USE OF REFUGIA BY CALIFORNIA GNATCATCHERS DISPLACED BY HABITAT LOSS

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Because the California Gnatcatcher (*Polioptila californica*) is one of the focal species for conservation of coastal sage scrub being planned under the state of California's Natural Community Conservation Planning (NCCP) program (Atwood and Noss 1994, Reid and Murphy 1995), the species' response to large-scale loss of habitat is an important factor that may influence both the design of habitat reserves and development of future habitat-management strategies. For example, can birds that are displaced by habitat loss be expected to move successfully into adjacent areas of undisturbed habitat? Or is suitable gnatcatcher habitat generally "saturated" in terms of the number of breeding pairs it is able to support, implying that birds displaced by destruction of coastal sage scrub will not successfully establish themselves in neighboring refugia?

An opportunity to examine these questions was presented in late October 1993, when the Laguna fire burned approximately 5261 ha (13,000 acres) of coastal sage scrub, chaparral, and grassland in the San Joaquin Hills of coastal Orange County (Bontrager et al. 1995). Pre-fire surveys conducted by Jones and Stokes Associates and Ed Almanza and Associates in 1992 suggest that habitat occupied by approximately 127 pairs of gnatcatchers was destroyed or severely degraded by the burn (Bontrager et al. 1995). Because the burn took place soon after the 1993 breeding season, when the population is augmented by recently fledged juveniles, as many as 500 individual gnatcatchers may have been affected. Surveys during spring 1994 found only 12 pairs within the burned area, 9% of the pre-fire (1992) estimate (Bontrager et al. 1995). During surveys immediately after the fire in November and December 1993, several experienced observers felt that many of the gnatcatchers seen in nearby unburned habitat were behaving as though they might have been displaced from their territories as a result of the fire (Bontrager et al. 1995). Additional gnatcatchers near the San Joaquin Hills were displaced in January and February 1994, when habitat that supported approximately five to ten breeding pairs in 1993 was destroyed during construction of a segment of the San Joaquin Hills Transportation Corridor north of Newport Coast Drive (E. Woehler pers. comm.).

In this study we compare the 1993–1995 population estimates of breeding California Gnatcatchers in coastal Orange County around the periphery of the Laguna fire with estimates from control sites unaffected by the burn. In particular, we ask two questions: (1) did breeding populations in habitat refugia show an increase during 1994 that might be attributed to displacement of birds by the Laguna fire, and (2) did any such increased densities of birds in the habitat refugia persist into the 1995 breeding season?

METHODS

In the San Joaquin Hills within 2 km of the Laguna fire's perimeter we identified five unburned refugia for which baseline (1993) population data were available (Figure 1; Table 1). Each site, which included variable amounts of coastal sage scrub, was isolated from other patches of scrub by a distance of at least 1 km. Under this operational definition, the sampling units referred to here differ slightly from those used by Bontrager et al.

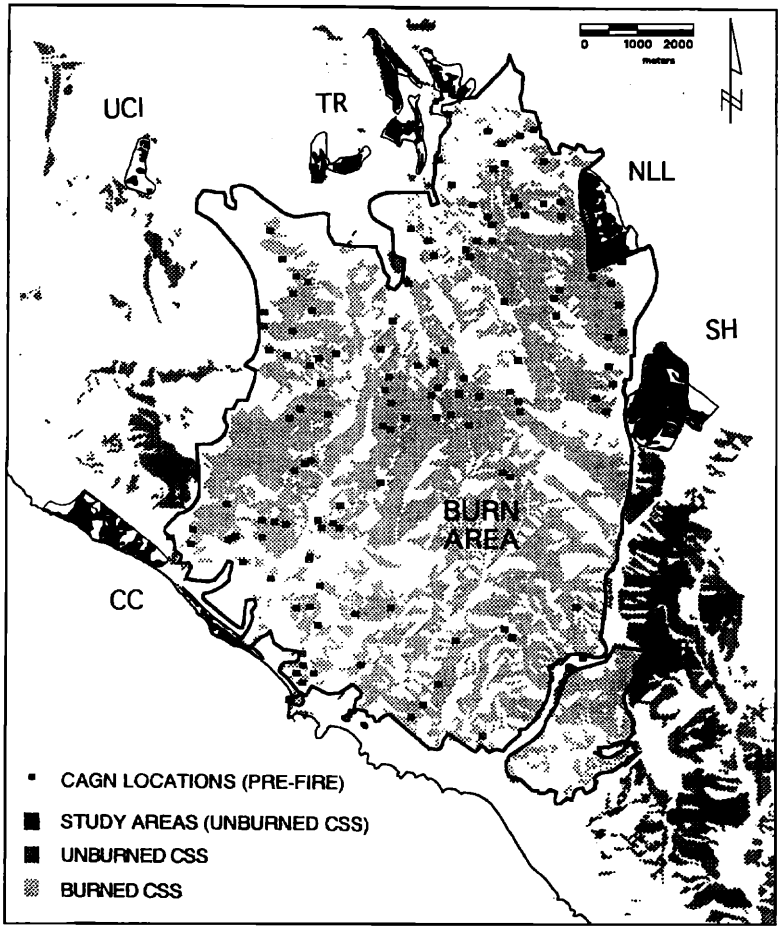

Figure 1. Habitat refugia surrounding the 1993 Laguna fire, including pre-fire (1992) distribution of coastal sage scrub and breeding pairs of the California Gnatcatcher within the burn area. TR, Turtle Rock, SH, Sycamore Hills, NLL, North Laguna Laurel; UCI, UC Irvine Ecological Preserve; CC, Crystal Cove State Park.

Table 1 Refugia and Control Sites for Study of the Laguna Fire

Location	Dominant vegetation[a]	Area (ha)[b]
Refugia		
Crystal Cove State Park	Sagebrush scrub; quail brush scrub	101
North Laguna Laurel	Sagebrush scrub; sagebrush–black sage scrub; black sage scrub; scrub-chaparral ecotone	80
Sycamore Hills	Sagebrush–buckwheat scrub; sagebrush–black sage scrub; black sage scrub; scrub–chaparral ecotone	151
UCI Ecological Preserve	Sagebrush–buckwheat scrub; southern cactus scrub; sagebrush–grassland; ruderal	25
Turtle Rock	Sagebrush–buckwheat scrub; sagebrush scrub; coyote brush scrub; mixed sage scrub; ruderal; southern cactus scrub	159
Control sites		
Agua Amarga Canyon	Sagebrush scrub; sagebrush–buckwheat scrub; southern cactus scrub	82
U.S Navy Fuel Depot	Sagebrush scrub; ruderal	57
"Location 2"[c]	Sagebrush–buckwheat scrub	100
"Moratorium" zone	Ruderal; sagebrush scrub; sagebrush–buckwheat scrub; southern cactus scrub; purple sage scrub; toyon–sumac chaparral; sage scrub–grassland ecotone	551
Ocean Trails	Southern cactus scrub; sagebrush–buckwheat scrub; ruderal; sagebrush scrub	114
Point Vicente	Sagebrush scrub; southern cactus scrub; ruderal	71

[a]Vegetation categories based on Jones and Stokes Associates (1993).

[b]Area estimates approximate, and not limited to areas of coastal sage scrub vegetation.

[c]Unnamed location in coastal Orange County; see Erickson and Miner (1998)..

(1995). Similarly, we identified six control sites on the Palos Verdes Peninsula, Los Angeles County (Atwood et al. 1998), and in coastal Orange County (Erickson and Miner 1998). Because these localities were far removed from the San Joaquin Hills and isolated by extensive areas of urban development, we used them to evaluate population changes in the habitat refugia that might have been associated with the Laguna fire.

Year-to-year consistency of survey methods and personnel was maintained within each study location. The estimated number of gnatcatcher pairs was based on cumulative observations made throughout each breeding season, often including the mapped locations of uniquely color-banded birds and simultaneously active nests.

RESULTS

The numbers of breeding pairs of California Gnatcatchers at five habitat refugia and six control sites are provided in Table 2. Estimates in the refugia for 1994 were significantly different from those for 1993 ($P = 0.043$, Wilcoxon signed-rank test); 1993 and 1994 estimates from the control sites did not differ significantly ($P = 0.256$). In 1994, all five refugia showed population increases ranging from 25% (Turtle Rock) to 105% (Crystal Cove

Table 2 Number of Breeding Pairs of California Gnatcatchers at Refugia and Control Sites

Location	Population estimate		
	1993	1994	1995
Refugia			
North Laguna Laurel	6	8	5
Sycamore Hills	10	16	18
UC Irvine Ecological Preserve[a]	4	7	6
Crystal Cove State Park	20	41	21
Turtle Rock[b]	51	64	43
Control sites			
Agua Amarga Canyon	8	6	4
U.S. Navy Fuel Depot	5	5	0
"Location 2"[c]	20	29	16
"Moratorium" zone	25	27	15
Ocean Trails	7	9	3
Point Vicente	3	3	1

[a]Fide E. Woehler. Excludes (from all three years) one pair present during 1993 and 1994 but which disappeared before the 1995 breeding season, apparently as a result of construction associated with the San Joaquin Hills Transportation Corridor in December 1994.

[b]Includes sites referred to by Bontrager et al. (1995) as Ridgeline, Sand Canyon Reservoir, Turtle Rock fragments, and Turtle Rock Reservoir.

[c]Unnamed location in coastal Orange County; see Erickson and Miner (1998).

State Park) (mean increase 59.6%, standard deviation 32.4). Among the control sites, from 1993 to 1994, the population increased at three, decreased at one, and did not change at two (Figure 2).

Populations at the control sites declined significantly from 1994 to 1995 ($P = 0.027$; Wilcoxon signed-rank test). Among the refugia there was no statistically significant change from 1994 to 1995 ($P = 0.138$; Wilcoxon signed-rank test), although numbers decreased at four of the five sites, including a decline of 49% at Crystal Cove State Park (Figure 2).

DISCUSSION

Increased numbers of California Gnatcatchers were found in unburned areas of coastal sage scrub immediately after a fire that burned over 5200 ha of coastal sage scrub, grassland, and chaparral (Bontrager et al. 1995). During the 1994 breeding season these unburned refugia supported significantly more breeding pairs than before the fire. Populations at the control sites distant from the Laguna fire did not increase significantly from 1993 to 1994.

In 1995, gnatcatcher populations declined at all of the control sites and at four of the five refugia. The single refugium where the population increased

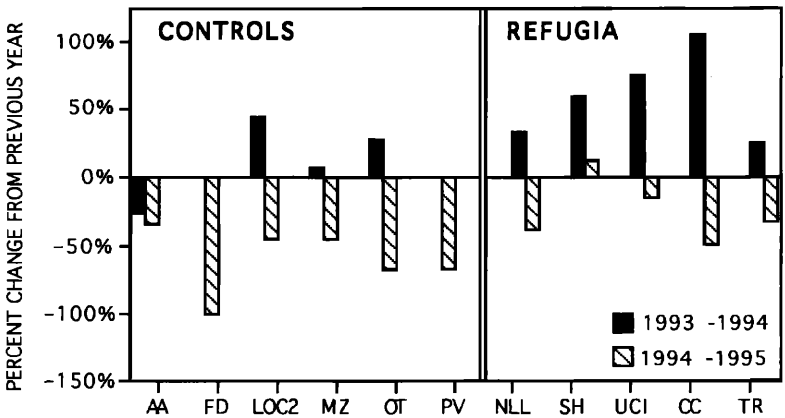

Figure 2. Gnatcatcher population changes in the San Joaquin Hills habitat refugia and control sites, 1993–1995. Abbreviations for habitat refugia as in Figure 1. Control sites: AA, Agua Amarga Canyon; FD, U.S. Navy Fuel Depot; LOC2, unnamed location in coastal Orange Co. (Erickson and Miner 1998); MZ, "Moratorium" zone; OT, Ocean Trails; PV, Point Vicente.

from 1994 to 1995 (Sycamore Hills) may have received immigrants displaced by adjacent construction that began in June 1994 and destroyed occupied gnatcatcher habitat (D. Bontrager unpubl. data).

At the time of the Laguna fire (October 1993), we hypothesized that gnatcatcher densities in unburned refugia located near the fire's perimeter might increase during the 1994 breeding season, but, if pre-fire occupancy of these areas was close to saturation level, populations within the refugia would revert approximately to their pre-fire levels by spring 1995. The observations reported here are consistent with the first part of this hypothesis, but we remain unsure if density-dependent factors contributed to the declines seen from 1994 to 1995. We believe that the evidence is strong that the increases observed in the refugia during 1994 were related to displacement of birds by the Laguna fire. Though the population declines seen from 1994 to 1995 are consistent with our prediction that density-dependent factors might have acted to restore gnatcatcher breeding densities in the refugia to their approximate pre-fire levels, the concurrent population declines at control sites confound this interpretation. If winter weather in 1994–1995 caused regional population declines (Erickson and Miner 1998), then any density-dependent effects in the habitat refugia might well have been obscured.

In experimental studies of the effect of forest fragmentation in the Amazon basin of Brazil, Bierregaard and Lovejoy (1989) documented short-term increases in densities of forest birds in habitat refugia adjacent to large-scale deforestation; after approximately 200 days, these elevated densities decreased to levels lower than those encountered prior to the displacement.

Darveau et al. (1995) found increased densities of forest birds along riparian corridors adjacent to recent clearcuts. Hagan et al. (1996) observed increased densities but reduced pairing success of Ovenbirds (*Seiurus aurocapillus*) in forest fragments adjacent to areas of recent lumbering and proposed that "an abrupt fluctuation of this magnitude caused by displaced individuals from lost habitat might impose behavioral pressures that destabilize some fragment[ed] bird populations." If correct, this hypothesis suggests that substantial synchronous loss of habitat might temporarily elevate the gnatcatcher's population levels within habitat refugia to a point where increased territorial interactions could reduce reproductive success. Thus, even though actual counts of breeding pairs might show short-term increases, density-dependent effects might ultimately cause population declines. Especially with a relatively short-lived species like the California Gnatcatcher which may, on average, have a life-time breeding expectancy of only one or two years (Atwood et al. 1998, Bontrager unpubl. data), such effects could have important ramifications for the dynamics of local populations.

These hypotheses suggest that extensive wildfires may damage gnatcatcher populations in unburned refugia as well as within the burn. Because fire is clearly one of the most important factors to consider in maintaining viable tracts of coastal sage scrub, understanding the relationships among burn extent, use of habitat refugia, and recolonization of recovering burned areas by sensitive species such as the California Gnatcatcher is important. Until these topics are better studied, we suggest that frequent small controlled burns within reserves of coastal sage scrub habitat are less likely to have long-term adverse effects on gnatcatcher populations than occasional large fires.

Population trends in the California Gnatcatcher are likely to be influenced by a variety of factors ranging from the effects of weather on reproductive success and survivorship to increased competition for resources caused by the immigration of birds displaced by habitat loss. Our understanding of how these and other factors interact to determine gnatcatcher population dynamics remains limited, yet the issue has critical implications for both the design and effective management of viable habitat reserves. Consequently, continuation of in-depth, long-term studies at various sites throughout the species' range in southern California remains an important objective for recovery.

SUMMARY

We analyzed annual estimates of the number of breeding pairs of California Gnatcatchers from 1993 to 1995 in five habitat refugia located adjacent to the October 1993 Laguna fire in coastal Orange County and at six control sites distant from the burn. Observations immediately after the fire suggested that many of the over 500 gnatcatchers whose habitat was burned were displaced rather than killed outright. During the 1994 breeding season counts in all habitat refugia were higher than during the previous year; among the control sites, there was no trend. These results suggest that gnatcatchers displaced by habitat loss may, at least in the short term, pack more densely into remaining areas of intact coastal sage scrub. Populations at both refugia and control sites decreased from 1994 to 1995, possibly as

a result of density-independent factors such as weather; we could not assess whether increased densities of breeding gnatcatchers in unburned refugia would have persisted over more extended periods of time.

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