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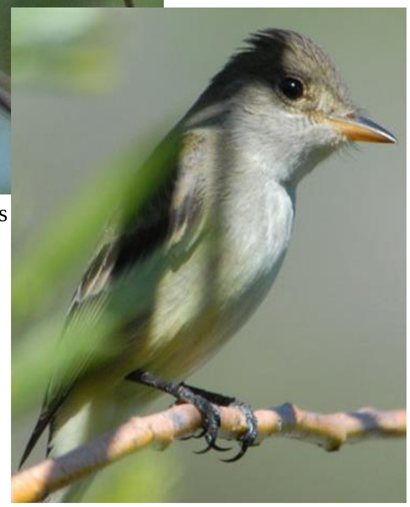

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ENDANGERED SPECIES ACT SECTION 6 PROGRAM GRANT, AGREEMENT NUMBER F17AP00065/ G1698094

Final Report: Southwestern Willow Flycatcher (Empidonax traillii extimus) and Western Yellow-billed Cuckoo (Coccyzus americanus occidentalis) Surveys and Habitat Availability Modeling on the Santa Clara River, California, 26 March 2020

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Executive Summary

Our project aimed to conduct population surveys for Southwestern Willow Flycatcher (*Empidonax trailii extimus*; SWFL) and Yellow-billed Cuckoo (*Coccyzus americanus*; YBCU) in 2018 and 2019, apply existing habitat models to illustrate and predict past, current, and future habitat suitabilities for these two species, and update and standardize classification and mapping of riparian vegetation to reflect recent conditions along the lower 50 miles of the Santa Clara River. Models developed by Hatten and Paradzick (2003), Hatten, et al. (2010), Hatten (2016), and Johnson et al. (2016) were applied to the SCR to provide California Department of Fish and Wildlife (CDFW) and the U.S. Fish and Wildlife Service (USFWS) with useful tools for management of resources for SWFL and YBCU.
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Objectives.--

1. To conduct surveys for SWFL and YBCU on properties throughout the Santa Clara River (SCR) during the breeding seasons of 2018 and 2019 to determine their population densities and distributions on the river.
2. To model current habitat availability for SWFL and YBCU on the SCR using existing predictive tools, Landsat imagery, and findings from fieldwork in 2018 and 2019.
3. To measure characteristics of breeding habitat used by the two species; and to summarize demographic and habitat use findings in relation to the habitat availability models.
4. To map current vegetation and habitat conditions using fine-scaled imagery supplemented with LIDAR data and coupled with focused field assessments.
5. To conduct a time-series analysis of habitat and vegetative changes on the SCR from 1986-2019 (using Landsat and other aerial imagery) for a historical overview of changes in habitat availability over time.
6. To create conceptual models of vegetation trajectories following disturbances from floods, fire, and active horticultural restoration.

Study Area.--The primary Study Area encompassed approximately 80 km (50 miles) of the mainstem of the SCR and associated riparian and floodplain habitat, from the estuary in Ventura County upstream to the confluence with Bouquet Canyon in Los Angeles County. Bird surveys were conducted on 20 properties owned and managed by TNC, Friends of the Santa Clara River, and Ventura Watershed Protection District in the Ventura County portion of the SCR, as well as on the Newhall property in the Los Angeles County portion of the river. Landsat-based modeling of SWFL and YBCU nesting habitat suitability was conducted for the entire study area.

Methods.--Southwestern Willow Flycatcher and Yellow-billed Cuckoo surveys were conducted per standard protocols (Sogge et al. 2010, Halterman et al. 2015) in 2018 and 2019 in predicted breeding habitat on the river. The application of Landsat-based SWFL and YBCU models to predict the distribution and abundance of suitable habitat along the SCR was conducted in spring 2018 and 2019 for SWFL, and in mid-June 2018 and 2019 for YBCU. Landsat 8 imagery was the primary input used in the models. Output for each species in each survey year included a continuous probability grid, a five-class probability grid, and a binary (predicted suitable or unsuitable) habitat grid, with higher cell values in each case indicating relatively better SWFL

and YBCU habitat. The models were first developed and calibrated during winter 2018 using available historical data on occurrence and nest sites for these two species along the SCR.

To create habitat time series of predicted SWFL and YBCU habitat summarized by reach and project area Hatten populated the satellite models with Landsat imagery from 1986 to 2019, summing predicted habitat by reach, and creating bar charts. The two habitat time series were created with Landsat imagery dating from 1986 to 2019, obtained from the Google Earth Engine satellite archive.

Stillwater Sciences drafted new vegetation maps using NAIP 2016 imagery and various existing data sources in March and April 2018, and then created a protocol for field verification that was conducted from May through July 2018. Field training in the use of the protocol occurred on April 18th-20th, and field verification was managed and conducted primarily by UC Santa Barbara, with some data also collected by the Western Foundation of Vertebrate Zoology (WFVZ) during field surveys, and by Dr. Orr during reconnaissance. A total of 345 data points in the SCR were sampled, with a full vegetation assessment form completed for 129 points, and a rapid assessment to note dominant species and any notable invasive plant species for 216 points.

In summer and fall 2018 Stillwater Sciences processed species composition and other vegetative data to assign the correct vegetation types (using Manual of California Vegetation – online version) and edited the draft vegetation map. In April 2019 they completed the preliminary vegetation classification and detailed vegetation map for the mainstem Santa Clara River riparian corridor and its major tributaries in Ventura and Los Angeles Counties, from Bouquet Canyon to the estuary (Stillwater Sciences 2019).

Results.--For flycatchers in 2018, 61 surveys in the Ventura County portion of the Santa Clara River, and 20 surveys in the Los Angeles County portion of the river (on Newhall land and the Natural Resource Management Plan protocol survey area) detected 13 apparently migratory Willow Flycatchers (WIFL). None of these flycatchers was detected during the critical third survey period (i.e., after 24 June), so none of the 13 detected birds was considered to be southwestern Willow Flycatchers. In 2019, in 74 surveys on the Ventura County portion of the river, 13 apparently migrant WIFL were detected, and no SWFL. On the Los Angeles portion of the study area, in 15 surveys, 12 migrant WIFL were detected, but no SWFL.

For cuckoos in 2018, 57 surveys the Ventura County portion of the river and 15 surveys in the Los Angeles County portion of the river detected one apparently migratory cuckoo in Bouquet Canyon, and apparently one cuckoo (although it may have been multiple birds) on 2, 23, and 27 July on the Hedrick Ranch Nature Reserve (HRNA), in predicted high quality breeding habitat (>80% probability class). In 2019 we had multiple detections of cuckoos on the southern and eastern sections of the Levy property, the Kenter Canyon property, and the HRNA, in 48 separate surveys and "listening events". One YBCU was detected opportunistically on 10 June at the southern edge of the Levy property, in mature willows lining Lost Creek and adjacent to the Hedrick Stables, during a SWFL playback survey. This was the exact same location where a cuckoo was detected, without playback, in 2017. At least three other detections of cuckoos occurred in response to playback surveys in 2019 on 22 June, 2 July, and 9 August. In addition, passive recordings of cuckoos with microphones were made in these same locations on 6/22, 7/3, 8/9, and 8/14. One of the recordings (at the Levy south location, right by the 10 June detection) was of an alarm-calling cuckoo on 6/22/19, which could have indicated a nesting bird. One "listening survey" without playback also detected a cooing bird, likely a female. Based on the different calls heard and patterns of the calls and recordings, we think, conservatively, that there was probably one male and one female regularly using the high-quality predicted habitat of the HRNA and the east-most high-quality predicted habitat of the Levy property. However, given the size of the area involved (i.e., from 80 to 270 ha of potential habitat in this section of the East Grove in 2019) there may have been more cuckoos, or cuckoo pairs, during the 2019 breeding season. However, although on 9 August we had a cuckoo come off a roost at dawn at the eastern end of the Levy property, and although we recorded an alarm-calling cuckoo on 22 June, no interactions between adult birds were heard, nor were any chick or fledgling begging calls heard.

Habitat Suitability Models.--The vegetative alliances and associations that characterized the SWFL breeding habitat models in 2018 and 2019 on the Ventura County portion of the Santa Clara River were: the *Salix laevigata* (red willow) Woodland Alliance, *Salix laevigata/Arundo donax* (giant reed) association, *Populus trichocarpa* (black cottonwood)- *Salix laevigata* association, *Populus trichocarpa - Salix laevigata/Arundo dona*x association, *Populus trichocarpa/Arundo donax* association, *Salix laevigata/Baccharis salicifolia* (mulefat) association, *Baccharis salicifolia* Shrubland Allicance, *Salix lasiolepis* (arroyo willow) Shrubland Alliance, *Salix lasiolepis/Arundo donax* association, *Sambucus nigra* (black elderberry) Shrubland Alliance (on Peto-McConica in 2019), *Phragmites australis* (common reed)-*Arundo donax* (on the Fillmore Cienaga in 2018), and the edges of the *Schoenoplectus* (*acutus, californicus*; bullrush) Herbaceous Alliance (on the HRNA). On the Los Angeles County/Newhall portion of the river the vegetative associations were: the *Salix laevigata* Woodland Alliance, *Salix laevigata/Arundo donax* association, *Salix laevigata - Salix lasiolepis* association, *Populus fremontii* (Fremont cottonwood)- *Salix laevigata* association, and in one small location, the *Tamarix* spp. (tamarisk) Shrubland Semi-Natural Alliance.

The vegetative alliances and associations that characterized the YBCU breeding habitat models in 2018 and 2019 on the Ventura County portion of the river were much less variable than for flycatchers, and included the *Salix laevigata* Woodland Alliance, *Salix laevigata/Arundo donax* association, *Populus trichocarpa - Salix laevigata* association, *Populus trichocarpa* Forest Alliance, and *Populus trichocarpa/Arundo donax* association. On the Los Angeles County/Newhall portion of the river the associations included the *Salix laevigata/Arundo donax* association, *Populus fremontii* Forest Alliance, and *Populus fremontii - Salix laevigata/Arundo donax* association.

The habitat suitability models for flycatchers and cuckoos used to delineate survey areas for the species in 2018 seemed to perform very well, i.e., when visited on the ground, the predicted breeding habitat generally met the characteristics of high-quality breeding vegetation. Only one factor (flowing water in June) seemed to be less abundant than we would have hoped for flycatchers in 2018, and thus may have led to flycatchers not settling to breed in predicted suitable vegetation in 2018.

In 2019 Hatten updated the habitat suitability models for SWFL and YBCU breeding habitat on the Santa Clara River. Landsat images from April 2019 (for flycatchers) and June 2019 (for cuckoos) were used. Due to the significant 2019 winter and spring rainstorms that occurred in southern California, and the resulting lush growth of annual native and non-native plants (especially black mustard [*Brassica nigra*]), the ≥40% probability habitat suitability maps for SWFL and YBCU in 2019 included <150 acres (<75 ha) of predicted breeding habitat that was of lower quality for the species. After visiting these locations during the first two rounds of SWFL surveys in May and early June, the PI (L. Hall, WFVZ) made the decision to skip surveys for both SWFL and YBCU, in these particular low-quality areas on the following TNC properties, because they were unsuitable for breeding: Peto-McConica, Prairie-Pacific, Veitch, and south Shiells .

Aside from some changes in plant cover and NDVI values in 2019, another factor that changed was the presence of strongly-flowing, turbid water outside of the usual high stormwater flow period. Although SWFL are known to breed near flowing water in riparian areas, this water is usually calm, clear, and relatively slow-moving, or even reduced to a very small amount of above-ground flow by early June when SWFL breed in the southwestern United States. In 2019, however, water releases were conducted from late May through mid-August from the Piru and Castaic reservoirs, causing a substantial increase in flow, which greatly increased speed and turbidity. We cannot tell if flycatchers that may have been prospecting along the SCR between late May and mid-June would have been discouraged from breeding in suitable habitat near the mainstem during this high waterflow, but it may have been a possibility, especially on the Levy and HRNA properties.

Another change between 2018 and 2019 in habitat suitability was the death of a grove of black cottonwood trees located in the highest quality predicted habitat for YBCU on the southern end of the Levy property. Most likely this grove died to infection from the invasive Polyphagous Shot Hole Borer (*Euwallacea* sp.; PSHB), a beetle that recently colonized the SCR, and causes relatively rapid mortality in many native trees species (*Salix laevigata* and *S. lasiolepis*, *Populus*, *Plantanus*, etc) in southern California.

Time-series analyses of habitat availability for SWFL and YBCU.--Hectares of suitable habitat for SWFL were estimated using the models and Landsat images from 1986 to 2019. The ≥40% probability model estimated a mean of 741 ha (±55.9 ha) of SWFL habitat river-wide from 1986 to 2019, across all reaches. The ≥60% probability model estimated a mean of 544 ha (±45.7 ha) river-wide from 1986 to 2019, across all reaches. Among reaches, the average hectares of habitat from 1986-2019 ranged from 0.5 to 234 ha for the ≥40 probability model, and from 0.2 to 191 ha for the ≥60% probability model. The years with the most predicted habitat available for SWFL were 2000, 2001, and 2003 for the ≥40% probability model, and 2000 and 2019 for the ≥60% probability model. The reach with the most predicted habitat over the 1986-2019 period was that from the middle of the Levy property to Aflalo (part of the "East Grove"), with an average of 234 ha under the ≥40% probability model, and 191 ha under the ≥60% probability model. Overall, the ≥60% probability model estimated a mean of 544 ha (± 121.0 ha) available river-wide from 1986 to 2019. Although habitat availability may be trending upward on the river for SWFL, R^2 values were <0.09, which represent very weak trends, likely due to wide fluctuations over the modeled time period.

Hectares of suitable habitat for YBCU were similarly estimated using the models and Landsat images from 1986 to 2019. The ≥40% probability model estimated a mean of 934 ha (±64.9 ha) river-wide from 1986 to 2019, across all reaches. The ≥60% probability model estimated a mean of 246 ha (±20.4 ha) river-wide from 1986 to 2019, across all reaches. Among reaches, the average hectares of habitat from 1986-2019 ranged from 0.1 to 260 ha for the ≥40% probability model, and from 0 to 77 ha for the ≥60% probability model. The years with the most predicted habitat available for YBCU were 2000 and 2009 using the ≥40% probability model, and 2009 and 2006 under the ≥60% probability model, however, in 2019 the amount of habitat predicted under both models increased over that predicted on the river in 2014 through 2018. Similar to the finding for flycatchers, the reach with the most predicted habitat for cuckoos over the 1986-2019 period was that from the middle of the Levy property to Aflalo (part of the "East Grove"), with an average of 260 ha using the ≥40% probability model, and 77 ha using the ≥60% probability model. Although habitat availability may be trending upward on the river for cuckoos, R^2 values were <0.147, which also were not very strong trends.

Vegetation mapping.-- The final vegetation map produced for this project includes 45 vegetation alliances, seven of which were further classified into 38 associations, and 10 broad land cover types, covering a total of 16,369.9 ac (6,624.7 ha). Three vegetation alliances and 15 associations are provisional types. Eighteen of the vegetation alliances are considered sensitive natural communities (CDFW 2018), covering a total of 4,750.5 ac (1,922.5 ha) or 27.8% of the Study Area. Ten vegetation alliances are dominated by naturalized non-native species (semi-natural stands), covering a total of 1,072.7 ac (434.1 ha) or 6.6% of the Study Area. The vegetation alliances and land cover types are summarized, but full descriptions of each type and a summary of the mapped vegetation types by reach and additional details of the vegetation classification and mapping effort are presented in Stillwater Sciences (2019). The vegetation/plant alliances and associations that were present in models of breeding habitat for SWFL and YBCU are also highlighted.

To help characterize the distribution and relative abundance of Arundo throughout the study area we estimated the percent cover (by cover class) of this species in each mapped polygon. This nonnative invasive species occurs throughout the Study Area, however, the largest infestations generally occur in reaches with perennial surface water and shallow groundwater.

Lidar-based assessment of habitat structure.-- Although it was not part of the scope of our Section 6 Grant, we also initiated a pilot study to explore the use of LIDAR to provide a more detailed estimate of vertical vegetation structure (from ground surface to top of canopy) that may be useful in modeling habitat suitability for other riparian wildlife species, such as the Least Bell's Vireo (*Vireo belli pusillus*; LBVI). All LIDAR products were developed from the October 2015 data set collected by the National Center for Airborne Laser Mapping for Restoration Science, LLC. A relative elevation GIS layer and set of maps were produced for the East Grove area using the LIDAR data collected in October 2015. The maps display topographic elevations relative to the low-flow channel elevation in the following categories: less than 0, 0–0.25, 0.25–0.50, 0.5–1, 1–1.5, 1.5-2, 2–3, 3–5, 5–10, and 10–20 m. Canopy height data, when available, may also improve the performance of some wildlife habitat suitability models, such as the Landsat-based YBCU model (J. Hatten, personal communication). A canopy-height GIS layer and set of maps also were produced for the East grove area. The maps display the following height categories: 0, 0–1, 1–3, 3–5, 5–7, 7–10, 10–20, 20-30, and >30 m.

Temporal Changes in Suitable Habitat for SWFL and YBCU from 1986-2019.--The results of the habitat suitability models indicated significant interannual variation in the amount of predicted suitable habitat for both SWFL and YBCU from 1986 through 2019, both at the full river corridor scale and at a more local reach scale, such as in the vicinity of the East Grove. Inspection of the graphed results suggests a correlation with factors such as floods and drought. For example, suitable habitat for both species generally declines immediately or the year after major flood events (e.g., 1992, 1995, 2005), and there was a pronounced decline during the recent multi-year drought. Examination of spatial and temporal patterns, beyond the scope of our current study, might allow additional factors to be correlated with habitat dynamics. For example, wildfire, human land disturbance, and surface water alterations would be expected to affect riparian vegetation and water availability, and hence alter predicted habitat suitability for both species

Changes in Riparian Forests and the River from the Early 1800s to Present.--The strongest drivers controlling the distribution of riparian vegetation in the SCR are groundwater and resulting perennial or intermittent surface flow conditions--as represented by longitudinal vegetation patterns--and flood disturbance, as represented by cross-sectional vegetation patterns. These drivers demonstrate the importance of surface water availability for vegetation recruitment and succession, and surface water or shallow groundwater for vegetation growth, and align well with those found in previous studies of riparian vegetation in semi-arid river systems, including the magnitude and frequency of flood disturbance, depth to groundwater (as reflected in preference for gaining versus losing reaches), and a combination of the two.

Building on the deeper historical analysis conducted by Beller et al. (2011, 2016), it is evident that the active river corridor in the Santa Clara River valley has progressively narrowed due to myriad land-use activities that have cumulatively encroached upon the floodplain since the mid-1800s, although available evidence suggests that most of the loss of active river corridor area occurred during the post-World War II boom in urban development in Ventura County. Salient activities included agriculture and ranching, urban development, flood-control infrastructure, instream aggregate mining, and surface water diversions. In particular, construction of levees and urban expansion along the river has substantially reduced the area available for floods to inundate and, therefore, for riparian forests to recruit and grow.

Temporal Dynamics of Riparian Vegetation and Habitat in the Historical East Grove.--Of the four major patches of forested wetland, only the East Grove remains close to its historical size with only an estimated reduction of 12% (from 250 to 220 ha). The other three patches have been fragmented and reduced by 53 – 67%. Aside from currently being the largest forested patch, the East Grove is also the least fragmented. The habitat suitability model predictions for SWFL and YBCU, as well as the finding of YBCU individuals in the area during the study, support the continued importance of the East Grove habitat patch, as well as the dynamic inter-annual changes in the quantity and quality of habitat. While there has been some reduction in total area of the East Grove and the active river corridor compared to historical conditions, and reduction in habitat quality from invasion by Arundo, this reach still experiences active river processes and maintains a very valuable shifting mosaic of riparian forest and other riparian and wetland habitats. The habitat suitability modeling for SWFL and YBCU supports this characterization: no other reach along the river matches it in quantity and apparent quality of woody riparian habitat.

There are four dominant woody species that characterize the primary cottonwood-willow riparian forests of the SCR that are important to SWFL, YBCU, and many other wildlife species: red willow, arroyo willow, Fremont cottonwood, and black cottonwood. These species are controlled by the following factors:

- Moderately high flow events (i.e., 5–10 year recurrence interval, or greater, flow events) are needed to create appropriate seedbed sites
- Declining limbs of high-flow hydrographs that coincide with the peak seed release periods (generally March–April for Fremont cottonwood and arroyo willow, and April to early May for black cottonwood and red willow).
- Maximum stage declines of 0.8–1.2 inches (2–3 cm) per day (for willows) and 1.4 inches (3.5 cm) per day (for cottonwoods) during the germination and seedling establishment period (i.e., first growing season, March–October).
- Depths to groundwater between 0.7 (0.2 m) and 6.7 feet (2 m) during the 2nd year growing season.
- Depths to groundwater of less than 20 feet (6 m) to maintain existing mature riparian vegetation.

Although the Santa Clara River riparian corridor is relatively intact, flood protection infrastructure, diversions, roads, agriculture, and urbanization have constrained or disrupted natural geomorphic and hydrologic processes, causing riparian and aquatic habitat degradation. As native riparian vegetation provides critical ecosystem services such as improved flood control, water quality, and terrestrial and aquatic habitat quality as well as increased local biodiversity, managing for healthy riparian vegetation is central to river management and restoration. The replacement of native scrub and mature forest communities by dense stands of Arundo, which does not provide any of the key habitat elements required by most riparian birds and other native wildlife, is prevalent throughout the SCR. Arundo is currently being managed through control and removal programs at selected locations throughout the watershed, which is expected to benefit both flycatchers and cuckoos, as well as other riparian-obligate species. Processes and inputs from upslope and upstream areas have a strong influence on local conditions and ecosystem dynamics. Explicit integration of natural ecosystem processes operating at appropriate scales is a fundamental part of planning, implementation, and adaptive management. Assessment of feedbacks between these processes and major stressors need to be integrated into the restoration design process. For example, the restoration of cottonwood and willow riparian forests on the SCR is generally appropriate only in gaining reaches (i.e, where groundwater rises towards the surface and feeds into the river channel) with reliable shallow groundwater, while more xeric types of riparian vegetation (e.g., alluvial scrub) are more appropriate restoration targets in losing reaches (i.e., where river water is being lost downward to the water table). Beller et al. (2015) identified four areas in gaining reaches that have consistently supported significant stands of forested wetlands dominated by cottonwoods and willows for at least the past two centuries, with the East Grove being the largest and most intact example. However, periods of prolonged and severe drought (e.g., 2012–2018) have negatively affected the native riparian forest and shrub habitats that provide breeding habitat for species such as SWFL and YBCU. The frequency and severity of key disturbance events (e.g., floods, droughts, wildfire) affecting riparian habitats in the SCR also are predicted to increase in coming decades due to climate change.

Discussion.-- Breeding southwestern Willow Flycatchers were not found on the river in 2018 or 2019, despite 174 surveys covering thousands of hectares of predicted suitable breeding habitat. Southwestern Willow Flycatcher numbers throughout southern California have been depressed over the past few years, possibly due to drought conditions from 2014-2017. Contrasting with the population status of SWFL, however, was the notable increase in availability of breeding habitat on the SCR in 2019: this year showed the largest amount of suitable habitat available since 2009. Conversely, the years 2014-2018 showed the lowest amounts available, due to drought conditions, which may have impacted long-term flycatcher numbers on the river. Ruegg et al. (2018) showed that small SWFL populations, such as those throughout California, are likely to be the worst affected by climate change in the future, due likely to their probable reduced thermal tolerance, caused by a mismatch between their current genotype and predicted future environmental stresses. Drought can have substantial negative impacts on breeding flycatchers and their habitat through reductions in vegetation quality and quantity, and prey availability. Because breeding SWFL typically nest in relatively dense riparian vegetation where surface water is present or soil moisture is high enough to maintain the appropriate vegetation characteristics (from Sogge et al 2010), the drought experienced on the SCR between 2014 and 2017 may have significantly impacted, or deterred, breeding SWFL. Fortunately, since SWFL are adapted to highly variable hydrological and habitat conditions, they are known to reappear at unoccupied breeding sites, even after 1-5 year absences (Sogge et al. 2010). The dynamic nature of breeding flycatcher populations, because of the dynamic nature of the areas they occupy, encourages hope for the population on the SCR to reappear in the future, especially because of the quality and quantity of restored habitat that is being created through (1) the removal of Arundo, (2) the active and passive planting of dense willow stands, and (3) the decreased abundances of female Brown-headed Cowbirds (*Molothrus ater*) observed on the river during the breeding season over the past few years.

Yellow-billed Cuckoos were found in medium and high probability breeding habitat, predominantly in the East Grove area of the river. The species' consistency on the southern and eastern parts of the Levy property, and throughout the north, central, and western parts of the HRNA, was predicted and expected based not only on the habitat suitability models, but also on other detections of cuckoos in this area between 2010 and 2017. Removal of Arundo followed by passive and active revegetation of native willow on the HRNA, in particular, over the past 15 years has clearly recreated suitable foraging and roosting habitat for YBCU, similar to what was found there historically. Questions about the establishment of a breeding population in the East Grove revolve around prey availability and abundance (e.g., frogs, large-bodied insects) with predicted climate change impacts. Monitoring of insect diversity and density on the SCR will be very important going forward, and all steps to increase native vegetation and to limit drawdowns of water from the River during droughts and during the breeding season also should be encouraged. Both YBCU and SWFL are historically associated with humid environments rather than dry ones, and so adequate moisture in the SCR to create humid conditions in the future will be imperative for these species. Reductions in the use of agricultural insecticides, which are suspected of contributing to cuckoo declines in the 1940s and 1950s (e.g., Gaines and Laymon 1984), and have recently been demonstrated to have reduced aerial insect numbers in areas of North America (e.g., Stanton et al. 2018) and to be linked to adverse outcomes for migratory bird populations (Eng et al. 2019), could positively influence cuckoo and other insectivorous bird populations.

We did not detect direct nesting behavior of cuckoos where we observed them in 2018 or 2019, however, recordings and timing of observations—and historical nesting records from throughout California—indicate that cuckoos could breed earlier on the river than we, and other California surveyors, have assumed, and that nesting could have occurred on the Levy property in mid-June, before we started our playback surveys and recordings. Thus, future nest searches will be very important in this area, and any future restoration activities must only be conducted during the non-breeding season in predicted high quality breeding habitat on the Levy, Hedrick Ranch, Taylor, and Kenter Canyon properties to avoid disturbing nesting cuckoos.

The habitat suitability models accurately predicted occupancy of high-quality habitat by cuckoos in the historic East Grove. This area alone made up approximately 30% of all high probability predicted habitat on the river. However, the models also predicted that cuckoos would occur in approximately another 700 ha of habitat on the SCR, where no detections were made. It could be that migrating, or even breeding, cuckoos were present in these predicted patches of habitat but were missed during sampling over the two years, since cuckoos seldom call without playback, have a relatively low level of responsiveness to playback, call infrequently, and have large home ranges (i.e., from 20 to 42 ha. Thus, after only two years of consecutive surveys it is difficult to say if the absence of cuckoos in predicted habitat was due to the birds being absent or the birds being missed during surveys. However, it was clear that the quality of the habitat patches outside of the East Grove seemed of lesser quality, and likelihood, of cuckoo occupancy. Thus, we recommend that surveys be conducted primarily in $\geq$60% probability class habitat, as well in the $\geq$40% probability habitat immediately around the higher quality habitat, because it could provide foraging areas for migrating and breeding cuckoos. In addition, in areas where formerly high quality predicted habitat changed dramatically from one season to the next, such as occurred on the southern Levy property due presumably to PSHB beetle infestations (and on the HRNA where many mature red willow trees died between 2018 and 2019, it would be prudent to continue surveying to see if cuckoos try to use the vegetation, and to determine how long it takes the vegetation to recover, if at all.

Overall, based on more than 240 surveys for flycatchers and cuckoos on the SCR in 2018 and 2019, we conclude that the 40% probability class projections for both species included more unsuitable habitat than expected, especially in 2019, and so suggest that the $\geq$60% probability models be used for most future surveys. Creating filters before each field season to remove pixels dominated by Arundo or other exotic plant species and adding agricultural filters that were developed during this project would save time, energy, and funding during future surveys .

***Recommendations.*—**We suggest 11 recommendations from this study:

1. Continue habitat restoration, especially Arundo removal on the SCR combined with passive or active replanting of native willow and suitable understory plants, within vegetative alliances and associations that modeled as potential breeding habitat for SWFL and YBCU.
2. Investigate impacts of out-of-season releases of imported water from Piru or Castaic reservoirs to establish management guidelines, such as setting an upper threshold on releases to avoid or minimize potential impacts to prospecting and/or nesting SWFL.

3. Focus monitoring for nesting activity of SWFL and YBCU in predicted ≥60% probability habitat areas on the SCR. Conduct monitoring in the highest probability areas of habitat on the Hedrick Ranch Nature Area, Taylor, Kenter Canyon, and eastern and southern Levy (i.e., the East Grove properties). Also, continue annual searches for nesting YBCU by permitted biologists on these same properties, and continue using recording devices to determine YBCU activity in the East Grove reach. In addition, experiment with the use of broadcasted SWFL vocalizations in high quality habitat to attract SWFL, as suggested by Barbara Kus in December 2019 (at the Riparian Birds Workshop, 4 December).
4. Before surveys occur, create filters for the habitat suitability models to remove pixels dominated by Arundo or other exotic plant species, and continue to use agricultural filters.
5. When satellite models are employed in other watersheds, and especially in basins with a lot of agriculture, wildfires, and foggy conditions, carefully delineate the project boundary used for masking purposes, and carefully inspect every satellite image to be used, to reduce spectral confusion.
6. Conduct insect and frog monitoring in the East Grove to determine if quantities of available prey for YBCU, and SWFL, will be suitable for supporting breeding within predicted high-quality breeding habitat on the SCR. After restoration of the Sespe Cienaga site with willow and cottonwood trees, begin insect and frog monitoring on this site to determine if prey abundances will be adequate for the support of nesting cuckoos and willow flycatchers.
7. Conduct periodic updating of the vegetation map, approximately every 10 years or following a major flood or fire event, to systematically track vegetation and habitat changes throughout the primary 50-mile SCR corridor. More detailed, finer-scaled site-specific vegetation classification and mapping should also be conducted for any proposed projects along the SCR.
8. More quantitative analysis of time-series data on vegetation dynamics and wildlife habitat suitability is needed to improve our understanding and ability to accurately predict future system trajectories in response to changes in natural or anthropogenic drivers. Such analyses would improve our conceptual models and, ideally, would lead to quantitative models to predict how changes in key drivers (such as flow, depth to groundwater, and surface water-groundwater interactions) or management actions (e.g. surface water diversion or augmentation, groundwater extraction and recharge, Arundo removal and revegetation of native riparian plants, or control of the PSHB beetle) would affect riparian ecosystem dynamics.

9. Conduct research into the ecology of the polyphagous shothole borer and its effects on native riparian cottonwood-willow habitats, and thus, by extension, on SWFL and YBCU populations, and potential control or management actions.
10. Test the utility and cost-effectiveness of LIDAR to improve our ability to assess and monitor vegetation and habitat structure, and to improve models of habitat suitability. In particular, we recommend detailed testing of the use of LIDAR to quantify vertical habitat structure to see if it can be used to model habitat suitability for avian species including SWFL, YBCU, and LBVI. In addition, to reduce the need for labor-intensive field estimates of such structure.
11. Consider recommending modifications to farmland management such as reducing pesticide inputs through integrated pest management, and maintaining or restoring uncultivated field margins for all agricultural lands bordering the SCR for the benefit of insectivorous bird species using the Santa Clara River corridor.

TABLE OF CONTENTS

1.0 **INTRODUCTION**

The Santa Clara River (SCR) watershed drains a biologically rich region at the junction of five of California's ten identified bioregions, and contains a particularly strong representation of the biodiversity in the South and Central Coast Bioregions. One of the few major river systems in the state that retains much of its natural hydrology, the SCR provides the ecosystem functions necessary to support many federally listed species and California State Species of Special Concern. However, as of 2017, river-wide surveys of the population size and breeding status of southwestern Willow Flycatcher (*Empidonax traillii extimus*; SWFL) and western Yellow-billed Cuckoo (*Coccyzus americanus occidentalis*; YBCU) had not been conducted, nor had suitable breeding habitat been modeled. Our project aimed to conduct population surveys for SWFL and YBCU in 2018 and 2019, and to apply existing habitat models to illustrate and predict past, current, and future habitat suitabilities for these species on the Santa Clara River. Models were developed by Hatten and Paradzick (2003), Hatten, et al. (2010), Hatten (2016), and Johnson et al. (2016) and applied to the SCR to provide California Department of Fish and Wildlife (CDFW) and the U.S. Fish and Wildlife Service (USFWS) with useful tools for management of resources for these species.

The products from this project will be useful for addressing multiple partners' needs (including CDFW, USFWS, The Nature Conservancy [TNC], Santa Clara River Conservancy, Ventura County Watershed Protection District [VCWD?], and Friends of the Santa Clara River [FSCR]) to manage SWFL and YBCU populations on the river, to assist in the ongoing evaluation of the status of SWFL and YBCU populations, and to assess the success of restoration actions for these species on the SCR.

2.0 OBJECTIVES

The specific objectives for this project were:

1. To conduct surveys for SWFL and YBCU on properties throughout the SCR during the breeding seasons of 2018 and 2019 to determine their population densities and distributions on the river.

2. To model current habitat availability for SWFL and YBCU on the SCR using existing predictive tools, Landsat imagery, and findings from fieldwork in 2018 and 2019. The goals for model usage were to identify and track changes in SWFL and YBCU habitat quality along the SCR; predict which areas on the SCR contained the highest quality breeding habitat for these species; indicate which site characteristics and habitat variables should be considered when planning and implementing habitat restoration for these species; and build a GIS database that contains the exploratory variables and the outcomes of the models.

3. To measure characteristics of breeding habitat used by the two species; and to summarize demographic and habitat use findings in relation to the habitat availability models.

4. To map current vegetation and habitat conditions using fine-scaled imagery supplemented with LIDAR data and coupled with focused field assessments.

5. To conduct a time-series analysis of habitat and vegetative changes on the SCR from 1986-2019 (using Landsat and other aerial imagery) for a historical overview of changes in habitat availability over time.

6. To create conceptual models of vegetation trajectories following disturbances from floods, fire, and active horticultural restoration.

3.0 STUDY AREA

The primary Study Area encompassed approximately 80 km (50 miles) of the mainstem of the SCR and associated riparian and floodplain habitat, from the estuary in Ventura County upstream to the confluence with Bouquet Canyon in Los Angeles County (Figure 1). Elevations in the Study Area range from 0 – 355 m (0 to 1,165 feet)) above sea level.

Bird surveys were conducted on 20 properties owned and managed by TNC, FSCR, and Ventura Watershed Protection District in the Ventura County portion of the SCR, as well as on the Newhall property in the Los Angeles County portion of the river. Landsat-based modeling of SWFL and YBCU nesting habitat suitability was conducted for the study area.

A vegetation map was created for 6,625 hectares (ha) (16,370 acres [ac]) (of river, riparian, and associated floodplain habitats along the lower mainstem of the SCR from the estuary to the confluence with Bouquet Canyon. The mapping area also included limited portions of the four largest tributaries to the mainstem Santa Clara River in Ventura and Los Angeles counties (Sespe, Piru, Castaic, and San Francisquito creeks), extending from their confluence with the SCR upstream between one and five miles (Figure 1). The mapping Study Area was determined using the Federal Emergency Management Agency (FEMA) 100-year floodplain boundary (FEMA National Flood Hazard Layer [Ventura County mapping based on a 2006 dataset; Los Angeles County mapping based on FEMA dataset dated 13 March 2017]) and extent of the 2005 Stillwater Sciences vegetation map (Stillwater Sciences and URS 2007).

To better assess longitudinal shifts in vegetation throughout the Study Area, the river was divided into 17 mainstem reaches and 3 tributary reaches (Table 1, Figure 2). The extent of these reaches, which are adapted from three previous studies (Stillwater Sciences and URS 2007; Stillwater Sciences 2011a, 2016), are presented in Figure 2. Table 1 shows the length of each reach, which includes a total to 80.7 km (50.4 miles) of mainstem SCR and 17.4 km (10.9 miles) of the lower portion of three major tributaries (Sespe, Piru, and Castaic creeks). The approximate lower mile of San Francisquito Creek is included in the mainstem Reach 13.

4.0 METHODS

4.1 SOUTHWESTERN WILLOW FLYCATCHER AND YELLOW-BILLED CUCKOO SURVEYS

4.1.1 Flycatcher Surveys

All surveys followed the flycatcher protocol outlined by Sogge et al. (2010) for "general surveys". Broadcast surveys were conducted in predicted (modeled) suitable habitat on 20 accessible properties along the SCR in Ventura and Los Angeles counties in 2018 and 2019. These properties were accessible because they are owned and/or managed by TNC, CDFW, and FSCR, who granted permission to the Western Foundation of Vertebrate Zoology (WFVZ) to work there; some properties with projected habitat were not accessible. Per discussion with USFWS and CDFW biologists in the winters of 2018 and 2019 it was decided that the first two of three surveys for flycatchers would be conducted in all areas predicted by the new habitat suitability models produced by Hatten (see Modeling Habitat Suitability, section 4.2, below) to have a $\geq$40% probability of being suitable for breeding by the species. For the third and in some instances fourth survey we concentrated our efforts in areas that had a predicted $\geq$60% or greater probability of being suitable for breeding by SWFL. In 2019, we modified survey areas for SWFL based on the results of the 2018 field surveys that indicated that habitat suitability was frequently over-estimated by the models (see Results section 5.0 below).

Broadcast surveys were conducted between 15 May and 17 July each year following standard protocol (Sogge et al. 2010). Surveys were conducted by permitted biologists who work with the WFVZ as employees and as sub-contractors (see list of surveyors in Appendix A). Standard protocol survey data sheets were used to note any detections of flycatchers, as well as to note the characteristics of the habitat surveyed. Information associated with flycatcher observations was measured from at least 20 m away from all birds to avoid disturbances (sensu Sogge et al 2010). Habitat variables summarized were those from the SWFL survey protocol data sheet, and included predominant tree/shrub foliar cover layers and plant species, and average canopy height. If territorial flycatchers had been noted after 15 June, documentation would have followed Sogge et al. (2010). If nests had been located a permitted biologist would have recorded locations from 20 m away to avoid disturbing nests, and after breeding had finished, would have returned to record nest micro-habitat characteristics at least 15 days after nests were found to avoid any potential disturbance to nesting flycatchers.

4.1.2 Cuckoo Surveys

Surveys followed the established YBCU protocol for broadcast point counts described in Halterman et al. (2015). Similarly to the surveys conducted for SWFL, the first two of three surveys for cuckoos were conducted in all areas predicted to have a $\geq$40% probability of being suitable for breeding by the species, and for the third and in some instances fourth survey we concentrated our efforts in areas that had a $\geq$60% probability of being suitable for breeding by YBCU (see section 4.2 below). In 2019 we also modified some survey areas for cuckoos because habitat was predicted to be of greater probability than it actually was on the ground (see Results, section 5.0, below).

Cuckoo surveys were conducted between 15 June and 15 August each year per standard protocol, using permitted biologists working as employees and subcontractors for the WFVZ (see Appendix A).

When YBCU were observed, data were entered onto standard protocol data sheets, and habitat characteristics were measured from at least 20 m away to avoid disturbances to the birds (Halterman et al. 2015). Habitat variables measured were those from the YBCU protocol data sheet, including overall vegetative composition; average canopy height and height of understory vegetation; percentages of canopy cover, understory cover, and composition by plant species; and information on surface water.

"Quiet listening surveys", during which no playback was used, occurred in areas where cuckoos were observed more than one time, to determine if nesting activity was occurring. If breeding activity had been noted, methods for documenting this activity would have followed Stanek (2014) and Halterman et al. (2015). If nests were located, a permitted biologist would have recorded the location from at least 20 m away to avoid disturbance. Only after breeding was completed (at least 15 days after nests had been found) would we have returned to measure nest micro-habitat characteristics.

4.2 MODELING HABITAT SUITABILITY AND VEGETATION COMPOSITION ON THE SANTA CLARA RIVER

4.2.1 Landsat-based Modeling of SWFL and YBCU Habitat

The advantages of predictive satellite models for identification of SWFL and YBCU breeding habitats include standardized and repeatable methods, prioritization of survey efforts, and cost savings. Specifically, this study applied existing Landsat-based habitat suitability models constructed by James Hatten (U.S. Geological Survey; USGS) and colleagues for SWFL (Hatten and Paradzick 2003, Hatten et al. 2010, Hatten 2016) and YBCU (Johnson et al. 2016) throughout the 50-mile study area.

Dr. Hatten conducted the application of his Landsat-based SWFL and YBCU models to predict the distribution and abundance of suitable habitat along the SCR in early spring 2018 and 2019 for SWFL, and in mid-June 2018 and 2019 for YBCU. Landsat 8 images? Scenes? from early spring 2018 and 2019 for SWFL, and mid-June 2018 and 2019 for YBCU, were the primary input used in the two models. Output for each species in each survey year included a continuous probability grid, a five-class probability grid, and a binary (predicted suitable or unsuitable) habitat grid, with higher cell values in each case indicating relatively better SWFL and YBCU habitat. The models were first developed and calibrated during winter 2018 using available historical data on occurrence and nest sites for these two species along the SCR.

4.2.1.1 Geospatial Database

We applied Hatten and Paradzick's (2003) Landsat-based model of predicted flycatcher and cuckoo breeding habitats to distinguish differences between those areas of predicted habitat and those confirmed by ground surveys. The satellite model (Hatten and Paradzick 2003) requires Landsat scenes to map "predicted flycatcher breeding habitat". The word "predicted" is used to distinguish areas the satellite model predicts as suitable flycatcher habitat from what is on the ground. Modeling utilized Landsat-5 (1986-2011) and Landsat-8 (2013 to present) collections made available via Google Earth Engine (GEE), a cloud-based modeling platform that automatically performs top-of-atmosphere correction and creates seamless mosaics (Shelestov et al. 2017), saving time and resources. Producing a habitat probability map and developing a habitat time series requires careful attention to image preparation and numerical adjustments because of differences in Landsat sensors and acquisition dates (Hatten 2016). Differences in predicted habitat owing to seasonal effects were minimized by selecting Landsat images that were acquired as close to 21 June as possible (Table 2), since surveys started on 15 June and predicted mid-June habitat would be expected to most closely match conditions the birds experience early in the breeding season when they select potential nesting sites. In the SCR basin, this was difficult because clouds and fog oftentimes obscured aerial views of the estuary, while wildfire smoke occasionally obscured views further upstream. In those circumstances, the first available Landsat scene with a clear aerial view of the project area was selected. For consistent habitat modeling results between Landsat sensors, numerical adjustments were made to imagery (Chander et al. 2009) and the normalized difference vegetation index (NDVI) (Hatten 2016).

4.2.1.2 Application of Satellite Models

James Hatten created the predictor variables necessary to populate the SWFL and YBCU logistic regression models with customized Javascripts housed and executed in the GEE modeling platform.

SWFL model: Four GIS variables (defined at end of paragraph) were extracted from Landsat-5 or Landsat-8 imagery and a 30-m resolution digital elevation model (Hatten and Paradzick 2003). Next, the logistic regression model was populated with the four GIS variables and a probability grid was created. Third, riparian vegetation was divided into probability classes based upon the likelihood that an area was SWFL habitat. The SWFL satellite model uses a logistic regression equation developed by Hatten and Paradzick (2003) to calculate the probability of flycatcher breeding habitat with the following equation:

$$\text{SWFL habitat probability} = \exp^{(\text{logit})} / 1 + \exp^{(\text{logit})} \quad (1)$$

where,

$$\text{logit is } 1.483(\text{NDVI})+0.098(\text{NDVIBEST})+0.034(\text{FLOODPL})+0.648(\text{NDVISTD})–6.074 \quad (2),$$

and whereby the four variables are defined as follows:

1. NDVI = dense vegetation (NDVI>0.33) within a 30 × 30-m cell (0.09 ha);
2. NDVIBEST = amount (percent) of densest vegetation (NDVI>0.41) within a 120-m radius (4.5-ha neighborhood);
3. FLOODPL = amount (percent) of floodplain or flat terrain (<2.5 degrees) within a 360-m radius (41-ha neighborhood);
4. NDVISTD = the standard deviation in NDVI (12 classes) within a 120-m radius (4.5-ha neighborhood).

The three vegetation variables were extracted from Landsat-5 or Landsat-8 imagery, and the FLOODPL variable was extracted from a 30-meter resolution DEM. Probability classes and thresholds were calculated at different values (i.e., 10% intervals, 20% intervals, and 40% and 60% thresholds) (Hatten and Paradzick, 2003, Hatten, 2016). Previous research has found the likelihood of habitat suitability and territory densities increase exponentially with class values. In the case of binary (threshold) grids, the probability of habitat or territory occurrences are significantly greater above a selected threshold (e.g., higher thresholds are expected to contain a greater density of SWFL or YBCU territories).

YBCU model: The YBCU satellite model uses a logistic regression equation developed by Johnson et al. (2017) to calculate the probability of YBCU breeding habitat with the following equation:

$$\text{YBCU habitat probability} = \exp^{(\text{logit})} / 1 + \exp^{(\text{logit})} \quad (3)$$

where,

$$\text{Logit is } 0.343(\text{NDBEST}) + 0.62(\text{ND\_SD480}) \quad (4),$$

and whereby the two variables are defined as follows:

1) NDBEST = amount (percent) of densest vegetation (NDVI>0.41) within a 120-m radius (4.5-ha neighborhood);
2) ND_SD480 = the standard deviation in NDVI (12 classes) within a 480-m radius (72-ha neighborhood).

The two vegetation variables were extracted from Landsat-5 or Landsat-8 imagery. Probability classes and thresholds were calculated at different values (i.e., 10% intervals, 20% intervals, and 40% and 60% thresholds) (Johnson et. al. 2017).

4.2.1.3 Habitat Time-Series Analyses

One of the project objectives was to create habitat time series of predicted SWFL and YBCU habitat summarized by reach and project area. We accomplished this by populating the satellite models with Landsat imagery from 1986 to 2019, summing predicted habitat by reach, and creating bar charts (Hatten et al. 2010; Orr et al. 2014). The two habitat time series were created with Landsat imagery dating from 1986 to 2019, obtained from the GEE satellite archive. Creating a habitat time series involved running the satellite model annually as close to the same date as possible and producing a habitat map for each respective year (Hatten et al. 2010). Habitat maps were created by applying a 40% or 60% probability threshold to the continuous probability grids output by the satellite model using the same methodology as outlined by Hatten (2016).

4.2.2 Vegetation and Habitat Mapping

This project created a comprehensive vegetation map representing current conditions (as of 2018) in the Santa Clara River. Classification and mapping followed current California and National Vegetation Classification standards. Stillwater Sciences (led by Dr. Bruce Orr) compiled previous vegetation maps in GIS, including the 2005 mapping of the Ventura County river reaches (Stillwater Sciences and URS Corporation 2007, Orr et al. 2011), a 2015 map of

TNC properties in Ventura County, a 2004 map of the Los Angeles County portion of the river, and maps prepared for the Newhall Ranch development in Los Angeles County in 2014. Contemporary aerial imagery was used to interpret the boundaries of polygons of discrete vegetation types that were not covered by the compiled maps or that had clearly changed since the maps were produced. Aerial imagery interpretation and previous vegetation surveys on the river were also used to assign vegetation types using *The Manual of California Vegetation* classification system (Sawyer et al. 2009, CNPS 2019; see Orr et al. 2011 for a summary of vegetation types on the Lower SCR), and *Arundo donax* (giant reed; hereafter Arundo) percent cover category to all map polygons. The resulting draft map was verified in the field during the vegetation growing season in 2018. Field verification time was donated by Restoration Sciences LLC and the WFVZ. Lastly, LIDAR data collected in October 2015 by the National Center for Airborne Laser Mapping (NCALM) for Dr. Tom Dudley (Restoration Science, LLC) were analyzed by Stillwater Sciences for the East Grove reaches (Figure 2) to provide high resolution data on vegetation canopy height and vertical structure.

4.2.3 Vegetation and Habitat Dynamics

Dr. Hatten used the SWFL and YBCU habitat models and Landsat data to create a time-series analysis of changes in the amount and distribution of suitable habitat for these two species from 1986-2019. Dr. Orr created a companion time-series analysis of available aerial photographs, and the 2005-2006 and updated 2018 vegetation maps, to document vegetation responses to disturbance for selected sites in the study area. This work was used to calibrate and validate the time-series modeling results, and to provide additional insight into the recovery trajectory of riparian vegetation and habitat structure following restoration implementation and disturbances from floods and wildfires. Comparison of vegetation conditions in the summer of 2005 after a major El Niño flood event with those in 2018 provide valuable insight into vegetation responses following disturbances. Dr. Orr also compared these more recent vegetation dynamics with our Team's knowledge of how the river and its riparian vegetation have changed over the last 150-200 years based on prior historical ecology work (Beller et al. 2015). This information is presented as a conceptual model of vegetation dynamics (see Section 5.5).

5.0 RESULTS

5.1 Population Status of Southwestern Willow Flycatchers and Yellow-billed Cuckoos on the Santa Clara River

5.1.1 2018 Survey Results

Permitted flycatcher biologists began surveys on 22 May 2018. A total of 19 properties were surveyed for SWFL (Tables 3 and 4); several of the properties (especially the Levy, Hedrick Ranch Nature Area, and Newhall properties) had to be divided into sub-units to facilitate thorough coverage. It was difficult to gain access through the Watershed Protection District's easements on the Ventura County portion of the river for several sites. Surveys were completed on 16 July 2018.

Modeled habitat for SWFL on the river is shown in Figure 3, and predicted amounts of ≥40% and ≥60% probability habitat in 2018 and 2019 are provided in Appendix B. Surveys in 2018 detected 13 apparently migratory Willow Flycatchers (WIFL), 10 of which were detected in the Newhall portion of the SCR (Tables 3 and 4). However, none of these flycatchers was detected during the critical third survey period (i.e., after 24 June), so none of the 13 detected birds was considered to be breeding on the river, and so were not considered to be southwestern Willow Flycatchers. Sixty-one total surveys were conducted for SWFL in 2018 on the Ventura County portion of the Santa Clara River, and 20 surveys were conducted in the Los Angeles County portion of the river, on Newhall land and the Natural Resource Management Plan protocol survey area (J. Feenstra, unpubl. report for the USFWS, Aug 2018).

Yellow-billed Cuckoo surveys were conducted by permitted biologists starting on 15 June 2018 and were completed on 11 August 2018. A total of 17 properties were sampled for cuckoos (Tables 3 and 5); several of the largest properties had to be divided into sub-units to facilitate sampling. Fifty-seven surveys were conducted for YBCU on the Ventura County portion of the river in 2018, and 15 surveys were conducted on the Los Angeles County portion of the river on Newhall Land and the Natural Resource Management Plan protocol survey area (J. Feenstra, unpubl. report to the USFWS, Aug 2018).

Modeled habitat for YBCU is shown in Figure 4, and predicted amounts of ≥40% and ≥60% probability habitat in 2018 and 2019 are provided in Appendix C. Surveys in 2018 detected one YBCU apparently as a migratory bird in Bouquet Canyon (not on a survey), and one on 2 July just south of the (HRNA) in citrus groves. A cuckoo also was detected twice in predicted high quality breeding habitat (>80% probability class) on the HRNA on 23 and 27 July 2018 (Tables 3 and 5; Figure 5). The plant community at this latter location was red willow (*Salix laevigata)* woodland, composed of saplings and mature trees. The cuckoo observed on 2 July may have been the same bird observed later in July nearby within high quality habitat. After 27 July 2018 no other cuckoos were observed.

5.1.2 2019 Survey Results

Thirteen migrant WIFL were detected on the Ventura County section of the SCR by the surveying team between 17 May and 24 June 2019 (Tables 3 and 4). One possible SWFL was detected on the southern edge of TNC's McGrath property on 19 June, in the vicinity of high quality breeding habitat, but it was not detected again on subsequent surveys (Tables 3 and 4), so also was presumed to be a migrating WIFL. Despite conducting 74 separate surveys on the Ventura County portion of the SCR, on 25 sections of the river, no SWFL were detected by our team in 2019, and no other reports of SWFL breeding on the River were obtained. On the Los Angeles portion of the river, on Newhall land and in the Natural Resource Management Plan protocol survey area, 12 migrant WIFL were detected, but no SWFL (Tables 3 and 4) (J. Feenstra, unpubl. report for the USFWS, Sep 2019).

Cuckoos were a different story in 2019, possibly because of high water presence and massive numbers of breeding frogs on the mainstem and terraces of the SCR. We had multiple detections of cuckoos on the southern and eastern sections of the Levy property, the Kenter Canyon property, and the HRNA (Tables 3 and 5). Nineteen different areas were surveyed for cuckoos in 2019, in 48 separate surveys and "listening events".

One YBCU was detected opportunistically on 10 June at the southern edge of the Levy property, in mature willows lining Lost Creek and adjacent to the Hedrick Stables, during a SWFL playback survey. This was the exact same location where a cuckoo was detected, without playback, in 2017. At least three other detections of cuckoos occurred in response to playback surveys in 2019 (Tables 3 and 5) on 22 June, 2 July, and 9 August. In addition, passive recordings of cuckoos with microphones (three left out for 2-week intervals from mid-June to mid-September on south and east Levy, and central HRNA) were made in these same locations on 6/22, 7/3, 8/9, and 8/14. One of the recordings (at the Levy south location, right by the 10 June detection) was of an alarm-calling cuckoo (on 6/22/19). Halterman (2009, 2015) stated that the adult alarm call is typically given in the vicinity of a nest or fledgling, but in our study area, no nesting activity was discovered. One "listening survey" without playback detected a cooing bird (likely a female per Halterman 2015) on 27 July.

Based on the different calls heard and patterns of the calls and recordings, we think, conservatively, that there was probably one male and one female regularly using the high quality predicted habitat of the HRNA and the east-most high quality predicted habitat of the Levy property (Figure 4 and 5). However, given the size of the area involved (i.e., from 80 to 270 ha of potential habitat in this section of the East Grove in 2019; Figures 4 and 5; Appendix C) there may have been more cuckoos, or cuckoo pairs, during the 2019 breeding season. However, on 9 August we had a cuckoo come off a roost at dawn at the eastern end of the Levy property (Figure 5), and although we recorded an alarm-calling cuckoo on 22 June, no interactions between adult birds were ever heard, nor were any chick or fledgling begging calls heard. Several sessions of quiet listening by 1-6 observers distributed on the HRNA trail system between 23 June and 15 August still did not detect any interactions in the vicinity (Table 3, Figure 5).

5.2 HABITAT SUITABILITY MODELING

The vegetative alliances and associations that characterized the SWFL breeding habitat models in 2018 and 2019 on the Ventura County portion of the Santa Clara River were: the *Salix laevigata* Woodland Alliance, *Salix laevigata/Arundo donax* Association, *Populus trichocarpa - Salix laevigata* Association, *Populus trichocarpa - Salix laevigata/Arundo donax* Association, *Populus trichocarpa/Arundo donax* Association, *Salix laevigata/Baccharis salicifolia* Association, *Baccharis salicifolia* Shrubland Alliance, *Salix lasiolepis* Shrubland Alliance, *Salix lasiolepis/Arundo donax* Association, *Sambucus nigra* Shrubland Alliance (on Peto-McConica in 2019), *Phragmites australis - Arundo donax* (on the Fillmore Cienaga in 2018), and the edges of the *Schoenoplectus (acutus, californicus)* Herbaceous Alliance (on the HRNA).

On the Los Angeles County/Newhall portion of the river the vegetative associations were: the *Salix laevigata* Woodland Alliance, *Salix laevigata/Arundo donax* Association, *Salix laevigata - Salix lasiolepis* Association, *Populus fremontii - Salix laevigata* Association, and in one small location, the *Tamarix* spp. Shrubland Semi-Natural Alliance.

The vegetative alliances and associations that characterized the YBCU breeding habitat models in 2018 and 2019 on the Ventura County portion of the river were much less variable than for flycatchers, and included the *Salix laevigata* Woodland Alliance, *Salix laevigata/Arundo donax* Association, *Populus trichocarpa - Salix laevigata* Association, *Populus trichocarpa* Forest Alliance, and *Populus trichocarpa/Arundo donax* Association. On the Los Angeles County/Newhall portion of the river the associations included the *Salix laevigata/Arundo donax* Association, *Populus fremontii* Forest Alliance, and *Populus fremontii - Salix laevigata/Arundo donax* Association.

5.2.1 2018 Habitat Suitability Model Performance

The habitat suitability models for flycatchers and cuckoos used to delineate survey areas for the species in 2018 seemed to perform very well, i.e., when visited on the ground, the predicted breeding habitat generally met the characteristics of high-quality breeding vegetation as described in Sogge et al. (2010) and Halterman et al. (2015). Only one factor (flowing water in June) seemed to be less abundant than we would have hoped for flycatchers in 2018, and thus may have led to flycatchers not settling to breed in predicted suitable vegetation in 2018. The satellite models do not contain a distance-to-water variable due to the resolution of Landsat imagery (30-m), effects of overhanging vegetation affecting detectability, and the intermittent/ephemeral nature of water along many reaches. There was some flow from winter 2017/2018 that persisted in the main channel even into August 2018, but outside of the *ca.* 10 m-wide main channel there was no other flowing water in the river.

5.2.2 2019 Habitat Suitability Model Performance

In 2019 Dr. Hatten updated the habitat suitability models for SWFL and YBCU breeding habitat on the SCR. Landsat imagery from April 2019 (for flycatchers) and June 2019 (for cuckoos) were used. Due to the significant 2019 winter and spring rainstorms that occurred in southern California, and the resulting lush growth of annual native and non-native plants (especially black mustard [*Brassica nigra*]), the $\geq$40% probability habitat suitability maps for SWFL and YBCU in 2019 included some predicted breeding habitat that was of lower quality for the species. This rapid greening of annual vegetation has been noted in other portions of SWFL range in the southwestern U.S. during wet years, and can result in increased commission errors, especially in the lower probability classes (Hatten 2016). After visiting these particular locations in our Study Area during the first two rounds of SWFL surveys in May and early June 2019, the PI made the decision to skip surveys in some of these areas for both species, because they were unsuitable for breeding (see notes in Tables 3-5).

Aside from some changes in plant cover and NDVI values in 2019, another factor that changed was the presence of strongly-flowing, turbid water outside of the usual high stormwater flow period. Although SWFL are known to breed near flowing water in riparian areas (Sogge et al. 2010), and this water is usually calm, clear, and relatively slow-moving, or even reduced to a very small amount of above-ground flow by early June when SWFL breed in the southwestern United States. In 2019, however, unusual water releases were conducted from late May through mid-August from the Piru and Castaic reservoirs, causing a substantial increase in flow on the SCR, which greatly increased speed and turbidity. We cannot tell if flycatchers that may have been prospecting along the river between late May and mid-June were discouraged from breeding in suitable habitat near the mainstem during this high flow, but it may have been a possibility, especially on the Levy and HRNA properties.

Another change between 2018 and 2019 in habitat suitability was the death of a grove of black cottonwood trees located in the highest quality predicted habitat for YBCU on the southern end of the Levy property (Figure 5). In 2018 this grove was included in the highest probability classes for YBCU (i.e., 9 and 10, or 90-100% probability), but in 2019 the model correctly reclassified this location as classes 7-8. Most likely this grove died due to infection from the invasive Polyphagous Shot Hole Borer (*Euwallacea* sp.; PSHB), a beetle that recently colonized the SCR (A. Lambert, unpubl. data), and causes relatively rapid mortality in many native trees species (*Salix laevigata* and *S. lasiolepis, Populus, Plantanus,* etc) in southern California (Mendel 2012).

5.2.3 Time-series analyses of habitat availability for SWFL

Hectares of suitable habitat for SWFL were estimated using the models and Landsat images from 1986 to 2019 (Figures 6 and 7, and Appendix B). The ≥40% probability model estimated a mean of 741 ha (±55.9 ha) of SWFL habitat river-wide from 1986 to 2019, across all reaches (Appendix B). The ≥60% probability model estimated a mean of 544 ha (±45.7 ha) river-wide from 1986 to 2019, across all reaches (Appendix B).

Among reaches, the average hectares of habitat from 1986-2019 ranged from 0.5 to 234 ha for the ≥40 probability model, and from 0.2 to 191 ha for the ≥60% probability model (Table 6 and Appendix B). The years with the most predicted habitat available for SWFL were 2000, 2001, and 2003 for the ≥40% probability model, and 2000 and 2019 for the ≥60% probability model (Figures 6a and 6b). The reach with the most predicted habitat over the 1986-2019 period was that from the middle of the Levy property to Aflalo (part of the "East Grove"), with an average of 234 ha under the ≥40% probability model, and 191 ha under the ≥60% probability model (Table 6, Figure 7).

The ≥60% probability model estimated a mean of 544 ha (± 121.0 ha) available river-wide from 1986 to 2019 (Appendix B). Although habitat availability may be trending upward on the river for SWFL (Figures 6a and b), the R^2 values were <0.09, which represent very weak trends, likely due to wide fluctuations over the modeled time period.

5.2.4 Time series analyses of habitat availability for YBCU

Hectares of suitable habitat for YBCU were similarly estimated using the models and Landsat images from 1986 to 2019 (Figures 8 and 9, and Appendix C). The ≥40% probability model estimated a mean of 934 ha (±64.9 ha) river-wide from 1986 to 2019, across all reaches (Appendix C). The ≥60% probability model estimated a mean of 246 ha (±20.4 ha) river-wide from 1986 to 2019, across all reaches (Appendix C).

Among reaches, the average hectares of habitat from 1986-2019 ranged from 0.1 to 260 ha for the ≥40% probability model, and from 0 to 77 ha for the ≥60% probability model (Table 7, Appendix C). The years with the most predicted habitat available for YBCU were 2000 and 2009 using the ≥40% probability model, and 2009 and 2006 under the ≥60% probability model

(Appendix C). However, in 2019 the amount of habitat predicted under both models increased over that predicted on the river in 2014 through 2018 (Figures 8a and 8b).

Similar to the finding for flycatchers, the reach with the most predicted habitat for cuckoos over the 1986-2019 period was that from the middle of the Levy property to Aflalo (part of the "East Grove"; Figures 2, 4, 5), with an average of 260 ha using the >40% probability model, and 77 ha using the >60% probability model (Table 7, Figure 9). Although habitat availability may be trending upward on the river for cuckoos (Figure 8a and b), the R^2 values were <0.147, which also were not very strong trends.

5.3 VEGETATION CLASSIFICATION AND MAPPING

5.3.1 2018 and 2019 Field Verification, Map Refinement, and Data Processing

To provide a more standardized and detailed understanding of current riparian vegetation conditions for the 50-mile study area, Dr. Orr and his team at Stillwater Sciences drafted new vegetation maps using NAIP 2016 imagery and various existing data sources in March and April 2018, and then created a protocol for field verification that was conducted from May through July 2018. Field training in the use of the protocol occurred on April 18th-20th, and field verification was managed and conducted primarily by Dr. Adam Lambert and his team at UC Santa Barbara, with some data also collected by the WFVZ during field surveys, and by Dr. Orr during reconnaissance. A total of 345 data points in the SCR were sampled, with a full vegetation assessment form completed for 129 points, and a rapid assessment to note dominant species and any notable invasive plant species for 216 points.

In summer and fall 2018 Stillwater Sciences processed species composition and other vegetative data to assign the correct vegetation types (using Manual of California Vegetation – online version, http://vegetation.cnps.org/), and edited the draft vegetation map.

During winter 2018/2019, Stillwater Sciences finished refining the draft vegetation map for the SCR, and in April 2019 completed their preliminary vegetation classification and detailed vegetation map for the mainstem SCR riparian corridor and its major tributaries in Ventura and Los Angeles Counties, from Bouquet Canyon to the estuary (see Stillwater Sciences 2019).

5.3.2 Vegetation Alliances and Land Cover Types

The final vegetation map includes 45 vegetation alliances, seven of which were further classified into 38 associations, and ten broad land cover types (Table 8), covering a total of 16,369.9 ac (6,624.7 ha). Three vegetation alliances and 15 associations are provisional types not described in MCV (CNPS 2019). Eighteen of the vegetation alliances are considered sensitive natural communities (CDFW 2018), covering a total of 4,750.5 ac (1,922.5 ha) or 27.8% of the Study Area (see Table 8 for the state rankings of these eighteen sensitive natural communities). Ten vegetation alliances are dominated by naturalized non-native species (semi-natural stands), covering a total of 1,072.7 ac (434.1 ha) or 6.6% of the Study Area. The vegetation alliances and land cover types are summarized in Table 8; for descriptions of each type and a summary of the mapped vegetation types by reach and additional details of the vegetation classification and mapping effort see Stillwater Sciences (2019). Those alliances and associations that were present in areas the models predicted to provide suitable breeding habitat for SWFL and YBCU (see section 5.2 above) are also highlighted in Table 8.

5.3.3 Arundo Distribution and Abundance

In addition to mapped stands of this semi-natural alliance (i.e., an alliance dominated by a naturalized non-native species) discussed above in Table 8, Arundo also occurs as an invasive component in many other vegetation types. To help characterize the distribution and relative abundance of Arundo throughout the study area we estimated the percent cover (by cover class) of this species in each mapped polygon. As can be seen in Table 9 (and in Figure 3 in Stillwater Sciences 2019), this nonnative invasive species occurs throughout the study area. However, the largest infestations generally occur in reaches with perennial surface water and shallow groundwater. Removal and control of Arundo is a major natural resource management challenge along the Santa Clara River (Orr et al. 2011, Stillwater Sciences 2011b).

5.3.4 LIDAR-based Assessment of Habitat Structure

Technological advances in airborne laser mapping (also referred to as light detection and ranging, or LIDAR) and other types of remote sensing are providing new tools for environmental assessment, conservation and restoration planning, and monitoring. Our current vegetation classification and mapping efforts are directly benefiting from the use of LIDAR to estimate canopy height of riparian vegetation stands and even individual trees, along with relative elevation (height above the low flow river water surface, which can serve as a proxy for factors such as depth to groundwater, which affects patterns of riparian plant distribution and establishment). The results of these efforts potentially can be incorporated into habitat suitability models for riparian bird species such as the SWFL or YBCU. Although it was not part of the scope of our Section 6 Grant, we also initiated a pilot study to explore the use of LIDAR to provide a more detailed estimate of vertical vegetation structure (from ground surface to top of canopy) that may be useful in modeling habitat suitability for other riparian wildlife species, such as the Least Bell's Vireo (*Vireo belli pusillus*; LBVI). All LIDAR products were developed from the October 2015 data set collected by the National Center for Airborne Laser Mapping for Restoration Science, LLC.

5.3.3.1 Relative Elevation

Existing information in the scientific literature, as well as personal observations and unpublished data, indicate that native riparian plant species tend to occur in particular topographic positions relative to the river channel. In particular, we have found that relative elevation above the low-flow, or baseflow, water surface in the river channel is a useful indicator for restoration potential. Relative elevation in a floodplain is generally correlated with depth to groundwater within a given reach (although the relationship will vary depending on whether it is a hydrologically gaining, stable, or losing reach), and frequency of surface saturation and inundation.

Thus, relative elevation, combined with other GIS layers and field data, provides a powerful tool for assessing restoration potential via passive (natural recruitment processes) or active (horticultural restoration) approaches. Although successful germination of native riparian seedlings depends on a variety of hydrologic and geomorphic variables, seedling survival of phreatophytes such as cottonwoods and willows following germination (or of planted cuttings or container stock under horticultural restoration) is above all contingent on constant contact with the water table and/or its capillary fringe throughout the growing season (McBride and Strahan 1984, Stromberg et al. 1991). Research indicates that when the water table decline is more rapid over a long period than the rate of root growth, seedlings of phreatophytic species become isolated from their water source and suffer high mortality (McBride et al. 1989, Stromberg et al. 1996, Stella et al. 2010). In addition to the importance of groundwater levels for seedling survival, research indicates that groundwater levels play an integral role in determining sapling survivorship and adult riparian community composition (Smith et al. 1991).

Furthermore, comparative studies indicate that some non-native invasive plant species, such as tamarisk (*Tamarix ramosissima)* tend to be more drought-tolerant than natives, and thus better able to compete along reaches with extreme inter- and intra-annual water table fluctuations (Smith et al. 1991; Freidman et al. 1995; Shafroth et al. 1998, 2000). Thus, in order to restore self-sustaining hardwood riparian forest, we need to better understand the role of groundwater in species survivorship across time and across species.

In the absence of data on groundwater depth, relative elevation can serve as a very useful proxy, at least within a given hydrological reach. In alluvial floodplains in hydrologically stable or gaining reaches, the relative elevation or height above the low flow river water surface is typically closely correlated with depth to groundwater (e.g., see Orr et al. 2014). The relationship is typically more complicated in hydrologically losing reaches, and especially in intermittent reaches. Within the study reach, relative elevation should be a good proxy for depth to groundwater in the area with shallow groundwater that supports good cottonwood-willow vegetation (i.e., the historical East Grove area), but may be less useful in the upstream areas that are notably drier and with greater and likely more variable depths to groundwater (i.e., transitional or losing reaches). Ideally, relative elevation mapping can be coupled with groundwater monitoring stations to increase our understanding of groundwater dynamics and increase rate of success when implementing riparian restoration, especially in areas where irrigation of new plantings may not be feasible (e.g., see Orr et al. 2014, and Orr et al. 2017). Such efforts are planned as part of ongoing *Arund*o removal and restoration efforts in the East Grove and Sespe Cienega (Fillmore Fish Hatchery) areas, and additional monitoring wells for shallow groundwater may be added during implementation of Groundwater Sustainability Plans currently under development for several groundwater basins along the SCR.

For the present project, a relative elevation GIS layer and set of maps were produced for the East Grove area using the LIDAR data collected in October 2015. The maps display topographic elevations relative to the low-flow channel elevation in the following categories: less than 0, 0–0.25, 0.25–0.50, 0.5–1, 1–1.5, 1.5-2, 2–3, 3–5, 5–10, and 10–20 m. Appendix D Figure D.3 provides an example for the East Grove area.

5.3.3.2 Canopy Height

The relationships between vegetation canopy height and presence of cottonwood, willow, or other native vegetation, and likely habitat structure and restoration potential, are supported by field observations and review of the previously classified vegetation (Stillwater Sciences 2019) and recent natural color imagery (Google Earth). Canopy height data, when available, may also improve the performance of some wildlife habitat suitability models, such as the Landsat-based YBCU model (J. Hatten, personal communication).

A canopy-height GIS layer and set of maps were produced for the East grove area using the October 2015 UCSB/NCALM. The maps display the following height categories: 0, 0–1, 1–3, 3–5, 5–7, 7–10, 10–20, 20-30, and >30 m. Appendix D Figure D.4 provides an example for the East Grove area.

The taller categories (>10 m) generally indicate the locations of mature patches of cottonwood-willow riparian forests. At the margins of the floodplain, these taller categories may indicate the presence of other native trees (e.g., coast live oak) on nonnative trees (e.g., eucalyptus).

5.3.3.3 Vertical Habitat Structure

We used the classified point cloud LIDAR data to model vertical vegetation structure along transects across the floodplain and in 25-m radius circular plots around bird survey point count stations previously established by avian biologist David Kisner as part of longer term monitoring effort organized by UCSB. This application was meant to serve as a limited pilot study to help us assess whether to seek funding for a more detailed study assessing the value of airborne LIDAR for accurately characterizing vertical vegetation structure for monitoring habitat conditions and modeling habitat suitability for species such as the LBVI.

Visualization of canopy structure is possible by creating a virtual belt-transect across selected portions of the floodplain. Appendix D Figure D.1 shows one such transect that runs across the SCR floodplain perpendicular to the mainstem in the vicinity of the Sespe Cienega. As can be seen in the figure, the data are useful for visualizing variations in canopy height and subcanopy density, including picking out the emergent canopy of an individual cottonwood tree and the adjacent canopy of a shrubby willow stand. Close inspection of the image also suggests the outline of the Arundo-dominated vegetation in the middle of the floodplain.

Appendix D Figures D.5-D.7 show the results of the pilot analysis of use of classified LIDAR point cloud data to visualize and quantify vertical structure in 25-m radius circular plots associated with selected bird point count stations.

5.4 Time-Series Analyses of Suitable Habitat and Vegetation Changes

5.4.1 Temporal Changes in Suitable Habitat for SWFL and YBCU from 1986-2019

The results of the habitat suitability models presented in Section 5.2 and Figures 6-9 indicate significant interannual variation in the amount of predicted suitable habitat for both SWFL and YBCU from 1986 through 2019, both at the full river corridor scale (Figures 6 and 8) and more local reach scale, such as in the vicinity of the East Grove (Figures 7 and 9). Inspection of the graphed results suggests a correlation with factors such as floods and drought. For example, suitable habitat for both species generally declines immediately or the year after major flood events (e.g, 1992, 1995, 2005), and there was a pronounced decline during the recent multi-year drought. Closer examination of spatial and temporal patterns, beyond the scope of our current study, might allow additional factors to be correlated with habitat dynamics. For example, wildfire, human land disturbance, and surface water alterations (diversions or enhancements) would be expected to affect riparian vegetation and water availability, and hence alter predicted habitat suitability for both species.

5.4.2 Changes in Riparian Forests from the Early 1800s to Present

The strongest drivers controlling the distribution of riparian vegetation in the SCR are groundwater and resulting perennial or intermittent surface flow conditions--as represented by longitudinal vegetation patterns--and flood disturbance, as represented by cross-sectional vegetation patterns (Stillwater Sciences 2007, Beller et al. 2011, Orr et al. 2011, Beller et al. 2016, Stillwater Sciences 2016). These drivers demonstrate the importance of surface water availability for vegetation recruitment and succession, and surface water or shallow groundwater for vegetation growth, and align well with those found in previous studies of riparian vegetation in semi-arid river systems, including the magnitude and frequency of flood disturbance (Bendix 1994, 1997; Harris 1999; Bendix and Hupp 2000), depth to groundwater (as reflected in preference for gaining versus losing reaches; Stromberg et al. 1996, Shafroth et al. 1998), and a combination of the two (Hupp and Osterkamp 1996, Lite 2003, Bagstad et al. 2006, Leenhouts et al. 2006, Osterkamp and Hupp 2010).

5.4.2.1 Historical and Recent Longitudinal Patterns and Groundwater Influence

Prior to Euro-American settlement in the late 1700s, mature stands of riparian woodland or forest were largely absent from the Santa Clara River corridor, with the exception of discrete patches of dense, persistent cottonwood-willow riparian forest that corresponded to hydrologically gaining reaches (Boughten et al. 2006, Stillwater Sciences 2007, Beller et al. 2011, Orr et al. 2011, Beller et al. 2016). Appendix E Figure E.1 maps the location and extent of the four primary historically persistent riparian forests along the SCR—the West Grove, East Grove, Cienega, and Del Valle—in relation to the underlying groundwater basin, which, as discussed earlier, strongly influences the groundwater reach type (e.g., gaining versus losing) and, therefore, surface water and shallow groundwater availability for riparian vegetation.

In their historical ecology study, Beller et al. (2011) documented the influence of gaining versus losing reaches on pre-European settlement vegetation conditions in the Ventura County-portion of the Santa Clara River:

> "…reach-level variability in vegetation was observed by early explorers, travelers, and surveyors. In the lower Oxnard, Santa Paula, and Sespe reaches, for example, the active channel was narrower, and substantial bottomlands—many supporting wetlands and dense riparian forests—developed along much of the river. In the wettest portions of these reaches, [General Land Office] surveyors recorded willows and a few alders and box elders on bottomland surfaces, along with live oaks and sycamores on the high banks (Norris 1853, Hoffman 1868b, Thompson 1869). In the perennial reaches, explorer Crespí's 1769 account describes the river with "a great many cottonwoods, a great deal of willows, and many live oaks" in addition to wild grapes (Del Valle reach), or with "vast numbers of lush plants (the grapevines still continue)" (Sespe reach), or with "trees on all the river bed…sycamores, live oaks, willows and white [Fremont] cottonwoods" (Santa Paula reach; Crespí and Brown 2001).
>
> Conversely, accounts of the river outside of these wetter reaches describe more dispersed trees. In the intermittent portion of the Oxnard reach near Saticoy, for example, Crespí notes that "no trees are to be seen nearby". One article describes the river with "no gigantic trees bordering its low banks, only a group of cottonwoods; and a clump of willows, here and there" (Clifford 1872), and another "small, isolated groves of cottonwoods and willows, with here and there an occasional sycamore" (Evermann 1886)."

Because the distribution of gaining and losing reaches is driven by geology, the general locations suitable for forested wetlands are unchanged from historical conditions, although surface water and shallow groundwater conditions are now influenced by surface water diversions, managed water releases, and treated wastewater releases. As a result, despite dramatic changes to the Santa Clara River valley and riparian corridor (see for example, descriptions presented in Beller et al 2011 and Stillwater Sciences 2016), remnants of the four historically persistent riparian-forested wetlands that were dominated by willows and cottonwoods are still supported (Orr et al. 2011, Beller et al. 2016). Appendix E Figure E.1 also maps the current distribution of riparian forest, where the largest patches are still found in the same West Grove, East Grove, Cienega, and Del Valle locations. The historical ecology study (Beller et al., 2011 and 2015) did not extend upstream into Los Angeles County, so we do not have good data indicating whether the current concentration of riparian forest along the SCR from the confluence of San Francisquito Creek downstream to the Casitas Creek confluence has been as persistent historically. There is evidence that baseflow in SCR has increased compared to historical conditions due to releases of imported water from Castaic Lake and effluent from wastewater treatment plants, such as the one in Santa Clarita (Hanson et al. 2003), as has been observed in some other urbanized watersheds in southern California (Thompson-Small et al 2013). The possibility that the current extent of riparian forests in this part of the upper SCR may be enhanced compared to historical conditions warrants further study.

Conversely, alluvial scrub or semi-desert wash scrub vegetation types, such as those dominated by California sagebrush (*Artemisia californica*) and California broomsage (*Lepidospartum* *squamatum*) continue to occur more frequently in the drier, losing reaches of the SCR (Stillwater Sciences 2007 and 2019, Orr et al. 2011, Beller et al. 2016). For example, the Freeman Diversion is upstream of one of these losing ("dry gap") reaches within the Oxnard Forebay groundwater basin that historically had intermittent surface flow conditions (see Figure 4 in Beller et al. 2016). Historical records of vegetation in this particular area (i.e., near Saticoy) describe "a wide, sandy and gravelly bed, destitute of vegetation except on a few higher patches where small poplar [black cottonwood] and willow trees grow, with low shrubbery, and which become islands in the high water of winter" (Cooper 1887, as cited and quoted by Beller et al. 2011).

Another longitudinal influence on riparian vegetation composition is the coastal fog belt. Differences in local climatic conditions between the coastal fog belt, where humidity is relatively high and evapotranspiration demand relatively low, and the more arid inland portions of the watershed are probably at least partly responsible for the distribution patterns of a number of native plant species. Specifically, black cottonwood (*Populus trichocarpa*) and arroyo willow (*Salix lasiolepis*) are generally found closer to the coast, while Fremont cottonwood (*Populus fremontii*) and other willow species are generally found further inland (Stillwater Sciences 2007b, Orr et al. 2011). This pattern has presumably existed since at least the early 1800s, but it may change to some degree in coming decades if the extent and duration of summer maritime fog alters as a result of climate change.

5.4.2.2 Reductions in River Corridor Width

Prior analysis (Stillwater Sciences 2007 a,b) has indicated that the riparian corridor of the lower SCR is currently much narrower, on average, than historical accounts, although the area of riparian vegetation has been dynamic over time (Table 10). The 1938 flood was the third largest flood analyzed, but inundated the greatest amount of floodplain (over 12,000 ac). The 1938 flood occurred before the construction of major dams and levees, so this year likely provides the most accurate example of historical flood extent (Stillwater Sciences 2007). By 1969, when the largest flood analyzed occurred, dams, levees, and development in the floodplain were already beginning to limit the extent of floodplain inundation (approximately 2,000 ac less than the smaller magnitude 1938 flood). The magnitude of the 1969 flood appears to have resulted in significant scour of riparian vegetation, as demonstrated by the small percent of vegetated area (26%). The moderate sized floods of 1978, 1995, and 1995 all inundated similar floodplain extents (7,246 to 7,951 ac) and had similar percentages of vegetated area (43 to 68%). The 2005 flood, which was similar in magnitude, although slightly larger than the 1938 flood, inundated nearly half the amount of floodplain as the 1938 flood and had a similar percentage of vegetated area (36%).

The 2005 flood inundated approximately 60% less area than the similarly sized 1938 flood. In addition, the total amount of riparian vegetation mapped in 2005 was approximately 50% less than that found in 1938 (Stillwater Sciences and URS Corporation 2007). These differences further demonstrate the dramatic effect of levees in constraining the floodplain and limiting the extent of riparian vegetation in the lower Santa Clara River. This loss, illustrated in Appendix E Figure E.2 is most acute in the lowest reaches of the river (river mile 0 to 7) where levees are most extensive and nearly 70% of the riparian corridor has been lost.

Building on the deeper historical analysis conducted by Beller et al. (2011, 2016), it is evident that the active river corridor in the Santa Clara River valley has progressively narrowed due to myriad land-use activities that have cumulatively encroached upon the floodplain since the mid-1800s (Freeman 1968; Simons et al. 1983; Schwatzberg and Moore 1995; AMEC 2005; Stillwater Sciences 2007a, 2011a; Beller et al. 2011; Downs et al. 2013), although available evidence suggests that most of the loss of active river corridor area occurred during the post-World War II boom in urban development in Ventura County (Beller et al 2011, 2016). Salient activities included agriculture and ranching, urban development, flood-control infrastructure, instream aggregate mining, and surface water diversions. In particular, construction of levees and urban expansion along the river has substantially reduced the area available for floods to inundate and, therefore, for riparian forests to recruit and grow. Appendix E Figure E.3 provides one example of how the geomorphically active river channel resulting from the 2005 flood event occupied approximately 60% less area than the active river channel area resulting from the similarly sized 1938 flood (Stillwater Sciences 2007a; 2011a, b). Channel encroachments have been greatest in the lowermost reaches (Reaches 1 and 2) due to urban encroachment and flood-control levee construction. This portion of the river historically supported the West Grove of forested wetland along its southern floodplain. Urban and agricultural development and levee construction eliminated the extensive primary stands comprising the historical West Grove, but smaller remnant patches still persist near the estuary and on the margins of the now highly constricted and channelized Reach 1.

Comparison of repeat views of the historical East Grove reach in the next section reveal in greater visual detail that this portion of the river has experienced changes readily attributed to both natural flood events and land-use activities (Appendix F). As discussed above, this area has been characterized as a hydrologically gaining reach, thus indicating that riparian vegetation has been naturally present here for centuries (Beller et al. 2011, 2015; Orr et al. 2011).

5.4.3 Temporal Dynamics of Riparian Vegetation and Habitat in the Historical East Grove

Of the four major patches of forested wetland, only the East Grove remains close to its historical size with only an estimated reduction of 12% (from 250 to 220 ha). The other three patches have been fragmented and reduced by 53 – 67% (for more details see Table 4 in Beller et al. 2011). Aside from currently being the largest forested patch, the East Grove is also the least fragmented (Appendix E Figure E.1). The habitat suitability model predictions for SWFL and YBCU, as well as the finding of YBCU in the area during the study, support the continued importance of the East Grove habitat patch, as well as the dynamic inter-annual changes in the quantity and quality of habitat.

Beginning with the 1927 aerial view, the channel exhibited a broad, braided morphology that had historically been subject to episodic, channel-resetting flood events (Appendix F). Large patches of dense, apparently mature cottonwood-willow forest are visible in the 1927, 1929, and 1938 aerial photographs with only relatively minor changes. For example, the flood in 1938 (peak flow of 120,000 cfs) scoured away portions of the forested patches near the central flood reset zone but left the majority of the forest intact. Only limited agricultural encroachment into the active floodplain is evident in 1927 – 1938. By 1945, more agricultural development is evident in the historical floodplain, and channelization of the lower portion of Santa Paula Creek can be seen at the downstream end of the East Grove. Recent flood scour is also evident in 1945, but the total extent of the riparian forest seems similar to that evident in 1938 and earlier. The flood of record (165,000 cfs) occurred in 1969 when two very high flow peaks were recorded (the other peak flood flow that year was 152,000 cfs). The high amount of flood scour combined with habitat losses from floodplain development since 1945 resulted in the lowest recorded amount of riparian forest in the East Grove (and in the lower SCR as a whole, see Table 10). By 1978 there was some recovery in and around the margins of the patches that survived the 1969 flood, but still much less riparian forest than was evident in 1927 – 1945. Signs of recent scour were clearly evident from the flood flow of 102,000 cfs that year. 1992 experienced a similar flood flow (104,000 cfs), but still had notably more riparian vegetation that was seen in 1978, particularly on a number of mid-channel bars. Extensive amounts of Arundo are also visible in the upstream portion of the East Grove in 1992. In addition, the majority of agricultural and urban encroachment seems to have occurred by 1992. From 1992 on we see relatively similar patterns of vegetation recovery following major floods (e.g., 110,000 cfs in 1995 and 136,000 cfs in 2005 which, similar to 1969, experience two large peak flood flows), with vegetation infilling on younger floodplain surfaces and forest stands maturing on older surfaces. Since 2005 we also see the signs of active and passive restoration of native riparian and wetland vegetation at HRNA, and reductions in Arundo at selected areas where control of this invasive species was undertaken.

In summary, while there has been some reduction in total area of the East Grove and the active river corridor compared to historical conditions, and reduction in habitat quality from invasion by Arundo, this reach still experiences active river processes and maintains a very valuable shifting mosaic of riparian forest and other riparian and wetland habitats. The habitat suitability modeling for SWFL and YBCU supports this characterization. No other reach along the river matches it in quantity and apparent quality of woody riparian habitat.

5.5 CONCEPTUAL MODELS OF VEGETATION AND HABITAT RESPONSES

Our current understanding of the dynamics of riparian vegetation and habitat along the SCR derives from a variety of sources, including: (1) literature summarizing research and conceptual models of riverine riparian ecosystems associated with alluvial rivers, particularly those in semi-arid or arid landscapes (e.g, Stillwater Sciences 2007, 2011, 2016; Orr et al. 2017a,b; Rasmussen and Orr 2017); (2) recent studies of fluvial geomorphic processes and riparian vegetation distribution and dynamics conducted for the California Coastal Conservancy and others in the lower SCR and various parts of its watershed (Stillwater Sciences 2007, 2011, 2016, 2019; Orr et al. 2011; Downs et al 2013); and (3) in-depth investigations of the historical ecology of the lower Santa Clara River (Beller et al. 2011, 2016). In this section, we summarize our understanding by using narrative and graphical conceptual models, starting with generalized conceptual model for alluvial rivers and cottonwood riparian forests, then providing more details based on SCR-specific information.

5.5.1 General Conceptual Model for Riverine Riparian Ecosystems Associated with Alluvial Rivers

Alluvial rivers are dynamic systems that are affected by complex interactions between numerous inputs and processes. Factors that vary at broad landscape scales, such as climate, topography and lithology, shape processes and attributes that affect the riparian community structure and composition through a hierarchy of interaction and feedback. A simplified conceptual model illustrating these interactions is shown in Appendix G Figure G.1. In the model, landscape context (climate, topography, geology) and natural watershed inputs (such as water, sediment, and nutrients) drive physical processes (such as sediment transport and channel migration) that, in turn, determine geomorphic attributes and physical habitat structure of the river-floodplain system. The geomorphic attributes and habitat structure drive biological responses and are important determinants of plant and animal species abundance, distribution, and composition. Modification of any of the key inputs or processes will influence channel and floodplain geomorphic attributes and, subsequently, affect riparian plant communities and fish and wildlife populations. For example, reduction in peak flows (a watershed input) can alter fluvial processes such as the timing, frequency, extent, and duration of floodplain inundation. This alteration in inundation patterns can result in changes in riparian plant species composition and age-class structure, which can alter habitat suitability for native birds and thus result in a shift in bird community species composition. In turn, riparian vegetation can feed back to hydraulic and geomorphic processes. For example, increased hydraulic roughness provided by newly established vegetation can increase sediment deposition and floodplain accretion, and encroachment of vegetation into the active channel following flow regulation commonly contributes to channel deepening. Natural and anthropogenic disturbances can occur at different scales, ranging from global climate change effects on regional temperatures, precipitation, and evapotranspiration rates, to a 20,000 ha wildfire in the watershed headwaters, to landslides or flood scour and deposition along a single alluvial reach, to vegetation removal and soil disturbance by invasive animal populations within a single floodplain site. The effects of these disturbances also can occur at multiple scales, including the scale of the original disturbance event, to finer scale processes and structures within a watershed, including habitat structure, complexity, connectivity, and biotic responses (Stillwater Sciences 2001, Vaghti and Greco 2007, Downs et al. 2011). Restoration ecologists need to understand how these landscape- and watershed-scale processes in and around their restoration area respond to abrupt and/or long-term (e.g., punctuated vs. press) sources of disturbance and stress in order to chart a path towards functional recovery or enhancement of resilient riparian ecosystems within the targeted restoration area (see Rasmussen and Orr 2017).

5.5.2 Cottonwood in California Forested Riparian Systems

5.5.2.1 Riparian Vegetation Dynamics in California Alluvial Rivers

Riparian vegetation dynamics are tightly coupled with riverine processes; flooding, scour, and sediment deposition strongly influence riparian plant species composition, distribution, and physical structure and are major drivers of riparian community succession along with depth to groundwater. At a fine scale, riparian zones can be seen as non-equilibrium ecosystems, in which patches of vegetation become established and are seasonally altered (and often extinguished) by inputs of water and nutrients and by deposition and scour of sediment (McBride and Strahan 1984; Stromberg et al. 1991; Bendix 1994, 1999; Stromberg 1997). At a coarser scale, riparian corridors can be seen as a steady-state landscape, in which the formation and annihilation of vegetation patches tend to balance out over the long term (assuming climatic and hydrologic regimes remain relatively constant), resulting in a shifting mosaic (or spatially heterogeneous, temporally dynamic patchwork) of habitats that have evolved under the influence of frequent disturbance (Johnson et al. 1976, Wiens 2002, Whited et al. 2007).

Riparian forests require periodic seedling recruitment and subsequent establishment to replace mature and dying trees, maintain the stand through time, and reset the process of vegetation succession. Recruitment (also known as initiation) refers to seedling germination following seed release. Establishment refers to the life stage when a plant has developed sufficient root-and-shoot architecture to survive annual environmental conditions (especially inundation, scour, and drought) and develop into a reproducing adult. Succession refers to a progressive replacement of different plant communities over time in response to internal competition among different plant species or outside disturbances such as floods and fire (Malanson 1993, Oliver and Larson 1996).

In addition to the establishment of pioneer species on newly deposited floodplain and bar surfaces, subsequent hydrologic, geomorphic, and ecological or successional processes alter vegetation composition in established riparian stands in a fairly predictable manner. Over time, pioneer vegetation traps sediment and adds litter and nutrient inputs to floodplain soils (Walker and Chapin 1986). As the floodplain develops and the riparian stand ages, other riparian species such as California walnut (*Juglans californica*), California sycamore (*Platanus racemosa*), coast live oak (*Quercus agrifolia*), and valley oak (*Quercus lobata*) (which has only been documented on the SCR in some of the LA County reaches) establish within the riparian zone. These "later successional" species typically produce larger seeds and are more shade-tolerant than the early pioneers, which allows them to persist in the seedbank and germinate under the forest canopy when soil temperature and moisture conditions are adequate. Recruitment of these species is not as dependent on flow and sediment conditions as for the willows and cottonwoods, and seedling recruitment typically occurs as chance events that depend on individual conditions such as microclimate and proximity to parent trees. Over time, these species further alter the soil, light, moisture, and nutrient conditions within the riparian zone and outlive or outcompete the original pioneer species.

At any one site, the spatial and temporal patterns of physical processes (such as flooding and sediment dynamics) and biological processes (such as plant establishment and competition) can be complicated and unpredictable, and vegetation composition is often more patchy than the generalized patterns described above. However, recent studies by Greco (1999), Trowbridge (2002), Wood (2003b) and Fremier (2003) indicate that the basic facilitation model of succession, as described above, which has been frequently proposed for Central Valley riparian systems, may be too simplified and deterministic. Actual vegetation dynamics may be much more complicated, with multiple types of middle and later seral stages possible with outcomes governed largely by local site conditions (e.g., soil texture, soil stratification, and depth to groundwater), the physical pathway that creates new surfaces (e.g., gradual meander migration versus cutoff events or channel avulsion), or historical factors (e.g., the seasonal timing of the initial resetting disturbance event, the pool of seeds and vegetative propagules available immediately after the disturbance event, founder effects, potential influence of non-native species). TNC's (2003b) analysis of factors affecting revegetation success at restoration sites provides further evidence of the importance of fine-scale, site-specific factors affecting vegetation development, particularly soil texture, soil profile stratification, and depth to groundwater. It is quite possible that multiple stable states may occur rather than a single climax plant community (Baker and Walford 1995).

5.5.2.2 Cottonwood as a Foundation Species

Some of our current understanding of riparian habitat dynamics and hypotheses regarding the effects of land and water management on cottonwoods and other riparian species are guided by a conceptual model adapted and modified by Battles et al. (2005) from Strange et al. (1999), of riparian community development (Appendix G Figure G.2). In the model ecosystem, components are classified as drivers, processes, patterns, and ecosystem functions. Climatic factors (i.e., precipitation and temperature) and basin characteristics (e.g., latitude, area, elevation, topography, and parent material) are the ecosystem drivers, and they are analogous to state factors in other ecosystem models (Jenny 1941, Likens et al. 1970, Groffman et al. 2004).

Our research and management focus is typically on the ecological processes and patterns (the shaded box in Appendix G Figure G.2) that result from the interaction of these drivers over annual and decadal scales. The most influential of these processes is flow regime, specifically flow timing, magnitude, and sediment dynamics. These processes especially determine the potential distribution (e.g., geographic range and population age structure) of cottonwood in a river system. Actual distributions are narrowed further by biotic interactions and human modification of the landscape and flow regime (including alterations of both surface flows and groundwater). Biotic interactions such as competition and herbivory are generally considered less important in structuring this non-equilibrium, disturbance-driven ecosystem than physical factors and dispersal (Mahoney and Rood 1998; Johnson 2000), although the introduction of invasive species, such as *Arundo donax* or *Tamarix* spp., can substantially alter biotic interactions and ecosystem structure and function.

Cottonwoods and willows generally dominate the early-successional phase of riparian community development. Therefore, the ecological properties of these populations (i.e., size structure, age distribution, density, and growth rate) serve as the landscape template on which the riparian ecosystem develops. This interaction between process and pattern governs important riparian functions such as energy inputs, habitat structure, microclimate modification to the instream and riparian environments, large woody debris production, and streambank stabilization.

Major human impacts to the ecosystem occur at all levels of the model by modifying drivers, processes, community structure, and landscape patterns. These are indicated as external inputs in the conceptual model (Appendix G Figure G.2). The most important alterations are to the climate (via global warming and consequent changes in precipitation and temperature influencing the natural hydrologic regime), anthropogenic flow regulation (with consequent changes in river hydrology and sediment regime), landscape modification (such as agricultural conversion, levee construction and bank protection), and introduction of nonnative invasive species.

5.5.3 Riparian Vegetation Dynamics in the Santa Clara River, and their Relation to the Birds Species of Interest

The Santa Clara River flows in a westerly direction from headwaters along the western edge of the Mojave Desert and the northern slopes of the San Gabriel Mountains in Los Angeles County, through the Santa Clara River Valley and the Oxnard Plain in Ventura County, and empties into the Pacific Ocean near the City of Ventura (Figure 1). Many large coastal southern California rivers (i.e., the Los Angeles, Santa Ana, and San Gabriel rivers) have largely been confined to concrete channels in their lower reaches to provide flood protection for surrounding urban areas, dramatically reducing (or eliminating) riparian vegetation and the fluvial geomorphic processes that maintain functioning ecological systems in river corridors. The SCR riparian corridor, however, has retained a significant amount of high-quality riparian habitat that supports a diversity of native wildlife.

The present-day Santa Clara River is a dynamic semi-arid ecological system driven primarily by periodic short duration, high intensity flood events (Stillwater Sciences 2007, 2011a). The channel borders between meandering and braided river forms, as defined by the gradient, discharge, and bed material grain size. Where natural processes prevail, the result is an unusual compound channel morphology that is braided at lower flows but more akin to a low sinuosity meandering channel during large flood events. The channel morphology is affected primarily by large flood flows rather than by the moderate discharges frequently used to characterize channel form response in temperate climates. These factors result in a mosaic of riparian vegetation that shifts in extent, structure, and composition in response to deposition, scour, and inundation by large flood flows (Stillwater Sciences 2007, Orr et al. 2011, Beller et al. 2015).

There are four dominant woody species that characterize the primary cottonwood-willow riparian forests of the SCR that are important to SWFL, YBCU, and many other wildlife species. A previous report (Stillwater Sciences 2016) reviewed existing scientific literature and available data for the SCR and determined that successful recruitment, establishment, and growth of these four species (red willow [*Salix laevigata*], arroyo willow [*S. lasiolepis*], Fremont cottonwood [*Populus fremontii]*, and black cottonwood [*P. trichocarpa]*) are controlled by the following factors:

- Moderately high flow events (i.e., 5–10 year recurrence interval, or greater, flow events) are needed to create appropriate seedbed sites
- Declining limbs of high-flow hydrographs that coincide with the peak seed release periods (generally March–April for Fremont cottonwood and arroyo willow, and April to early May for black cottonwood and red willow).
- Maximum stage declines of 0.8–1.2 inches (2–3 cm) per day (for willows) and 1.4 inches (3.5 cm) per day (for cottonwoods) during the germination and seedling establishment period (i.e., first growing season, March–October).
- Depths to groundwater between 0.7 (0.2 m) and 6.7 feet (2 m) during the 2nd year growing season.

- Depths to groundwater of less than 20 feet (6 m) to maintain existing mature riparian vegetation.

Although the Santa Clara River riparian corridor is relatively intact, flood protection infrastructure, diversions, roads, agriculture, and urbanization have constrained or disrupted natural geomorphic and hydrologic processes, causing riparian and aquatic habitat degradation. As native riparian vegetation provides critical ecosystem services such as improved flood control, water quality, and terrestrial and aquatic habitat quality as well as increased local biodiversity, managing for healthy riparian vegetation is central to river management and restoration. The replacement of native scrub and mature forest communities by dense stands of Arundo, which does not provide any of the key habitat elements required by most riparian birds and other native wildlife, is prevalent throughout the SCR. Arundo is currently being managed through control and removal programs at selected locations throughout the watershed, which is expected to benefit both flycatchers and cuckoos, as well as other riparian-obligate species.

As described above, in our general conceptual models we start with the coarser landscape and watershed scales and proceed stepwise to the finer reach and site-specific spatial scales following the principle that processes and inputs from upslope and upstream areas have a strong influence on local conditions and ecosystem dynamics. Explicit integration of natural ecosystem processes operating at appropriate scales is a fundamental part of planning, implementation, and adaptive management. Assessment of feedbacks between these processes and major stressors need to be integrated into the restoration design process. Thus, landscape and watershed context matters. For example, the restoration of cottonwood and willow riparian forests on the SCR is generally appropriate only in gaining reaches (i.e, where groundwater rises towards the surface and feeds into the river channel) with reliable shallow groundwater, while more xeric types of riparian vegetation (e.g., alluvial scrub) are more appropriate restoration targets in losing reaches (i.e., where river water is being lost downward to the water table) (Orr et al. 2011), especially those reaches that have historically gone dry in most years by late summer (i.e., the “dry gaps” discussed in Beller et al. 2015). Variations in the structure and location of underlying bedrock creates groundwater basins filled with alluvial sediments. Groundwater is typically forced to the surface at the downstream end of such a basin where bedrock and the water table are near the surface, while groundwater is often lost to a deeper water table where the river enters the upstream end of the basin. These physical geological controls can create patterns of intermittent and perennial flow that are consistent over decades or centuries, which in turn can create patterns of vegetation (such as large areas of cottonwood-willow forests and wetlands in gaining reaches and alluvial scrub in losing reaches) which are also persistent over those same temporal scales (Beller et al. 2015). For example, Beller et al. (2015) identified four areas in gaining reaches that have consistently supported significant stands of forested wetlands dominated by cottonwoods and willows for at least the past two centuries, with the East Grove being the largest and most intact example (see discussion in section 5.4.2.1, above).

However, periods of prolonged and severe drought (e.g., 2012–2018) have negatively affected the native riparian forest and shrub habitats that provide breeding habitat for species such as SWFL and YBCU, as discussed more below. The frequency and severity of key disturbance events (e.g., floods, droughts, wildfire) affecting riparian habitats in the SCR also are predicted to increase in coming decades due to climate change.

6.0 DISCUSSION

6.1 POPULATION STATUS, DISTRIBUTION, AND HABITAT AVAILABILITY FOR SOUTHWESTERN WILLOW FLYCATCHER ON THE SANTA CLARA RIVER

6.1.1 Southwestern Willow Flycatchers

Breeding SWFL were not found on the river in 2018 or 2019, despite 174 surveys covering thousands of hectares of predicted suitable breeding habitat. Southwestern Willow Flycatcher numbers throughout southern California have been depressed over the past few years, possibly due to drought conditions from 2014-2017 (B. Kus and others, pers. comm. and unpubl. data, Riparian Bird Working Group, 4 Dec 2019). Contrasting with the population status of SWFL, however, was the notable increase in availability of breeding habitat on the Santa Clara River in 2019: this year showed the largest amount of suitable habitat available since 2009. Conversely, the years 2014-2018 showed the lowest amounts available, due to drought conditions, which may have impacted long-term flycatcher numbers on the river. Suboptimal conditions on the wintering grounds in Central America and possibly northern South America, as well as along the migration route, may also be contributing to the California decline in SWFL numbers, since migration is the period of highest mortality within the flycatcher's annual cycle (Paxton et al. 2007). Notably, a recent publication by Ruegg et al. (2018) showed that small SWFL populations, such as those throughout California, also are likely to be the worst affected by climate change in the future, due likely to their probable reduced thermal tolerance, caused by a mismatch between their current genotype and predicted future environmental stresses.

As summarized in Sogge et al. (2010), drought can have substantial negative impacts on breeding flycatchers and their habitat through reductions in vegetation quality and quantity, and prey availability. Because breeding SWFL typically nest in relatively dense riparian vegetation where surface water is present or soil moisture is high enough to maintain the appropriate vegetation characteristics (from Sogge et al 2010), the drought experienced on the SCR between 2014 and 2017 may have significantly impacted, or deterred, breeding SWFL. On the SCR, tree mortality has been extensive since 2016 (L. Hall and others, pers. obs.), coinciding both with the drought, and starting in 2018, with the arrival of polyphagous shothole borer beetle infestation. Fortunately, since SWFL are adapted to highly variable hydrological and habitat conditions (e.g., Ahlers and Moore 2009), they are known to reappear at unoccupied breeding sites, even after 1-5 year absences (Sogge et al. 2010). In addition, small populations can be ephemeral and last only a few years (Durst et al. 2008), whereas other populations can persist for longer periods (Kus et al. 2003). The dynamic nature of breeding flycatcher populations, because of the dynamic nature of the areas they occupy, encourages hope for the population on the SCR to reappear in the future, especially because of the quality and quantity of restored habitat that is being created through (1) the removal of Arundo, (2) the active and passive planting of dense willow stands, and (3) the decreased abundances of Brown-headed Cowbirds (*Molothrus ater*) observed on the river over the past few years (L. Hall, unpubl. data and reports, e.g., Hall 2014, 2017; Hall and Searcy 2018).

As summarized by Sogge et al. (2010), the greatest factor in the decline of SWFL has been the extensive loss, fragmentation, and modification of riparian breeding habitat. Parasitism is now generally no longer considered among the primary rangewide threats to flycatcher conservation (USFWS 2002). Instead, aside from outright modification of breeding habitat, projected impacts to SWFL populations from climate change will likely be the most significant stressors in the foreseeable future (*sensu* Ruegg et al. 2018). These stressors include increased summer temperatures and their effects on river moisture and air humidity, vegetative quality and quantity, and prey abundance and availability, which will likely affect all bird species in Ventura County over the next 30 years, based on recent climate projections (e.g., Oakley and Hatchett 2019, unpublished presentation).

6.1.2 Other Willow Flycatcher subspecies

Significantly for the two other western Willow Flycatcher subspecies (*E. t. brewsteri* and *E. t. adastus*), the SCR seems to be a significant migration corridor. Thirteen Willow Flycatchers in 2018, and 25 WIFL in 2019, were detected during surveys, and in 2018, an additional 7-8 were detected via other studies during spring migration (Table 4, from GWB and D. Kisner, pers. comm., 2018). The importance of the SCR to migrating Willow Flycatchers has probably not been determined to the degree that we were able to ascertain in this study, although it has been known previously (J. Greaves, pers. obs.). However, the importance of the river—with increased vegetative restoration, and as one of the few natural river corridors running from the coast to the southern Sierra in a growing maze of southern California urbanization—will likely only magnify over time.

6.2 Population status, distribution, and habitat availability for western Yellow-billed Cuckoo on the Santa Clara River

During the study, Yellow-billed Cuckoos were found in medium and high probability breeding habitat, predominantly in the East Grove area of the river. The species' consistency on the southern and eastern parts of the Levy property, and throughout the north, central, and western parts of the Hedrick Ranch Nature Area, was predicted and expected based on other detections of cuckoos in this area between 2010 and 2017 (L. Hall and A. Searcy, unpubl. reports; S, Hedrick, pers. obs.). Removal of Arundo followed by passive and active revegetation of native willow on the HRNA, in particular, over the past 15 years has clearly recreated suitable foraging and roosting habitat for YBCU (HRNA, unpublished data) similar to what was found there historically (i.e., see Appendix E Figure E.1, and Appendix F): a nest record from near Santa Paula on 4 June 1904 documented breeding by this species in the vicinity of the East Grove (Willet 1912), and they were described as "fairly common" in the region until the mid-1930s (summarized in Gaines and Laymon (1984). A new detection of a cuckoo in 2019, foraging on the Kenter Canyon property (Figure 5), also was encouraging, since this area had extensive Arundo removal treatments between 2015 and 2017, and revegetation efforts between 2017 and 2019 (A. Lambert, pers. comm.). The property now seems to be of higher quality foraging potential for cuckoos.

One question about continued occupancy, and breeding, by cuckoos on the Santa Clara River regards prey for the species. Prey items for cuckoos include a variety of large arthropods (e.g., cicadas, katydids, grasshoppers, and caterpillars), and also small lizards, frogs, spiders, and tent caterpillars (Halterman 2015). With the resumption of above-ground waterflow throughout the mainstem and also in the braided side channels in winter and spring 2018 and 2019 in many areas along the SCRs (especially on the HRNA property), we observed thousands (if not hundreds of thousands) of juvenile frogs between April and June 2019. We suspect that cuckoos were foraging heavily on such froglets, given their protein content, and had one observation of 22 June 2019 of a cuckoo flying in from the direction of the flooded floodplain in response to playback. However, continued high frog abundances may not occur with predicted future drought conditions due to climate change (N. Oakley and B. Hatchett 2019, unpublished presentation), and large arthropod abundances seem generally to be very low on the SCR (L. Hall, pers. obs., 2010-2019). Monitoring of large insect abundances (as well as small insects, for SWFL and LBVI) on the SCR will be very important going forward, and is being conducted in some measure by Dr Adam Lambert of U.C. Santa Barbara, but in the meantime, all steps to increase native vegetation and to limit drawdowns of water from the River during droughts and during the breeding season also should be encouraged, so that native amphibian populations can be sustained, and so that riparian insect abundances also have adequate moisture in which to thrive. Yellow-billed Cuckoos—and Southwestern Willow Flycatchers--also are historically associated with humid environments, rather than dry ones, and so adequate moisture in the SCR to create humid conditions in the future will be imperative for these species.

In addition, it has long been suspected that heavy use of pesticides for agriculture throughout riverine valleys in California contributed to cuckoo declines in the 1940s and 1950s (e.g., Gaines and Laymon 1984), and evidence for other species using similar environments shows that the impact of pesticides is continuing. Analysis of eggshell thicknesses of cuckoos breeding in southern California, and chemical analysis of the carcass of a bird killed by a window-strike in Anaheim in 2019, is currently underway (by the PI, D. Tracy, and S. McNeil), and will lend insight into this conversation. However, ample evidence already exists that aerial insect numbers are reduced in agricultural areas of North America, and that this, combined with rapid changes in farming practices and widespread conversion of valley lowlands to agriculture, have contributed to significant declines in aerial insectivore bird numbers (e.g., Stanton et al. 2018). Pesticides have been specifically linked to adverse outcomes for migratory bird populations (Eng et al. 2019), and subtle interference with behavior and physiology also have been reported through sublethal pesticide toxicity. Stanton et al. (2018) conducted a review of 122 studies and found that pesticides (42% of all studies), followed by habitat loss or alterations (27%), were most predominant in negatively affecting farmland birds, with pesticides (93% negative) and mowing/harvesting (81% negative) having the most consistently negative effects. They recommended that modifications to farmland management such as reducing pesticide inputs through integrated pest management and maintaining or restoring uncultivated field margins and native habitat – such as that on the SCR at the edges of intensive agriculture in Ventura County -- could positively influence birds. Thus, we strongly suggest that such measures be considered for all agricultural lands bordering the SCR.

Despite abundant and accessible food resources in the form of frogs for YBCU in 2018 and 2019, we did not detect outright nesting behavior in the locations where we observed cuckoos in either year. Nor did we ever see or hear interacting birds, witness copulations, or find active nests or fledglings. Thus, it is possible that we do not yet have an actively breeding population.

However, early nesting dates for YBCU from Ventura County (e.g., Santa Paula 4 June 1904) in addition to another 11 historical early laying dates from 15 May to 17 June (Table 11), may also signal that cuckoos could breed earlier on the river than we, and other California surveyors, have assumed. For example, we saw a cuckoo in high quality habitat near Lost Creek on the southern end of the Levy property on 10 June, and recorded an alarm-calling cuckoo at the same place on 22 June 2019. Alarm-calling is usually associated with defensiveness by nesting cuckoos (Halterman et al. 2015), and although we never had a cuckoo respond to our playback in this vicinity in 2018 or 2019, and we did conduct quiet listening surveys in this same area in July 2018 and 2019, we never observed any nesting behavior or other sign of cuckoos, nor did the microphone record any additional calls. However, nesting could have already finished by the time we conducted quiet listening, and it could even be that observations of cuckoos calling or responding to playback into July and August east onto the HRNA were from a family group on south Levy. Thus, future quiet listening surveys will be very important in this zone, and any future restoration activities must only be conducted during the non-breeding season in predicted high quality breeding habitat on the Levy, Hedrick Ranch, Taylor, and Kenter Canyon properties to avoid disturbing nesting cuckoos.

The habitat suitability models accurately predicted occupancy of high quality habitat by cuckoos in the historic East Grove. This area alone made up approximately 30% of all high probability predicted habitat on the river. However, the models also predicted that cuckoos would occur in approximately another 700 ha of habitat on the SCR, and so it was enlightening to note their absence in this remaining habitat on the river, even in predicted habitat on the Newhall property. It could be that migrating, or even breeding, cuckoos were present in these predicted patches of habitat but were missed during sampling over the two years: cuckoos seldom call without playback, and have a relatively low level of responsiveness to playback (Halterman 2009). In addition, cuckoos call infrequently, at a rate of only about one call/hour, and they have large home ranges, from approximately 20 to 42 ha (summarized in Halterman 2009, Halterman et al. 2015), and so even if a cuckoo was using a particular patch of habitat, it might not have been present in the immediate area being surveyed at any given time. Halterman et al. (2015) summarized that population studies have indicated that the cuckoo is adapted to locating and utilizing resources that are highly variable in time and space, requiring multiple years of surveying to obtain a reasonable estimation of occupancy, habitat use, and distribution in particular habitat patches. Thus, after only two years of consecutive surveys it is difficult to say if the absence of cuckoos in predicted habitat was due to the birds being absent or the birds being missed during surveys. However, even with this taken into consideration, it was clear that the quality of the habitat patches outside of the East Grove seemed of lesser quality, and likelihood, of cuckoo occupancy. No sign of cuckoos was ever detected in areas at the estuary end of the SCR, for example, nor on Shiells or on the Fillmore Cienaga, because the habitat quality is too low (currently). Thus, our recommendation is that surveys be conducted primarily in $\geq$60% probability class habitat, as well in in the $\geq$40%probability habitat immediately around the higher quality habitat, because it could provide foraging areas for migrating and breeding cuckoos. Low probability class habitat that is not in proximity to higher probability class habitat need not be surveyed unless sufficient funds and personnel are available. The exception to this would be areas where formerly high quality predicted habitat changed dramatically form one season to the next, such as occurred on the southern Levy property due presumably to PSHB beetle infestations (and on the HRNA where many mature red willow trees died between 2018 and

2019). In these formerly high-quality habitat patches it would be prudent to continue surveying to see if cuckoos try to use the vegetation, and to determine how long it takes the vegetation to recover, if at all.

6.3 HABITAT SUITABILITY MODEL APPLICATION AND PERFORMANCE

The application of the SWFL and YBCU models in the Santa Clara River followed a standardized approach as outlined in numerous publications (Hatten and Paradzick, 2003, Johnson et al., 2016, Hatten et al., 2010, Hatten 2016). Two important factors employed in this study that improved overall model performance (i.e., reduced commission and omission errors) were: (1) the careful delineation of the project boundary used for masking purposes, and (2) inspection of every satellite image used in our analysis. The high-resolution project boundary we created greatly reduced spectral confusion caused by agricultural fields adjacent to the riparian corridor, and image inspection reduced spectral confusion resulting from cloudy or smoky conditions frequently observed in the project area. We recommend that these two process steps be utilized when the satellite models are employed in other watersheds, but especially in basins with a lot of agriculture, wildfires, and foggy conditions.

For verification of the habitat suitability models, with no detections of Southwestern Willow Flycatchers other than one bird observed by Griffith Wildlife Biology on the Limoneira property in predicted high probability breeding habitat in 2018 (Table 4), it was difficult to determine how well the SWFL models performed. However, the opinions of the surveyors on the ground did provide a human evaluation of the accuracy of the models. Specifically, in 2018, most surveyors felt that the model provided accurate representation of breeding flycatcher habitat. However, they did question the utility of using the 40% probability class in several instances, because it included areas that had no flowing water, or where the soil saturation was very low, or where there was predominantly mulefat or Arundo as opposed to much cover by native willow (e.g., on Veitch, on central Levy, and from approximately Victoria Rd to Harbor Blvd in the mainstem of the river). All surveyors felt that the ≥60% model did a better job of predicting more suitable mesic, native, and dense areas for breeding SWFL. In 2019, the same opinion held, but was even more relevant: the 40% probability class included completely unsuitable vegetation-–namely black mustard—where it grew copiously on the outer edges of some properties (most notably Prairie-Pacific and Peto-McConica).

For western Yellow-billed Cuckoos, surveyors generally thought that the model performed well, primarily because less unsuitable habitat was included, especially in 2019. However, the occurrence of Arundo in heavy amounts, mixed in with otherwise suitable vegetation in predicted areas, was discouraging – although not something that the models could screen out, because the Arundo was so thoroughly mixed in with the native vegetation. For example, willow-dominated habitat near flowing water on the eastern Peto-McConica property, in the highest quality areas on western Levy, and on the Taylor property, was filled with Arundo, which likely decreases prey abundances for cuckoos, and certainly also decreases the amount of suitable nesting habitat. In addition, in 2019 the ≥40% YBCU model again included black mustard-dominated patches on the Peto-McConica property.

Overall, based on more than 240 surveys for flycatchers and cuckoos on the SCR in 2018 and 2019, we concluded that the 40% probability class projections for both species included more unsuitable habitat than expected, especially in 2019, and so suggest that the $\geq$60% probability models be used for most future surveys. In addition, to save time, energy, and funding during future surveys it would be helpful to create filters before each field season to remove pixels dominated by Arundo or other exotic plant species, in addition to the agricultural filters that were developed during this project..

The characteristic vegetation alliances and associations documented in the 60% probability class areas (see beginning of Section 5.2 above) are of particular importance as targets for restoration planning and implementation, and long-term monitoring, in portions of the SCR with more reliable perennial surface flow and shallow groundwater (i.e., those areas most capable of supporting forested wetlands, such as the historical East Grove). The pilot level analyses of vertical habitat structure in the East Grove area suggest that LIDAR could be used to help predict, map, and monitor potential habitat for YBCU and other focal specie of riparian birds (such a Least Bell's Vireo). Further analysis of habitat structure using LIDAR and field data is warranted to further guide future restoration and monitoring efforts in those areas most likely to be capable of providing suitable nesting habitat for cuckoos.

7.0 RECOMMENDATIONS

Findings from the project suggest 11 recommendations for the management of populations of SWFL and YBCU on the Santa Clara River, including management of the habitat for the two species, as well as for future modeling and mapping projects:

1. Continue habitat restoration, especially Arundo removal on the SCR combined with passive or active replanting of native willow and suitable understory plants, within vegetative alliances and associations that modeled as potential breeding habitat for SWFL and YBCU. Within treatment areas, care should be taken to avoid disturbance of existing habitat, with especial care during the breeding seasons for these species.

2. Investigate impacts of out-of-season releases of imported water from Piru or Castaic reservoirs to establish management guidelines, such as setting an upper threshold on releases during specified seasonal windows to avoid or minimize potential impacts to prospecting and/or nesting SWFL.

3. Focus monitoring for nesting activity of SWFL and YBCU in predicted $\geq$60% probability habitat areas on the SCR. If funding is severely limited, at a minimum, conduct monitoring in the highest probability areas of habitat on the Hedrick Ranch Nature Area, Taylor, Kenter Canyon, and eastern and southern Levy (i.e., the East Grove properties). Also, continue annual searches for nesting YBCU by permitted biologists on these same properties, and continue using recording devices to determine YBCU activity in the East Grove reach. In addition, experiment with the use of broadcasted SWFL vocalizations in high quality habitat to attract SWFL, as suggested by Barbara Kus in December 2019 (at the Riparian Birds Workshop, 4 December).

4. Before surveys occur, create filters for the habitat suitability models to remove pixels dominated by Arundo or other exotic plant species, and continue to use agricultural filters.

5. When satellite models are employed in other watersheds, and especially in basins with a lot of agriculture, wildfires, and foggy conditions, carefully delineate the project boundary used for masking purposes (blocking out background to reduce noise), and carefully inspect every satellite image to be used, to reduce spectral confusion.

6. Conduct insect and frog monitoring in the East Grove to determine if quantities of available prey for YBCU, and SWFL, continue to be suitable for supporting breeding within predicted high quality breeding habitat on the SCR. After restoration of the Sespe Cienaga site with willow and cottonwood trees and associated wetlands, begin insect and frog monitoring on this site to determine if prey abundances will be adequate for the support of nesting cuckoos and willow flycatchers.

7. Conduct periodic updating of the vegetation map, approximately every 10 years or following a major flood or fire event, to systematically track vegetation and habitat changes throughout the primary 50-mile SCR corridor. More detailed, finer-scaled site-specific vegetation classification and mapping should also be conducted for any proposed projects along the SCR. This is particularly important since a number of locally rare plant alliances and associations generally occur in patch sizes too small to be picked up by river corridor-scale mapping, and often (especially for herbaceous vegetation types) can only be accurately classified by field surveys.

8. More quantitative analysis of time-series data on vegetation dynamics and wildlife habitat suitability is needed to improve our understanding and ability to accurately predict future system trajectories in response to changes in natural or anthropogenic drivers. Such analyses would improve our conceptual models and, ideally, would lead to quantitative models to predict how changes in key drivers (such as flow, depth to groundwater, and surface water-groundwater interactions) or management actions (e.g. surface water diversion or augmentation, groundwater extraction and recharge, Arundo removal and revegetation of native riparian plants, or control of the polyphagous shothole borer) would affect riparian ecosystem dynamics.

9. Conduct research into the ecology of the PSHB and its effects on native riparian cottonwood-willow habitats--and thus, by extension, on SWFL and YBCU populations--and potential control or management actions.

10. Test the utility and cost-effectiveness of LIDAR to improve our ability to assess and monitor vegetation and habitat structure, and to improve models of habitat suitability. In particular, we recommend detailed testing of the use of LIDAR to (1) quantify vertical habitat structure to see if it can be used to model habitat suitability for avian species including SWFL, YBCU, and LBVI, and (2) assess its potential to reduce the

need for labor-intensive field estimates of such structure (e.g, human observer estimates using the stacked cube method, as used in developing an LBVI habitat suitability model (Kus 1998)).

11. Stanton et al. (2018) recommended that modifications to farmland management such as reducing pesticide inputs through integrated pest management, and maintaining or restoring uncultivated field margins in addition to restoring native habitat, can positively influence bird populations that are declining throughout the United States. Thus, we strongly suggest that such measures be considered for all agricultural lands bordering the SCR, for the benefit of insectivorous bird species using the SCR corridor.

In closing, the SCR clearly provides available high quality breeding habitat for SWFL and YBCU. With continued restoration and management of habitat, and water, for these species, the river should provide resources for local populations to flourish, given overall population growth and expansions in the future.

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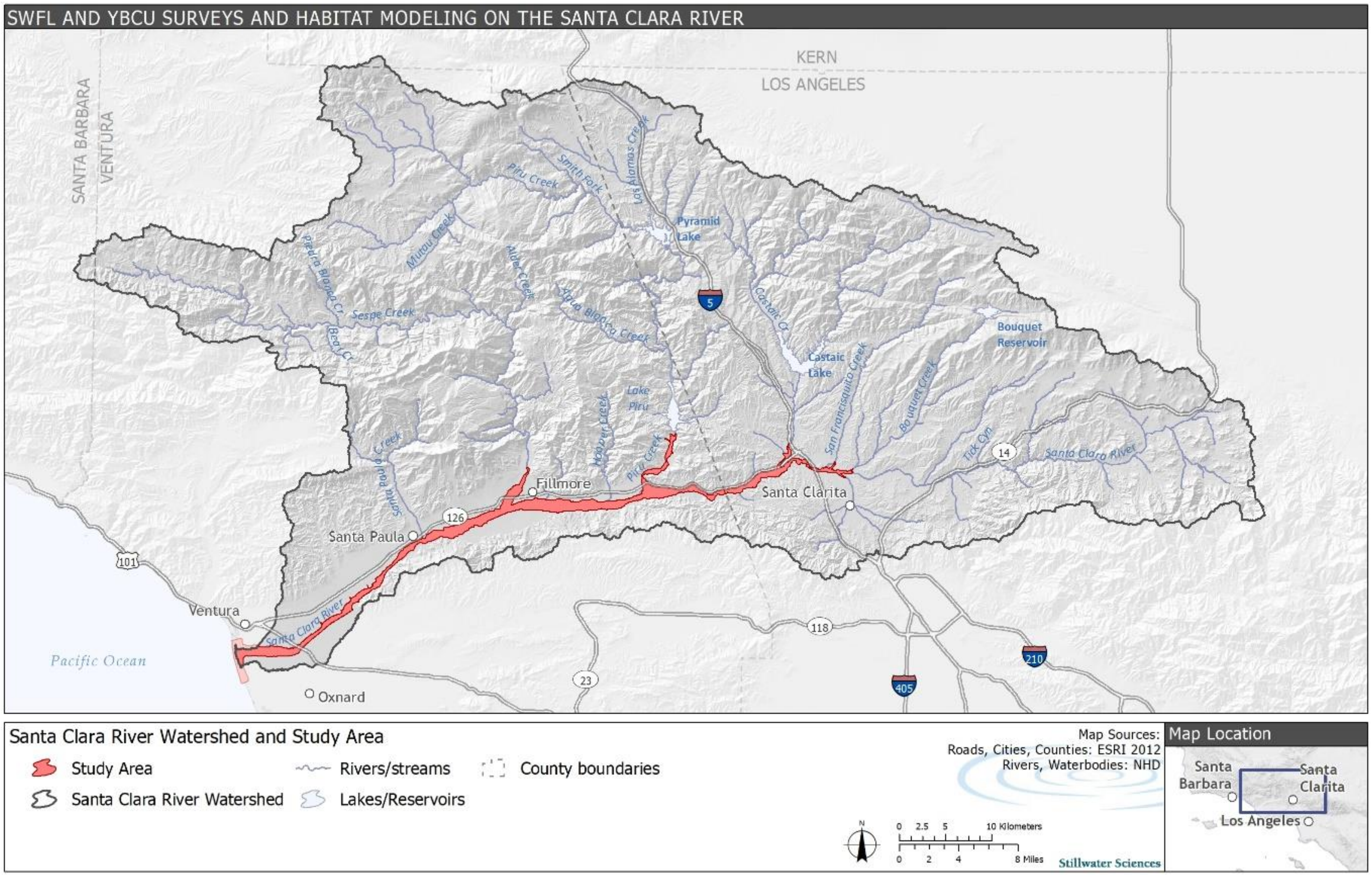
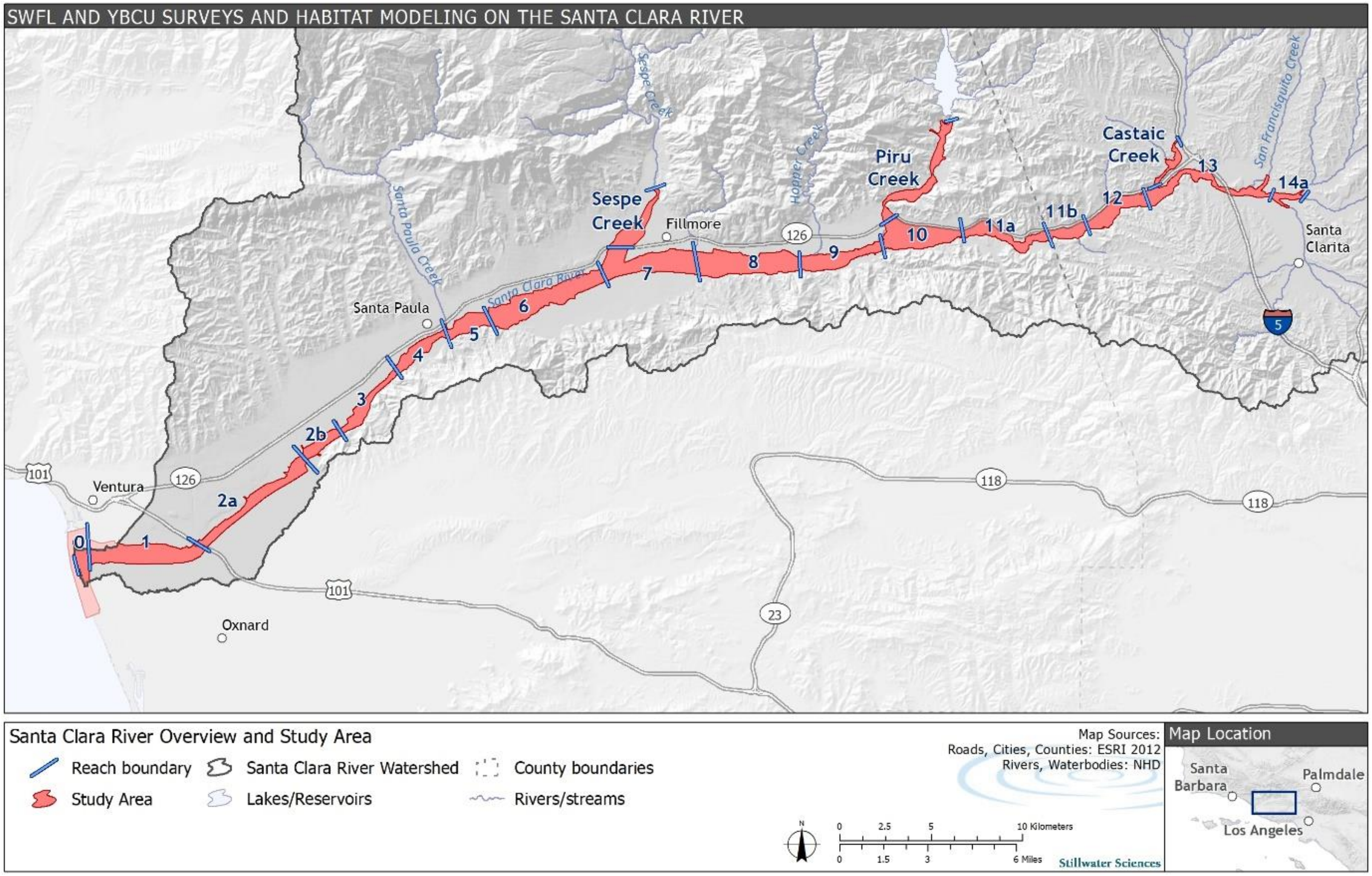
9.0 FIGURES

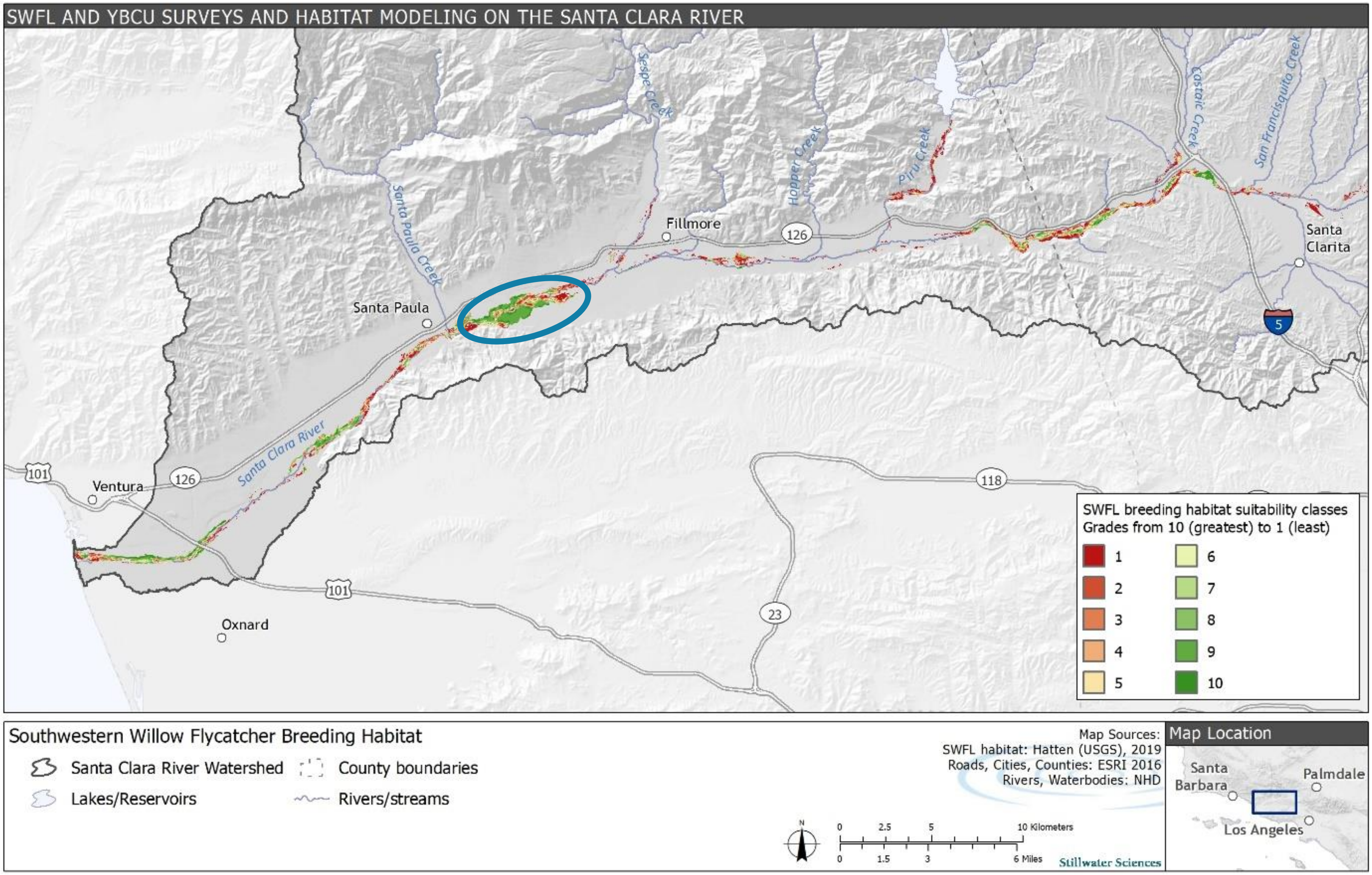
9.1 FIGURE 1. STUDY AREA FOR SOUTHWESTERN WILLOW FLYCATCHER AND WESTERN YELLOW-BILLED CUCKOO SURVEYS, HABITAT MODELING, AND VEGETATION MAPPING ON THE SANTA CLARA RIVER, IN VENTURA AND LOS ANGELES COUNTIES, CALIFORNIA, 2018-2019.



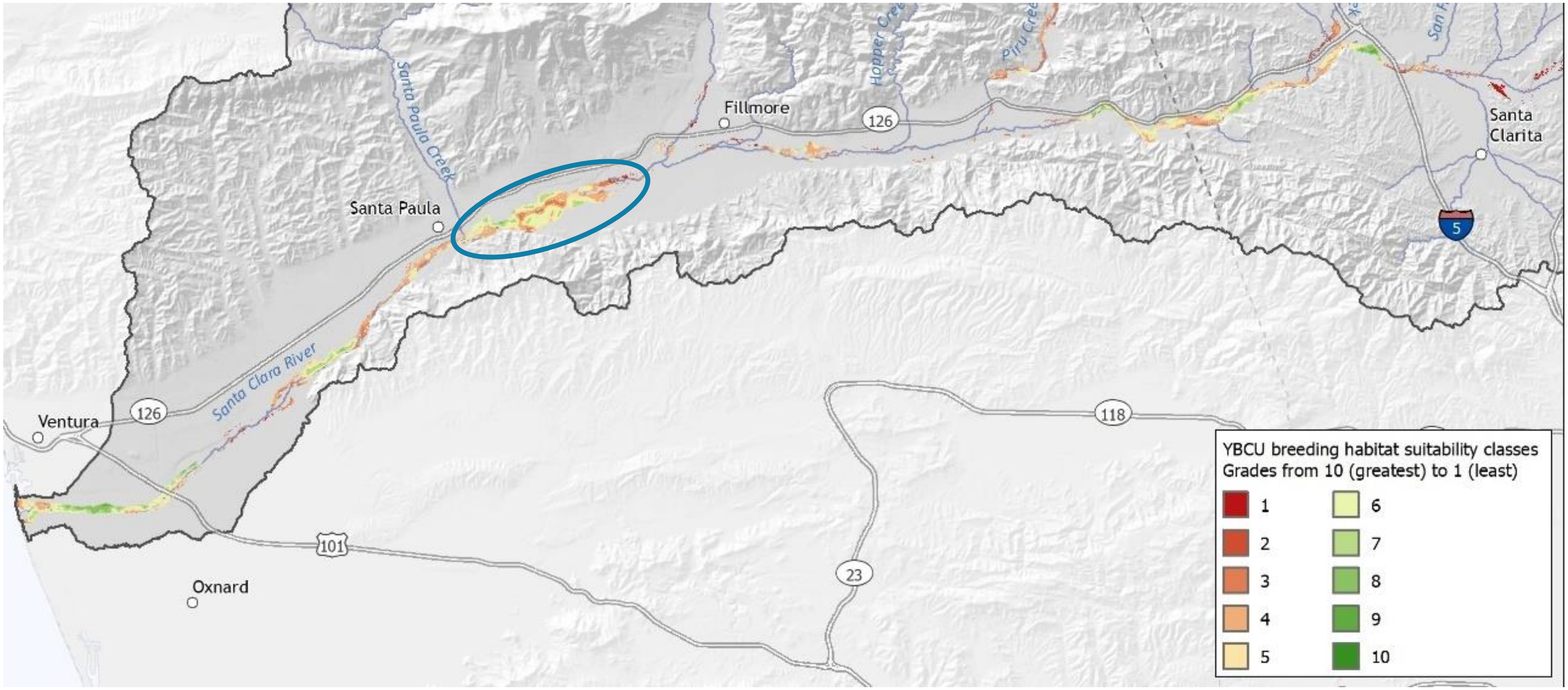
9.2 FIGURE 2. SANTA CLARA RIVER REACHES SURVEYED, MODELED, AND MAPPED DURING THE PROJECT, 2018-2019. SEE ALSO TABLE 1 FOR ADDITIONAL DETAILS. NOTE THAT REACHES 5 AND 6 (THE "EAST GROVE" REFERRED TO IN TEXT) CONTAIN THE HIGHEST PROBABILITY CLASSES OF SWFL AND YBCU HABITAT ON THE VENTURA COUNTY SECTION OF THE RIVER.



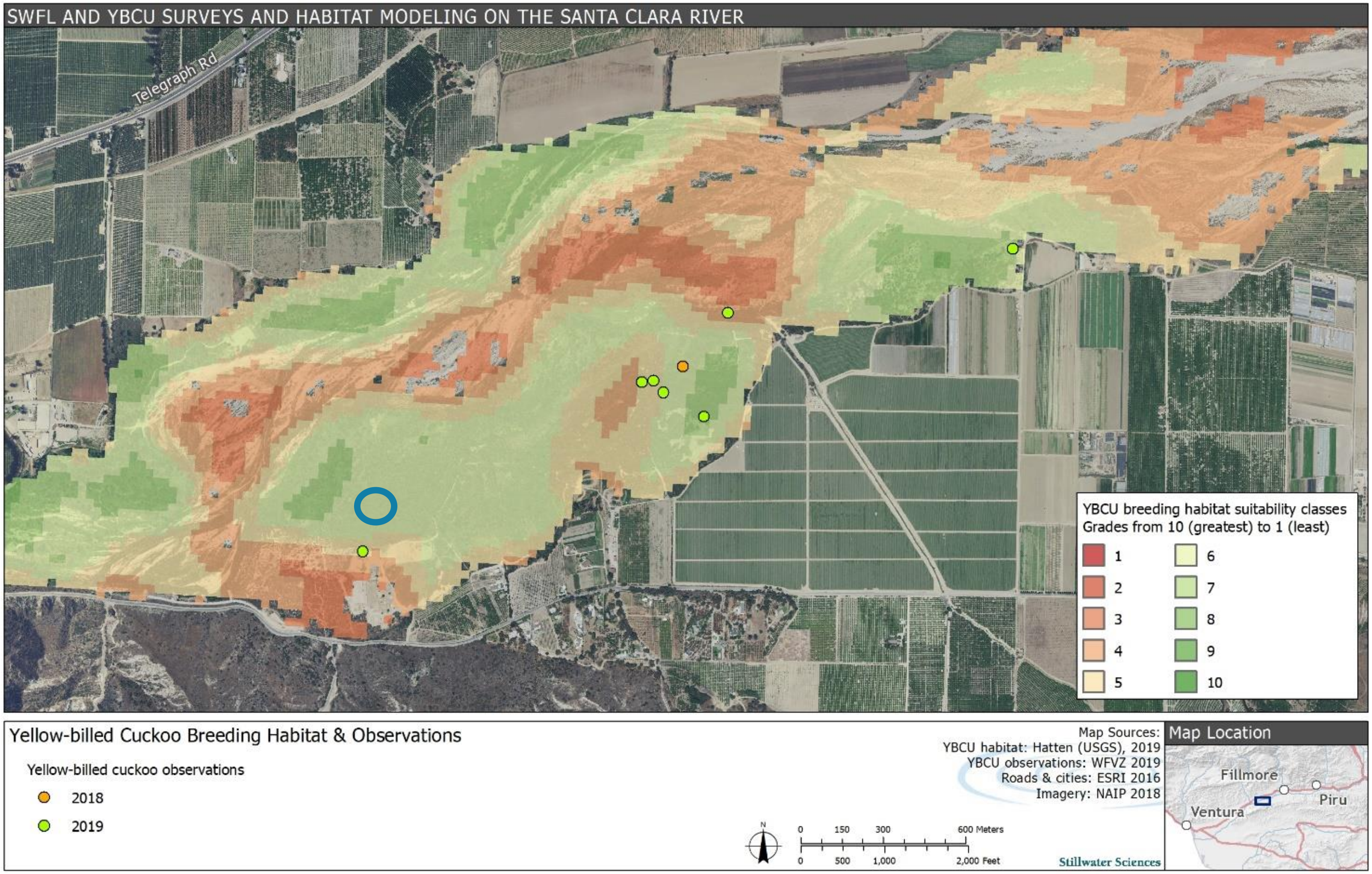
9.3 Figure 3. Modeled breeding habitat for SWFL on the Santa Clara River, Ventura and Los Angeles counties, California, 2018-2019. Area circled east of Santa Paula represents the East Grove reach.



9.4 Figure 4. Modeled breeding habitat for YBCU on the Santa Clara River, Ventura and Los Angeles counties, California, 2018-2019. Area circled east of Santa Paula represents the East Grove reach

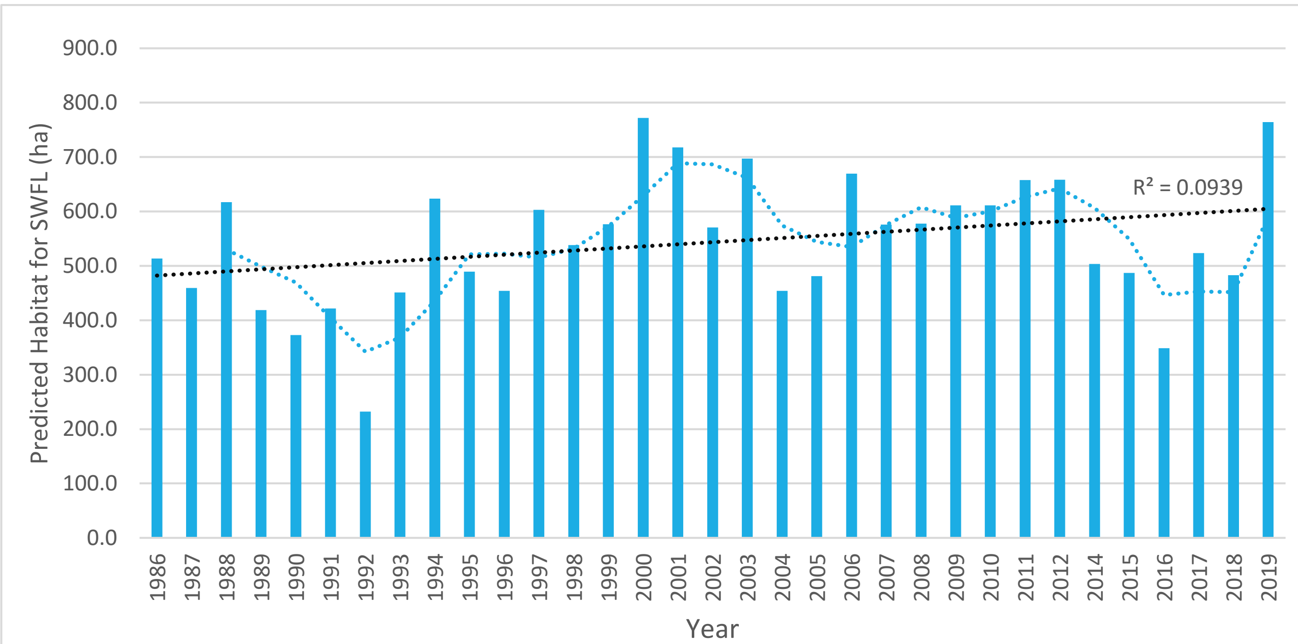


9.5 Figure 5. "East Grove" locations of YBCU (dots) during the 2018 and 2019 breeding season, overlaying habitat suitability model for 2019. Orange dot represents 2018 location, and yellow dots represent 2019 locations. Recordings of cuckoos on the Hedrick Ranch Nature Area and the Levy property are not shown. Note the location of the dots in probability classes 3 through 9. Also note that the blue-circled area shows the approximate location of a grove of black cottonwood trees that died between 2018 and 2019, most likely due to polyphagous shothole borer beetle damage.

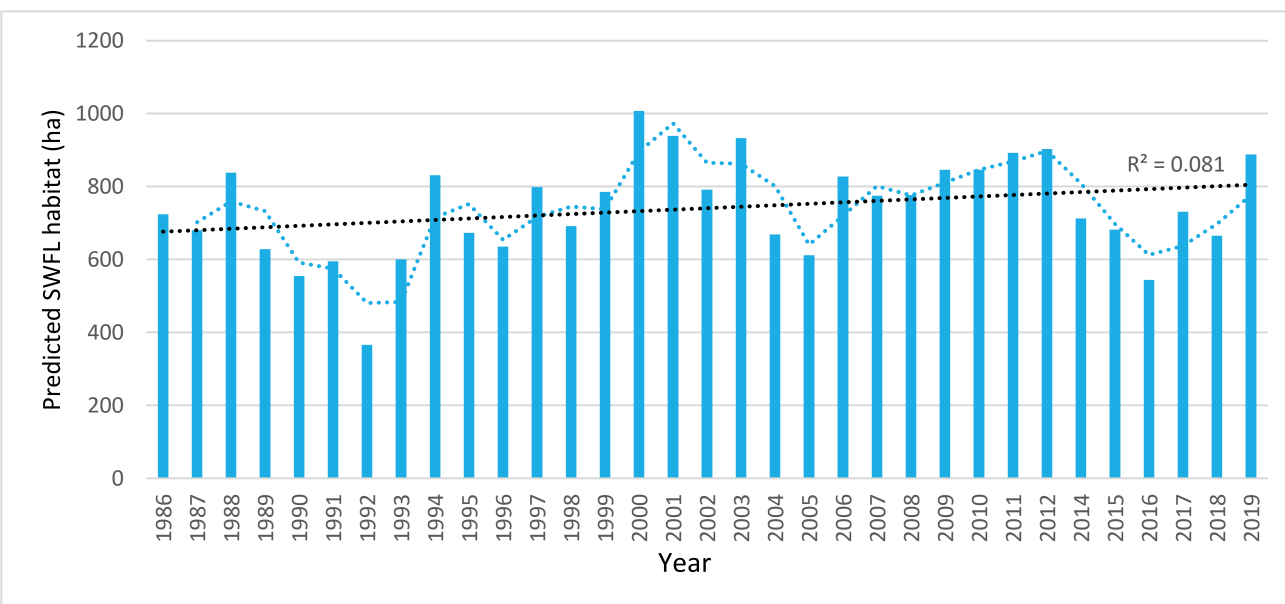


9.6 6A AND 6B. TIME SERIES GRAPHS OF PREDICTED SWFL BREEDING HABITAT (IN HA) ON ALL OF THE SANTA CLARA RIVER FROM 1986 TO 2019. THE DASHED BLUE LINE INDICATES THE RUNNING 3-YEAR AVERAGE; THE DOTTED BLACK LINES SHOWS THE REGRESSIONS ACROSS THE YEARS. GRAPH 6A SHOWS ≥60% PROBABILITY HABITAT ESTIMATES RIVER-WIDE; GRAPH 6B SHOWS ≥40% PROBABILITY HABITAT ESTIMATES RIVER-WIDE. SEE APPENDIX B FOR HABITAT EXTENTS BY REACH AND BY YEAR.

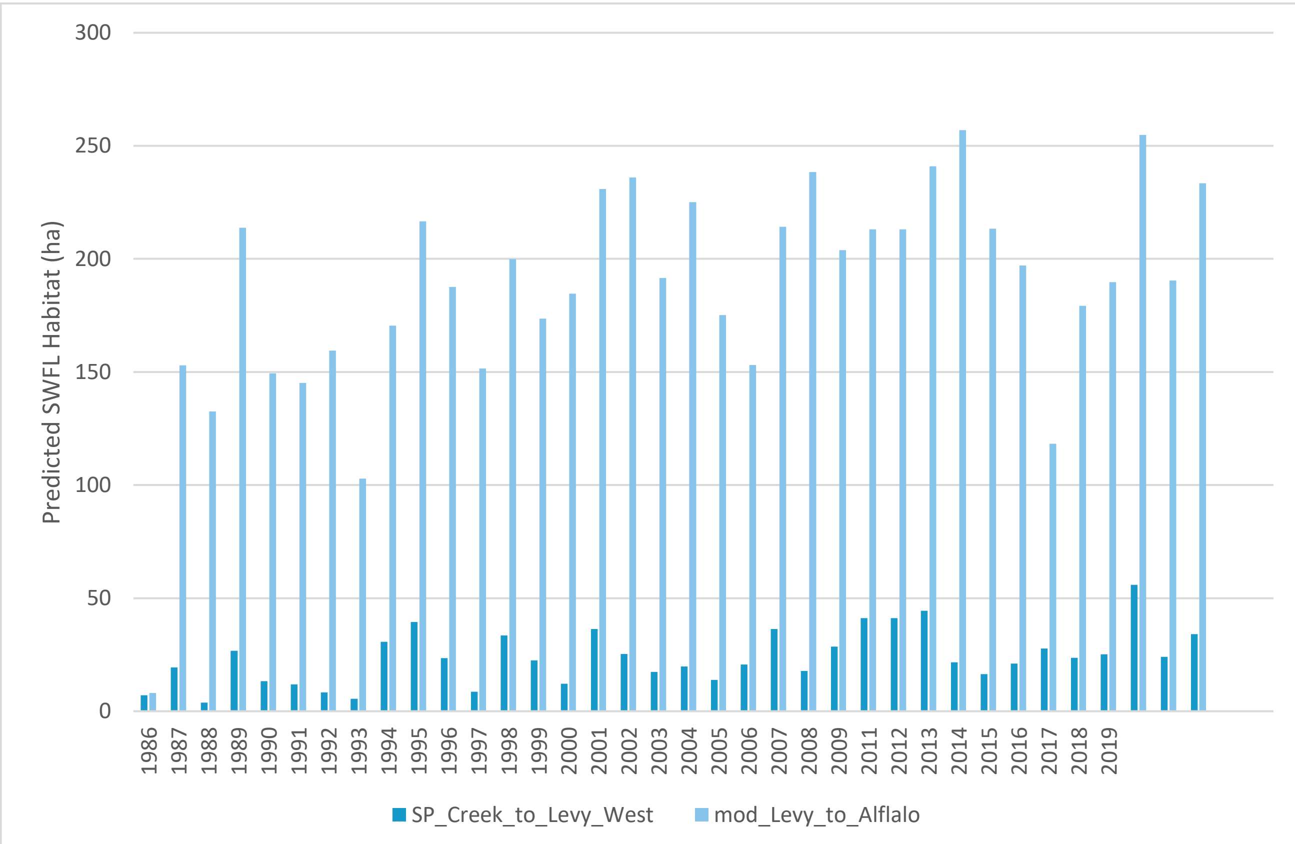
6a.



6b.

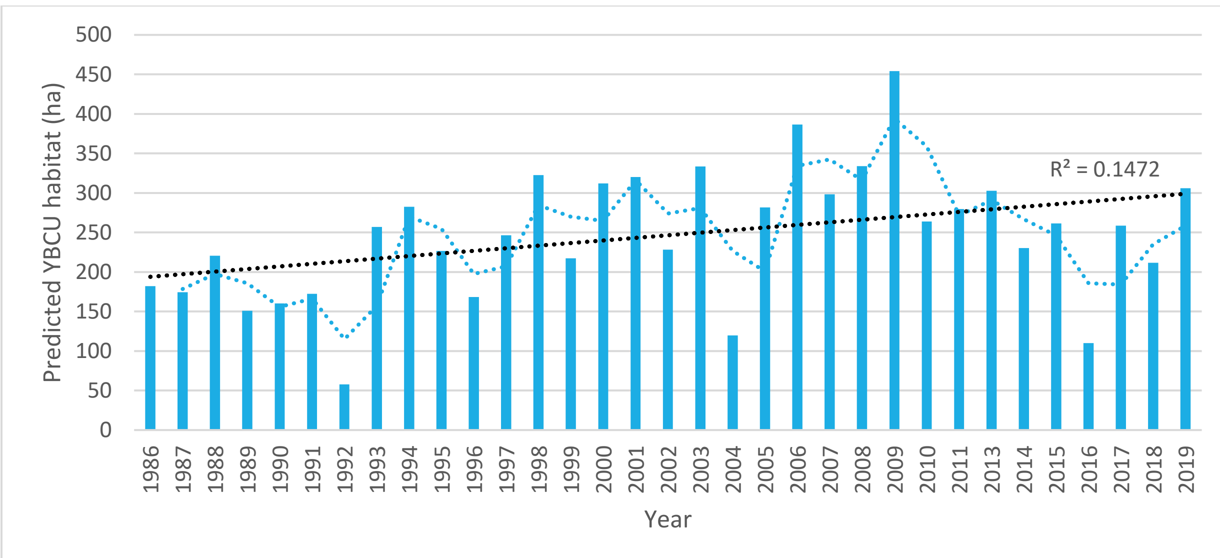


9.7 Figure 7. Predicted amounts of SWFL habitat (in ha) in the "East Grove" reaches from 1986 through 2019, from the confluence of Santa Paula Creek and the Santa Clara River, east to Aflalo. Dark blue histograms show habitat estimates from the confluence east through Peto-McConica to the western side of the Levy property; light blue histograms show habitat estimates from the middle of Levy through the Hedrick Ranch Nature Area, Taylor, Kenter Canyon, and Aflalo properties.

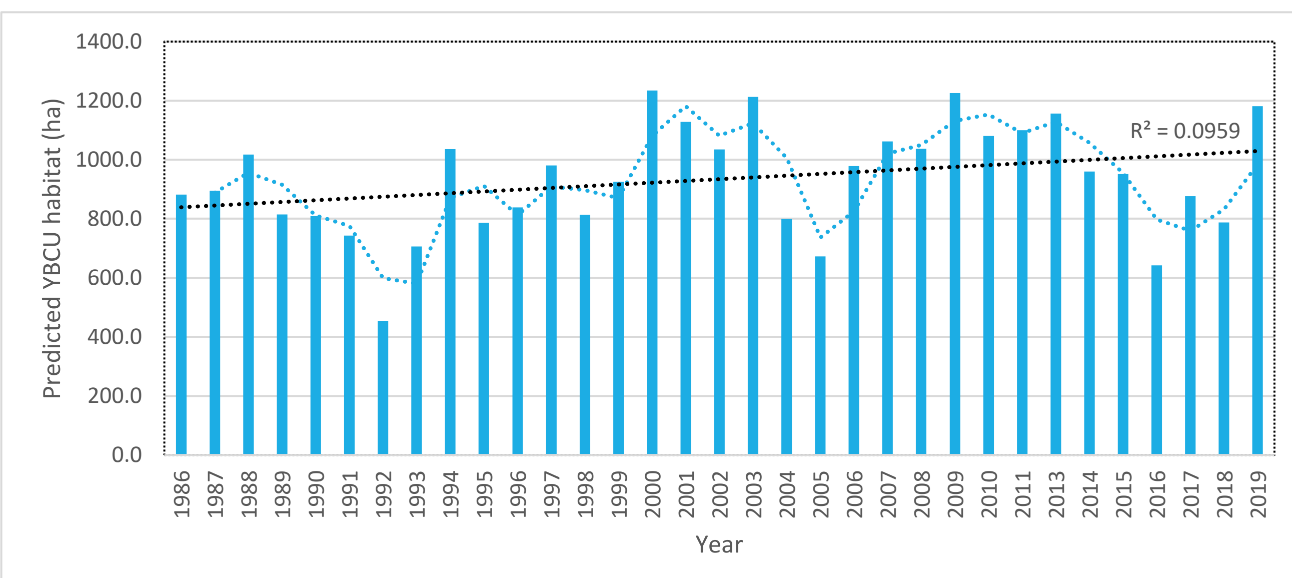


9.8 Figures 8a and 8b. Time series graph of predicted YBCU breeding habitat (in ha; for 60% probability and above) on all of the Santa Clara River from 1986 to 2019. The dashed blue line indicates the running 3-year average; the dotted black lines shows the regressions across the years. Graph 8a shows ≥60% probability habitat estimates river-wide; graph 8b shows ≥40% probability habitat estimates river-wide. See Appendix C for habitat extents by reach and by year.

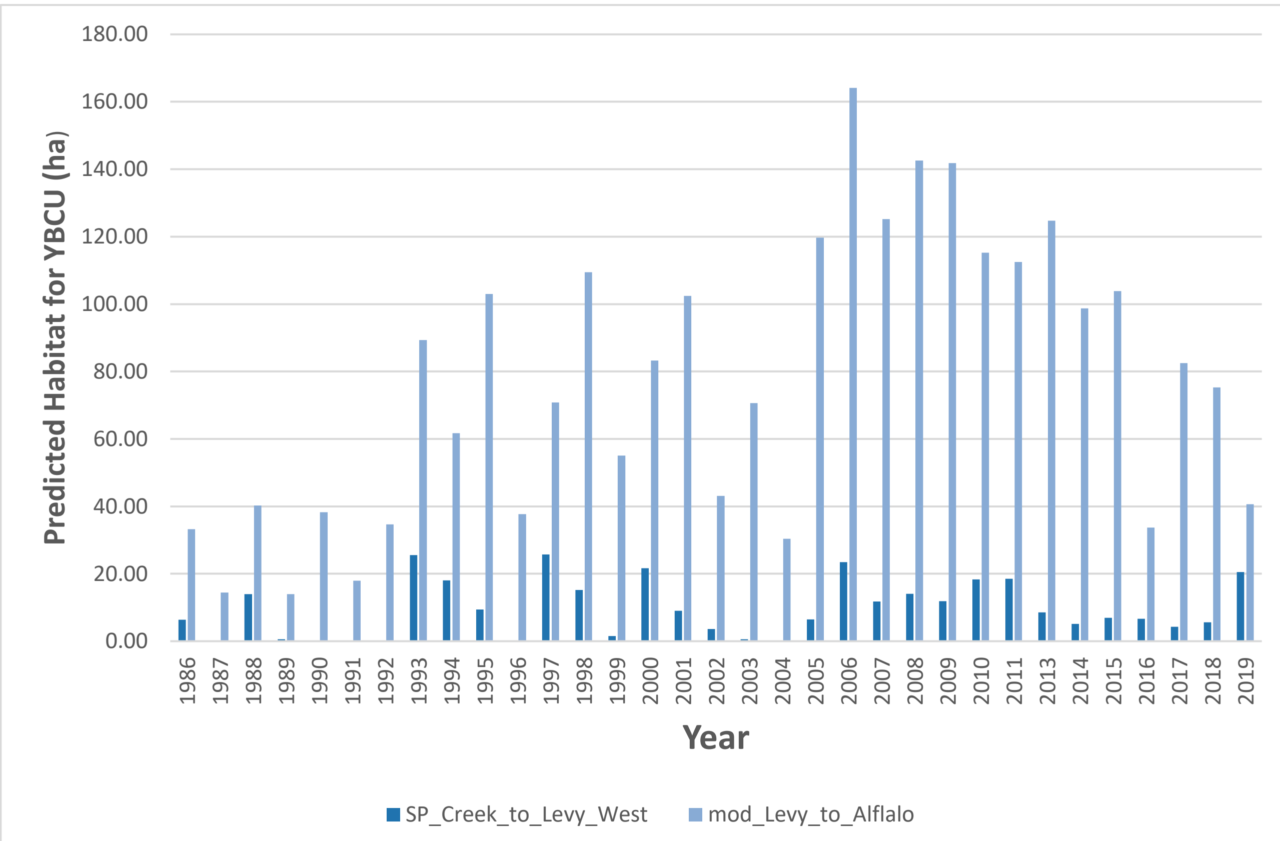
8a.



8b.



9.9 FIGURE 9. PREDICTED AMOUNTS OF YBCU HABITAT (IN HA) IN THE "EAST GROVE" REACHES FROM 1986 THROUGH 2019, FROM THE CONFLUENCE OF SANTA PAULA CREEK AND THE SANTA CLARA RIVER, EAST TO AFLALO. DARK BLUE HISTOGRAMS SHOW HABITAT ESTIMATES FROM THE CONFLUENCE EAST THROUGH PETO-MCCONICA TO THE WESTERN SIDE OF THE LEVY PROPERTY; LIGHT BLUE HISTOGRAMS SHOW HABITAT ESTIMATES FROM THE MIDDLE OF LEVY THROUGH THE HEDRICK RANCH NATURE AREA, TAYLOR, KENTER CANYON, AND AFLALO PROPERTIES.



10.0 TABLES

10.1 TABLE 1. REACHES WITHIN THE STUDY AREA ON THE SANTA CLARA RIVER, FROM DOWNSTREAM TO UPSTREAM (I.E., VENTURA COUNTY TO LOS ANGELES COUNTY).

Reach	Length in miles (km)
0	0.7 (1.1)
1	4.1 (6.6)
2a	4.8 (7.7)
2b	1.7 (2.7)
3	3.1 (5.0)
4	2.3 (3.7)
5	1.8 (2.9)
6	4.5 (7.2)
7	3.4 (5.4)
Sespe Creek	4.0 (6.4)
8	3.7 (5.9)
9	3.0 (4.8)
10	2.9 (4.6)
Piru Creek	4.9 (7.8)
11a	3.8 (6.1)
11b	1.5 (2.4)
12	2.5 (4.0)
13	5.5 (8.8)
Castaic Creek	2.0 (3.2)
14a	1.1 (1.8)
Total	**61.3 (98.1)**

10.2 Table 2. Acquisition dates for Landsat imagery used in habitat mapping and time series analysis within the Santa Clara River project area.

Year	Acquisition date	Comments
1986	6/20/1986	nice image
1987	8/11/1987	nice image
1988	6/10/1988	nice image
1989	7/15/1986	nice image
1990	9/4/1990	Good
1991	8/21/1991	late season (clear image); all other scenes had issues
1992	8/24/1992	late season (clear image); all other scenes had issues
1993	5/22/1993	Good
1994	6/27/1994	nice image
1995	7/16/1995	a few small clouds near mouth
1996	8/20 to 9/20	2-image composite, nothing else worked
1997	5/1/1997	nice image
1998	6/6/1998	Good
1999	6/9/1999	very good image
2000	5/9/2000	great image
2001	6/13/2001	very good image
2002	6/17/2002	Excellent
2003	8/6/2003	great image
2004	5/5/2004	great image
2005	6/9/2005	Good
2006	7/13/2006	light haze near mouth
2007	6/14/2007	Good
2008	7/3/2008	Good
2009	7/5/2009	Excellent

2010	5/22/2010	Good
2011	5/25/2011	Good
2013	5/29/2013	beautiful image
2014	7/3/2014	a couple clouds near mouth, but not bad
2015	6/21/2015	beautiful image
2016	4/1 to 5/15	best I could find; some haze
2017	6/25/2017	a few clouds offshore
2018	6/12/2018	a few clouds offshore
2019	7/1/2019	most other dates had fog at estuary

10.3 TABLE 3. SUMMARY OF ALL WIFL/SWL AND YBCU DETECTED DURING THE PROJECT ON THE SANTA CLARA RIVER, 2018-2019.

SCR Properties	SWFL Detected 2018	SWFL Detected 2019	SWFL Notes	YBCU Detected 2018	YBCU Detected 2019	YBCU Notes
Ventura Wastewater Tx ponds + N side of estuary	0	0	Not good habitat for SWFL in 2019. Surveyors should be accompanied for safety because of homeless people.	n/a	n/a	did not model as suitable habitat for YBCU in 2018 or 2019
McGrath State Park	n/a	n/a	did not model as suitable habitat for SWFL in 2018 or 2019	0	0	2019: only surveyed once because was poor quality habitat for YBCU
McGrath (TNC property)	0	1 late WIFL, but it didn't stay in channel to breed; 0 SWFL	Didn't model out as >40% probability or above in 2019, so did not survey McGrath property in 2019.	0	0	2019: only surveyed once because was poor quality habitat for YBCU
Mainstem from McGrath and/or TotlCom I to Golf Course	0	0	Surveyors should be accompanied for safety because of homeless people.	0	0	2019: only surveyed once because was poor quality habitat for YBCU

Strathmore and White-Mason to mainstem below McGrath property	0	1 late WIFL, but it didn't stay in channel to breed; 0 SWFL	Surveyors should be accompanied for safety because of homeless people.	0	0	2019: only surveyed once
Just S and just N of 101 bridge, on VCWPD property	0	0	Only surveyed once in 2019 because poor quality habitat for SWFL. Surveyors should be accompanied for safety because of homeless people.	n/a	n/a	did not model as suitable habitat for YBCU in 2018 or 2019
Camp-Westbrook (TNC property)	0	0	Surveyors should be accompanied for safety because of homeless people.	0	0	2019: surveyed twice
N of 118 bridge and south of Limoneira property	n/a	n/a	Surveys never occurred because access was denied by landowner	n/a	n/a	did not model as suitable habitat for YBCU in 2018 or 2019
Hanson (TNC)	0	0	2019: Conducted 2 surveys in modeled habitat, then surveyed twice along flowing mainstem water only	0	0	2019: conducted 4 surveys

Prairie-Pacific/Banman (TNC)	1 WIFL; 0 SWFL	0	2019: poor habitat quality off mainstem on SW section	0	0	2019: only surveyed once because was poor quality habitat for YBCU
Peto-McConica (TNC), west and central (from Hallock)	0	5 WIFL; 0 SWFL	2019: Conducted 2 surveys in modeled habitat, then surveyed once along flowing mainstem water only	0	0	2019: surveyed twice obly, because habitat mostly of poor quality for YBCU
Peto-MC part 2, east (from Levy property, off Willard Rd)	0	0	2019: Conducted 2 surveys in modeled habitat, then surveyed twice along flowing mainstem water only	0	0	2019: conducted 3 surveys
Levy property NW/W	0	0	2019: Conducted 2 surveys in modeled habitat, then surveyed once along flowing mainstem water only	0	0	2019: conducted 3 surveys
Levy central (middle)	0	0	2019: Conducted 2 surveys in modeled habitat, then surveyed once along flowing mainstem water only	0	0	2019: only conducted one survey

Levy N + NE	0	2 WIFL; 0 SWFL	2019: Conducted 3 surveys in modeled habitat, then surveyed once along flowing mainstem water only	0	0	2019: conducted 3 surveys
Levy South (from Hedrick Stables)	0	0	2019: Conducted 2 surveys in modeled habitat, then surveyed once along flowing mainstem water only	0	0	
Levy S through S end by VCWPD access	0	0	2019: 2 surveys only	0	0	
Levy core (from Hedrick Stables)	0	0	2019: Conducted 2 surveys in modeled habitat, then surveyed once along flowing Lost Creek only	0	1 (plus recording)	
Levy East 1 -- from HRNA and Hedrick pasture area	0	0	2019: Conducted 2 surveys in modeled habitat, then surveyed twice along flowing water only	1+	1+	2019: conducted 2 surveys with playback, and 4 surveys without (as listening surveys), because cuckoos(s) detected multiple times in this area between 2 July and 14 August.

						Detections also recorded on a microphone placed in this area in mid-June.
Hedrick Ranch Nature Area central and north central	0	2 WIFL; 0 SWFL	2019: Conducted 2 surveys in modeled habitat, then surveyed four times along flowing water only	1	1+	2019: conducted 3 surveys with playback, and three without (listened for vocalizations).
Hedrick central south and southwest	0	0	2019: Conducted 5 surveys in modeled habitat	1	1	2019: conducted 3 surveys with playback in modeled habitat. One cuckoo heard call after it came off a roost at dawn on the Levy East 1 property and probably moved south about 400 m.
Taylor (TNC) and Kenter Canyon	0	0	2019: Conducted 3 surveys in modeled habitat, then surveyed one along flowing water at north end	0	1	
North side of USC (TNC)	0	0	2019: only one survey because habitat not suitable for SWFL	n/a	n/a	did not model as suitable habitat for YBCU in 2018 or 2019

Veitch and Aflalo (TNC)	1 WIFL; 0 SWFL	n/a	2018: surveyed Veitch twice; 0 WIFL, however, 1 WIFL detected on Aflalo. 2019: no surveys conducted on either property because habitat not suitable	n/a	n/a	
Shiells (TNC)	2 WIFL; 0 SWFL	1 WIFL; 0 SWFL	2019: Conducted 2 surveys in modeled habitat, then surveyed once along flowing channel	n/a	n/a	did not model as suitable habitat for YBCU in 2018 or 2019
Fillmore Cienaga property (CDFW)	0	1 late WIFL but it didn't stay to breed; 0 SWFL	2019: Conducted 3 surveys in native habitat area, then surveyed once along flowing channel only			did not model as suitable habitat for YBCU in 2018 or 2019
Piru	2 WIFL; 0 SWFL	n/a	Protocol surveys conducted in 2018 but not in 2019	0	n/a	Protocol surveys conducted in 2018 but not in 2019
Limoneira and Freeman Div Dam area	2-3 WIFL; 1 SWFL	unknown	Conducted standard protocol surveys in 2018 and 2019	0	unknown	Conducted protocol surveys in 2018, but unknown if surveys were conducted in 2019

Newhall	10 WIFL; 0 SWFL	12 WIFL; 0 SWFL	Conducted standard protocol surveys in both 2018 and 2019	0	n/a	YBCU surveys only conducted in 2018 on Newhall and in the NRMP protocol survey area
Bouquet Canyon	n/a	n/a	n/a	1	n/a	Seen sitting in top of small cottonwood, being mobbed by Oak Titmice. Not detected in response to playback. Flew toward west and not seen again. Observed by John Garrett.

10.4 TABLE 4. LOCATION DETAILS FOR ALL WILLOW FLYCATCHERS DETECTED ON SANTA CLARA RIVER SURVEYS FOR SOUTHWESTERN WILLOW FLYCATCHERS IN 2018 AND 2019.

Location	Date Observed	Decimal Latitude/Longitude	Notes
Newhall	5/17/2018	34.41842, -118.631932	Singing in response to playback.
Newhall	5/18/2018	34.435369 -118.600372	Singing in response to playback
Newhall	6/1/2018	34.405745 -118.670053	Calling in response to playback
Newhall	6/1/2018	34.405314 -118.674270	Singing and calling in response.
Newhall	6/1/2018	34.405191 -118.674828	Calling in response to playback
Newhall	6/2/2018	34.418671 -118.635866	Singing in response to playback
Newhall	6/2/2018	34.415103 -118.656001	Silent. No response to playback.
Newhall	6/2/2018	34.412481 -118.659272	Calling in response to playback
Newhall	6/11/2018	34.408187 -118.666728	Singing in response to playback
Newhall	6/11/2018	34.40518 -118.674225	Calling spontaneously. Stopped after playback.
Lower Piru Creek	6/11/2018	34.44008, -118.759121	Singing. Detected by Jane Griffith
Lower Piru Creek	6/11/2018	34.44034, -118.760077	Singing. Detected by Jane Griffith
Aflalo	6/1/2018	34.376107, -118.95658	Singing and calling in response to playback on the Aflalo property. Detected by Andrew Forde.
Prairie Pacific	6/2/2018	34.347636, -119.05274	Singing and calling in response to playback on the Prairie Pacific/Banman property. Detected by Mark Bellini.
Newhall	5/18/19	34.415475, -118.65534	Calling in response to playback
Newhall	5/18/19	34.417312 -118.651432	Calling in response to playback
Newhall	5/18/19	34.417572 -118.64802	Calling in response to playback
Newhall	5/18/19	34.418748 -118.638287	Calling in response to playback
Newhall	5/18/19	34.418822 -118.639472	Singing spontaneously
Newhall	5/18/19	34.418957 -118.64798	Calling in response to playback

Newhall	5/18/19	34.419005 -118.636622	Calling in response to playback
Newhall	5/18/19	34.419301 -118.643811	Silently foraging
Newhall	5/20/19	34.432588 -118.616447	Calling in response to playback
Newhall	5/20/19	34.406539 -118.724545	Singing spontaneously
Newhall	6/2/19	34.407321 -118.670973	Calling in response to playback
Newhall	6/5/19	34.418863 -118.637152	Calling in response to playback
Strathmore/White-Mason to McGrath	6/19/2019	34.235641, -119.221986	Observed in main channel below TNC's McGrath property. Not observed again on subsequent days.
Peto-McConica West	5/20/2019	312444, 3803316	Calling in response to playback
Peto-McConica West	5/20/2019	312471, 3803383	Calling in response to playback
Peto-McConica West	5/20/2019	312578, 3803227	Calling in response to playback
Peto-McConica West	5/20/2019	312822, 3803518	Calling in response to playback
Peto-McConica West	5/20/2019	313303, 3803422	Calling in response to playback
Levy N	5/27/2019	315623, 3804823	Calling in response to playback
Levy N	5/27/2019	315296, 3804811	Calling in response to playback
Levy East 1	5/20/2019	315765, 3803971	Calling in response to playback
HRNA C/NC	5/20/2019	316113, 3804317	Calling in response to playback
HRNA C/NC	5/20/2019	316065, 3804321	Calling in response to playback
Shiells	6/5/2019	327678, 3806957	Observed on point count
Cienega	5/30/2019	34.388090, -118.886563	Calling in response to playback
Cienega	6/6/2019	34.388311, -118.886288	Observed without playback; foraging silently
Additional Records of WIFL/SWFL on the Santa Clara River in 2018			
Southwestern Willow Flycatcher	Summer 2018	Not provided	1 Female. On Limoneira property. Detected by Griffith Wildlife Biology.

Willow Flycatcher	5/22/2018	34.388768 -118.882609	Singing male detected anecdotally on the Shiells property by David Kisner
Willow Flycatcher	6/5/2018	34.387982, -118.889679	Singing male detected anecdotally by David Kisner near the Shiells property
Willow Flycatcher	2018	Not provided	3 WIFL (1 pair + 1 singing male). On Heritage Valley Park. Detected by Griffith Wildlife Biology
Willow Flycatcher	2018	Not provided	2-3 observed upstream of the Freeman Diversion Dam. Detected by Griffith Wildlife Biology.

10.5 Table 5. Location details for all western Yellow-billed Cuckoos detected on Santa Clara River surveys in 2018 and 2019.

Location/Type of Survey	Date	Decimal Latitude/Longitude of Observation	Notes
Bouquet Canyon Anecdotal Observation	6/13/2018	34.421814, -118.508324	Sitting perched. Likely migrating. Seen sitting in top of small cottonwood, being mobbed by Oak Titmice. Flew toward west and not seen again Observed by John Garrett.
Santa Clara River Mainstem Surveys: south end of HRNA	7/2/2018	34.355657, -119.001991	Probably foraging. Heard "kowlp" call from approximately 250 m south from where call was broadcast, within citrus grove. Also heard a “coo” call later in morning when observers quietly listened within grove. South of Hedrick Ranch Nature Area.
HRNA core area	7/23/2018	34.361615, -119.000198	Possibly breeding. Bird heard give "coo" call twice in response to playback, estimated to be about 75 m from where call was broadcast from. On Hedrick Ranch Nature Area, in predicted high quality habitat.
HRNA core area	7/27/2018		Possibly breeding. Cuckoo heard call very briefly from an area west of the bird heard on 7/23/18.
Hedrick Stables and Levy south edge, by Lost Creek	6/10/2019	34.355352°, -119.012690°	Sitting perched; foraging. Bird detected without playback, during SWFL survey (seen and heard)
HRNA west/Levy east, by pump	7/2/2019	34.363393°, -118.998466°	Flying. Bird detected in response to playback on YBCU survey; made Kowlp call
HRNA near end of pump trail	6/22/2019	34.361128°, -119.001358°	Possibly breeding. Bird detected in response to playback on YBCU survey; made Kowlp call and was seen
HRNA south end, at edge of	6/22/2019	34.359980°, -118.999320°	Bird called in response to playback during YBCU survey; may have been same bird as at

more open meadow			north end of pump trail, but this location was at least 400 m south
Kenter Canyon restoration area	7/14/2019	34.365690°, -118.987250°	Foraging. Bird responded to playback during survey. Seen in relatively open woodland, and then called.
HRNA west/Levy east, south of pump and east of Loftus Rd trail	7/27/2019	34.360759°, -119.000949°	Possibly breeding. Bird gave "coo call" in early morning without the use of playback
HRNA west/Levy east, by pump	8/9/2019	34.362954°, -118.998408°	Sitting/flying. Bird came off roost just at dawn , calling.

10.6 TABLE 6. AVERAGE AMOUNTS OF PREDICTED HABITAT FOR SWFL FROM 1986-2019 FOR 17 REACHES ACROSS THE SANTA CLARA RIVER FROM THE ESTUARY TO BOUQUET CANYON ROAD, FOR THE >40% AND >60% HABITAT SUITABILITY MODELS.

Santa Clara River Reaches	**Average amount of predicted habitat by >60% model (ha)**	**Average amount of predicted habitat by >40% model (ha)**
Estuary	13.1	17.0
Estuary_to_101	70.7	94.4
101_to_Limoneira	13.8	20.0
Limoneira_to_Freeman_Dam	30.5	40.4
Hanson_to_Bunn-Birrell	25.2	36.4
Bunn-Birrell_to_Prairie-Pacific	24.5	32.7
SP_Creek_to_Levy_West	24.1	34.1
mod_Levy_to_Alflalo	**190.5**	**233.5**
Sespe_Confluence_to_Heritage_Valley_Park	6.7	9.9
Shiells_to_west_Lagomarsino	37.6	44.6
Lagomarsino_to_Piru_Confluence	0.2	0.5
Piru_Confluence_to_east_Vulcan	5.5	11.6
East_Vulcan_to_County_Line	22.8	43.8
County_Line_to_Wolcot_Way	24.9	44.7
Wolcott_Way_to_McBean_Parkway	53.0	76.1
McBean_Pkwy_to_Bouquet_Cyn_Rd	0.4	0.8

10.7 Table 7. Average amounts of predicted habitat for YBCU from 1986-2019 for 17 reaches across the Santa Clara River from the estuary to Bouquet Canyon Road, for the ≥40% and ≥60% habitat suitability models.

Santa Clara River Reaches	**Average amount of predicted habitat by ≥60% model (ha)**	**Average amount of predicted habitat by ≥40% model (ha)**
Estuary	14.38	40.40
Estuary_to_101	45.69	149.20
101_to_Limoneira	3.78	17.50
Limoneira_to_Freeman_Dam	10.46	45.50
Hanson_to_Bunn-Birrell	7.89	42.20
Bunn-Birrell_to_Prairie-Pacific	11.72	40.10
SP_Creek_to_Levy_West	9.50	42.60
mod_Levy_to_Alflalo	**76.67**	**260.20**
Sespe_Confluence_to_Heritage_Valley_Park	1.59	11.90
Shiells_to_west_Lagomarsino	18.49	50.30
Lagomarsino_to_Piru_Confluence	0.02	1.70
Piru_Confluence_to_east_Vulcan	1.19	19.30
East_Vulcan_to_County_Line	5.34	65.10
County_Line_to_Wolcot_Way	7.92	61.60
Wolcott_Way_to_McBean_Parkway	31.81	86.30
McBean_Pkwy_to_Bouquet_Cyn_Rd	0.00	0.10

10.8 Table 8. Vegetation alliances and land cover types in the Santa Clara River Study Area (from Stillwater Sciences 2019). Vegetation alliances that modeled as present in SWFL breeding habitat are highlighted in light gray; those that were present in both YBCU and SWFL breeding habitat are highlighted in light green. No alliances were only associated with YBCU breeding habitat.

Type	Sensitive natural community[1]	Acres	Percent total
Vegetation Alliance			
Forest and Woodlands			
Eucalyptus spp. - *Ailanthus altissima* - *Robinia pseudoacacia* Woodland Semi-Natural Alliance	–	74.4	0.5%
Juglans californica Woodland Alliance	S3.2	6.0	0.0%
Olea europaea Woodland Semi-Natural Alliance [Provisional]	–	2.7	0.0%
Platanus racemosa Woodland Alliance	S3	4.6	0.0%
Populus fremontii Forest Alliance	S3.2	807.9	4.9%
Populus trichocarpa Forest Alliance	S3	431.9	2.6%
Quercus agrifolia Woodland Alliance	–	58.5	0.4%
Quercus lobata Woodland Alliance	S3	6.0	0.0%
Salix laevigata Woodland Alliance	S3	1,800.7	11.0%
Salix lucida Woodland Alliance	S3.2	27.2	0.2%
Schinus (molle, terebinthifolius) - *Myoporum laetum* Woodland Semi-Natural Alliance	–	42.3	0.3%
Shrublands			
Artemisia californica Shrubland Alliance	–	110.1	0.7%
Artemisia californica - *Salvia mellifera* Shrubland Alliance	–	6.7	0.0%
Artemisia tridentata Shrubland Alliance	–	87.6	0.5%
Atriplex canescens Shrubland Alliance	–	2.2	0.0%
Atriplex lentiformis Shrubland Alliance	–	33.9	0.2%
Baccharis pilularis Shrubland Alliance	–	77.2	0.5%
Baccharis salicifolia Shrubland Alliance	–	3,260.2	19.9%

Type	Sensitive natural community[1]	Acres	Percent total
Encelia californica - Eriogonum cinereum Shrubland Alliance	S3	51.1	0.3%
Eriogonum fasciculatum Shrubland Alliance	–[2]	41.6	0.3%
Lepidospartum squamatum Shrubland Alliance	S3	439.1	2.7%
Lotus scoparius Shrubland Alliance	–	6.5	0.0%
Pluchea sericea Shrubland Alliance	S3.3	79.7	0.5%
Ricinus communis Shrubland Semi-Natural Alliance [Provisional]	–	2.2	0.0%
Salix exigua Shrubland Alliance	–	207.5	1.3%
Salix lasiolepis Shrubland Alliance	–	486.7	3.0%
Salvia apiana Shrubland Alliance	S3	4.9	0.0%
Salvia leucophylla Shrubland Alliance	–	1.1	0.0%
Sambucus nigra Shrubland Alliance	S3	41.4	0.3%
Tamarix spp. Shrubland Semi-Natural Alliance	–	54.6	0.3%
Herbaceous			
Abronia latifolia - Ambrosia chamissonis Herbaceous Alliance	S3	103.5	0.6%
Brassica nigra - Raphanus spp. Herbaceous Semi-Natural Alliance	–	12.1	0.1%
Bromus (diandrus, hordeaceus) - Brachypodium distachyon Herbaceous Semi-Natural Alliance	–	104.4	0.6%
Bromus rubens - Schismus (arabicus, barbatus) Herbaceous Semi-Natural Alliance	–	2.3	0.0%
Corethrogyne filaginifolia - Eriogonum (elongatum, nudum) Herbaceous Alliance	–	9.6	0.1%
Cressa truxillensis - Distichlis spicata Herbaceous Alliance	S2	4.2	0.0%
Distichlis spicata Herbaceous Alliance	–	2.1	0.0%
Heterotheca (oregona, sessiliflora) Herbaceous Alliance	S3	678.3	4.1%
Leymus cinereus - Leymus triticoides Herbaceous Alliance	S3	0.9	0.0%

Type	Sensitive natural community[1]	Acres	Percent total
Mesembryanthemum spp. - *Carpobrotus* spp. Herbaceous Semi-Natural Alliance	–	73.9	0.5%
Phragmites australis - Arundo donax Herbaceous Semi-Natural Alliance	–	703.8	4.3%
Pseudognaphalium leucocephalum Herbaceous Alliance [Provisional]	–	0.2	0.0%
Sarcocornia pacifica (Salicornia depressa) Herbaceous Alliance	S3	4.9	0.0%
Schoenoplectus (acutus, californicus) Herbaceous Alliance	S3	64.3	0.4%
Typha (angustifolia, domingensis, latifolia) Herbaceous Alliance	–	5.5	0.0%
Land Cover Type			
Agriculture		4,061.6	24.8%
Beach		93.3	0.6%
Developed		791.6	4.8%
Developed - park/open space		140.4	0.9%
Disturbed		386.5	2.4%
Non-native Grass and Forb Mapping Unit		128.6	0.8%
Ocean		253.2	1.5%
Riverwash		294.1	1.8%
Riverwash herbaceous		66.3	0.4%
Water		127.9	0.8%
Total		**16,369.9**	**100.0%**

[1] State Ranks:
S3 = Vulnerable. Vulnerable in the state due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors making it vulnerable to extirpation from the state.
0.2 = threatened
0.3 = no current threat known
-- = not considered a sensitive natural community

2 Contains 13.9 ac of *Eriogonum fasciculatum – Artemisia tridentata* Association, a sensitive association (CDFW 2018).

10.9 Table 9. Summary statistics for acres of *Arundo donax* cover in the Santa Clara River Study Area, by cover class and reach.

Reach	Percent *Arundo donax* cover								Total acres
	<1	**1–5**	**5–10**	**10–25**	**25–50**	**50–75**	**75–95**	**>95**	
0	899.3	68.2	70.5	30.3	21.7	1.8	5.7	4.1	1,101.8
1	910.3	126.8	79.8	135.1	221.5	37.7	35.4	1.1	1,547.7
2a	286.9	149.1	326.4	34.6	81.1	2.7	55.5		936.3
2b	74.4	96.6	65.0	80.5	2.4	5.9	20.4		345.2
3	51.0	105.3	175.7	23.5	111.1	18.3	5.9		490.9
4	134.9	113.4	36.3	93.8	11.4	37.3	29.4		456.5
5	136.3	84.2	56.1	96.5	55.3	42.7	10.5		481.6
6	455.7	205.5	650.1	115.3	137.9	65.9	48.1	32.8	1,711.3
7	647.0	88.7	71.0	101.3	526.8	28.5	23.2	0.0	1,486.7
Sespe Creek	467.3	28.7	87.5	1.2	2.6	0.6			587.9
8	869.7	165.7	117.9	205.8	75.1	53.2	119.3	4.2	1,610.9
9	216.5	359.7	9.4	175.6	17.1	2.9	1.1		782.2
10	636.3	345.2	0.9	12.2	134.6	70.0	27.3		1,226.6
Piru Creek	729.9	24.9							754.7
11a	290.3	81.2	63.1	47.3	68.9	82.3	26.2		659.2
11b	115.0	39.7	85.1	36.5	48.3				324.6
12	394.8	44.0	1.7	155.2	73.3				669.0
13	265.0	93.4	72.9	87.4	311.3	11.8			841.9
Castaic Creek	53.4	50.0	40.4	46.4			0.8		191.0
14a	83.3	37.8	42.2	0.4					163.8
Total	**7,717.4**	**2,308.0**	**2,052.1**	**1,478.9**	**1,900.5**	**461.8**	**409.0**	**42.2**	**16,369.9**

10.9 Table 10. Area of vegetated and unvegetated floodplain affected by selected floods on the Santa Clara River, from 1938 to 2005.

Year	Flood Magnitude (cfs)	Area (acres)				Percent Vegetated
		Total Floodplain Area	**Scoured Channel Bed**	**Partially Vegetated Floodplain**	**Highly Vegetated Floodplain**	
1938	120,000	12,364	7,497	3,272	1,595	39
1969	165,000	10,508	7,727	1,616	1,165	26
1978	102,200	7,951	4,501	1,377	2,073	43
1992	104,000	7,246	2,350	2,388	2,508	68
1995	110,000	7,825	3,407	1,040	3,378	56
2005	**136,000**	**7,233**	**4,664**	**7,91**	**1,778**	**36**

10.10 Table 11. Dates and locations of egg sets from California in the collection of the Western Foundation of Vertebrate Zoology. Sets collected in May and early June in the late 1800s and early 1900s are highlighted in gray.

Month	Day	Year	County	Closest City or Landmark	Locality Description (if available)	Collector
Aug	30	1988	Butte	Ord	Sacramento River, 2 miles southeast of	Halterman, M.D.
Aug	2	1990	Butte	Chico Landing	Sacramento River	Laymon, S.A.
Jun	17	1883	Fresno	Fresno	San Joaquin River, near	Hubbard, Samuel
Jun	10	1883	Fresno	Fresno	San Joaquin River; about 9 miles north of	Hubbard, Samuel
Aug	1	1990	Glenn	Jacinto	Sacramento River	Laymon, S.A.
Jul	26	1990	Glenn	Phelan Island	Sacramento River	Laymon, S.A.
Jul	8	1921	Kern	Buena Vista Lake		van Rossem, A.
May	2	1893	Los Angeles	San Fernando		Hewitt, A.
Jun	22	1902	Los Angeles		Watson's Pasture	Jay, Antonin
Jun	22	1902	Los Angeles		Watson's Pasture	Jay, Antonin
Jul	12	1903	Los Angeles		Watsons Pasture	Jay, Alphonse
Jun	14	1903	Los Angeles		Watsons Pasture	Jay, Alphonse
Jul	10	1904	Los Angeles		Watson's Pasture	Jay, Alphonse
Jul	10	1904	Los Angeles		Watson's Pasture	Jay, Alphonse
Jul	16	1905	Los Angeles		Watson's Pasture	Jay, Alphonse
Jul	9	1905	Los Angeles		Watson's Pasture	Jay, Alphonse
Jun	4	1905	Los Angeles		Watson's Pasture	Jay, Alphonse
Jul	1	1906	Los Angeles		Watson's Pasture	Jay, Antonin
Jul	1	1906	Los Angeles		Watson's Pasture	Jay, Antonin
Jun	24	1906	Los Angeles		Watson's Pasture	Jay, Antonin
Jun	20	1906	Los Angeles		Watson's Pasture	Jay, Antonin

Jul	4	1907	Los Angeles	Los Angeles	Watson's Pasture	Jay, Antonin
Jul	14	1907	Los Angeles	Compton	Near	Willett, G.
Jun	30	1907	Los Angeles		Watson's Pasture	Jay, Antonin
Jul	10	1910	Los Angeles		Watson's Pasture	Jay, Antonin
Jul	24	1910	Los Angeles	Compton	Near	Willett, G.
Jul	24	1910	Los Angeles		Watson's Pasture	Jay, Antonin
Jun	22	1912	Los Angeles	Artesia		Jay, Antonin
Jun	7	1914	Los Angeles			Reis, Cletus O.
Jul	7	1919	Los Angeles		Santa Ana River	Edwards, H. Arden
Jun	15	1921	Los Angeles	Dominguez		Edwards, H. Arden
Jun	23	1923	Los Angeles	Long Beach	Los Angeles River, near	Nokes, Irwin D.
May	15	1881	Napa			Denton, S.M.; for
May	15	1881	Napa	Napa	Near	Denton, Shelley W.
Jul	10	1918	Orange	Santa Ana	Near	Edwards, H. Arden
Jun	8	1894	Riverside	Riverside		Heller, Edmund
Jun	24	1916	San Bernardino	Colton	Santa Ana River, near	Pemberton, John R.
Jun	30	1919	San Bernardino	Colton	3 miles Northeast of	Hanna, Wilson C.
Jul	5	1920	San Bernardino	Colton	5 miles NE of	Hanna, Wilson C.
Jun	10	1920	San Bernardino	Colton	Santa Ana River bottom, 3 miles SW of	Hanna, Wilson C.
Jun	6	1920	San Bernardino	Urbita Swamp	3 miles NE of Colton	Hanna, Wilson C.
Jun	19	1922	San Bernardino	Warm Creek	Thicket, 2 miles E of San Bernardino	Hanna, Wilson C.
May	29	1923	San Bernardino	Colton	Santa Ana River thicket, 3 miles SW of	Hanna, Wilson C.
Jun	27	1925	San Bernardino			Booth, Ernest J.
Jul	6	1927	San Bernardino	Colton	willow and water weed thicket, SW of	Hanna, Wilson C.

Jul	7	1928	San Bernardino	Colton		Hanna, Wilson C.
Jun	17	1899	Santa Clara	Milpitas	Near	Atkinson, W.L.
Jun	24	1923	Sonoma		Santa Rosa Valley	Wells, Gurnie
Jul	18	1920	Ventura		Santa Clara River, near mouth	Badger, M.C.
Jul	31	1921	Ventura	Montalvo	Near	Peyton, L.G.
Jul	8	1933	Ventura			Reis, Cletus O.
Jul	13	1935	Ventura			Reis, Cletus O.
Jul	4	1936	Ventura	Port Hueneme	Near	Badger, M.C.
Jul	21	1936	Ventura	Port Hueneme	Near	Badger, M.C.
Jul	10	1938	Ventura		Hueneme	Badger, M.C.
Jul	4	1942	Ventura	Montalvo		Stevens, Lawrence T.

11.0 APPENDICES

11.1 APPENDIX A: LIST OF WFVZ EMPLOYEES AND SUBCONTRACTORS WHO CONDUCTED SOUTHWESTERN WILLOW FLYCATCHER AND WESTERN YELLOW-BILLED CUCKOO SURVEYS DURING THE STUDY, IN 2018 AND 2019.

Permitted Surveyor Name, Title	Tasks During Project	Species surveyed for in 2018	Species surveyed for in 2019
Linnea Hall, Exec Director WFVZ (employee)	PI; surveyor; reporting (2018 and 2019)	YBCU	SWFL and YBCU
Adam Searcy, Field Assistant WFVZ (employee)	Surveyor 2018 and 2019; reporting 2019	YBCU	SWFL and YBCU
René Corado, Field Assistant WFVZ (employee)	Surveyor 2018 and 2019	YBCU	YBCU
Mark Bellini, surveyor (sub-contractor)	Surveyor 2018 and 2019	SWFL	SWFL (and listening surveys for vocalizing YBCU; no playback used)
Andy Forde, surveyor (sub-contractor)	Surveyor 2018 and 2019	SWFL	SWFL (and listening surveys for vocalizing YBCU; no playback used)
Jennifer Sexton, surveyor (sub-contractor)	Surveyor 2018 and 2019	SWFL	SWFL
Scott Werner, surveyor (sub-contractor)	Surveyor 2018 and 2019	SWFL	SWFL
Ethan Ripperger, surveyor (volunteer)	Surveyor 2018 and 2019	YBCU	YBCU

Jane Griffith (sub-contractor and separate, independent biologist)	Surveyor in 2018 for WFVZ; separate in 2019	SWFL, YBCU	SWFL (YBCU unknown)
Jonathan Feenstra (separate, independent biologist)	Surveyor 2018 and 2019 in LA County on Newhall property	SWFL, YBCU	SWFL

11.2 APPENDIX B: HABITAT SUITABILITY TIME SERIES DATA, FOR SOUTHWESTERN WILLOW FLYCATCHER HABITAT ON THE SANTA CLARA RIVER, FOR YEARS 1986-2019 (EXCEPT 2013). VALUES ARE HA OF HABITAT PREDICTED FOR SWFL IN THE ≥40% (YELLOW) AND ≥60% (GREEN) PROBABILITY CATEGORIES.

Reach Names	**86**	**87**	**88**	**89**	**90**	**91**	**92**	**93**	**94**	**95**	**96**	**97**	**98**	**99**	**00**	**01**	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**
Estuary (40%)	19.6	19.3	19.1	0.0	21.8	28.9	14.9	25.3	25.1	0.0	31.0	27.5	29.2	23.5	0.9	31.5	26.3	34.5	23.9	26.1	11.2	10.5	17.1	17.1
Estuary (60%)	13.3	14.5	14.6	0.0	17.4	23.4	5.9	21.4	20.8	0.0	24.8	23.7	24.3	17.1	0.7	25.1	19.8	28.7	17.8	20.4	8.6	6.9	11.8	11.1
Estuary_to_101 (40%)	62.5	69.5	81.1	85.3	71.4	108.0	55.2	91.9	111.6	85.4	94.6	111.4	102.9	117.7	106.3	110.3	97.5	126.0	107.2	90.9	106.7	111.1	106.9	110.8
Estuary_to_101 (60%)	45.3	44.0	58.9	46.8	43.3	81.2	27.3	75.9	85.9	62.5	60.3	84.7	86.7	88.8	85.7	85.1	62.3	96.4	78.8	71.9	91.5	76.0	74.5	79.3
101_to_Limoneira (40%)	18.2	5.2	10.2	1.5	1.0	13.0	11.1	10.9	19.3	13.2	12.7	19.8	11.6	18.5	20.2	16.2	9.3	17.0	14.3	12.6	35.9	20.3	28.4	31.3
101_to_Limoneira (60%)	12.6	3.2	7.6	0.5	0.5	8.6	7.9	7.7	13.5	9.7	8.4	13.5	7.0	9.1	11.1	9.8	4.4	9.0	6.0	7.8	27.2	13.4	21.7	21.4
Limoneira_to_Freeman_Dam (40%)	47.8	53.9	61.4	61.9	31.3	33.0	13.8	29.0	40.4	27.8	27.9	41.4	38.1	42.3	47.0	40.3	46.2	46.6	19.6	30.9	38.1	24.8	22.7	36.4
Limoneira_to_Freeman_Dam (60%)	35.9	37.8	47.2	48.9	21.7	23.5	7.7	21.6	27.9	21.6	19.0	32.3	33.0	33.6	40.3	32.3	35.5	34.4	9.7	24.3	29.5	19.0	15.8	21.9
Hanson_to_Bunn-Birrell (40%)	3.3	15.6	11.6	39.8	27.0	36.2	16.3	9.6	51.1	29.6	41.9	49.0	30.8	45.3	55.3	50.7	49.1	46.4	21.7	40.8	52.6	54.4	44.3	51.1
Hanson_to_Bunn-Birrell (60%)	1.1	7.0	4.1	25.7	14.8	20.9	7.6	4.2	37.2	19.7	29.7	35.0	23.8	36.0	41.4	40.6	34.3	31.2	12.5	34.3	46.3	39.2	33.1	33.6
Bunn-Birrell_to_Prairie-Pacific (40%)	39.8	30.2	43.8	32.5	35.1	44.6	33.6	38.6	46.2	42.1	34.7	38.9	39.5	43.5	46.2	55.3	40.6	60.0	26.8	35.6	36.9	8.0	26.5	36.3
Bunn-Birrell_to_Prairie-Pacific (60%)	28.9	21.6	32.1	24.2	26.4	36.3	27.4	32.5	40.1	35.7	26.6	31.1	33.7	33.9	37.7	45.4	30.9	50.9	17.2	29.1	28.1	4.4	17.1	22.3
SP_Creek_to_Levy_West (40%)	32.0	4.6	38.2	20.6	20.1	19.9	13.6	41.4	57.1	37.8	13.1	42.5	31.1	24.2	43.1	35.8	24.9	30.1	25.3	31.9	43.7	26.5	36.4	50.9
SP_Creek_to_Levy_West (60%)	19.4	3.9	26.8	13.3	11.8	8.3	5.5	30.8	39.4	23.5	8.7	33.5	22.5	12.2	36.4	25.4	17.4	19.8	13.8	20.7	36.4	17.9	28.5	41.2
mod_Levy_to_Alflalo (40%)	210.4	189.4	270.6	206.7	195.9	210.0	143.1	208.7	268.8	230.0	200.3	242.3	215.7	238.1	287.2	289.3	242.5	275.7	235.6	173.5	233.9	285.1	231.5	257.0
mod_Levy_to_Alflalo (60%)	152.9	132.6	213.8	149.4	145.1	159.5	102.9	170.6	216.7	187.6	151.6	199.9	173.6	184.7	230.9	236.0	191.6	225.0	175.2	153.1	214.2	238.5	203.9	213.0
Sespe_Confluence_to_Heritage_Valley_Park (40%)	16.6	12.9	22.3	9.1	1.4	1.1	3.1	6.0	10.0	7.0	10.9	12.2	14.0	16.7	25.2	22.8	9.4	8.7	8.1	4.3	18.3	8.5	9.1	13.0
Sespe_Confluence_to_Heritage_Valley_Park (60%)	9.9	9.2	16.4	6.1	0.9	0.6	1.6	3.3	6.0	3.3	7.5	8.3	9.2	12.5	18.0	15.2	7.2	5.4	4.4	2.3	14.0	5.8	6.4	9.2
Shiells_to_west_Lagomarsino (40%)	55.7	49.2	60.5	29.8	1.3	4.3	32.3	30.7	72.3	59.8	66.3	63.3	59.0	62.8	71.3	67.8	53.2	53.9	54.6	46.0	69.7	56.2	60.6	61.5
Shiells_to_west_Lagomarsino (60%)	48.5	40.5	51.2	23.6	0.7	3.3	21.8	23.6	61.5	51.7	58.1	53.2	54.4	55.8	63.8	62.3	45.8	44.1	40.6	43.9	62.3	49.2	53.2	46.7
Lagomarsino_to_Piru_Confluence (40%)	0.0	0.0	1.4	0.7	1.1	1.1	0.7	0.8	0.8	0.1	0.4	0.1	0.2	0.1	0.8	0.3	0.2	0.7	0.4	0.1	3.1	0.0	0.0	0.3
Lagomarsino_to_Piru_Confluence (60%)	0.0	0.0	1.0	0.4	0.9	0.8	0.4	0.0	0.6	0.0	0.1	0.0	0.1	0.0	0.4	0.0	0.0	0.4	0.0	0.1	0.9	0.0	0.0	0.0
Piru_Confluence_to_east_Vulcan (40%)	7.7	18.6	22.7	16.9	17.8	9.6	4.9	10.8	14.5	9.5	8.4	13.4	13.0	13.8	28.3	22.4	14.0	26.3	7.5	3.9	10.3	8.2	8.7	5.7
Piru_Confluence_to_east_Vulcan (60%)	3.3	10.2	14.2	7.2	7.5	2.8	2.6	7.2	9.2	6.6	5.0	7.7	8.9	7.1	14.1	14.6	8.4	14.4	2.8	1.6	5.0	1.7	1.7	0.5
East_Vulcan_to_County_Line (40%)	46.3	52.7	50.6	41.6	29.4	18.6	0.5	23.1	23.0	37.5	30.4	41.4	31.1	43.2	80.9	52.5	51.7	61.7	24.2	27.0	36.5	51.6	43.0	46.3

East_Vulcan_to_County_Line (60%)	28.1	21.2	30.1	17.9	9.9	3.4	0.0	9.0	4.6	13.3	10.4	19.8	15.3	20.4	53.6	28.6	31.4	41.1	11.5	16.7	23.9	31.9	17.8	28.2
County_Line_to_Wolcot_Way (40%)	62.3	69.8	44.7	15.7	21.3	3.7	0.5	25.2	16.5	25.7	1.8	32.5	27.4	19.1	77.1	36.4	28.4	31.9	30.3	36.7	54.6	50.9	53.6	50.6
County_Line_to_Wolcot_Way (60%)	36.5	43.8	22.4	6.7	11.0	0.2	0.2	14.0	9.5	12.7	0.3	15.5	16.8	12.5	51.3	19.7	14.0	17.7	16.9	20.4	29.5	28.7	29.1	29.7
Wolcott_Way_to_McBean_Parkway (40%)	101.7	89.3	99.5	64.9	76.1	62.0	22.5	47.9	73.2	64.9	59.9	61.0	46.5	75.1	116.3	106.7	97.5	113.0	69.2	51.2	75.9	58.6	87.4	77.4
Wolcott_Way_to_McBean_Parkway (60%)	78.1	70.4	77.1	47.3	59.3	48.8	13.2	29.2	50.8	40.3	43.1	44.0	28.1	51.8	86.1	77.2	67.6	78.6	46.8	34.4	52.0	43.2	63.2	53.2
McBean_Pkwy_to_Bouquet_Cyn_Rd (40%)	0.0	0.0	0.0	1.2	2.3	0.7	0.0	0.5	0.8	3.0	0.8	1.9	1.2	1.4	1.4	0.8	1.0	0.7	0.2	0.3	0.1	0.0	0.4	0.2
McBean_Pkwy_to_Bouquet_Cyn_Rd (60%)	0.0	0.0	0.0	1.0	1.5	0.1	0.0	0.0	0.0	1.2	0.6	0.7	1.1	1.1	0.5	0.6	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total (40%)	723.7	680.3	837.8	628.0	554.5	594.8	366.2	600.3	830.8	673.4	635.0	798.7	691.2	785.2	1007.6	939.1	791.9	933.1	668.8	611.8	827.6	774.9	776.6	846.0
Total (60%)	513.8	459.7	617.4	418.8	372.7	421.7	232.1	450.9	623.7	489.4	454.0	602.8	538.5	576.6	771.8	717.9	570.9	697.0	454.0	481.0	669.4	575.8	577.8	611.1

Reach Names	2010	2011	2012	2014	2015	2016	2017	2018	2019
Estuary (40%)	17.1	15.1	12.0	0.0	10.8	0.0	17.3	5.2	0.0
Estuary (60%)	11.1	10.7	8.9	0.0	6.4	0.0	12.2	3.0	9.5
Estuary_to_101 (40%)	110.8	119.5	107.1	81.7	98.1	38.6	117.5	90.1	30.2
Estuary_to_101 (60%)	79.3	90.2	70.7	52.0	62.9	20.1	87.2	61.1	116.8
101_to_Limoneira (40%)	31.3	35.8	28.6	25.1	23.6	22.4	37.4	33.4	50.6
101_to_Limoneira (60%)	21.4	26.4	21.5	19.6	17.5	13.5	29.8	25.7	38.1
Limoneira_to_Freeman_Dam (40%)	36.4	39.9	52.0	48.9	50.2	46.3	48.6	47.5	61.9
Limoneira_to_Freeman_Dam (60%)	21.9	28.3	40.1	38.3	39.2	29.6	37.8	39.0	56.0
Hanson_to_Bunn-Birrell (40%)	51.1	54.2	43.4	36.1	30.4	14.5	27.5	24.9	43.9
Hanson_to_Bunn-Birrell (60%)	33.6	36.9	29.2	24.4	20.6	5.9	16.7	17.5	33.7
Bunn-Birrell_to_Prairie-Pacific (40%)	36.3	37.2	26.6	23.3	6.7	2.6	6.2	1.6	24.6
Bunn-Birrell_to_Prairie-Pacific (60%)	22.3	24.2	16.5	11.6	3.3	0.6	0.9	0.0	15.7
SP_Creek_to_Levy_West (40%)	50.9	53.3	32.6	26.4	30.8	38.5	35.3	34.7	76.6
SP_Creek_to_Levy_West (60%)	41.2	44.4	21.6	16.4	21.1	27.8	23.6	25.1	55.9
mod_Levy_to_Alflalo (40%)	257.0	286.6	305.6	252.8	232.1	155.0	218.7	232.0	225.4
mod_Levy_to_Alflalo (60%)	213.0	240.9	256.9	213.4	197.1	118.2	179.3	189.8	254.8
Sespe_Confluence_to_Heritage_Valley_Park (40%)	13.0	15.7	12.5	2.3	2.0	2.5	2.8	4.2	1.2
Sespe_Confluence_to_Heritage_Valley_Park (60%)	9.2	8.8	8.8	1.4	1.8	1.2	2.2	2.3	4.1

Shiells_to_west_Lagomarsino (40%)	61.5	69.2	60.1	10.2	0.3	1.7	3.5	3.6	20.6
Shiells_to_west_Lagomarsino (60%)	46.7	54.2	52.9	8.2	0.2	1.2	2.5	1.4	13.4
Lagomarsino_to_Piru_Confluence (40%)	0.3	0.4	0.5	0.2	0.0	0.3	1.1	0.7	0.0
Lagomarsino_to_Piru_Confluence (60%)	0.0	0.0	0.0	0.0	0.0	0.2	0.5	0.3	0.5
Piru_Confluence_to_east_Vulcan (40%)	5.7	4.1	6.0	10.8	3.5	7.1	3.9	9.2	15.3
Piru_Confluence_to_east_Vulcan (60%)	0.5	1.2	1.6	5.3	1.6	3.1	0.6	1.7	1.4
East_Vulcan_to_County_Line (40%)	46.3	49.3	54.6	48.3	47.7	57.6	49.0	46.4	102.6
East_Vulcan_to_County_Line (60%)	28.2	26.4	29.9	25.3	26.1	28.9	27.6	26.4	45.9
County_Line_to_Wolcot_Way (40%)	50.6	49.4	71.0	71.1	67.4	71.0	78.8	71.9	127.3
County_Line_to_Wolcot_Way (60%)	29.7	24.7	37.8	35.7	37.6	43.7	47.5	47.0	60.4
Wolcott_Way_to_McBean_Parkway (40%)	77.4	62.5	88.6	74.0	78.1	83.6	82.6	58.5	108.4
Wolcott_Way_to_McBean_Parkway (60%)	53.2	40.2	60.5	51.2	51.5	54.0	54.9	42.2	57.4
McBean_Pkwy_to_Bouquet_Cyn_Rd (40%)	0.2	0.4	2.0	1.6	0.4	2.3	0.6	0.9	0.1
McBean_Pkwy_to_Bouquet_Cyn_Rd (60%)	0.0	0.0	1.1	1.0	0.2	1.0	0.2	0.5	0.8
Total (40%)	846.0	892.5	903.1	712.6	682.1	543.9	730.8	664.8	888.5
Total (60%)	611.1	657.5	658.1	503.8	487.1	348.8	523.5	482.7	764.6

11.3 APPENDIX C: HABITAT SUITABILITY TIME SERIES DATA, FOR YELLOW-BILLED CUCKOO HABITAT ON THE SANTA CLARA RIVER, FOR YEARS 1986-2019 (EXCEPT 2013). VALUES ARE HA OF HABITAT PREDICTED FOR CUCKOOS IN THE ≥40% (LIGHT GREEN) AND ≥60% (BLUE) PROBABILITY CATEGORIES.

Reach Names	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Estuary (40%)	49.0	51.0	49.0	0.0	60.1	59.6	34.2	53.7	62.0	0.0	68.1	59.9	52.7	49.1	0.3	62.1	56.7	62.1	51.0	48.0
Estuary (60%)	11.5	9.2	11.1	0.0	14.1	25.6	1.5	29.6	30.8	0.0	21.2	32.1	32.3	23.7	0.0	30.6	27.3	38.3	22.5	24.5
Estuary_to_101 (40%)	88.6	140.0	143.5	158.3	153.4	172.1	135.8	124.2	150.9	113.0	158.4	152.9	120.7	170.6	136.5	159.4	156.1	185.3	166.4	108.5
Estuary_to_101 (60%)	19.6	22.7	34.1	52.5	36.5	80.1	1.6	64.1	63.4	41.1	38.1	46.1	66.7	48.9	34.3	49.5	45.0	79.1	22.9	40.1
101_to_Limoneira (40%)	19.9	0.3	3.1	0.0	0.0	0.0	1.0	1.7	10.4	2.9	3.7	12.2	3.0	7.9	23.6	17.2	8.1	20.3	9.5	16.6
101_to_Limoneira (60%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	1.2
Limoneira_to_Freeman_Dam (40%)	56.0	65.1	77.9	71.4	39.6	31.3	6.3	28.0	48.8	18.5	27.1	53.8	42.0	44.3	65.1	46.3	65.4	60.7	11.7	34.8
Limoneira_to_Freeman_Dam (60%)	17.1	10.6	20.6	27.4	6.2	1.8	0.0	4.6	6.7	4.6	3.7	10.9	15.2	9.0	26.0	13.7	13.0	8.6	0.0	6.8
Hanson_to_Bunn-Birrell (40%)	4.4	17.0	4.9	59.3	29.2	54.8	0.8	4.8	70.5	28.1	54.0	64.0	39.6	50.5	79.6	67.3	59.9	64.1	14.9	44.2
Hanson_to_Bunn-Birrell (60%)	0.0	0.0	0.0	6.1	1.6	0.4	0.0	0.0	6.2	0.0	0.8	4.8	9.0	10.6	15.1	13.0	14.1	7.3	0.0	15.8
Bunn-Birrell_to_Prairie-Pacific (40%)	49.1	30.2	50.7	40.8	36.5	56.1	37.4	48.6	53.3	46.7	43.6	49.0	59.2	51.5	71.0	75.0	57.1	75.6	34.5	46.7
Bunn-Birrell_to_Prairie-Pacific (60%)	14.1	6.5	12.4	4.1	6.9	17.6	10.4	18.9	31.5	25.6	10.7	21.5	28.2	17.8	18.9	39.0	2.3	39.8	1.0	25.6
SP_Creek_to_Levy_West (40%)	46.5	0.5	49.1	29.3	22.2	18.2	3.7	51.8	85.4	51.0	12.6	58.7	36.5	33.9	61.8	41.4	26.2	38.1	33.5	37.3
SP_Creek_to_Levy_West (60%)	6.4	0.0	13.9	0.6	0.1	0.0	0.0	25.5	18.0	9.4	0.0	25.7	15.2	1.5	21.7	9.0	3.6	0.6	0.0	6.5
mod_Levy_to_Alflalo (40%)	253.8	212.8	283.6	210.7	232.6	224.3	151.5	255.8	287.3	279.3	233.3	267.9	242.1	261.0	298.7	312.9	274.3	313.1	260.8	190.1
mod_Levy_to_Alflalo (60%)	33.3	14.5	40.2	14.0	38.3	17.9	34.6	89.4	61.8	103.0	37.7	70.8	109.5	55.1	83.3	102.5	43.1	70.6	30.4	119.7
Sespe_Confluence_to_Heritage_Valley_Park (40%)	22.9	16.4	31.9	9.9	0.7	0.5	1.9	8.2	14.0	11.2	14.3	15.0	23.2	19.2	38.6	24.4	12.5	8.3	8.1	4.3
Sespe_Confluence_to_Heritage_Valley_Park (60%)	0.1	0.3	4.3	0.5	0.0	0.0	0.0	0.0	1.2	0.0	0.3	0.0	3.4	3.0	6.5	1.6	2.8	1.4	0.3	0.0
Shiells_to_west_Lagomarsino (40%)	63.0	58.1	60.9	41.2	4.2	10.1	46.3	42.5	81.6	83.1	76.7	60.7	64.1	58.2	74.3	67.6	59.2	62.2	72.5	46.0
Shiells_to_west_Lagomarsino (60%)	19.9	21.0	17.8	4.2	0.1	0.9	7.4	20.5	22.9	27.6	30.0	8.9	41.9	17.5	22.2	18.9	19.4	17.6	23.1	38.3
Lagomarsino_to_Piru_Confluence (40%)	0.0	0.0	1.2	0.8	1.1	0.6	0.0	3.5	1.4	3.0	0.5	5.7	8.4	0.5	11.4	2.8	0.6	0.9	0.7	0.9
Lagomarsino_to_Piru_Confluence (60%)	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.2	0.0	0.0
Piru_Confluence_to_east_Vulcan (40%)	10.2	33.7	34.8	32.9	35.7	21.7	8.1	22.8	26.2	18.0	15.9	16.7	25.5	9.7	42.5	30.2	28.2	42.9	19.7	3.9
Piru_Confluence_to_east_Vulcan (60%)	0.0	6.2	2.8	2.1	7.6	1.6	0.0	0.5	1.1	0.5	0.0	0.1	0.9	0.0	0.9	0.3	0.4	6.0	0.0	0.0
East_Vulcan_to_County_Line (40%)	52.3	77.7	73.5	75.8	69.6	15.1	0.0	20.6	32.8	36.0	49.0	55.9	35.2	70.3	83.4	65.3	85.6	105.2	13.4	30.0
East_Vulcan_to_County_Line (60%)	2.3	15.2	10.5	4.2	0.5	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.2	1.5	7.2	0.0	13.3	16.3	0.0	2.6
County_Line_to_Wolcot_Way (40%)	62.1	101.5	46.6	8.0	39.4	2.4	0.4	9.3	12.6	30.1	6.8	25.6	24.6	16.9	120.5	30.4	32.7	38.3	29.0	23.8
County_Line_to_Wolcot_Way (60%)	7.0	22.7	1.4	0.0	0.0	0.0	0.0	0.5	0.0	1.5	0.0	0.0	0.0	0.0	20.4	0.0	2.5	2.4	0.0	0.0
Wolcott_Way_to_McBean_Parkway (40%)	103.9	90.2	106.7	76.4	82.7	75.6	27.3	31.0	98.2	65.1	74.4	82.4	36.4	82.2	127.3	125.8	112.7	135.3	73.9	37.4
Wolcott_Way_to_McBean_Parkway (60%)	50.7	45.6	51.3	35.4	48.0	26.4	2.1	3.6	39.1	13.5	25.0	25.4	0.0	28.5	55.5	42.0	41.4	45.5	19.7	0.8

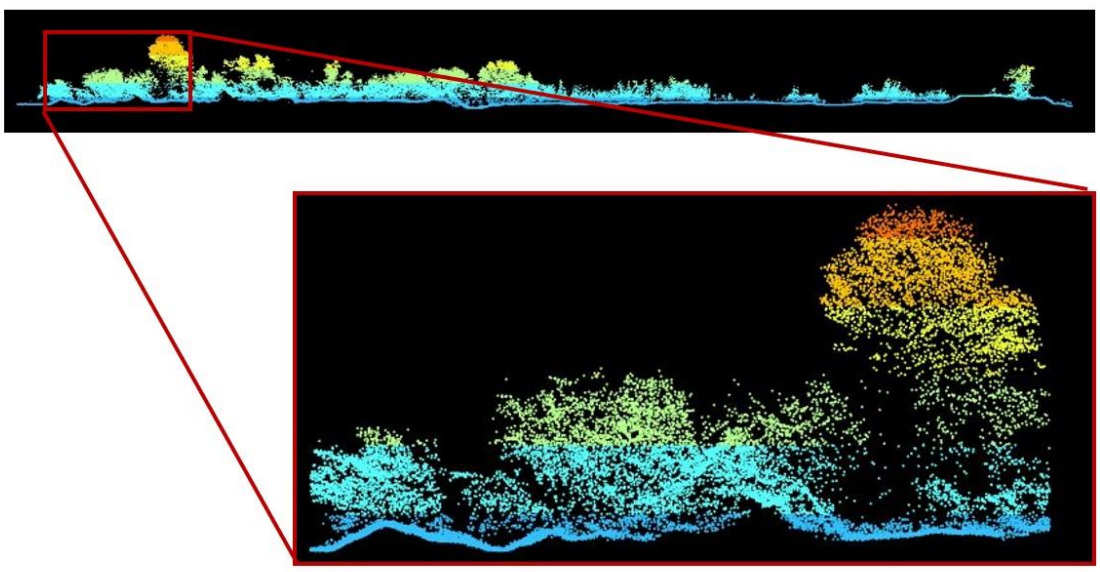
McBean_Pkwy_to_Bouquet_Cyn_Rd (40%)	0.0	0.0	0.0	0.0	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
McBean_Pkwy_to_Bouquet_Cyn_Rd (60%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Predicted YBCU habitat (40%)	881.8	894.7	1017.3	814.8	808.7	742.6	454.6	706.5	1035.4	786.0	838.4	980.3	813.2	925.8	1234.6	1128.1	1035.3	1212.4	799.6	672.5
Predicted YBCU hab (60%) (60%)	182.1	174.4	220.4	151.1	160.2	172.4	57.8	257.2	282.6	226.8	168.2	246.4	322.5	217.2	312.2	320.1	228.2	333.6	120.0	281.8

Reach Names	2006	2007	2008	2009	2010	2011	2013	2014	2015	2016	2017	2018	2019
Estuary (40%)	15.7	51.9	52.6	58.6	40.7	33.0	28.5	0.0	36.6	0.0	42.7	6.3	37.8
Estuary (60%)	0.4	5.0	15.1	35.9	8.0	3.2	3.0	0.0	7.9	0.0	1.7	0.0	8.2
Estuary_to_101 (40%)	142.3	169.0	162.8	174.7	165.4	173.6	176.3	111.6	171.0	53.5	173.2	157.2	197.4
Estuary_to_101 (60%)	56.0	29.0	42.6	83.6	36.0	48.3	36.5	26.2	44.8	2.8	79.5	41.3	94.6
101_to_Limoneira (40%)	18.8	27.9	31.4	24.9	43.6	47.2	29.7	26.0	26.4	26.7	35.0	32.6	45.5
101_to_Limoneira (60%)	2.9	5.7	7.1	9.7	11.6	14.5	10.4	5.6	7.6	4.5	14.5	10.1	19.4
Limoneira_to_Freeman_Dam (40%)	39.6	31.8	13.1	32.0	46.8	51.5	61.5	54.9	51.9	52.9	50.9	52.9	69.2
Limoneira_to_Freeman_Dam (60%)	8.6	2.3	1.6	4.2	4.7	9.0	19.0	16.5	22.6	6.8	8.5	13.1	21.9
Hanson_to_Bunn-Birrell (40%)	53.1	58.9	43.0	68.5	53.3	57.5	51.2	37.9	46.5	17.2	29.5	22.8	42.6
Hanson_to_Bunn-Birrell (60%)	26.3	20.5	7.9	25.4	3.3	13.0	22.4	8.5	13.3	0.0	0.5	0.0	14.3
Bunn-Birrell_to_Prairie-Pacific (40%)	47.1	9.3	39.7	29.3	42.4	45.1	36.0	27.8	3.3	1.7	1.2	0.1	27.6
Bunn-Birrell_to_Prairie-Pacific (60%)	18.5	0.0	3.2	0.3	4.5	7.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SP_Creek_to_Levy_West (40%)	62.2	32.1	47.1	55.5	66.5	73.4	47.5	37.3	47.3	41.9	31.1	32.6	92.7
SP_Creek_to_Levy_West (60%)	23.5	11.8	14.0	11.9	18.3	18.5	8.5	5.1	6.9	6.7	4.2	5.7	20.5
mod_Levy_to_Alflalo (40%)	253.7	323.4	266.0	314.1	298.6	316.7	338.6	291.3	273.6	155.8	207.3	229.5	271.9
mod_Levy_to_Alflalo (60%)	164.1	125.2	142.5	141.8	115.3	112.5	124.7	98.7	103.8	33.7	82.5	75.2	40.6
Sespe_Confluence_to_Heritage_Valley_Park (40%)	17.9	9.6	8.8	12.7	13.3	15.6	13.5	0.7	2.1	2.1	2.5	2.4	6.9
Sespe_Confluence_to_Heritage_Valley_Park (60%)	4.4	3.7	4.8	5.3	2.2	4.1	2.1	0.0	0.0	0.0	0.3	0.0	0.3
Shiells_to_west_Lagomarsino (40%)	90.6	67.0	66.7	74.5	66.8	59.0	62.0	10.8	0.1	0.8	4.7	1.1	25.0
Shiells_to_west_Lagomarsino (60%)	51.2	38.3	37.3	43.0	22.2	21.2	14.0	1.9	0.0	0.0	0.0	0.0	1.1
Lagomarsino_to_Piru_Confluence (40%)	5.4	0.0	0.0	0.1	1.5	1.3	0.0	0.0	0.3	1.2	0.3	0.0	0.6
Lagomarsino_to_Piru_Confluence (60%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Piru_Confluence_to_east_Vulcan (40%)	15.7	17.1	10.3	20.5	16.2	9.6	7.0	16.6	2.0	11.6	1.8	10.6	18.4
Piru_Confluence_to_east_Vulcan (60%)	0.8	0.7	0.9	2.7	0.1	0.0	0.3	3.0	0.0	0.0	0.0	0.0	0.0
East_Vulcan_to_County_Line (40%)	46.7	101.8	81.2	113.1	70.4	71.2	77.1	120.0	79.9	77.1	57.3	87.7	119.3
East_Vulcan_to_County_Line (60%)	4.2	9.2	7.9	21.0	1.4	3.4	9.3	14.6	2.6	4.7	3.8	4.8	14.8
County_Line_to_Wolcot_Way (40%)	86.0	92.6	103.2	123.7	66.5	69.9	115.9	142.6	110.2	96.8	127.6	107.8	127.9
County_Line_to_Wolcot_Way (60%)	4.0	15.1	6.5	20.3	6.2	6.7	18.1	13.2	15.7	11.4	22.6	30.8	32.2

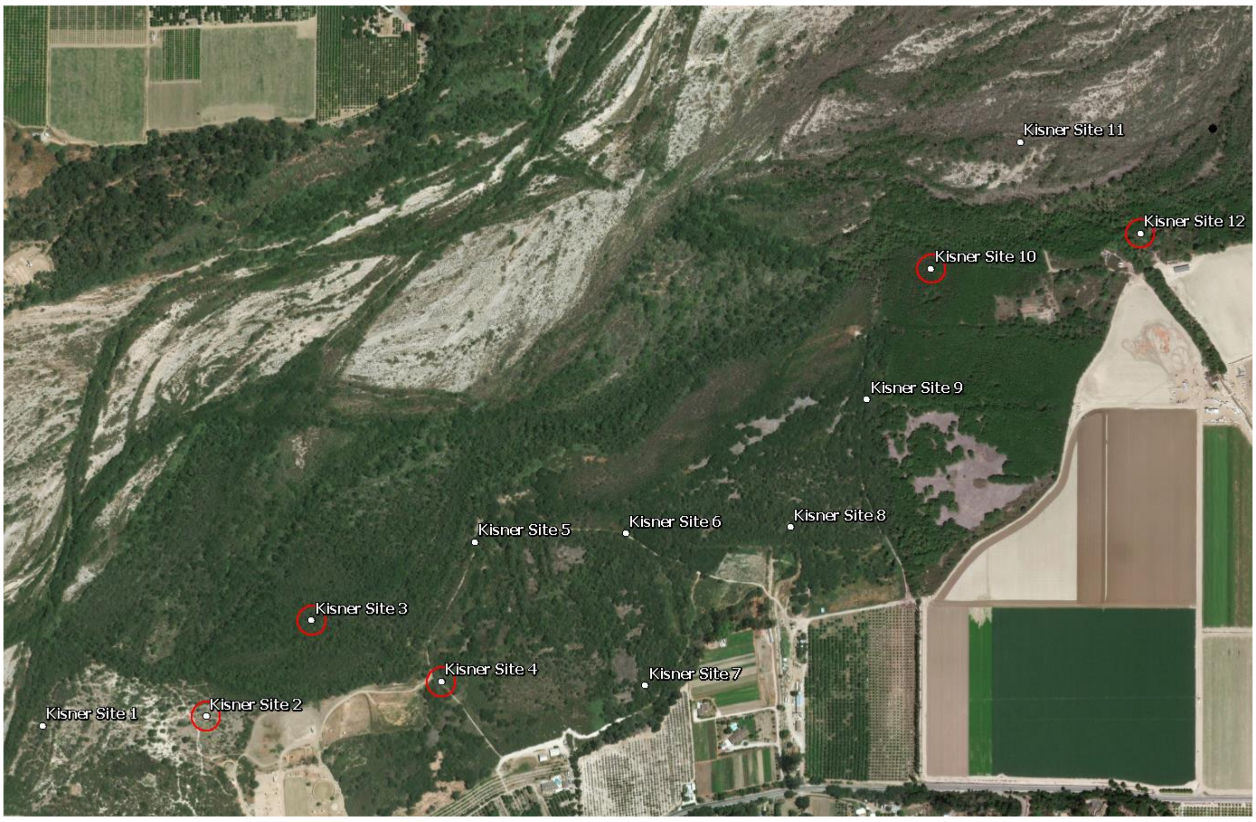
Wolcott_Way_to_McBean_Parkway (40%)	83.9	69.6	111.5	123.8	88.8	75.7	111.0	82.0	100.5	102.9	111.1	44.4	98.5
Wolcott_Way_to_McBean_Parkway (60%)	21.6	31.8	42.6	49.4	30.2	17.9	34.7	37.1	36.4	39.3	40.5	30.6	38.1
McBean_Pkwy_to_Bouquet_Cyn_Rd (40%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.2
McBean_Pkwy_to_Bouquet_Cyn_Rd (60%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Predicted YBCU habitat (40%)	978.7	1062.0	1037.4	1226.1	1080.7	1100.4	1155.8	959.6	951.6	642.3	876.1	788.0	1181.6
Predicted YBCU hab (60%) (60%)	386.6	298.2	334.1	454.3	263.9	279.6	302.8	230.3	261.6	109.9	258.6	211.5	306.0

11.4 APPENDIX D: FIGURES FOR LIDAR VERTICAL STRUCTURE (SECTION 5.3.3)

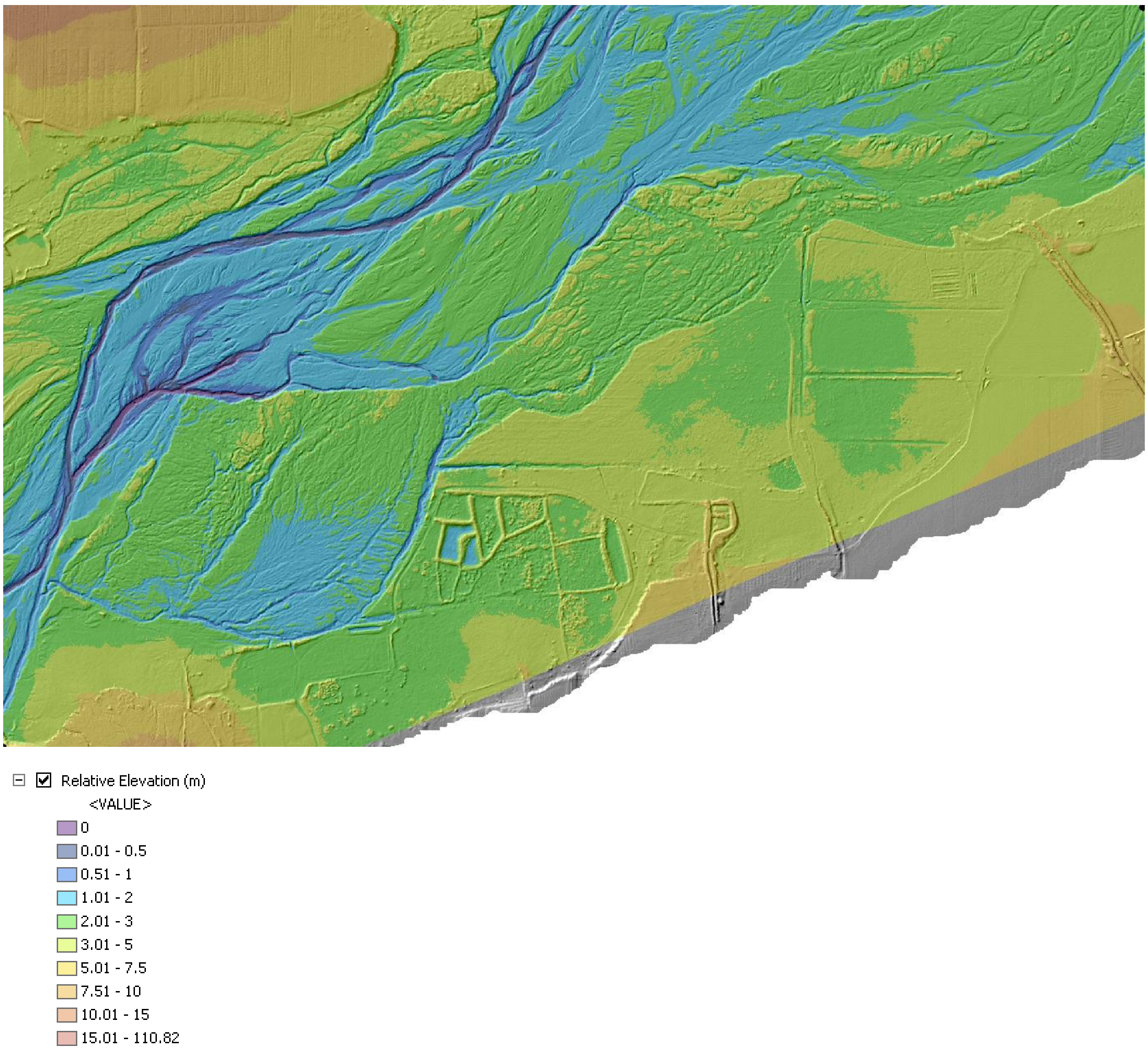
This appendix provides figures from a pilot study that was conducted outside of the scope of the Section 6 grant to explore the potential use of LIDAR point cloud data to assess vertical structure of riparian vegetation. In particular, we assessed if these data might allow prediction of habitat suitability for riparian bird species (such as Least Bell's Vireo) that are known to respond to vertical habitat structure. The results of this pilot study are relevant to the conservation and management of riparian birds and their habitat along the Santa Clara River, so we have included them here to provide an indication to USFWS and CDFW, and other readers, of the potential to develop new decision support tools using LIDAR.



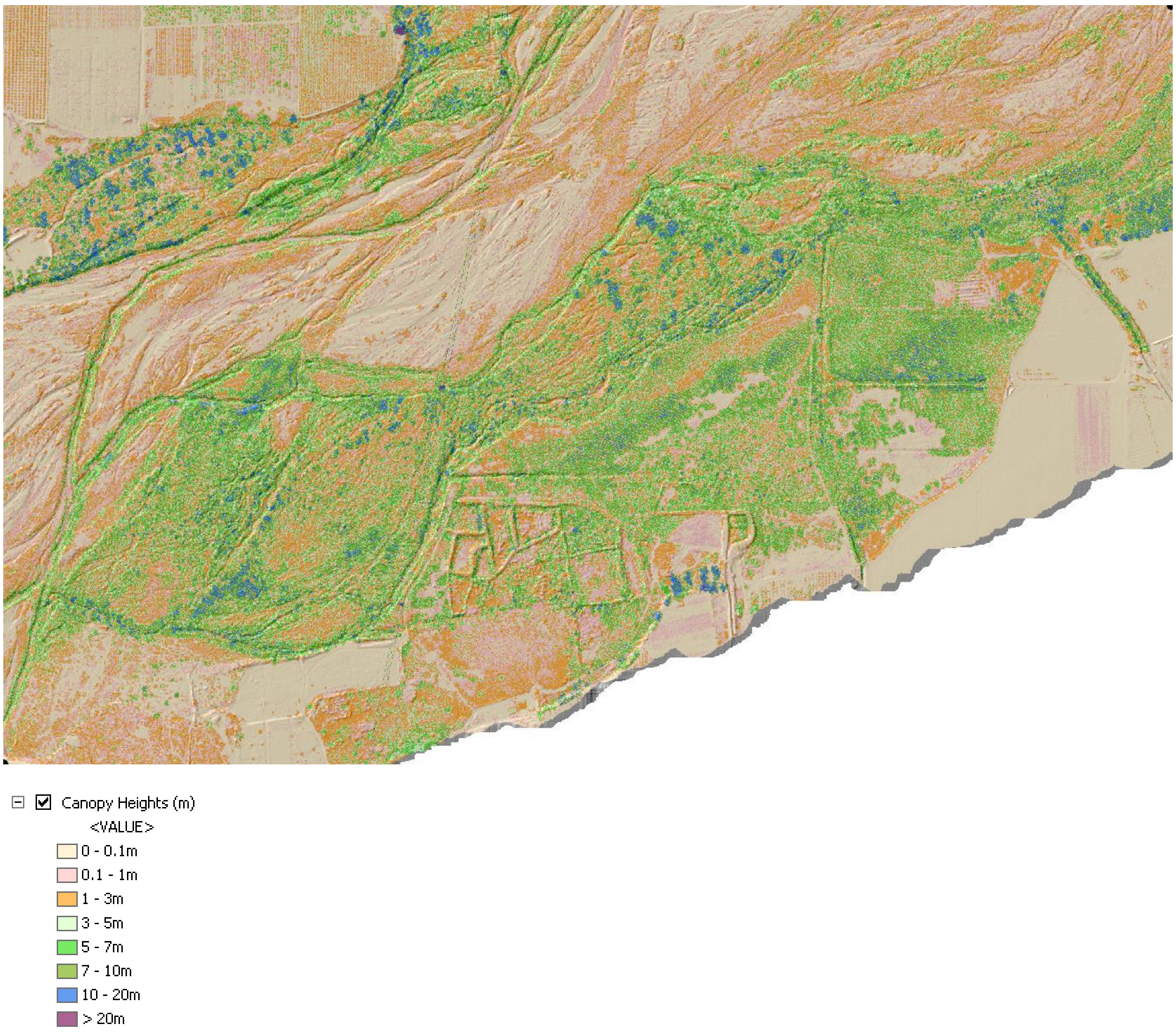
11.4.1 Figure D.1. A cross-sectional view of classified LIDAR point cloud data along a transect running North-South across the Santa Clara River floodplain near the Fillmore Fish Hatchery. The color scheme indicates elevation relative to the ground surface which is shown in darker blue (indicate LIDAR "last return" points from at or near the ground surface). The orange colors capture the higher vegetation structure associated with an emergent cottonwood tree.



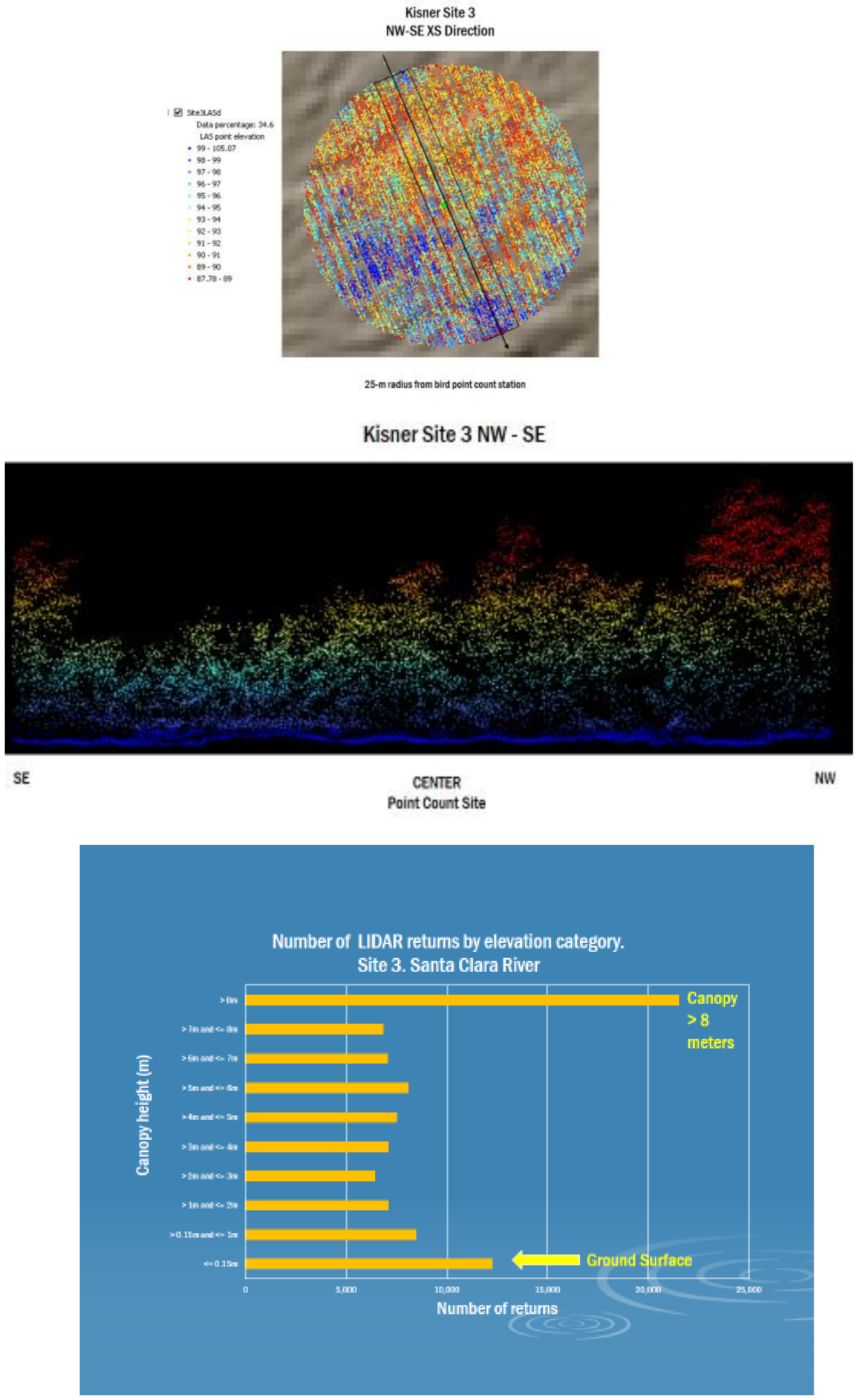
11.4.2 Figure D.2. Aerial image of a portion of the East Grove area including the Hedrick Ranch Nature Area (HRNA). Bird point count stations established by David Kisner are indicated in white. Red circles indicate point count stations selected for the pilot study of the use of LIDAR to assess vertical vegetation/habitat structure.



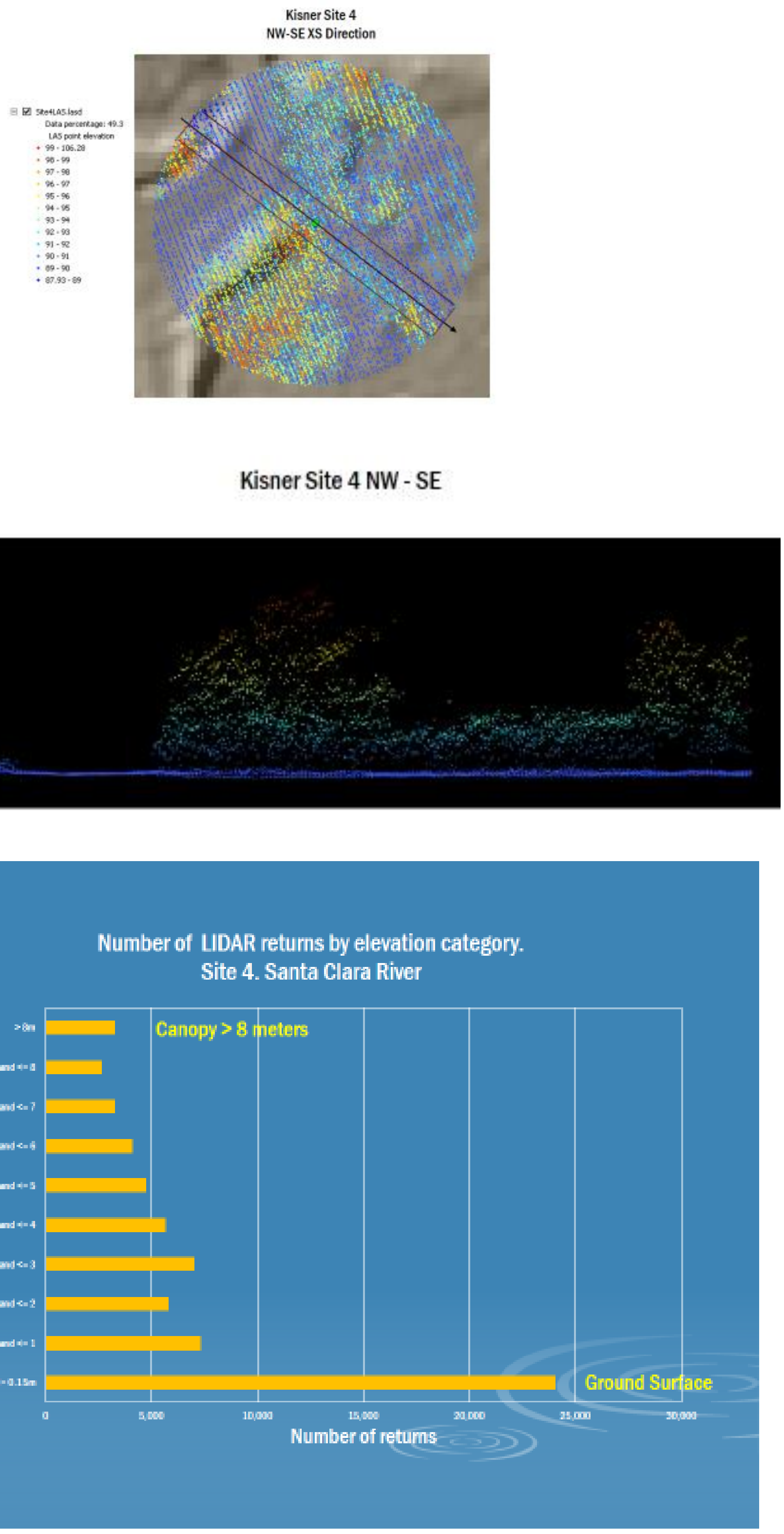
11.4.3 **Figure D.3. LIDAR-based relative elevation map for the same area shown in Figure D.2.**



11.4.4 Figure D.4. LIDAR-based canopy height map for the same area shown in Figure D.2.

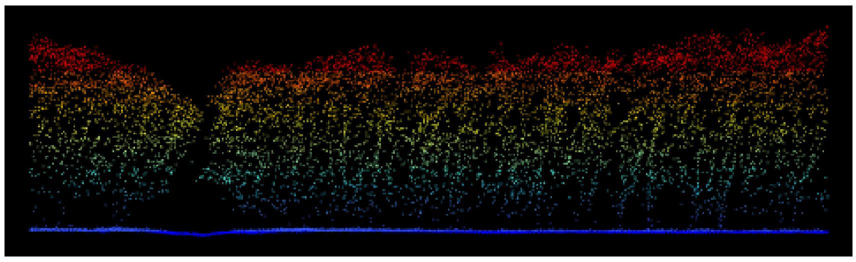


11.4.5 Figure D.5. TOP. 25-m circular plot of LIDAR data associated with Kisner Survey Site 3 (see Figure D.2). MIDDLE. Cross-sectional visualization of a belt transect taken through the circular plot. BOTTOM. Histogram of the number of return points by vertical strata within the circular plot.

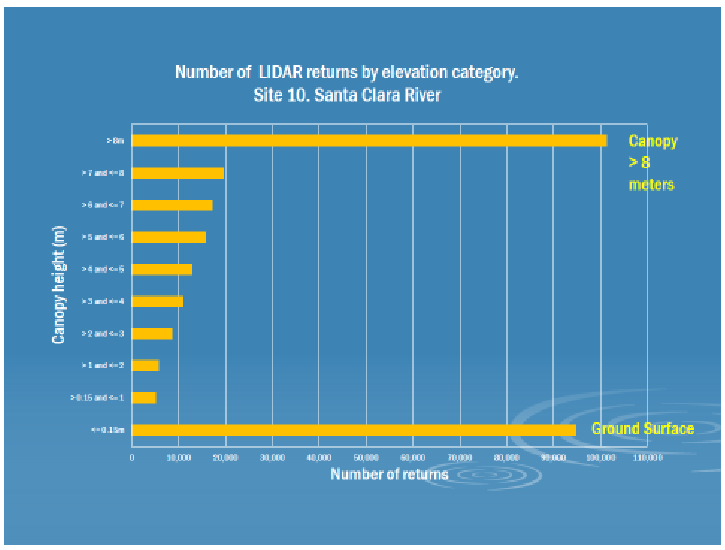


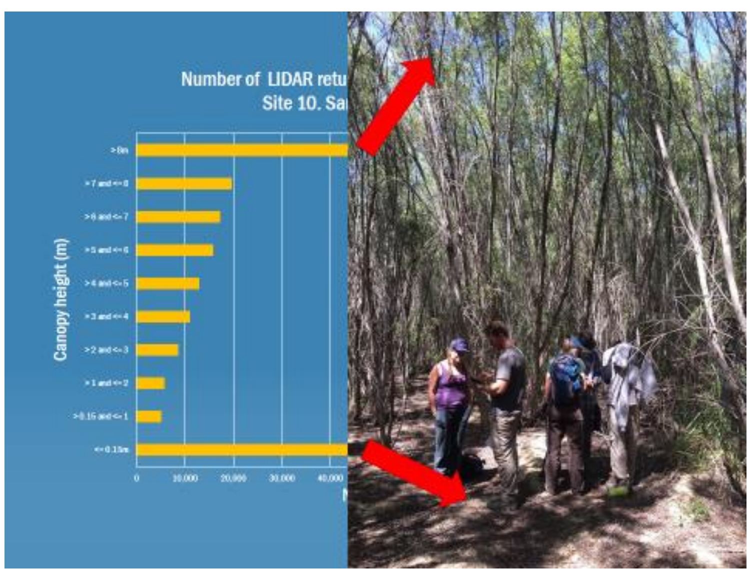
11.4.6 **Figure D.6. TOP. 25-m circular plot of LIDAR data associated with Kisner Survey Site 4 (see Figure D.2). MIDDLE. Cross-sectional visualization of a belt transect taken through the circular plot. BOTTOM. Histogram of the number of return points by vertical strata within the circular plot.**

Kisner Site 10 NNE - SSW



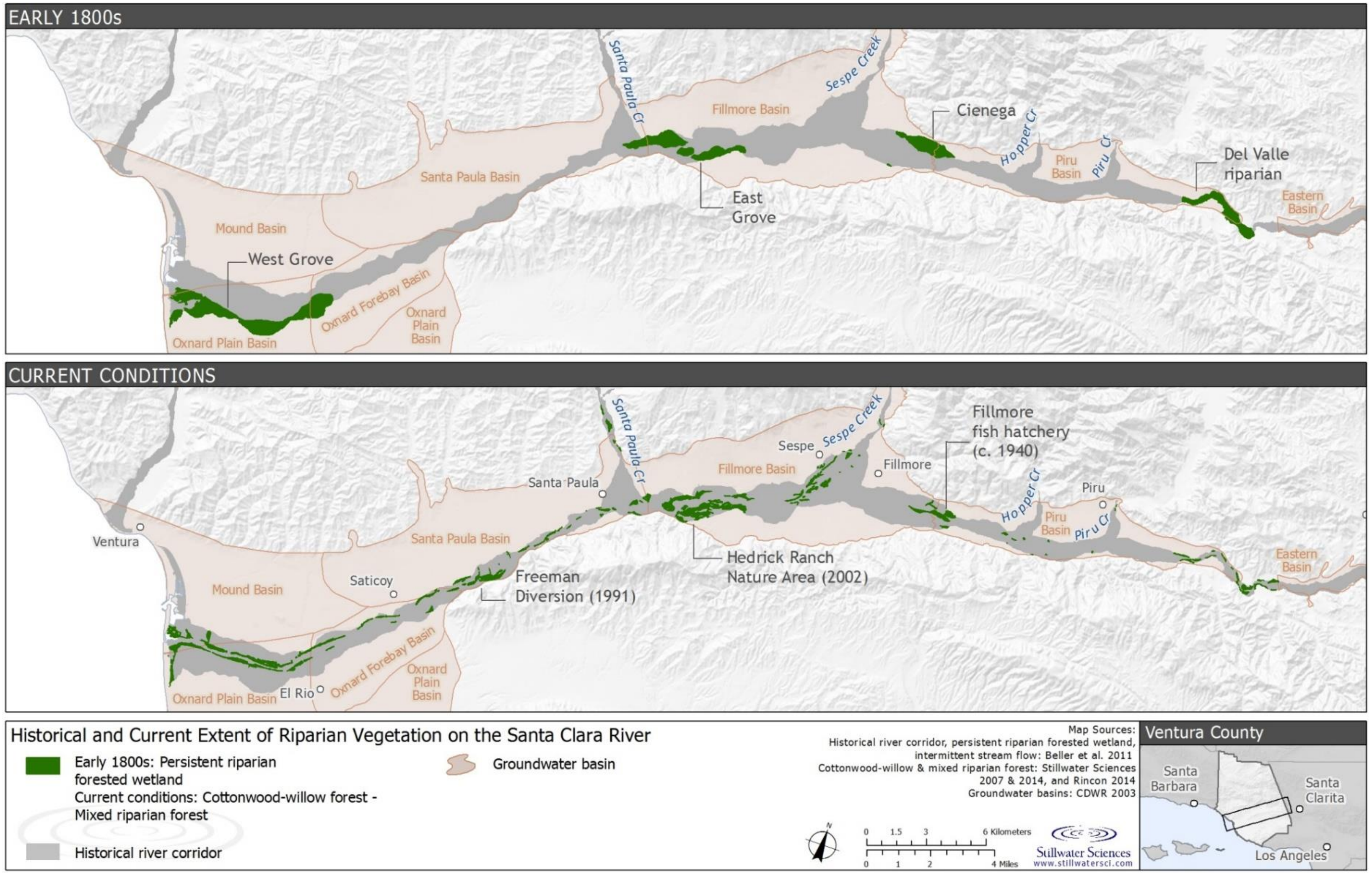
Example of an even-aged willow stand that recruited naturally after the 2005 flood event.
Yellow-billed cuckoo observed in this area during 2018 breeding season



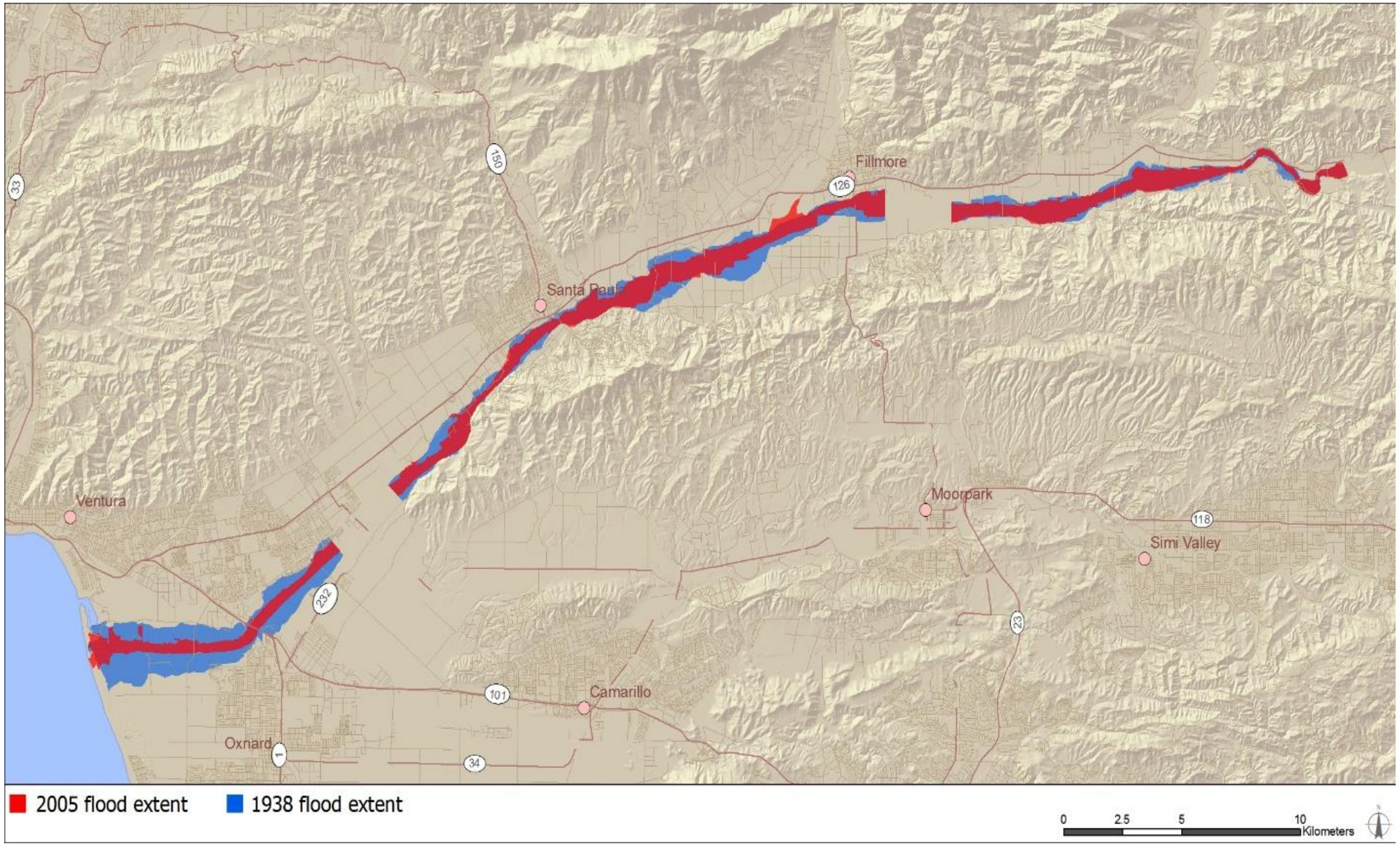


11.4.7 **Figure D.7. TOP. Cross-sectional visualization LIDAR point cloud date along a belt transect taken through the 25-m circular plot associated with Kisner Site 10 (see Figure D.2). MIDDLE. Histogram of the number of return points by vertical strata within the circular plot. BOTTOM. Photograph taken near the site in Spring 2018 indicating the highest density of returns from the ground surface and taller canopy strata, and relatively limited structure in the subcanopy layers.**

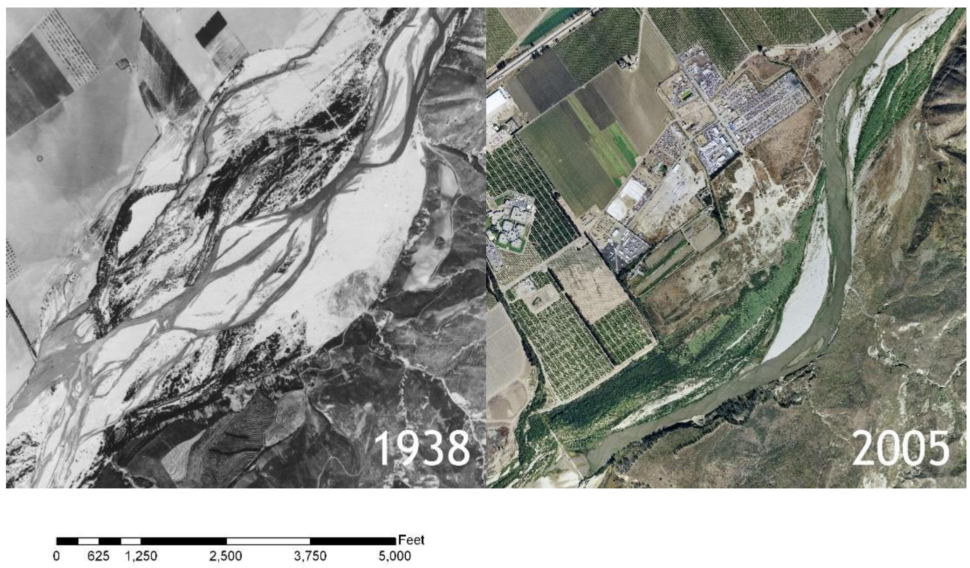
11.5 APPENDIX E: FIGURES FOR TIME SERIES (SECTION 5.4)



11.5.1 Figure E.1. Riparian forest extent along the Santa Clara River under historical and current conditions. Note the persistence of the four main forested wetland patches identified from historical source from at least the early 1800s to the present. Of the four, the East Grove area (which includes the present-day Hedrick Ranch Nature Area) is the largest and most intact under current conditions.

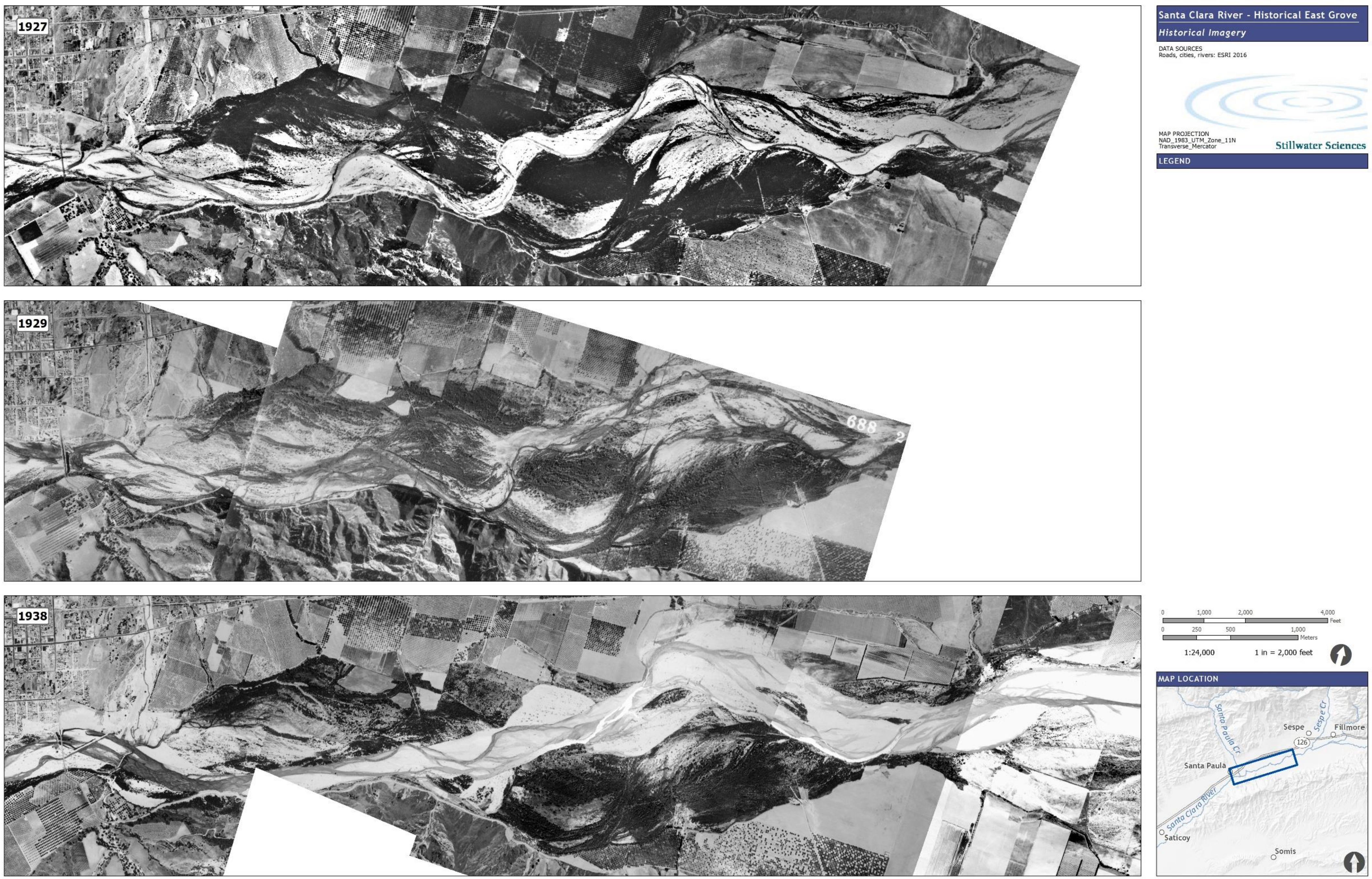


11.5.2 Figure E.2. Extent of the floods of 1938 (in blue) and 2005 (in red), based on analysis of aerial photographs (Stillwater 2007).



11.5.3 **Figure E.3. Riparian corridor conditions at river mile 11 (lower portion of Reach 3) in 1938 and 2005. The Freeman Diversion is visible in the lower left corner of the 2005 photograph.**

11.6 APPENDIX F: HISTORICAL TIME SERIES IMAGES OF THE SANTA CLARA RIVER



Santa Clara River - Historical East Grove

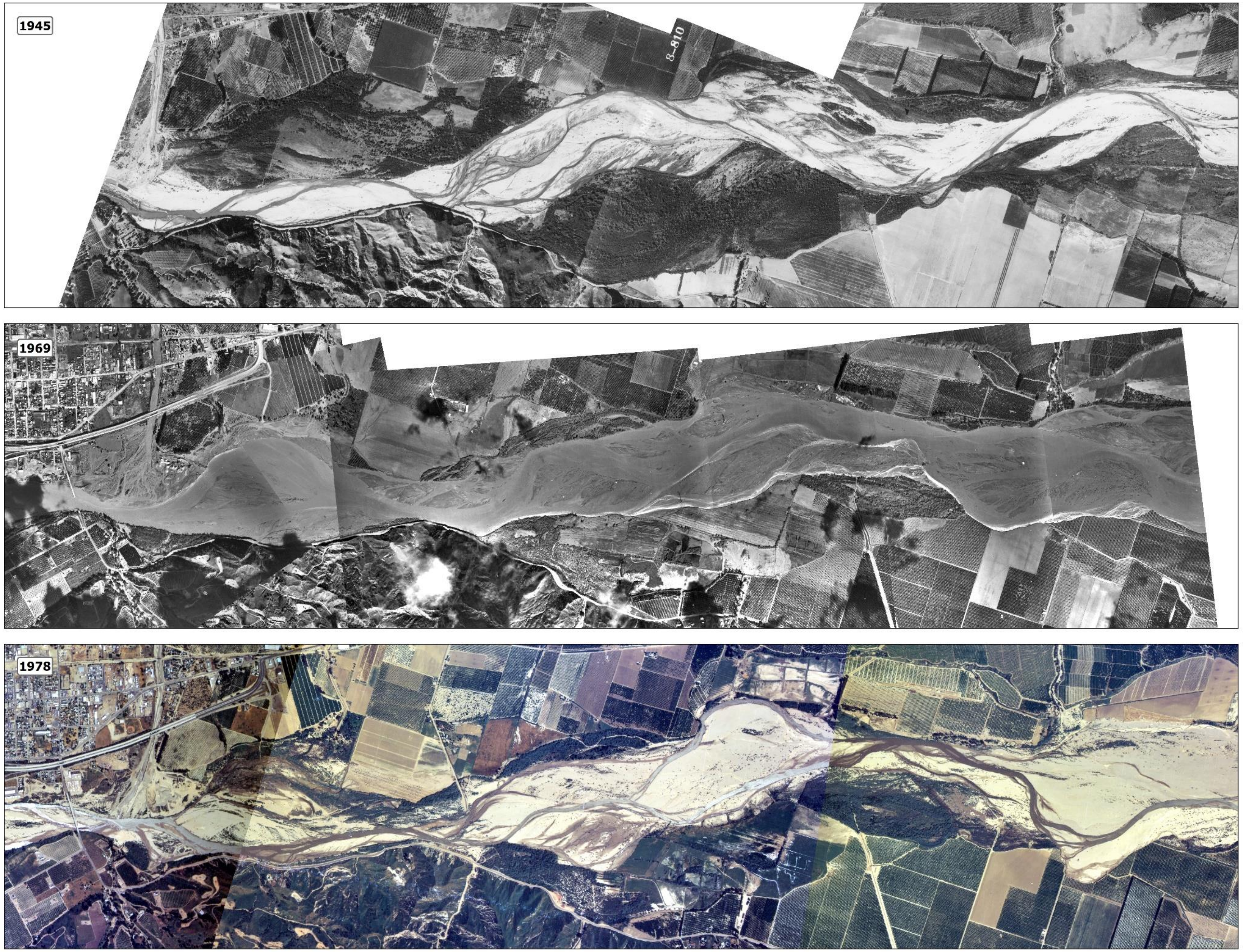
Historical Imagery

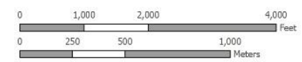
DATA SOURCES
Roads, rivers, cities: ESRI 2016

MAP PROJECTION
NAD 1983 UTM Zone 11N
Transverse_Mercator

Stillwater Sciences

LEGEND





1:24,000 1 in = 2,000 feet

MAP LOCATION

Santa Clara River - Historical East Grove

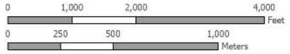
Historical Imagery

DATA SOURCES
Roads, rivers, cities: ESRI 2016

MAP PROJECTION
NAD_1983_UTM_Zone_11N
Transverse_Mercator

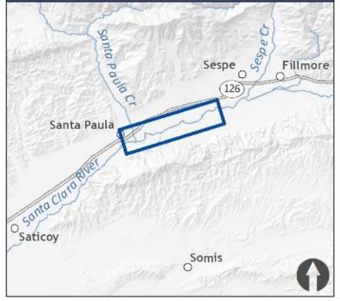
Stillwater Sciences

LEGEND



1:24,000 1 in = 2,000 feet

MAP LOCATION



Santa Clara River - Historical East Grove

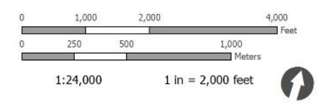
Historical Imagery

DATA SOURCES
Roads, rivers, cities: ESRI 2016

MAP PROJECTION
NAD_1983_UTM_Zone_11N
Transverse_Mercator

Stillwater Sciences

LEGEND



MAP LOCATION

Santa Clara River - Historical East Grove

Historical Imagery

DATA SOURCES
Roads, rivers, cities: ESRI 2016

MAP PROJECTION
NAD_1983_UTM_Zone_11N
Transverse_Mercator

Stillwater Sciences

LEGEND

0 1,000 2,000 4,000 Feet
0 250 500 1,000 Meters

1:24,000 1 in = 2,000 feet

MAP LOCATION

Santa Clara River - Historical East Grove

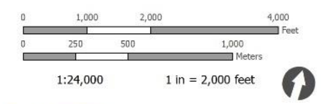
Historical Imagery

DATA SOURCES
Roads, rivers, cities: ESRI 2016

MAP PROJECTION
NAD_1983_UTM_Zone_11N
Transverse_Mercator

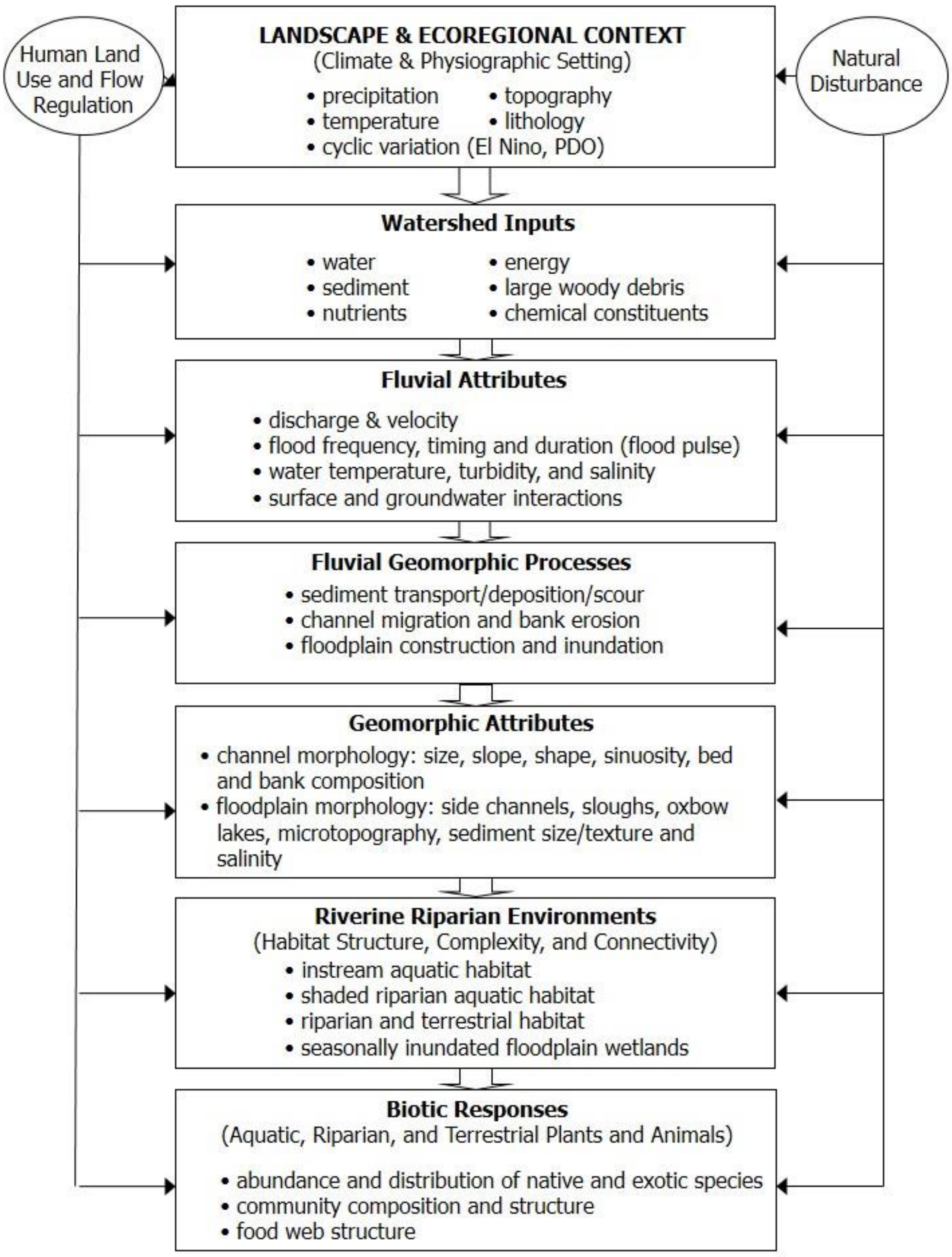
Stillwater Sciences

LEGEND

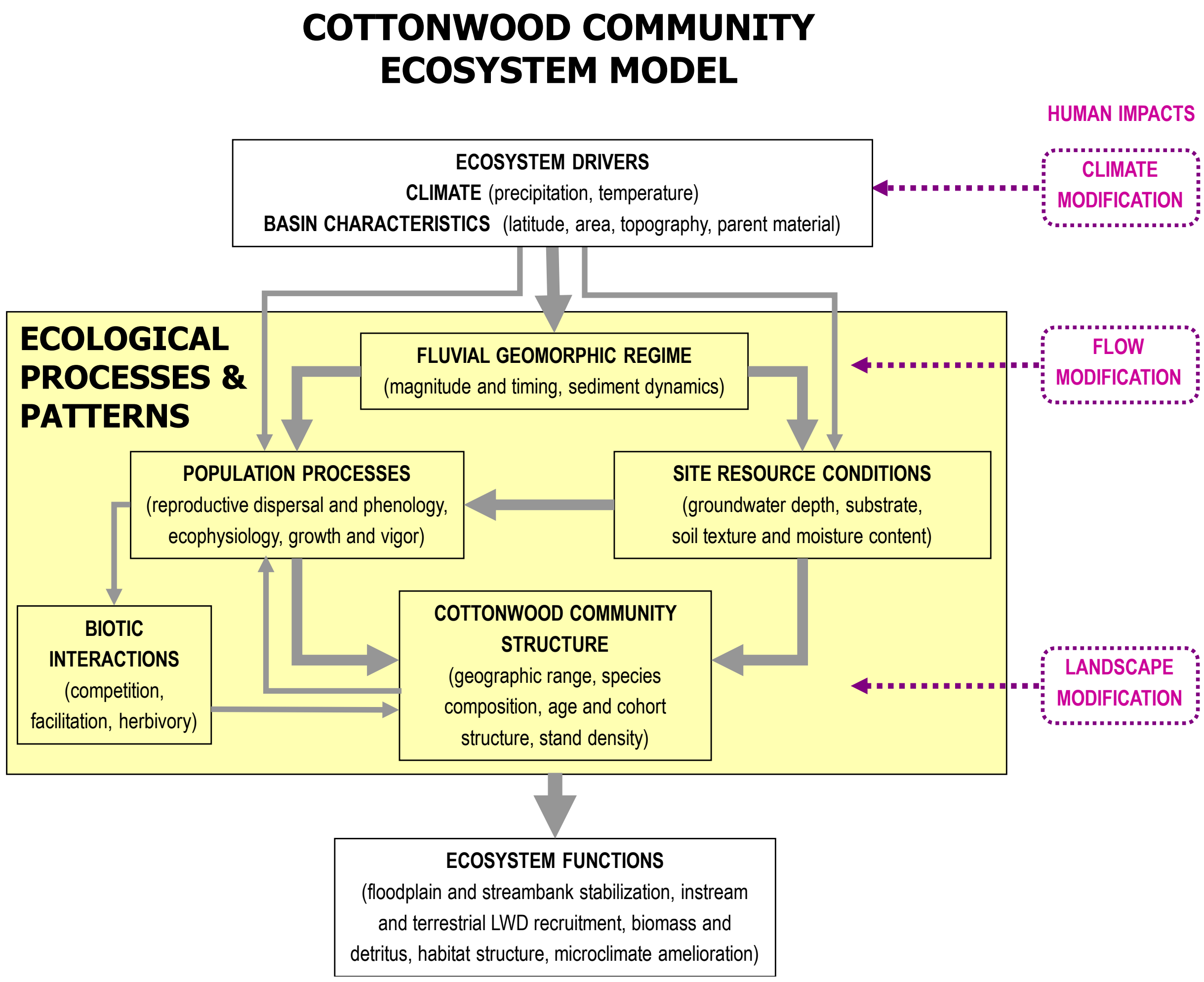


MAP LOCATION

11.7 APPENDIX G: CONCEPTUAL MODELS



11.7.1 **Figure G.1. Conceptual physical and biological framework for alluvial river systems illustrating key ecological linkages and interactions. Adapted and modified from Stillwater Sciences (2001) and Vaghti and Greco (2007).**



11.7.2 Figure G.2. Conceptual model of key ecosystem drivers, ecological patterns and processes, and ecosystem functions plus primary categories of human impacts for Cottonwood ecosystems.