

Ecosystems Mission Area—Species Management Research Program

Least Bell's Vireos and Southwestern Willow Flycatchers at the San Luis Rey Flood Risk Management Project Area in San Diego County, California: Breeding Activities and Habitat Use—2022 Annual Report



Open-File Report 2023–1040

Cover: Least Bell's Vireo (*Vireo bellii pusillus*) nest with two vireo nestlings at the lower San Luis Rey River. Photograph by Shannon Mendia, U.S. Geological Survey, 2022.

Least Bell's Vireos and Southwestern Willow Flycatchers at the San Luis Rey Flood Risk Management Project Area in San Diego County, California: Breeding Activities and Habitat Use—2022 Annual Report

By Alexandra Houston, Lisa D. Allen, Shannon M. Mendia, and Barbara E. Kus

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Conversion Factors

International System of Units to U.S. customary units

Multiply	By	To obtain
Length		
centimeter (cm)	0.394	inch (in)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
Area		
hectare (ha)	2.471	acre (ac)
Flow		
cubic meter per second (m³/s)	35.315	cubic feet per second (ft³/s)
kilometer per hour (km/h)	0.6214	mile per hour (mi/h)

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

°C = (°F –32) / 1.8.

Datum

Horizontal coordinate information is referenced to the World Geographic System of 1984 (WGS 84).

Abbreviations

AIC _c	Akaike's Information Criterion for small sample sizes
DSR	daily survival rate
FNWS	Fallbrook Naval Weapons Station
GLM	generalized linear model
GPS	Global Positioning System
MCBCP	Marine Corps Base Camp Pendleton
Project Area	San Luis Rey Flood Risk Management Project Area
USFWS	U.S. Fish and Wildlife Service

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Executive Summary

We completed four protocol surveys for Least Bell's Vireos (*Vireo bellii pusillus*; vireo) during the breeding season, supplemented by weekly territory monitoring visits. We identified a total of 133 territorial male vireos; 114 were confirmed as paired, and 3 were confirmed as single males. For the remaining 16 territories, we were unable to confirm breeding status. Two transient vireos were detected in 2022. The vireo population in the Project Area increased by 9 percent from 2021 to 2022. The vireo population at Marine Corps Base Camp Pendleton also increased (4 percent), whereas the population at Marine Corps Air Station remained relatively stable (decreased from 10 pairs to 9) and the Otay River population decreased by 10 percent (2 territories).

We used an index of treatment (Treatment Index) to evaluate the effect of on-going vegetation clearing on the Project Area vireo population. The Treatment Index measures the cumulative effect of vegetation treatment within a territory (since 2005) by using the percentage area treated weighted by the number of years since treatment. We determined that the Treatment Index for unoccupied habitat was more than four times that of occupied habitat, indicating that vireos selected habitat that was less treated in which to settle.

We monitored vireo nests at three general site types: (1) within the flood channel where exotic and native vegetation removal has occurred regularly (Channel), (2) three sites near the flood channel where limited exotic and native vegetation removal has occurred (Off-channel), and (3) three sites that have been actively restored by planting native vegetation (Restoration). Nesting activity was monitored in 80 territories, 3 of which were occupied by single males and 1 by a male whose breeding status could not be confirmed. Overall, 38 percent of completed nests were successful and nest success did not differ among the three sites. In 2022, there were no differences with regard to clutch size, hatching, or fledging success among Channel, Off-channel and Restoration sites. Overall breeding success and productivity were

slightly higher in 2022 than in 2021, with 72 percent of pairs fledgling at least one young and pairs fledging an average of 2.2 ± 1.7 young.

To investigate if the cumulative years of treatment had an effect on vireo reproductive effort, we looked at the effects of the Treatment Index on reproductive parameters. Results from generalized linear models indicated that treatment did not have an effect on vireo nesting effort or the number of vireo fledglings per pair produced in 2022. Similarly, we did not detect an effect of Treatment Index on daily survival rate (DSR) of nests.

Analysis of vegetation data collected at vireo nests from 2006 to 2022 did not reveal an effect of vegetation cover at the nest on DSR. We did find, however, that Channel nests were placed higher in the host plant than Off-channel nests. In the Channel and Off-channel sites, successful nests were placed closer to the edge of the host plants than unsuccessful nests. Additionally, successful Off-channel nests were placed lower in the vegetation, in shorter host plants, and closer to the edge of the vegetation clump than unsuccessful nests.

Red/arroyo willow (*Salix laevigata* or *Salix lasiolepis*) were the species most commonly selected for nesting by vireos in all three site types. Black willow (*Salix gooddingii*) and mule fat (*Baccharis salicifolia*) also were commonly used. Vireos used a wider variety of species for nesting in Channel and Off-channel sites (eight and six species, respectively) compared to Restoration sites (two species), although there was limited nesting in Restoration sites in 2022.

There were 43 vireos banded before the 2022 breeding season that were resighted and identified at the Project Area in 2022, all of which were originally banded in the Project Area. Adult birds of known age ranged from 1 to 7 years old. A total of 146 vireos were newly banded in 2022. There were 8 adult vireos banded with a unique color combination, and 138 nestlings were banded with a single dark blue numbered federal band on the left leg. Between 2006 and 2022, survivorship of males (66 ± 11 percent) was consistently higher than that of females (59 ± 12 percent). First-year birds from 2006 to 2022 had an average annual survivorship of 15 ± 6 percent.

First-year dispersal in 2022 averaged 6.7 ± 7.4 kilometers (km), with the longest dispersal (15.3 km) by a male that was recaptured at Fallbrook Creek, Fallbrook Naval Weapons Station (FNWS). From 2007 to 2011, most returning first-year vireos returned to the Project Area, whereas from 2014 to 2016, the majority of returning birds dispersed to areas outside of the Project Area. From 2018 to 2021, the trend shifted, and more first-year vireos returned to the Project area. In 2022, only one first-year vireo returned to the project area and two dispersed to sites outside the Project Area (upstream to the middle San Luis Rey River and to Fallbrook Creek, FNWS). However, the total number of identified first-year vireos was low and the trend in 2022 will likely shift as additional returning first-year vireos are identified in subsequent years.

Most of the returning adult male vireos showed strong between-year site fidelity to their previous territories. Seventy-three percent of males (27/37) occupied a territory in 2022 that they had defended in 2021 (within 100 meters [m]). There were no females (0/4) detected in 2022 that returned to a territory they occupied in 2021; however, 50 percent of females (2/4) detected in 2022 returned to areas adjacent to their previous territories (within 300 m). The average between-year movement for returning adult vireos was 0.3 ± 0.7 km. The amount of treatment at adults' 2021 territories did not affect the distance adults moved to their 2022 territories.

We completed four protocol surveys for the endangered Southwestern Willow Flycatcher (*Empidonax traillii extimus*; flycatcher) at the Project Area between May 16 and July 25, 2022. Four transient Willow Flycatchers were detected in the Project Area in 2022. Two transients were detected in Reach 1, one in Reach 3a, and one in Pilgrim Pond. There were not any resident flycatchers documented in the Project Area in 2022.

A total of 46 vegetation transects (528 points) were sampled at the Project Area in 2022. Seventy-one percent (378/528) of points were located in the Channel, and 22 percent (115/528) were in Upper Pond. The remaining 7 percent (35/528) of points were at the Whelan Restoration site. Foliage cover below 2 m was higher at the Channel points compared to Upper Pond and Whelan Restoration, which can be attributed to the dense herbaceous vegetation that grows after mowing. Above 2 m, foliage cover was similar at the Channel and Whelan Restoration sites and was higher than at Upper Pond. Average canopy height was higher in the Channel (5.6 ± 3.4 m) compared to Upper Pond (4.7 ± 2.9 m) and Whelan Restoration (4.6 ± 1.9 m). From 2006 to 2022, total foliage cover declined above 2 m in the Channel, in contrast to Upper Pond and Whelan Restoration, where little directional change in vegetation cover has occurred and where vegetation cover has largely recovered to 2006 levels. Within the Channel, the steepest declines occurred between 2009 and 2013 and between 2014 and 2016. Since 2016, we observed an increase in foliage cover, largely herbaceous, between 0 and 2 m within the Channel. The percent cover remained below levels detected before 2009 for other height classes.

We sampled vegetation at 44 vireo nests and 44 random plots ("territory" plots) within territories in the Channel and Upper Pond after the 2022 breeding season. Vireos in the Channel established territories in areas with significantly more cover from 3 to 6 m but less cover below 2 m relative to the available habitat. Within territories, Channel vireos selected nest sites with significantly more foliage cover from 2 to 3 m. Vireos at Upper Pond established territories in areas with significantly more foliage cover from 5 to 6 m and below 1 m relative to available habitat. However, within territories, Upper Pond vireos selected nest sites with significantly less foliage cover from 5 to 6 m and below 1 m.

Data either are not available or have limited availability owing to restrictions of the funding entity (U.S. Army Corps of Engineers). Please contact Christopher Chabot, Planning Division, Los Angeles District, U.S. Army Corps of Engineers, for more information.

Introduction

Least Bell's Vireo

The Least Bell's Vireo (*Vireo bellii pusillus*; vireo) is a small, migratory, songbird that breeds in southern California and northwestern Baja California, Mexico, from April through July (Kus and others, 2020). Historically abundant within lowland riparian ecosystems, vireo populations began declining in the late 1900s as a result of habitat loss and alteration associated with urbanization and conversion of land adjacent to rivers and agriculture (Franzreb, 1989; U.S. Fish and Wildlife Service, 1998; Riparian Habitat Joint Venture, 2004). Additional factors contributing to the vireo's decline have been the expansion in range of the brood-parasitic Brown-headed Cowbird (*Molothrus ater*; cowbird), to include the Pacific Coast (U.S. Fish and Wildlife Service, 1986; Franzreb, 1989; Kus, 1998, 1999; Kus and others, 2020), and the introduction of invasive exotic plant species such as giant reed (*Arundo donax*) into riparian systems. By 1986, the vireo population in California numbered just 300 territorial males (U.S. Fish and Wildlife Service, 1986).

In response to the dramatic reduction in numbers of vireos in California, the California Fish and Game Commission listed the species as endangered in 1980, with the U.S. Fish and Wildlife Service (USFWS) following suit in 1986. Since listing, the vireo population in southern California has rebounded, which is largely in response to cowbird control and habitat restoration and preservation (Kus, 1999; Kus and Whitfield, 2005). As of 2006, the statewide vireo population was estimated to be approximately 2,500–3,000 territories (U.S. Fish and Wildlife Service, 2006a), of which approximately 10 percent were along the San Luis Rey River between Interstate 15 and Interstate 5.

Male vireos arrive on breeding grounds in southern California in mid-March. Male vireos are vocally conspicuous and frequently sing their diagnostic primary song from exposed perches throughout the breeding season. Females arrive approximately 1–2 weeks after males and are more secretive. Often, females are seen early in the season traveling through habitat with the male. The female, with the male's help, builds an open cup nest in dense vegetation approximately 1 meter (m) above the ground. Clutch size for vireos averages three to four eggs. Typically, the female and male incubate the eggs for 14 days and young fledge from the nest at 11–12 days of age. It is not unusual for vireos to re-nest after a failed attempt provided ample time remains within the breeding season. Vireos rarely fledge more than one brood in a season, although double-brooding can be more common during years when breeding conditions are favorable (early initiation, high early fledging success; Ferree and Kus, 2008b; Houston and others, 2017, 2019). Nesting lasts from early April through July, but adults and juvenile birds remain on the breeding grounds into late September through early October before migrating to their wintering grounds in southern Baja California, Mexico (Kus and others, 2020).

Southwestern Willow Flycatcher

The Southwestern Willow Flycatcher (*Empidonax traillii extimus*; flycatcher) is one of four subspecies of Willow Flycatcher in the United States, with a breeding range that includes southern California, Arizona, New Mexico, extreme southern parts of Nevada, Utah, and Colorado, and western Texas (Unitt, 1987; U.S. Fish and Wildlife Service, 2002; Sedgwick, 2020). Restricted to riparian habitat for breeding, the flycatcher has declined in recent decades in response to widespread habitat loss throughout its range and, possibly, brood-parasitism by cowbirds (Remsen, 1978; Unitt, 1987; Schlorff, 1990; Whitfield and Sogge, 1999; U.S. Fish and Wildlife Service, 2002; Sedgwick, 2020). By 1993, the species was believed to number approximately 70 pairs in California (U.S. Fish and Wildlife Service, 1993), in small, disjunct populations. The flycatcher was listed as endangered by the State of California in 1992 and by the USFWS in 1995.

Flycatchers in southern California co-occur with vireos; however, unlike the vireo, which has increased tenfold since the mid-1980s in response to management alleviating these threats (U.S. Fish and Wildlife Service, 2006a), flycatcher numbers have remained low. Currently (2022), most flycatchers in California are concentrated at one site: the upper San Luis Rey River at Lake Henshaw in San Diego County (Howell and Kus, 2022). Outside of this site, flycatchers occur as small, isolated populations of one to six pairs.

Male flycatchers typically arrive in southern California in early to mid-May, whereas females arrive approximately 1 week later. While on the breeding grounds, males sing repeatedly from exposed perches. Once the pair bond is established, the female builds an open cup nest that usually is placed in a branch fork of a willow (*Salix* spp.) or plant with a similar branching structure approximately 1–3 m above the ground. The typical clutch of three to four eggs is laid in May–June. Females incubate for approximately 12 days, and nestlings fledge within 12–15 days, in early July. Adults usually depart from their breeding territory in mid-August through early September to their wintering grounds in central America and northern South America (U.S. Fish and Wildlife Service, 2002).

San Luis Rey Flood Risk Management Project Area

The San Luis Rey Flood Risk Management Project Area (Project Area) spans approximately 233 hectares (ha; 576 acres) of the lower San Luis Rey River in northwestern San Diego County, California (fig. 1; table 1). Authorized in 1970 and constructed during the late 1980s and early 1990s, the flood control Project Area includes single- and double-levee reaches and six off-channel detention ponds, five of which also serve as mitigation sites for effects to biological resources within the channel. Operation and maintenance of the flood control project within the channel includes periodic vegetation clearing, exotic plant removal, and sediment removal to ensure that sufficient water conveyance capacity is maintained (U.S. Fish and Wildlife Service, 2006b). Management of the off-channel ponds involves adaptive habitat management, such as vegetation clearing, exotic plant removal, and planting native vegetation.

Riparian vegetation communities at the Project Area include willow-dominated riparian, mixed mule fat (*Baccharis salicifolia*) and sandbar willow (*Salix exigua*) riparian scrub, freshwater marsh, and areas dominated by non-native giant reed. Dominant plants include red/arroyo willow (*Salix laevigata*/*Salix lasiolepis*; we did not distinguish between these species), black willow (*Salix gooddingii*), Fremont cottonwood (*Populus fremontii*), sandbar willow, mule fat, and giant reed. Adjacent habitat and land-use types include coastal sage scrub, non-native grassland, and urban housing and commercial developments. Human disturbances such as transient camps, recreation, illegal dumping, introduction of invasive exotic plants and feral animals, and use by pets from neighboring houses are pervasive throughout the Project Area (table 2).

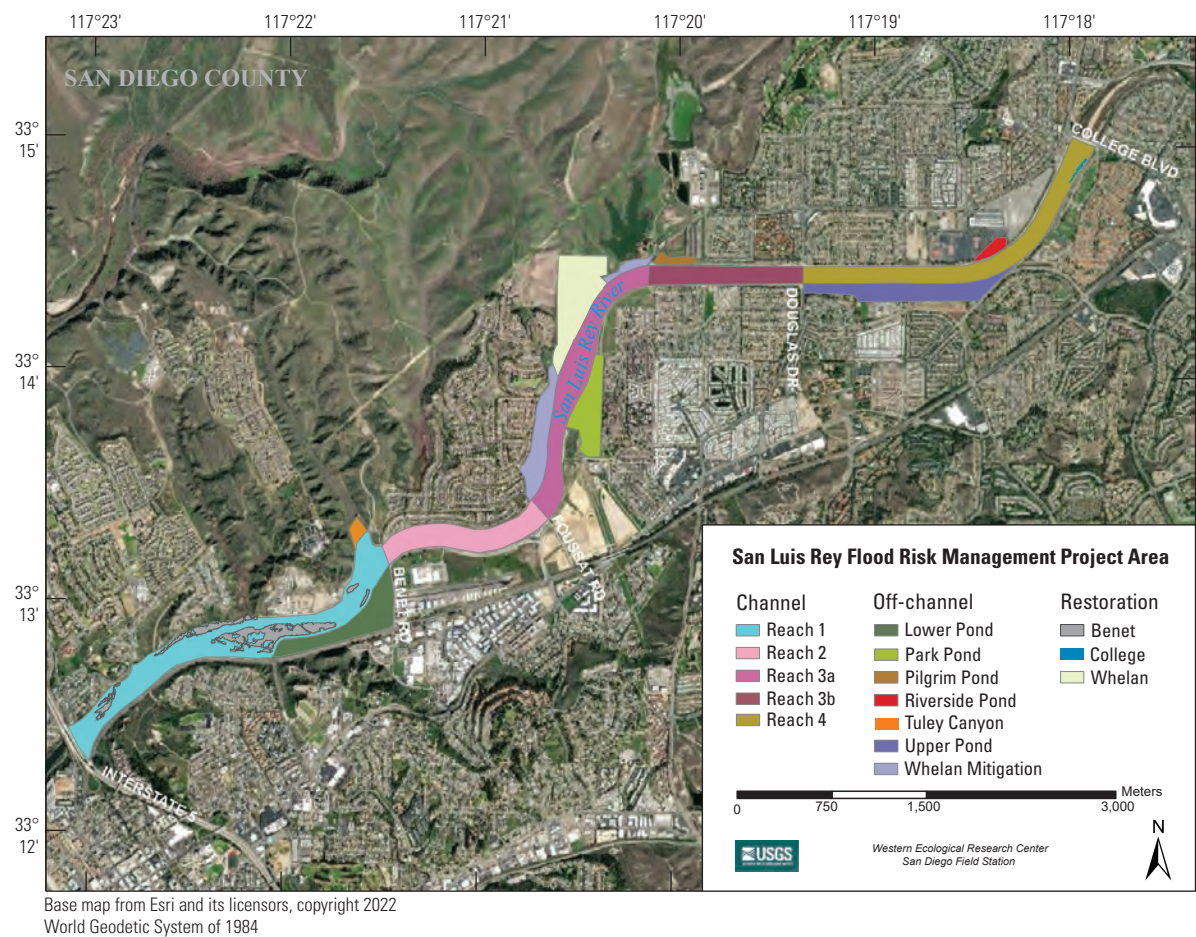


Figure 1. Least Bell’s Vireo and Southwestern Willow Flycatcher survey and monitoring sites at the San Luis Rey Flood Risk Management Project Area, California, in 2022.

Table 1. Least Bell’s Vireo and Southwestern Willow Flycatcher survey sites at the San Luis Rey Flood Risk Management Project Area, California, in 2022.

Survey site		Description	
Channel sites		Off-channel sites—Continued	
Reach 1	From Interstate 5 to Benet Road.	Pilgrim Pond	Detention pond with historic restored habitat, north of Reach 4.
Benet Restoration	Active restoration begun in 2012.	Riverside Pond	Detention pond with historic restored habitat, north of Reach 3b.
Reach 2	From Benet Road to Fousat Road.	Tuley Canyon	Detention pond with historic restored habitat, west of Benet Road and north of the levee.
Reach 3a	From Fousat Road to Whelan canal.	Upper Pond	Detention pond with historic restored habitat located south of levee between College Boulevard and Douglas Drive. Adaptive habitat management (mowing in 2015 and planting in 2017).
Reach 3b	From Whelan canal to Douglas Drive.	Whelan Mitigation	Historic restored habitat north of levee, between Whelan canal and Fousat Road.
Reach 4	From Douglas Drive to College Boulevard.	Whelan Restoration	Active restoration begun in 2014.
College Restoration	Active restoration begun in 2014.		
Off-channel sites			
Lower Pond	Detention pond with historic restored habitat, west of Benet Road and south of the levee.		
Park Pond	Detention pond with historic restored habitat, located south of the levee, between Douglas Drive and Fousat Road. Adaptive habitat management (mowing in 2015 and planting in 2017).		

Table 2. Site attributes of the Channel, Off-channel, and Restoration monitoring sites at the San Luis Rey Flood Risk Management Project Area, California, in 2022.

[Channel: Reach 1, Reach 2, Reach 3a, Reach 3b, and Reach 4 survey sites]

Attribute	Channel	Off-channel			Restoration		
		Park Pond	Upper Pond	Whelan Mitigation	Benet Restoration	Whelan Restoration	College Restoration
Size: hectares	148	11	19	22	12	10.5	0.4
Habitat type ¹	Mixed willow	Riparian scrub	Riparian scrub/mixed willow	Mixed willow/riparian scrub	Mixed willow	Mixed willow/riparian scrub	Mixed willow
Dominant canopy species	Red/arroyo willow, black willow	Sandbar willow, mule fat	Sandbar willow, mule fat, red/arroyo willow, black willow	Black willow, mule fat, red/arroyo willow	Red/arroyo willow, black willow	Sandbar willow, mule fat, red/arroyo willow, black willow	Black willow, mule fat, red/arroyo willow
Dominant exotic species	Exotic herbaceous cover	Exotic herbaceous cover	Exotic herbaceous cover	Exotic herbaceous cover	Exotic herbaceous cover	Exotic herbaceous cover	Exotic herbaceous cover
Disturbance	Transient camps; moderate-heavy human use	Transient camps, pets, recreation; heavy human use	Transient camps, pets, recreation; heavy human use	Transient camps; moderate-heavy human use	Exotic plant control; moderate transient use	Exotic plant control; some transient use	Exotic plant control; some transient use

¹Listed in order of dominance.

The Project Area includes a channelized 10.7-kilometer (km) section of the lower San Luis Rey River from Interstate 5 to College Boulevard and six detention ponds outside of the channel in Oceanside, California ([table 1](#)). The Project Area is divided into 12 survey sites: 5 of which are primarily within the flood control channel (hereafter “Channel”) and 7 that are outside of the channel (hereafter “Off-channel”; [table 1](#)). The seven Off-channel sites include one historic restored site north of the levee and west of Whelan Lake and six in the detention ponds. There are two large restoration sites: one in Reach 1 (Benet Restoration) and one in Whelan Mitigation (Whelan Restoration). One smaller restoration site is in Reach 4 (College Restoration).

Before the 2006 vireo breeding season, the U.S. Army Corps of Engineers began two flood risk management activities for the San Luis Rey Flood Risk Management Project: (1) exotic species eradication and (2) flood risk management of river channel vegetation. Exotic species eradication primarily included removal and control of giant reed, but other exotic species such as pepperweed (*Lepidium latifolium*), tamarisk (*Tamarix ramosissima*), and other non-native tree species also were targeted for removal. Exotic species were physically removed or treated with herbicide. The purpose of the flood risk management was to remove vegetation from the San Luis Rey flood control channel to provide a level of flood conveyance of 2,016 cubic meters per second (m^3/s ; equivalent to a 150-year flood; U.S. Fish and Wildlife Service, 2006b). In addition, a one-time mowing and mulching task was performed in 2005 to reduce the risk of flooding during the 2006 rainy season. On-going flood risk management of river channel vegetation includes rotational and annual vegetation mowing in phases. Phase 1 includes vegetation clearing in Reaches 1–4 to achieve a minimum flow conveyance of 1,500 m^3/s (equivalent to a 100-year flood). Phase 2 expanded the area mowed beyond that of Phase 1 and included creation of habitat for vireos and flycatchers. Phase 3 includes mowing associated with maintaining the Phase 1 mowing area as well as small sections of vegetation mowing in Reach 1 and Reach 3a. Rotational mowing is done every 5 years, alternating between two 18–23-m-wide strips of vegetation (rotations 1 and 2) such that each strip is mowed every 10 years.

Prior to the 2022 vireo breeding season, there was mowing that occurred in the river channel. In fall 2021, annual Phase 1 and 2 mowing in Reaches 1–4 was completed as part of the overall Flood Risk Management Project efforts. For a detailed description of the timeline and vegetation treatments and management see [appendix 1](#).

There were three Restoration areas within the Project Area: an exotic plant removal program in Reach 1 (Benet Restoration) that began in October 2012 and two projects that started in March 2014 ([appendix 2](#), [figs. 2.1–2.4](#)). The largest project, focused on providing flycatcher habitat, was

on the north side of the river channel in the eastern section of the Whelan Mitigation site (Whelan Restoration). A rock levee was removed and graded to below ground level, allowing flooding from the main channel to mimic more natural river flows. A second, smaller project occurred on the south side of Reach 4 near the College Boulevard bridge (College Restoration). Restoration activities included planting, bi-monthly watering, and spraying weeds with herbicide through 2015. Since 2016, there has been no watering or herbicide treatment, but we continued to classify these areas as Restoration sites and evaluate them separately. In addition to the three Restoration sites, in spring 2014, several small areas of the river were planted with pole cuttings, and in 2017, two of the Off-channel ponds were planted as a part of adaptive habitat management. These areas were considered passive restoration and were not included with our Restoration sites or in any of our analyses of Treatment Index.

Purpose and Scope

The purpose of this study was to document the status of vireos and flycatchers at the Project Area and characterize habitat structure and composition within the Project Area. Specifically, our goals for vireos were to (1) determine the size and composition of the vireo population; (2) characterize habitat used by vireos; (3) band vireos and resight banded vireos to estimate vireo survivorship, site fidelity, and dispersal; and (4) assess the effects of vegetation removal on vireo reproductive success and productivity by monitoring established nest plots in the Channel and Off-channel sites. Our goals for flycatchers were to (1) determine the size and composition of the Willow Flycatcher population at the Project Area, (2) document and monitor nesting activities of resident flycatchers, and (3) band and resight all flycatchers to facilitate the estimation of flycatcher survivorship and movement. The purpose of the habitat component of the study was to (1) provide post-treatment data on the habitat composition and structure of the Project Area, including areas that underwent vegetation removal in 2005, 2007–12 and 2014–15, 2017–19, and 2021 and (2) characterize habitat use by vireos in response to vegetation management at the Project Area. The USGS has been monitoring the vireo population in the Project Area since 2006. These data, when combined with data from other years, will inform natural resource managers about the status of these endangered species at the Project Area and guide modification of land-use and management practices as appropriate to ensure the species' persistence. Surveys and monitoring for the endangered Least Bell's Vireo were performed at the San Luis Rey Flood Risk Management Project Area (Project Area) in the city of Oceanside, San Diego County, California, between April 11 and July 8, 2022.

Methods

Surveys

Vireo and flycatcher surveys have been performed at the Project Area every year since 2006. Four protocol vireo surveys were completed between April 11 and July 8, 2022. The surveys were done by following standard survey techniques developed and recommended by the California Least Bell's Vireo Working Group (now known as the California Riparian Birds Working Group) and USFWS Least Bell's Vireo survey guidelines (U.S. Fish and Wildlife Service, unpub. data, 2001). We supplemented these protocol surveys with weekly territory monitoring visits; therefore, most survey sites were visited more than 10 times throughout the breeding season, resulting in complete coverage of the Project Area. During the surveys and monitoring, we used recorded callbacks (as needed) to confirm absence of vireos in areas in which no birds were detected and to attract males to check leg bands. Vireo field work was done by Alexandra Houston, Suellen Lynn, Jessica Medina, Shannon Mendia, Ryan Pottinger, Devin Taylor, and Stéphane Vernhet (all under USFWS permit ESPer0004080_0), with assistance provided by Rafal Banas and Ynez Diaz.

We completed four protocol flycatcher surveys of the Project Area between May 16 and July 25, 2022, completing one survey during each of four survey periods (U.S. Fish and Wildlife Service, 2000, Sogge and others, 2010). Flycatcher field work was done by Aaron Gallagher, Alexandra Houston, Suellen Lynn, Shannon Mendia, and Ryan Pottinger (all under USFWS permit ESPer0004080_0), with assistance provided by Rafal Banas, Ynez Diaz, Devin Taylor, and Stéphane Vernhet.

For both species, observers moved slowly (1–2 kilometers per hour) through the riparian habitat while searching and listening for vireos or flycatchers. Observers walked along the north and south levees to survey the flood control channel. In wider stands, observers traversed the habitat to detect all birds throughout its extent. Surveys were completed between dawn and early afternoon, depending on wind and weather conditions. For each bird encountered, investigators recorded age (adult or juvenile), sex, breeding status (paired, single, unknown, or transient), and if the bird was banded. Birds were considered transients if they were not detected on two or more consecutive surveys after an initial detection. Vireo locations were mapped using Environmental Systems Research Institute (Esri) Field Maps (Environmental Systems Research Institute, 2022a) and Survey 123 (Environmental Systems Research Institute, 2022b) on Samsung Galaxy S7 and S8 and LG G5 mobile phones with Android operating systems and built in Global Positioning

System (GPS) to determine geographic coordinates (World Geographic System of 1984, WGS 84). Distance to the nearest surface water was recorded for each flycatcher location. Dominant native and exotic plants were recorded within each vireo and flycatcher territory, and percent cover of native vegetation was estimated using cover categories of less than 5 percent, 5–50 percent, 51–95 percent, and greater than 95 percent. Overall habitat type was specified according to the following categories:

Mixed willow riparian: Habitat dominated by one or more willow species, including black willow, arroyo willow, and red willow, with mule fat as a frequent co-dominant.

Willow-cottonwood: Willow riparian habitat in which cottonwood is a co-dominant.

Willow-sycamore: Willow riparian habitat in which California sycamore (*Platanus racemosa*) is a co-dominant.

Sycamore-oak: Woodlands in which California sycamore and coastal live oak (*Quercus agrifolia*) occur as co-dominants.

Riparian scrub: Dry or sandy habitat dominated by sandbar willow or mule fat, with a few other woody species.

Upland scrub: Coastal sage scrub adjacent to riparian habitat.

Non-native: Areas vegetated exclusively with non-native species, such as giant reed and tamarisk.

Nest Monitoring

We monitored vireo nests to evaluate the effects of native and exotic vegetation removal on nest success and productivity. Nest monitoring was performed from April 4 until the last nest fledged on July 31, 2022. We performed work at three general site types: (1) within the flood channel where exotic and native vegetation removal has occurred regularly (Channel); (2) at three sites next to the flood channel where limited exotic and native vegetation removal has occurred (Upper Pond, Park Pond, and Whelan Mitigation; Off-channel); and (3) at three sites that have been restored (Restoration), two of which were within the Channel (Benet Restoration in Reach 1 and College Restoration in Reach 4) and one situated Off-channel (Whelan Restoration within Whelan Mitigation).

Territory boundaries were delineated by biologists in the field by circumscribing vireos' nesting, singing, and foraging locations. In 2017, we began excluding areas in a vireo's territory that were obviously avoided (for example, the vireo used the edges of the river channel but avoided the center) by creating two unconnected polygons, as opposed to a single large one spanning the area. We classified territories quantitatively by site type in ArcGIS (version 10.8.1; Environmental Systems Research Institute, 2020) using territory boundaries and the boundaries of the three site types (Channel, Off-channel, and Restoration). If a territory straddled more than one site type, we assigned it to the site type that comprised more than 50 percent of the territory. There were 61 Channel territories (60 pairs and 1 single male), 16 Off-channel territories (14 pairs, 1 single male, and 1 male whose breeding status could not be confirmed), and 3 Restoration territories (2 pairs and 1 single male) that were monitored during the 2022 breeding season.

Pairs were observed for evidence of nesting, and their nests were located. We visited nests as infrequently as possible to minimize the chances of leading predators or cowbirds to nests; typically, there were three to four visits per nest. The first visit was timed to determine the number of eggs laid, the next visits to determine hatching and age of young, and the last to band nestlings (see the "[Banding](#)" section). We removed cowbird eggs from nests depending on when they were found. In nests with fewer than three vireo eggs, cowbird eggs were removed no sooner than the seventh day of incubation to minimize the possibility of nest abandonment in response to the removal. We removed cowbird eggs from nests that contained three or more vireo eggs as they were detected. Cowbird nestlings were removed immediately from nests. Fledging was determined through direct observation of fledglings in the territory or, in some rare cases, inferred from an accumulation of feather dust and fecal material in the nest, which is indicative of vireo fledging. We recorded characteristics of nests, including nest height, host plant species, host height, distance to edge of host plant, and distance to edge of host clump after abandonment or fledging of nests.

Analysis of Nesting Data

We used Pearson's chi-square analysis and Fisher's Exact tests to determine if there were differences in nest success, hatching rates, and fledging rates among Channel, Off-channel, and Restoration pairs. We included a "Mixed" category for instances where (1) a territory was categorized as one site type, but the vireos placed at least one nest in another site type or (2) vireos nested in two different site types within the same territory. For example, we had territories that were categorized as "Restoration" (50 percent or more of the total territory area fell within the boundaries of the Restoration), but the vireos placed their nest(s) within the Channel, avoiding areas of active restoration. In total, four territories were considered "Mixed" in 2022. For analyses involving the nest as the unit of analysis, we used the location of the nest (for example, a territory categorized as Channel could have a nest in a Restoration site). For any analyses of reproductive success or productivity that involved a measure of success per pair or territory, we analyzed Mixed territories separately. Chi-square tests were used when sample sizes were sufficient; Fisher's Exact tests were used when one or more categories contained fewer than five samples. We used two-sample *t*-tests, Mann-Whitney *U*-tests (two groups), and Kruskal-Wallis tests (three or more groups) to determine if there were differences in nest site characteristics between successful and unsuccessful nests within and among the Channel, Off-channel, and Restoration sites. *T*-tests were used when distributions were normal and variances were similar; Mann-Whitney *U*-tests or Kruskal-Wallis tests were used when the data violated these assumptions. We used Analysis of Variance and Tukey's post-hoc pair-wise comparisons to determine if there were differences among Channel, Off-channel, and Restoration sites in average clutch size and average number of young per pair in 2022 and average clutch size and number of young fledged per pair by year (2006–22).

Effects of Treatment

We created an index of treatment (Treatment Index) to evaluate the cumulative effects of vegetation removal over time for 2021 and 2022 vireo territories. We restricted treatment type for this index to the vegetation removal that occurred from 2005, 2007–12, 2014–15, 2017–19 or 2021, in which vegetation (native or exotic) was cleared to the ground. We did not include any restoration or herbicide treatments because these treatments were distinct from vegetation removal and analysis of them was beyond the scope of this project. We limited our analysis of Treatment Index to territories in the Channel because Off-channel adaptive habitat management activities mitigated the effect of the vegetation removal, making the Treatment Index for those territories unsuitable for our analyses. We calculated the percentage of each territory area that was treated in each year (2005, 2007–12, 2014–15, 2017–19, and 2021) by overlaying the 2021 and 2022 territory boundaries with the treatment areas in ArcGIS (version 10.8.1; Environmental Systems Research Institute, 2020). Territory boundaries were created to include the bird location points collected using GPS throughout the field season. Treatment boundaries were generated from the location data collected using GPS in the field by a RECON Environmental, Inc. (<https://www.recon-us.com/>) biologist who walked the treatment boundary during vegetation removal activities. Because treatments have been occurring since 2005, it was possible to have multiple years of treatments as well as overlap among treatments within a single territory. Because early successional vegetation can recover quickly after disturbance, we assumed that the influence of the vegetation removal diminished over time; therefore, when there was overlap in treated areas among years, we used the most recent treatment year to calculate the Treatment Index (fig. 2). To calculate the Treatment Index, we used the percentage of the territory area treated weighted by the squared inverse of the time (t^2) since treatment summed across all treatment years. We chose t^2 , rather than t because we wanted to capture the effect of the treatment diminishing quickly over time. We used the following formula:

$$\text{Treatment Index} = \sum_{t=2005}^{2021} \text{percent Territory Area Treated}_t \times 1/n_t^2 \quad (1)$$

where

- t is the year of treatment,
- n is the years since treatment, and
- $n=1$ is the first breeding season after treatment.

Note that there was no treatment in 2006, 2013, 2016 or 2020, so values for these years = 0 and drop out of the equation.

We performed three sets of analyses using the Treatment Index. For all analyses of the Treatment Index, we excluded territories that overlapped with areas of active restoration:

1. We compared the Treatment Index between occupied (monitored and non-monitored) territories and unoccupied vireo habitat within the Channel using a two-sample t -test. To generate a Treatment Index for unoccupied habitat, we used historic territory boundaries from 2006 to 2021 as a guide and sub-divided habitat that was unoccupied in 2022 into units approximating vireo territories in size. We calculated the Treatment Index for the unoccupied historical territories within the Channel that did not overlap with restoration, creating a distribution of Treatment Indices for unoccupied habitat that allowed statistical comparisons with occupied territories. Habitat never occupied by vireos (for example, marsh, open water) during this study and unoccupied patches too small (less than or equal to 0.2 ha [0.5 acres]) for a territory were excluded from analysis. We hypothesized that the Treatment Index in occupied habitat would be lower than that of the unoccupied habitat, indicating that vireos were preferentially selecting habitat that was less treated or was treated less recently.

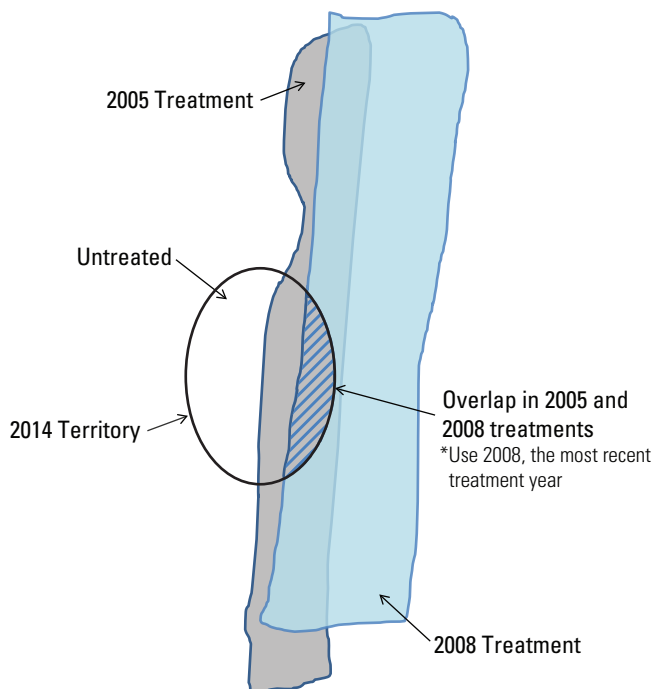


Figure 2. Least Bell's Vireo territory boundary with two treatments (2005 and 2008 vegetation removal) and a section of overlap between the two treatments at the San Luis Rey Flood Risk Management Project Area, California, 2022.

2. We used generalized linear models (GLMs) in Program R (R Core Team, 2021) to evaluate if treatment (Treatment Index) had an effect on vireo reproductive parameters for monitored territories within the Channel, including the total number of (1) nests, (2) completed nests, and (3) fledglings per territory in 2022. We limited our analysis to Channel territories since 2018 because passive restoration, including some planting, weeding, and watering, occurred at two of our Off-channel sites in 2017, confounding the effect of the vegetation removal. We hypothesized that there would be an inverse relationship between the reproductive parameters and the Treatment Index (for example, the number of fledglings would decrease as the Treatment Index increased) and a positive relationship between the Treatment Index and the number of nests, as we might expect to see higher levels of nest failure in the lower quality (more treated) habitat. Treatment Index was a continuous, fixed effect. We assumed a Poisson distributed response to the reproductive parameters.
3. Finally, we used a GLM to test for the effect of the expected Treatment Index for 2021 territories (that is, the Treatment Index in 2022 if the bird had occupied exactly the same territory boundaries as 2021) on the distances that banded vireos moved between 2021 and 2022. We hypothesized that birds whose previous territories were heavily treated (had high Treatment Indices) would shift their territories a greater distance than those whose territories were less affected by, or were temporally further removed from, the treatment.

Nest Survival Analysis

We used RMark (Laake, 2013) to model the effects of vegetation treatment on daily survival rate (DSR) of vireo nests (or the probability that a nest survived from 1 day to the next; Dinsmore and others, 2002). We used RMark (Laake, 2013) to run program MARK (White and Burnham, 1999) to calculate DSR, which accounts for the variability in exposure days across nests detected at different stages of the nesting cycle and allows for the analysis of the effects of covariates on DSR. In this study, we evaluated the effects of Treatment Index (for Channel territories only) on DSR in 2022. We studied habitat structure at the nest (2006–22) to determine if it was correlated with DSR by analyzing the relationship between total vegetation cover at each height category (see the “[Vegetation Study Design](#)” section) and DSR.

We calculated nest survival across a 32-day cycle (2 days to complete the nest and rest before the first egg is laid, 4 days egg-laying, 14 days incubation, 12 days nestling period), in which incubation begins with the penultimate egg.

We calculated age of nests at the time they were discovered by forward- or backward-dating of nests in relation to known dates of nest building, laying, or hatching. We used an information-theoretic approach (Burnham and Anderson, 2002) to evaluate support for statistical models reflecting a priori hypotheses regarding the effect of treatment and habitat variables on DSR. We hypothesized that DSR would be inversely related to the Treatment Index and would increase with increasing foliage cover at nest sites, particularly understory cover within 2 m of the ground, where vireos place their nests. We used logistic regression with a logit link to build models. First, we generated a constant survival model to serve as a reference for the effect of treatment and habitat variables on DSR. We then modeled the treatment and habitat covariates individually and evaluated support for each model in relation to the constant survival model and each other. To evaluate the effect of covariates within our top models, we calculated the odds ratio for each covariate (the odds that the covariate had an effect on DSR where “no effect” equals 1, negative effect is less than 1, positive effect is greater than 1). We then calculated the 95-percent confidence interval of the odds ratio to determine the likelihood that the effect was significant. Where the confidence interval did not include 1 (was greater than or less than 1), we concluded that we had 95-percent confidence that the covariate had an effect on DSR relative to the reference.

Banding

The primary goals of banding vireos at the San Luis Rey Flood Risk Management Project Area were to (1) assess vireo site fidelity in response to vegetation management, (2) examine natal dispersal within and outside of the Project Area in response to vegetation management, and (3) understand how vegetation removal and alteration affected vireo demography. We banded nestlings from monitored nests at 6–7 days of age with a single, dark blue anodized numbered federal band on the left leg. We captured adult vireos in mist nets at monitoring sites as needed to clarify identity among neighbors and banded them with a unique combination of colored plastic and anodized metal federal bands, including an anodized dark blue band to designate the San Luis Rey River as the bird's site of origin. Adults previously banded with a single numbered metal federal band as nestlings (natal birds) were target netted to determine their identity, and their original band was supplemented with other bands to generate a unique color combination. These data will supplement banding data currently being gathered by the U.S. Geological Survey (USGS) and other investigators regarding nearby vireo populations on the upper San Luis Rey River and the Santa Margarita River on Marine Corps Base Camp Pendleton (MCBCP).

Survivorship Estimates

During surveys and nest monitoring activities, we attempted to resight all vireos to determine if they were banded, and if so, to confirm the vireos' identity by reading the unique color band combination or by recapturing birds with single federal bands. We used resighting and recapture data to calculate annual survivorship or the fraction of all individuals present at the Project Area in 1 year that returned the following year.

Imperfect detectability of banded individuals is typical of mark-recapture studies and occurs for various reasons (for example, females are more cryptic and may be missed on surveys, birds were detected as banded but their full color combinations [and thus identities] were not obtained, or birds with single federal bands were not recaptured, so their identities were not determined). To account for individuals that were present but not detected, we used RMark (Laake, 2013) which uses program MARK (White and Burnham, 1999) to model annual survivorship. Annual survivorship was calculated from 2006 to 2022 by creating an encounter history matrix of all individual vireos detected in the Project Area and if they were observed in each year from 2006 through 2022. Vireos were grouped by age (originally encountered as a juvenile [first-year; usually nestling but sometimes fledglings] versus originally encountered as an adult) and sex (female versus male). Survivorship was assumed to be constant for adults once they survived their first year. We created two sets of models. The first set included only adult captures, in which we modeled the influence of sex, year and bio-year (July 1–June 30), and precipitation (National Oceanic and Atmospheric Administration, 2022) on vireo survivorship and the influence of sex on detection probability. For precipitation, we used precipitation data from the previous bio-year. For example, to model survival from 2021 to 2022, we used bio-year precipitation data from July 2020 through June 2021. The second model set included both adult and first-year vireos and modeled the influence of age, year, and precipitation on survivorship. This model set did not include sex because we were unable to determine sex of vireos banded as juveniles unless they returned and were recaptured and identified as adults. Therefore, only the juveniles that survived their first

winter were retroactively classified as “male” or “female,” which would severely bias the estimate of sex-related survivorship of first-year vireos.

Models created for survivorship in RMark (Laake, 2013) included only detections from sites at which survey effort has been consistent from 2006 through 2022 (for example, lower San Luis Rey River Project Area, middle San Luis Rey River, and MCBCP core survey areas). Incidental resights outside of these survey sites were excluded from analysis. We excluded one adult of unknown sex from our first model-set analysis because we were not interested in defining characteristics of this group.

We used an information-theoretic approach (Akaike's Information Criterion for small sample sizes [AIC_c]; Burnham and Anderson, 2002) to evaluate support for the models. To evaluate the influence of sex and year on detection probability, we compared models holding survivorship constant. For the adults-only models, we determined that detection probability was influenced by sex, so it was included in all models of vireo survivorship. For models with adults and first-year vireos, we determined that detection probability varied by year. However, because detection probability and survival are confounded for the final time interval (in this case, the current year) in fully time-dependent models (with year affecting survival and detection probability), we modeled detection probability as a constant to get a more reliable estimate of survival for the most recent time interval. We compared estimates of annual survival from 2006 to 2021 generated by models where detection probability varied by year with those where detection probability was constant and determined that the survival estimates were very similar, yielding the same long-term means. We concluded that the similarity in estimates justified using the simpler model because it would yield a more reliable estimate of survival for the 2021–22 time interval. We used logistic regression with a logit link to build and rank models by AIC_c and present annual real estimates from the top model. If there was support for multiple models (change in AIC_c [ΔAIC_c] less than 2), we averaged all models using AIC_c weights to obtain annual real estimates of survivorship for adult females, adult males, all adults, and all first-year vireos. We also evaluated the effect of covariates within our top models by calculating the odds ratio for each covariate (see the “[Nest Survival Analysis](#)” section).

Site Fidelity and Movement

We determined site fidelity of adult banded vireos by measuring the distance between the center of an individual's breeding territory in 2021 and the center of the same individual's breeding territory in 2022. We considered vireos to have exhibited site fidelity if they returned to within 100 m of their 2021 territory. Site fidelity was calculated for the same categories analyzed for survivorship (see previous section), except that only individuals with known territory locations during the last year they were detected before 2022 were included (for example, juvenile birds banded after fledging were excluded because their natal territories could not be confirmed in light of their capacity for substantial movement). We examined site fidelity to identify patterns indicative of relaxation of site fidelity in response to habitat alteration associated with vegetation clearing. We analyzed the distance moved by territorial males, hypothesizing that movement would be greater (site fidelity weaker) in years after vegetation treatment than in years where vegetation was undisturbed. We investigated the effect of a Treatment Index (see the “[Effects of Treatment](#)” section) on the movement of birds between 2021 and 2022. We focused on banded males because sample sizes for banded females were low, and females, in general, tend to exhibit lower site fidelity than males.

We examined first-year dispersal in 2022 and compared it to dispersal in previous years. We compared the proportion of first-year vireos that originated at the Project Area and returned to the Project Area to the proportion of first-year vireos that returned to nearby areas outside of the Project Area. Because some natal vireos were not detected or identified during their first year of dispersal but were recaptured in subsequent years, our initial estimates were adjusted to include vireos that were not detected during their first year of dispersal. Although we were unable to determine their exact territory location during their first year, we can conclude that birds recaptured outside of the Project site were not likely present at the Project Area because of our high success in recapturing and resighting vireos within the Project Area.

Vegetation Study Design

We sampled vegetation along permanent linear transects within three of the vireo monitoring sites (Channel, Upper Pond and Whelan Restoration). Sampling points consisted of 2- by 2-m quadrats located at 10-m intervals along each transect; the number of points sampled varied with the length of each transect ([fig. 3](#)). Transects were originally established in 2006 using a systematic sampling design. To capture the range of variability of riparian vegetation structure and composition, we positioned transects perpendicular to the river channel. To provide uniform coverage, we placed transects at fixed distances from each other; distances varied with the size of the site. In the Channel, transects were placed at 200- or 400-m intervals depending on the width of the river. In

Upper Pond, transects were placed every 100 m. In addition, we sampled two 350-m transects at Whelan Mitigation (Whelan Restoration) that were initially surveyed from 1991 to 1993 to monitor riparian restoration by the U.S. Army Corps of Engineers (Kus, 1998). The Whelan Restoration transects were 75 m apart and oriented approximately parallel (320 degrees) to the flood control channel. Before 2014, this site was sampled and used as an Off-channel site in analyses. However, in 2014, it became a Restoration site and has been analyzed separately from the Channel and the Upper Pond sites since then.

We used several permanent and semi-permanent methods to ensure that transects could be re-sampled in future years. First, a 1.5-m metal rebar was driven into the ground, leaving 75 centimeters above ground to mark the start of each transect. We spray-painted the rebar pink or orange and placed them at the intersection of the south levee and the riverbed. From the rebar, using a compass and tape measure, two field personnel measured the distances between sampling points. A numbered wooden stake, spray-painted pink or orange, was placed in the ground and colored plastic flagging was tied nearby to aid in locating the points. Finally, we recorded geographic coordinates for each rebar and wooden stake using a GPS unit (Garmin GPS 12).

Vireo Habitat Use Study Design

In addition to sampling vegetation along transects, we collected vegetation data at 44 randomly selected vireo territories. We sampled one nest and one paired random plot within each territory (hereafter “nest plots” and “territory plots,” respectively) in the Channel and at Upper Pond. We did not sample vegetation at Restoration site nests because the sample was small, and our focus was to determine the response of vireos to treatments (measured by the Treatment Index) rather than their response to restoration activities. Nest and territory plots consisted of four 2- by 2-m quadrats; one quadrat centered on the nest (or center for random plots) and the remaining three quadrats located 10 m from the nest/center and oriented at 0, 120, and 240 degrees from it ([fig. 4](#)). Territory plot locations were constrained using the Buffer tool in ArcGIS (Environmental Systems Research Institute, 2020) to create a 10-m negative buffer on the territory boundaries. This negative buffer ensured that the random sampling point for the quadrats at 0, 120, or 240 degrees would not fall outside of the territory boundaries. A positive 2-m buffer was created around nest locations and vegetation transect points to exclude these locations and prevent duplicating vegetation sampling. We then used the “Create Random Points” tool on the territory boundary buffer to select one random point between the buffered areas to serve as the center quadrat. Territories were excluded from analysis if they were too narrow to allow a 10-m negative buffer, were in the “mixed” type category, or overlapped with Restoration.

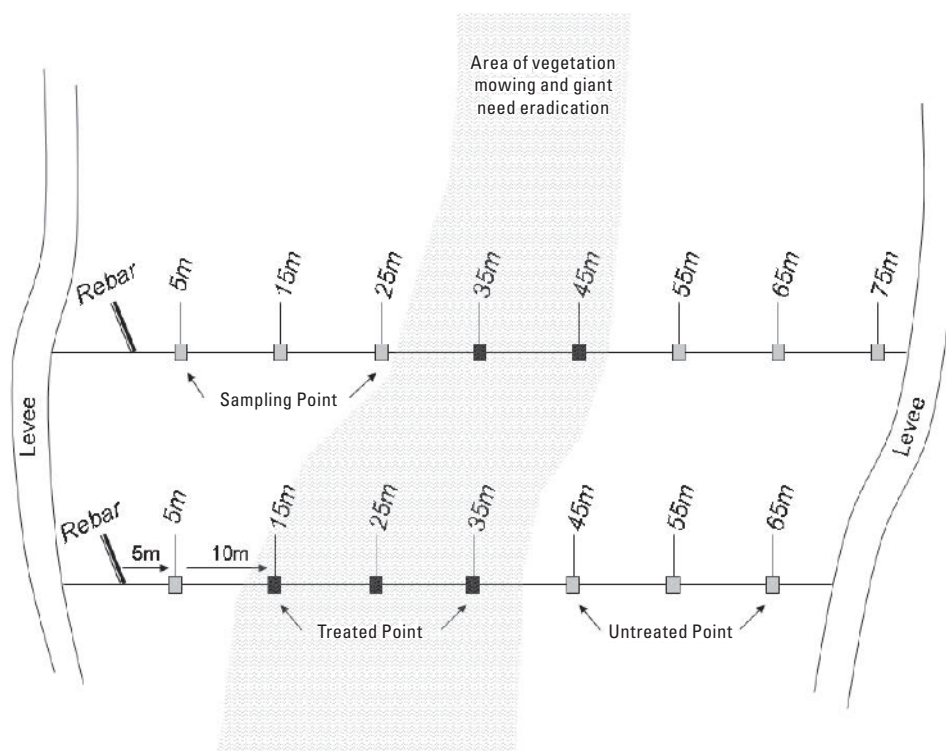


Figure 3. Vegetation transects in the Channel at the San Luis Rey Flood Risk Management Project Area, California, 2022.

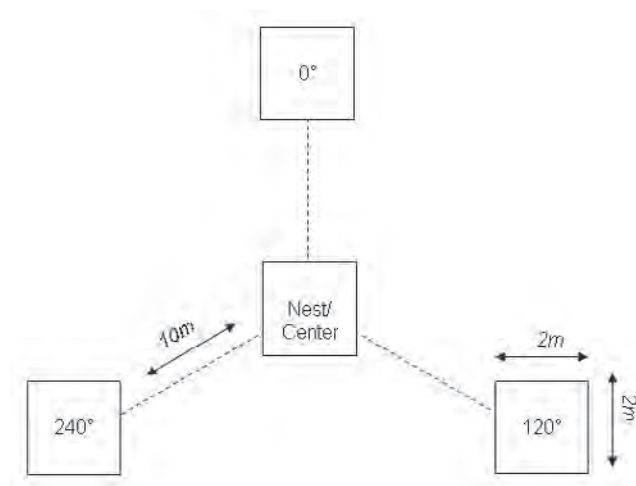


Figure 4. Nest-centered and territory vegetation plots sampled at the San Luis Rey Flood Risk Management Project Area, California, 2022. Abbreviation: m, meter.

Vegetation Sampling

Foliage cover at 1-m height intervals was estimated using the “stacked cube” method, developed specifically to characterize canopy architecture in structurally diverse riparian habitat (Kus, 1998). At each sampling point along a vegetation transect or in a nest or territory plot, we recorded canopy height and percent cover of vegetation, by species, within 1-m-height intervals, using a modified Daubenmire (1959) scale with cover classes: less than 1, 1–10, 11–25, 26–50, 51–75, 76–90, and greater than 90 percent. The sampling units were 2- by 2- by 1-m-high cubes, which were stacked vertically between the ground and the top of the canopy. Four 2-m-length PVC pipes were placed on the ground to define quadrat boundaries, and a 7.5-m-tall fiberglass telescoping pole, demarcated in 1-m intervals, was used to determine height class and canopy height. Vegetation data were collected by USGS biologists Lisa Allen, Rafal Banas, Annabelle Bernabe, Ynez Diaz, Aaron Gallagher, Alexandra Houston, Scarlett Howell, Suellen Lynn, Jessica Medina, Shannon Mendia, Ryan Pottinger, Devin Taylor, Michelle Treadwell, and Stéphane Vernhet.

Vegetation Data Analysis

For analysis, we converted cover codes to class midpoints, which were then used to quantify foliage cover at each sampling point for nine height classes: 0–1 m, 1–2 m, 2–3 m, 3–4 m, 4–5 m, 5–6 m, 6–7 m, 7–8 m, and greater than 8 m. We examined percent cover for plant species that occurred at greater than 5 percent of the sampling points (more than 25 points). Species that were less common (less than 5 percent of the sampling points) were grouped together by plant life form, including tree, shrub, dead woody species, and freshwater marsh. Herbaceous species also were grouped together and included annual and perennial species (native and exotic), with the exception of nine exotic species: poison hemlock (*Conium maculatum*), pepperweed, fennel (*Foeniculum vulgare*), white sweet clover (*Melilotus alba*), black mustard (*Brassica nigra*), wild radish (*Raphanus sativus*), thistle (*Cirsium* sp.), ivy (*Hedera* sp.), and all grass species. These nine exotic species were combined and analyzed as exotics. We calculated average foliage cover across all height classes separately for the Channel, Upper Pond, and Whelan Restoration sites. We used linear regression to examine the cumulative effects of vegetation management activities at these sites over time (2006–22) and to investigate any temporal trends that existed in percent cover at all height classes for each site. We focused on a cumulative approach because it allowed us to analyze the long-term effects of vegetation management within the Project Area. Comparisons between the intensively managed Channel sites and the

less-managed Off-channel sites provided insight into how annual vegetation management has affected the structure of the vegetation in the Channel through time.

We used data from the vegetation transects, nest plots, and territory plots to examine vireo habitat selection at two spatial scales. First, we compared vegetation structure at nest plots to that at territory plots to assess if vireos were selecting nest sites non-randomly, relative to the vegetation available in the territory. Next, we compared territory plot data to transect data to evaluate if vireos were establishing territories non-randomly with regard to the habitat available to them throughout the site. We performed these comparisons separately for the Channel and Upper Pond to evaluate the effect of vegetation treatment on vireo nest and territory placement. We used *t*-tests to test for differences in foliage cover between nest sites and the territory and between territories and the available habitat.

Averages are presented with standard deviations. We considered *P* less than or equal to 0.10 to be significant for all statistical tests to avoid overlooking potentially important biological relationships relevant to the recovery of these endangered birds. Data were analyzed using Program R (R Core Team, 2021). Data from the Project Area from 2006 to 2021 used in comparisons with current data can be found in Ferree and Kus, 2007, 2008a, 2008b; Ferree and others, 2010a, 2010b, 2011, 2012, 2014, 2015; and Houston and others, 2015, 2016, 2017, 2018, 2019, 2021, 2022.

Results

Least Bell's Vireo

Population Size and Distribution

We identified a total of 133 vireo territories during surveys and weekly territory monitoring (table 3; appendix 2, figs. 2.1–2.4). The number of vireo territories increased from 122 in 2021, which is a 9 percent increase (table 4; fig. 5). Of the 133 territorial males, 114 (86 percent) were confirmed as paired and 3 (2 percent) were confirmed as single males. We were unable to confirm pair status for the remaining 16 territories. We detected two transient vireos during surveys in 2022 (table 3).

Seventy-four percent of the territories (98/133) were within the Channel. The remaining 26 percent of the territories (35/133) were located Off-channel. Six Channel territories

were in Benet Restoration, two in College Restoration, and the remaining 90 Channel territories were outside of Restoration areas. Of the Off-channel territories, 3 were within Whelan Restoration, 7 were within Whelan Mitigation but outside of the Restoration area, and 25 were in other retention ponds (tables 3, 4; appendix 2, figs. 2.1–2.4).

From 2021 to 2022, the number of vireo territories in the Channel increased by 14 percent (from 86 to 98) and decreased by 3 percent (from 36 to 35) within Off-channel sites (table 4). Vireo territory numbers increased for all Channel sites except for Reach 2 and Reach 3b, which decreased by one and three territories respectively. The largest increase was in Reach 3a (six territories, 60-percent increase). In most of the Off-channel sites, the number of vireo territories did not change from 2021 to 2022; the exceptions were Lower Pond, which increased by one territory, and Upper pond, which decreased by two territories (table 4).

Table 3. Number and breeding status of Least Bell's Vireos at the San Luis Rey Flood Risk Management Project Area, California, 2022.

Survey site	Known pairs	Unknown status	Single males	Total territories	Total transients
Channel sites					
Reach 1	19	8	0	27	1
Benet Restoration	5	1	0	6	0
Reach 2	11	0	0	11	0
Reach 3a	16	0	0	16	0
Reach 3b	8	0	1	9	0
Reach 4	26	1	0	27	0
College Restoration	2	0	0	2	0
Off-channel sites					
Lower Pond	7	1	0	8	1
Tuley Canyon	0	1	0	1	0
Whelan Mitigation	7	0	0	7	0
Whelan Restoration	2	0	1	3	0
Park Pond	2	3	0	5	0
Pilgrim Pond	0	0	1	1	0
Upper Pond	9	1	0	10	0
Riverside Pond	0	0	0	0	0
Total	114	16	3	133	2

Table 4. Number and distribution of Least Bell’s Vireo territories at the San Luis Rey Flood Risk Management Project Area, California, 2006–22.

[—, no data]

Survey Site	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Channel sites																	
Reach 1	13	7	10	23	23	17	10	13	14	22	15	22	27	17	26	21	27
Benet Restoration	—	—	—	—	—	—	—	6	6	2	4	4	5	6	6	5	6
Reach 2	15	14	16	18	22	16	6	6	6	3	6	7	12	13	12	12	11
Reach 3a	14	19	23	28	26	17	14	18	16	12	8	10	15	16	17	10	16
Reach 3b	13	14	13	17	16	18	5	4	6	5	4	7	11	10	16	12	9
Reach 4	21	21	25	32	24	18	10	14	15	16	12	10	20	22	27	26	27
College Restoration	—	—	—	—	—	—	—	—	2	0	0	0	0	0	1	0	2
Total	76	75	87	118	111	86	45	61	65	60	49	60	90	84	105	86	98
Off-channel sites																	
Lower Pond	3	2	3	7	7	4	1	7	7	7	6	7	9	8	7	7	8
Tuley Canyon	1	1	1	1	1	0	0	0	1	2	2	1	1	1	2	1	1
Whelan Mitigation	14	9	12	15	16	12	11	13	6	6	4	6	8	13	15	7	7
Whelan Restoration	—	—	—	—	—	—	—	—	4	3	3	3	5	3	5	3	3
Park Pond	3	2	4	4	4	6	3	5	5	4	3	4	6	6	6	5	5
Pilgrim Pond	1	1	1	1	0	2	0	2	0	0	0	1	1	1	1	1	1
Upper Pond	20	17	21	24	17	19	15	14	11	12	11	11	10	12	18	12	10
Riverside Pond	1	1	1	1	1	1	1	1	1	1	0	0	0	0	2	0	0
Total	43	33	43	53	46	44	31	42	35	35	29	33	40	44	56	36	35
Grand total	119	108	130	171	157	130	76	103	100	95	78	93	130	128	161	122	133

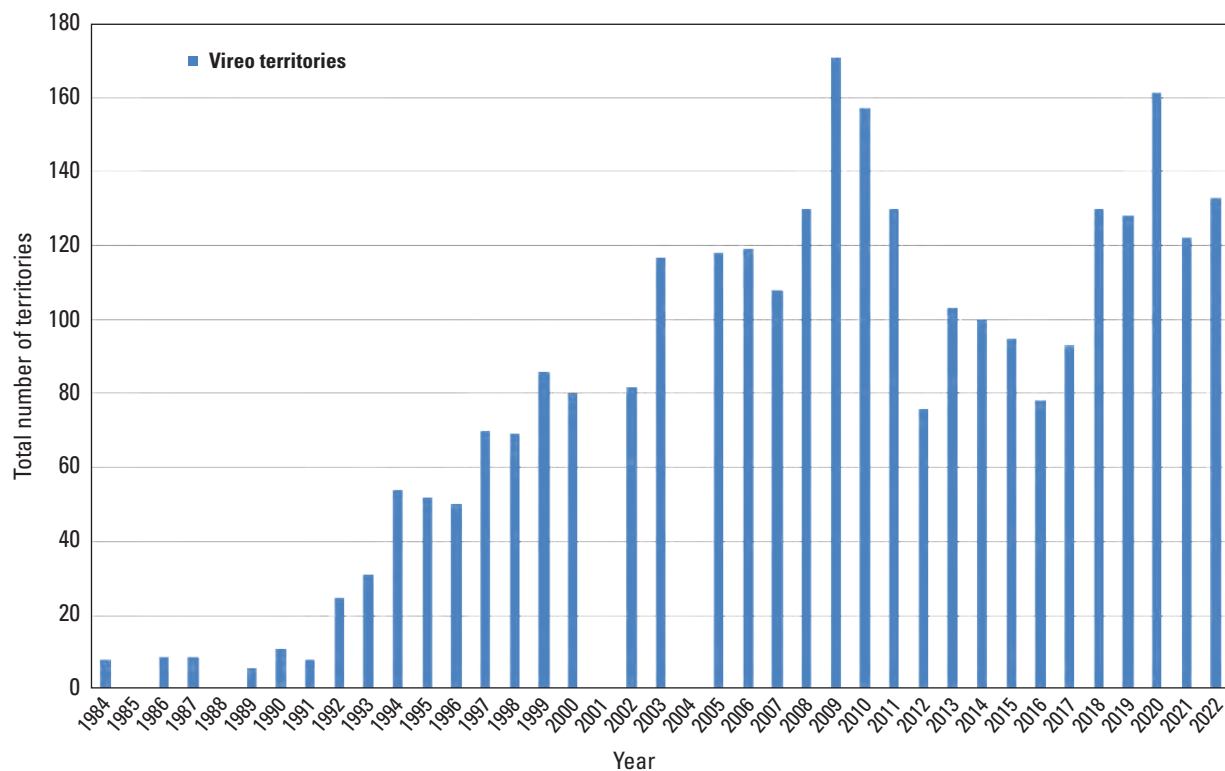


Figure 5. Number of Least Bell's Vireo territories from 1984 to 2022 at the San Luis Rey Flood Risk Management Project Area, California. Surveys were not conducted during 1985, 1988, 2001, or 2004.

Effects of Treatment on Habitat Use

To investigate if vireos were selecting territories in habitat that was less affected by vegetation removal, we compared the Treatment Index of occupied vireo territories in the Channel to the Treatment Index of territories previously occupied, but unused, in 2022. The average Treatment Index of unoccupied habitat (0.27 ± 0.31 , $n=86$) was 4.5 times that of habitat occupied by vireos in 2022 (0.06 ± 0.10 , $n=77$; $t = -5.9$, $df=105$, $P<0.01$), indicating that vireos avoided the more heavily treated sections of the river channel.

Nest Monitoring

We monitored nesting activity in 80 territories within the San Luis Rey River Flood Risk Management Project Area monitoring areas (table 5; appendix 2, figs. 2.1–2.4). These territories were fully monitored, meaning that all nests within the territory were located and monitored during the breeding season. Of the 80 monitored territories, 3 were occupied by single males and 1 by a male whose breeding status could not be confirmed; therefore, these 4 territories were excluded from nesting analyses. A total of 161 nests were monitored during

the breeding season (appendix 3, table 3.1). Fifteen of these nests were not completed monitored and subsequently were excluded from calculations of nest success and productivity, unless otherwise noted.

Nesting Attempts

In 2022, the average number of nesting attempts per territory (including incomplete nests) was 2.1 ± 1.0 (table 5). A total of 72 percent (55/76) of pairs re-nested after their first nest attempt, and 38 percent (21/55) of these pairs initiated at least a third nesting attempt. A total of 11 pairs (22 percent, 11/51) attempted a re-nest after a successful nest; of these, 4 pairs (36 percent, 4/11) successfully fledged 2 broods.

Most of the first nesting attempts in 2022 were initiated in mid- to late-April (fig. 6). The peak of nest initiation was during the weeks of April 10 and April 17 when 38 percent (29/76) of first nests were initiated. Nesting was earlier in 2022 (median Julian day 115; April 25) compared to 2021 (median Julian day 126; May 6) and was similar to the 16-year average (mean median Julian day 114.3 [April 24–25], 2006–21; fig. 7).

Table 5. Number of Least Bell’s Vireo territories and nests monitored at the San Luis Rey Flood Risk Management Project Area, California, 2022.

[Mixed territories had a territory classification that differed from one or more nest classifications (two territories were classified as Off-channel but had a nest located in the Channel, one territory was classified as Channel, but nested Off-channel, and one territory was classified as Restoration, but had nests in the Channel). Incomplete nests were partially built, but not completed. False nests were partially built by the male only. **Abbreviations:** —, no data; \pm , plus or minus]

Category	Channel	Off-channel	Restoration	Mixed	Total
Territories	60	14	2	4	80
Total number of pairs	59	12	1	4	76
Total number of nests monitored	131	27	¹ 3	—	161
Incomplete nests	12	3	0	—	15
Total number of completed nests	119	24	3	—	146
Completed nests/pair	1.9 ± 0.8	1.6 ± 0.7	3.0 ± 0.0	2.8 ± 1.0	1.9 ± 0.8
Total number of nest attempts/pair	2.1 ± 1.0	1.8 ± 0.8	3.0 ± 0.0	3.0 ± 0.8	2.1 ± 1.0

¹All nests were in Whelan Restoration.

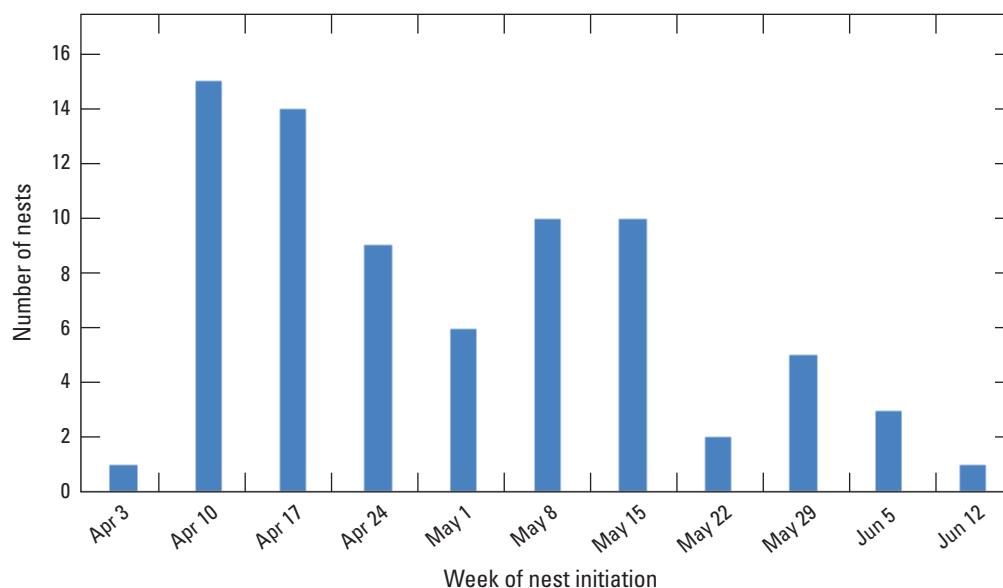


Figure 6. Number of first Least Bell's Vireo nests initiated (date first egg laid) by week at the San Luis Rey Flood Risk Management Project Area, California, 2022.

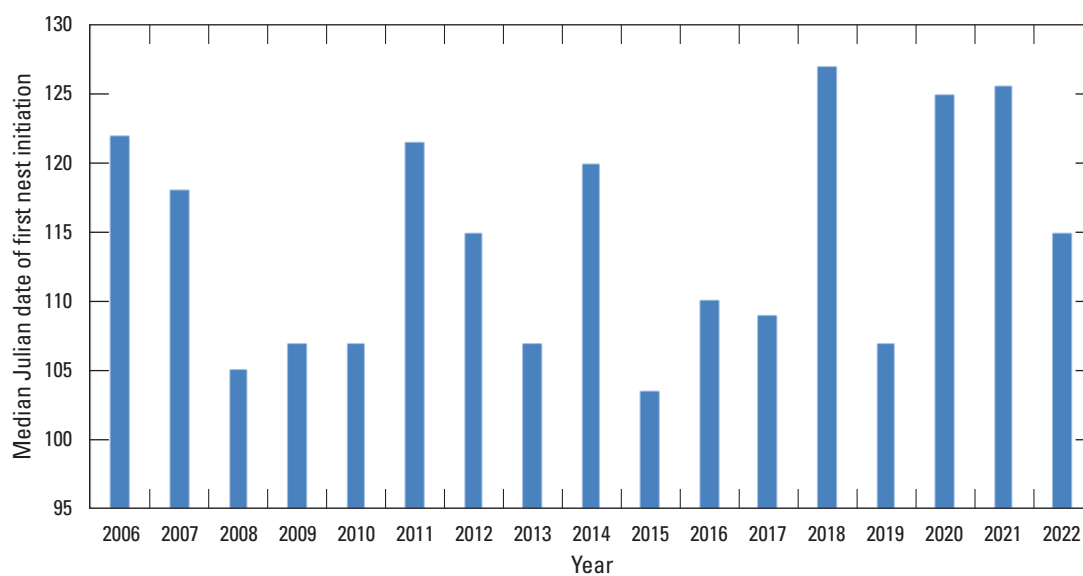


Figure 7. Annual median initiation dates of first nests (re-nests excluded) at the San Luis Rey Flood Risk Management Project Area, California, 2006–22.

Apparent Nest Success

Overall, 38 percent (55/146) of completed nests were successful (table 6). A total of 39 percent (46/119) of nests in the Channel, 38 percent (9/24) of Off-channel nests, and 0 percent (0/3) of Restoration nests fledged young. Nest success did not statistically differ among the three site types ($P=0.57$, Fisher's Exact test).

Causes of nest failure were similar among the Channel, Off-channel, and Restoration site nests. Predation was the primary source of nest failure for all sites (table 6). Predation accounted for 62 percent (45/73), 80 percent (12/15), and 67 percent (2/3) of nest failures in the Channel, Off-channel, and Restoration sites, respectively. Most predators were believed to be birds, mammals, or snakes. Overall, 38 percent (45/119) of Channel nests, 50 percent (12/24) of Off-channel nests, and 67 percent (2/3) of Restoration nests were lost to predation.

Although we could attribute most nest failures to predation in 2022, there were 23 nests that failed for other or unknown reasons. Of these nests, 2 failed with infertile eggs, 1 was found after it had already failed, 1 was found with vireo and cowbird eggs under the nest, 1 failed because

a female vireo removed an egg, 2 were abandoned with eggs, and 16 nests failed for unknown reasons before eggs were documented.

Brown-headed Cowbird Parasitism

We documented 40 instances of Brown-headed Cowbird parasitism in 2022, which is a 14-percent increase from 2021 (35 instances). In total, 40 nests (27 percent of completed nests) in 27 territories (36 percent of territories) were parasitized with 46 eggs, which is much higher than the 16-year average of 6 percent of completed nests parasitized (table 7; fig. 8). Nine nests failed as a result of parasitism (abandoned). We removed cowbird eggs from 30 nests, of which 10 (33 percent) were ultimately successful. Of the remaining parasitized nests, 19 were depredated, 1 failed after the removal of a cowbird egg, and 1 was found after it had failed with a broken vireo egg and cowbird egg below the nest.

Parasitism was first observed during the third week of nesting (April 17), which is when 7 percent of completed nests were parasitized. The average weekly parasitism rate for completed nests from April 3 to July 3, 2022, was 31 percent (range 0–67 percent; fig. 9).

Table 6. Fate of completed Least Bell's Vireo nests at the San Luis Rey Flood Risk Management Project Area, California, 2022.

[Proportion of total completed nests shown in parentheses]

Nest fate	Number of nests			Total
	Channel	Off-channel	Restoration	
Successful	46	9	0	55 (0.38)
Failed				
Predation	45	12	2	59 (0.40)
Parasitism	8	0	1	9 (0.06)
Other/unknown	20	3	0	23 (0.16)
Failed total	73	15	3	91 (0.62)
Total completed nests	119	24	3	146 (1.00)

Table 7. Number and fate of Least Bell's Vireo nests parasitized by Brown-headed Cowbirds at the San Luis Rey Flood Risk Management Project Area, California, 2022.

Category	Channel	Off-channel	Restoration	Total
Nests parasitized	33	4	3	40
Total cowbird eggs laid	39	4	3	46
Fate of parasitized nests				
Abandoned	8	0	1	9
Not abandoned				
Successful	10	0	0	10
Unsuccessful	¹ 15	4	2	21

¹One nest abandoned after the removal of cowbird egg; one nest found with vireo and cowbird eggs below nest.

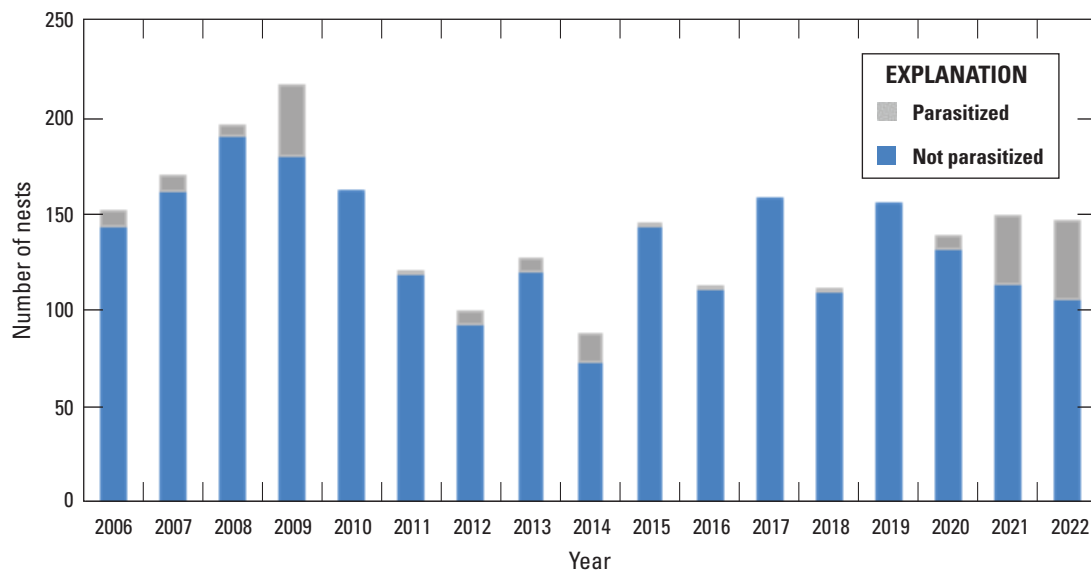


Figure 8. Number of completed Least Bell's Vireo nests (by year) that were parasitized by Brown-headed Cowbirds at the San Luis Rey Flood Risk Management Project Area, California, 2006–22.

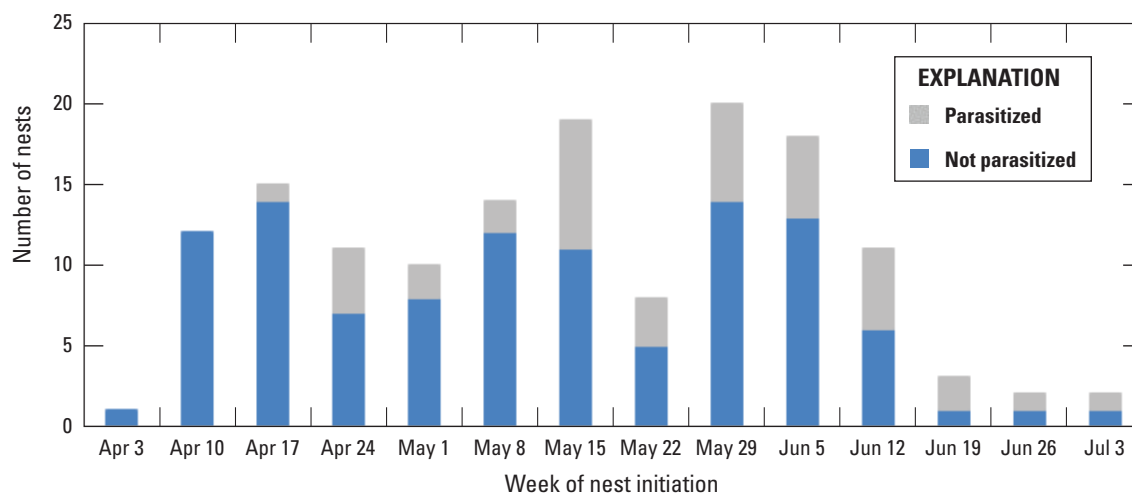


Figure 9. Number of completed Least Bell's Vireo nests initiated and those that were parasitized by Brown-headed Cowbirds (by week) at the San Luis Rey Flood Risk Management Project Area, California, 2022.

Reproductive Success and Productivity

Hatching and fledging success were similar in 2022 and 2021. Overall, 60 percent of nests with eggs hatched at least one egg, and 77 percent of nests with nestlings fledged at least one young (table 8), compared to 64 and 74 percent in 2021. Overall, clutch size of non-parasitized nests (3.2 ± 0.5) was similar to 2021 (3.3 ± 0.6) and the 16-year average (2006–21; 3.4). In 2022, there were no statistical differences among Channel, Off-channel and Restoration sites, with regard to clutch size, hatching, or fledging success.

In 2022, Project Area vireos fledged 2.2 ± 1.7 young per pair, which was slightly higher than productivity in 2021 (1.9 ± 1.7 young per pair) but lower than the 16-year average (2.5 ± 0.2 , table 9; fig. 10). There was no difference

Table 8. Reproductive parameters for nesting Least Bell's Vireos at the San Luis Rey Flood Risk Management Project Area, California, 2022.

[Nests were categorized based on their locations within Channel, Off-channel, and Restoration sites rather than based on the pair's territory site category. Standard deviations presented with means. Channel includes Reaches 1, 2, 3a, 3b, and 4, excluding restoration sites. Off-channel includes Upper Pond and Whelan Mitigation, excluding restoration sites. Restoration includes Benet Restoration, College Restoration, and Whelan Restoration. **Abbreviations:** ±, plus or minus; NA, not applicable; %, percent]

Parameter	Channel	Off-channel	Restoration	Overall
Nests with eggs	103	22	3	128
Eggs laid	295	63	9	367
Average clutch size ¹	3.3±0.6	3.1±0.3	NA	3.2±0.5
Hatchlings	172	38	4	214
Nests with hatchlings	63	13	1	77
Hatching success				
Eggs ²	58%	60%	44%	58%
Nests ³	61%	59%	33%	60%
Fledglings	134	26	4	164
Nests with fledglings	49	9	1	59
Fledging success				
Hatchlings ⁴	78%	68%	100%	77%
Nests ⁵	78%	69%	100%	77%

¹Based on 55 Channel and 12 Off-channel nests with a full clutch (One-way ANOVA: F -ratio=0.97, P =0.33).

²Percent of all eggs that hatched, among all three sites: P =0.68, Fisher's Exact test.

³Percent of all nests with eggs in which at least one egg hatched, among all three sites: P =0.71, Fisher's Exact test.

⁴Percent of all hatchlings that fledged, among all three sites: P =0.25, Fisher's Exact test.

⁵Percent of all nests with hatchlings in which at least one young fledged, among all three sites: P =0.61, Fisher's Exact test.

in productivity (the number of young fledged per pair) or in the proportion of pairs fledgling one or more young among site types. Overall, 72 percent (55/76) of pairs fledged at least one young in 2022, which was slightly higher than in 2021 (66 percent) but similar to the 16-year average of 74 percent. In 2022, 5 percent of pairs (4/76) successfully fledged two broods, which was lower than the 8 percent observed in 2021 and below the 16-year average of 13 percent. Without the rescue effect of removing Brown-headed Cowbird eggs from parasitized nests, thus allowing them to potentially fledge young, productivity and nest success would have been lower. Had cowbird eggs not been removed from parasitized nests, the fledging rate would have been only 1.8 ± 1.7 vireo young per pair, with only 57 percent of pairs successfully fledging at least one young.

Effects of Treatment on Vireo Reproduction

The Treatment Index for fully monitored 2022 vireo territories within the Channel that did not overlap with active restoration averaged 0.07 ± 0.11 (n =59, range, 0–0.49; fig. 11). In 2022, there were three fully monitored vireo territories (5 percent, 3/59) within the Channel that had no treatment. There was no effect of Treatment Index on any measures of nesting effort or productivity (number of nests, number of completed nests, or number of fledglings per pair; table 10; fig. 12).

Table 9. Productivity of nesting Least Bell's Vireos at the San Luis Rey Flood Risk Management Project Area, California, 2022.

[±, plus or minus; %, percent]

Parameter	Channel	Off-channel	Restoration	Mixed	Overall
Number of pairs	59	12	1	4	76
Average number of young fledged per pair ¹	2.2±1.8	2.2±1.3	4.0±0.0	1.3±1.5	2.2±1.7
Pairs fledging at least one young ²	43 (73%)	9 (75%)	1 (100%)	2 (50%)	55 (72%)
Pairs fledging two broods ³	4 (7%)	0 (0%)	0 (0%)	0 (0%)	4 (5%)

¹One-way ANOVA: F -ratio=0.77, P =0.51.

² P =0.78, Fisher's Exact test.

³ P =1.00, Fisher's Exact test.

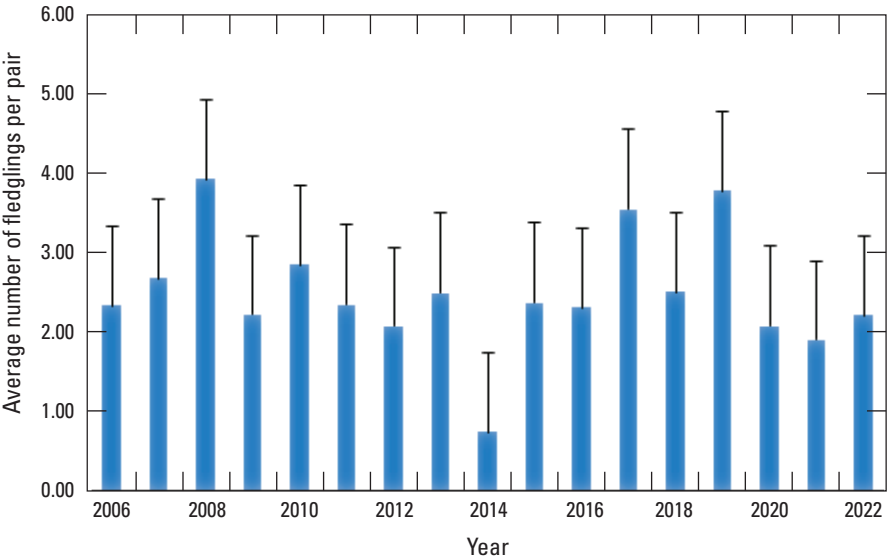


Figure 10. Average number of fledglings per pair (by year) at the San Luis Rey Flood Risk Management Project Area, California, 2006–22. Bars are standard deviations.

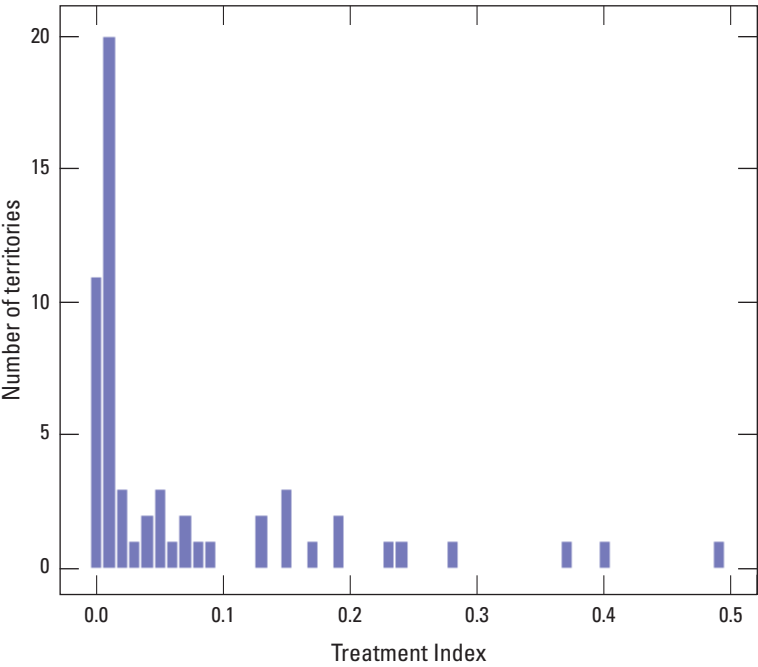


Figure 11. Treatment Index of monitored vireo territories within the Channel at the San Luis Rey Flood Risk Management Project Area, California, 2022. Territories overlapping with active restoration are not included.

Table 10. Generalized linear model (GLM) results, parameter estimate, standard error (SE), Z statistic, and P-values for Least Bell’s Vireo reproductive parameters as a function of Treatment Index within the Channel at the San Luis Rey Flood Risk Management Project Area, California, 2022.

[SE, standard error; Z, Z-statistic; P, P-value; <, less than; estimate, parameter estimate]

Variable	Estimate	SE	Z	P
Number of nests				
(Intercept)	0.8	0.1	7.9	<0.01
Treatment index	−1.4	1.0	−1.4	0.16
Number of completed nests				
(Intercept)	0.7	0.1	6.2	<0.01
Treatment index	−0.9	1.0	−1.0	0.34
Number of fledglings				
(Intercept)	0.8	0.1	7.8	<0.01
Treatment index	−0.9	0.9	−1.0	0.31

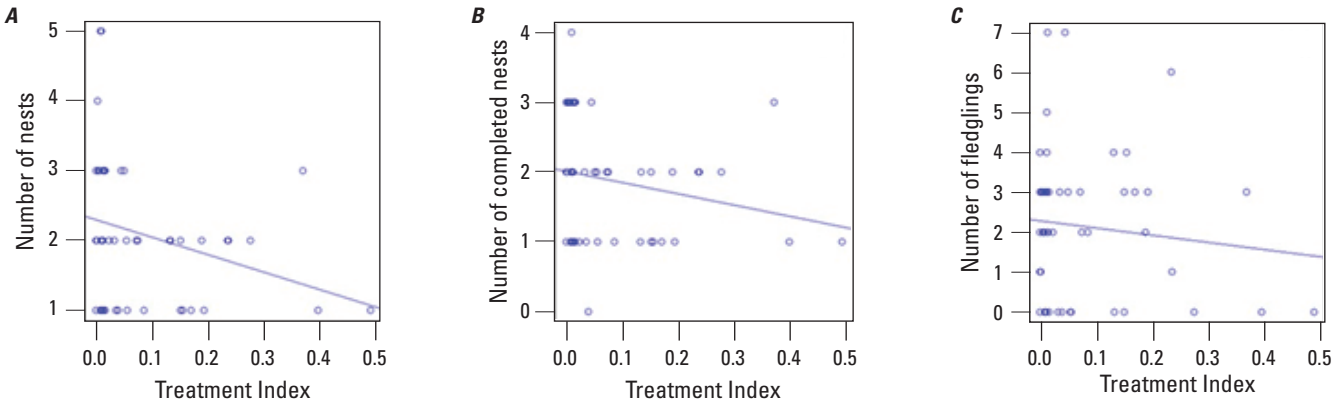


Figure 12. Effect of Treatment Index on Least Bell’s Vireo reproductive parameters (per pair) in *A*, number of nests per pair; *B*, number of completed nests per pair; and *C*, number of fledglings per pair at the San Luis Rey Flood Risk Management Project Area, California, 2022. Lines represent linear regression.

We analyzed 2022 nest survival to determine if there was an effect of Treatment Index on DSR (within the Channel only). The best model for DSR was the constant model (table 11). There was some support for the model that included Treatment Index (ΔAIC_c equal to 2); however, an analysis of the odds ratio indicated that it was not a significant contributor to the model ($\beta = -0.01$, $SE = 0.04$, odds ratio = 0.99, 95-percent confidence interval = 0.93–1.07).

Nest Survival and Habitat Use

We investigated the effect of habitat structure at vireo nest sites on nest survival by constructing a series of models relating the vegetation cover variables to the daily nest

survival rate (table 12). The best model was the constant DSR model; however, there was support for several of the other models (ΔAIC_c less than or equal to 2). We looked at the beta estimates for the first two models: the model that included percent cover 0–1 m+1–2 m and the model that included percent cover 1–2 m. For both of these models, the beta values for the percent cover estimates were low (0–0.01), with the confidence interval for the odds ratio spanning one, so we can conclude that percent cover 0–1 m and 1–2 m were not significant contributors to the models (table 13).

Table 11. Logistic regression models for the effects of Treatment Index (within the Channel only) on daily nest survival of Least Bell's Vireos at the San Luis Rey Flood Risk Management Project Area, California, 2022.

[Models are ranked from best to worst based on Akaike's Information Criterion for small samples (AIC_c), ΔAIC_c , and Akaike weights. AIC_c is based on $-2 \times \log_e$ likelihood, the number of parameters in the model, and sample size. **Abbreviations:** ΔAIC_c , difference in AIC_c compared with the top model (lowest AIC_c)]

Model	Deviance	Number of parameters	AIC_c	ΔAIC_c	AIC_c weight
Constant	330.0	1	332.0	0.0	0.73
Treatment index	329.9	2	334.0	2.0	0.27

Table 12. Logistic regression models for the effects of habitat structure on daily nest survival of Least Bell's Vireos at the San Luis Rey Flood Risk Project Area, California, 2006–22.

[Models are ranked from best to worst based on Akaike's Information Criterion for small samples (AIC_c), ΔAIC_c , and Akaike weights. AIC_c is based on $-2 \times \log_e$ likelihood, the number of parameters in the model, and sample size. **Abbreviations:** ΔAIC_c , difference in AIC_c compared with the top model (lowest AIC_c); DSR, daily survival rate; +, plus; m, meter]

Model	Deviance	Number of parameters	AIC_c	ΔAIC_c	AIC_c weight
Constant DSR	2,252.7	1	2,254.7	0.00	0.17
Percent cover 0–1 m+1–2 m	2,248.7	3	2,254.7	0.04	0.17
Percent cover 1–2 m	2,251.7	2	2,255.7	1.04	0.10
Percent cover 5–6 m	2,252.3	2	2,256.3	1.56	0.08
Percent cover 6–7 m	2,252.3	2	2,256.3	1.60	0.08
Percent cover 3–4 m	2,252.4	2	2,256.4	1.73	0.07
Percent cover 4–5 m	2,252.5	2	2,256.5	1.84	0.07
Percent cover 0–1 m	2,252.6	2	2,256.6	1.88	0.07
Canopy height	2,252.6	2	2,256.6	1.92	0.07
Percent cover 7–8 m	2,252.6	2	2,256.6	1.94	0.06
Percent cover 2–3 m	2,252.7	2	2,256.7	2.00	0.06
Percent cover 2–3 m+3–4 m+4–5 m+5–6 m+6–7 m+7–8 m	2,250.9	7	2,264.9	10.23	0.00

Table 13. Parameter estimate (β), standard error (SE), odds ratios, and 95-percent confidence intervals (CI) for models explaining the effect of habitat structure on the daily survival rate of Least Bell's Vireos at the San Luis Rey Flood Risk Management Project Area, California, 2006–22.

[Models are in order of best-supported to least-supported.

Abbreviations: +, plus; m, meter]

Effect	β	SE	Odds ratio	95-percent CI
Percent cover 0–1 m+1–2 m				
Intercept	3.82	0.15	45.66	33.97–61.39
0–1 m	–0.01	0.01	0.99	0.98–1.00
1–2 m	0.01	0.01	1.01	1.00–1.03
Percent cover 1–2 m				
Intercept	3.73	0.14	41.71	31.59–55.06
1–2 m	0.00	0.00	1.00	1.00–1.01

Nest Characteristics

Channel nests were placed higher in the host plant than Off-channel nests, but there were no other differences in nest placement or host plant size among Channel, Off-channel, and Restoration nests (table 14). Host height, distance to edge of host, and distance from edge of clump were similar in all site types. Within sites, we detected some differences between successful and unsuccessful nests. In the Channel, successful nests were placed closer to the edge of the host plant than unsuccessful nests. The same pattern was discovered in Off-channel nests, with successful nests placed closer to the edge of the host. We also determined that Off-channel successful nests were placed lower in the vegetation, in shorter host plants, and closer to the edge of the vegetation clump than unsuccessful nests.

Table 14. Least Bell's Vireo nest characteristics and results of Kruskal-Wallis and Mann-Whitney *U*-tests comparing Channel, Off-channel, and Restoration nests and successful versus failed nests at the San Luis Rey Flood Risk Management Project Area, California, 2022.

[Standard deviation presented in parentheses. Asterisks indicate a significant difference. *N*, Sample size; *H*, Kruskal-Wallis *H* statistic; *P*, *P*-value; *U*, Mann-Whitney *U* statistic. **Abbreviations:** m, meter; <, less than; NA, not applicable; —, no data]

Nest characteristic	Channel	<i>N</i>	Off-channel	<i>N</i>	Restoration	<i>N</i>	<i>H</i>	<i>P</i>
Overall								
Average nest height (m)	1.0 (0.4)	117	0.8 (0.4)	25	1.3 (0.2)	3	8.6	0.01*
Average host height (m)	4.1 (2.4)	119	4.1 (3.0)	25	2.5 (1.5)	3	4.5	0.11
Average distance to edge of host (m)	0.9 (0.8)	115	0.8 (0.6)	25	0.4 (0.2)	3	1.2	0.56
Average distance to edge of clump (m) ¹	1.3 (0.9)	117	1.1 (0.6)	25	0.6 (0.4)	3	3.3	0.2
	Channel	Successful	<i>N</i>	Unsuccessful	<i>N</i>	<i>U</i>	<i>P</i>	
Average nest height (m)		1.0 (0.3)	44	1.1 (0.5)	73	1,748	0.43	
Average host height (m)		3.6 (2.3)	45	4.3 (2.4)	74	1,843	0.4	
Average distance to edge of host (m)		0.8 (0.9)	44	1.0 (0.8)	71	1,866.5	0.08*	
Average distance to edge of clump (m)		1.5 (1.0)	45	1.3 (0.9)	72	1,460	0.37	
Off-channel								
Average nest height (m)		0.6 (0.2)	9	1.0 (0.4)	16	122	<0.01*	
Average host height (m)		2.2 (1.5)	9	5.1 (3.2)	16	108.5	0.04*	
Average distance to edge of host (m)		0.6 (0.6)	9	0.9 (0.6)	16	102	0.09*	
Average distance to edge of clump (m)		0.8 (0.5)	9	1.2 (0.6)	16	108	0.04*	
Restoration								
Average nest height (m)		NA	NA	1.3 (0.2)	3	—	—	
Average host height (m)		NA	NA	2.5 (1.5)	3	—	—	
Average distance to edge of host (m)		NA	NA	0.4 (0.2)	3	—	—	
Average distance to edge of clump (m)		NA	NA	0.6 (0.4)	3	—	—	

¹Clump boundaries were defined where leaves and branches of neighboring plants no longer overlapped.

Red/arroyo willow were the species most commonly selected for nesting by vireos in all three site types (50 percent of nests in the Channel, 48 percent in Off-channel sites, and 67 percent in Restoration sites; [table 15](#)). Other species commonly used by vireos (greater than 10 percent of all nests) included black willow and mule fat. Vireos used a wider variety of species for nesting in Channel and Off-channel sites (eight and six species, respectively) compared to Restoration sites (two species), although there was limited nesting in Restoration in 2022. Four nests were placed in exotic species in 2022.

Banded Birds

We determined banding status for 92 percent (231/251) of adult vireos (134 males, 99 percent of all males and 97 females, 84 percent of all females) observed at the San Luis Rey Flood Risk Management Project Area in 2022. Of these adult vireos, 43 had been banded before the 2022 breeding season, and their identities were verified through resighting or recapture. There were 11 vireos (2 males and 9 females) that could not be identified: 2 because the resight was incomplete and the band combinations could not be confirmed and 9 because they were banded with only a single numbered metal federal band as a nestling (natal), and we were unable to recapture them in 2022 ([table 16](#); [appendix 4](#)).

Of the 43 returning adults with a known identity, 42 were banded with full color band combinations before 2022, and 1 was a natal vireo recaptured and color banded in 2022. All banded adults (43) were originally banded in the Project Area ([table 16](#)). Adult birds of known age ranged from 1 to 7 years old ([table 17](#)).

Emigrants

Four vireos that were originally banded in the San Luis Rey River Project Area as nestlings or adults were detected in areas outside of the Project Area in 2022 ([tables 16, 18](#); [appendix 5](#)). All vireos were recaptured in 2022 and banded with unique color band combinations at two drainages within MCBCP, at the middle San Luis Rey River (upstream from the Project Area), and at Fallbrook Creek (FNWS; U.S. Geological Survey, unpub. data, 2022).

New Captures

A total of 146 vireos were banded for the first time during 2022. These newly banded birds included 8 adults that were captured and banded with a unique color combination and 138 nestlings that were banded with a single numbered dark blue metal federal band. These newly banded vireos were not included in survivorship, fidelity, or movement analyses.

Table 15. Host plant species used by Least Bell’s Vireos for nesting at the San Luis Rey Flood Risk Management Project Area, California, 2022.

[Numbers in parentheses are proportions of total nests. Abbreviation: —, no data]

Host species	Number of Channel nests			Number of Off-channel nests			Number of Restoration nests		
	Successful	Unsuccessful	Total	Successful	Unsuccessful	Total	Successful	Unsuccessful	Total
Red/arroyo willow	18	42	60 (0.50)	3	9	12 (0.48)	0	2	2 (0.67)
Mule fat	11	10	21 (0.18)	3	4	7 (0.28)	—	—	—
Black willow	9	12	21 (0.18)	—	—	—	0	1	1 (0.33)
Poison oak (<i>Toxicodendron diversilobum</i>)	5	8	13 (0.11)	—	—	—	—	—	—
Giant reed	0	2	2 (0.02)	—	—	—	—	—	—
Coyote bush (<i>Baccharis pilularis</i>)	1	0	1 (0.01)	—	—	—	—	—	—
Castor bean (<i>Ricinus communis</i>)	1	0	1 (0.01)	—	—	—	—	—	—
Sandbar willow	0	1	1 (0.01)	2	1	3 (0.12)	—	—	—
Fremont cottonwood	—	—	—	0	1	1 (0.04)	—	—	—
Evening primrose (<i>Oenothera elata</i>)	—	—	—	1	0	1 (0.04)	—	—	—
Common fig (<i>Ficus carica</i>)	—	—	—	0	1	1 (0.04)	—	—	—

Table 16. Banding status of Least Bell's Vireos detected at the San Luis Rey Flood Risk Management Project Area, California, 2022, and those that emigrated from the Project Area, 2022.

[Project Area includes two natal immigrant vireos. Natal: natal vireos were originally banded as nestlings with a single numbered federal band. **Abbreviation:** —, no data]

Banding status	Project area			Emigrants			Total
	Male	Female	Subtotal	Male	Female	Subtotal	
Known-identity vireos							
Banded prior to 2022	37	5	42	—	—	—	42
Natal, recaptured in 2022	1	—	1	2	2	4	5
Subtotal	38	5	43	2	2	4	47
Unidentified vireos							
Natal, not recaptured	—	9	9	—	—	—	9
Incomplete resight	2	—	2	—	—	—	2
Grand total	40	14	54	2	2	4	58

Table 17. Number of banded adult Least Bell's Vireos at the San Luis Rey Flood Risk Management Project Area, California, 2022, by original year banded, age, and sex.

[**Year originally banded:** Year banded with a single numbered metal federal band as a nestling or with a unique color band combination as an adult; **Age in 2022:** Exact ages determined from single numbered metal federal band observed during recapture; estimated age applies to a bird captured as an unbanded adult; **Unknown:** Natal vireos banded with single numbered metal federal band or identity unknown because of incomplete resight, so year originally banded was unknown. **Abbreviations:** yr, year; ≥, greater than or equal to; —, not applicable]

Year originally banded	Age in 2022	San Luis Rey River		Marine Corps Base Camp Pendleton	Total
		Male	Female	Female	
2015	7 yrs	1	0	0	1
2016	6 yrs	1	0	0	1
2017	5 yrs	4	0	0	4
2018	≥5 yrs	0	1	0	1
	4 yrs	1	0	0	1
2019	≥4 yrs	7	0	0	7
	3 yrs	6	2	0	8
2020	≥3 yrs	8	1	0	9
	2 yrs	7	1	0	8
2021	≥2 yrs	2	0	0	2
	1 yr	1	0	0	1
Subtotal	—	38	5	0	43
Unknown	≥1 yr	¹ 2	² 7	³ 2	11
Total	—	40	12	2	54

¹Two vireos seen with an incomplete resight of the bands so identity and origin are unknown.

²Vireos seen with a single metal dark blue numbered band, indicating that they were originally banded on the San Luis Rey River before 2022.

³Two vireos seen with a single metal gold numbered band, indicating that they were originally banded at Marine Corps Base Camp Pendleton before 2022.

Table 18. Number of emigrant Least Bell's Vireos detected outside of the Project Area that originated in the San Luis Rey Flood Risk Management Project Area, California, by original year banded, age, 2022 location, and sex.

[**Year originally banded:** Year banded with a single numbered metal federal band as a nestling or with a unique color band combination as an adult; **MCBCP:** Marine Corps Base Camp Pendleton; **Middle San Luis Rey River:** Upstream from the Project Area, between College Boulevard and Interstate 15. **Abbreviations:** yr, year, —, no data]

Year originally banded	Age in 2022	2022 location drainage			Total
		MCBCP drainages (female)	Middle San Luis Rey River (male)	Other drainages (male)	
2018	4 yrs	¹ 1	—	—	1
2019	3 yrs	² 1	—	—	1
2021	1 yr	—	1	³ 1	2
Total	—	2	1	1	4

¹Detected at Aliso Creek.

²Detected at Santa Margarita River.

³Detected at Fallbrook Creek, Fallbrook Naval Weapons Station.

Survivorship, Fidelity, and Movement

Survivorship Models—Adults-Only

The best model explaining adult annual survivorship included effects of sex and year on adult survival (table 19) and the effect of sex on detection probability. Detection probability was somewhat higher for males (0.88) than for females (0.76) but was high for both sexes. Male survivorship was higher than female survivorship, and survivorship varied by year, with significantly lower survival in 2010–11, 2011–12, 2019–20, and 2020–21, relative to the reference (2006–07, tables 20, 21). We found little support for models that included bio-year precipitation, suggesting that precipitation on the breeding grounds was not the primary driver of annual fluctuations in survivorship in this system (table 19).

We used the top model to calculate annual survivorship for adult males and adult females (table 21). Annual survival for females was consistently lower than for males, averaging 59±12 percent (range of 37–71 percent). For males, annual survivorship averaged 66±11 percent (range of 44–79 percent).

Survivorship Models—Adults and First-Year Vireos

The best supported model for vireo survival was the model that included the effects of age and year on survival (table 22). Analysis of the odds ratio showed that survival of adult vireos was significantly higher than that of first-year vireos and that survival varied by year for both age classes, with higher survival in 2008–09 and lower survival in 2010–12 and 2019–22, relative to the reference (2006–07; table 23).

Survival estimates for 2021–22 were low relative to previous years (adult survival was estimated at 50 percent and first-year survival was 7 percent). Average annual

survival across all years for adults was 67±12 percent (range of 50–82 percent) and 15±6 percent (range of 7–25 percent; table 24) for first year birds.

First-year Dispersal 2022

Three first-year vireos (all male) that fledged from nests in the Project Area in 2021 were recaptured in 2022 (table 25). Of these vireos, one was recaptured within the Project Area and two were recaptured outside of the Project Area (one at Fallbrook Creek and one at the middle San Luis Rey River, upstream from the Project Area between College Boulevard and Interstate 15 [U.S. Geological Survey, unpub. data, 2022]; table 25; appendix 6). Average dispersal distance by first-year vireos was 6.7±7.4 km (range 2.3–15.3 km). The longest dispersal distance was 15.3 km by a male vireo recaptured at Fallbrook Creek, FNWS.

First-year Dispersal 2007–22

We examined the return locations of first-year vireos in 2022 and compared them to dispersal observed in previous years. From 2007 to 2011, the majority (67–86 percent) of returning first-year vireos returned to the Project Area (table 25). As habitat in the Project Area became more limited following the commencement of mowing in 2012, proportionately more birds dispersed to sites outside of the Project Area, a trend that continued until about 2017. Since 2018, the proportion of first-year vireos returning to the Project Area has been generally increasing, although still below the proportions observed before vegetation mowing. In 2022, the total number of returning first-year vireos was low, and only one of the three first-year vireos returned to the Project Area.

Table 19. Survivorship models for the effects of sex, year, and precipitation on adult survival for Least Bell's Vireos at the San Luis Rey Flood Risk Project Area, California, 2006–22.

[The effect of sex on detection probability was included in all models. Models are ranked from best to worst based on Akaike's Information Criterion for small samples (AIC_c), ΔAIC_c, and Akaike weights. AIC_c is based on -2 x log_e likelihood, the number of parameters in the model, and sample size. **Abbreviation:** +, plus]

Model	Deviance	Number of parameters	AIC _c	ΔAIC _c	AIC _c weight
Sex+year	260,287.8	19	263,454.8	0.0	0.73
Year	260,292.1	18	263,457.2	2.3	0.23
Sex+precipitation	260,322.2	5	263,461.0	6.2	0.03
Precipitation	260,327.5	4	263,464.2	9.4	0.01
Sex	260,369.9	4	263,506.7	51.9	0.00
Constant	260,375.0	3	263,509.8	55.0	0.00

Table 20. Parameter estimate (β), standard error (SE), odds ratios, and 95-percent confidence intervals (CI) for the top model explaining annual survivorship (Phi) of adult Least Bell's Vireos at the San Luis Rey Flood Risk Project Area, California, 2006–22.

[The Intercept (reference) represents female vireos, 2006–07. All other effects values are the difference between that parameter and the Intercept.

Abbreviation: +, plus]

Effect	β	SE	Odds ratio	95-percent CI
Sex+year				
Intercept	0.89	0.35	2.44	1.23–4.86
Male¹	0.31	0.15	1.36	1.02–1.80
2007–08	–0.09	0.47	0.91	0.37–2.27
2008–09	0.11	0.41	1.12	0.50–2.48
2009–10	–0.26	0.38	0.77	0.37–1.62
2010–11¹	–0.94	0.37	0.39	0.19–0.80
2011–12¹	–1.35	0.37	0.26	0.12–0.54
2012–13	–0.13	0.42	0.88	0.38–2.00
2013–14	–0.15	0.41	0.86	0.39–1.91
2014–15	–0.22	0.40	0.80	0.36–1.77
2015–16	–0.70	0.39	0.49	0.23–1.07
2016–17	–0.23	0.42	0.79	0.35–1.80
2017–18	–0.75	0.39	0.47	0.22–1.01
2018–19	–0.25	0.39	0.78	0.37–1.67
2019–20¹	–1.04	0.37	0.35	0.17–0.74
2020–21¹	–1.42	0.37	0.24	0.12–0.50
2021–22	–0.78	0.43	0.46	0.20–1.06

¹Significant effect.

Table 21. Annual survivorship for adult female and adult male Least Bell's Vireos at the San Luis Rey Flood Risk Project Area, California, 2006–22.

[Survivorship and estimates were derived from the top model]

Years	Adult female survivorship	Adult male survivorship
2006–07	0.71	0.77
2007–08	0.69	0.75
2008–09	0.73	0.79
2009–10	0.65	0.72
2010–11	0.49	0.56
2011–12	0.39	0.46
2012–13	0.68	0.74
2013–14	0.68	0.74
2014–15	0.66	0.73
2015–16	0.55	0.62
2016–17	0.66	0.72
2017–18	0.53	0.61
2018–19	0.66	0.72
2019–20	0.46	0.54
2020–21	0.37	0.44
2021–22	0.53	0.60

Table 22. Survivorship models for the effect of age, year, and precipitation on survival of Least Bell's Vireos at the San Luis Rey Flood Risk Project Area, California, 2006–22.

[Detection probability was modeled as constant. Models are ranked from best to worst based on Akaike's Information Criterion for small samples (AIC_c), ΔAIC_c , and Akaike weights. AIC_c is based on $-2 \times \log_e$ likelihood, the number of parameters in the model, and sample size. Abbreviations: ΔAIC_c ; difference in AIC_c compared with the top model (lowest AIC_c)]

Model	Deviance	Number of parameters	AIC_c	ΔAIC_c	AIC_c weight
Age + year	3,513.6	18	6,678.5	0.0	1.00
Age + precipitation	3,626.1	4	6,762.8	84.3	0.00
Age	3,646.7	3	6,781.4	102.9	0.00
Year	4,714.9	17	7,877.8	1,199.3	0.00

Table 23. Parameter estimate (β), standard error (SE), odds ratios, and 95-percent confidence intervals (CI) for the top model explaining annual survivorship of Least Bell's Vireos at the San Luis Rey Flood Risk Project Area, California, 2006–22.

[The Intercept (reference) represents first-year vireos, 2006–07. All other effects values are the difference between that parameter and the Intercept]

Effect	β	SE	Odds ratio	95-percent CI
Age+year				
Intercept	–1.52	0.17	0.22	0.16–0.31
Adults¹	2.57	0.08	13.06	11.19–15.25
2007–08	–0.25	0.24	0.78	0.49–1.25
2008–09¹	0.45	0.21	1.56	1.04–2.35
2009–10	–0.07	0.22	0.94	0.61–1.45
2010–11¹	–0.84	0.22	0.43	0.28–0.67
2011–12¹	–0.97	0.23	0.38	0.24–0.60
2012–13	0.17	0.25	1.18	0.72–1.93
2013–14	–0.35	0.23	0.70	0.45–1.10
2014–15	0.06	0.27	1.06	0.62–1.80
2015–16	–0.27	0.24	0.76	0.48–1.21
2016–17	–0.11	0.24	0.90	0.56–1.44
2017–18	0.09	0.22	1.10	0.71–1.69
2018–19	–0.19	0.23	0.82	0.52–1.29
2019–20¹	–0.55	0.22	0.58	0.37–0.90
2020–21¹	–0.92	0.25	0.40	0.25–0.64
2021–22¹	–1.05	0.28	0.35	0.20–0.60

¹Significant effect.

Table 24. Annual survivorship for adult and first-year Least Bell's Vireos at the San Luis Rey Flood Risk Project Area, California, 2006–22.

[% , percent]

Years	Adult survivorship	First-year survivorship
2006–07	74%	18%
2007–08	69%	15%
2008–09	82%	25%
2009–10	73%	17%
2010–11	55%	9%
2011–12	52%	8%
2012–13	77%	20%
2013–14	67%	13%
2014–15	75%	19%
2015–16	68%	14%
2016–17	72%	16%
2017–18	76%	19%
2018–19	70%	15%
2019–20	62%	11%
2020–21	53%	8%
2021–22	50%	7%

Table 25. Number of first-year Least Bell's Vireos that originated at the San Luis Rey Flood Risk Management Project Area and returned to the Project Area or returned to areas outside of the Project Area, 2007–22, by year and sex.

[Numbers in parentheses indicate the percentage of returning first-year vireos that returned to that area. Middle San Luis Rey River is upstream from the Project Area, between College Boulevard and Interstate 15. **Abbreviations:** %, percent, —, no data]

Return year	Drainage location									
	San Luis Rey Project Area			Marine Corps Base Camp Pendleton		Middle San Luis Rey River		Other drainages		Outside Project Area total
	Male	Female	Project Area total	Male	Female	Male	Female	Male	Female	
2007	9	9	18 (75%)	—	3	1	1	¹ 1	—	6 (25%)
2008	16	4	20 (67%)	7	1	1	1	—	—	10 (33%)
2009	40	19	59 (79%)	8	1	3	—	² 3	³ 1	16 (21%)
2010	10	8	18 (69%)	4	1	2	—	⁴ 1	—	8 (31%)
2011	11	7	18 (86%)	1	—	1	—	⁵ 1	—	3 (14%)
2012	6	5	11 (61%)	5	1	—	—	⁶ 1	—	7 (39%)
2013	9	4	13 (57%)	2	2	3	—	⁷ 3	—	10 (43%)
2014	4	1	5 (31%)	4	3	2	1	⁸ 1	—	11 (69%)
2015	3	2	5 (50%)	4	—	—	1	—	—	5 (50%)
2016	9	5	14 (41%)	7	5	4	2	⁹ 2	—	20 (59%)
2017	9	4	13 (57%)	4	3	1	1	—	¹⁰ 1	10 (43%)
2018	35	14	49 (68%)	11	6	2	2	³ 1	¹¹ 1	23 (32%)
2019	5	5	10 (53%)	1	3	4	—	¹² 1	—	9 (47%)
2020	16	8	24 (60%)	5	4	3	4	—	—	16 (40%)
2021	9	1	10 (63%)	1	—	4	—	—	¹² 1	6 (37%)
2022	1	—	1 (33%)	—	—	1	—	¹³ 1	—	2 (67%)
Total	192	96	288 (64%)	64	33	32	13	16	4	162 (36%)

¹Detected at Elanus Creek, San Diego County.

²One detected at the Santa Ana River in Orange County, one detected at San Dieguito River, and one detected at Agua Hedionda, San Diego County.

³Detected at the San Diego River, San Diego County.

⁴Detected at Chollas Creek, San Diego County.

⁵Detected at Bonita Creek, Orange County.

⁶Detected at the San Dieguito River, San Diego County.

⁷One detected at the San Gabriel River, Los Angeles County, one detected at the Sweetwater River, and one detected at Moody Creek, San Diego County.

⁸Detected at Escondido Creek, San Diego County.

⁹One detected at the Tijuana River and one detected at Otay River, San Diego County.

¹⁰Detected at the Tijuana River, San Diego County.

¹¹Detected at the upper Santa Margarita River, upstream (12 kilometers) from Marine Corps Base Camp Pendleton.

¹²Detected at Whelan Lake, San Diego County.

¹³Detected at Fallbrook Creek, Fallbrook Naval Weapons Station.

Adult Site Fidelity

Resighting banded birds allowed us to identify individuals that either returned to the same territory they used in a previous year (within 100 m) or moved to a different location. There were 41 adult vireos (37 males and 4 females) identified in 2021 at the Project Area that were resighted in 2022 (appendix 7). Of the 41 returning adults, 27 vireos (66 percent of all adults; 73 percent of males; no females) occupied a territory in 2022 that they had defended in 2021 (within 100 m; appendix 7). Six vireos (15 percent of all adults; 4 males, 11 percent of males; 2 females, 50 percent of females) detected in 2022 returned to areas adjacent to their previous territories (within 300 m). The remaining 8 vireos (20 percent of all adults; 6 males, 16 percent of males; 2 females, 50 percent of females) detected in 2022 returned to areas more than 300 m from their previous territories. The average distance moved by returning 2022 adult vireos was 0.3±0.7 km, range 0.0–4.0 km for males; 0.6±0.4 km, range 0.2–1.1 km for females.

Effect of Treatment on Adult Site Fidelity

Because we were interested in the cumulative effect of vegetation treatment on the movement of returning banded vireos over the years, we performed a linear regression on the distance moved by banded vireos as a function of the expected Treatment Index for the vireos' 2021 territories (that is, the Treatment Index in 2022 if the bird had occupied exactly the same territory boundaries as in 2021). The residuals were skewed, so we log-transformed the data for analysis. We restricted our analysis to birds nesting in the Channel to avoid the confounding effects of passive habitat restoration that occurred Off-channel in 2017. We detected no effect of expected Treatment Index on distance moved between 2021 and 2022 ($P=0.86$, table 26).

Table 26. Generalized linear model (GLM) results, parameter estimate, standard error (SE), t statistic, and P -values (P) for banded Least Bell's Vireo movement (log-transformed) as a function of the expected Treatment Index for 2021 territories at the San Luis Rey Flood Risk Management Project Area, California, 2022.

[<, less than]

Variable	Estimate	SE	t	P
Intercept	4.1	0.5	8.6	<0.01
Expected Treatment Index	0.4	2.1	0.2	0.86

Southwestern Willow Flycatcher

Population Size and Distribution

Four transient Willow Flycatchers of unknown subspecies were detected within the Project Area between May 24 and June 9, 2022. Two transients were detected in Reach 1, one in Reach 3a, and one in Pilgrim Pond (appendix 8, figs. 8.1–8.2). No flycatcher pairs were detected within the Project Area in 2022.

Habitat Characteristics

Two transient flycatchers used mixed willow riparian habitat, one used willow-cottonwood habitat, and one used riparian scrub habitat in 2022 (table 27). The dominant native species in three of the flycatcher locations were red/arroyo willow. One flycatcher was detected in habitat dominated by mule fat. Two flycatchers were located in habitat with 5–50-percent exotic vegetation and two were in habitat with less than 5-percent exotic vegetation. Poison hemlock was the most common exotic species at flycatcher locations. Flycatchers were detected between 0 and 1.3 km away from surface water.

Vegetation Study

A total of 46 transects (528 sampling points) were sampled in the Project Area in 2022 (table 28; appendix 9, figs. 9.1–9.4). Seventy-one percent (378/528) of points were in the Channel and 22 percent (115/528) were located Off-channel in Upper Pond. The remaining 7 percent (35/528) of points were in the Whelan Restoration site. The number of points per transect varied between 4 and 18. One point was in a transient camp and was not sampled in 2022. GPS coordinates for the start and end point of each transect are provided in appendix 10.

Vegetation Structure and Composition

There was more foliage cover below 2 m in the Channel than in Upper Pond and Whelan Restoration (fig. 13). Above 2 m, foliage cover was similar at the Channel and Whelan Restoration and was greater than at Upper Pond. Overall, foliage cover was low above 5 m but was highest in the Channel. Average live canopy height and maximum canopy height (including live and dead vegetation) was higher in the Channel (5.6±3.4 m) compared to Upper Pond (4.7±2.9 m), and Whelan Restoration (4.6±1.9 m).

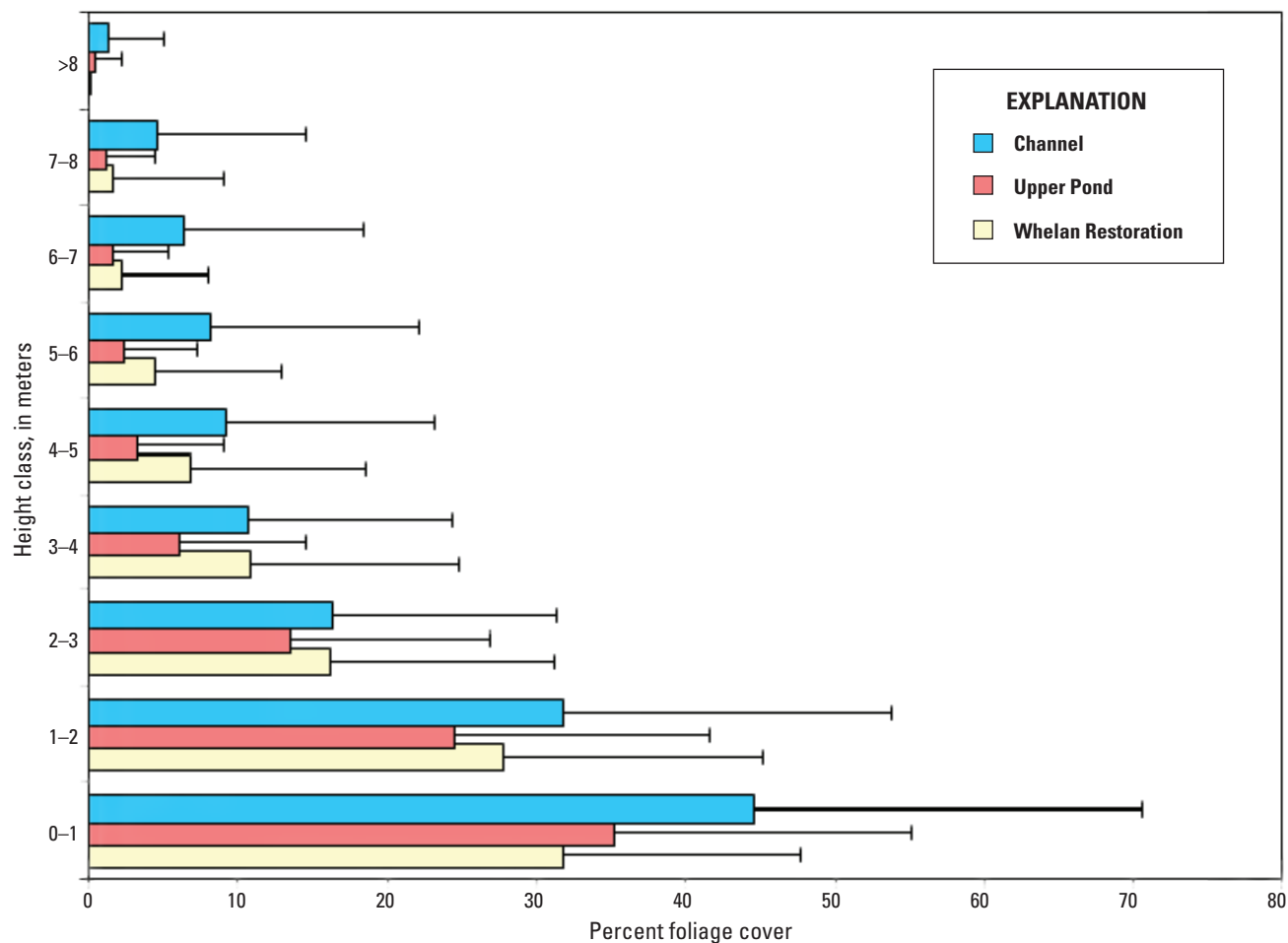
Table 27. Habitat characteristics of transient Willow Flycatchers at the San Luis Rey Flood Risk Management Project Area, California, 2022.

[ID, identification; km, kilometer; <, less than, —, no data]

Bird ID	Date first detected	Habitat type	Dominant species	Percent cover exotics	Dominant exotics	Distance to surface water (km)
BT01F	May 24	Mixed willow	Red/arroyo willow	5–50	Poison hemlock	1.3
BT03F	May 24	Willow-cottonwood	Red/arroyo willow	<5	—	0.4
DO01F	May 24	Riparian scrub	Mule fat	5–50	Poison hemlock	1.0
WH01F	July 9	Mixed willow	Red/arroyo willow	<5	—	0.3

Table 28. Number of vegetation transects and sampling points at the San Luis Rey Flood Risk Management Project Area, California, 2022.

Site type	Transects	Sampling points
Channel	31	378
Upper Pond	13	115
Whelan Restoration	2	35
Total	46	528

**Figure 13.** Average percent foliage cover by height class at the San Luis Rey Flood Risk Management Project Area, California, 2022. Bars are standard deviations.

Vegetation composition in the Channel differed from that in Upper Pond and Whelan Restoration (fig. 14). Tree cover, dominated by red/arroyo willow, was higher in the Channel (43 percent) and Whelan Restoration (44 percent) compared to Upper Pond (22 percent). In contrast, shrub cover was substantially lower in the Channel (12 percent) than in Upper Pond (43 percent) and Whelan Restoration (32 percent). Mule fat was the dominant shrub species at all three sites. Herbaceous cover was at least 2 times greater in both the Channel (22 percent) and Upper Pond (19 percent) than in Whelan Restoration (8 percent). Marsh species such as bulrush (*Scirpus* sp.), sedge (*Carex* sp.), and cattail (*Typha latifolia*) comprised 59 percent of the total herbaceous cover in the Channel. Exotic species cover also was higher in the Channel (19 percent) than at Whelan Restoration (11 percent) and Upper Pond (4 percent). Giant reed comprised 42 percent of the total exotic cover in the Channel. Dead woody cover was highest in Upper Pond (12 percent) compared to Whelan Restoration (5 percent) and the Channel (4 percent). Dead vegetation in Whelan Restoration was primarily red/arroyo willow, whereas most dead vegetation at Upper Pond and the Channel could not be identified.

Vegetation Changes 2006–22

When we examined the cumulative effects of management activities on vegetation structure over time at the Project Area, we detected significant changes from 2006 to 2022 in the Channel (fig. 15). We detected significant negative trends for all height classes above 2 m (2–3 m: $R^2=0.21$,

$P=0.03$; 3–4 m: $R^2=0.14$, $P=0.07$; 4–5 m: $R^2=0.12$, $P=0.09$; 5–6 m: $R^2=0.18$, $P=0.05$; 6–7 m: $R^2=0.30$, $P=0.01$; 7–8 m: $R^2=0.37$, $P=0.00$; greater than 8 m: $R^2=0.60$, $P=0.00$ [fig. 15]). Decreases were steeper during 2008–13 and 2014–16 than during 2006–08. Beginning in 2016, percent foliage cover increased at all height classes. Herbaceous cover doubled between 2016 (13 percent) and 2021 (29 percent) and has remained high through 2022 (22 percent). Although increases were observed at all height classes after 2016, overall percent foliage cover has remained lower than levels detected before 2009.

At Upper Pond, especially in the lower height classes, we detected very few trends or patterns with regard to vegetation cover from 2006 to 2022. Vegetation under 4 m has fluctuated annually with no discernable pattern and, in 2022, had cover levels comparable to what was observed in 2006. For the higher strata, which represented only a small fraction of the overall cover at Upper Pond, we detected a significant negative trend from 2006 to 2022 at the 4–5 m height class (4–5 m: $R^2=0.31$, $P=0.01$ [fig. 16]).

At Whelan Restoration, we detected a significant positive trend for the 5–6 m height class ($R^2=0.12$, $P=0.09$) and a significant negative trend for the highest height class (above 8 m [$R^2=0.34$, $P=0.01$]); however, overall cover in these strata make up only a small percentage of the total cover at this site. The general pattern observed at Whelan Restoration has been one of decline and recovery, with foliage cover declining at all height classes from 2006 to 2010, after which cover has steadily increased at most height classes. Current (2022) cover is similar to 2006 levels for most height classes (fig. 17).

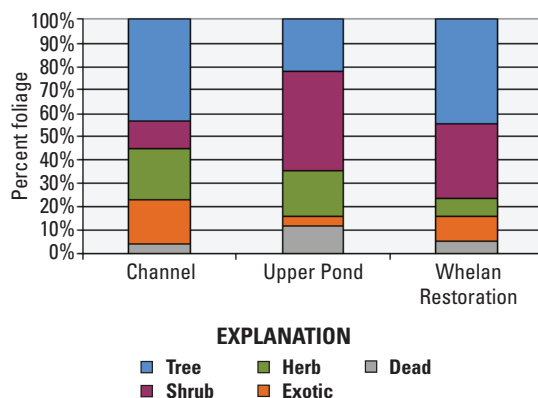


Figure 14. Percent of total foliage cover by vegetation type at Channel, Upper Pond, and Whelan Restoration sites at the San Luis Rey Flood Risk Management Project Area, California, 2022.

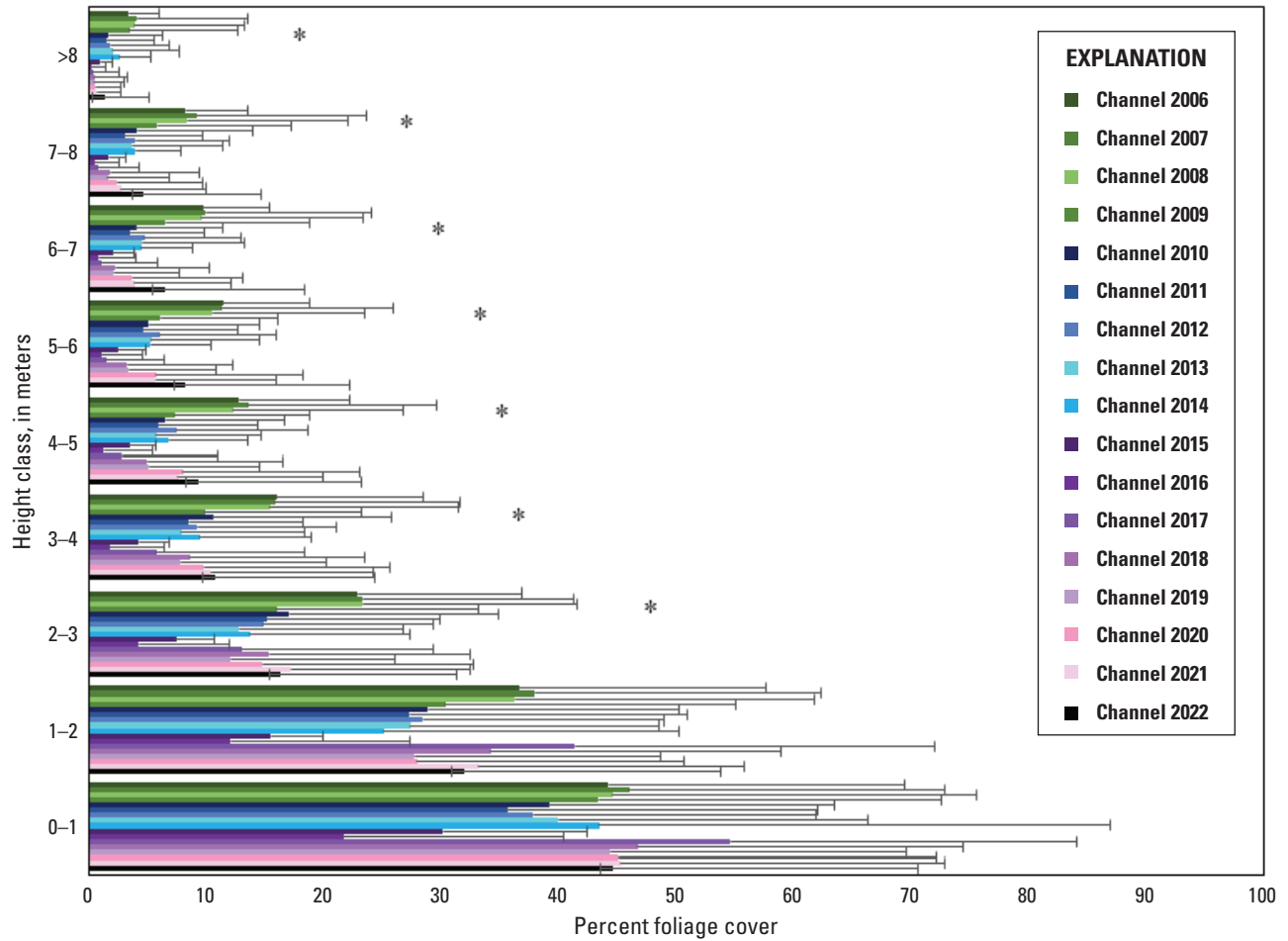


Figure 15. Average percent foliage cover by height class (meters) for the Channel at the San Luis Rey Flood Risk Management Project Area, 2006–22. Bars are standard deviations. Asterisks (*) indicate statistically significant trends ($P \leq 0.10$, linear regression).

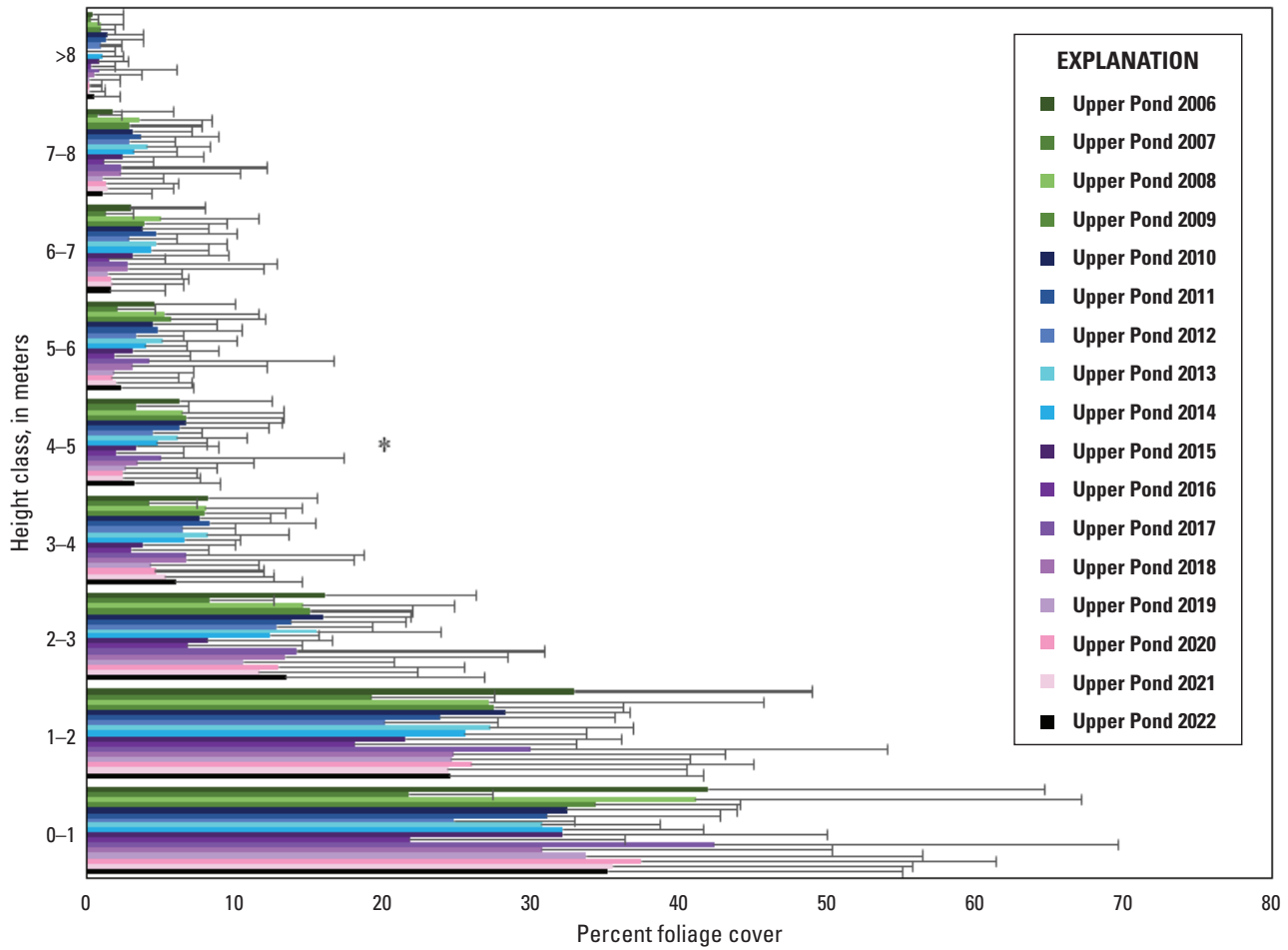


Figure 16. Average percent foliage cover by height class (meters) for Upper Pond at the San Luis Rey Flood Risk Management Project Area, 2006–22. Bars are standard deviations. Asterisks (*) indicate statistically significant trends 2006–22 ($P \leq 0.10$, linear regression).

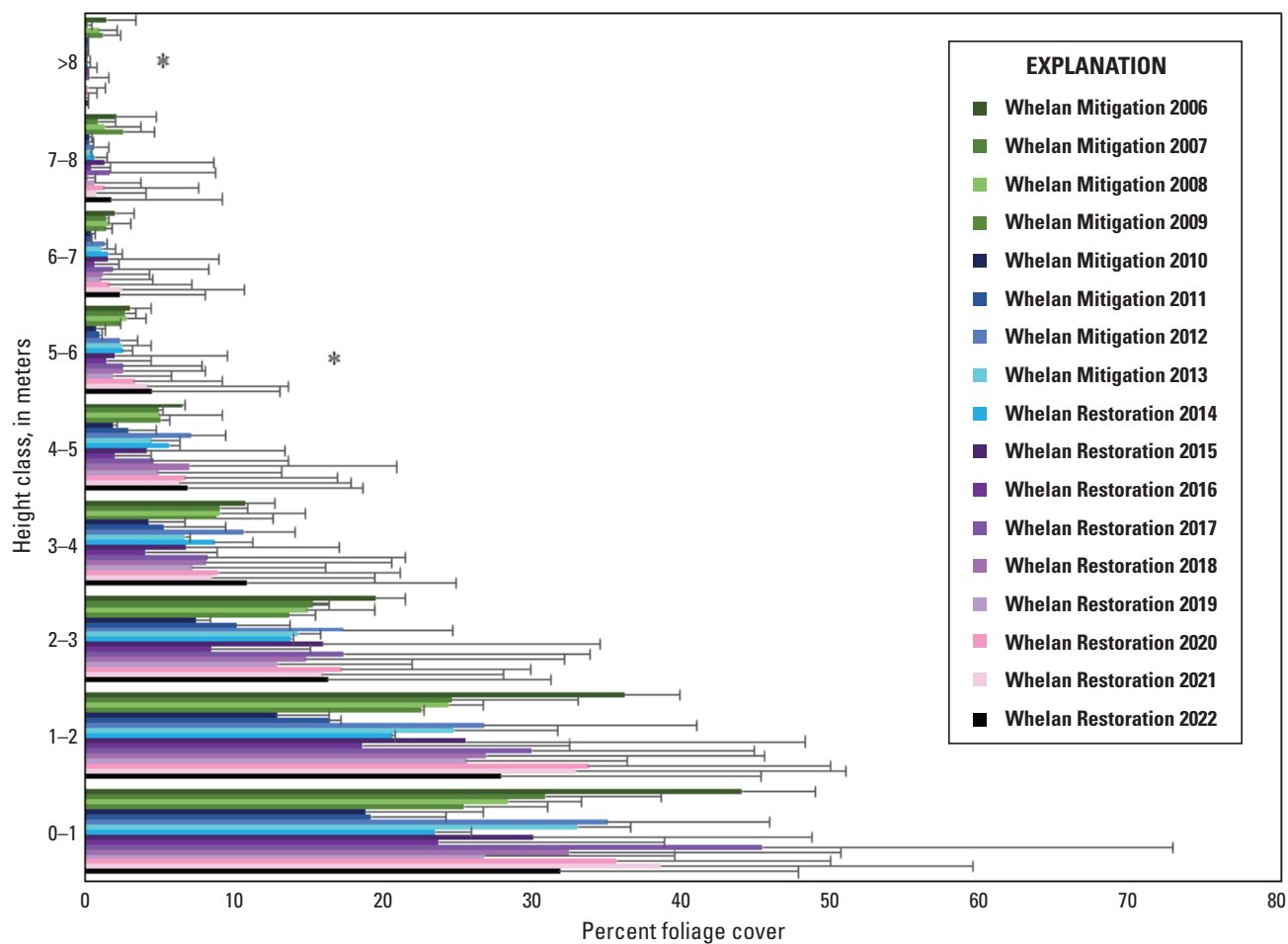


Figure 17. Average percent foliage cover by height class (meters) for Whelan Restoration and Whelan Mitigation at the San Luis Rey Flood Risk Management Project Area, 2006–22. Vegetation points are the same throughout; however, Whelan Restoration was referred to as “Whelan Mitigation” before 2014. Bars are standard deviations. Asterisks (*) indicate statistically significant trends 2006–22 ($P \leq 0.10$, linear regression).

Vireo Habitat Use

We measured vegetation characteristics at 35 nest plots and 35 territory plots (280 sampling points) within the Channel and 9 nest and 9 territory plots (72 sampling points) at Upper Pond. In the Channel, we determined that vireos were selective with regard to territory, establishing territories in areas with greater foliage cover between 3 and 6 m and less cover below 2 m compared to available habitat. With regard to nest selection, we determined that vireos selected nest sites within their territories largely at random, with the exception

that nest sites had more foliage cover between 2 and 3 m than in the rest of the territory (fig. 18). In Upper Pond, the pattern was less clear. Vireos were generally less selective with regard to territory establishment compared to Channel birds, occupying territories with more cover below 1 m and between 5 and 6 m than was available. However, the trend was reversed for nest site selection, with vireos selecting nest sites with less cover below 1 m and between 5 and 6 m relative to available habitat within the territory (fig. 19).

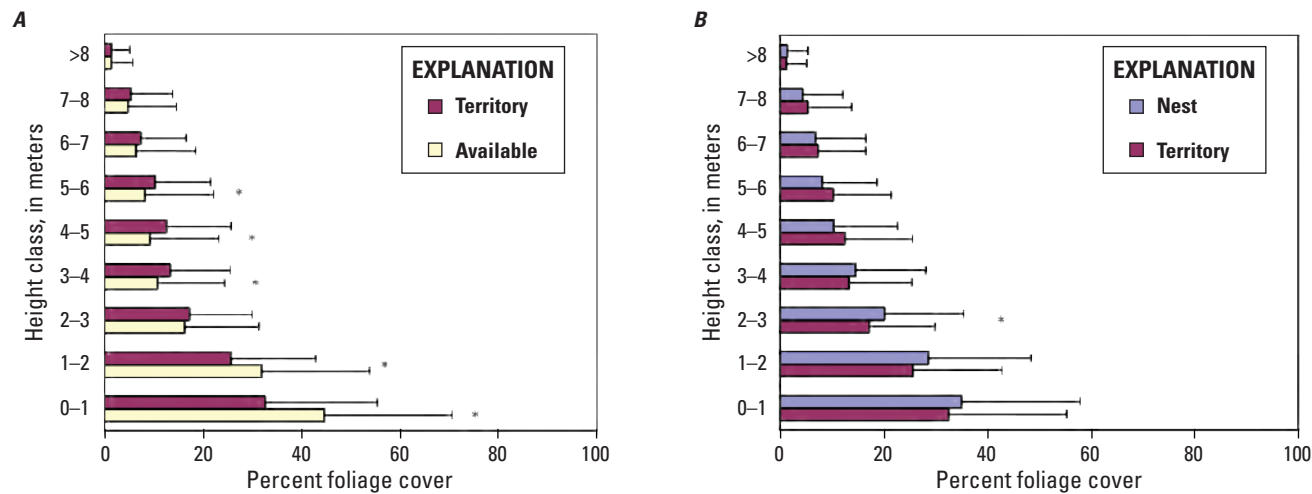


Figure 18. A, Average percent foliage cover for territory plots ($n=35$) compared to vegetation transects ($n=31$; shown as “available”); and B, nest plots ($n=35$) compared to territory plots ($n=35$) by height class in the Channel at the San Luis Rey Flood Risk Management Project Area, California, 2022. Bars are standard deviations. Asterisks (*) denote significant differences between plots by height class ($P \leq 0.10$).

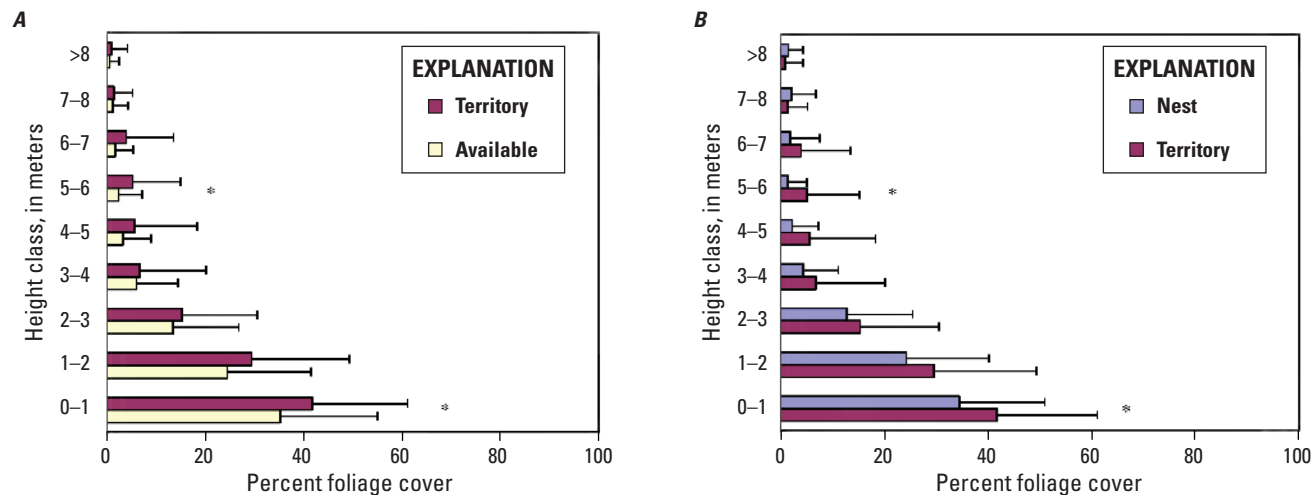


Figure 19. A, Average percent foliage cover for territory plots ($n=9$) compared to vegetation transects ($n=13$; shown as “available”); and B, nest plots ($n=9$) compared to territory plots ($n=9$) by height class in the Upper Pond at the San Luis Rey Flood Risk Management Project Area, California, 2022. Bars are standard deviations. Asterisks (*) denote significant differences between plots by height class ($P \leq 0.10$).

Discussion

The Least Bell's Vireo population (133 territories) at the San Luis Rey Flood Risk Management Project Area increased by 9 percent between 2021 and 2022 and was similar to populations observed in recent years (130 in 2018, 128 in 2019, and 122 in 2021). From the time surveys were initiated in 1984, the population grew steadily until it peaked in 2009, likely the result of an increase in suitable riparian habitat during the 1990s, cowbird control, and high productivity of nesting pairs (Kus and Whitfield, 2005). After the 2009 peak, the population experienced several years of declines before reaching a low of 76 territories in 2012, after which it hovered for 5 years between 78 and 103 territories. In 2018, the population increased and has remained higher (greater than 120 territories) since that time, including a population spike in 2020, likely in response to high productivity in 2019. During the past 5 years, the vireo population in the Project Area has largely tracked regional trends. However, in 2022, we saw a similar increase (4 percent) at MCBCP (U.S. Geological Survey, unpub. data, 2022) but different trends on other drainages with a 10-percent decrease (one territory) at Marine Corps Air Station and an 11-percent decrease (two territories) on the Otay River (K. Ferree, San Diego Natural History Museum, written commun., 2022).

Using the Treatment Index to create a quantitative snapshot in time of the vegetation removal from 2006 through the present incorporates spatial and temporal variability in vegetation structure and provides a useful approach for explaining vireos' reproductive and behavioral responses to habitat alteration. In 2022, like in 2015–21, our analyses did not reveal a relationship between the Treatment Index and reproductive parameters, such as the number of fledglings produced per pair. Vireo territory selection, however, continued to respond to vegetation removal as represented by the Treatment Index. Since 2015, we have determined that vireos have selected territories in less treated habitat and moved to avoid heavily treated areas. In 2022, the average Treatment Index of unoccupied habitat was more than four times that of occupied habitat, indicating an avoidance of more recently treated habitat because vireos selected territories along the Channel edges that have been less affected by mowing. However, unlike in 2016 and 2017, but similar to 2018–21, we did not find an effect of territory treatment on the movement of individual banded birds between 2021 and 2022.

Our analysis of vireo habitat supported the finding that vireos tend to avoid more recently and heavily treated sections of the river when selecting their territories. In the Channel, most of the herbaceous and exotic growth occurred in the middle, where vegetation has been mowed. Vireos tended to avoid the middle of the Channel and instead limited their territories to the edges, where more mature, woody vegetation persisted. Vireo territories in the Channel had less total cover below 2 m and more cover at 3–6 m compared to what was available, which describes the strips of mature habitat along the edges of the Channel. Within territories,

however, Channel vireos placed nests largely at random, selecting nest sites that had slightly more cover between 2 and 3 m, but were otherwise similar to the rest of the territory in vegetation structure. Similar to 2021 but in contrast to historical observations, in Upper Pond, vireos were somewhat selective with regard to territory selection, preferring territories with greater cover from 0 to 1 and from 5 to 6 m. Within territories, however, vireos selected nest sites with less cover in those same height classes. Before 2021, vireos selected territories largely at random and within territories selected nest sites with more cover. Upper Pond continues to have the highest proportion of dead cover compared to Whelan and the Channel, and vireos are likely avoiding the most drought-affected areas dominated by dead vegetation and selecting territories in habitat that is recovering.

Since mowing of the Channel began in 2005, we have documented a steady decline in total percent foliage cover at all height classes above 2 m. Steeper annual declines in percent cover coincided with large mowing events. Herbaceous (native and exotic) cover recovered quickly after mowing and made up the bulk of the vegetation in the Channel in 2022, in contrast to Upper Pond and Whelan Restoration, which had a greater proportion of shrub cover. In general, shrub cover has not recovered in the Channel (and was limited to the Channel edges) because significant negative trends were detected for all height classes over 2 m. We detected fewer significant negative trends from 2006 to 2022 in percent foliage cover at Upper Pond and Whelan Restoration. At Upper Pond, we documented annual fluctuations, likely primarily in response to environmental conditions, such as variations in annual precipitation. At Whelan Restoration, we documented an initial decline at most height classes, likely in response to drought, followed by steady increases in vegetation cover as it has recovered to 2006 levels.

Nest success was similar in 2022 (38 percent of completed nests successful) and 2021 (39 percent of completed nests successful) and did not differ by site type. Vireo breeding productivity was slightly higher in 2022 (2.2 young per pair) compared to 2021 (1.9 young per pair) but remained lower than the 16-year average. Double-brooding was low for the third year in a row, which is well below the long-term average. Lower breeding productivity in 2022 is likely, in part, a response to increased cowbird parasitism and low precipitation (20.0 centimeters [cm] for the 2021–22 bio-year). Precipitation influences primary productivity, with drier years producing limited annual vegetation growth, which limits cover available for foraging, arthropod abundance, and nesting cover for vireos. We have documented strong links between vireo productivity and precipitation since 2006, with years of highest breeding productivity (greater than 2.5 young per pair) occurring in years with higher precipitation (greater than 30 cm, 2008, 2010, 2017, and 2019) and years of lowest breeding productivity (less than 2 young per pair) occurring in years with lower precipitation (less than 15 cm, 2014 and 2021).

Parasitism by Brown-headed Cowbirds has increased dramatically during the past 2 years. With only two exceptions (2009 and 2014), before 2021, we had never documented more than seven instances of cowbird parasitism per year in the Project Area, and between 2015 and 2019, the maximum number of nests parasitized in a year was two. In 2021, however, we documented 35 instances of parasitism. In 2021, we attributed the increase in cowbird parasitism to a delay in the traps being opened. Cowbird trapping typically begins on April 1 of each year, but in 2021, traps in the Project Area were not opened until late April. Historically, the majority of cowbirds have been captured and removed from the population during the month of April (J.Sexton, T.W. Biological Services, written commun., 2021). Having the traps closed during April likely allowed cowbirds to become established on the river during that time.

In 2022, although the traps in the Project Area were opened on time, there was a delay in opening traps at MCBCP, where cowbird traps were not opened until late May (B. Leatherman, Leatherman BioConsulting, Inc., written commun., 2022). Although no instances of parasitism were documented in vireo monitoring areas at MCBCP, a male vireo was seen outside of the monitoring sites feeding a cowbird fledgling. In addition, cowbirds were detected on a higher proportion of MCBCP surveys than in any other year (45 percent of surveys in 2022, compared with the 2006–21 average of 14 percent of surveys; U.S. Geological Survey, unpub. data, 2022). It is possible that the delay in opening traps at MCBCP may have contributed to the high rates of parasitism observed in the Project Area.

Banding of vireos with unique color combinations (starting in 2006) has allowed us to estimate adult and first-year survival rates and examine adult and first-year movement between and within years at the Project Area and across drainages throughout southern California. Since 2020, however, the number of banded birds in the Project Area has been declining. In 2022, we documented only 52 banded vireos, which is down from 108 in 2019 and 2020. This decrease is, in part, a result of our reduced effort to band unmarked adults, but it does not explain why we also continue to have fewer banded birds in older age classes. In 2022, we did not have any birds older than 7 years. Of the banded birds in the Project Area in 2022, only eight (15 percent) were banded before 2019. There has been a steady decline in the oldest age classes since 2017. Recent annual survival estimates reflect this trend, with lower-than-average estimates of survival for the last 3 years. Adult vireo site fidelity, although remaining high (61 percent), also has been declining since 2019, when 75 percent of banded adults returned to within 100 m of their previous year's territory.

Beginning in 2012, and especially between 2014 and 2016, we detected a shift in the proportion of first-year vireos returning to the Project Area to breed, with more birds dispersing to areas outside of the Project Area. This shift may be attributed to a decrease in available habitat within the Project Area, likely a result of increased vegetation removal in 2014 and 2015 coupled with drought conditions. Between 2017 and 2021 the trend shifted, with first-year vireos more likely to return to the Project Area for breeding. This shift also coincided with increased precipitation in 3 of the 5 years and more moderate mowing, which has likely contributed to an increase in habitat available for new breeders in the Project Area. In 2022, however, we documented only one returning first-year vireo, whereas two dispersed out of the Project Area for a first-year return rate of just 33 percent. The low return of first-year birds in 2022 was likely influenced by poor capture success of natal vireos. There were nine birds observed with a single blue metal band (identifying that they were banded as nestlings in the Project Area) that we were unable to capture and identify this year. Many of these birds were likely first-year vireos.

Southwestern Willow Flycatcher

There were not any breeding pairs of flycatchers detected in 2022; this was the 16th year that the Project Area has not been occupied by Willow Flycatchers since it was colonized and monitoring began in 2000 (Kus and Rourke, 2005). It is unknown why flycatchers did not breed in the Project Area, although conditions in the historical flycatcher territories have been gradually changing since 2006, when three pairs occupied the Project Area. At Whelan Restoration in particular, large canopy trees such as red/arroyo willows and black willows have died. This historic breeding habitat is likely still too dry, sparse, and open for flycatchers.

Vegetation clearing does not appear to have played a role in the decline of the flycatcher in the San Luis Rey Flood Risk Management Project Area population. More likely explanations, in addition to habitat change, include other life history factors, such as first-year or adult mortality experienced during migration or on the wintering grounds. At nearby Marine Corps Base Camp Pendleton, the resident population of flycatchers also declined for 10 years, from 26 individuals in 2007 to 0 individuals in 2017 (S. Howell, U.S. Geological Survey, unpub. data, 2017). In 2018, a social attraction study commenced at Camp Pendleton. In 2018–21, there were between one and three resident breeders documented; however, there were no breeders documented in 2022 (S. Howell, U.S. Geological Survey, unpub. data, 2018, 2019, 2020, 2021, 2022). Collection of more information is warranted for this declining species.

Conclusion

The vireo population increased slightly in 2022 and was comparable to population levels during the past several years, which have been high relative to the long-term averages. Nest success and productivity, although higher than in 2021, remain lower than average, which is likely in response to increased levels of cowbird parasitism and lower-than-average precipitation in the preceding winter. Although we continued to find no effect of vegetation treatment on measures of reproductive success, we did find a strong effect of treatment on vireo territory selection. For the past 8 years, we have documented an avoidance of recently treated habitat, even in years in which there was no treatment, indicating that vireos require more than 1 year of habitat recovery between mowing events for territory selection. Mowing of the channel has resulted in two distinct habitat types, neither of which is ideal for vireos. The herbaceous middle of the Channel is too dense in the lower height classes, lacks canopy cover, and has less woody substrate that vireos prefer for nesting. The edges of the Channel are possibly becoming too mature, lacking cover diversity in the lower height classes. A gradient in habitat successional stages within the Project Area and increased cowbird trapping could help to ensure that vireos will be able to continue breeding successfully in the Project Area.

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Appendix 1.

Table 1.1. Timeline and description of vegetation treatments at the San Luis Rey Flood Risk Management Project Area, California, 2005–22.

[ha, hectare; —, no data; m, meter; km, kilometer; GPS, Global Positioning System]

Date	Vegetation treatment	Vegetation management	Treatment location	Area [ha (acres)]	Comments
December 2005	Giant reed removal	First phase of Risk Reduction ¹ was to remove large stands of giant reed.	Reaches 2–4	9.4 (23.2)	Giant reed was mowed using a large mower with biomass chipped or shredded <i>in situ</i> .
March 2006	Vegetation removal	Second phase of Risk Reduction was to mow/mulch vegetation 30 m wide.	Reaches 2–4	18.0 (44.5)	30-m swath of vegetation in the river channel from Benet Road to College Boulevard (7.5 km) was mowed and mulched, overlapping when possible with the giant reed eradication areas.
2006 Least Bell's Vireo breeding season (April–July)					
October 2006	Herbicide treatment	Giant reed sprayed with herbicide.	Reach 4 (below College Boulevard)	0.4 (1.0)	This spraying was an experimental effort to see if the herbicide after mowing approach would be effective.
2007 Least Bell's Vireo breeding season (April–July)					
November–December 2007	Herbicide treatment	Giant reed sprayed with herbicide.	Reach 1 (Benet Road to Interstate 5 and south of main river channel)	11.9 (29.4)	—
February–March 2008	Vegetation removal	First Phase 1 ² mowing, not completed.	Reach 1	6.5 (16.1)	Only 7 days of mowing completed before rains and vireo breeding season began.
2008 Least Bell's Vireo breeding season (April–July)					
July 2008	Herbicide treatment	Pepperweed sprayed.	Reach 1 (downstream of Benet Road)	0.08 (0.2)	—
September–December 2008	Vegetation removal	First Phase 1 mowing.	Reaches 2–4	37.9 (93.7)	Phase 1 mowing continued after vireo breeding season.
September–October 2008	Giant reed removal and herbicide treatment	Re-treatment of giant reed sprayed in 2005.	Reaches 2–4	2.3 (5.7)	Extensive mowing and chemical re-treatment of some giant reed areas that had been targeted in 2005 were done from Benet Road to College Boulevard. This completed the initial clearing of Phase 1.
March 2009	Herbicide treatment	Re-treatment of giant reed sprayed in 2005.	Reaches 3b and 4	3.2 (7.9)	—
2009 Least Bell's Vireo breeding season (April–July)					
October–November 2009	Vegetation removal	Mowing with material hand-removed.	Reach 1	5.1 (12.6)	—

Table 1.1. Timeline and description of vegetation treatments at the San Luis Rey Flood Risk Management Project Area, California, 2005–22.—Continued

[ha, hectare; —, no data; m, meter; km, kilometer; GPS, Global Positioning System]

Date	Vegetation treatment	Vegetation management	Treatment location	Area [ha (acres)]	Comments
October–December 2010	Herbicide treatment	Giant reed sprayed.	Reach 1	8.2 (20.3)	—
2010 Least Bell's Vireo breeding season (April–July)					
December 2010	Vegetation removal	Second Phase 1 mowing not completed.	Reaches 3a and 3b	8.8 (21.7)	Phase 1 mowing by the City of Oceanside. Mowing not completed because of rains.
February 2011	Herbicide treatment	Giant reed sprayed with herbicide.	Reach 1	5.0 (12.4)	Resprouted giant reed was sprayed with herbicide within the area of Reach 1 that was mowed in 2009.
2011 Least Bell's Vireo breeding season (April–July)					
August–December 2011	Herbicide treatment	Weed eradication throughout Project Area, except annually mowed area.	Reaches 1–4	34.4 (85.0)	Benet Road to Interstate 5 and College Boulevard to 152 m downstream from Fousat Road were treated before stopping for the season. Lower Pond, Tuley Canyon, and Park Pond also treated.
September–October 2011	Vegetation removal	Third Phase 1 mowing completed.	Reaches 1, 2, and 4	32.8 (81.1)	Phase 1 mowing by the City of Oceanside.
2012 Least Bell's Vireo breeding season (April–July)					
July–September 2012	Herbicide treatment	Giant reed sprayed in Phase 1 mowed area.	Reaches 2–4	— ³	—
October–November 2012	Herbicide treatment	Giant reed sprayed.	Reach 1 (west of Benet Road, north side of the river channel)	— ³	—
November–December 2012	Vegetation removal	First Phase 2 ⁴ mowing completed, all reaches.	Reaches 1–4	18.1 (44.7)	—
October 2012	Active restoration	Planting started.	Reach 1	11.9 (29.4)	—
2013 Least Bell's Vireo breeding season (April–July)					
September 2013–January 2014	Exotic vegetation removal	Exotic plant and tree removal throughout Project Area.	Reaches 1–4, Upper Pond, Whelan Mitigation	— ³	No GPS data recorded so exact location and acreage affected is not available.
March–April 2014	Pole cuttings	Remedial planting	Reaches 1, Reach 2, Reach 3a and Reach 3b	0.2 (0.5)	—
2014 Least Bell's Vireo breeding season (April–July)					
October 2014	Vegetation removal	Phase 1, Phase 2, Rotation 1	Reaches 1–4	56.0 (138.4)	—
September–November 2014	Active restoration	Planting early March; Bi-monthly watering, herbicide treatment and weed control	Reach 1	11.9 (29.4)	—

Table 1.1. Timeline and description of vegetation treatments at the San Luis Rey Flood Risk Management Project Area, California, 2005–22.—Continued

[ha, hectare; —, no data; m, meter; km, kilometer; GPS, Global Positioning System]

Date	Vegetation treatment	Vegetation management	Treatment location	Area [ha (acres)]	Comments
March–November 2014	Active restoration	Planting early March; Bi-monthly watering, herbicide treatment and weed control	Reach 4	0.4 (1.0)	—
March–November 2014	Active restoration	Earthwork March 6–April 20, 2014; Planting May–June 2014; Bi-weekly watering May–November 2014	Whelan Mitigation	10.5 (25.9)	—
2015 Least Bell's Vireo breeding season (April–July)					
November–December 2015	Vegetation removal	Annual mowing Phase 1, Phase 2, and Phase 3; Rotational mowing Rotation 1 and Rotation 2	Reaches 1–4	65.8 (162.6)	—
December 2015–January 2016	Restoration enhancement	Manual trimming and mowing	Upper Pond	2.5 (6.2)	—
December 2015–January 2016	Restoration enhancement	Manual trimming and mowing	Park Pond	4.0 (9.9)	—
December 2015–January 2016	Restoration enhancement	Manual trimming and mowing	Reach 3a	0.1 (0.2)	—
2016 Least Bell's Vireo breeding season (April–July)					
October–November 2016	Herbicide treatment	Spraying	Project-wide	18.3 (45.1)	Hand spraying of exotic weeds throughout Project Area.
2017 Least Bell's Vireo breeding season (April–July)					
September–October 2017	Vegetation removal	Annual mowing Phase 1 and boundary mowing	Reach 1, 3, 4	28.2 (69.7)	Boundary mowing occurred in Reach 1 in preparation for sediment removal.
November 2017	Restoration enhancement	Herbicide spraying	Upper Pond and Park Pond	— ³	Spraying and cutting of exotic weeds in Upper Pond and Park Pond. No GIS data collected to calculate area.
February 2018	Vegetation removal	Giant reed cut and removed	Upper Pond and Park Pond	— ³	Giant reed was cut and removed from Upper Pond and Park Pond. No GIS data collected to calculate area.
2018 Least Bell's Vireo breeding season (April–July)					
Fall 2018	Vegetation removal	Annual mowing Phase 1 and Phase 2	Reach 2	16.2 (40.1)	—
April 2018	Herbicide spraying	Weed eradication	Upper Pond and Park Pond	— ³	Herbicide applied to exotic weeds around pole plantings in Upper Pond and Park Pond. No GIS data collected to calculate area.

Table 1.1. Timeline and description of vegetation treatments at the San Luis Rey Flood Risk Management Project Area, California, 2005–22.—Continued

[ha, hectare; —, no data; m, meter; km, kilometer; GPS, Global Positioning System]

Date	Vegetation treatment	Vegetation management	Treatment location	Area [ha (acres)]	Comments
November–December 2019	Vegetation removal	Annual mowing Phase 1 and Phase 2	2019 Least Bell's Vireo breeding season (April–July) Reaches 1–4	31.2 (77.2)	—
November–December 2020	Herbicide spraying	Herbicide Spraying	2020 Least Bell's Vireo breeding season (April–July) Reach 1 and Whelan restoration	— ³	Spraying of exotic weeds in restoration areas. No GPS data recorded so exact location and acreage affected is not available.
November–December 2021	Vegetation removal	Annual mowing Phase 1 and Phase 2	2021 Least Bell's Vireo breeding season (April–July) Reaches 1–4	31.8 (78.5)	—

¹Risk Reduction was implemented in 2005 to reduce the risk of flooding during the 2006 rainy season.²Phase 1 mowing was the first phase of the San Luis Rey Flood Risk Management Project to remove vegetation from the San Luis Rey River flood control channel to reduce the risk of flooding.³Acreage not available.⁴Phase 2 mowing includes mowing associated with maintaining the Phase 1 mowed area.

Figure 2.1. Locations of Least Bell's Vireo territories in the Reach 1, Lower Pond, and Tuley Canyon survey sites at the San Luis Rey Flood Risk Management Project Area, California, 2022.



Figure 2.2. Locations of Least Bell's Vireo territories and nests in the Reach 2 survey site at the San Luis Rey Flood Risk Management Project Area, California, 2022.

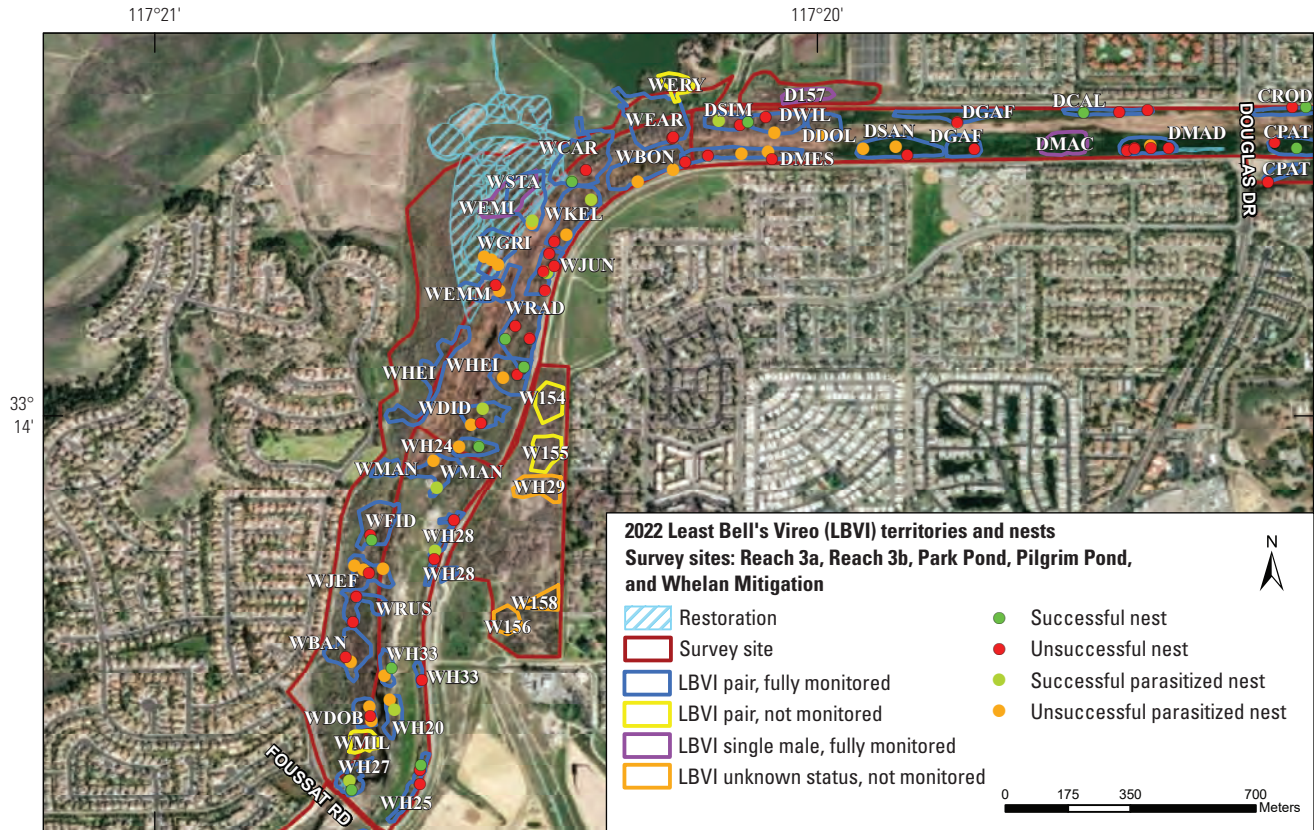


Figure 2.3. Locations of Least Bell's Vireo territories and nests in the Reach 3a, Reach 3b, Park Pond, Pilgrim Pond, and Whelan Mitigation survey sites at the San Luis Rey Flood Risk Management Project Area, California, 2022.

Appendix 3.

Table 3.1. Status and nesting activities of Least Bell's Vireos at the San Luis Rey Flood Risk Management Project Area, California, 2022

[Nest fate: INC, nest never completed; OTH, reason for nest failure known, such as substrate failure; PAR, failed as a result of Brown-headed Cowbird parasitism; PRE, nest failure caused by predation event; SUC, fledged at least one Least Bell's Vireo young; UNK, reason for nest failure/abandonment unknown. **Abbreviations:** —, no data; BHCO, Brown-headed Cowbird]

Survey site	Territory	Nest	Nest fate	Number fledged	Comments
Channel					
Reach 2	FAQU	1	PRE	0	—
Reach 2	FBRI	1	PRE	0	—
Reach 2	FO2	1	SUC	4	—
Reach 2	FO5	1	SUC	4	—
Reach 2	FO6	1	SUC	3	—
Reach 2	FNER	1	SUC	4	—
Reach 2	FRAS	1	SUC	4	—
Reach 2	FO7	1	PRE	0	—
Reach 2	FGOO	1	SUC	3	—
Reach 2	FO40	1	PAR	0	Failed with one BHCO egg.
Reach 2	FAQU	2	PRE	0	Removed one BHCO egg.
Reach 2	FBRI	2	SUC	2	Removed one BHCO egg.
Reach 2	FO2	2	PRE	0	—
Reach 2	FO5	2	UNK	0	Abandoned with eggs.
Reach 2	FO7	2	PRE	3	—
Reach 2	FO11	1	PRE	0	—
Reach 2	FO40	2	PRE	0	—
Reach 2	FNER	2	UNK	0	Removed one BHCO egg, abandoned.
Reach 2	FRAS	2	PRE	0	—
Reach 2	FO5	3	SUC	3	—
Reach 2	FO2	3	SUC	3	—
Reach 3a	WBON	1	PRE	0	Removed two BHCO eggs.
Reach 3a	WCAR	1	PRE	0	—
Reach 3a	WDID	1	PRE	0	Removed one BHCO egg.
Reach 3a	WJUN	2	INC	0	—
Reach 3a	WJUN	3	PRE	0	—
Reach 3a	WKEL	1	UNK	0	Eggs never confirmed.
Reach 3a	WH24	1	PRE	0	Removed one BHCO egg.
Reach 3a	WH25	1	PRE	0	—
Reach 3a	WH25	2	PRE	0	—
Reach 3a	WH27	1	SUC	3	—
Reach 3a	WH28	1	PRE	0	—
Reach 3a	WH33	1	UNK	0	Eggs never confirmed.
Reach 3a	WH33	2	PRE	0	Removed one BHCO egg.
Reach 3a	WDID	2	PRE	0	—
Reach 3a	WHEI	1	PAR	0	Removed two BHCO eggs, but nest failed prior to removal.
Reach 3a	WJUN	4	SUC	2	Removed one BHCO egg.

Table 3.1. Status and nesting activities of Least Bell's Vireos at the San Luis Rey Flood Risk Management Project Area, California, 2022—Continued

[Nest fate: INC, nest never completed; OTH, reason for nest failure known, such as substrate failure; PAR, failed as a result of Brown-headed Cowbird parasitism; PRE, nest failure caused by predation event; SUC, fledged at least one Least Bell's Vireo young; UNK, reason for nest failure/abandonment unknown. **Abbreviations:** —, no data; BHCO, Brown-headed Cowbird]

Survey site	Territory	Nest	Nest fate	Number fledged	Comments
Channel—Continued					
Reach 3a	WEMM	1	PRE	3	Removed one BHCO egg.
Reach 3a	WKEL	2	PRE	0	Removed one BHCO egg.
Reach 3a	WMAN	1	PAR	0	Removed two BHCO eggs, but nest failed prior to removal.
Reach 3a	WMAN	2	SUC	2	Removed one BHCO egg.
Reach 3a	WRAD	1	INC	0	—
Reach 3a	WRAD	2	UNK	0	Eggs never confirmed.
Reach 3a	WH20	1	PRE	0	Removed one BHCO egg.
Reach 3a	WH24	2	SUC	3	—
Reach 3a	WH25	3	SUC	2	—
Reach 3a	WH28	2	PRE	0	—
Reach 3a	WH33	3	SUC	3	—
Reach 3a	WRAD	3	UNK	0	Eggs never confirmed.
Reach 3a	WBON	2	PRE	3	Removed one BHCO egg.
Reach 3a	WKEL	3	SUC	2	Removed one BHCO egg.
Reach 3a	WRAD	4	SUC	3	—
Reach 3a	WHEI	2	SUC	1	—
Reach 3a	WDID	3	SUC	3	Removed one BHCO egg.
Reach 3a	WH28	3	SUC	3	Removed one BHCO egg.
Reach 3a	WH20	2	SUC	2	Removed one BHCO egg.
Reach 3a	WH27	2	SUC	2	Removed one BHCO egg.
Reach 3a	WEMM	2	UNK	0	Eggs never confirmed.
Reach 3a	WCAR	2	SUC	4	—
Reach 3a	WEAR	1	INC	0	—
Reach 3a	WEAR	2	UNK	0	Eggs never confirmed.
Reach 3a	WJUN	5	INC	0	—
Reach 3a	WJUN	1	UNK	0	Found after it had failed.
Reach 3b	DCAL	1	UNK	0	Eggs never confirmed.
Reach 3b	DGAF	1	PRE	0	—
Reach 3b	DMAD	1	INC	0	—
Reach 3b	DMES	1	INC	0	—
Reach 3b	DSIM	1	PRE	0	—
Reach 3b	DWIL	1	PRE	0	—
Reach 3b	DCAL	2	UNK	0	Eggs never confirmed.
Reach 3b	DCAL	3	SUC	3	—
Reach 3b	DDOL	1	PRE	0	Removed one BHCO egg.
Reach 3b	DMAD	2	UNK	0	Eggs never confirmed.
Reach 3b	DMES	2	PRE	0	—
Reach 3b	DMES	3	PAR	0	Failed with one BHCO egg.
Reach 3b	DSAN	1	PAR	0	Failed with two BHCO eggs.

Table 3.1. Status and nesting activities of Least Bell's Vireos at the San Luis Rey Flood Risk Management Project Area, California, 2022—Continued

[Nest fate: INC, nest never completed; OTH, reason for nest failure known, such as substrate failure; PAR, failed as a result of Brown-headed Cowbird parasitism; PRE, nest failure caused by predation event; SUC, fledged at least one Least Bell's Vireo young; UNK, reason for nest failure/abandonment unknown. **Abbreviations:** —, no data; BHCO, Brown-headed Cowbird]

Survey site	Territory	Nest	Nest fate	Number fledged	Comments
Channel—Continued—Continued					
Reach 3b	DSAN	2	UNK	0	Eggs never confirmed.
Reach 3b	DSIM	2	SUC	1	Removed two BHCO eggs.
Reach 3b	DWIL	2	PAR	0	Failed with two BHCO eggs.
Reach 3b	DGAF	2	PRE	0	—
Reach 3b	DMAD	3	UNK	0	Eggs never confirmed.
Reach 3b	DMAD	4	OTH	0	Egg laid and then removed by female.
Reach 3b	DMAD	5	OTH	0	Failed with one LBVI and one BHCO egg under the nest.
Reach 3b	DMES	4	PRE	0	Removed one BHCO egg.
Reach 3b	DSAN	3	PRE	0	Removed one BHCO egg.
Reach 3b	DWIL	3	SUC	1	—
Reach 3b	DMES	5	INC	0	—
Reach 4	CJAS	1	UNK	0	Eggs never confirmed.
Reach 4	CJAS	2	SUC	2	—
Reach 4	CPAT	1	INC	0	—
Reach 4	CACD	1	PRE	0	—
Reach 4	CBIL	1	SUC	2	—
Reach 4	CDIA	1	SUC	3	—
Reach 4	CMAC	1	INC	0	—
Reach 4	CROD	1	PRE	0	—
Reach 4	CROD	2	SUC	1	—
Reach 4	CSOC	1	SUC	4	—
Reach 4	C21P	1	UNK	0	Eggs never confirmed.
Reach 4	C21P	2	PRE	0	—
Reach 4	CBAN	1	SUC	3	—
Reach 4	CBON	1	PRE	0	—
Reach 4	CIRO	1	SUC	3	—
Reach 4	CLAD	1	INC	0	—
Reach 4	CMET	1	INC	0	—
Reach 4	CPAS	1	SUC	4	—
Reach 4	CPOW	1	PRE	0	—
Reach 4	CSAT	1	SUC	2	—
Reach 4	CSCH	1	OTH	0	Infertile eggs.
Reach 4	CJAS	3	PRE	0	—
Reach 4	CPAT	3	SUC	3	—
Reach 4	CACD	2	SUC	3	—
Reach 4	CBOB	2	PRE	0	—
Reach 4	CBOB	1	PRE	0	—
Reach 4	CCHA	1	PRE	0	—
Reach 4	CHOO	1	SUC	3	—

Table 3.1. Status and nesting activities of Least Bell's Vireos at the San Luis Rey Flood Risk Management Project Area, California, 2022—Continued

[Nest fate: INC, nest never completed; OTH, reason for nest failure known, such as substrate failure; PAR, failed as a result of Brown-headed Cowbird parasitism; PRE, nest failure caused by predation event; SUC, fledged at least one Least Bell's Vireo young; UNK, reason for nest failure/abandonment unknown. **Abbreviations:** —, no data; BHCO, Brown-headed Cowbird]

Survey site	Territory	Nest	Nest fate	Number fledged	Comments
Channel—Continued—Continued—Continued					
Reach 4	CMET	2	SUC	4	—
Reach 4	CMYS	1	SUC	2	—
Reach 4	CNED	1	SUC	2	—
Reach 4	CPOW	2	PRE	0	—
Reach 4	CSAT	2	INC	0	—
Reach 4	CSCH	2	SUC	3	—
Reach 4	CSOC	2	SUC	2	—
Reach 4	CSPK	1	PRE	0	—
Reach 4	C21P	3	SUC	4	—
Reach 4	CCHC	1	SUC	3	—
Reach 4	CLAD	2	PRE	0	—
Reach 3a	WSTA	1	PAR	0	Failed with one BHCO egg.
Reach 3a	WSTA	2	SUC	2	Removed one BHCO egg.
Reach 3a	WDOB	2	UNK	0	Eggs never confirmed.
Reach 3a	WDOB	3	PRE	0	Removed one BHCO egg.
Reach 3a	WJEF	3	PAR	0	Failed with one BHCO egg.
Off-channel					
Upper Pond	CPAT	2	PRE	0	—
Upper Pond	CSTA	1	INC	0	—
Upper Pond	CSTA	2	PRE	0	—
Upper Pond	CBUT	1	SUC	3	—
Upper Pond	CRED	1	PRE	0	—
Upper Pond	CSAN	1	INC	0	—
Upper Pond	CSNE	1	PRE	0	—
Upper Pond	CACA	1	PRE	0	—
Upper Pond	CQTI	1	SUC	2	—
Upper Pond	CSNE	2	SUC	3	—
Upper Pond	CACA	2	SUC	3	—
Upper Pond	CCOT	1	PRE	0	—
Upper Pond	CRED	2	SUC	3	—
Upper Pond	CSAN	2	SUC	3	—
Upper Pond	CSCR	1	SUC	3	—
Upper Pond	CSTA	3	PRE	0	—
Upper Pond	CSTA	4	SUC	3	—
Whelan Mitigation	WBAN	1	UNK	0	Eggs never confirmed but found ripped down.
Whelan Mitigation	WBAN	2	PRE	0	Removed one BHCO egg.
Whelan Mitigation	WFID	1	SUC	3	—
Whelan Mitigation	WJEF	1	PRE	0	Removed one BHCO egg.
Whelan Mitigation	WDOB	1	PRE	0	Removed one BHCO egg.

Table 3.1. Status and nesting activities of Least Bell’s Vireos at the San Luis Rey Flood Risk Management Project Area, California, 2022—Continued

[Nest fate: INC, nest never completed; OTH, reason for nest failure known, such as substrate failure; PAR, failed as a result of Brown-headed Cowbird parasitism; PRE, nest failure caused by predation event; SUC, fledged at least one Least Bell’s Vireo young; UNK, reason for nest failure/abandonment unknown. **Abbreviations:** —, no data; BHCO, Brown-headed Cowbird]

Survey site	Territory	Nest	Nest fate	Number fledged	Comments
Off-channel—Continued					
Whelan Mitigation	WRUS	1	PRE	0	—
Whelan Mitigation	WRUS	2	OTH	0	Eggs never hatched.
Whelan Mitigation	WJEF	4	PRE	0	Removed one BHCO egg.
Whelan Mitigation	WFID	2	INC	0	—
Whelan Mitigation	WJEF	2	UNK	0	Found after it had failed.
Restoration					
Whelan Mitigation	WGRI	1	PRE	0	Removed one BHCO egg.
Whelan Mitigation	WGRI	2	PRE	4	Removed one BHCO egg.
Whelan Mitigation	WGRI	3	PAR	0	Removed one BHCO egg.

Appendix 4.

Table 4.1. Banded adult Least Bell's Vireos at the San Luis Rey Flood Risk Management Project Area, California, 2022

[**Band combination:** unique combination of colored leg bands: BKBK, plastic black; BKYE, plastic black-yellow split; BPST, plastic black-pink striped; BWST, plastic blue-white striped; BYST, plastic black-yellow striped; DBDP, plastic dark blue-dark pink split; DBWH, plastic dark blue-white split; DPDB, plastic dark pink-dark blue split; DPDP, plastic dark pink; DPWH, plastic dark pink-white split; gogo, metal gold; Mdb, dark blue numbered federal band; Mgo, gold numbered federal band; pupu, metal purple; PUPU, plastic purple; PUWH, plastic purple-white split; PUYE, plastic purple-yellow split; WHDB, plastic white-dark blue split; WHDP, plastic white-dark pink split; WHPU, plastic white-purple split; WHWH, plastic white; YEBK, plastic yellow-black split; YEPU, plastic yellow-purple split; YEYE, plastic yellow. **Age:** Exact age determined from uniquely numbered metal band observed during recapture; estimated age applies to an unbanded bird captured as an adult. **Sex:** M, male; F, female. **Abbreviations:** yr, year; ≥, greater than or equal to]

Territory	Band combination (left leg:right leg)	Age	Sex	Comments
BBOA	DBWH Mdb:PUYE	2 yrs	M	Banded as a nestling in FO12 territory in 2020. Color banded in BBOA territory in 2021.
BFIL	PUWH Mdb:PUYE	2 yrs	M	Banded as a nestling in FNER territory in 2020. Color banded in BFIL territory in 2021.
BKEN	YEBK:WHDP Mdb	3 yrs	M	Banded as a nestling in CJET territory in 2019. Color banded in DNIC territory in 2021.
BPAM	?:PUYE	≥1 yr	M	Banded at the San Luis Rey River before 2022.
BT02	pupu:PUWH Mdb	1 yr	M	Banded as a nestling in FO8 territory in 2021. Color banded in BT02 territory in 2022.
BT03	WHPU Mdb:PUYE	2 yrs	M	Banded as a nestling in FGOO territory in 2020. Color banded in BBUT territory in 2021.
BTOK	BYST Mdb:PUYE	2 yrs	M	Banded as a nestling in FGOO territory in 2020. Color banded in BTOK territory in 2021.
BTOK	BPST:Mdb	3 yrs	F	Banded as a nestling in WH25 territory in 2019. Color banded in BFIL territory in 2020.
CACA	BWST Mdb:WHPU	≥1 yr	M	Banded as an adult in CACA territory in 2022.
CBAN	PUWH Mdb:DBDP	≥4 yrs	M	Banded as an adult in CDIA territory in 2019.
CBIL	:Mdb	≥1 yr	F	Banded as a nestling at the San Luis Rey River before 2022.
CBON	DPDB Mdb:DPWH	≥1 yr	M	Banded as an adult in CBON territory in 2022.
CBUT	YEBK:BWST Mdb	≥4 yrs	M	Banded as an adult in CBUT territory in 2019.
CCHA	DPWH Mdb:pupu	≥1 yr	M	Banded as an adult in CCH territory in 2022.
CCOT	DBWH Mdb:	7 yrs	M	Banded as a nestling in CSCH territory in 2015. Color banded in CCOT territory in 2016.
CLAN	Mdb:	≥1 yr	F	Banded as a nestling at the San Luis Rey River before 2022.
CNED	WHDB Mdb:?	≥1 yr	M	Banded at the San Luis Rey River before 2022.
CPAS	WHDP Mdb:YEPU	≥3 yrs	M	Banded as an adult in CPAS territory in 2020.
CRED	DPDP:PUYE Mdb	3 yrs	M	Banded as a nestling in WOUT territory in 2019. Color banded in CTRO territory in 2020.
CROD	PUYE:WHDB Mdb	≥4 yrs	M	Banded as an adult in CSCR territory in 2019.
CSAT	DPDB pupu:Mdb	3 yrs	F	Banded as a nestling in CFLO territory in 2019. Color banded in CRED territory in 2021.
CSNE	pupu:BPST Mdb	5 yrs	M	Banded as a nestling in WKEL territory in 2017. Color banded in CACE territory in 2018.
CSOC	Mdb:BPST	2 yrs	F	Banded as a nestling in CNED territory in 2020. Color banded in CPOW territory in 2021.
CWIL	DBDP Mdb:PUWH	≥4 yrs	M	Banded as an adult in CSOC territory in 2019.
DCAL	BPST Mdb:gogo	≥3 yrs	M	Banded as an adult in DBOW territory in 2020.
DDOL	:Mdb	≥1 yr	F	Banded as a nestling at the San Luis Rey River before 2022.

Table 4.1. Banded adult Least Bell's Vireos at the San Luis Rey Flood Risk Management Project Area, California, 2022—Continued

[**Band combination:** unique combination of colored leg bands: BKBK, plastic black; BKYE, plastic black-yellow split; BPST, plastic black-pink striped; BWST, plastic blue-white striped; BYST, plastic black-yellow striped; DBDP, plastic dark blue-dark pink split; DBWH, plastic dark blue-white split; DPDB, plastic dark pink-dark blue split; DPDP, plastic dark pink; DPWH, plastic dark pink-white split; gogo, metal gold; Mdb, dark blue numbered federal band; Mgo, gold numbered federal band; pupu, metal purple; PUPU, plastic purple; PUWH, plastic purple-white split; PUYE, plastic purple-yellow split; WHDB, plastic white-dark blue split; WHDP, plastic white-dark pink split; WHPU, plastic white-purple split; WHWH, plastic white; YEBK, plastic yellow-black split; YEPU, plastic yellow-purple split; YEYE, plastic yellow. **Age:** Exact age determined from uniquely numbered metal band observed during recapture; estimated age applies to an unbanded bird captured as an adult. **Sex:** M, male; F, female. **Abbreviations:** yr, year; ≥, greater than or equal to]

Territory	Band combination (left leg:right leg)	Age	Sex	Comments
DMAC	BYST Mdb:PUWH	≥3 yrs	M	Banded as an adult in DGAF territory in 2020.
DMES	pupu:BKBK Mdb	≥3 yrs	M	Banded as an adult in WSHA territory in 2020.
DSIM	DBDP:YEBK Mdb	≥3 yrs	M	Banded as an adult in WEAR territory in 2020.
DWIL	YEPU Mdb:WHDB	6 yrs	M	Banded as a nestling in BSAV territory in 2016. Color banded in DWIL territory in 2017.
FNER	DBDP Mdb:gogo	≥4 yrs	M	Banded as an adult in FNER territory in 2019.
FO11	Mgo:	≥1 yr	F	Banded as a nestling at the Santa Margarita River (MCBCP) before 2022.
FO2	BKBK Mdb:YEBK	2 yrs	M	Banded as a nestling in DCHE territory in 2020. Color banded in FO2 territory in 2021.
FO40	Mdb:	≥1 yr	F	Banded as a nestling at the San Luis Rey River before 2022.
FO5	BKYE:DPDP Mdb	5 yrs	M	Banded as a nestling in BGRA territory in 2017. Color banded in FO1 territory in 2018.
FO6	BWST Mdb:BPST	≥2 yrs	M	Banded as an adult in FO4 territory in 2021.
FO7	DBDP Mdb:BPST	≥2 yrs	M	Banded as an adult in FO7 territory in 2021.
W154	pupu:DPDB Mdb	3 yrs	M	Banded as a nestling in DDOL territory in 2019. Color banded in W153 territory in 2020.
W155	YEPU:BKYE Mdb	5 yrs	M	Banded as a nestling in FNER territory in 2017. Color banded in WTHA territory in 2018.
W155	:Mdb	≥1 yr	F	Banded as a nestling at the San Luis Rey River before 2022.
WBAN	DPDB Mdb:DBDP	2 yrs	M	Banded as a nestling in CCOT territory in 2020. Color banded in WH33 territory in 2021.
WCAR	WHDB pupu:Mdb	≥1 yr	M	Banded as an adult in WCAR territory in 2022.
WDOB	:Mgo	≥1 yr	F	Banded as a nestling at the Santa Margarita River (MCBCP) before 2022.
WEAR	DPDB:PUWH Mdb	≥1 yr	M	Banded as an adult in WEAR territory in 2022.
WEMI	BWST pupu:Mdb	≥1 yr	M	Banded as an adult in WEMI territory in 2022.
WFID	DPWH:BPST Mdb	≥4 yrs	M	Banded as an adult in WFID territory in 2019.
WFID	DPWH Mdb:WHDP	≥5 yrs	F	Banded as an adult in WRAD territory in 2018.
WGAF	DPDB:YEYE Mdb	3 yrs	M	Banded as a nestling in WGAR territory in 2019. Color banded in WGAF territory in 2021.
WH20	BWST:BKYE Mdb	≥1 yr	M	Banded as an adult in WH20 territory in 2022.
WH20	:Mdb	≥1 yr	F	Banded as a nestling at the San Luis Rey River before 2022.
WH24	PUWH Mdb:YEBK	≥4 yrs	M	Banded as an adult in CFOR territory in 2019.
WH25	DPDB Mdb:WHPU	4 yrs	M	Banded as a nestling in DBEL territory in 2018. Color banded in WH25 territory in 2019.
WH28	DBWH Mdb:BKYE	≥3 yrs	M	Banded as an adult in WH01 territory in 2020.
WH29	DBDP:WHWH Mdb	3 yrs	M	Banded as a nestling in CCHA territory in 2019. Color banded in WH29 territory in 2020.
WJEF	PUWH Mdb:WHDP	2 yrs	M	Banded as a nestling in DSAN territory in 2020. Color banded in WH22 territory in 2021.
WJUN	BPST Mdb:PUPU	≥3 yrs	F	Banded as an adult in WKEL territory in 2020.

Table 4.1. Banded adult Least Bell's Vireos at the San Luis Rey Flood Risk Management Project Area, California, 2022—Continued

[**Band combination:** unique combination of colored leg bands: BKBK, plastic black; BKYE, plastic black-yellow split; BPST, plastic black-pink striped; BWST, plastic blue-white striped; BYST, plastic black-yellow striped; DBDP, plastic dark blue-dark pink split; DBWH, plastic dark blue-white split; DPDB, plastic dark pink-dark blue split; DPDP, plastic dark pink; DPWH, plastic dark pink-white split; gogo, metal gold; Mdb, dark blue numbered federal band; Mgo, gold numbered federal band; pupu, metal purple; PUPU, plastic purple; PUWH, plastic purple-white split; PUYE, plastic purple-yellow split; WHDB, plastic white-dark blue split; WHDP, plastic white-dark pink split; WHPU, plastic white-purple split; WHWH, plastic white; YEBK, plastic yellow-black split; YEPU, plastic yellow-purple split; YEYE, plastic yellow. **Age:** Exact age determined from uniquely numbered metal band observed during recapture; estimated age applies to an unbanded bird captured as an adult. **Sex:** M, male; F, female. **Abbreviations:** yr, year; \geq , greater than or equal to]

Territory	Band combination (left leg:right leg)	Age	Sex	Comments
WKEL	BPST Mdb:DBDP	≥ 3 yrs	M	Banded as an adult in DBRU territory in 2020.
WMAN	YEBK:DBDP Mdb	5 yrs	M	Banded as a nestling in BMAL territory in 2017. Color banded in WMAN territory in 2021.
WMIL	Mdb:DPDB	≥ 1 yr	M	Banded as an adult in WMIL territory in 2022.
WRAD	YEBK:WHPU Mdb	3 yrs	M	Banded as a nestling in FO4 territory in 2019. Color banded in WANI territory in 2021.
WRAD	:Mdb	≥ 1 yr	F	Banded as a nestling at the San Luis Rey River before 2022.
WSTA	PUWH Mdb:PUWH	≥ 3 yrs	M	Banded as an adult in WEMI territory in 2020.

Appendix 5.

Table 5.1. Between-year movement of emigrant Least Bell's Vireos from the San Luis Rey Flood Risk Management Project Area to other areas outside of the Project Area, California, 2022.

[**Location:** MCBCP, Marine Corps Base Camp Pendleton; FNWS, Fallbrook Naval Weapons Station. **Band combination:** unique combination of colored leg bands: BKBK, plastic black; BPST, plastic black-pink striped; DPDB, plastic dark pink-dark blue split; gogo, metal gold; Mdb, dark blue numbered federal band; pupu, metal purple; WHWH, plastic white; YEYE, plastic yellow. **Age:** Exact age determined from uniquely numbered metal band observed during recapture; estimated age applies to an unbanded bird captured as an adult; **Sex:** M, male; F, female. **Abbreviations:** km, kilometer, yr, year]

Drainage/natal territory	2022 Drainage/territory/location	Dispersal distance (km)	Band combination (left leg:right leg)	Age in 2022	Sex
San Luis Rey River/WTHA	Aliso Creek/AL02/MCBCP	9.84	BPST Mdb:BKBK	4 yrs	F
San Luis Rey River/CBOB	Santa Margarita River/AE02/MCBCP	8.65	gogo:WHWH Mdb	3 yrs	F
San Luis Rey River/WDID	Fallbrook Creek/6SA-02/FNWS	15.30	pupu:YEYE Mdb	1 yr	M
San Luis Rey River/CQTI	Middle San Luis Rey River/MSL108	2.66	DPDB:Mdb	1 yr	M

Appendix 6.

Table 6.1. Between-year movement of Least Bell's Vireos banded as juveniles in 2021 at the San Luis Flood Risk Project Area, redetected in 2022.

[**Location:** FNWS, Fallbrook Naval Weapons Station. **Band combination:** unique combination of colored leg bands; DPDB, plastic dark pink-dark blue split; Mdb, dark blue numbered federal band; pupu, metal purple; PUWH, plastic purple-white; YEYE, plastic yellow. **Sex:** M, male; F, female. **Abbreviation:** km, kilometer]

2021 Drainage/natal territory	2022 Drainage/territory	Dispersal distance (km)	Band combination (left leg:right leg)	Sex
San Luis Rey River/FO8	San Luis Rey River/BT02	2.28	pupu:PUWH Mdb	M
San Luis Rey River/WDID	Fallbrook Creek/6SA-02/FNWS	15.30	pupu:YEYE Mdb	M
San Luis Rey River/CQTI	Middle San Luis Rey River/MSL108	2.66	DPDB:Mdb	M

Appendix 7.

Table 7.1. Between-year movement of adult Least Bell's Vireos at the San Luis Rey Flood Risk Management Project Area, 2022.

[Year last detected for all detections was 2021. **Drainage Codes:** SLR, San Luis Rey River. **Band combination:** unique combination of colored leg bands; BKBK, plastic black; BKYE, plastic black-yellow split; BPST, plastic black-pink striped; BWST, plastic blue-white striped; BYST, plastic black-yellow striped; DBDP, plastic dark blue-dark pink split; DBWH, plastic dark blue-white split; DPDB, plastic dark-pink dark-blue split; DPDP, plastic dark pink; DPWH, plastic dark pink-white split; gogo, metal gold; Mdb, dark blue numbered federal band; PUPU, plastic purple; pupu, metal purple; PUWH, plastic purple-white split; PUYE, plastic purple-yellow split; WHDB, plastic white-dark blue split; WHDP, plastic white-dark pink split; WHPU, plastic white-purple split; WHWH, plastic white; YEBK, plastic yellow-black split; YEPU, plastic yellow-purple split; YEYE, plastic yellow; **Age:** Exact age determined from uniquely numbered metal band observed during recapture; estimated age applies to an unbanded bird captured as an adult; **Sex:** M, male; F, female. **Abbreviations:** km, kilometer; yrs, years; ≥, greater than or equal to]

Return to territory (within 0.1 km)	Last year detected drainage/territory	2022 Drainage/territory	Distance moved (km)	Band combination (left leg:right leg)	Age in 2022	Sex
Yes	SLR/WH29	SLR/WH29	0.00	DBDP:WHWH Mdb	3 yrs	M
Yes	SLR/CCOT	SLR/CCOT	0.00	DBWH Mdb:	7 yrs	M
Yes	SLR/W154	SLR/W154	0.00	pupu:DPDB Mdb	3 yrs	M
Yes	SLR/CRED	SLR/CRED	0.01	DPDP:PUYE Mdb	3 yrs	M
Yes	SLR/W155	SLR/W155	0.01	YEPU:BKYE Mdb	5 yrs	M
Yes	SLR/CPAS	SLR/CPAS	0.01	WHDP Mdb:YEPU	≥3 yrs	M
Yes	SLR/CROD	SLR/CROD	0.01	PUYE:WHDB Mdb	≥4 yrs	M
Yes	SLR/CWIL	SLR/CWIL	0.01	DBDP Mdb:PUWH	≥4 yrs	M
Yes	SLR/DBOW	SLR/DCAL	0.01	BPST Mdb:gogo	≥3 yrs	M
Yes	SLR/FNER	SLR/FNER	0.01	DBDP Mdb:gogo	≥4 yrs	M
Yes	SLR/WH22	SLR/WJEF	0.02	PUWH Mdb:WHDP	2 yrs	M
Yes	SLR/WFID	SLR/WFID	0.02	DPWH:BPST Mdb	≥4 yrs	M
Yes	SLR/BFIL	SLR/BFIL	0.02	PUWH Mdb:PUYE	2 yrs	M
Yes	SLR/WANI	SLR/WRAD	0.02	YEBK:WHPU Mdb	3 yrs	M
Yes	SLR/DWIL	SLR/DWIL	0.02	YEPU Mdb:WHDB	6 yrs	M
Yes	SLR/BBUT	SLR/BT03	0.02	WHPU Mdb:PUYE	2 yrs	M
Yes	SLR/FO4	SLR/FO6	0.02	BWST Mdb:BPST	≥2 yrs	M
Yes	SLR/WGAF	SLR/WGAF	0.02	DPDB:YEYE Mdb	3 yrs	M
Yes	SLR/CBAN	SLR/CBAN	0.03	PUWH Mdb:DBDP	≥4 yrs	M
Yes	SLR/BBOA	SLR/BBOA	0.03	DBWH Mdb:PUYE	2 yrs	M
Yes	SLR/FO7	SLR/FO7	0.04	DBDP Mdb:BPST	≥2 yrs	M
Yes	SLR/FO2	SLR/FO2	0.04	BKBK Mdb:YEBK	2 yrs	M
Yes	SLR/DMES	SLR/DMES	0.05	pupu:BKBK Mdb	≥3 yrs	M
Yes	SLR/WEMI	SLR/WSTA	0.06	PUWH Mdb:PUWH	≥3 yrs	M
Yes	SLR/CSCR	SLR/CBUT	0.08	YEBK:BWST Mdb	≥4 yrs	M
Yes	SLR/WH33	SLR/WBAN	0.09	DPDB Mdb:DBDP	2 yrs	M
Yes	SLR/WMAN	SLR/WMAN	0.09	YEBK:DBDP Mdb	5 yrs	M
No	SLR/FGOO	SLR/FO5	0.12	BKYE:DPDP Mdb	5 yrs	M
No	SLR/BTOK	SLR/BTOK	0.14	BYST Mdb:PUYE	2 yrs	M
No	SLR/WH21	SLR/WH25	0.14	DPDB Mdb:WHPU	4 yrs	M
No	SLR/CPOW	SLR/CSOC	0.15	Mdb:BPST	2 yrs	F
No	SLR/CSTR	SLR/CSNE	0.20	pupu:BPST Mdb	5 yrs	M
No	SLR/WJEF	SLR/WFID	0.26	DPWH Mdb:WHDP	≥5 yrs	F
No	SLR/WH26	SLR/WH28	0.31	DBWH Mdb:BKYE	≥3 yrs	M

Table 7.1. Between-year movement of adult Least Bell's Vireos at the San Luis Rey Flood Risk Management Project Area, 2022.—
Continued

[Year last detected for all detections was 2021. **Drainage Codes:** SLR, San Luis Rey River. **Band combination:** unique combination of colored leg bands; BKBK, plastic black; BKYE, plastic black-yellow split; BPST, plastic black-pink striped; BWST, plastic blue-white striped; BYST, plastic black-yellow striped; DBDP, plastic dark blue-dark pink split; DBWH, plastic dark blue-white split; DPDB, plastic dark-pink dark-blue split; DPDP, plastic dark pink; DPWH, plastic dark pink-white split; gogo, metal gold; Mdb, dark blue numbered federal band; PUPU, plastic purple; pupu, metal purple; PUWH, plastic purple-white split; PUYE, plastic purple-yellow split; WHDB, plastic white-dark blue split; WHDP, plastic white-dark pink split; WHPU, plastic white-purple split; WHWH, plastic white; YEBK, plastic yellow-black split; YEPU, plastic yellow-purple split; YEYE, plastic yellow; **Age:** Exact age determined from uniquely numbered metal band observed during recapture; estimated age applies to an unbanded bird captured as an adult; **Sex:** M, male; F, female. **Abbreviations:** km, kilometer; yrs, years; \geq , greater than or equal to]

Return to territory (within 0.1 km)	Last year detected drainage/territory	2022 Drainage/territory	Distance moved (km)	Band combination (left leg:right leg)	Age in 2022	Sex
No	SLR/DO01	SLR/DMAC	0.52	BYST Mdb:PUWH	≥ 3 yrs	M
No	SLR/WANI	SLR/DSIM	0.78	DBDP:YEBK Mdb	≥ 3 yrs	M
No	SLR/WFID	SLR/WJUN	0.79	BPST Mdb:PUPU	≥ 3 yrs	F
No	SLR/DBRU	SLR/WKEL	1.00	BPST Mdb:DBDP	≥ 3 yrs	M
No	SLR/CRED	SLR/CSAT	1.06	DPDB pupu:Mdb	3 yrs	F
No	SLR/DGWE	SLR/WH24	2.03	PUWH Mdb:YEBK	≥ 4 yrs	M
No	SLR/DNIC	SLR/BKEN	4.03	YEBK:WHDP Mdb	3 yrs	M

Appendix 8.

Locations of Transient Willow Flycatchers at the San Luis Rey Flood Risk Management Project Area, 2022

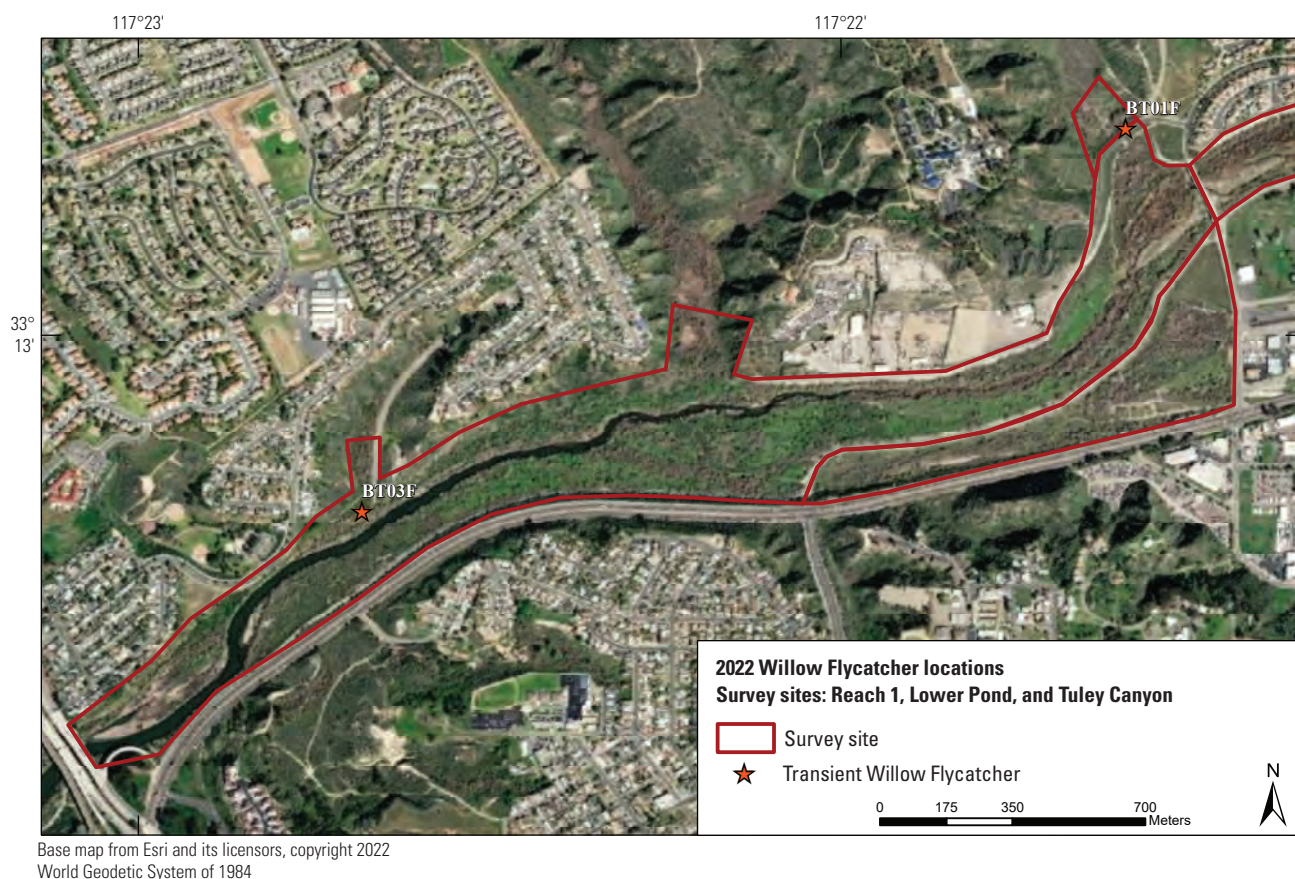


Figure 8.1. Locations of transient Willow Flycatchers in Reach 1, Lower Pond, and Tuley Canyon survey sites at the San Luis Rey Flood Risk Management Project Area, California, 2022.



Figure 8.2. Locations of transient Willow Flycatchers in Reach 3a, Reach 3b, Park Pond, Pilgrim Pond, and Whelan Mitigation survey sites at the San Luis Rey Flood Risk Management Project Area, California, 2022.

Appendix 9.

Vegetation Transects, Nest-Centered Vegetation Plots, and Vegetation Treatments at the San Luis Rey Flood Risk Management Project Area, 2022

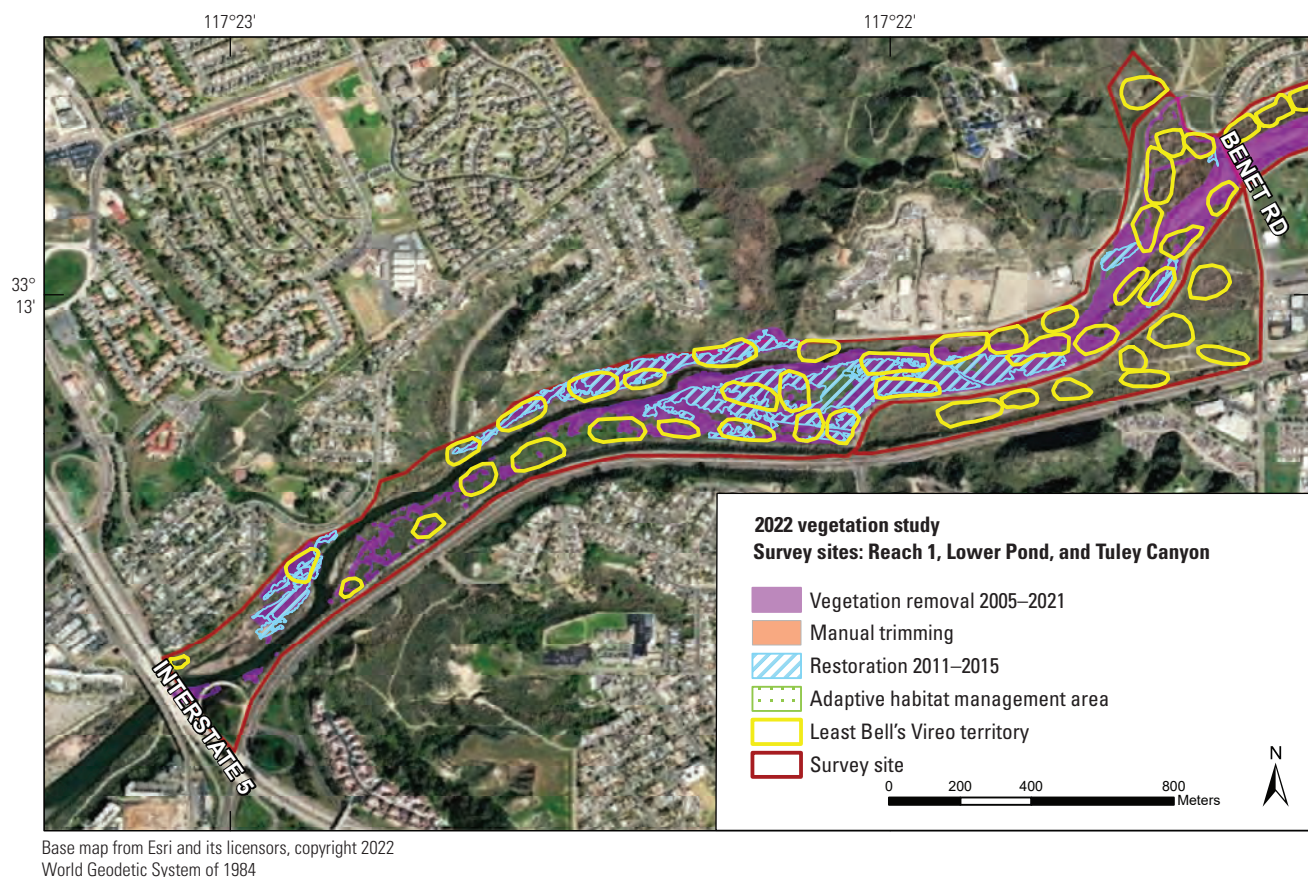


Figure 9.1. Locations of vegetation treatments in Reach 1, Lower Pond, and Tuley Canyon survey sites at the San Luis Rey Flood Risk Management Project Area, California, 2022.



Figure 9.2. Locations of vegetation transects and territory plots in the Reach 2 survey site at the San Luis Rey Flood Risk Management Project Area, California, 2022.

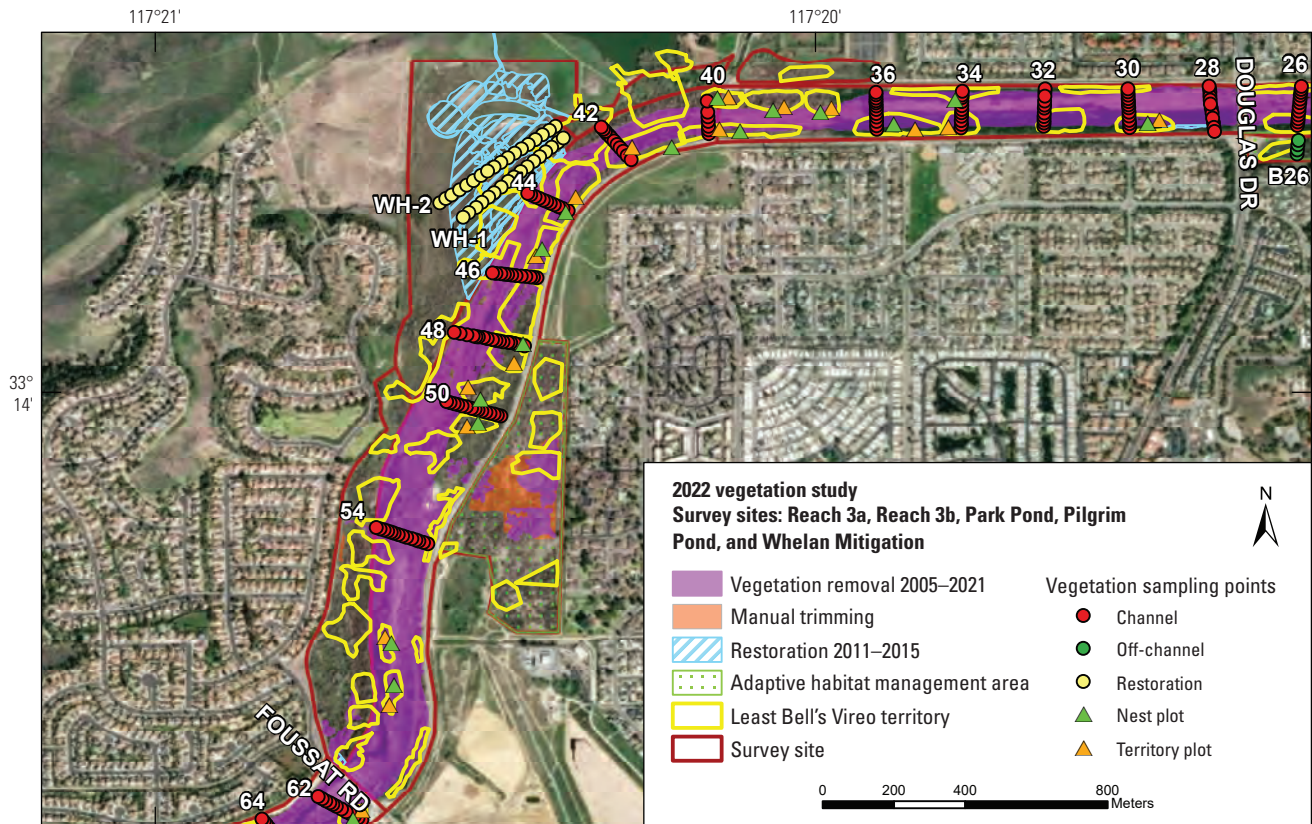


Figure 9.3. Locations of vegetation transects and territory plots in the Reach 3a, Reach 3b, Park Pond, Pilgrim Pond, and Whelan Mitigation survey sites at the San Luis Rey Flood Risk Management Project Area, California, 2022.

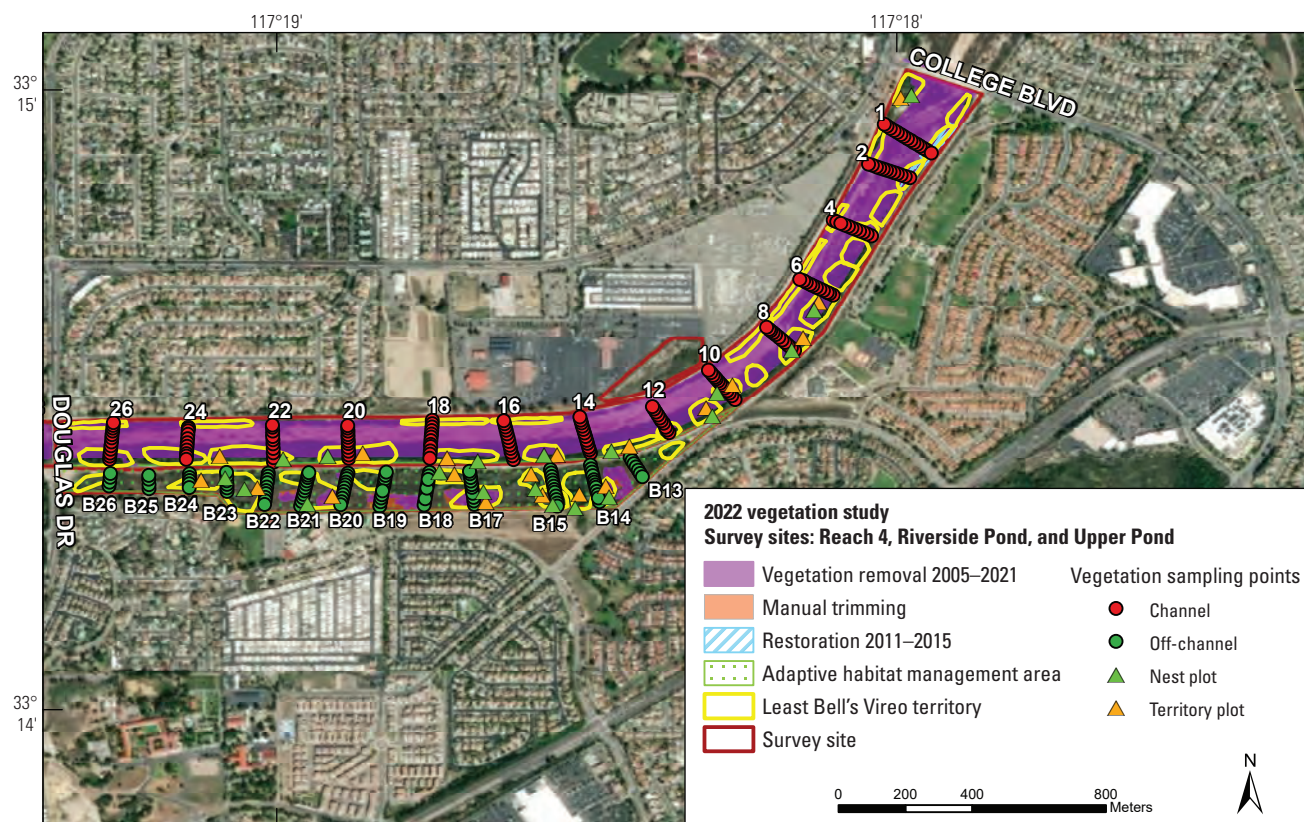


Figure 9.4. Locations of vegetation transects and territory plots in Reach 4, Riverside Pond, and Upper Pond survey sites at the San Luis Rey Flood Risk Management Project Area, California, 2022.

Appendix 10.

Table 10.1. Global Positioning System coordinates (decimal degrees; World Geographic System of 1984 [WGS 84]) for the start and end points (quadrat) of each vegetation transect sampled at the San Luis Rey Flood Risk Management Project Area, 2006–22.

[Quad indicates the distance in meters along a transect. **Abbreviations:** ID, identification; =, equals; —, not applicable]

Transect ID	Quad	X-West	Y-North	Transect bearing
Reach 4				
1	5	–117.29912	33.24834	Bearing=304 degrees
1	145	–117.30033	33.24907	—
2	5	–117.29964	33.24763	Bearing=310 degrees
2	115	–117.30074	33.24805	—
4	5	–117.30067	33.24607	Bearing=300 degrees
4	105	–117.30170	33.24649	—
6	5	–117.30167	33.24445	Bearing=300 degrees
6	105	–117.30260	33.24490	—
8	5	–117.30274	33.24299	Bearing=314 degrees
8	105	–117.30349	33.24361	—
10	5	–117.30434	33.24167	Bearing=330 degrees
10	115	–117.30506	33.24246	—
12	5	–117.30612	33.24078	Bearing=330 degrees
12	95	–117.30656	33.24148	—
14	5	–117.30823	33.24023	Bearing=352 degrees
14	115	–117.30851	33.24111	—
16	5	–117.31030	33.24005	Bearing=358 degrees
16	115	–117.31056	33.24110	—
18	5	–117.31255	33.23992	Bearing=358 degrees
18	115	–117.31248	33.24111	—
20	5	–117.31473	33.24009	Bearing=2 degrees
20	115	–117.31476	33.24105	—
22	5	–117.31675	33.23999	Bearing=2 degrees
22	105	–117.31678	33.24098	—
24	5	–117.31910	33.24006	Bearing=2 degrees
24	105	–117.31904	33.24093	—
26	5	–117.32116	33.24006	Bearing=2 degrees
26	115	–117.32106	33.24105	—
Reach 3b				
28	5	–117.32325	33.23991	Bearing=0 degrees
28	105	–117.32339	33.24101	—
30	5	–117.32537	33.24037	Bearing=0 degrees
30	115	–117.32544	33.24099	—
32	5	–117.32756	33.24004	Bearing=0 degrees
32	105	–117.32753	33.24099	—
34	5	–117.32965	33.24000	Bearing=0 degrees
34	105	–117.32968	33.24073	—

Table 10.1. Global Positioning System coordinates (decimal degrees; World Geographic System of 1984 [WGS 84]) for the start and end points (quadrat) of each vegetation transect sampled at the San Luis Rey Flood Risk Management Project Area, 2006–22.—Continued

[Quad indicates the distance in meters along a transect. **Abbreviations:** ID, identification; =, equals; —, not applicable]

Transect ID	Quad	X-West	Y-North	Transect bearing
Reach 3b—Continued				
36	5	–117.33178	33.23997	Bearing=0 degrees
36	115	–117.33180	33.24090	—
Reach 3a				
40	5	–117.33602	33.23986	Bearing=0 degrees
40	95	–117.33606	33.24068	—
42	5	–117.33802	33.23924	Bearing=332 degrees
42	115	–117.33872	33.24006	—
44	5	–117.33963	33.23798	Bearing=296 degrees
44	105	–117.34059	33.23835	—
46	5	–117.34036	33.23622	Bearing=278 degrees
46	115	–117.34148	33.23634	—
48	5	–117.34067	33.23450	Bearing=284 degrees
48	165	–117.34229	33.23481	—
50	5	–117.34127	33.23273	Bearing=286 degrees
50	145	–117.34264	33.23309	—
54	5	–117.34311	33.22950	Bearing=286 degrees
54	135	–117.34445	33.22993	—
Reach 2				
62	5	–117.34478	33.22253	Bearing=304 degrees
62	125	–117.34586	33.22306	—
64	5	–117.34641	33.22144	Bearing=326 degrees
64	145	–117.34730	33.22255	—
66	5	–117.34839	33.22074	Bearing=346 degrees
66	135	–117.34877	33.22220	—
70	5	–117.35272	33.22096	Bearing=6 degrees
70	145	–117.35252	33.22219	—
73	5	–117.35612	33.22054	Bearing=347 degrees
73	135	–117.35654	33.22166	—
Upper Pond				
B13	5	–117.30713	33.24002	Bearing=172 degrees
B13	65	–117.30683	33.23959	—
B14	5	–117.30823	33.23991	Bearing=172 degrees
B14	115	–117.30807	33.23901	—
B15	5	–117.30930	33.23978	Bearing=172 degrees
B15	115	–117.30912	33.23880	—
B17	5	–117.31148	33.23974	Bearing=172 degrees
B17	105	–117.31135	33.23885	—
B18	5	–117.31256	33.23971	Bearing=182 degrees
B18	105	–117.31270	33.23883	—
B19	5	–117.31372	33.23972	Bearing=182 degrees

Table 10.1. Global Positioning System coordinates (decimal degrees; World Geographic System of 1984 [WGS 84]) for the start and end points (quadrat) of each vegetation transect sampled at the San Luis Rey Flood Risk Management Project Area, 2006–22.—Continued[Quad indicates the distance in meters along a transect. **Abbreviations:** ID, identification; =, equals; —, not applicable]

Transect ID	Quad	X-West	Y-North	Transect bearing
Upper Pond—Continued				
B19	105	–117.31391	33.23874	—
B20	5	–117.31475	33.23970	Bearing=182 degrees
B20	105	–117.31495	33.23881	—
B21	5	–117.31580	33.23972	Bearing=182 degrees
B21	105	–117.31602	33.23880	—
B22	5	–117.31689	33.23969	Bearing=182 degrees
B22	95	–117.31699	33.23885	—
B23	5	–117.31802	33.23968	Bearing=182 degrees
B23	55	–117.31800	33.23920	—
B24	5	–117.31901	33.23964	Bearing=182 degrees
B24	45	–117.31902	33.23930	—
B25	5	–117.32011	33.23963	Bearing=182 degrees
B25	35	–117.32010	33.23927	—
B26	5	–117.32110	33.23955	Bearing=182 degrees
B26	35	–117.32118	33.23925	—
Whelan Mitigation				
WH-1	5	–117.33969	33.23975	Bearing=345 degrees
WH-1	325	–117.34222	33.23774	—
WH-2	5	–117.33989	33.24004	Bearing=345 degrees
WH-2	345	–117.34281	33.23811	—

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