Western Riverside County

Multiple Species Habitat Conservation Plan

Biological Monitoring Program

2021 Coastal California Gnatcatcher Survey and Nest Monitoring Report

California Gnatcatcher (*Polioptila californica californica*) fledglings. Photo by Masanori Abe.

April 2022

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NOTE TO READER:

This report is an account of survey activities conducted by the Biological Monitoring Program for the Western Riverside County Multiple Species Habitat Conservation Plan (MSHCP). The MSHCP was permitted in June 2004. Reserve assembly is ongoing and is expected to take 20 or more years to complete. The Conservation Area includes lands acquired under the terms of the MSHCP and other lands that have conservation value in the Plan Area (called public or quasi-public lands in the MSHCP). In this report, the term "Conservation Area" refers to these lands as they were understood by the Monitoring Program at the time the surveys were conducted.

The Monitoring Program monitors the status and distribution of the 146 species covered by the MSHCP within the Conservation Area to provide information to Permittees, land managers, the public, and the Wildlife Agencies [i.e., the California Department of Fish and Wildlife (CDFW, formerly California Department of Fish and Game) and the U.S. Fish and Wildlife Service]. Monitoring Program activities are guided by defined conservation objectives for each Covered Species, other information needs identified in MSHCP Section 5.3 or elsewhere in the document, and the information needs of the Permittees. A list of the lands where data collection activities were conducted in 2021 is included in Section 8.0 of the Western Riverside County Regional Conservation Authority (RCA) Annual Report to the Wildlife Agencies.

The primary author of this report was Field Biologist Masanori Abe, who led this project under the guidance of the 2021 Avian Program Lead, Nicholas Peterson. This report should be cited as:

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While we have made every effort to accurately represent our data and results, it should be recognized that data management and analysis are ongoing activities. Any reader wishing to make further use of the information or data provided in this report should contact the Monitoring Program to ensure that they have access to the best available or most current data.

Please contact the Monitoring Program Administrator with questions about the information provided in this report. Questions about the MSHCP should be directed to the Executive Director of the RCA. Further information on the MSHCP and the RCA can be found at www.wrc-rca.org.

Contact Information:

Executive Director
RCA/Riverside County
Transportation Commission
4080 Lemon Street, 3rd Floor
P.O. Box 12008
Riverside, CA 92502
Ph: (951) 787-7141

Monitoring Program Administrator
Western Riverside County MSHCP
Biological Monitoring Program
1835 Chicago Ave., Suite C
Riverside, CA 92507
Ph: (951) 320-2168

INTRODUCTION

The Coastal California Gnatcatcher (*Polioptila californica californica;* gnatcatcher) is one of 45 bird species covered by the Western Riverside County Multiple Species Habitat Conservation Plan (MSHCP) and is designated as species of special concern in California and listed as threatened at the Federal level. Gnatcatchers are specialists of coastal sage scrub (CSS) habitat, one of the unique plant communities found in coastal and inland southern California and Baja California. This habitat type is characterized by low-growing, drought-deciduous, and semi-woody shrubs, such as California buckwheat (*Eriogonum fasciculatum*), coast brittle-bush (*Encelia farinosa*), California sagebrush (*Artemisia californica*), black sage (*Salvia mellifera*), and white sage (*S. apiana*; Dudek & Associates 2003). CSS habitat is one of the most endangered habitats in the U.S. In western Riverside County, suitable CSS habitat for gnatcatchers has declined by 48% since the 1980s (Hulton VanTassel et al. 2017). Significant declines, however, were not reported for gnatcatcher populations in southern California between 1966 and 2000 (Mock 2004); regardless, intensive monitoring is critical due to the rapid decline of this species' breeding habitat.

Gnatcatchers are non-migratory insectivores and are distributed from southern Ventura County in California to Baja California in Mexico (Atwood and Bontrager 2020). Gnatcatchers primarily occupy CSS, but they may also inhabit desert scrub and Riversidean alluvial fan scrub vegetation habitats for breeding (Dudek & Associates 2003). Their breeding season starts in approximately mid-March and ends in July in Riverside County. Gnatcatchers defend breeding territories that average 3.4 hectares (ha) in size (Braden et al.1997a) and build open cup nests in relatively dense stands of CSS shrubs, such as California buckwheat, coast brittle-bush, white sage, black sage, and California sagebrush. Gnatcatchers in southern California usually lay three or four eggs and incubate for a mean of 14 days, and then nestlings fledge approximately 14 days after hatching. Adults continue to care for fledglings up to three weeks post-fledging (Atwood and Bontrager 2020).

The distribution of the gnatcatchers within the Plan Area is widespread. The MSHCP designated principally the southwestern region as the gnatcatcher survey Core Areas, especially in the Riverside Lowlands and San Jacinto Foothills Bioregions along the Interstates 15/215 corridor from the Santa Ana River to Temecula, and into the Vail Lake/Wilson Valley area (Dudek & Associates 2003); however, they also occur in the northeastern region of the Plan Area.

In the spring and summer of 2021, we monitored the reproductive success of Coastal California Gnatcatchers by searching for and monitoring their nests in their nine Core Areas, which are Alberhill, El Cerrito/Lake Mathews/Estelle Mountain, Hogbacks/Murrieta Hot Springs, Lake Skinner/Buck Road to Pourroy Road east of Murrieta Hot Springs (hereafter referred to "Lake Skinner"), North Peak Conservation Bank/Meadowbrook, Quail Valley, Railroad Canyon/Sedco Hills, Vail Lake/Wilson Valley/Temecula Creek, and Wasson Canyon (Figure 1). The MSHCP objectives for gnatcatchers require documentation of distribution and successful

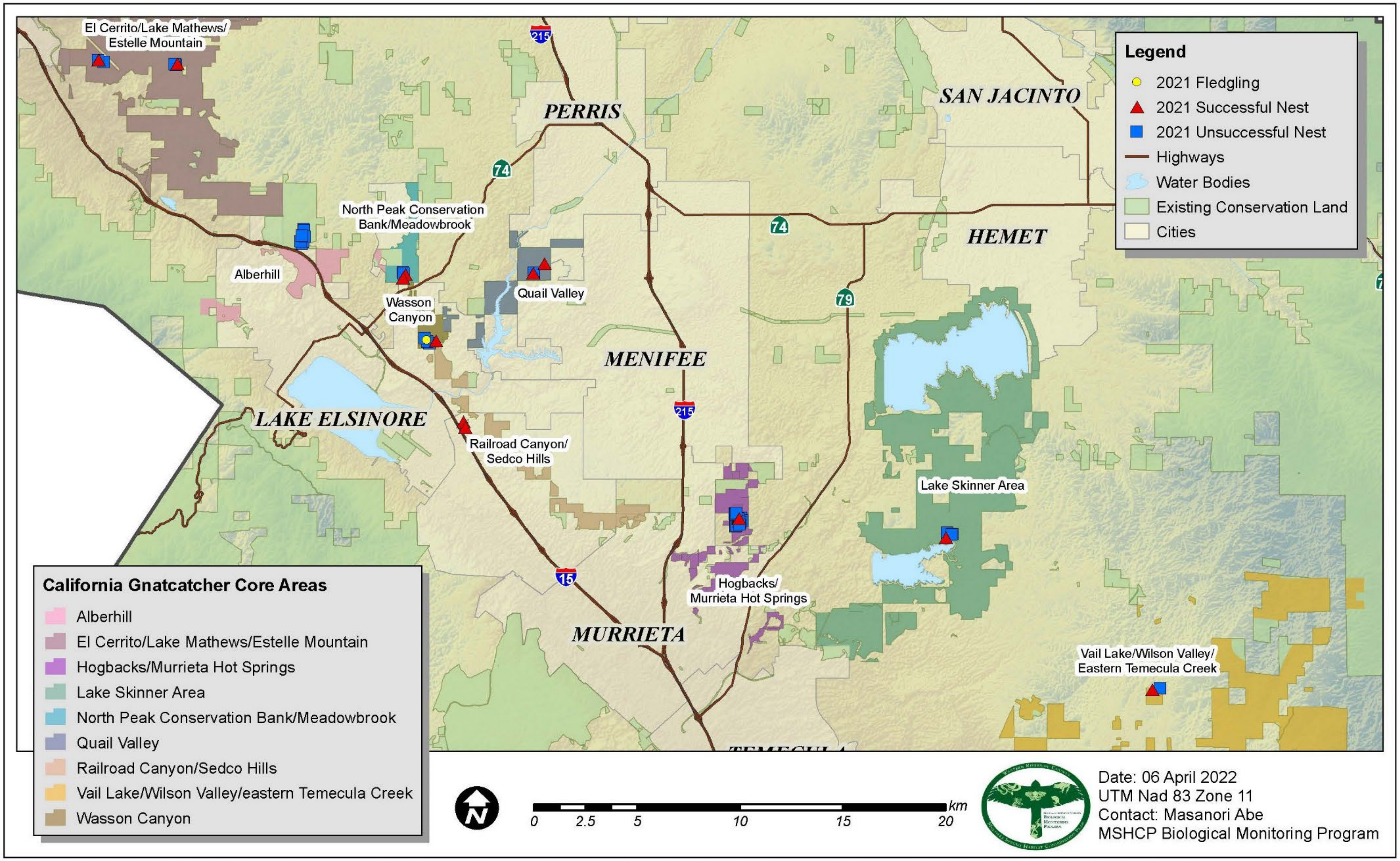

Figure 1. Coastal California Gnatcatcher survey Core Areas and nest and fledgling detections in 2021. See Table 1 in report for details on nest and fledgling detections.

reproduction within at least 75% of specified Core Areas once every three years, with successful reproduction defined as a nest that produces at least one fledgling (Dudek & Associates 2003). We documented that gnatcatchers met the distribution objective in 2020 during the USGS California Gnatcatcher Regional Survey, so we focused our survey effort in 2021 on the reproductive objective. We used a modified area search method to study the reproduction of gnatcatchers and monitored nests until they failed or fledged young. We continued nest searching and monitoring in each Core Area until we documented successful reproduction by gnatcatchers in at least 75% of their Core Areas, or mid-August 2021, whichever occurred first.

Survey Goals and Objectives

Explicitly list each goal of this survey whether it involves meeting the species objective(s), testing a protocol, or gathering additional information about the ecology of the species.

1. Determine whether gnatcatchers are successfully breeding in at least 75% of their Core Areas.
   a. Locate and monitor active gnatcatcher nests until either fledging or failure occurs.

2. Estimate nest survival of gnatcatchers.
   a. Use the nest survival model included with Program MARK to estimate the nest's daily survival rate (DSR; White and Burnham 1999; Dinsmore et al. 2002).

METHODS

Survey Design

We conducted nest searching and monitoring on the MSHCP Plan Area within each Core Area (Figure 1), specifically within 250 m × 250 m (6.25 ha) grid cells that were delineated using ArcGIS (Esri 2019). We then selected grid cells that were located in apparently suitable gnatcatcher habitat in which the cover of CSS plants was >20% (Atwood and Bontrager 2020), and common nest substrates were available (Dudek & Associates 2003).

We began this project by visiting the locations within Core Areas where we detected gnatcatcher pairs or nests during previous surveys in 2008, 2011, 2014, and 2018 (Biological Monitoring Program 2009, 2012, 2015, 2019). If any property had been recently acquired for Conservation, or did not have any prior gnatcatcher records, we used Google Earth satellite imagery, or conducted ground-truthing, to identify whether the sites were suitable for gnatcatcher nest searching, according to our survey experiences and previous studies (Grishaver et al. 1998; Sockman 2000; Mock 2004).

Once we arrived at survey grid cells, we conducted an area search to confirm suitable gnatcatcher habitat, and then searched for pairs of gnatcatchers. We started surveys using a passive method that consisted of walking in a survey area and trying to find a California Gnatcatcher pair by visual and auditory cues. If we could not find any pair after 30 minutes of searching, we used gnatcatcher call playbacks. We played a maximum of two 20-second call bouts, then searched again for gnatcatchers. We played broadcasts again after 30 minutes of searching if we had not found any gnatcatchers. We conducted nest searches for gnatcatchers without time-of-day constraints.

Field Methods

Nest Searching

We uploaded assigned survey grid cells on a handheld GPS unit. When we found a pair of gnatcatchers during a survey within an assigned survey grid cell, we stayed in that cell and observed the birds' behaviors until we had recorded the data necessary to determine the status of the pair. The carrying and delivery of nesting materials or food, or begging or alarm calls usually indicated an active nest. We recorded on the datasheets (Appendices A and B) and maps any behaviors and locations associated with nesting. During observations, we maintained a safe distance (>20 m) from the target gnatcatchers to minimize stress on them and avoid the likelihood of potential nest predators being drawn to the nest. When we located active nests were nearby due to the aforementioned behaviors, we began checking shrubs systematically within approximately 25 m of the active nest. If it was too difficult to observe these behaviors due to rough terrain or dense vegetation cover, we tried to identify the primary area used by the gnatcatchers, then systematically checked each shrub within this area (Reynolds 1981).

During the previous four nesting survey efforts conducted in 2008, 2011, 2014 and 2018 by the Monitoring Program, the most commonly selected gnatcatcher nest substrates were California buckwheat (n = 43 nests), coast brittle-bush (n = 24), white sage (n = 20), California sagebrush (n = 12), yellow bush-penstemon (*Keckiella antirrhinoides*) (n = 11), and black sage (n = 10) (Biological Monitoring Program 2009, 2012, 2015, 2019). Therefore, we paid particular attention to those species that occurred within our search areas.

Upon identifying a potential nest site, we approached the site and attempted to determine whether it was active. We marked the location of the nest using a handheld GPS unit and recorded the nest information as required for the nest datasheet (Appendix A). Initial data collected include the GPS coordinates of the nest, the substrate and substrate height, and the nest height. We marked the location as close to the nest as possible without disturbing the nest itself to enable biologists to easily relocate the nest.

Nest Monitoring

We attempted to revisit each nest approximately every seven days (an average of 7.4 days, range 2–14 days), and during these follow-up visits we determined whether the nest was active by approaching briefly. During each follow-up visit we documented the nest status; the behavior(s) of the male and female gnatcatcher; a count of gnatcatcher eggs, nestlings, and fledglings; and a count of cowbird eggs and nestlings. Investigation of the actual nest was as brief and non-intrusive as possible.

If we observed avian predators, we waited until they were no longer visible, or we monitored nests by watching the behavior of the adults from a safe distance. Doing this allowed us to determine the nest's stage (e.g., incubation or nestling) while minimizing risk of predation and stress on the adults.

We tried to follow identified pairs throughout the season until young fledged to determine extra information such as, clutch size, number of nest attempts until first success, and annual reproductive success. We assumed clutches were completed when the number of eggs reached four or the number of eggs did not change between consecutive visits. Annual reproductive success was defined as the number of fledglings per female per year. We identified distinct pairs based upon behavioral cues and their territories within our search areas, not from individual markings.

When we needed to approach the nest to check the stage, we minimized time spent near the nest. We also took different paths to the nest during each visit to avoid making a clear path to the nest, and conducted mock nest searches in nearby vegetation before and after investigating the actual nest, decreasing the chance of predators detecting the nest (Martin and Geupel 1993). We kept in mind that the primary focus of this project was to document successful gnatcatcher nests, and of distant secondary importance was gathering information about clutch size, incubation stage duration, etc. If investigating a nest's content would lead to damaging the nest substrate, or unnecessarily stressing the adults (e.g., because the nest was in dense foliage), we forewent assessing the nest contents and instead observed whether it was active by watching the behaviors of the adults from a safe distance (Heath et al. 2008). Additionally, we never touched nests and nest contents before a nest failed. Even if we observed Brown-headed Cowbird (*Molothrus ater*) eggs in the nest, we left them untouched. We conducted follow-up visits until the nest fledged young or failed. To verify fledging we documented the begging calls of young birds and observed adults delivering food to areas other than the nest (Heath et al. 2008).

Data Analysis

We analyzed parameters using 2021 data and pooled data from all gnatcatcher surveys in 2008, 2011, 2014, 2018, 2021 in this report. The result from the pooled data made analysis more robust and avoided biases from low sample sizes. We used pooled data to evaluate the effect of Core Areas and year on DSR, the effect of the nest substrate on nest survival, and demographic variables, such as annual reproductive success.

Nest Survival

We estimated the DSR of gnatcatcher nests, and overall nest survival rate, in 2021 by using the nest survival model in Program MARK (White and Burnham 1999; Dinsmore et al. 2002). DSR represents the probability (0.0–1.0) that an active nest on day t will survive to day $t + 1$. We pooled all reproductive data from the Core Areas when estimating DSR. For sample sizes that are too small for estimation of an area-dependent DSR, we used a constant model (i.e., no covariates) for estimating the DSR. Finally, DSR estimates, when raised exponentially to a power that is equal to the length of a nesting cycle, from first egg laid until the first chick fledges (31 d for California Gnatcatchers; Atwood and Bontrager 2020), provides us with an overall nest survival rate estimate for California Gnatcatchers.

We also pooled 2008, 2011, 2014, 2018 and 2021 data to analyze Core Area and year effects on the DSR in Program MARK (White and Burnham 1999; Dinsmore et al. 2002). We then ranked candidate models using Akaike's Information Criterion for small samples (AIC_C), and Akaike weights.

RESULTS

We documented successful reproduction of gnatcatchers in eight (88.9%) of their nine designated Core Areas in 2021 (Figure 1, Table 1). The one Core Area in which we did not document successful nesting was Alberhill, where we monitored six pairs and a total of eight nests throughout the breeding season; all of these nests were ultimately depredated or abandoned.

We monitored a total of 48 nests in the nine Core Areas in 2021 (Table 1), 12 (25.0%) of which succeeded, and 36 (75.0%) of which failed. Additionally, we found fledglings within the Wasson Canyon Core Area without finding their nest. We detected gnatcatcher nests most frequently within the Hogbacks/Murrieta Hot Springs Core Area (n = 15), followed by the Alberhill Core Area (n = 8; Table 1). Of the 36 failed nesting attempts, 32 (88.9%) were depredated. Of the 32 depredated nests, five were parasitized by Brown-headed Cowbirds prior to depredation. Further, 18 of the depredated nests were intact, so we assumed avian or snake predation. Eight of the depredated nests were torn out of the nesting substrate, and the structural status of the remaining six depredated nests was not recorded. Interestingly, we also observed one gnatcatcher that laid an egg following nest depredation in the same nest that was depredated. Of the remaining four failed nests that were not depredated, one (2.7%) was parasitized, with none of the eggs hatching; one (2.7%) was abandoned during the nestling period and four dead nestlings were found in the nest; one (2.7%) failed with unhatched eggs; and one (2.7%) failed for unknown reasons. Finally, we documented four cases of gnatcatchers reusing old nest materials following nest failure, with the adults making frequent trips between the new and old nest sites to gather material.

The number of nesting pairs per Core Area that we monitored in 2021 varied from seven in the Hogbacks/Murrieta Hot Springs Core Area to two in the Railroad Canyon/Sedco Hills Core Area (Table 1). However, these numbers were just the sample we monitored during this survey and did not reflect the total numbers of pairs in the Core Areas, i.e., these data do not mean there were relatively more gnatcatchers in the Hogbacks/Murrieta Hot Springs Core Area, or relatively few in the Sedco Hills Core Area.

Table 1. Distribution, abundance, and outcome of California Gnatcatcher pairs, nests, and family groups detected within designated Core Areas in 2021.

			No. nests per outcome (% of known nests in Core Area)		
Core Area	No. pairs	No. nests	Successful	Failed	No. family groups[1]
Alberhill	6	8	0 (0)	8 (100)	0
Hogbacks/Murrieta Hot Springs	7	15	1 (7)	14 (93)	0
El Cerrito/Lake Mathews/Estelle Mountain	4	6	2 (33)	4 (67)	0
Lake Skinner	5	4	1 (25)	3 (75)	0
North Peak Conservation Bank/Meadowbrook	4	4	2 (50)	2 (50)	0
Quail Valley	3	3	2 (67)	1 (33)	0
Railroad Canyon/Sedco Hills	2	2	2 (100)	0	0
Vail Lake/Wilson Valley/Temecula Creek	4	2	1 (50)	1 (50)	0
Wasson Canyon	4	4	1 (25)	3 (75)	1
Total	39	48	12 (25)	36 (75)	0

[1] We detected this family group without finding a nest location.

Nest Survival and Reproduction

We estimated a DSR in 2021 for gnatcatcher nests of 0.965 (95% CI = 0.948–0.977), implying an overall nest survival rate estimate of 0.331 (95% CI = 0.191–0.486), assuming an average of 31 days from the initiation of egg-laying to fledging (Grishaver et al. 1998; Atwood and Bontrager 2020). We included data from 36 gnatcatcher nesting attempts in the nest survival analysis and excluded 12 nests. Of the 12 excluded nests, seven were found during the construction stage but failed before we confirmed egg-laying, and five were found after being depredated. We did not have enough data to calculate variations in nest survival based upon Core Areas or nest stages in 2021.

We pooled the 2021 data with all previous surveys, which included data from 2008, 2011, 2014 and 2018 (Biological Monitoring Program 2009, 2012, 2015, 2019), to evaluate the effects of year and Core Area on DSR (Table 2). The model including Core Area showed weak support (AIC_C weight (w_i) = 0.57, Table 3) than the models with year or without covariates (Constant; Table 3), suggesting that Core Area effects were a little stronger than the other two variables. However, it is not strongly supported by the analyses. The El Cerrito/Lake Mathews/Estelle Mountain and Railroad Canyon/Sedco Hills Core Areas showed higher DSR, 0.986 and 0.994, respectively, whereas the Lake Skinner and Hogbacks/Murrieta Hot Springs Murrieta Core Areas showed lower DSR, 0.949 and 0.945, respectively (Table 2). The effect of survey year on DSR was not supported based upon AIC_C (w_i = 0.13; Table 3).

Table 2. Nest daily survival rates (DSR) and nest survival rates using Program MARK nest survival analysis for each covariate, with standard error (SE) and upper and lower confidence intervals (CI) included. Site covariates are abbreviated as follows: *AL* (Alberhill); *EM* (El Cerrito/Lake Mathews/Estelle Mountain); *MSR* (Lake Skinner); *MH* (Hogbacks/Murrieta Hot Springs); *NP* (North Peak Conservation Bank/Meadowbrook); *QV* (Quail Valley); *SH* (Railroad Canyon/Sedco Hills); *WC* (Wasson Canyon); and *WV* (Vail Lake/Wilson Valley/Temecula Creek).

Covariates	DSR	SE	CI Upper	CI Lower	Nest Survival
Constant	0.965	0.004	0.971	0.956	0.331
2008	0.942	0.013	0.963	0.91	0.157
2011	0.970	0.011	0.986	0.939	0.389
2014	0.978	0.008	0.989	0.956	0.502
2018	0.966	0.007	0.977	0.95	0.342
2021	0.965	0.007	0.977	0.948	0.331
AL	0.952	0.013	0.971	0.919	0.218
EM	0.986	0.007	0.995	0.964	0.646
MSR	0.949	0.011	0.967	0.921	0.197
MH	0.945	0.02	0.974	0.889	0.183
NP	0.962	0.011	0.979	0.933	0.3
QV	0.967	0.012	0.984	0.932	0.353
SH	0.994	0.006	0.999	0.961	0.830
WC	0.968	0.01	0.982	0.941	0.365
WV	0.963	0.012	0.981	0.93	0.311

Table 3. Model selection results for California Gnatcatcher nest survival models from Program MARK. Models are ranked based on Akaike's Information Criterion for small samples (AIC_C).

Model	K [a]	Deviance	AIC_C	ΔAIC_C	w_i [b]
Cores	9	360.7146	378.8038	0	0.57
Constant	1	378.1260	380.1280	1.3242	0.29
Year	5	371.6630	381.6927	2.8889	0.13

[a] Number of parameters
[b] AIC_C weight

The average number of nesting attempts per pair was 2.0, and annual reproductive success was 1.77 (SE ± 0.38, $n = 22$) fledglings per female per year in 2021. The average clutch size was 3.6 eggs (SE ± 0.1, $n = 27$).

Nest Parasitism

We found evidence of nest parasitism by Brown-headed Cowbirds in eight (31%) out of 26 nests in which we confirmed completed clutches (i.e., the nest proceeded from the laying stage to the incubation stage). Only one (12.5%) of these eight nests fledged gnatcatchers. Two of the parasitized nests were in the Alberhill Core Area and six were in the Hogbacks/Murrieta Hot Springs Core Area. Nests in the latter Core Area seemed to exhibit a high rate of parasitism, with six (75%) of eight completed clutch nests parasitized, and only one (16.7%) of the parasitized nests fledging gnatcatchers. In the Hogbacks/Murrieta Hot Springs Core Area, none of the cowbird eggs hatched, but all gnatcatcher eggs in three parasitized nests hatched; one of these nests successfully fledged two gnatcatcher nestlings and the other two were ultimately depredated. The cowbird egg from one parasitized nest disappeared, probably depredated, during the incubation period, but three gnatcatcher eggs remained. Of these three eggs, two hatched but were depredated later. Of the five nests that were depredated, two failed during the incubation period. Additionally, we observed egg dumping behavior by a cowbird; specifically, a cowbird laid one egg in an empty nest after the gnatcatcher eggs were depredated. Finally, in the Alberhill Core Area, one parasitized nest was depredated during incubation, and the other parasitized nest was incubated longer than normal; none of the eggs in this nest hatched and the nest was eventually abandoned. Ultimately, we did not observe any cowbird nestlings during the survey in 2021.

Nest Substrates

In 2021, the most commonly used substrates were coast brittle-bush (n = 17, or 35.4%), California buckwheat (n = 9, or 18.8%), and white sage (n = 9, or 18.8%; Table 4). Gnatcatchers used 13 species as nest substrates during the 2008, 2011, 2014, 2018 and 2021 breeding seasons (Table 4). The most commonly used nest substrates across years were California buckwheat (n = 52 nests, or 29.4% of nests overall), followed by coast brittle-bush (n = 41, or 23.2%), white sage (n = 29, or 16.4%), and yellow bush-penstemon (n = 17, or 9.6%). The apparent nest survival rates, including all survey years and common nest substrates that were used more than 10 times, varied from 41.2% in yellow bush-penstemon to 21.4% in white sage (Table 4). The average nest height in 2021 was 0.9 m (SE ± 0.03, range = 0.5–1.4 m; n = 45 nests).

Table 4. Count of nesting substrates used by California Gnatcatchers in 2021 and during previous survey years (2008, 2011, 2014, 2018), and frequency of successful nests built within each substrate.

Substrate	No. nests in 2021	No. nests in 2008, 2011, 2014, 2018	% of nests within substrate that were successful across all years
Coast brittle-bush	17	24	33.3
California buckwheat	9	43	39.2
White sage	9	20	21.4
Yellow bush-penstemon	6	11	41.2
California sagebrush	4	12	25.0
Black sage	1	10	30.0
San Diego County viguiera	1	0	0
Scalebroom	1	0	0
Thick-leaved yerba santa	0	5	0
Big sagebrush	0	1	0
Fragrant sumac	0	1	NA
Tamarisk	0	1	0
White-flowered currant	0	1	100
Total	49	129	

DISCUSSION

We documented successful reproduction in eight (88.9%) of the nine California Gnatcatcher Core Areas. Therefore, the reproductive objective is currently being met for gnatcatchers within the current reporting period (2019–2021). We did not detect fledglings in the Alberhill Core Area; however, due to land access restrictions, we were only able to survey in the eastern side of the Core Area in 2021, where gnatcatcher habitat is low quality and only occurs in small patches. During previous gnatcatcher surveys, we documented successful reproduction in the western portions of the Alberhill Core Area, which generally has larger patches of high-quality habitat for gnatcatchers. Over the course of these surveys, we have documented successful reproduction in a minimum of 89% of the gnatcatcher Core Areas during each survey effort (Biological Monitoring Program 2009, 2012, 2015, 2019).

We monitored 48 nests and followed 39 pairs in 2021, which represent only a subsample of the actual number of gnatcatchers that were present in the Core Areas. We found the greatest number of nests and followed the highest number of pairs in the Hogbacks/Murrieta Hot Springs Core Area, followed by the Alberhill Core Area. This likely reflected our increased efforts to find nests in these Core Areas following a high rate of nest failure, rather than indicating that these Core Areas supported the highest number of gnatcatchers. We presume that the highest number of California Gnatcatchers is in the Lake Skinner Core Area due to the amount of high-quality habitat. Similarly, the Vail Lake/Wilson Valley/Temecula Creek Core Area supports a relatively large number of gnatcatchers. The remaining Core Areas contain less gnatcatcher habitat and thus have fewer gnatcatchers.

Nest Survival and Reproduction

The estimated DSR in 2021 was almost the same as the DSR in 2018 (Biological Monitoring Program 2019) and is similar to the DSR in 2011 and 2014 (Biological Monitoring Program 2012, 2015). The DSR in 2008 was the lowest of our survey years (Table 2). The reason why the DSR in 2008 was lower than others is not entirely clear, but it may have occurred because of a comparatively small sample size that led to a large estimate bias. The DSR estimates in 2021, 2018, 2014, and 2011 were similar to other studies (Sockman 1997; Grishaver et al. 1998; Braden 1999). These results suggest that reproductive rates of gnatcatchers in western Riverside County may be relatively stable.

We could not statistically differentiate the Cores model from Constant model (w_i = 0.57 (Cores), w_i = 0.29 (Constant), ΔAIC_C = 1.32, Table 3). The AIC_C weight of this model did not reach the value w_i = 0.9 that Burnham and Anderson (2002) recommend if selecting just one model from *a priori* models as a best model. However, we could observe weak variation of nest survival rates among Core Areas during our current and previous surveys, so we will carefully monitor this phenomenon in our subsequent survey efforts. Our nest sampling design did not focus on evaluating DSR for Core Areas, which would have required sampling randomization. We designed our sampling for documenting successful reproduction in each Core Area, so we put more survey efforts into the Core Areas where we had not yet documented successful reproduction in 2021. This resulted in a larger sample size in the Core Areas in which nest failure occurred more frequently; on the other hand, the Core Areas in which early-season nests succeeded, had small sample sizes. Even though our survey design did not allow us to focus on this topic, we could show some trends if total sample sizes become large enough to compare covariates of the models.

The DSR estimate of nests within the El Cerrito/Lake Mathews/Estelle Mountain Core Area was higher than those in other Core Areas. The surveyed areas contained relatively steep hillsides with dense coast brittle-bush covering much of the gnatcatcher territories, which likely provided suitable cover from avian predators. This dense cover may be advantageous to gnatcatchers by hiding nests and flight paths from predators. The DSR of passerines is influenced by terrain, vegetation composition, and density (Braden 1999; Reidy et al. 2017), so the higher nest survival rates in this Core Area suggest this microhabitat provides ideal breeding condition for gnatcatchers.

The Hogbacks/Murrieta Hot Springs and Lake Skinner Core Areas showed relatively lower DSR values during our last five surveys. The reasons are not clear, but we hypothesize several potential reasons here. First, we documented a relatively high nest parasitism rate in 2021 in the Hogbacks/Murrieta Hot Springs Core Area, and a few cases of parasitism occurred in the Lake Skinner Core Area in 2018. Although none of the cowbird eggs hatched this year, the adverse effect of parasitism on behaviors and adult condition may be large and may increase predator pressure (Briskie et al. 1992; Ruiz-Raya et al. 2018). Changing behaviors and adult condition may reduce the nest defense abilities, thereby reducing DSR. Second, the number of predators may be higher. Because the majority of nest failures occur as a result of predation, increased numbers of predators can negatively affect DSR. Third, when habitat patch size is small, as it is within the Hogbacks/Murrieta Hot Springs Core Area, nest predation rate increases due to edge effects (Andren and Angelstam 1988; Batary and Baldi 2004), thereby reducing DSR.

The effect of survey year on DSR was not supported based upon AIC_C (w_i = 0.13; Table 3), suggesting that yearly variation of DSR did not strongly influence variations in the survival rates of gnatcatcher nests. We reiterate, however, that we documented relatively low DSR in 2008, with the DSR in other survey years being higher and similar to one another. The year 2008 was the only time we have documented a DSR below 0.95 (Table 2), implying the overall nest survival rate in 2008 was lower than 20%.

The mean number of nesting attempts per pair whose nests we located was 2.0 ± 0.9 SD in 2021, which was a little higher than we observed in 2018 (mean = 1.56 nesting attempts; Biological Monitoring Program 2019). These numbers are lower than what investigators reported in Los Angeles (3.0 ± 0.62 SD), Orange (3.3 ± 1.67 SD), and San Diego counties (4.2 ± 0.84 SE; Grishaver et al. 1998; Atwood and Bontrager 2020). The number of nesting attempts documented in our study may have been an underestimate because we likely missed nests due to a shortage of biologists working on the project. Further, our visits to each site occurred infrequently enough that we missed nesting attempts, especially those that failed early in the nesting season. Finally, gnatcatchers breed in western Riverside County from late March through mid-July, during which time they quickly rebuild after each failed nesting attempt. This would further suggest that pairs in our study area likely attempted more than the two nests per pair we documented in 2021.

The estimated annual reproductive success (± SD) in 2021 was 1.77 (± 1.82) fledglings per female, which is lower than what we observed in 2018 (1.95 (± 1.76); Biological Monitoring Program 2019). The values we reported in 2018 and 2021 may be an underestimate and are lower than has been reported elsewhere in southern California gnatcatcher populations. Previous investigations found average (± SD) gnatcatcher annual reproductive success values of 3.0 (± 0.62) in Los Angeles County, 2.5 (± 0.48) in Orange County (Atwood and Bontrager 2020), and 2.4 (± 1.16) in San Diego County (Grishaver et al. 1998). Our estimates may be low for the same reasons described above for the average number of nesting attempts, specifically infrequent visits to sites that potentially caused us to miss some nest attempts. Because annual reproductive success is an important metric to consider when monitoring avian species across multiple years (Thompson et al. 2001) and many gnatcatcher investigators in southern California use this value to monitor and compare gnatcatcher reproductive status, we will continue to monitor as many nesting attempts as possible in subsequent gnatcatcher survey efforts to acquire accurate estimates. However, our estimated DSR was not exceptionally low compared with other passerine species, so we do not consider that gnatcatcher reproduction at these locations in western Riverside County is comparatively low even if the annual reproductive success estimate was lower than in previous investigations in surrounding counties.

Nest Parasitism

In 2021, none of monitored cowbird eggs hatched, although some gnatcatcher eggs from parasitized nests hatched. We documented eight cases of Brown-headed Cowbird parasitism; six occurred in the Hogbacks/Murrieta Hot Springs Core Area and two were in the Alberhill Core Area. We observed that all except one gnatcatcher eggs from four of eight parasitized nests hatched, and in one nest which had two gnatcatcher eggs and one cowbird egg during the incubation period, two gnatcatcher eggs hatched and successfully fledged. The reason why none of the cowbird eggs hatched in 2021 breeding season is unknown, but it is possible that all eggs were infertile. All cowbird eggs we observed were normal and without damage. Cowbird eggs usually hatch earlier or at the same time as host eggs (Lowther 2020); however, we observed only gnatcatcher eggs hatching in 2021, suggesting gnatcatcher incubation proceeded normally and cowbird eggs were infertile. In 2018, we documented two cases of brood parasitism in the Lake Skinner Core Area. One nest was ultimately depredated during the incubation stage and the other nest fledged one cowbird while three gnatcatcher eggs remained unhatched. While monitoring one of the parasitized nests in 2018, we observed only the male gnatcatcher carrying food to the cowbird nestling. Of 131 nests we monitored prior to 2018, we did not observe any nest parasitism (Biological Monitoring Program 2019).

We observed higher cases of brood parasitism during survey 2021, especially in the Hogbacks/Murrieta Hot Springs Core Area. We have never observed such a high rate of brood parasitism anywhere in our Plan Area since the 2008 survey season. Parasitism by cowbirds was common in Riverside County, especially in the area near Lake Skinner (Braden et al. 1997b), although we monitored 31 gnatcatcher nests in the Lake Skinner area from 2008 to 2014 without detecting parasitism. Cowbird trapping as part of the recovery efforts for Least Bell's Vireo (*Vireo bellii pusillus*) has likely decreased the brood parasitism rates near Lake Skinner (Braden et al. 1997b), and this may explain why it has occurred so rarely in our past studies. The reason of this sudden increase is unknown, but we need to closely monitor this phenomenon during upcoming studies.

Nest Substrates

Nest substrate selection by gnatcatchers in 2021 likely reflected the availability of plants within the sites. In most of the areas in western Riverside County, California buckwheat is the most dominant CSS species, followed by coast brittle-bush. As a result, gnatcatchers in 2021 used coast brittle-bush most commonly as a nest substrate, followed by California buckwheat. In the Hogbacks/Murrieta Hot Springs and Lake Skinner Core Areas, where white sage is common, gnatcatchers built nine of the 19 nests we monitored in 2021 in white sage; interestingly, the availability of white sage in these Core Areas did not exceed the availability of California buckwheat. As a result, it is possible that gnatcatchers are preferentially selecting white sage as a nesting substrate. During our previous survey efforts, we hypothesized that gnatcatchers were disproportionately selecting for white sage as a nesting substrate, compared to its availability in the landscape (Biological Monitoring Program 2019), but this was only apparent in 2021 in the above-mentioned two Core Areas.

Interestingly, the potential selection for white sage did not appear to be associated with an increased nest survival rate. The nest survival rate of the nests in white sages was the lowest compared to the nests in other nest substrates (Table 4). White sages usually do not provide dense cover around nests, so nests in white sages were oftentimes visible from a considerable distance; further, the shrubs were not dense enough to hide adult movements to and from the nests. This might be a reason why we see the lowest nest survival rate, and the highest nest predation rate, in white sage nests. Additionally, the areas where white sages are common are the same areas that nest survival rates were low, regardless of nest substrate. Ultimately, we do not have enough data to analyze the relationships between the abundance of nest predators at these sites, the availability of nest substrate species, and the selection of nest substrates by gnatcatchers, so our interpretation of the data is conjecture. We will continue to monitor these relationships in subsequent survey efforts.

The nests in yellow bush-penstemon showed the highest nest survival rate, followed by California buckwheat. Yellow bush-penstemon was the only species in which nest survival exceeded 40%. This species provides dense cover for nests and further precludes access by predators due to its overall habit. These characteristics might conceal nests and adult movements well around nests; as a result, the rate of nest survival increased. Nest survival rates in other nest substrates did not strongly differ among species. Our sample sizes of nests within each substrate were small, likely accounting for at least some of the differences seen in Table 4. Finally, we did not see any strong selection for particular species as a nest substrate.

Overall, these results suggest that gnatcatchers are generalists when selecting for nest substrates within CSS habitat, because they nested in 13 different substrate species that were available in the CSS habitat. Gnatcatchers are a specialist of CSS habitat but not a specialist within CSS habitat. One study in San Diego County showed that gnatcatcher populations were positively correlated with California sagebrush, and negatively correlated with black sage (Winchell and Doherty 2018); however, in our studies in western Riverside County, gnatcatchers frequently used the habitat where black sage was common and used this shrub as a nest substrate 11 times from 2008–2021. The nest survival rate of nests in black sage did not differ from those in other substrates (Table 4).

Recommendations

Future Surveys

The number of detections of brood parasitism by Brown-headed Cowbirds increased from survey efforts prior to 2018. The locations in which this parasitism occurred were the Hogbacks/Murrieta Hot Springs and Alberhill Core Areas in 2021, and the Lake Skinner Core Area in 2018. In 2021, none of the cowbird eggs hatched, but we observed successful fledging of cowbirds in 2018 at the Lake Skinner Core Area. We will continue to monitor whether this phenomenon is increasing in frequency in subsequent survey efforts. If it is increasing, we will make recommendations on how to manage cowbirds for the benefit of gnatcatcher populations.

The other important finding is the nest survival rate in white sage. White sage was one of the most important nest substrates of gnatcatchers (Biological Monitoring Program 2019), and we see some evidence of selection for the substrate by gnatcatchers in some Core Areas; however, nest survival rate according to our data was the lowest compared to other nest substrates. We need to collect more samples and monitor them to evaluate whether this trend is valid. The sample size of each year was small so long-term data are valuable.

Reproductive information is a key factor when estimating the future trend of sensitive species and evaluating pertinent habitat attributes (Shaffer 2004). Moreover, the abundance of birds, itself, is not always related to reproductive success, habitat quality, or future population trends. Monitoring reproductive results makes the survey results more robust and useful for estimating species' future trends (Van Horne 1983). As previously mentioned, our demographic results were likely underestimates due to small sample sizes. One of the best measures of reproduction in avian species is annual reproductive success, specifically number of young produced per female per year (Thompson et al. 2001). Previous investigations of gnatcatchers in and surrounding Riverside County have used this value to assess reproductive success of the species, and for our data to be comparable we must visit study sites more frequently in future survey efforts. This will also help to increase the nest sample size, which will allow us to perform more robust analyses.

Nest searching and monitoring requires many trained biologists and is very time-consuming. Our sample size for analysis of reproduction was small due to the limited availability of a small group of trained biologists in 2021. Increasing the accuracy of this analysis, and thus estimating future population trends more accurately, requires us to spend more time training biologists and conducting nest searches, and monitoring more nests, which could increase the sample size for data analysis. Moreover, a comparison of the nest vegetation characteristics of successful and unsuccessful nests could guide future habitat management and estimates of population trends, but also requires a larger sample size.

Finally, for future analyses, we plan on using the most recent robust nest survival model, a general Bayesian hierarchical model by WINBUGS (Spiegelhalter et al. 2003), to estimate the DSR (Schmidt et al. 2010) and compare with the DSR calculated by program MARK. The nest survival model used in Program MARK is based on a binomial distribution framework, which is generally restrictive when fitting field data and commonly lacks heterogeneity and independence. As a result, the DSR calculated by binomial distribution is often underestimated (Schmidt et al. 2010). However, an advantage to using Program MARK is that the software is user-friendly and estimating DSR is a relatively simple process, whereas the Bayesian hierarchical model by WINBUGS is much more complicated and difficult to understand. Ultimately, the Bayesian hierarchical model is a robust tool for evaluating nest survival, so we will continue studying the process in anticipation of future surveys. We will then be able to compare these two models and determine how much the results differ and which model will be most useful for future nest survival analysis.

Core Area Definitions

We recommend including Lake Perris (Existing Core H), Badlands/Potrero (Proposed Core 3), and Tule Valley (Proposed Core 6) as additional Core Areas for California Gnatcatchers. We have frequently detected the species in these locations for at least the last 15 years and including these as Core Areas would help us to better understand their status in western Riverside County.

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Appendix A. Nesting datasheet for 2021 California Gnatcatcher surveys.

MSHCP Biological Monitoring Program
2021 CAGN Nest Monitoring Data Sheet

General Nest Information

Grid ID:	Nest ID:
Nesting substrate:	Substrate height (m):
Nest height (m):	XY Coordinates:

Visit Information

			Behavior[1]		Target Species			BHCO	
Observer	Date (mm/dd/yyyy)	Nest Status[2]	Male	Female	# eggs	# nestlings	# fledglings	# eggs	# nestlings

Notes:

[1] Visible, Singing, Calling, CaRry nest material, Carry/give Food, Incubating, Carry fEcal sac, Brooding, or NL (Not Located)
[2] Construction, LaYing, Incubating, Nestlings, Fledged, Depredated, Abandoned, FaiLed, Unknown, or NL (Not Located)

Data entered by _____ on __________

Data checked by _____ on __________

Appendix B. Survey datasheet for 2021 California Gnatcatcher surveys.

MSHCP California Gnatcatcher Reproduction Survey Data Sheet, 2021

Purpose: Grid Survey or Follow up or Pair Monitoring

Grid ID:		Date:		Start Temp:	
Core Area:		Start Time:		End Temp:	
Observer:		End Time:		Sky Code:	

Pair Info:

Pair ID:	UTM E:	UTM N:	M Behav:	F Behav:	Nest ID:	Nstage:	Notes:

Unpaired Info:

UTM E:	UTM N:	Age:	Sex:	Behav:	Notes:

Notes: