observed. There were four detections, representing one probable breeding pair (multiple food carries, Table 1-5).

CIBOLA VALLEY CONSERVATION AREA

La Paz County, AZ

Cibola Valley Conservation Area (CVCA) is located 24.2 km south of Blythe, CA, south and east of the Colorado River and the CA/AZ border. Within Cibola Valley, 407.6 ha (1,019 ac) of land owned by the Mohave County Water Authority have been identified for riparian restoration, as outlined in the Cibola Valley Conservation Area Restoration Development Plan (LCR MSCP 2007). Since 2006, 101 ha (250 ac) of native riparian trees have been planted in three phases. Phases 1 and 2 are located in adjacent fields, and Phase 3 is approximately 2.6 km to the west. Agricultural fields dominate the area surrounding the sites.

Cibola Valley Conservation Area Phase 1 (CVCA1) ELEVATION 72 M, 34.8 HA

This site consists of six fields planted in 2006. Fremont cottonwood, Goodding's willow and coyote willow are the dominant tree species. Canopy height ranges from 5-16 m with about 90% canopy closure. There is little understory at the site (approximately 30%), groundcover consists of alfalfa and exotic grasses. The site was periodically flood-irrigated throughout the season. The Colorado River flows approximately 100 m from the northern edge of the site. River Road and several dirt access roads define the perimeter of CVCA1 and additional dirt roads cross the site. Cuckoo surveys were first conducted at CVCA1 in 2008. In 2010 there were 19 survey detections and three confirmed breeding pairs (3 nests) (Table 1-5).

Cibola Valley Conservation Area Phase 2 (CVCA2) ELEVATION 72 M, 24.7 HA

CVCA2 was planted in 2008 and is adjacent and to the south of CVCA1, separated by a dirt access road and a concrete-lined irrigation ditch. Fremont cottonwood and Goodding's willow are the co-dominant trees, with heights ranging from 3 to 7 m, and canopy cover of approximately 90%. Phase 2 was surveyed for the first time in 2009. In 2010 there were 13 survey detections at this site and three confirmed breeding pairs (Table 1-5).

Cibola Valley Conservation Area Phase 3 (CVCA3) ELEVATION 72 M, 37 HA

CVCA Phase 3 is located 2.6 km west of CVCA1 and CVCA2, and 400 m east of the Colorado River. The site was planted in 2007 with Fremont cottonwood, Goodding's willow and coyote willow. Tree heights vary from 2-9 m and canopy cover averages 80%. Dirt access roads are found on all sides and between the plantings. Surveys were first conducted at this site in 2009. In 2010 there were six survey detections at this site, representing one possible breeding pair (Table 1-5).

Cibola National Wildlife Refuge

La Paz County, AZ (Colorado River Drainage)

Cibola NWR is 29.8 km south of Blythe, CA in the historic floodplain of the Colorado River. The Refuge, exceeding 6,475 ha (16,000 ac), was established in 1964 and is managed by the USFWS to preserve and protect wildlife habitat. The Refuge includes both the historic Colorado River channel as well as a new channel constructed in the late 1960s. The old channel still receives irrigation water and portions are maintained as wildlife habitat, while the new channel carries the Colorado River flow and is extensively levied.

Within the Refuge, fields of alfalfa and grain crops border extensive tamarisk and mesquite dominated uplands. Four sites at Cibola NWR were surveyed in 2010.

Cibola North (CIBNTH) ELEVATION 71 M, 8.6 HA

Cibola North is a more open, structurally homogeneous site with a cottonwood overstory averaging 8 m high and providing around 60% canopy closure. The ground cover is dominated by Bermuda grass. Fallow fields dominated by sparse tamarisk, arrowweed, and quailbush extend to the east and west of the site. The Cibola Nature Trail is 580 m to the south and is separated from this site by three agricultural fields. The site is bordered on its northern edge by Baseline Road and agricultural fields. There was a single survey detection in 2010, with no evidence of breeding (Table 1-5).

Cibola Nature Trail (CIBCNT) ELEVATION 75 M, 62.3 HA

This restoration site was first planted in 1999. The route follows a well-maintained walking trail that winds through the habitat. The species composition and height varies across the site, creating structural diversity. Cottonwoods dominate a 5-11 m tall canopy providing about 40% canopy cover. The understory includes Goodding's willow, honey and screwbean mesquite, seep willow, coyote willow and young cottonwoods. Average understory measures 3 m with approximately 50% cover. In 2008 this site was extended to include restored patches to the west (mass planting and crane roost). This site was periodically flooded during the survey season. Much of the surrounding area is agricultural fields. There were thirteen survey detections in 2010, one confirmed breeding pair (nest) and two additional possible breeding pairs (Table 1-5).

Cibola Eucalyptus (CIBEUC) ELEVATION 70 M, 29.4 HA

Cibola Eucalyptus is adjacent to the Refuge, and is a mixed native restoration site composed of cottonwood and Eucalyptus west of the levee road and cottonwood, tamarisk, Goodding's willow and mesquite to the east. Overstory cover in the two patches is approximately 10% and height varies from 3-12 m. The understory is mostly sparse with about 30% cover. A mixed understory of arrowweed, quailbush, palo verde, tamarisk, mesquite and Goodding's willow averages 3 m high. The surrounding area consists of winter wheat and alfalfa fields to the north, west, and south, and the Colorado River main channel to the east. There were three survey detections in 2010, but no observed breeding activity (Table 1-5).

Cibola Island South (CIBSTH) ELEVATION 65 M, 126.8 HA

Cibola Island South combines a band of Goodding's willow along an irrigation channel surrounded by extensive mesquite plantings with a mature cottonwood-dominated restoration patch located on the Island Unit of Cibola NWR. Mature cottonwoods 4-8 m tall provide 25% cover in the southern part of this dry site. A sparse (about 25% cover) layer of mesquite, tamarisk and seep willow create an understory 1-4 m tall. The northern portion of this site is composed primarily of a Goodding's willow overstory and an understory including mesquite, tamarisk and seep willow, with a ground cover of cattails and Bermuda grass. The site is surrounded by historic Colorado River floodplain dominated by tamarisk, mesquite, arrowweed, quailbush, and agricultural fields used for wildlife enhancement crops. There were six survey detections at this site in 2010 and one possible breeding pair (Table 1-5).

Picacho State Recreation Area

Imperial County, CA (Colorado River Drainage)

Picacho State Recreation Area (SRA) is a historic mining town site, currently state-owned and managed by the California State Parks Department. It is 38.6 km north of Winterhaven, California, on the Colorado River.

Picacho State Recreation Area (PICSRA) ELEVATION 59 M, 14.8 HA

Picacho SRA is a cottonwood and willow dominated restoration site situated where Picacho Wash flows into the Colorado River. The vegetation at this site appears naturalized and is structurally diverse. Fremont cottonwood, Goodding's willow, and honey and screwbean mesquite dominate the 6-17 m tall canopy, averaging 30% cover. A diverse understory of arrowweed, quailbush, blue palo verde (*Cercidium floridum*), seep willow, mesquite, willow and cottonwood provides about 50% cover. The site is bordered by the Picacho SRA campground and adjacent Sonoran Desert uplands to the west, and the river to the east. There were nine survey detection in 2010, representing one probable breeding pair (Table 1-6).

Imperial National Wildlife Refuge

Yuma County, AZ (Colorado River Drainage)

Imperial NWR was established in 1941 and encompasses 10,307 ha (25,768 ac) of riparian area and associated Sonoran Desert uplands. The headquarters is 40.3 km north of Yuma, off Martinez Lake Road. The Refuge follows 48.3 km of the Colorado River,

including some of the last remaining unchannelized stretches. Refuge management activities include protecting backwater lakes, managing marshes, farming crops as food for wintering waterfowl, and restoring wetlands and associated riparian vegetation.

Imperial South Restoration (IMPSTH) ELEVATION 60 M, 13 HA

Imperial South (INWR Forest) consists of a small native nursery planted in 1994, and a band of cottonwood and willow habitat lining a finger of Martinez Lake. The nursery site comprises mature 5-14 m tall Fremont cottonwood, Goodding's willow, and mesquite, with approximately 60% canopy closure. There is a low, sparse (about 5% cover) understory of young cottonwood, mesquite, arrowweed, common reed, seep willow and tamarisk. Surrounding habitat includes an open field, impoundment ponds, and wetlands to the north. There were three survey detections in 2010, and one possible breeding pair (Table 1-6).

LAGUNA

Imperial County, CA

Two sites are located on BLM-managed lands near Imperial Dam. The sites are made up of several small habitat patches. A third site was surveyed in 2009 but dropped in 2010 (Laguna 1).

Laguna 2-3 (LAG2, LAG3) ELEVATION 50 M; 3.9 & 3.8 HA

Goodding's willow is the dominant tree at the Laguna sites, providing an overstory 8-12 m high and canopy cover averaging 70%. A small amount of Fremont cottonwood and tamarisk are also present. The understory consists of tamarisk, cattails and arrowweed. The sites are separated by 500 m of desert upland habitat. LAG3 is bisected by Imperial Rd. These sites were first surveyed in 2009. There was one detection at LAG3 in 2010 and no breeding activity (Table 1-5).

Mittry Lake Wildlife Management Area

Yuma County, AZ (Colorado River Drainage)

Mittry Lake WMA is managed by Arizona Game and Fish Department (AGFD) for wildlife habitat and outdoor recreation. The area is 24.2 km northeast of Yuma, between Laguna and Imperial Dams on the Colorado River.

Pratt Restoration (MLPR) ELEVATION 40 M, 14 HA

Pratt Restoration is a cooperative restoration planted in 1999 on a BLM agricultural lease. The overstory is 5-11 m with around 70% canopy cover, and comprises approximately 80% cottonwood and 20% Goodding's and coyote willow. There is about 30% understory cover (< 5 m) of seep willow, Goodding's willow, mesquite, cottonwood and tamarisk. Actively farmed alfalfa fields border the north and east sides of the site, while a young restoration site abuts the southeastern edge. The amount of available habitat approximately doubled in 2010. There were four detections at this site in 2010, representing one possible breeding pair (Table 1-6).

YUMA WETLANDS

Yuma County, AZ (Colorado River Drainage)

Yuma East and West Wetlands are restoration sites along the banks of the Colorado River near Yuma. Until recently the area was a mixture of exotic plants, trash dumps and squatter camps. Yuma West Wetlands is a 55 ha (135 acre) city park managed by the Yuma Department of Parks and Recreation. Yuma East Wetlands is part of the Yuma Crossing Natural Heritage Area, under joint management by the City of Yuma, the Quechan Tribe, AGFD, and private ownership. Planting at Yuma West began in 1999, and clearing and planting at Yuma East began in the winter of 2003-2004.

Yuma East Wetlands (YUEW) ELEVATION 36 M, 9 HA

This site was first surveyed in 2009. The site is immediately east of the Ocean to Ocean Bridge, and lies on both the north and south banks of the Colorado River, approximately 1.2 km upstream of Yuma West Wetlands. The restored habitat consists of a mosaic of Fremont cottonwood, Goodding's willow and mesquite spp. Overstory at the site ranges from 3-9 m with 50% canopy cover. Surveys were conducted from the south side. There was one survey detection in 2010 and no breeding activity (Table 1-6).

Yuma West Wetlands (YUWW) ELEVATION 36 M, 24.3HA

The Yuma West Wetlands consists of a mosaic of Fremont cottonwood, Goodding's willow and mesquite. Overstory at the site ranges from 6-12 m with an estimated 30% canopy cover. Arrowweed, saltbush, seep willow, mesquite, and tamarisk, as well as young naturally regenerating willow and cottonwood make up a diverse understory. Site

management includes regular understory clearing for fuel reduction and safety. The Colorado River borders the northern edge of the site, and residential areas border the south, east, and west. There was one survey detection in 2010 and no breeding activity (Table 1-6).

Quigley Wildlife Management Area

Yuma County, AZ (Gila River Drainage)

Quigley WMA is 4.0 km north of Tacna, in the Gila River floodplain. This 244.8 ha (612 acre) WMA is owned and managed by AGFD for wildlife and recreation. Potentially suitable cuckoo habitat at this site includes mixed exotic/native historic floodplain and a native-dominated restoration area.

Quigley WMA (GRQP) ELEVATION 75 M, 10.6 HA

A native restoration plot and the adjacent mixed native habitat form the Quigley Pond site. The restoration area contains a small plot of mature cottonwood, tamarisk, willow, and mesquites. This patch has an overstory ranging from 5-15 m tall that provides about 30% canopy cover. Tamarisk, arrowweed, seep willow, mesquite, willow and cottonwood provide an understory 1-5 m high, with approximately 70% canopy cover. The western mixed native section contains scattered, dead, and stressed cottonwoods and mesquites. The site is surrounded by agricultural fields on three sides and the dry Gila River floodplain to the west. There were three survey detections in 2010, representing one possible breeding pair (Table 1-6).

Appendix B. Breeding evidence and pair estimates at all LCR survey sites, 2010.

Site	Visits to Site	First-Last Detection Date	Total Days[1]	Breeding Status[2]	Behaviors Observed
Wilson Pond	5	6/24-7/07	13	1 POS	Detections in vicinity 6/24-7/07
Topock	9	6/29-8/08	41	1 POS	Detections in vicinity 6/29-8/08
Pintail Slough	15	7/8-7/24	16	1 PRB	Detections in vicinity 7/8-7/24
North Dike	8	7/8-7/20	13	1 POS	Detections in vicinity 7/8-7/20
Beal	23	6/22-8/05	44	1 COB	Nest found 7/20
Cave Wash	16	5/30-8/07	69	3 POS	Detections in vicinity 5/30-8/07
				1 COB	Multiple copulations (AF)
Cottonwood Patch	10	6/18-8/19	62	1 POS	Detections in vicinity 6/18-8/19
				1 COB	Juvenile
Honeycomb Bend	11	6/20-8-24	65	2 POS	Detections in vicinity 6/20-8-24
				3 COB	Three nests
Mineral Wash	8	6/27 -8/12	46	1 POS	Detections in vicinity 6/27 -8/12
				1 COB	Multiple food carries
				1 COB	Two juveniles
Esquerra Ranch	9	6/16-7/31	45	1 POS	Detections in vicinity 6/16-7/31
Cougar Point	10	6/18-8/15	58	2 COB	Two nests
				1 COB	Two juveniles
Gibraltar Rock	6	6/21-7/23	32	1 POS	Detections in vicinity 6/21-7/23
Kohen Ranch	6	6/21-8/15	45	2 POS	Detections in vicinity 6/21-8/15
				1 COB	Two juvenile YBCU
Sandy Wash	14	6/25-7/30	35	2 POS	Detections in vicinity 6/25-7/30
				1 COB	Nest
Borrow Pit	9	7/2-8/14	43	1 POS	Detections in vicinity 7/2-8/14
Cross River	7	6/29- 8/12	44	2 POS	Detections in vicinity 6/29- 8/12
Mosquito Flats	10	6/17-8/21	65	1 POS	Detections in vicinity 6/17-8/21
Middle Delta	5	6/20-7/18	28	2 POS	Detections in vicinity 6/20-7/18
				1 POS	Detections in vicinity 6/20-7/18
Cibola Nature Trail	30	6/18-8/02	45	2 POS	Multiple detections in vicinity 6/18-8/02
				1 COB	Nest
Cibola South	18	6/16-7/15	29	1 POS	Multiple detections in vicinity 6/16-7/15
CVCA Phase 1	40	6/22-8/29	68	3 COB	Three nests
CVCA Phase 2	43	6/26-8/27	62	3 COB	Three nests
CVCA Phase 3	13	6/15-7/19	34	1 POS	Detections in vicinity 6/15-7/19
PVER Phase 2	19	6/14-7/28	43	1 POS	Multiple detections in vicinity 6/14-7/28
				1 COB	Nest
PVER Phase 3	13	6/22-8/02	41	1 POS	Multiple detections in vicinity 6/22-8/02
				1 COB	Nest
PVER Phase 4	19	7/26-8/21	25	1 PRB	Three ybcu, multiple food carries, possible juv
Picacho SRA	4	6/26-7/ 21	25	1 PRB	Detections 6/26-7/12 Pair together, VEX
Imperial South	6	6/29-7/21	22	1 POS	Detections in vicinity 6/29-7/27
Mittry Lake/Pratt	5	6/28- 7/12	14	1 POS	Detections in vicinity 6/28-7/12
Quigley WNA	4	6/26-7/09	13	1 POS	Detections in vicinity 6/26-7/9
Total				32 POS, 3 PRB, 22 COB	

Appendix C. Mist net attempts, LCR 2010.

Site Code	Date	Net open	Capture Time	Net close	YBCU ID	# YBCU detected[1]
HAVBR	6/23	6:00	6:20	6:30	LB	3
HAVBR	7/1	8:30		10:00		3
HAVBR	7/2	5:30		8:00		3
HAVBR	7/9	6:30		9:30		2
HAVBR	8/4	7:00		10:00		1
HAVBR	8/5	7:00		8:30		1
HAVND	7/14	6:30		7:30		1
HAVPS	7/10	6:30	7:00	7:00	PC	2
HAVPS	7/14	8:30	9:15	9:15	TB	1
BWBP	7/5	7:00		8:45		2
BWCP	6/19	6:00	6:46	6:46	GZ	1
BWCP	7/04	5:42	5:56	6:00	AF	1
BWCP	7/11	5:40		7:30		2
BWCP	7/13	5:50		6:45		2
BWCP	7/13	9:10		9:10		3
BWCW	6/20	8:30		8:30		1
BWHB	6/20	5:40		5:40		2
BWMW	6/28	6:00		8:00		3
BWMW	6/28	8:40	8:52	8:57	RAL	3
PVER2	6/21	6:13		6:45		1
PVER2	6/21	7:12		8:00		0
PVER2	6/21	8:24		9:15		0
PVER2	7/1	5:30	6:20	7:06	PD	5
PVER2	7/1	6:30	7:06	7:06	LL	5
PVER3	7/7	5:40	6:35	6:35	AA	3
PVER3	7/30	5:30	6:15	6:18	LG	1
PVER4	7/28	5:35	6:37	6:44	MBS	3
PVER4	8/12	7:35	7:41	7:42	LIB	2
CVCA1	6/23	5:25	5:30	5:50	LJ[2]	3
CVCA1	6/23	5:25	5:45	5:50	BA	3
CVCA1	6/24	8:10	8:30	8:32	YB	7
CVCA1	6/24	8:32	9:10	9:13	TGB	7
CVCA1	7/11	5:36		6:36		3
CVCA1	7/18	5:41		8:30		4
CVCA1	7/18	5:41		8:30		4
CVCA2	7/25	5:25	6:12	7:07	LJ	2
CVCA2	7/25	5:25	6:20	7:07	PQ	2
CVCA2	7/31	6:05	6:10	6:11	SJR[2]	2
CVCA2	7/31	8:05		8:59		3
CVCA2	7/31	9:40	9:58	10:05	TA	2
CVCA2	8/5	8:08		8:08		2
CVCA2	8/5	5:57	5:59	6:00	FZ	1
CVCA2	8/13	6:51	7:40	7:40	TGB	4
CVCA3	6/23	8:33		9:26		1
CVCA3	7/8	6:03	6:25	6:27	GO	5

Site Code	Date	Net open	Capture Time	Net close	YBCU ID	# YBCU detected[1]
CVCA3	7/8	8:21	8:40	9:00	GG	5
CIBCNT	6/19	5:51		6:45		0
CIBCNT	6/19	7:35	8:52	8:52	RP	3
CIBCNT	7/5	5:15		6:30		0
CIBCNT	7/5	7:20	7:25	7:27	KW	3
CIBCNT	7/11	9:15	9:50	9:50	KS	1
CIBSTH	6/17	6:13		6:53		0
CIBSTH	6/17	8:30	9:01	9:10	WFF	1
CIBSTH	7/3	8:03	8:39	8:39	PM	1
CIBSTH	7/5	9:24		10:18		2
CIBSTH	7/6	5:10		5:35		0
IMPSTH	7/22	5:30		6:30		0

1. # YBCU detected=#individual cuckoos detected while mist netting. 2. Bird banded in 2009.

Appendix D. Vegetation sampling methodology.

2009 VEGETATION SAMPLING INSTRUCTIONS

I. Setting up a Vegetation Plot

At a vegetation point, two sizes of circular plots are established:

1) A **5** meter radius plot is used to measure ground cover, count small trees, and count shrub and sapling stems.
2) An **11.3** m radius plot used to count the stems of trees.

The 5 m plot is nested within and centered on the same point as the 11.3 m plot.

Establish 4 quadrants to facilitate estimates and stem counting; then count stems in each quadrant separately.

II. Filling out the Data Sheet

SITE CODE
Enter the survey site code.

VEG PLOT NAME
This is a unique combination of letters and numbers. No other points in any of the survey areas or sites will have the same identification. This is generally the site code followed by a number, and should be the same number that is on the Veg. Plot Establishment Form.

UTM NAD
Enter the NAD used when marking points with GPS. This should be NAD 83.

UTM ZONE
Enter the appropriate zone.

ACCURACY
Enter the GPS reading accuracy, in number of meters.

UTM E and N
Enter the easting and northing readings for the center of the circular plot.

Measurements Made from the Center of Vegetation Plots

The following measures are taken while standing at the center of the plot (nest, or systematic vegetation sampling point).

DOMINANT PLANT SPECIES IN CANOPY
Species name of plant species that dominates the high canopy. Species' dominance is determined by eye. Record the species name for any that accounts for at least 40% of the high canopy present. Leave blank if no single plant species represents > 40% of the high canopy present.

PERCENT OF DOMINANT CANOPY SPECIES
This is the percent of high canopy present that is occupied by the DOMINANT CANOPY SPECIES.

CO-DOMINANT PLANT SPECIES IN CANOPY
Species name of plant species that co-dominates the high canopy. Use this variable when there are 2 plant species that each represent > 40% of the high canopy present. Leave blank if there is not a second plant species that represents > 40% of the high canopy that is present.

PERCENT OF CO-DOMINANT CANOPY SPECIES
This is the percent of high canopy occupied by CO-DOMINANT CANOPY SPECIES.

HABITAT TYPE and %
Write the two or three letter code (Anderson and Ohmart) for the dominant habitat type present at the vegetation plot (See Habitat Card). If the Habitat type is Cottonwood-Willow (CW), include a percentage of cover (10-19%=**1**, 20-49%=**2**, 50-89%=**3**, 90-100%=**4**). This is the percentage of the plot that is shaded by this species when the sun is directly overhead.

STRUCTURAL TYPE
Record the Structural Type of the habitat at the vegetation plot (1-6, see Habitat Card).

OPENNESS
This number represents the amount of cover above the shrub layer (0-24%=Open, 25-74%=Medium, 75-100%=Closed). Record the Openness within the 11.3m plot. If >100m to the nearest change record >100.

DISTANCE TO HABITAT CHANGE
Measure the distance to the nearest 11.3 m radius (.1 acre) patch of habitat, which is a different Habitat Type or Structure Type (Anderson and Ohmart) than that at the center of the veg. plot (CW IV to SSM IV, or CW I to CW III). If we

DIST. TO WATER
Record the distance from the center of the plot to the nearest water. If you know there was water (present persistently throughout the season) nearby during June, July, or August record the distance to where this water was.

ASPECT
The direction the plot faces in degrees. Take a compass bearing, in degrees, from the highest point to the lowest point (of the 11.3m plot. (What direction would water run?)

SLOPE
Measure the slope across the 11.3m plot from the bottom to the top of the plot in degrees. Standing upright, look across the plot to something at eye-height, and read the left hand scale of the clinometer. Alternatively a compass with a slope measuring tool can be used. To do this, align the top edge of the compass with your eye and an object at the same height across the plot, then read the slope arrow.

TABLE I: DENSIOMETER COVER (0-96)

AVG Height-Using a range finder (or a clinometer and the tree height estimation sheet) determine the average height of the overall canopy cover. This is all canopy cover above 1.4m (all

Dominant Species-Record the species that makes up the greatest percentage of the canopy cover.

Total Canopy Cover- Using a spherical densiometer estimate the total canopy cover by standing at the center of the plot and recording cover in each of the four cardinal directions (N, E, S, W).

How to use a spherical densiometer: Hold the densiometer in front of you at breast height. Imagine four equally spaced dots in each of the squares outlined on the mirror. Count the number of

these imaginary dots covered by vegetation. Write the total number of dots covered by vegetation on the data sheet. This number should be between 0 and 96. This number divided by 96 then multiplied by one hundred will give us the percent canopy cover (We will do this once the data is entered).

TABLE II: VISUAL COVER ESTIMATES (%)
Visually estimate the percent cover for each vegetation layer within each quadrant. The observer must move around the plot to get a good feel for this.

*****For all visually estimated percent cover data record no cover as 0, <3% as 1, and for all other estimates round to the nearest 5 percent*****

High Canopy Layer- This layer is any canopy above 5 meters in height.
Main Canopy Layer- Can overlap with high canopy, but this layer provides the most cover/shade. This layer does not overlap with the Shrub/Sapling Layer.
Sub Canopy Layer- Record this layer when there is a distinct canopy layer between the main and the shrub/sapling layer. *This layer is often absent.*
Shrub/Sapling Layer- this layer is composed of all shrubs and sapling species, as well as any tree species that is less than 1.4 meters in height.

Table III-V NEAREST LIVE SHRUB, LIVE TREE, and TREE ≥6.0cm DBH
The next measurements are taken at all plots. These measures are all based on the point-centered quarter method of estimating densities of plants (e.g., Mueller-Dombois and Ellenberg 1974). For these measurements, stand at the center of the plot, and locate the nearest live tree, live shrub, or snag (dead tree) within each of the quarters of the circle surrounding you. This measure should be taken regardless of its distance (do not leave blank if there is not a *live shrub/live tree/tree ≥6.0cm* within the plot). Divide the circle into quadrates along the cardinal compass directions. Within each quadrate, record the following information:

SPECIES, NEAREST *LIVE SHRUB/LIVE TREE/TREE* ≥6.0cm *DBH*
Species name of closest *live shrub/live tree/tree ≥6.0cm DBH*, for each quadrate (1-4). For Table V count the closest tree that is larger than 6.0cm in diameter at breast height (1.4m) and ≥3m tall.

DISTANCE TO NEAREST *LIVE SHRUB/LIVE TREE/TREE* ≥6.0cm *DBH*
The distance (in meters) from the center of the plot, to the selected *live shrub/live tree/tree ≥6.0cm DBH.*

HEIGHT OF NEAREST *LIVE SHRUB/LIVE TREE/TREE* ≥6.0cm *DBH*
Height (in meters) of the selected *live shrub/live tree.*

MAX WIDTH OF NEAREST *LIVE SHRUB*
The Max Width is the maximum crown width (in meters) of the selected *live shrub.*

PERP WIDTH OF NEAREST *LIVE SHRUB*
The perpendicular width is the width of the *live shrub* measured at a right angle to the maximum width.

DIAMETER AT BREAST HEIGHT (DBH) OF NEAREST *LIVE TREE/TREE* ≥6.0cm *DBH*
Record the diameter at breast height (measured in centimeters) of the closest *live tree/tree ≥6.0cm DBH* to the center of the plot in each of the four quadrates. If more than one stem/trunk, take the DBH of the largest.

CROWN WIDTH, NEAREST *LIVE TREE/TREE* ≥6.0cm *DBH*

The Crown Width is the average width (in meters) of the crown (drip line to drip line), of the closest *live tree/tree ≥6.0cm DBH* to the center of the plot in each of the four quadrates. Measure the largest, and the smallest width of the crown, then estimate the average.

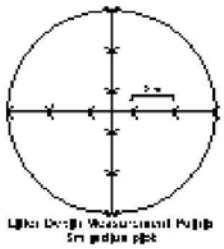
CANOPY COVER, NEAREST *LIVE TREE*
Standing under the selected tree, use the densiometer to measure the canopy cover of the closest tree.

Measurements Taken Within the Small (5 Meter) Plot

In each of the 5m plots we measure the depth of organic litter, ground cover of categories of ground cover, and counts of shrubs and saplings.

Table VI: Measuring Litter Depth
Measure the depth of organic litter, using a stake or other tool (meter stick, ruler) to dig a small hole down to where individual leaf parts are no longer visible (leaf veins usually decompose last), to where the soil layer starts. We are interested in the depth of leaf litter and partially decomposed organic matter that accumulates on top of the mineral soil. Litter depth is measured at 2m intervals along the ropes and within the 5m plots. If any of these 12 points land on a log or a rock, move the meter stick slightly to a location where you are actually measuring litter depth. Note if you are in an area covered in water, leave Litter Depth blank, and do not record litter depth as zero: there is litter...just not at the surface.

LOCATIONS FOR LITTER DEPTH MEASUREMENTS



Organic litter depth (in mm) should be measured across the center of the plot parallel and perpendicular to the slope of the plot. Measures should be made at 12 points as shown in the figure, above.

Table VII: Percent Ground Cover
These vegetation measurements, made within the 5m plots, are estimates of different types of ground cover. For each of the 4 quadrants in the 5m plot, make an ocular estimate of the percent of the ground covered from 50cm above ground, to ground level.

There are two types of ground cover that affect cover estimation rules; tall sparse cover that can overlap with low cover types, and low dense cover that cannot overlap with other low cover

types. Percent cover in low cover types (*Grass, Leaf Litter*, *Downed Logs*, *Bare Ground*, and *Water*) alone must sum to 100%, the remaining cover categories can sum to more than 100% because of vertical stratification of plant layers. However no single layer of *Shrub*, *Forb*, *Sedge*, *Marsh Vegetation*, or *Brush* can be greater than the value for *All Green Cover*.

% LEAF LITTER COVER

Percent *Leaf Litter* is the percent of ground covered by leaf litter (including tamarisk needles). This value should be independent of taller, sparser vegetation (litter + tall sparse vegetation can sum to more than 100%), but is dependent on low dense vegetation (litter + low dense vegetation sum to 100% or less). Example: a plot with a layer of small shrubs/saplings covering 80% of the ground at 50 cm can have little plant cover at ground level so more than 20% of the ground could be leaf litter. However, a plot with 80% coverage of short, dense grass could have no more than 20% leaf litter cover.

% GRASS COVER

The % *Grass Cover* is the percentage of the ground covered by grasses below 50 cm in height. This value should be independent of taller, sparser vegetation (can sum to more than 100%), but dependent on low dense vegetation (sum to 100% or less). SEE GRASS COVER EXAMPLE.

% DOWNED LOGS COVER

The % *Downed Logs* is the percent of ground covered by downed logs (logs >12cm diameter). This value should be independent of taller, sparser vegetation (can sum to more than 100%), but dependent on low dense vegetation (sum to 100% or less). SEE GRASS COVER EXAMPLE.

% BARE GROUND

The % *Bare Ground* is the percent of open ground not covered by leaf litter or any other low, dense cover. This value should be independent of taller, sparser vegetation, but dependent on low dense vegetation. SEE GRASS COVER EXAMPLE.

% WATER COVER

The % *Water Cover* is the percent of ground covered by standing water. This value should be independent of taller, sparser vegetation, but dependent on low dense vegetation. SEE GRASS COVER EXAMPLE.

% ALL GREEN COVER

The percent *All Green Cover* is the percentage of the ground covered by green vegetation that is below 50 cm in height. This includes grass, shrubs, forbs, and marsh vegetation.

% SHRUB COVER

The % *Shrub Cover* is the percentage of ground covered by woody perennial plants that are below 50 cm tall. This layer cannot be greater than the % *All Green Cover*.

% FORB COVER

The % *Forb Cover* is the percentage of ground covered by broad-leafed non-woody plants below 50 cm height. This layer cannot be greater than the % *All Green Cover*.

% MARSH VEGETATION

The % *Marsh Vegetation* is the percentage of ground covered by marsh vegetation (vegetation undifferentiated by species or type that is growing in water). This layer cannot be greater than the % *All Green Cover*.

% BRUSH COVER

The % *Brush Cover* is the percentage of ground covered by small dead woody vegetation (i.e. dead shrubs and bramble) less than 50 cm above the ground. This layer cannot be greater than the % *All Green Cover*.

Table VIII. Measuring Shrubs and Saplings within 5m Radius Circle

The following are the measurements to be taken within the 5m radius plot. One measurement taken is a count of the numbers of stems of shrubs that exist within the plot circle. Stems of all saplings and shrubs should be counted by species within each 5m plot at 10cm above the ground. The number of stems of each species should be counted for each of two size classes (<2.5 cm diameter or >2.5 cm diameter). We make no distinction in the data between shrubs and saplings, but different criteria must be used to place shrubs (often having no main stem) and saplings (often having a single, main stem) in one of the two size classes into which we place shrubs (see below). Separate counts are made of the number of stems of each species of shrub/sapling within the plot. Please note: growth form and size class **do not** constitute 4 different categories. We are **only** categorizing stems as small or large, not as single stem small, multiple stem large, etc. Count the numbers of stems that fit any of these criteria:

No single central stem at which DBH can be measured:

Small Size Class: < 2.5cm stem diameter at 10cm above ground
Large Size Class: > 2.5cm stem diameter at 10cm above ground

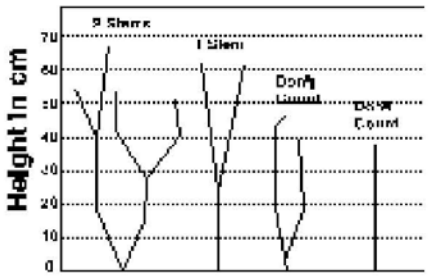
With a single central stem

Small Size Class: < 2.5cm DBH, or less than 1.4m tall
Large Size Class: 2.5 - 8.0cm DBH

Many plant species break into multiple stems fairly close to the ground. In these situations, it is reasonable to assume that birds respond to stem densities rather than individual plant numbers. Therefore, we count vertical stems, not individual plants.

Rules for counting stems:

Plants/stems less than 50cm (i.e. approximately knee height) high are not counted
Count the number of vertical stems at 10cm above the ground (ankle level), i.e if a stem branches above 10cm then it is counted as 1 (see figure, below).



SHRUB or SAPLING SPECIES
Enter the species name for each species encountered in the 5m plot, and then tally the number of stems for each species, placing the tallies in the appropriate size class. Species do not have to be placed in any specific order. Use as many entries as necessary for the species of shrubs encountered. Rare species can be pooled into the group "OTHER".

Tables IX, X, and XI. Measuring Small /Large Tree/Snag Species
Small Trees are counted within the 5m circle only, and *Large Trees* and *Snags* are counted in the 11.3m circle. Live trees are separated into the size classes given in the table, below. Separate counts should be made for each species of tree in the plot. If you can accurately identify the species of snag, enter this, otherwise put unknown.

TREE SIZE CLASSES

Live Trees (measure the DBH for each species separately)	Small trees (within 5m circle): 8 -- 23cm Medium trees (within 11.3m circle): 23 -- 38cm Large trees (within 11.3m circle): >38cm
Snags (count within 11.3m circle)	Small snags: < 12cm DBH and > 1.4m tall Medium snags: > 12cm DBH and > 1.4m tall

Use as many lines in the table as needed to record each species encountered in the large plot. Rare species can be pooled into the category "OTHER".

SMALL/ LARGE TREE/SNAG SPECIES
Record the species name for each species encountered on the large vegetation plot (11.3m radius circle). There is no specific order in which tree species must be presented. If you can accurately identify the species of snag, enter this, otherwise put unknown.

NUMBER OF STEMS (SMALL/ LARGE TREE/SNAG)
Count the total number of live stems for each size class, of each species within the large vegetation plot. Enter the total on the right of the tally marks.

RIPARIAN PLANTS OF THE LOWER COLORADO RIVER AND FOUR LETTER CODES

Common Name	*Genus*	*Species*	Code	Growth Form
Whitethorn Acacia	*Acacia*	*constricta*	ACCO	Shrub
Catclaw Acacia	*Acacia*	*gregii*	ACGR	Shrub
Giant Reed	*Arundo*	*donax*	ARDO	Grass
Arundo	*Arundo*	*sp.*	ARSP	Cane
Four Winged Saltbush	*Atriplex*	*canescens*	ATCA	Shrub
Desert Holly	*Atriplex*	*hymenelytra*	ATHY	Shrub
Alkalai Saltbush	*Atriplex*	*polycarpa*	ATPO	Shrub
Atriplex sp.	*Atriplex*	*sp.*	ATSP	Shrub
Quailbush or Big Saltbush	*Atriplex*	*lentiformis*	ATSP	Shrub
Emory Baccharis	*Baccharis*	*emoryi*	BAEM	Shrub
Seep Willow/Mulefat	*Baccharis*	*salicifolia*	BASAL	Shrub
Desert Broom	*Baccharis*	*sarathroides*	BASAR	Shrub
Unspecified Baccharis	*Baccharis*	*sp.*	BASP	Shrub
Blue Palo Verde	*Cercidium*	*floridum*	CEFL	Tree
Yellow Palo Verde	*Cercidium*	*microphyllum*	CEMI	Tree
Unspecified Palo Verde	*Cercidium*	*sp.*	CESP	Tree
Salt Grass	*Distichlis*	*spicata*	DISP	Grass
Russian Olive	*Elaeagnus*	*angustifolia*	ELAN	Tree
Unspecified Eucalyptus	*Eucalyptus*	*sp.*	EUSP	Tree
Alfalfa	*Medicago*	*sp.*	MESP	Forb
Common Reed	*Phragmites*	*australis*	PHAU	Grass
Arroweed	*Pluchea*	*sericea*	PLSE	Shrub
Fremont Cottonwood	*Populus*	*fremontii*	POFR	Tree
Honey Mesquite	*Prosopis*	*glandulosa*	PRGL	Tree
Screwbean Mesquite	*Prosopis*	*pubescens*	PRPU	Tree
Unspecified Mesquite	*Prosopis*	*sp.*	PRSP	Tree
Velvet Mesquite	*Prosopis*	*velutina*	PRVE	Tree
Coyote Willow	*Salix*	*exigua*	SAEX	Shrub
Gooding's Black Willow	*Salix*	*goodingii*	SAGO	Tree
Johnson Grass	*Sorghum*	*halapense*	SOHA	Grass
Tamarisk	*Tamarix*	*sp.*	TASP	Tree
Unknown Aster			UNAS	
Unknown			UNK	
California Fan Palm	*Washingtonia*	*filifera*	WAFI	Tree

Appendix E. Vegetation variables included in data analyses (Chapters 4 and 7).

Code	Description	Cuckoo Vegetation Analysis (Ch. 4)	Cicada Vegetation Analysis (Ch. 7)
AR	Area (size of site in hectares)	X	X
BP	Percent Bare Ground (within 5 m)	X	X
DW	Distance to Water (River)	X	
FP	Percent Forb Cover (5 m)	X	
GNP	Percent Green (ground cover) (5 m)	X	
GP	Percent Grass (5 m)	X	
HCC	High Canopy (>5 m) Average Height	X	X
HC	Percent High Canopy Cover (>5 m)	X	X
LOP	Percent Log Cover (5 m)	X	
LP	Percent Leaf Litter (ground cover) (5 m)	X	
LTD	Large Tree (>23 cm DBH) Density (within 11.3 m, stems/area)	X	X
MC	Main Canopy (layer providing most shade) Average Height	X	X
MCC	Percent Main Canopy Cover (layer providing most shade)	X	
MV	Percent Marsh Vegetation (5 m)	X	X
NLT	Native Large Tree (>23 cm DBH) Density (11.3 m, stems/area)	X	X
NSSD	Native Shrub/Sapling Density (5 m, stems/area)	X	
NST	Native Small Tree (8-23 cm DBH) Density (5 m, stems/area)	X	X
PD	*Populus fremontii* Density (5 m, stems/area)	X	X
PR	*Prosopis spp*. Density (5 m, stems/area)	X	X
RS	Restoration Site (yes or no)	X	X
SAD	*Salix gooddingii* Density (5 m, stems/area)	X	X
SP	Percent Sedge (5 m)	X	
SSD	Shrub/Sapling Density (5 m) (stems/area)	X	
SHP	Percent Low Shrub (<50 cm high) Cover (5 m)	X	
SM	Average Soil Moisture (within 10 m)		X
STD	Small Tree (8-23 cm DBH) Density (5 m) (stems/area)	X	X
TC	Percent Total Canopy Cover (all canopy layers)	X	X
TD	Tamarisk Density (5 m, stems/area)	X	X
TH	Total Canopy (all canopy layers) Average Height	X	X
TLD	*Tamarix spp.* Large Tree Density (11.3 m, stems/area)		X
TSD	*Tamarix spp.* Small Tree Density (5 m, stems/area)		X
TSSD	*Tamarix spp.* Sapling Density (5 m, stems/area)	X	X
WP	Percent Standing Water (5 m)	X	X
YS	Year Sampled	X	X

Appendix F. Variables included in vegetation analysis of site occupancy, plot occupancy, and nest occurrence.

Vegetation Variable	Used in Analysis	Sig	Comments/Description
Salix exigua Sapling Density (5 m)	No	-	Combined with other variables
Area of Site	Yes	1	
Aspect (11.3 m)	No	-	Removed due to lack of importance
Atriplex spp. Density (5 m)	No	-	Combined with other variables
Bare Percent Cover (5 m)	Yes	1	
Baccharis spp. Density (5 m)	No	-	Combined with other variables
Brush Percent Cover (5 m)	Yes	2	
Distance to Structural Transition (ecotone)	No	-	Removed due to lack of data (collected beginning 2008)
Distance to River	No	-	Removed due to lack of data
Distance to Water (any standing)	Yes	2*	Only analyzed for 2008 data (and 2008/2010 nest data) need more data to determine true influence
Forb Percent Cover (5 m)	Yes	1	Seems to be associated with restoration sites
Grass Percent Cover (5 m)	Yes	1	Seems to be associated with restoration sites
Green Ground Percent Cover (5 m)	Yes	1	Seems to be associated with restoration sites
High Canopy (>5m high) Average Height (11.3 m)	Yes	1	Removed due to lack of data
Percent High Canopy Cover (11.3 m)	Yes	1	
High Canopy Dominant Species (11.3 m)	No	-	Removed due to lack of data
Large Tree Density (11.3 m)	Yes	2	
Leaf Litter Percent Cover (5 m)	Yes	1	
Litter Depth Average (10 m)	No	-	Removed due to lack of data
Log Percent Cover (5 m)	Yes	1	
Main Canopy Average Height (11.3 m)	Yes	1	
Percent Main Canopy Cover (11.3 m)	Yes	1	
Main Canopy Dominant Species (11.3 m)	No	-	Removed due to lack of data
Marsh Percent (5 m)	Yes	3	
Native Shrub Density (5 m)	Yes	2	
Native Small Tree Density (5 m)	Yes	1	
Native Large Tree Density (11.3 m)	Yes	2	
Percent Habitat of Site	Yes	1*	Only analyzed for 2009 data need more data
Pluchea sericea Density (5 m)	No	-	Combined with other variables
Populus fremontii Density (5 m)	Yes	1	
Populus fremontii Large Tree Density (11.3 m)	No	-	Combined with other variables
Populus fremontii Small Tree Density (5 m)	No	-	Combined with other variables
Populus fremontii Sapling Density (5 m)	No	-	Removed due to lack of data
Prosopis spp. Density (5 m)	Yes	3	Combined with other variables
Prosopis spp. Sapling Density (5 m)	No	-	Combined with other variables
Prosopis spp. Large Tree Density (11.3 m)	No	-	Combined with other variables
Prosopis spp. Small Tree Density (5 m)	No	-	Combined with other variables
Restoration Site (yes/no)	Yes	1	
Salix exigua Small Tree Density (5 m)	No	-	Combined with other variables
Salix gooddingii Density (5 m)	Yes	3	
Salix gooddingii Sapling Density (5 m)	No	-	Combined with other variables

Vegetation Variable	Used in Analysis	Sig	Comments/Description
Salix gooddingii Large Tree Density (11.3 m)	No	-	Combined with other variables
Salix gooddingii Small Tree Density (5 m)	No	-	Combined with other variables
Sedge Percent (5 m)	Yes	3	
Shrub/Sapling Density (5 m)	Yes	2	
Low Shrub Percent Cover (5 m)	Yes	1	
Slope (11.3 m)	No	-	Removed due to lack of importance
Small Tree Density (5 m)	Yes	1	
Soil Moisture Average (10 m)	No	-	Removed due to lack of data
Shrub/Sapling Layer Dominant Species (11.3 m)	No	-	Removed due to lack of data
Subcanopy Average Height (11.3 m)	No	-	Removed due to lack of data
Percent Subcanopy Cover (11.3 m)	No	-	Removed due to lack of data
Tamarisk Density (5 m)	Yes	1	
Tamarisk Shrub Density (5 m)	No	-	Combined with other variables
Tamarisk Large Tree Density (11.3 m)	No	-	Combined with other variables
Tamarisk Small Tree Density (5 m)	No	-	Combined with other variables
Total Canopy Average Height (11.3 m)	Yes	1	
Total Canopy Dominant Species (11.3 m)	No	-	Removed due to lack of data
Total Canopy Cover (11.3 m)	Yes	1	
Water (Percent Standing) (5 m)	Yes	2	
Year Sampled	Yes	1	
Shrub/Sapling Layer Dominant Species (11.3 m)	No	-	Removed due to lack of data
Shrub/Sapling Layer Average Height (11.3 m)	No	-	Removed due to lack of data
Shrub/Sapling Layer Percent Cover (11.3 m)	No	-	Removed due to lack of data

Significance: 1=Significant in at least one model ($P < 0.05$), 2= May be important ($0.05 < p < 0.40$ in at least one model), 3= Not found to be important in any model ($P > 0.4$).