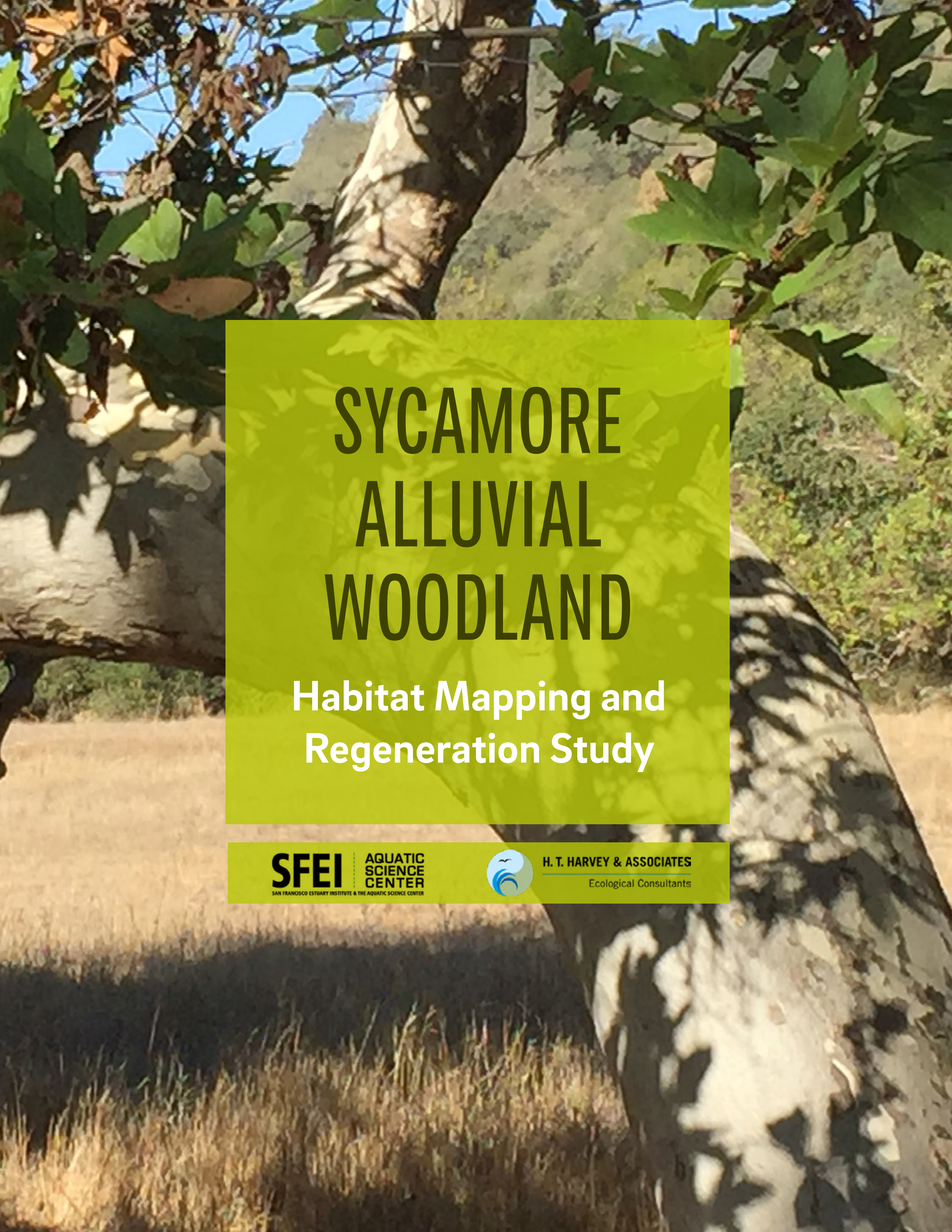

SYCAMORE ALLUVIAL WOODLAND

Habitat Mapping and Regeneration Study

SFEI AQUATIC SCIENCE CENTER
SAN FRANCISCO ESTUARY INSTITUTE & THE AQUATIC SCIENCE CENTER

H. T. HARVEY & ASSOCIATES
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FEBRUARY 2017

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REPORT AVAILABILITY

Report is available on SFEI's website at www.sfei.org/projects/saw

COVER CREDITS

Photo of sycamore tree, Palassou Ridge near Coyote Creek (Amy Richey, SFEI, 2015).

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CONTENTS

1 • INTRODUCTION

This study investigates the relative distribution, health, and regeneration patterns of two major stands of sycamore alluvial woodland (SAW), representing managed and natural settings. Using an array of ecological and geomorphic field analyses, we discuss site characteristics favorable to SAW health and regeneration, make recommendations for restoration and management, and identify next steps. Findings from this study will contribute to the acquisition, restoration, and improved management of SAW as part of the Santa Clara Valley Habitat Plan (VHP).

California sycamore (*Platanus racemosa*) is an iconic tree species native to California and northern Baja California. It is the defining feature of SAW, a habitat type defined as open to moderately closed, winter-deciduous broad-leafed riparian woodland dominated by well-spaced California sycamore (Holland 1986), often associated with intermittent, braided stream reaches with relatively stable groundwater levels and periodic flooding (Keeler-Wolf et al. 1996). It also occurs in the "*Platanus racemosa* woodland alliance" with white alder (*Alnus rhombifolia*), southern black walnut (*Juglans californica*), Fremont cottonwood (*Populus fremontii*), bay laurel (*Umbellularia californica*), and a variety of oak (*Quercus* spp.) and willow (*Salix* spp.) species (Sawyer et al. 2009).

Vulnerable wildlife species are often associated with this habitat type. For instance, western pond turtles (*Actinemys marmorata*) tend to prefer the deep scour pools and complex channel habitat typical of sycamore alluvial woodland systems (Belli 2015). Steelhead trout (*Oncorhynchus mykiss*) may achieve larger size in sycamore-dominated streams, with frequent and intense flows that accumulate gravel and sand (Casagrande 2010). Sycamores provide substantial nesting and roosting habitat for a variety of bird species, as well as seed and insect food sources, relative to many other riparian trees, given their large size and significant dead wood subsidy (Bock and Bock 1981).

Regionally, the physical processes which create and maintain SAW have largely been interrupted. Natural flood events are critical to deposit fresh alluvial sediment, carry and deposit seeds, and recharge groundwater levels, which then draws down over time (Keeler-Wolf et al. 1996). These conditions are necessary for sycamores to produce and lay a successful seed set for sexual reproduction (Keeler-Wolf et al. 1996). Yet in most California watersheds, dams have cut off peak flows, thus limiting substantial flood events, coarse sediment deposition, and scour, and altered hydrographs. These dams and other water management practices have often transformed intermittent streams into perennial streams (Kamman Hydrology 2009). Groundwater pumping has altered natural draw-down curves, altering the subsurface conditions to which the sycamore species likely evolved (Gilles 1998, King 2004). Grazing, vegetation management, and other land use changes such as road encroachments and habitat conversion have further altered conditions that support SAW.

In California, sycamore-alluvial woodland habitat is relatively rare. The distribution and regeneration of SAW has been greatly limited by the loss of such habitat over the past 200 years, largely as a result of changes to flow and sediment dynamics from dams and the removal of floodplains from the influence of regular flooding (Keeler-Wolf et al. 1996). It has been mapped in just 17 occurrences along intermittent streams in California totaling approximately

SYCAMORE BARK

SYCAMORE LEAF

SYCAMORE TREE, NEAR UPPER COYOTE CREEK

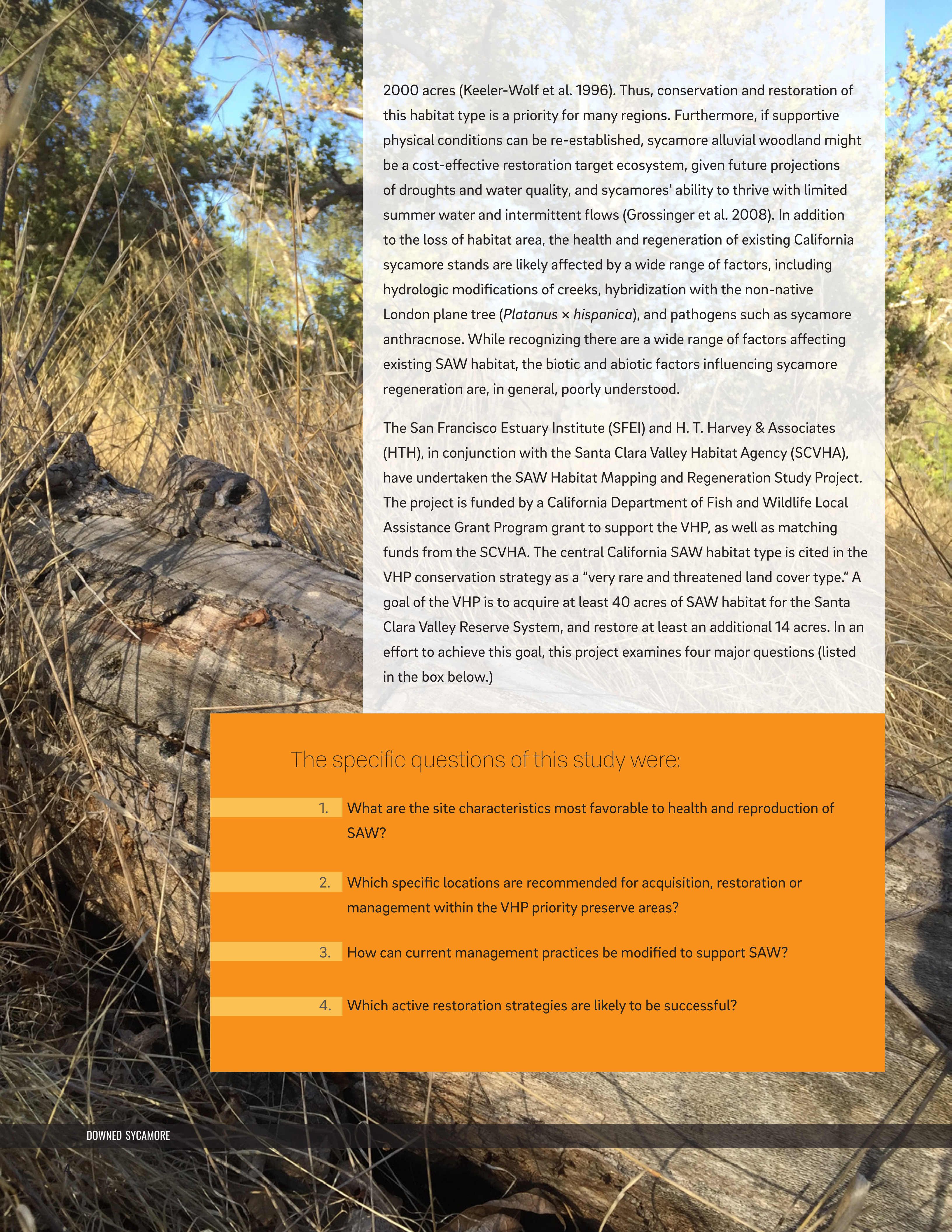
SYCAMORE TREES WITH POOLS, UPPER COYOTE CREEK

2000 acres (Keeler-Wolf et al. 1996). Thus, conservation and restoration of this habitat type is a priority for many regions. Furthermore, if supportive physical conditions can be re-established, sycamore alluvial woodland might be a cost-effective restoration target ecosystem, given future projections of droughts and water quality, and sycamores' ability to thrive with limited summer water and intermittent flows (Grossinger et al. 2008). In addition to the loss of habitat area, the health and regeneration of existing California sycamore stands are likely affected by a wide range of factors, including hydrologic modifications of creeks, hybridization with the non-native London plane tree (*Platanus* × *hispanica*), and pathogens such as sycamore anthracnose. While recognizing there are a wide range of factors affecting existing SAW habitat, the biotic and abiotic factors influencing sycamore regeneration are, in general, poorly understood.

The San Francisco Estuary Institute (SFEI) and H. T. Harvey & Associates (HTH), in conjunction with the Santa Clara Valley Habitat Agency (SCVHA), have undertaken the SAW Habitat Mapping and Regeneration Study Project. The project is funded by a California Department of Fish and Wildlife Local Assistance Grant Program grant to support the VHP, as well as matching funds from the SCVHA. The central California SAW habitat type is cited in the VHP conservation strategy as a "very rare and threatened land cover type." A goal of the VHP is to acquire at least 40 acres of SAW habitat for the Santa Clara Valley Reserve System, and restore at least an additional 14 acres. In an effort to achieve this goal, this project examines four major questions (listed in the box below.)

The specific questions of this study were:

1. What are the site characteristics most favorable to health and reproduction of SAW?
2. Which specific locations are recommended for acquisition, restoration or management within the VHP priority preserve areas?
3. How can current management practices be modified to support SAW?
4. Which active restoration strategies are likely to be successful?



DOWNED SYCAMORE

This study will gather and generate data that can be used by the Santa Clara Valley Habitat Agency to guide the acquisition, management, and enhancement of California sycamore habitat to meet VHP conservation goals. It also contributes to understanding the biotic and abiotic factors influencing stand health and natural regeneration. In addition, this study will increase knowledge of the ecology of California sycamore–dominated habitats and help identify restoration actions for these areas. The development of a conservation and regeneration strategy for SAW is critical, as it has become increasingly difficult to find unhybridized California sycamore propagules for replanting, and there has been little success with direct propagation from cuttings. This study is the first step toward identifying the locations and conditions of extant stands; however, future studies will address nursery propagation of unhybridized California sycamores.

This study includes a review of California sycamore ecology literature (found at www.sfei.org/projects/saw), mapping of sycamore-dominated habitats, develops a study plan covering two SAW stands, and collects and analyzes field data. Two study sites were identified in southeastern Santa Clara County: one site with "natural" hydrology (Upper Coyote Creek) and one site with "reservoir" managed hydrology (Pacheco Creek) (Figure 1). The Upper Coyote Creek and Pacheco Creek study sites are owned by public agencies (Santa Clara Valley Open Space Authority (OSA) and California Department of Transportation (Caltrans), respectively). They are located in drainages that provide some of the most important SAW habitat in Santa Clara County, with good-quality habitat located both upstream and downstream of the sites. Both sites are also considered Conservation Focus Areas by the VHP.

Upper Coyote Creek

Upper Coyote Creek (watershed area 833 km^2) is the headwaters of Coyote Creek, the largest drainage in Santa Clara County, flowing into the San Francisco Bay near Milpitas. The study area is located upstream of two major reservoirs on the creek (Anderson and Coyote Reservoirs) and drains approximately 271 km^2 of steep, rugged terrain. The study area consists of an open floodplain, with intact historical side channels, alluvial braids, natural flows, and mature SAW. The riparian corridor is broad, with perennial flows that actively re-work well-sorted cobbles and gravels into deep scour pools and gravel bars. It is one of the few areas in the county with relatively unmodified hydrology, and provides a unique opportunity for studying the dynamics of SAW. The study site (~2 km long) is located in an alluvial reach, within OSA's Palassou Ridge Preserve, approximately 6 km east of Gilroy (Figure 1). The site is subject to periodic grazing and encroachment from an adjacent public road.

SYCAMORE TREE ON EDGE OF CHANNEL, COYOTE CREEK

Pacheco Creek

Pacheco Creek, which has a watershed area of 435 km^2, is tributary to the Pajaro River, which flows into the Pacific Ocean near Moss Landing. Historically, the alluvial portion of Pacheco Creek in the study area was a broad, braided, gravel- and cobble-bedded channel with seasonally intermittent flow (Grossinger et al. 2008). It supported substantial stands of sycamore-alluvial woodland on bar and floodplain surfaces slightly elevated above the main channel (Grossinger et al. 2008). However, the construction of Pacheco Reservoir on North Fork Pacheco Creek in 1935 altered the creek's hydrologic regime; late spring/early summer reservoir releases have increased dry-season flows and converted the creek into a generally perennial system (Gillies 1998, Casagrande 2010). However, the creek is still dry during much of the summer and fall (Dave Johnston, Pers. Comm.).

SYCAMORE TREE AND DRY SIDE CHANNEL, PACHECO CREEK

Land cover in the upper watershed is predominantly grassland and oak woodland (SCVOSA 2014). The study site (~2 km long) is located in an alluvial reach approximately 20 km east of Gilroy (Figure 1). The river corridor is broad and multi-threaded at this location, with sycamores, willows, and mulefat (*Baccharis salicifolia*) dominant in the inner floodplain and pastureland and mature sycamores in the outer floodplain. A tributary to Pacheco Creek, Harper's Creek, also impounded, is located at the western edge of the site. Anthropogenic disturbances to Pacheco Creek, aside from the upstream dam, include bank revetments, road (State Highway 152) encroachment, fire, gravel mining, and livestock grazing. During 1991–1994, Caltrans planted California sycamore in the study area as mitigation for Hwy 152 construction impacts on sycamore woodland (Caltrans 1996, Keeler-Wolf et al. 1996). The sycamores that were planted may be hybrids between native California sycamore and non-native London plane tree (Whitlock 2003, Byington 2016).

A suite of data was collected at each of the two study sites to identify factors that negatively or positively affect sycamore health and regeneration. Vegetation data collected included tree condition, health and vigor; location of trees relative to geomorphic zones; size class; structure; seed production; associated species; substrates; and anthracnose infestation severity. Geomorphic data collection included mapping initial elevations from LiDAR data, field-fitting the map, and the collection of tree ring data for analysis with geomorphic analysis.

Figure 1. (Opposite right) Location of two sites within Santa Clara County.

Coyote Creek Study Site
Pacheco Creek Study Site
Anderson Lake
Morgan Hill
Coyote Lake
San Martin
Coyote Creek
101
Gilroy
152
Pacheco Creek
San Felipe
Lake
SANTA CLARA COUNTY
SAN BENITO COUNTY
Pajaro River
SAN
FRANCISCO
BAY
STUDY AREA
California
N
4 miles
Hollister
San Juan Bautista

HYPOTHESES

This project examines and compares the relative distribution, health, and regeneration patterns of the two stands, given that the two sites have undergone different modifications and are subject to different physical drivers and land management strategies.

Below, we describe the hypotheses underlying the field study (Table 1). In the discussion section, we revisit this table with findings, lessons learned, and next steps. The following schematic provides a general framework for what we predict to observe in a more natural-flow system and from a managed versus reservoir-flow managed system.

SYCAMORE LEAVES IN SUNLIGHT

Table 1. Hypotheses and expected results

HOW ARE SYCAMORES DISTRIBUTED AT EACH SITE?

	Expected Results in "Natural" System [UPPER COYOTE]	**Expected Results** in "Managed" System [PACHECO]
By geomorphic zone	Younger trees are concentrated along the primary channel, older trees are concentrated in the older floodplain.	Younger trees are concentrated along the primary channel, older trees are concentrated in the older floodplain.
By distance from channel	Younger trees are located closer to the channel, older trees are located further from the channel.	Younger trees are located closer to the channel, older trees are located further from the channel.

Sycamores survive well on intermittent flows, but generally establish on newly formed gravel bars where these trees may have best comparative advantage for establishment (Kamman Hydrology 2009). As a result, we would expect to find younger trees in highest densities in the zones in close proximity to the stream, and older trees further away from the stream. We would expect this result across sites.

WHAT IS THE GENERAL HEALTH OF SYCAMORES?

	Expected Results in "Natural" System [UPPER COYOTE]	**Expected Results** in "Managed" System [PACHECO]
By health / vigor score	Trees are relatively ***healthier.***	Trees are relatively ***less healthy.***
By mortality	Trees suffer ***less mortality.***	Trees suffer ***greater mortality.***
By anthracnose symptoms	Trees have ***lower incidence.***	Trees have ***greater incidence.***

Reservoir-managed systems would likely support relatively less healthy trees under all metrics, all things equal. Less frequent and less intense disturbances may decrease gravel bar accumulation and increase organic and silt sediment loads, fail to sweep away anthracnose-infected litter, and allow more competition from riparian trees, all of which may disadvantage sycamores (Shanfield 1984, Gilles 1998, King 2004, Sycamore Associates 2004, Kamman Hydrology 2009, Casagrande 2010, Beagle et al. 2014). Younger tree health may depend on grazing intensity and frequency allowed at the site.

Table 1. (continued, above and below) Hypotheses and expected results

HOW ARE SYCAMORES REGENERATING?

	Expected Results in "Natural" System [UPPER COYOTE]	**Expected Results** in "Managed" System [PACHECO]
By new growth	Significant ***new generation.***	Relatively ***less regeneration.***
By root sprouts	Trees have ***higher root sprout production.***	Trees have ***lower root sprout production.***
By seed production	Trees have ***more seed production.***	Trees have ***less seed production.***

We would expect natural systems to support more regeneration and higher root sprouts and seed production, as sycamores may be more stressed (given the reasons listed above) and have less reproductive fitness under a managed hydrologic regime. Regeneration success could also depend on hybridization and gene pool contamination with London plane tree.

2 • METHODS

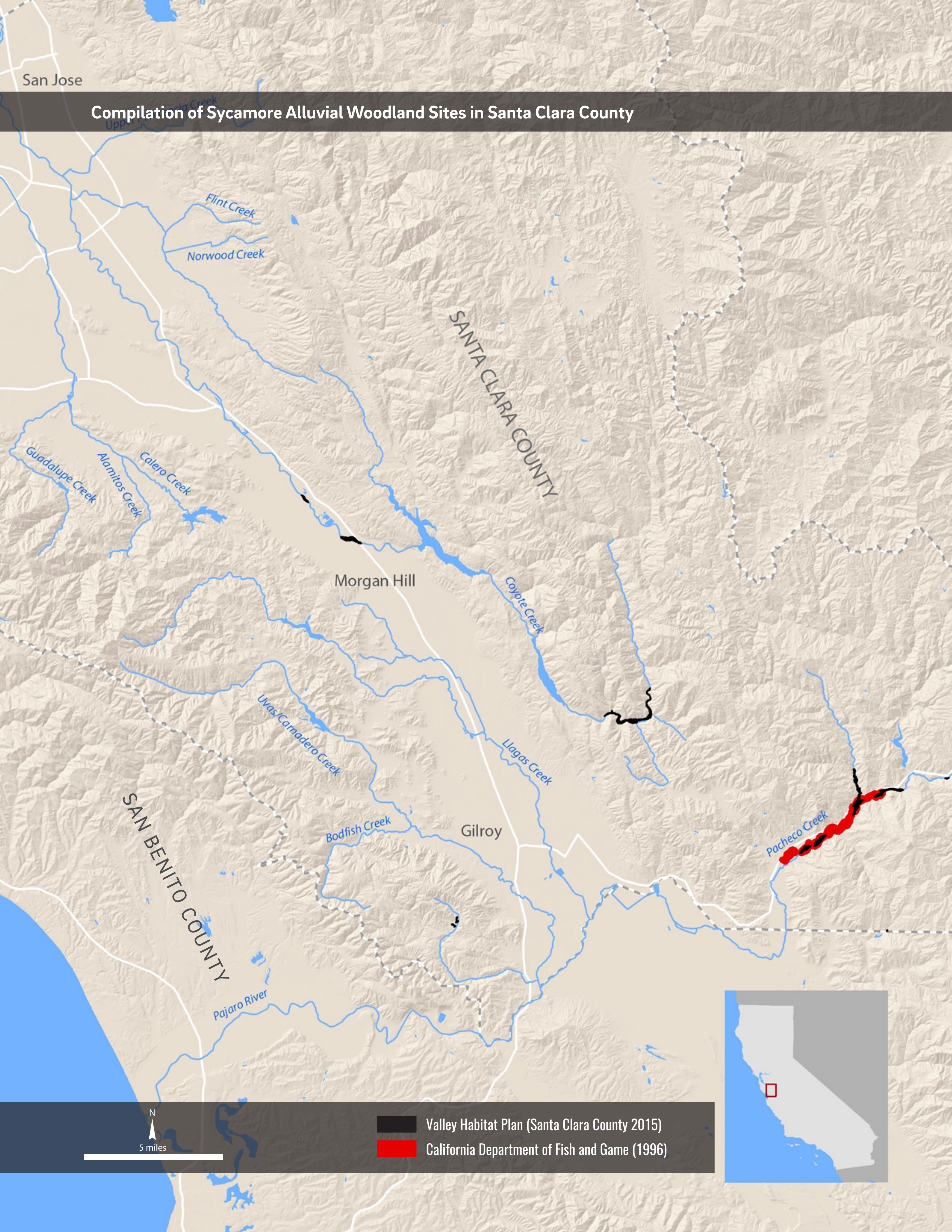
LARGE SYCAMORE TREE NEAR PACHECO CREEK

LITERATURE REVIEW

HTH and SFEI conducted an extensive review of documents, mapping efforts, and scientific literature pertaining to factors that influence California sycamore health and regeneration in central California. A range of topics has been studied, including: sycamore ecology, historical ecology, habitat management, hybridization, regeneration, restoration, pests, and sycamore anthracnose. HTH and SFEI also gathered existing maps and conducted supplemental mapping of the current distribution of large stands of California sycamores in Santa Clara County. An annotated bibliography that resulted from the review of documents, mapping efforts, and personal communications is presented as a separate document.

REGIONAL SYCAMORE ALLUVIAL WOODLAND MAPPING

Due to the habitat value of SAW, the extreme loss of this rare habitat type, and the importance of sycamores in Santa Clara County, CDFW has conducted fairly extensive studies, including a state-wide survey and inventory of the remaining SAW stands. The study found only approximately 2,000 acres left in 17 occurrences of 10 acres or more (Keeler-Wolf et al. 1996). The study documented direct mortality, as well as continuing threats to and degradation of these remaining stands. The Santa Clara County VHP documented additional remaining areas dominated by sycamores in the county (Figure 2), which will be critical for assessing the range of potential sites for the conservation and restoration of SAW required by the VHP. HTH staff made supplemental observations of SAW stands in Santa Clara County during the course of this study, which could be used to determine areas for future study and acquisition priorities.



Compilation of Sycamore Alluvial Woodland Sites in Santa Clara County

DATA COLLECTION

HTH and SFEI collected data to assess the health, distribution, and regeneration in two existing California sycamore populations in Santa Clara County, at Upper Coyote Creek and Pacheco Creek. The selection and extent of the study sites were determined by a geomorphic analysis of active and historical floodplains, in-channel bar features, and other active surfaces; where California sycamores are generally found, and where individuals were observed to occur in stands as the dominant tree species at the study sites. In the case of the Pacheco Creek site, the limits of the California Department of Transportation (Caltrans) ownership also factored into the size of the study area. The methods for data collection at both study sites were the same and are described below.

Geomorphic Zone Mapping

Prior to conducting field work, SFEI segmented the study sites into geomorphic zones using an analysis of a LiDAR-derived digital elevation model (DEM) and aerial photos. These zones were defined by distinct topographic changes and geomorphic features such as the primary channel, inner channel corridor, and outer floodplain. These zones were then used by the field crews on October 5 and 6, 2015 (SFEI staff Julie Beagle, and Micha Salomon, and HTH staff Pat Reynolds) to collect information both about individual sycamore trees within the zones, and also about the zones themselves. Detailed geomorphic zone data collection was conducted during field work to refine the zones used for data analysis. Data collected within each zone is explained below.

Geomorphic Zone. SFEI staff field-fit the LiDAR-derived geomorphic zone map during the site visit, verifying the geomorphic zones and creating new GPS polygons, or modifying existing polygons, as necessary.

Dominant Substrate. The dominant substrate was characterized in each geomorphic zone polygon. Categories included: cobble; gravels; sand; silt; vegetated surface (grasses); and vegetated surface (woody vegetation). Notes were made if the polygon was too heterogeneous to characterize.

Median pebble size (D50). In three geomorphic zones per field site, the field team performed a Wolman pebble count to obtain the median pebble size (Wolman 1954). This allowed the team to utilize simple models after the fact to simulate flood extents with given discharges.

Land Cover Type. The existing habitat mapping for the VHP was used to label the habitat type of each geomorphic zone polygon. This mapping was updated in the field to reflect actual conditions. Habitat types include: Mixed Riparian Forest and Woodland; Central California Sycamore Alluvial Woodland; Willow Riparian Forest and Scrub; California Annual Grassland; Valley Oak Woodland;

DATA COLLECTION AT COYOTE CREEK

Figure 2. (Opposite) Compilation of sycamore alluvial woodland sites mapped by CDFW and VHP in Santa Clara County.

DATA COLLECTION, HARPER CREEK AT PACHECO CREEK SITE

Notes. Notable observations were recorded for each tree where necessary. These included, for example, evidence of anthropogenic disturbance, and evidence of regeneration.

Representative photographs were taken during field work to document the range of conditions encountered, including photos of each size class and health rating, as well as seed production, associated species, and anthropogenic disturbance.

Mixed Oak Woodland and Forest; and Pond. The VHP has much of the area mapped as Mixed Riparian Forest and Woodland. This predominantly includes Sycamore Alluvial Woodland, but may also include some annual grassland and valley oak woodland. It should be noted that CNDDB mapping calls the Pacheco study area SAW, but the VHP does not map the study area as Central California Sycamore Alluvial Woodland.

Associated Vegetation. The associated plant species present in each geomorphic zone polygon were characterized by assessing the entire polygon and recording the 5 most common species in descending order of abundance. Species were described by a 4 letter code of its scientific name to species level. Bare ground or leaf litter were included if dominant. Examples: polygon 1: BRDI (*Bromus diandrus*), STMI (*Stipa miliacea*), BRNI (*Brassica nigra*), BASA (*Baccharis salicifolia*), PLRA (*Platanus racemosa*).

Evidence of recent flows. While observing each polygon, the field team recorded evidence of recent flow events, such as debris hanging in trees (high water marks), wrack lines on the ground, evidence of scour in channels, and presence of well-sorted bed forms. "None" was also used, if no evidence of flows was found.

Channel bed forms. In the channel polygons only (inner channel corridor, gravel bar, secondary channel, historical side channel, tributary channel), the field team characterized dominant bed forms. For example, the presence of pool/riffle sequence, general braiding, or simplified glides.

Anthropogenic disturbance. Field teams noted evidence of grazing, fire, trails, excavation or ground disturbance, etc.

Photo documentation. Photos were taken within the GIS pro app of the dominant substrate, channel bed forms, evidence of scour, habitat type, and dominant vegetation.

Individual Tree Assessment

Each individual California sycamore tree at the study sites was assessed with regard to its landscape position, size class, health, and reproductive status of each tree. HTH staff Will Spangler and Kaitlin Schott, SFEI staff Amy Richey, and ICF staff Torrey Edell conducted individual tree field work on October 5 and 6, 2015. The parameters that were assessed for each tree are described below.

Tree ID. Each tree was mapped using GPS and assigned a numeric tree ID code.

Live/Dead. Data were collected for each live and dead tree.

Tree Location. The geomorphic zone of each tree was described in accordance with the mapping by SFEI. This was initially assigned in the field based on preliminary mapping and updated per final geomorphic zone mapping.

Size Class. A size class was assigned to each tree based on a visual assessment of stem size and height. Each tree was assigned a Seedling/Sucker, Sapling, Medium, or Large size class. Seedling/Sucker was used to describe the smallest California sycamore life-form and capture vegetative or sexual regeneration to the extent feasible, It was not always possible to definitively determine if a seedling/sucker was the result of vegetative or sexual regeneration.

Number of Stems. Each tree was defined as having a single or multiple stems because California sycamore trees are known to stump sprout and spread vegetatively. Professional judgment was used to determine when a tree ID was an individual tree with multiple stems/suckers or multiple individual trees in close proximity. When stems were not clearly connected at or just below the soil surface, it was assumed that separate stems were individual trees.

Stump/Root Sprouting. The presence or absence of stump or root sprouting at or near the base of each tree was noted and recent stump or root sprouting was recorded as a tree with multiple stems.

Health Index. A health index rating was applied to each live tree based on a visual assessment of its foliage and structure. Foliage was assessed by visual observation of the amount of healthy material, leaf color, leaf structure, browse damage, and evidence of anthracnose defoliation or other pathogens. Structure was assessed based on the overall form of the tree, density of crown, die-back of stems and branches, fire scars, and the presence of epicormic branching. The rating system is further described in Table 2. The foliage and structure ratings were summed for a combined health index score for each tree. The lowest possible health index score is 2; the highest possible score is 6. Dead trees were not assigned a health index rating.

Table 2. Health Index Rating System

Foliage Characteristics	Structure Characteristics
3: 66%–100% healthy foliage	**3:** Large and dense canopy, many live branches, minimal branch or twig die-back.
2: 33%–66% healthy foliage	**2:** Moderately large and dense canopy with moderate branch or twig die-back
1: 0–33% healthy foliage	**1:** Thin canopy, substantial branch and twig die-back, presence of epicormic branching

COLLECTING FIELD DATA WITH DATA TABLETS, PACHECO CREEK

COLLECTING GEOMORPHIC DATA, UPPER COYOTE CREEK

Seed Production. The presence and relative abundance of seed production was visually assessed for each tree. Because seed is required for sexual reproduction, the presence and relative abundance of seed will be used to assess the likelihood that there is reproductive material at the study site. Each tree was rated as having None, Some, or Substantial seed production. Trees with 'Some' seed production had few seed heads relative to the amount of healthy foliage and branches, and trees with 'Substantial' seed production had many seed heads relative to the amount of healthy foliage and branches.

Associated Species. The dominant plant species present around each tree were characterized by visually observing the area beneath and approximately five feet beyond the canopy of each tree and recording the five most common species in descending order of abundance. Species were described by a four letter code of their scientific name to species level. Bare ground or leaf litter were included if dominant.

The wetland indicator status of each species was obtained from the Arid West 2016 Regional Wetland Plant List (Lichvar et al. 2016). Wetland indicator species are designated according to their frequency of occurrence in wetlands. For instance, a species with a presumed frequency of occurrence of 67–99% in wetlands is designated a facultative wetland indicator species. Table 3 lists the wetland indicator groups, indicator symbol, and frequency of occurrence of species within wetlands.

Table 3. Wetland Indicator Categories

Indicator Category	Symbol	Frequency of Occurrence within Wetlands
Obligate	OBL	greater than 99%
Facultative Wetland	FACW	67–99%
Facultative	FAC	34–66%
Facultative Upland	FACU	1–33%
Upland	UPL	less than 1%

Source: *U.S. Corps of Engineers Wetlands Delineation Manual* (Environmental Laboratory 1987)

Obligate (OBL) and facultative wetland indicator (FACW) species are hydrophytes that occur "in areas where the frequency and duration of inundation or soil saturation produce permanently or periodically saturated soils of sufficient duration to exert a controlling influence on the plant species present" (Environmental Laboratory 1987). Facultative indicator species (FAC) may be considered wetland indicator species when found growing in hydric soils that experience periodic saturation. Plant species that are not on the regional list of wetland indicator species are upland species.

Substrates. The two most dominant substrates at each tree were characterized in accordance with the methods used to characterize the dominant substrate of each geomorphic zone polygon. Substrates included: cobbles, gravels, sand, silt, vegetated surface (grasses), and vegetated surface (woody vegetation).

Anthracnose Evaluations

On April 26, 2016, HTH assessed anthracnose infestations on sycamore trees at Upper Coyote Creek and Pacheco Creek. Anthracnose is a common pathogen with relatively obvious signs characterized by blight of leaves and shoots, cankers and die-back of twigs, deformation of branches and formation of trunk cavities (Sinclair et al. 1987). Such dead wood and cavities provide important foraging substrate and nesting sites for birds; however, severe damage by anthracnose may weaken trees and contribute to a lack of regeneration. Prior to the assessment, one third of the sycamore trees in each geomorphic zone were randomly selected across each site. Trees were then rated in the field based on the severity of symptoms presented in Table 4.

Anthracnose data were collected in April 2016 and analyzed with health and vigor and geomorphic zone data that were collected in October 2015.

Table 4. Sycamore Anthracnose Infestation Rating System

Code	Rating	Foliage Characteristics	Structure Characteristics
3	High	67%–100% of leaves show blight	Substantial twig die-back and/or cankers; overall structure of tree potentially compromised
2	Moderate	34%–66% of leaves show blight	Moderate twig die-back and/or cankers present
1	Low	1–33% of leaves show blight	Little or no twig die-back; cankers generally absent

EVIDENCE OF ANTHRACNOSE IN SYCAMORE LEAVES

Hydrologic conditions and tree ring analysis

Floods delivering sediment and water to floodplain surfaces where sycamores can establish are hypothesized to be critical for both sexual and clonal sycamore regeneration, particularly when flood timing coincides with the spring growing season (Gillies 1998). However, links between specific flood timing and frequencies and sycamore regeneration have not been extensively studied. If resetting flood events are an essential part of sycamore regeneration, we posit that sycamores should establish on surfaces affected by particular flood events, and thus the ages of trees in those locations should link to those events.

In an effort to understand the relationship of flood history and sycamore regeneration at the two sites in this study, we examined the hydrologic records at both study sites, and used minimal data collected in the field with a broad-brush numerical model developed by SFEI to estimate flood depths and extents for different return interval storm events over a typical cross section at each site. We then cored several trees at each site to attempt to observationally correlate large flood events to the location and age of sycamore stands.

If there is a relationship between flood frequency and sycamore regeneration, there may be opportunities to positively influence the management of SAW sites by modifying reservoir operations and managing the hydrograph to encourage sycamore regeneration.

Two key questions guided this pilot phase of the research:

(1) What are the estimated inundation depths and extents associated with different recurrence-interval discharges?

(2) How do specific historical flood events relate to the location of existing sycamore stands along the creek?

SFEI staff used an increment borer to core a total of nine trees between the two field sites on October 26, 2016. The trees chosen for coring met specific criteria, namely that they were part of an ongoing genetics study underway by HTH, were single-stemmed, and were in stratified geomorphic positions. After extracting the cores from the trees, they were stored in paper tubes while in the field. In the lab, tree cores were glued and sanded on wooden mounts, and then analyzed with a compound microscope. Tree rings were counted on each core to develop a best guess of the number of rings and associate an age with each tree.

In parallel, we assessed the local water flow gage data for both sites and calculated flood frequency curves, from which we could determine flood return intervals. In order to relate the flood discharges to stage height, and estimate wetted areas of particular floods of the past, we used the Riparian Zone Estimator Tool's Hydrologic Connectivity Module (RipZET) to construct a rating curve and calculate the average flow depth and width associated with 2-year, 10-year, and 50-year recurrence interval events. RipZET is an Excel-based tool that uses a modified form of Manning's equation ($u=(R^{2/3}S^{1/2})/n$, where u=velocity, R=hydraulic radius, S=slope, and n=roughness coefficient) to assess reach-scale inundation extent as a function of cross-sectional topography, slope, and boundary roughness (SFEI 2015).

Inputs to the model were a) a cross section derived from the 1-meter LiDAR digital elevation model, b) slope calculated from the 1-meter LiDAR digital elevation model, c) D50 (median pebble size) data collected at the site of the cross section in the field, d) roughness values (n) estimated from field observations. The model creates a stage-discharge relationship which can be plotted onto the cross section to estimate flood stage at different return intervals. We performed this analysis at one cross-section per site. While there are many assumptions and limitations to this approach, it serves as a first cut estimator to understand if floods are a critical driver for sycamore regeneration. Full discussion of the uncertainty in the RipZet model can be found here (www.sfei.org/content/ripzet-and-users-manual).

Finally, HTH staff visited the site during and immediately following large storm events during the 2016 water year to document flooding and field-verify hydrological conditions.

DATA ANALYSIS

SFEI and HTH used descriptive statistics to summarize the data, draw inferences, and reveal patterns in the landscape to understand the distribution, health, and regeneration patterns of the sycamores observed. Means and standard error were calculated using Microsoft Excel. The data were organized to address questions related to: 1) sycamore distributions (tree size and geomorphic position), 2) health and survivorship, 3) regeneration patterns across sites. Additional analysis explored the relationship between flood stage and tree age, as well as distribution of anthracnose infestations.

CORING SYCAMORE TREES, PACHECO CREEK

3 • RESULTS

In this section, we discuss the results of the study by examining three key questions related to the overall study goal of identifying site characteristics most favorable to health and reproduction of SAW. We examined: 1) How sycamores are distributed across the two sites, 2) What is the status of the existing SAW stands, and 3) What are the patterns of SAW regeneration at the two sites. We also present the results of the tree coring and hydrologic analysis of the two sites.

WOODLAND IN FOG, UPPER COYOTE CREEK

Distribution of Sycamores by Size at Upper Coyote Creek

A total of 310 live sycamores were counted at Upper Coyote Creek. These included one seedling/sucker, one sapling, 132 medium, and 176 large trees (Figure 3). Trees were most concentrated on the historical side channel and the inner channel corridor. The greatest density of large trees was along the inner channel corridor, while the greatest density of medium trees was concentrated along the historical side channel (Figure 4). There was only one seedling/sucker and one sapling in the whole study area.

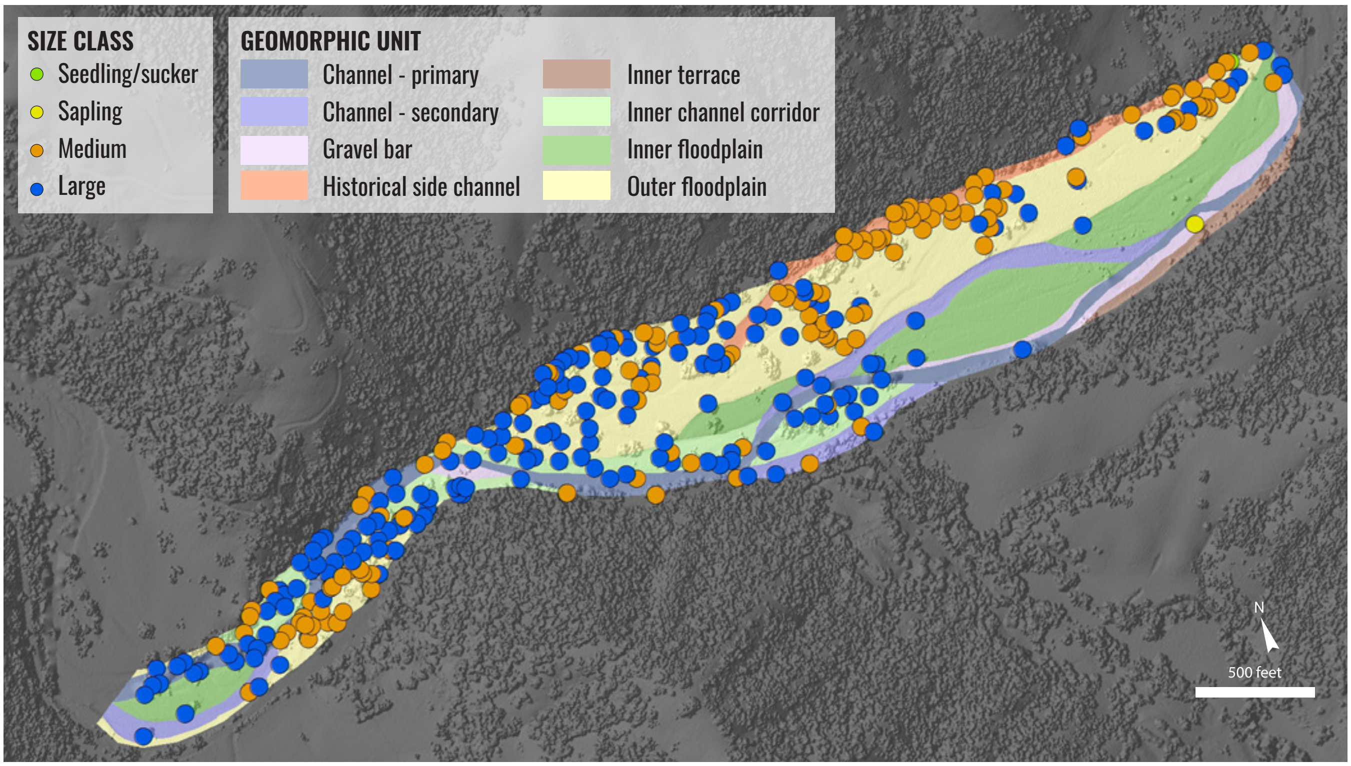
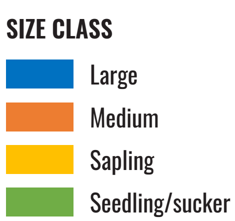


Figure 3. Map of distribution of sycamores by geomorphic zone and size class, Upper Coyote Creek.



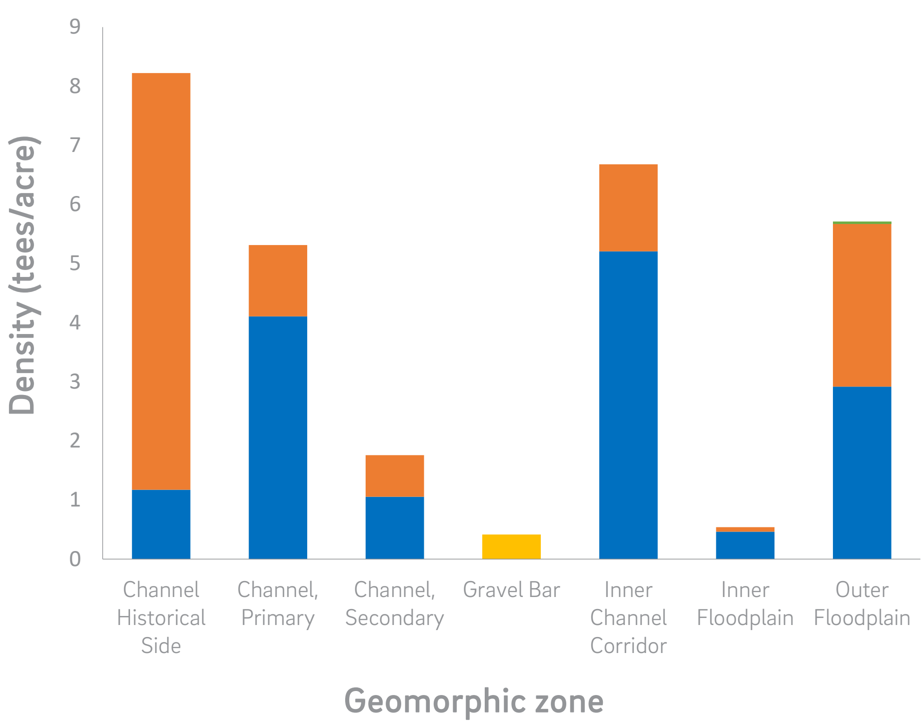


Figure 4. Density of live sycamores by geomorphic zone and size class at Upper Coyote Creek.

Distribution of Sycamores by Size at Pacheco Creek

A total of 147 live sycamores were counted at Pacheco Creek. These included 19 seedling/sucker, 38 sapling, 75 medium, and 15 large trees (Figure 5). Trees in general were most concentrated on the primary channel and inner channel corridor. The greatest density of large trees was along the inner channel corridor and/or associated with the main tributary Harper's Creek, while the greatest density of medium trees was concentrated along the primary channel (Figure 6). Seedlings/suckers were concentrated along the primary channel and the inner channel corridor.

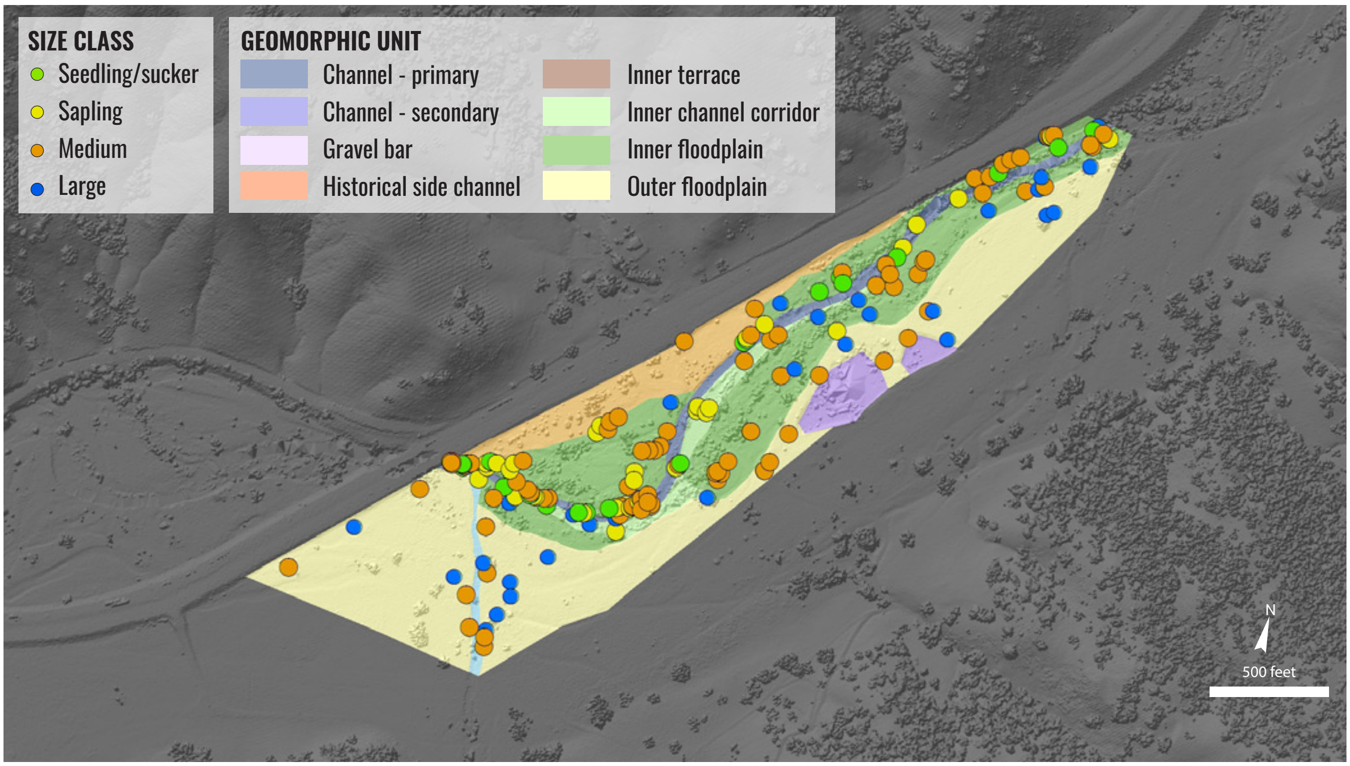


Figure 5. Map of distribution of sycamores by geomorphic zone and size class, Pacheco Creek.

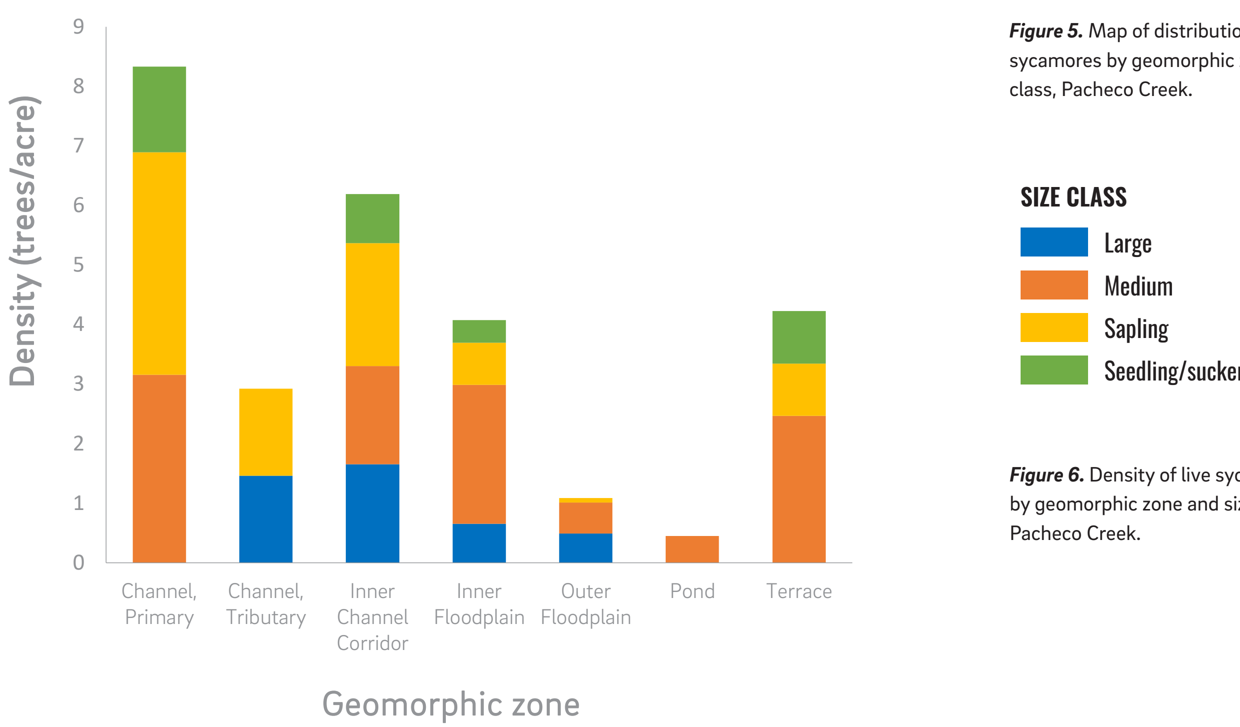


Figure 6. Density of live sycamores by geomorphic zone and size class at Pacheco Creek.

Distribution by Distance to Channel at Upper Coyote Creek

We hypothesized that larger trees would be farther from the channel and smaller trees would be closer to the channel, as this might correlate to extents of inundation. However, at Upper Coyote Creek there is no obvious, consistent pattern (Figure 7). This may be due to the changing location of the primary channel over time. As shown, medium trees are located furthest from the primary channel, while older trees on average are located an intermediate distance. Note the seedling/sucker and sapling input values are n=1 for these two size classes.

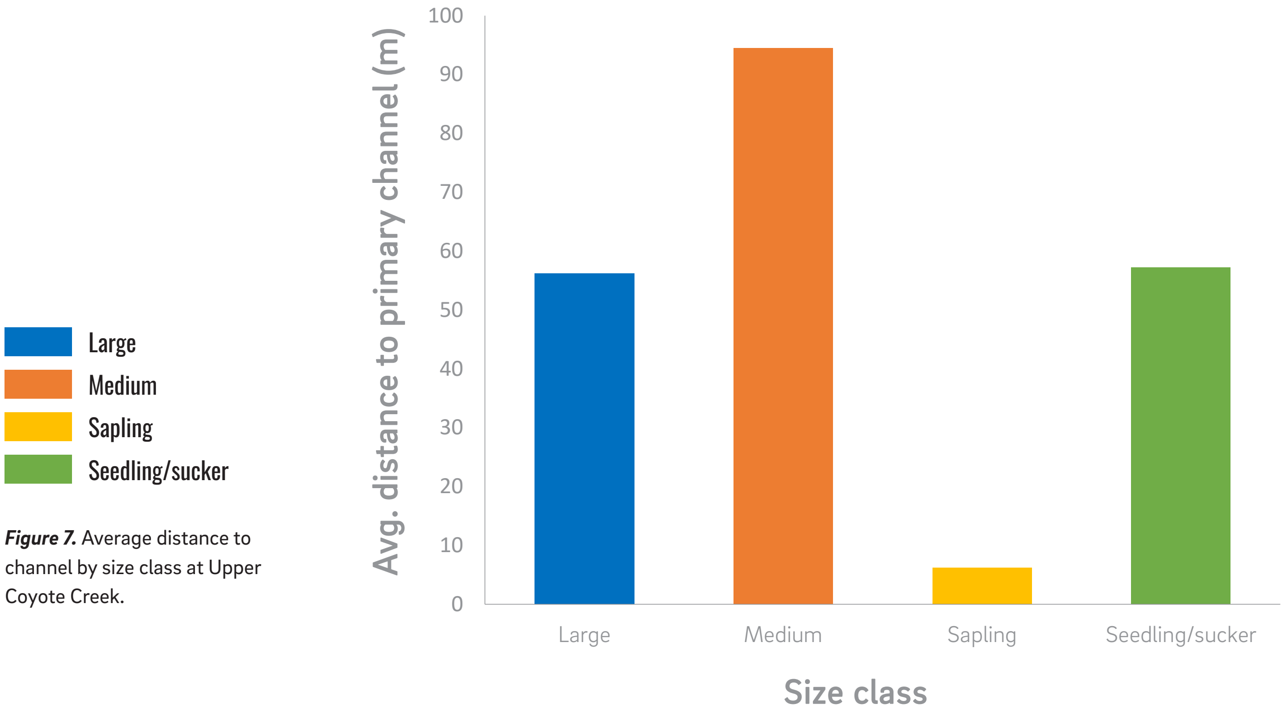


Figure 7. Average distance to channel by size class at Upper Coyote Creek.

SYCAMORE LEAF IN FALL, PACHECO CREEK

Distribution by Distance to Channel at Pacheco Creek

As hypothesized, tree size consistently increases with distance to the primary channel at Pacheco Creek. In other words, older growth is located further from the current channel, on average and newer growth is on average closer to the primary channel (Figure 8). At Pacheco Creek there were 38 suckers, and 19 seedling/saplings recorded.

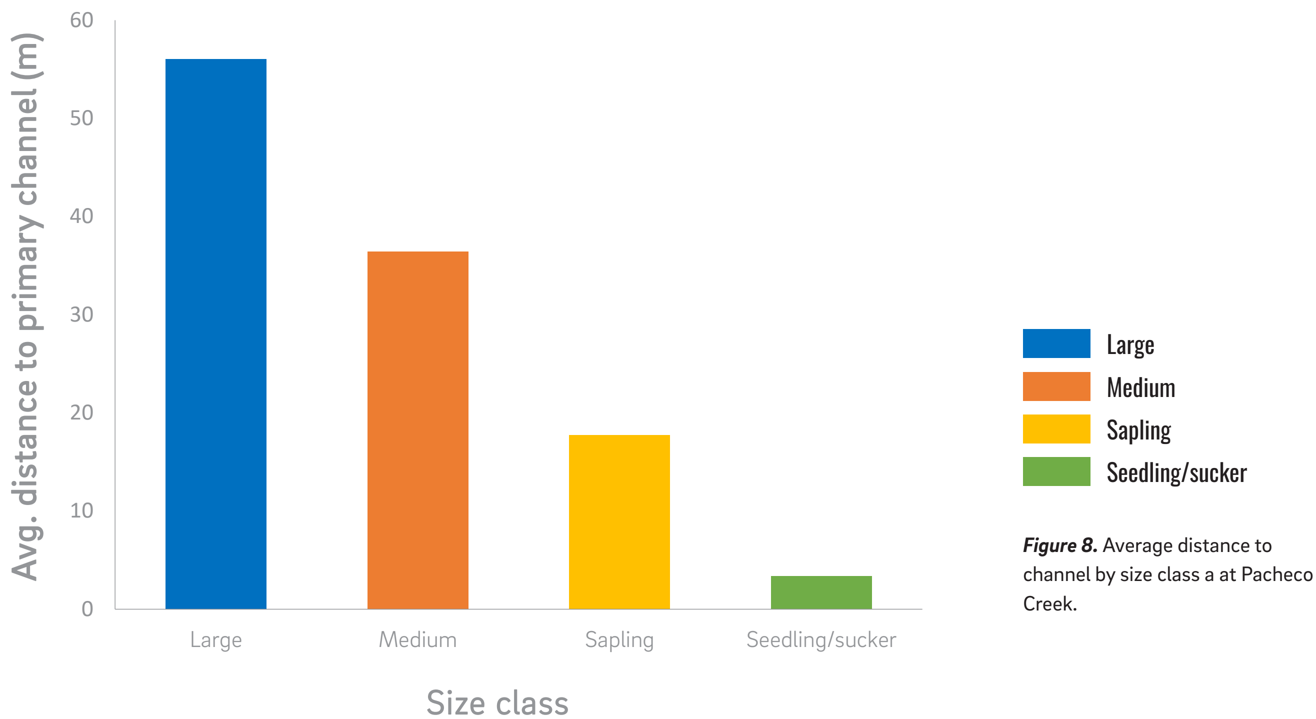


Figure 8. Average distance to channel by size class a at Pacheco Creek.

SYCAMORES AT PACHECO CREEK

SYCAMORE HEALTH PATTERNS ACROSS SITES

Evaluating general tree health can provide valuable information on overall species fitness in an area and provide a possible link to the ability of the species to successfully reproduce and sustain a viable population. There are many factors that may influence tree health, including physical damage from flood flows, insufficient groundwater levels, competition with riparian vegetation, grazing by cattle or wildlife, pests and pathogens, and anthropomorphic disturbance. This study used a combined health and vigor rating based on foliage and structure and incidence of anthracnose as general indicators of overall tree health.

POOLS AND SYCAMORES, UPPER COYOTE CREEK

MULTISTEM TREE WITH WOODPECKER GRANARY, UPPER COYOTE CREEK

ACORN WOODPECKER, UPPER COYOTE CREEK

TREE WITH SNAG, UPPER COYOTE CREEK

SYCAMORE SEEDLING, PACHECO CREEK

Health Index Score by Geomorphic Zone at Upper Coyote Creek

At Upper Coyote Creek, trees are on average relatively healthy throughout the study site (Figure 9). There is no consistent, obvious gradient of tree health across geomorphic zones.

Both the highest densities and proportions of unhealthy trees are located on the historic side channel and inner channel corridor (Figure 10). Healthy trees as a proportion are somewhat evenly distributed across the site. Survivorship is remarkably high (above 98%) across size classes. Out of 304 trees, just three medium trees and one large tree was classified as dead. Survivorship was relatively consistent across geomorphic zones, with just n=4 total dead sycamores spread out in the historical side channel, primary channel and outer floodplain.

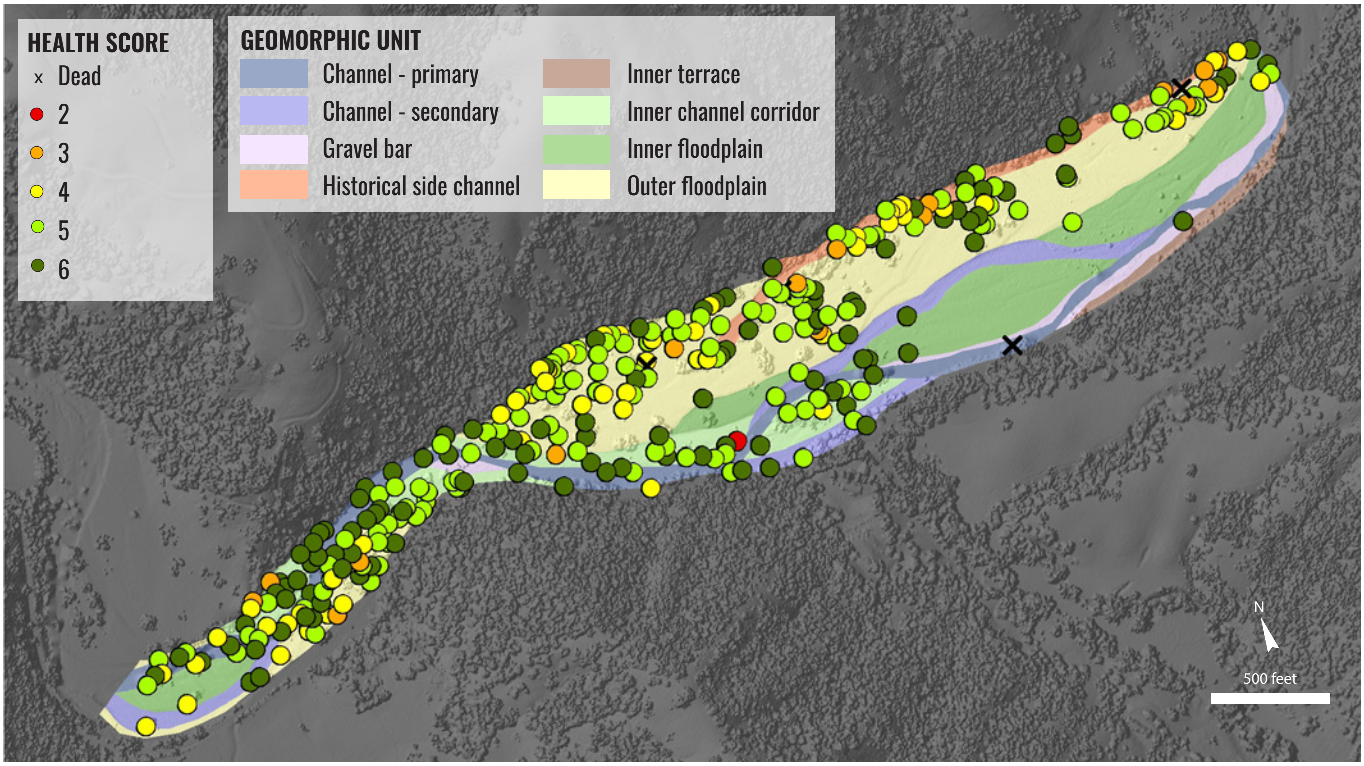


Figure 9. Distribution of trees by health index score at Upper Coyote Creek.

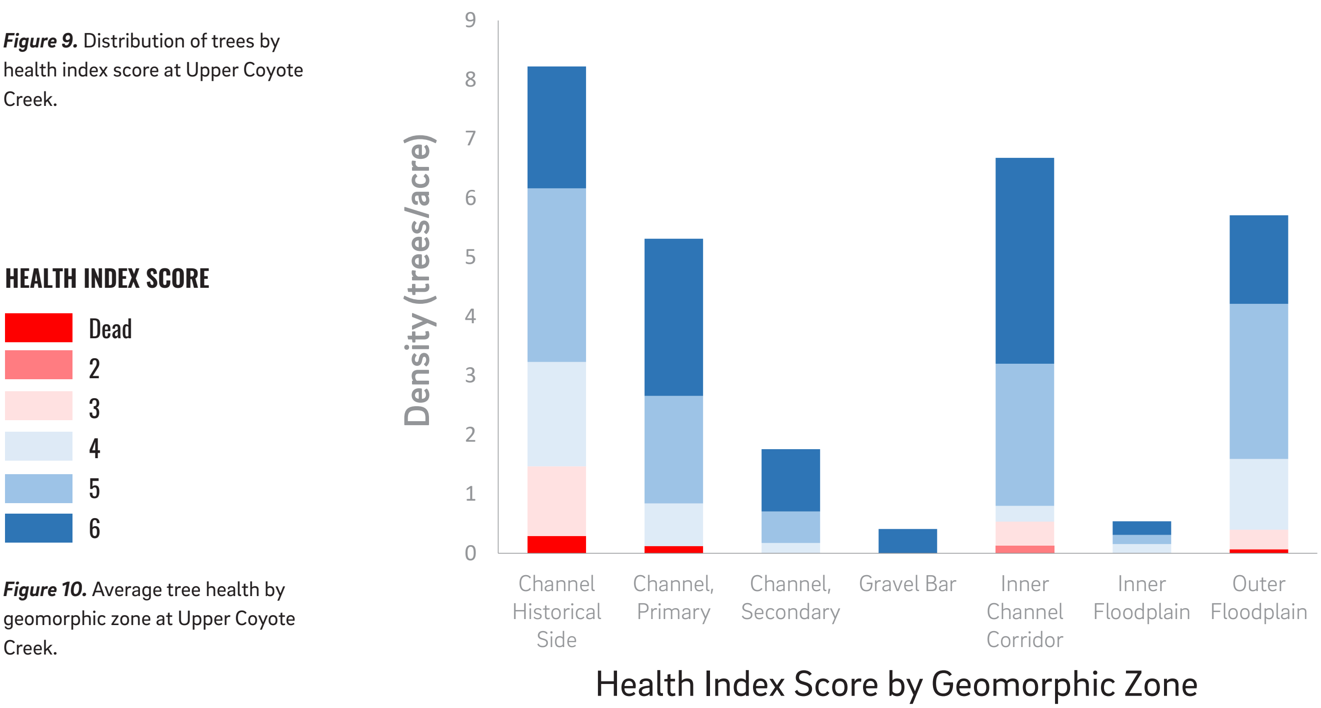


Figure 10. Average tree health by geomorphic zone at Upper Coyote Creek.

Health Index Score by Geomorphic Zone at Pacheco Creek

At Pacheco Creek, there is no consistent gradient of tree health across geomorphic zones (Figure 11). The highest proportions of healthy trees were found in the primary channel, inner channel corridor and terrace. The highest number of dead trees were found on the outer floodplain and tributary channel (Figure 12). Close to 50% of large trees and around 15% of medium trees were classified as dead.

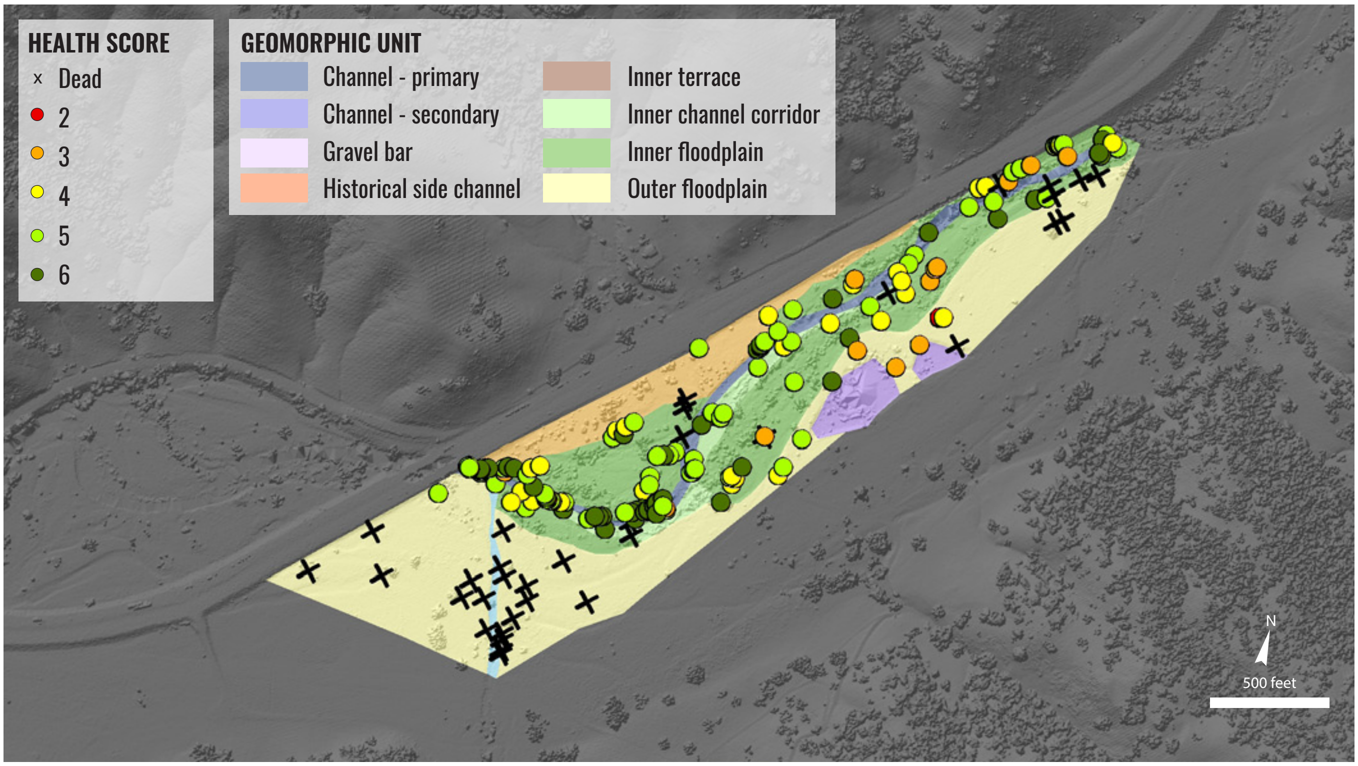


Figure 11. Distribution of trees by health index score at Pacheco Creek.

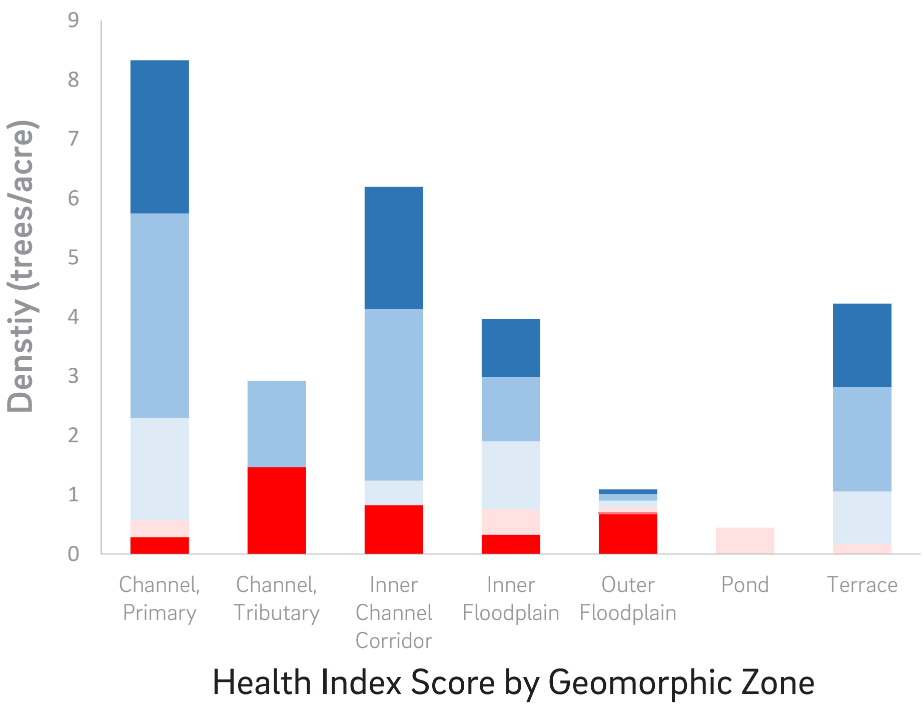


Figure 12. Average tree health by geomorphic zone at Pacheco Creek.

Health Index Score by Distance to Channel at Upper Coyote Creek

At Upper Coyote Creek, live trees were on average closer to the primary channel (~70 m), while dead trees were on average >90 m from the active channel (Figure 13). The healthier trees are generally located closer to the channel. However, one should consider the small sample size for very unhealthy trees (N=1 for health score of "2").

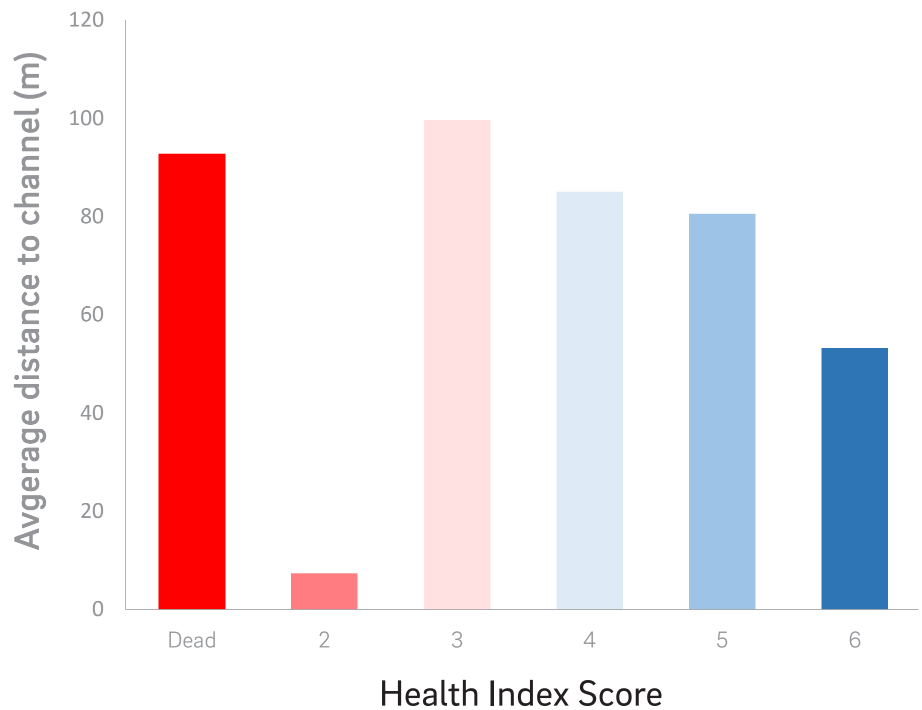


Figure 13. Relationship between health and distance to primary channel at Upper Coyote Creek.

BASE OF SYCAMORE, UPPER COYOTE CREEK

Health Index Score by Distance to Channel at Pacheco Creek

At Pacheco Creek, healthier trees were generally located closer to the channel (Figure 14). On average, dead trees were more than 90 m from the active channel, and live trees average 20 m from the active channel. Department of Fish and Wildlife staff have observed die-back of large sycamore trees at Pacheco Creek in the last several years, cause unknown (Dave Johnston, Pers. Comm.).

CLONAL REGENERATION, PACHECO CREEK

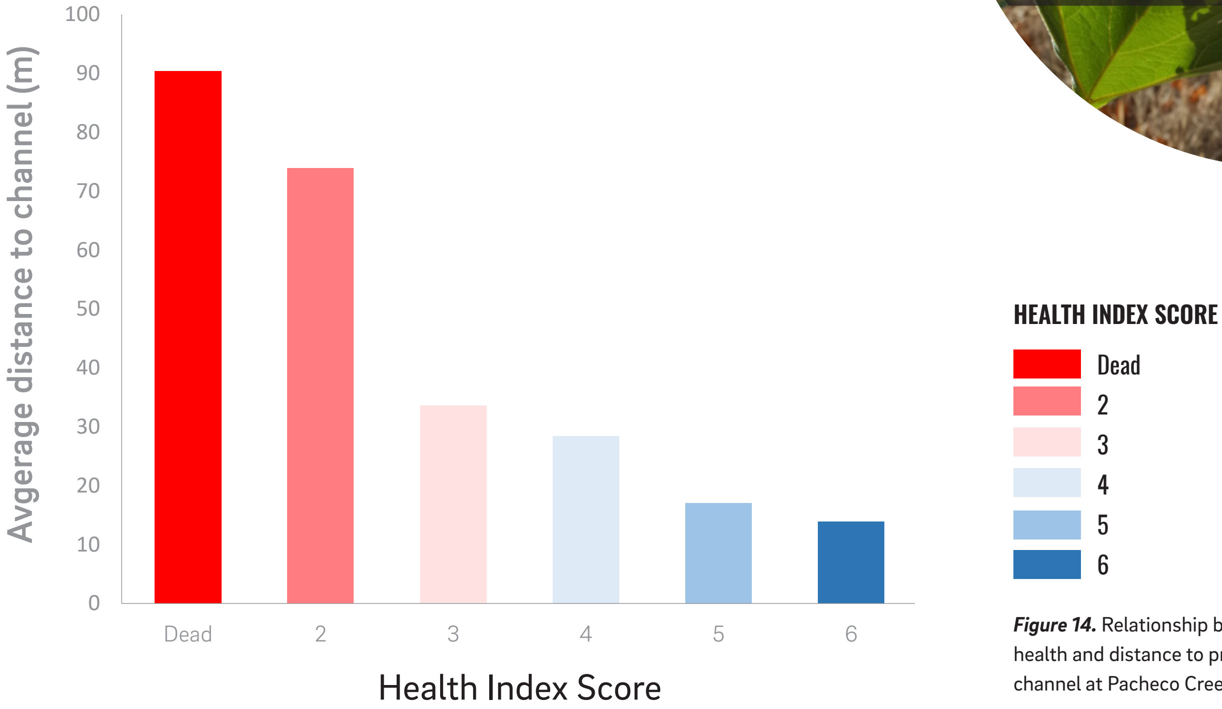


Figure 14. Relationship between health and distance to primary channel at Pacheco Creek.

BURNED SYCAMORE WITH HOLLOWED-OUT TRUNK, PACHECO CREEK

Anthracnose Incidence at Upper Coyote Creek

A total of 108 trees were surveyed for anthracnose at Upper Coyote Creek. Most of the trees exhibited high foliage infestations and substantial twig die-back and/or cankers (Figure 15).

The average health and vigor of trees was medium-high and did not vary substantially by anthracnose infestation severity (Figure 16).

Anthracnose infestation severity was high across all geomorphic zones, except for one sucker/sapling on a gravel bar that exhibited minimal foliage infestation and no twig die-back.

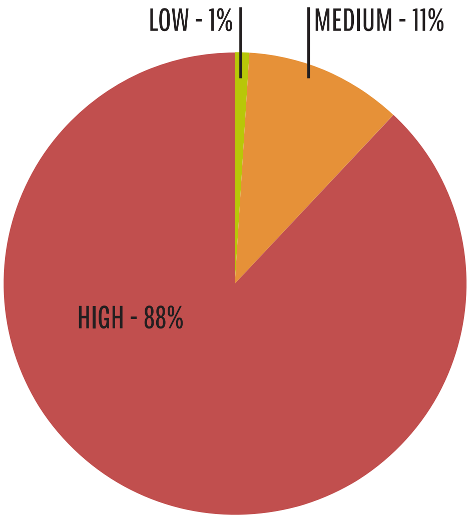


Figure 15. Mean Health and Vigor of Sycamore Trees by Anthracnose Infestation Severity Category at Upper Coyote Creek.

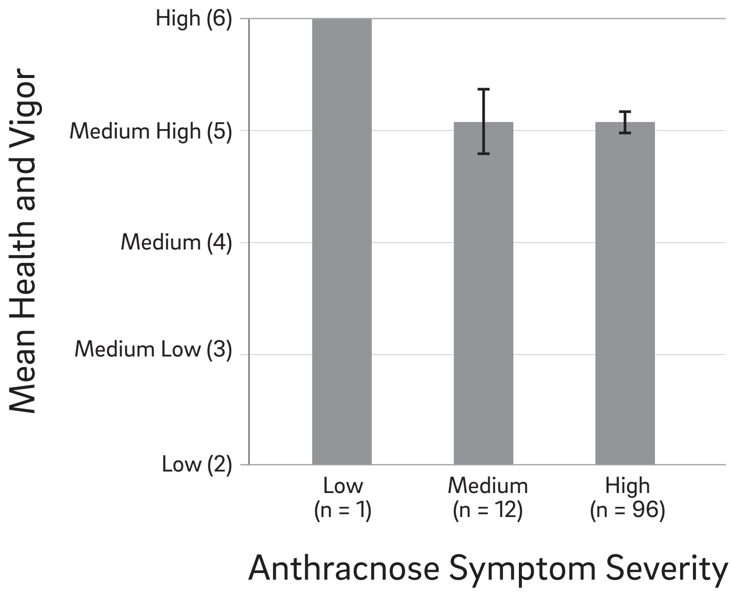
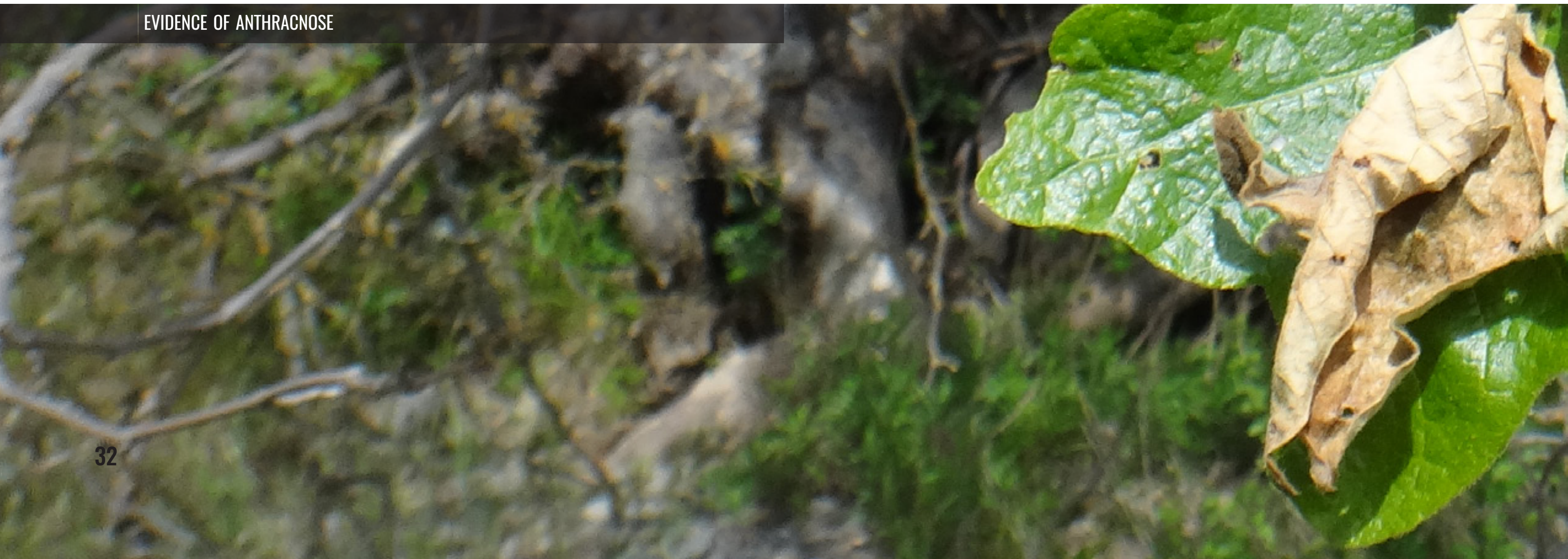


Figure 16. Mean Health and Vigor of Sycamore Trees by Anthracnose Infestation Severity Category at Upper Coyote Creek.



EVIDENCE OF ANTHRACNOSE

Anthracnose Incidence at Pacheco Creek

A total of 55 trees were surveyed at Pacheco Creek. Most of the trees exhibited low foliage infestations and little or no twig die-back (Figure 17).

The average health and vigor of trees with low anthracnose infestation severity was medium-high. The average health and vigor of trees with medium and high anthracnose infestations was medium (Figure 18). In other words, anthracnose infestation and health and vigor ratings appeared to be correlated at Pacheco, though this pattern is not strongly apparent at Coyote. Additionally, other factors such as geomorphic position are also correlated with health and vigor ratings.

Anthracnose infestation severity was low in the primary channel, tributary channel, inner channel corridor, and terrace. Anthracnose infestation severity was moderate on the inner floodplain. One tree exhibited high anthracnose infestation severity near the pond.

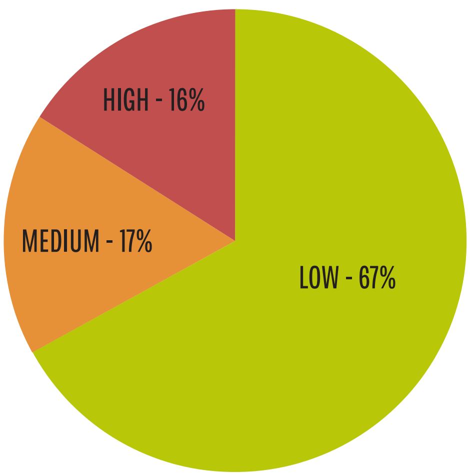


Figure 17. Percentage of Low, Medium, and High Anthracnose Infested Trees at Pacheco Creek.

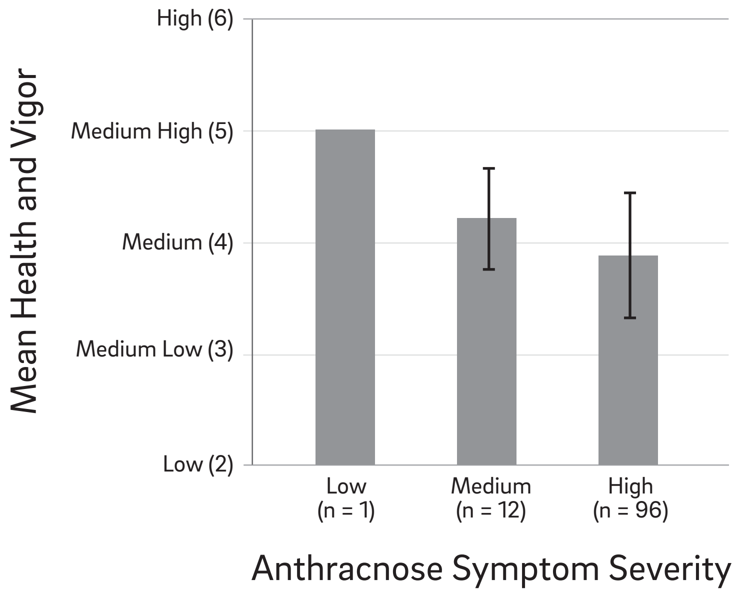


Figure 18. Mean Health and Vigor of Sycamore Trees by Anthracnose Infestation Severity Category at Pacheco Creek.

SYCAMORE REGENERATION PATTERNS ACROSS SITES

Regeneration of sycamores is generally associated with a combination of a gravel or cobble substrate (preferably recently disturbed), adequate moisture at appropriate time intervals, and adequate light. Regeneration may be limited by factors including competition from riparian vegetation, lack of freshly deposited bars and floodplains, insufficient groundwater levels, grazing from cattle or other wildlife, diseases such as anthracnose, heart rot, and climatic conditions wherein seed production and flooding do not align.

Regeneration Patterns of Sycamores at Upper Coyote Creek

Only one seedling/sucker and one sapling was found at Upper Coyote Creek, indicating that regeneration at the time of the field study was very low. Figure 19 shows the regeneration strategy observed by percentage of trees in each geomorphic zone. Some trees were sprouting, some producing seeds, some both, and some exhibited neither indicator of regeneration at the time of the field work.

Root sprouting (light green and dark green) was concentrated in the highest proportions in the inner channel corridor and the primary channel among large and medium trees. Seed production of live trees is proportionately most prolific in the inner floodplain and historical side channel. Seeds are produced almost exclusively on medium or large trees. All of the trees documented on gravel bars and in the inner channel floodplains were reproducing in some form.

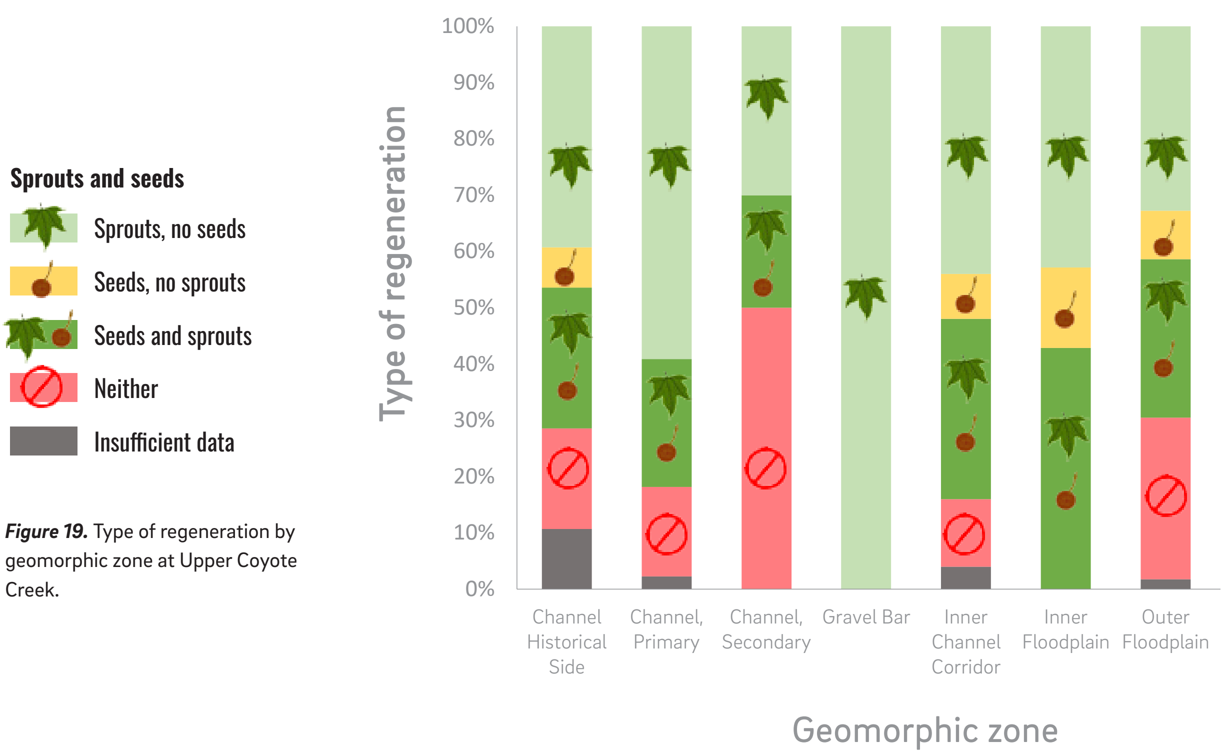


Figure 19. Type of regeneration by geomorphic zone at Upper Coyote Creek.

Regeneration Patterns of Sycamores at Pacheco Creek

Root sprouting was concentrated in the highest proportions in the inner channel corridor and inner floodplain. Seed production of live trees was proportionately most prolific in the inner floodplain and inner channel corridor. Seeds were produced almost exclusively on large or medium trees. Almost 40% of the trees on the primary channel, and 50% on the terrace, were not producing seeds or sprouts. Figure 20 shows the relative proportions of trees using different reproduction strategies.

SYCAMORES RESPROUTING AT UPPER COYOTE CREEK

At Pacheco Creek, 19 seedling/suckers and 38 saplings were found. Regeneration was highest in the primary channel and inner channel corridor, while more recent seedlings were also concentrated along the terrace. Cobble was a dominant substrate for younger trees across habitat types, with grassy and woody surfaces also utilized. Regeneration followed a trend of increased growth the closer a tree is to the primary channel (Figure 21).

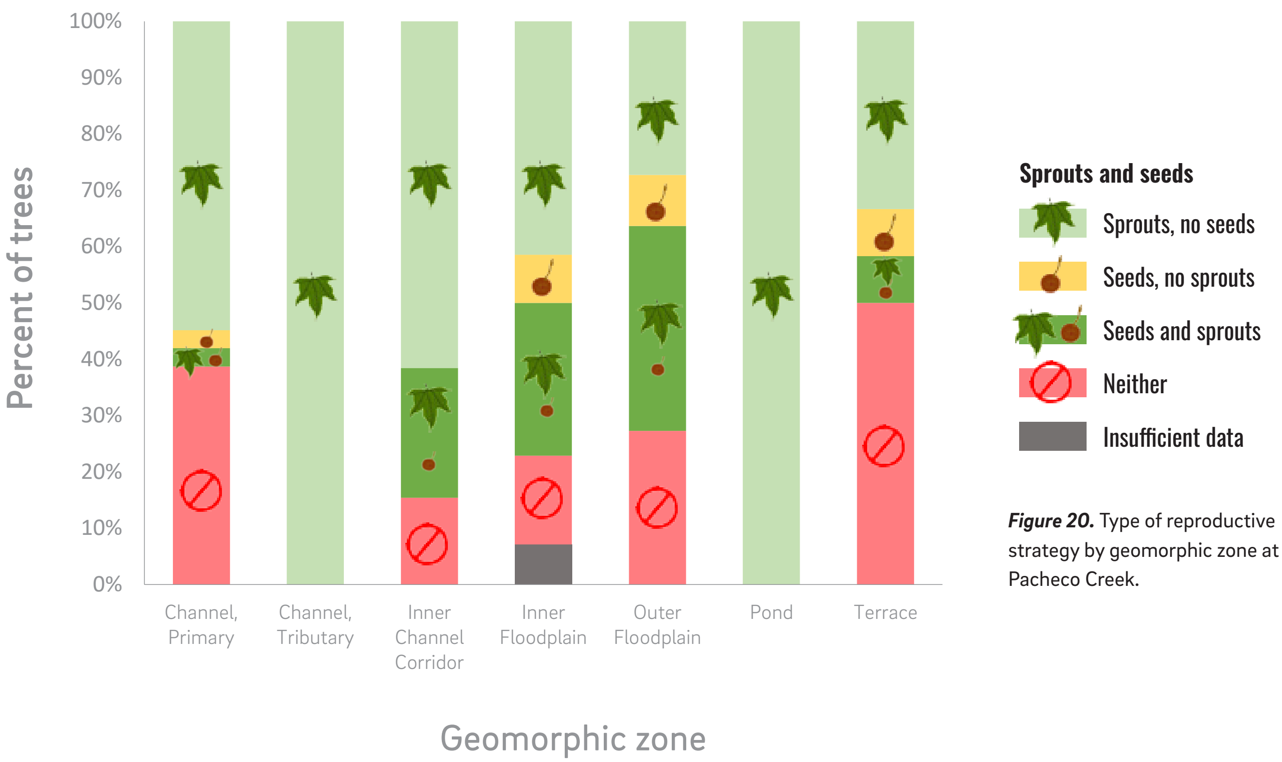


Figure 20. Type of reproductive strategy by geomorphic zone at Pacheco Creek.

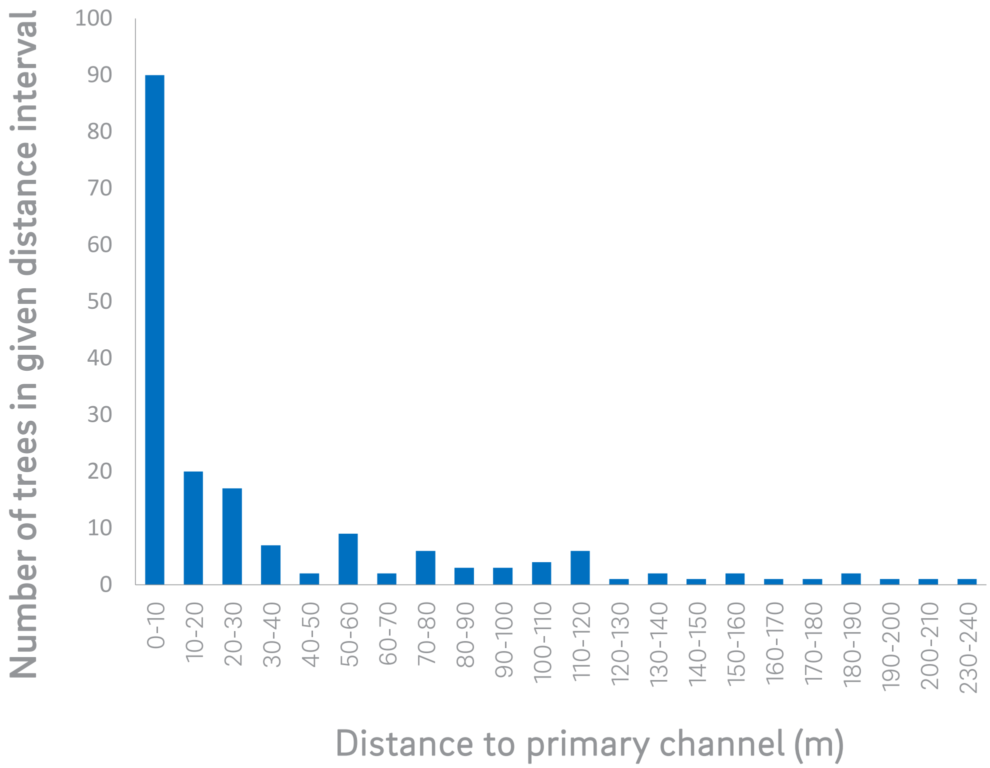


Figure 21. Regeneration of seedling/sucker & sapling by distance to channel at Pacheco Creek.

Regeneration Patterns: Species associations at Upper Coyote Creek

The species associated with regenerating sycamore trees (seedlings/suckers and saplings) at Upper Coyote Creek are described in Table 5. Most of these species occur widely in the region and are notably drought-tolerant. Only two species with a wetland indicator status of 'Facultative' or wetter were observed to be associated with regenerating sycamore trees. The percent of sycamore seedlings/suckers and saplings listed in Table 5 does not necessarily indicate actual associations between plant species and regenerating sycamores because the small sample size of two seedling/sucker sycamore trees has very low statistical power. Nonetheless, the list of species does give some indication of which dominant species are present around each of the two seedling/sucker trees at Upper Coyote Creek.

Table 5. Most Common Plant Species Associated with Regenerating Sycamore Trees (Seedlings/Suckers and Saplings) at Upper Coyote Creek

Scientific Name	Common Name	Origin	Growth Form	Wetland Indicator Status	Percent of Sycamore Seedlings/suckers and Saplings (n = 2) (%)
Avena fatua	Wild oats	Nonnative	Grass	UPL	50.0
Bromus diandrus	Ripgut brome	Nonnative	Grass	UPL	100.0
Baccharis pilularis	Coyote brush	Native	Shrub	UPL	50.0
Baccharis salicifolia	Mulefat	Native	Shrub	FAC	50.0
Brassica nigra	Black mustard	Nonnative	Herb	UPL	50.0
Juncus patens	Spreading rush	Native	Herb	FACW	50.0
Toxicodendron diversilobum	Poison oak	Native	Shrub	FACU	50.0

Regeneration Patterns: Species associations at Pacheco Creek

The species associated with the 58 regenerating sycamore trees (seedlings/suckers and saplings) at Pacheco Creek are described in Table 6. Many of these species had a wetland indicator status of facultative or wetter, which may indicate that regeneration of sycamore trees occurred in locations with wetland hydrology.

Table 6. Most Common Plant Species Associated with Regenerating Sycamore Trees (Seedlings/Suckers and Saplings) at Pacheco Creek

Scientific Name	Common Name	Origin	Growth Form	Wetland Indicator Status	Percent of Sycamore Seedlings/suckers and Saplings (n = 58) (%)
Baccharis pilularis	Coyote brush	Native	Shrub	UPL	19.0
Brickellia californica	Brickel bush	Native	Herb	FACU	6.9
Juncus mexicanus	Mexican rush	Native	Herb	FACW	22.4
Juncus xiphioides	Iris leaved rush	Native	Herb	OBL	10.3
Persicaria amphibia	Water smartweed	Native	Herb	OBL	6.9
Rumex salicifolia	Willow dock	Native	Herb	FACW	34.5
Salix lasiolepis	Arroyo willow	Native	Shrub	FACW	6.9
Sambucus nigra spp. *caerulea*	Blue elderberry	Native	Shrub	FAC	15.5
Solanum sp.	Nightshade	Unknown	Unknown	Unknown	8.6
Toxicodendron diversilobum	Poison oak	Native	Shrub	FACU	44.8

Regeneration Patterns: Substrate type by size class at Upper Coyote Creek

Approximately 62.1% of the sycamores were located on vegetated substrate dominated by grasses, including one seedling/sucker, 90 medium trees, and 89 large trees (Table 7). Nineteen percent of the sycamores were located on cobbles, including one sapling, 14 medium trees, and 40 large trees. Approximately 13.4% of the sycamores were located on vegetated substrate dominated by woody vegetation, including 14 medium trees and 25 large trees. The remaining 5.5% of the sycamores were located on gravels, bare soil, or other substrates.

Table 7. Percentage and Number of Sycamores within Substrate Type by Size Class at Upper Coyote Creek

	Percentage and Number (n) of Live Sycamores by Size Class				
Substrate	Seedling/sucker	Sapling	Medium	Large	Total
Cobbles	0.0 (0)	1.8 (1)	25.5 (14)	72.7 (40)	19.0 (55)
Gravels	0.0 (0)	0.0 (0)	14.3 (1)	85.7 (6)	2.4 (7)
Soil	0.0 (0)	0.0 (0)	100.0 (3)	0.0 (0)	2.1 (6)
Vegetated Surface (grasses)	0.6 (1)	0.0 (0)	50.0 (90)	49.4 (89)	1.0 (3)
Vegetated Surface (woody)	0.0 (0)	0.0 (0)	35.9 (14)	64.1 (25)	62.1 (180)
Other	0.0 (0)	0.0 (0)	33.3 (2)	66.7 (4)	13.4 (39)

Regeneration Patterns: Substrate type by size class at Pacheco Creek

At Pacheco Creek, approximately 39.2% of the sycamores were located on vegetated substrate dominated by grasses, including two seedling/sucker, 10 saplings, 36 medium trees, and eight large trees (Table 8). Twenty-eight percent of the sycamores were located on cobbles, including nine seedlings/suckers, 17 saplings, 11 medium trees, and three large trees. Approximately 16.1% of the sycamores were located on vegetated substrate dominated by woody vegetation, including three seedlings/suckers, nine saplings, nine medium trees and two large trees. The remaining 16.8% of the sycamores were located on gravels, bare soil, or other substrates.

Table 8. Percentage and Number of Sycamores within each Substrate Type by Size Class at Pacheco Creek

	Percentage and Number (n) of Live Sycamores by Size Class				
Substrate	Seedling/sucker	Sapling	Medium	Large	Total
Cobbles	22.5 (9)	42.5 (17)	27.5 (11)	7.5 (3)	28.0 (40)
Gravels	0.0 (0)	0.0 (0)	100.0 (4)	0.0 (0)	2.8 (4)
Soil	30.0 (3)	0.0 (0)	50.0 (5)	20.0 (2)	7.0 (10)
Vegetated Surface (grasses)	3.6 (2)	17.9 (10)	64.3 (36)	14.3 (8)	39.2 (56)
Vegetated Surface (woody)	13.0 (3)	39.1 (9)	39.1 (9)	8.7 (2)	16.1 (23)
Other	20.0 (2)	0.0 (0)	80.0 (8)	0.0 (0)	7.0 (10)

RESULTS OF HYDROLOGIC ASSESSMENT AND TREE CORING

Floods that carry seeds, deliver sediment, and inundate floodplains may play a key role in sycamore regeneration. Over the past 180 years, changes to flow and sediment dynamics from dams and the removal of floodplains from the influence of regular flooding have greatly impacted the distribution and regeneration of sycamore-alluvial woodlands (Keeler-Wolf et al. 1996). Specific flood timing and frequencies links to sycamore regeneration are currently not well understood.

In order to improve management approaches that support SAW, we need to understand the specific flood requirements for large-scale regeneration. This understanding can help identify opportunities to improve regeneration of SAW sites through modifications to reservoir operations and flow hydrographs.

In an effort to understand the relationship of flood history and sycamore regeneration at the two sites in this study, we used hydrologic records and geomorphic information at both study sites with a simple hydraulic model to estimate flood depths and extents for several flood events. We then cored several trees at each site to correlate large flood event magnitude with sycamore regeneration (for a full discussion of methods, see pages 20-21).

Two primary questions guided this phase of the research:

(1) What are the estimated inundation depths and extents associated with different recurrence-interval discharges?

(2) How do specific historical flood events relate to the location of existing sycamore stands along the creek?

Hydrologic/Hydraulic Results

We calculated flood frequency curves using gage data from Coyote Creek near Gilroy (USGS gage 11169800), which is 1.5 km downstream of the study site, and Pacheco Creek near Dunneville (USGS gage 11153000), which is 6 km downstream of the Pacheco Creek study site (Tables 9 and 10). Using the calculated flood frequency curves and the hydraulic model on one cross section per site, we estimated the inundation height for a range of return intervals at both sites.

Table 9. Flood frequency analysis for Upper Coyote Creek

Return Period (year)	Estimated Discharge (cfs)
1.5	1800
2	3200
5	7200
10	9800
50	15000
100	16000

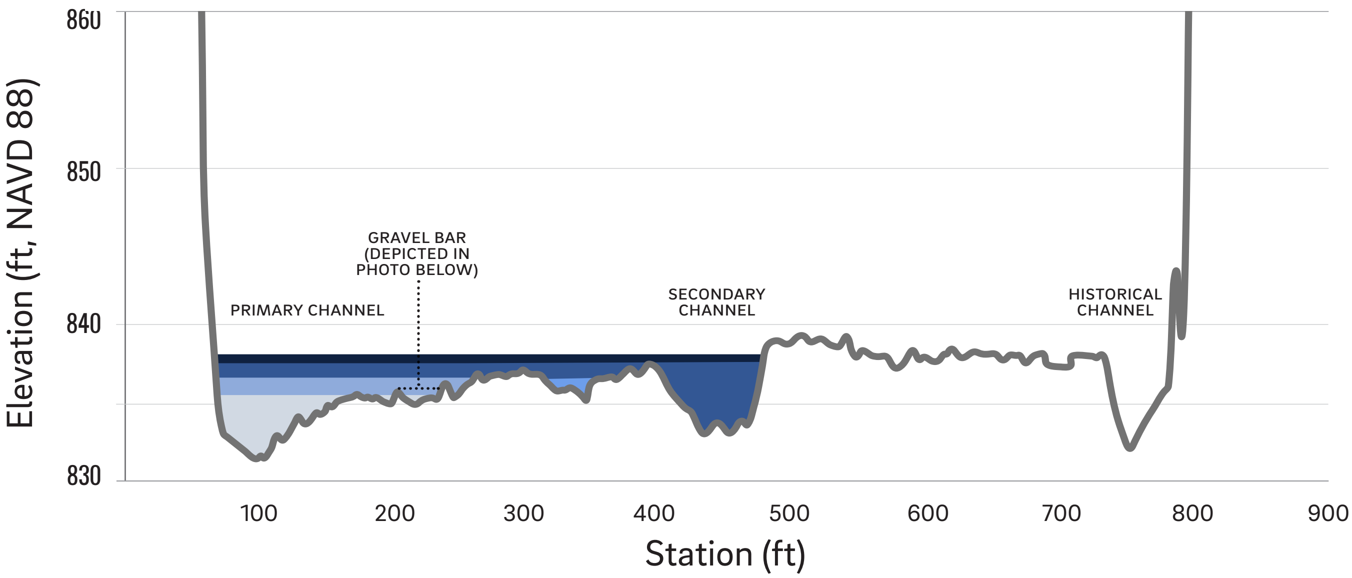
Table 10. Flood frequency analysis for Pacheco Creek

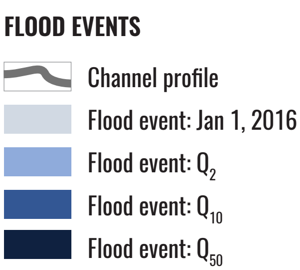
Return Period (year)	Estimated Discharge (cfs)
1.5	700
2	1700
5	6400
10	11000
50	24000
100	29000

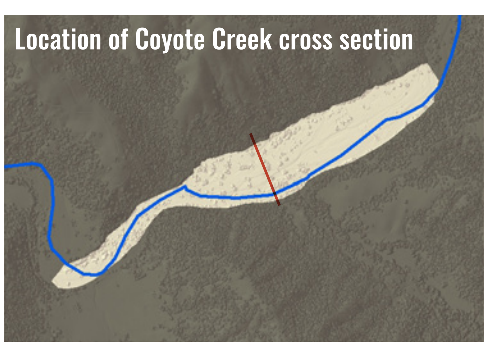
Figure 22. (below) LiDAR-derived cross section on Upper Coyote Creek site with modeled flood inundation depths.

Figure 23. (below right) Flooded primary channel and gravel bar at Upper Coyote Creek site, January 24, 2016. Dotted red line indicates extent of flooding. Photo by Dan Stephens HTH.

Upper Coyote Creek Initial results from the hydraulic mode model, using a LiDAR-derived cross-section and slope estimate (0.0046), pebble count data from the primary channel (D50= 100 mm), roughness values estimated from the field, and other sources (n=0.045, (Barnes, 1967), suggest that the two-year flood event (Q_2 event) fills the primary channel, and inundates part of inner floodplain. High flow indictors observed after the January 19-20, 2016 high flow event, which was estimated be a 1.5-year flood, corroborate this finding. We also found that the Q_{10} and higher flood events inundate the primary and secondary channel, as well as the gravel bar and inner floodplain (Figure 22). These results also suggest that it takes a Q_{50} event to flood the entire valley. Further study is needed to understand when the "historical channel" was active (presumably as the primary channel), and when it presumably anastamosed, or jumped, to the current primary channel location.

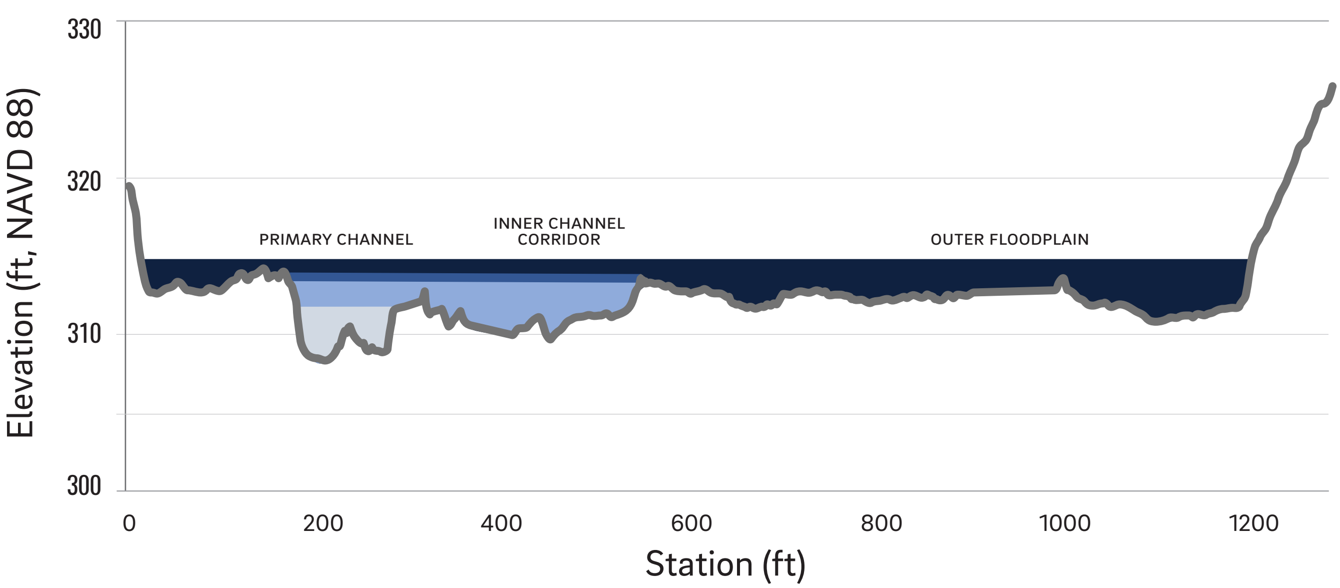






Pacheco Creek According to the hydraulic model, using a LiDAR-derived cross-section and slope estimate (0.0095), pebble count data from the primary channel (D50=45 mm), and roughness values estimated from the field, and other sources (n=0.056; Barnes, 1967), as well as gaging data adjusted by a 12% reduction in drainage area between the gage and the site, the Q_2 flow stays within the primary channel while the Q_5 and Q_{10} floods fill the primary channel and inundate the inner channel corridor. Between Q_{10} and Q_{50} floods, the inner floodplain becomes inundated. These findings suggest that the mature sycamore stands on Pacheco Creek's outer floodplain (which were not mapped as part of this study) were established during at least a 25-year flood flow, which occurred in 1956 and 1969.

It is important to note that the analyses presented here are estimates based on the best available data and a simple hydraulic analysis. As such, they should be considered a first approximation of flooding depths and extents. A next step to refine these results could be done by conducting a more detailed hydraulic modeling analysis that includes other factors such as changes to channel dimensions during large flood events.



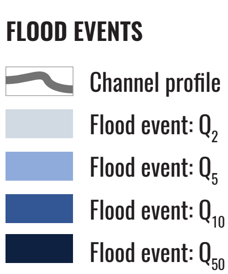
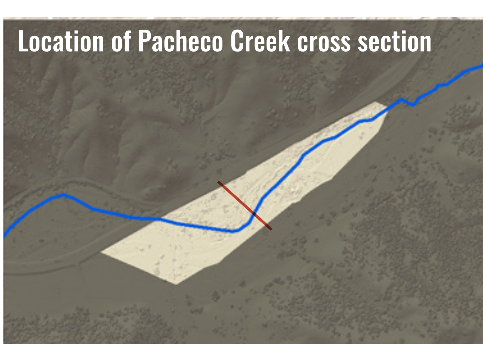


Figure 24. LiDAR-derived cross section on Pacheco Creek site with modeled flood inundation depths.



Tree Coring Results

We cored individual sycamores at the two sites to help determine the relationship between specific flood events and sycamore recruitment in the study area. In October 2016, SFEI staff cored five trees at Upper Coyote Creek and three trees at Pacheco Creek. Initial tree selection occurred before the field effort using criteria described on page 20. While in the field, we discovered that several pre-selected trees did not meet our study criteria and we were forced to find alternates. Several trees were found to have heart rot and complete cores were not possible to obtain.

Upper Coyote Creek At Coyote Creek, we cored three trees in the historical channel, one tree in the secondary channel, and one tree in the primary channel (Figure 25). The results are shown in Table 11.

Figure 25. Locations of trees cored on Upper Coyote Creek. (NAIP 2014)

Table 11. Results of trees ring analysis on Upper Coyote Creek

Site	Tree ID	Length of core (cm)	Age (est)	Error (+/-)	% Error	Heart Rot	Minimum year est.
Coyote	65	12.1	35	4	11.4	Yes	na
Coyote*	41	12.6	32	6	18.8	Yes	na
Coyote*	41	14.9	42	5	11.9	Yes	na
Coyote	9	18.2	67	6	9.0	Yes	na
Coyote	27	44.7	99	15	15.2	No	1917
Coyote	55	8.8	33	3	9.1	Yes	na

*two cores were taken for tree 41, and both had heart rot.

Because of the presence of heart rot, we were unable to attain a complete core for four of the five trees, preventing the determination of absolute age in those trees. This led to further questions about the health of older sycamore trees at Upper Coyote. Tree 27, for which it was possible to obtain an age, was not rotten at the center. Tree 27 was very straight and did not have the snags, snarls and shape of other nearby sycamores, suggesting it might be a hybrid (Figure 26). Whitlock (2003) expressed concern that sycamore hybrids may be less susceptible to diseases that cause deadwood and cavities within trunks that provide important habitats for several riparian species.

The age of Tree 27, which is located along the secondary channel, was estimated to be 99 years old with a 15% error margin. This would date the tree to around 1917 plus or minus 15 years, which is approximately three decades before the gaging records start at Upper Coyote Creek. However, using a regression analysis with gage data from a nearby gage on Alameda Creek at Niles Canyon, we were able to estimate the Coyote Creek peak flood discharge for this time period (Figure 27). From this analysis, we estimate that large storm events took place in 1911, 1919, and 1922. These were in the vicinity of 25-year storm events,according to the flood frequency analysis. Our simple hydraulic analysis shows this size storm would have inundated both the main and secondary channels, and could possibly have provided the disturbance needed to support the establishment of Tree 27 and others. This size storm also occurred at the site in 1995 and 1998, yet trees in the range of 20-22 years old are not found at the site. On January 10, 2017, Upper Coyote Creek flowed at over 10,000 cfs, which is approximately a 25-year event in this system, and similar in size to the 1919, 1922, 1995, and 1998 events. It remains to be seen what, if any, regeneration stems from this event. However, if past floods are an indication, it is possible that a 25-year event is a minimum threshold for vegetation "resetting" at this site.

ROOT SPROUTING AND HOLLOW STUMP AT UPPER COYOTE CREEK

SYCAMORE 'TREE 27', PROBABLY OVER 100 YEARS OLD. COYOTE CREEK

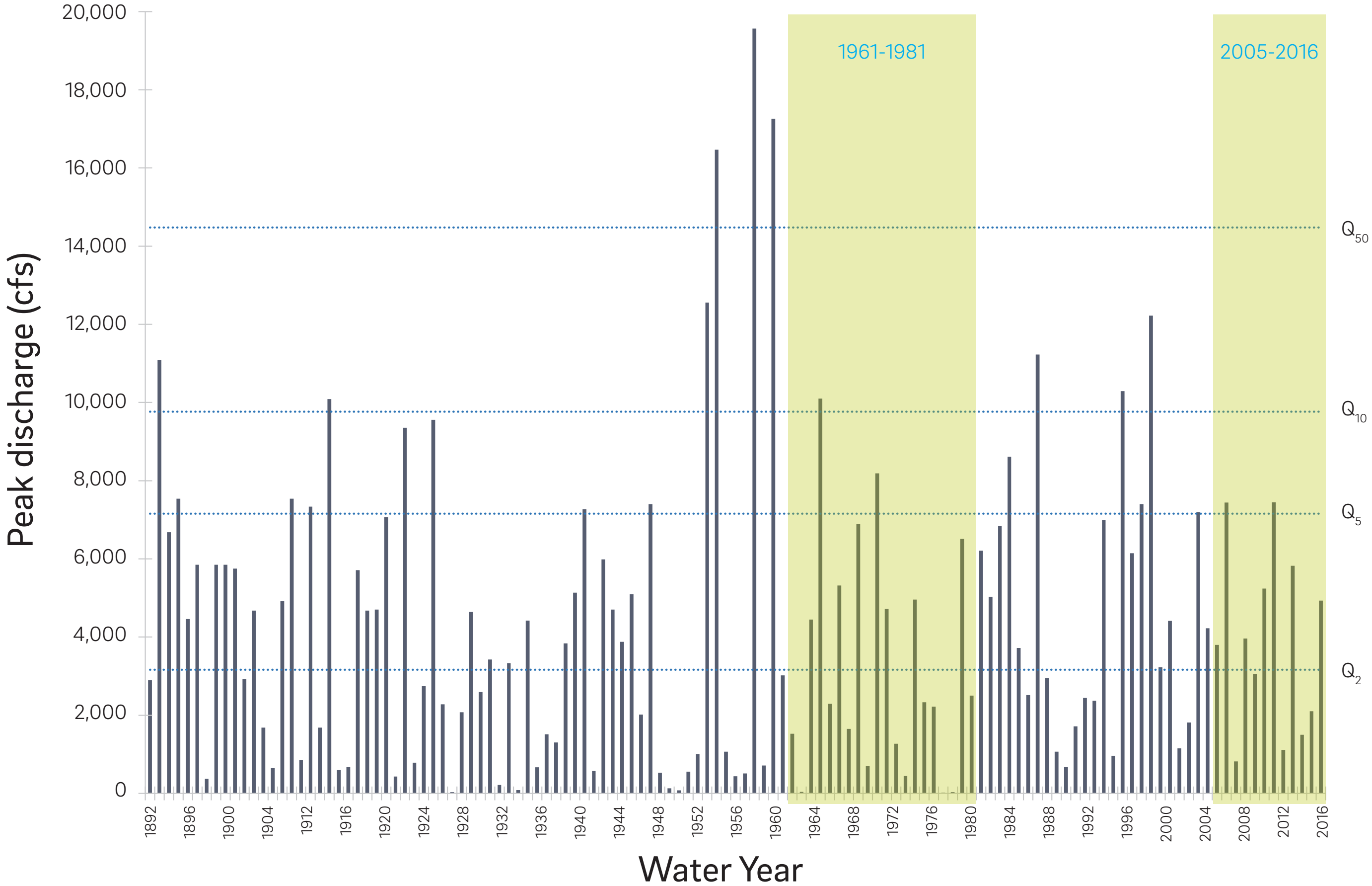


Figure 27. Annual peak discharges from Coyote Creek (1961-1981, 2005-2016) highlighted in green are directly from the USGS gaging station (11169800). All other dates use a regression from Alameda Creek at Niles gaging station (11179000).

TREE CORE AT PACHECO CREEK

Pacheco Creek Three medium-sized trees were cored along the inner floodplain of Pacheco Creek (Figure 28). The results of the tree ring analysis are shown in Table 12.

In contrast to the trees at Upper Coyote Creek, all three of the trees cored at Pacheco Creek did not have heart rot and it was possible to analyze complete cores for age. The trees cored at Pacheco were all relatively small, with diameter at breast height values under 10 inches. They also had straight trunks, and no snags, boles, or other complexities (Figure 29). It is possible that these trees may be hybrids, or may have been planted under a CalTrans mitigation program. The trees were, at a minimum, between 13 and 20 years of age. We did not hit pith at the center of the tree, and thus are not certain that we captured the true age of the trees. However, the ages of the trees cluster around the late 1990s and early 2000s. Large storms in that time period included the floods of 1995 and 1998. Unfortunately, no gaging data exists for this time period but large events occurred in these years throughout the region. According to our simple hydraulic analysis, the inner floodplain, where the trees are located, is an area that would be inundated above a 10-year flood event. Similar to Coyote Creek, the January 11, 2017 flood was a 25-year event on Pacheco Creek (11,400 cfs at the Pacheco Creek near Dunneville gage). It remains to be seen what, if any, regeneration is caused by this event.

While this pilot analysis was not conclusive, it lays the groundwork for understanding the role of flood disturbance in the successful recruitment and germination of sycamores in the recent past, suggesting conditions that may support conservation and restoration success in the future. Ultimately, such analyses have implications for the flow conditions necessary for the successful restoration of SAW habitat.

Table 12. Results of tree ring analysis on Pacheco Creek

Site	Tree ID	Length of core (cm)	Age (est)	Error (+/-)	% Error	Heart Rot	Minimum year est.
Pacheco	103	9.9	18	3	16.7	No	1998
Pacheco	93	14.3	13	5	38.5	No	2003
Pacheco	43	17.2	20	3	15.0	No	1996

Figure 28. (Above) Locations of trees cored on Pacheco Creek. (NAIP 2014)

TREE 43 AT PACHECO CREEK

4 • DISCUSSION

SYCAMORE SNAG WITH WOODPECKER GRANARY, UPPER COYOTE CREEK

SUMMARY OF RESULTS

In the following section, we revisit the hypotheses posited at the beginning of this study, addressing three major study questions, and reconcile them with the results derived from the field effort, anthracnose analysis, hydrologic assessment, tree coring, and literature review. In the “result” column, a green check mark indicates that the result of the study matched the hypothesis, a question mark indicates that the result was mixed or inconclusive, and a red X-mark indicates that the result did not match the hypothesis.

*HOW ARE SYCAMORES **DISTRIBUTED** AT EACH SITE?*

	Expected Results in "Natural" System [UPPER COYOTE]	Result	**Expected Results** in "Managed" System [PACHECO]	Result
By geo-morphic zone	Younger trees are concentrated along the primary channel, older trees are concentrated in the older floodplain.	?	Younger trees are concentrated along the primary channel, older trees are concentrated in the older floodplain.	✓
By distance from channel	Younger trees are located closer to the channel, older trees are located further.	?	Younger trees are located closer to the channel, older trees are located further.	✓

DISTRIBUTION • In general, we expected to find a positive relationship between size class and distance to the primary channel. This is what we found at Pacheco - young trees were most concentrated close to the channel and in the inner floodplain and primary channel geomorphic zones, and larger, older trees were found at relative higher densities further from the channel. This is consistent with literature that suggests sycamores develop on newly-formed alluvial deposits near the channel (Stromberg 2001). At Upper Coyote Creek, we did not observe this pattern. This was perhaps due to historic migration of the channel over time. However, the distribution of large trees at Upper Coyote may reflect a historical path of an older channel along the northern edge of the floodplain.

COBBLES AND MULEFAT AT PACHECO CREEK

WHAT IS THE GENERAL HEALTH OF SYCAMORES?

	Expected Results in "Natural" System [UPPER COYOTE]	Result	**Expected Results** in "Managed" System [PACHECO]	Result
By health / vigor score	Trees are relatively ***healthier.***	?	Trees are relatively ***less healthy.***	?
By mortality	Trees suffer ***less mortality.***	✓	Trees suffer ***greater mortality.***	✓
By anthracnose symptoms	Trees have ***lower incidence.***	X	Trees have ***greater incidence.***	X

HEALTH • In general, we expected to find healthier trees in the more dynamic, more flood prone, less hydrologically managed, and more "natural" system at Upper Coyote Creek. More frequent and intense flood events would be expected to promote conditions more conducive to sycamore growth - availability of cobble sediment, removal of anthracnose-infected litter, and thinning of competitor species. This was not definitively supported by all the metrics examined.

By the health/vigor score, the trees did not differ substantially across size class, geomorphic zone or on average between sites. Healthier trees were generally located closer to and concentrated near the active channel at both sites.

By the mortality score, trees suffered minimal mortality at Upper Coyote Creek – survivorship was around 99%. At Pacheco Creek, mortality was more pronounced, with close to 50% of large trees and around 15% of medium trees dead. The tributary and outer floodplain suffered the highest proportional densities of mortality. Further, dead trees were located further from the channel on average at both sites. The fact that mortality was much higher at the managed site is congruent with initial predictions. A more natural, dynamic site such as Upper Coyote Creek would be expected to experience higher survivorship. Furthermore, many of the dead trees at Pacheco Creek may be associated with Harper Creek, a tributary at the western edge of the site, but CDFW observations of general die-back of sycamores throughout the site remains unexplained. Groundwater pumping and stream diversions may be the cause of some of the mortality both along Harper Creek, and the main stem of Pacheco. Three stilling wells were found on the outer floodplain at Pacheco Creek; however we were unable to obtain the data associated with those wells. Groundwater levels are a critical element to the survival of sycamore trees, and further studies are recommended to assess the groundwater conditions at both sites.

By anthracnose incidence, Upper Coyote Creek suffered a larger proportion of trees with high-severity symptoms than Pacheco Creek. Symptom severity did not vary much across zone or tree size at either site. Further, results from tree coring data suggest many trees at Upper Coyote Creek trees suffer from heart rot. Anthracnose stress may have led to greater heart rot incidence at Upper Coyote Creek. It is possible that many of the sycamores at Pacheco Creek could be hybrids of

ANTHRACNOSE AFFECTED LEAVES

California sycamore and non-native London plane tree. London plane tree is thought to be less susceptible to sycamore anthracnose than California sycamore (Sinclair et al. 1987, Oswald 2002). London plane tree's resistance to sycamore anthracnose may result in less dead wood and trunk cavities compared with California sycamore (Johnson et al. 2016). Some studies have suggested that natural systems experience more intense, more frequent flood events to wash away anthracnose-infected litter (Kamman Hydrology 2009), which, by implication, would reduce local infestation intensity.

Sampling time frame may explain these results in part – these data points were collected in one season only. Perhaps across many seasons, anthracnose-infected litter would be generally washed away, reducing probability of local spread. Depending on litter distribution, Pacheco Creek may experience greater litter removal from less intense but more frequent events from the perennial flow, particularly if Pacheco Creek's channel is more incised, which is true in some locations. Upper Coyote Creek also does not appear to be experiencing much mortality, so perhaps there is simply high variability in local incidence – literature suggests that anthracnose as a stressor is rarely lethal in isolation (Stuart 2001, Crump 2009). However, these observations, combined with noted heart rot, may forecast an impending threat for many of the sycamores at Upper Coyote Creek. Differences in microclimate may also contribute to observed differentials in disease vectors. Many other factors affect tree health; further research will be required to understand the primary drivers of sycamore health and abundance.

HOW ARE SYCAMORES REGENERATING?

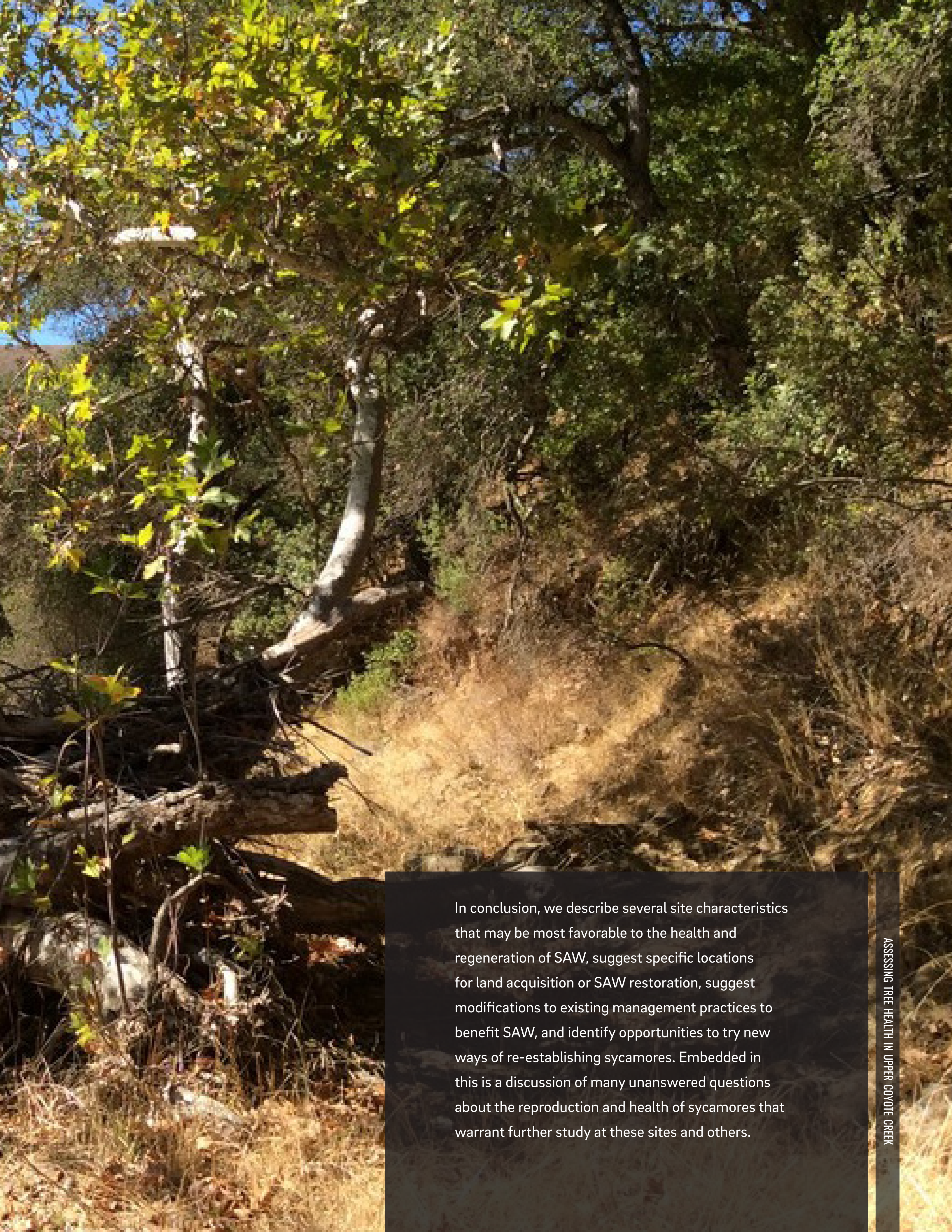
	Expected Results in "Natural" System [UPPER COYOTE]	Result	**Expected Results** in "Managed" System [PACHECO]	Result
By new growth	Significant ***new generation.***	X	Relatively ***less regeneration.***	X
By root sprouts	Trees have ***higher root sprout production.***	?	Trees have ***lower root sprout production.***	?
By seed production	Trees have ***more seed production.***	?	Trees have ***less seed production.***	?

DEAD SYCAMORE TREE AT PACHECO CREEK

REGENERATION • Regeneration at Pacheco Creek followed a predictable pattern of decreased newer growth with greater distance from the channel. Though we expected natural systems to support more regeneration at Upper Coyote Creek, this result was not supported, as Upper Coyote Creek experienced very little recruitment. This could be due to multiple factors. One potential explanation for this observed trend is differences in grazing management. There was cattle exclusion fencing at both Pacheco Creek and Upper Coyote Creek. While there were no signs of active grazing observed at Pacheco Creek, observations of cattle tracks and dung at Upper Coyote Creek indicate some degree of trespass grazing. Given the absence of more palatable competitors such as cottonwood (Shanfield 1984) and the new production (but not apparent persistence) of seedlings and suckers, cattle grazing may be limiting regeneration at Upper Coyote Creek. Another explanation for this differential in recruitment could be explained by anthracnose incidence. As discussed in the Health section, anthracnose incidence is more prevalent and severe at Upper Coyote. Anthracnose affects new leaves and has been hypothesized to affect seed production (Shanfield 1984), which suggests that high site anthracnose incidence may be a limiting factor for regeneration. One final potential explanation is the length of the study period; perhaps under longer time scales, we would observe more flood events and regeneration at Upper Coyote Creek. Conditions for establishment of sycamores are highly specific – flood events must deposit alluvial sediment, sycamores must produce and lay a successful seed set, with timing such that a high initial water table that allows for seedling establishment then has sufficient draw-down to allow root aeration (Keeler-Wolf 1996). Perhaps regeneration is currently infeasible due to the water table levels, but could resume with a large flood event (the last one at this site was 1998). This data "snapshot" likely provides an incomplete picture of full, dynamic regeneration patterns. Further study could include the seed production of sycamores upstream in the canyon above the Upper Coyote Creek site, which could provide seed sources in a large flood event.

Data from seed production and root sprouting provided mixed results. Overall, seed production and root sprouting did not seem to differ dramatically between sites. Seeds were present almost exclusively on medium or large trees at both sites. In general, the observed reproductive strategy was clonal regeneration, which is well supported by the literature (which confirms generation from seed is rare (Shanfield 1984, Bock and Bock 1989, Finn 1991, Stromberg 2002). There appeared to be no obvious pattern of substrate with new growth, though we expect new growth from seed to be on cobbles and near the channel. However, our metrics for substrate were coarse and could be more refined (by examining subsurface sediments) in future studies to better capture this association. There also was no obvious pattern of species associations with new growth.

5 • CONCLUSION, RECOMMENDATIONS, AND FUTURE STUDY



In conclusion, we describe several site characteristics that may be most favorable to the health and regeneration of SAW, suggest specific locations for land acquisition or SAW restoration, suggest modifications to existing management practices to benefit SAW, and identify opportunities to try new ways of re-establishing sycamores. Embedded in this is a discussion of many unanswered questions about the reproduction and health of sycamores that warrant further study at these sites and others.

SITE CHARACTERISTICS AND OBSERVATIONS THAT MAY BE FAVORABLE TO HEALTH AND REGENERATION OF SAW

Sycamores appear to do well when they are near an active channel with intermittent flow. Pacheco Creek follows hypothesized patterns of sycamore distribution and regeneration, with smaller and younger trees located nearest to the active channel. Patterns of distribution at Upper Coyote Creek are harder to explain given the small sample size for younger size classes and a channel that has migrated over time. In general, healthier and living trees were located closer to the channel than dead or unhealthy trees, at both sites. However, it is possible that "unhealthy" sycamore trees (with cavities, heart rot, snags) may be more beneficial for wildlife than "healthy" trees, such as those we see a Pacheco Creek.

Natural hydrographs alone do not guarantee healthy regeneration, but flooding is necessary. While the hydrology of Upper Coyote Creek is less modified, Pacheco Creek is a much more varied site in terms of sycamore patterns: Pacheco Creek has experienced significant mortality and regeneration, while Upper Coyote Creek experiences very little (though trees at Upper Coyote contribute a more dispersed and more dense seed pool). This is also visible in the size class distribution – Upper Coyote Creek is mostly composed of long-lived, larger trees, while Pacheco Creek has a more even size/age distribution. However, such even-aged stands may result when large (>100 year) flood events remove old (possibly hollowed out and weakened) trees and a new, young, even-aged stand is generated. Such large flood events have not been seen in the past 65 years, and occur very infrequently. Pacheco Creek's flooding cycle may have been interrupted by the dam, but encroachment of dense woody vegetation (by mulefat) along the main channel may allow for a "nursery" like condition which protects sycamore seedlings from grazing and/or provides a favorable seed germination microclimate. We would expect reproduction to be more favorable where there are natural flows, fresh deposition, and organization of coarse sediment as we see at Upper Coyote Creek. However we observe more regeneration at Pacheco Creek, where there is an armored bed, a modified hydrograph, and more anthropogenic disturbance.

Anthracnose may affect California sycamore regeneration. At Upper Coyote Creek, anthracnose infestation severity was high and regeneration was low. In contrast, at Pacheco Creek, anthracnose infestation severity was low and regeneration was high. Site history at Pacheco is not fully known, and there is some question about whether the seedlings/suckers and saplings at Pacheco Creek were planted. The average health and vigor of sycamores was medium-high at both study sites. Thus, sycamore anthracnose may have little effect on the apparent health and vigor of California sycamores; however, anthracnose may reduce the overall reproductive fitness of California sycamore by limiting seed and root sprout production.

It is necessary to understand the effects of hybridization between California sycamore and London plane tree on California sycamore regeneration. Hybridization between California sycamore and London plane tree has been documented in both natural and horticultural settings and may result in the extinction of the native genotype and a loss of habitat values for wildlife (Byington 2016, Johnson et al. 2016). A genetics study is underway that will examine the nature of hybridization between California sycamore and London plane tree at Pacheco Creek and Upper Coyote Creek and inform future studies on sycamore hybridization and regeneration. Other studies are proposed to analyze the physical structure of California sycamore, London plane tree, and hybrids to determine whether there are potential differences in wildlife habitat values to guide the management and restoration of SAW.

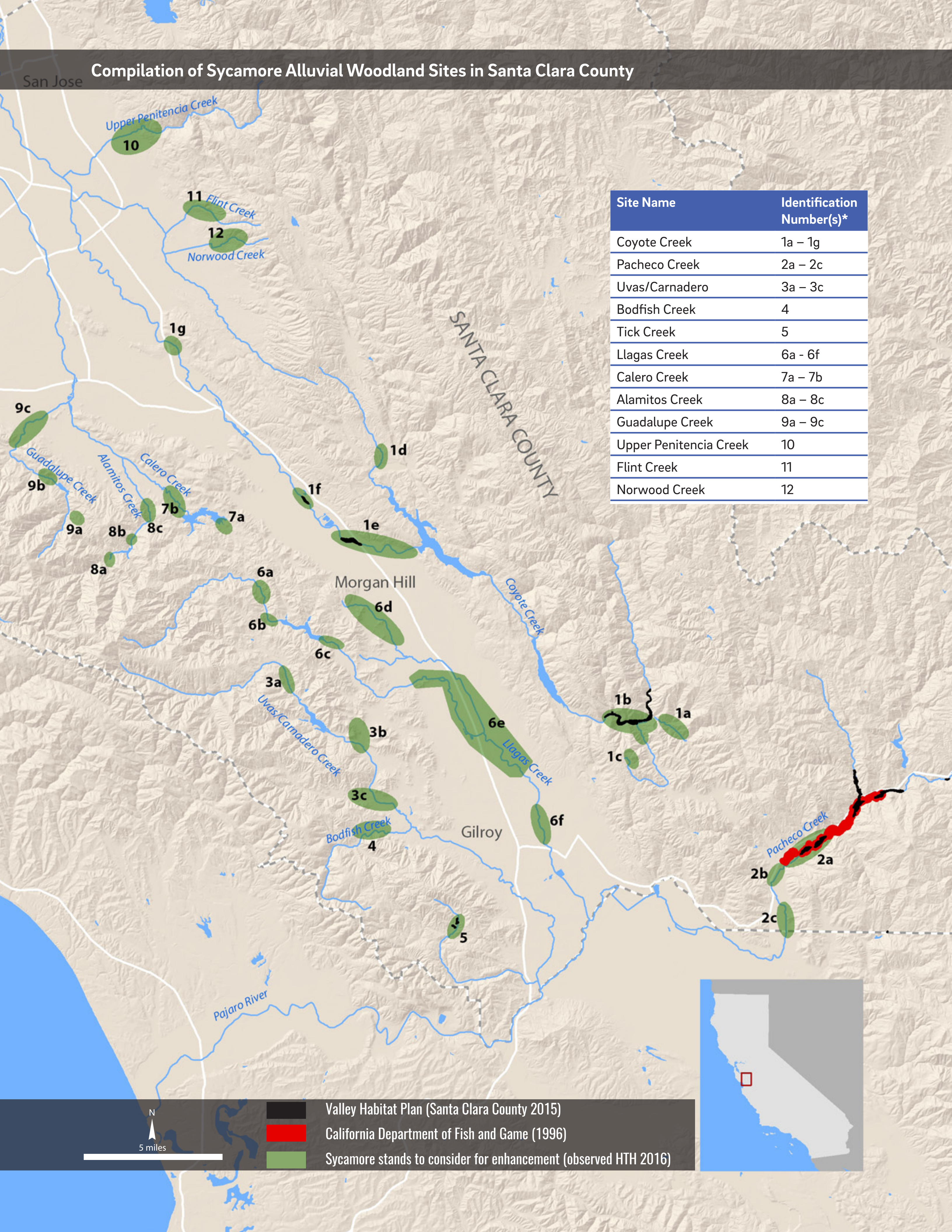
Regeneration success may be impacted by grazing and browsing. While not directly evaluated during this study, grazing and browsing may be a key limiting factor for sycamore regeneration. An experiment in exclusion fencing could inform management techniques at both sites. It is possible that the flow requirements are met at Upper Coyote Creek, but the seedlings and suckers are limited by grazing and browsing pressures and are not surviving. Gaining a better understanding about the difference in management between the two sites, and doing exclusion-fence testing will be critical to understanding if seedlings are establishing at Upper Coyote Creek, but not surviving, or if the health and age of the trees has an impact on their ability to reproduce.

SPECIFIC LOCATIONS ARE RECOMMENDED FOR ACQUISITION, RESTORATION, OR MANAGEMENT WITHIN THE VHP PRIORITY PRESERVE AREAS

Based on the local knowledge of HTH staff, and previous mapping efforts in the County, there are several sites preliminarily recommended for enhancement of SAW. To determine whether or not these sites are suitable for SAW enhancement, further site-specific investigations should examine the following parameters: location relative to the VHP Priority Preserve Areas; ownership; hydrology (managed versus natural); range of geomorphic zones; livestock grazing; and potential for acquisition, restoration, or management. We recommend the following locations be considered (Figure 30):

- Calero Creek (below dam)
- Upper Coyote Creek (from Anderson Dam to Hellyer Park)
- Guadalupe Creek
- Hellyer County Park
- Coe Park- Hunting Hollow parking lot to approximately 0.5 miles upstream
- Llagas Creek (outside SCVWD project/mitigation area) from Morgan Hill to San Martin
- Pacheco Creek (upstream/downstream of Caltrans site)
- Springbrook mitigation site on Norwood Creek
- Upper Penitencia Creek
- Uvas Creek

Compilation of Sycamore Alluvial Woodland Sites in Santa Clara County



Site Name	Identification Number(s)*
Coyote Creek	1a – 1g
Pacheco Creek	2a – 2c
Uvas/Carnadero	3a – 3c
Bodfish Creek	4
Tick Creek	5
Llagas Creek	6a - 6f
Calero Creek	7a – 7b
Alamitos Creek	8a – 8c
Guadalupe Creek	9a – 9c
Upper Penitencia Creek	10
Flint Creek	11
Norwood Creek	12

HOW CAN CURRENT MANAGEMENT PRACTICES BE MODIFIED TO SUPPORT SAW?

From this study, several recommendations to consider for site-specific practices supporting SAW at Upper Coyote and Pacheco Creeks are discussed below.

Use pulsed flows from reservoir at Pacheco Creek. By further studying the flows required to create the geomorphic disturbance that spurs sycamore regeneration, restoration managers may be able to provide more beneficial hydrology to sites such as Pacheco Creek, which is just downstream from an under-used reservoir upstream. Initial results from the tree coring and hydrologic analysis suggest that a minimum 10-25 year flood event may be necessary to activate regeneration of sycamores at Pacheco Creek. Further study should focus on testing this early finding and monitoring the sites carefully after such large flows do occur.

Modify grazing patterns at Upper Coyote Creek to limit herbivory on young sycamore trees. Restoration managers should consider modifying grazing patterns at both sites, but particularly at Upper Coyote Creek where seedlings/saplings either do not establish, or do not survive. Creating experiment plots with exclusion fencing may be a way to test whether survivorship is the issue. Pacheco Creek also has had a varied grazing history, but seedlings seem to be surviving with higher success rates (perhaps because they are protected by woody plant "nurseries").

Control woody invasive species that grow in geomorphic zones where sycamore are most likely to regenerate. As observed at Pacheco Creek, sycamore seedlings and saplings appeared to thrive along the primary channel and inner channel corridor, often within stands of mulefat. Other woody species such as tamarisk or tree of heaven may compete with sycamores for light and space, and could be controlled to preferentially support sycamore survival within primary channels and inner channel corridors.

RECOMMENDATIONS FOR ACTIVE RESTORATION METHODOLOGIES OF SAW

Several concepts for actively restoring and managing SAW stands are discussed below:

Plant California sycamore in inner channel geomorphic zones along tributaries. California sycamore prefers to grow/establish along intermittent stream channels on low terraces of the inner channel corridor and floodplain. These zones, where water availability is high relative to other geomorphic zones, may be appropriate places to install container stock and/or cuttings. California sycamore propagule sources should be of pure genetic stock to ensure that sycamore hybrids are not planted. The restoration plantings should be installed between October and December when rainfall has saturated the soils. Irrigate the plantings during hot summer months to help them become established, especially in years with below average rainfall. Control weeds throughout the planting area to reduce competition with invasive plants. HTH and SFEI are developing a pilot restoration project to test different techniques that could be used to establish California sycamores, as described below under "Further investigations."

Use exclusionary fencing for grazing. Experimentally exclude livestock from portions of SAW habitats (e.g. within the inner channel corridors) to test the effects of grazing on the natural recruitment of California

Figure 30. Compilation of sycamore sites in Santa Clara County, including mapping by CDFW, the Santa Clara Valley VHP, and observations by HTH staff.

sycamore. Exclude livestock from portions of the restoration site to test the effects of grazing on California sycamore establishment. Examine how differences in soil compaction, herbaceous biomass, and damage to leaves and stems affect the natural recruitment and establishment of California sycamore.

Improve methods to propagate California sycamore planting stock for restoration projects. Propagation of California sycamore for restoration projects is typically done using seed. However, the plants produced using this technique often are hybrids between California sycamore and London plane tree. To ensure that pure California sycamore plants are available for restoration projects, they must be propagated vegetatively from pure stock. Vegetative propagation of California sycamore is extremely difficult. Only approximately 10% of the cuttings taken ultimately result in a plant that can be used for restoration purposes. Vegetative propagation studies should seek to improve on this poor performance to advance the science of vegetative propagation of California sycamore and to improve the cost-effectiveness of vegetative propagation of California sycamore. Such a study, funded by the Santa Clara Valley Water District (SCVWD), is underway (see below, under Next Steps).

KEY UNCERTAINTIES

Many uncertainties remain surrounding the distribution, health, and regeneration patterns of sycamores which could be studied in the future.

Relationship of flooding to sycamore regeneration. More work should be done to understand the magnitude and timing of floods and their relationship to sycamore regeneration. This will be essential for influencing management actions like reservoir pulses. This could be accomplished by investigating the ages and locations of more sycamores using dendrochronology methods, observing sites before and after flood events, and tracking the location and timing of new seedlings and saplings.

Groundwater conditions. A major uncertainty not investigated in this study relates to the groundwater conditions necessary to sustain SAW stands. The relationship between groundwater conditions and sycamore regeneration and survival at the two sites, as well as others in Santa Clara Valley is not well known. Future studies should consider installing piezometers to track groundwater dynamics over time, as well as incorporating data that has already been collected at Pacheco Creek.

Plant pathogens. Uncertainties exist concerning the effects of the plant pathogen *Phytophthora megasperma* on sycamore regeneration. *Phytophthora* is a fungus-like watermold found in plant nurseries, landscapes, agricultural fields, and native habitats that can damage and kill host plants. It infects leaves, stems, and roots, causing leaf blight, cankers, and branch die-back. *Phytophthora* can invade the water conducting wood (xylem) of trees beneath the inner bark, and cause water stress symptoms in all or part of the canopy. In California, introduced *Phytophthora* has affected a number of plant communities in a variety of soils and climates (Swiecki and Bernhardt 2014). California sycamore is a host for *Phytophthora*. Very little is known about how this species affects California sycamore regeneration, or whether California sycamore is a host for other species of *Phytophthora*.

Hybridization of sycamores. Uncertainties also exist concerning the effects of California sycamore hybridization with London plane tree on regeneration of California sycamore. London plane tree is thought to be less susceptible to sycamore anthracnose than California sycamore (Sinclair et al. 1987, Oswald 2002). Thus, it is reasonable to assume that hybrid trees would be less susceptible to anthracnose than

California sycamore. Anthracnose infestations can cause tree limbs to die and trunk cavities to form (Sinclair et al. 1987). Such dead wood and cavities provide important foraging substrate and nesting sites for birds; however, severe damage by anthracnose may weaken trees and contribute to a lack of regeneration. Further investigation is needed to determine how hybridization between California sycamore and London plane tree may affect California sycamore regeneration and the habitat values of California sycamores and sycamore hybrids in riparian habitat. Hybridization between the California sycamore and the London plane tree has become a major challenge to restoration goals and potentially threatens the continued genetic distinctiveness of this native species (Johnson et al. 2016; see also Next Steps, below, for genetics study currently underway). For these reasons, local restoration nurseries have attempted to find a viable approach for reproducing non-hybrid California sycamore plant material. Unfortunately, seed collected from large, seemingly pure California sycamore has been observed to produce seedlings that by leaf morphology are thought to be hybrids, thus frustrating efforts to use seed to produce native stock. Vegetative propagation of California sycamore has proven to be very challenging, with most attempts yielding few if any viable seedlings that can be used for restoration, but it remains the only means of reliably producing native stock. Further investigations will seek to advance the science of vegetative propagation of California sycamore and improve the cost-effectiveness of vegetation propagation of California sycamore.

NEXT STEPS

Because of increasing interest in restoring this rare and important habitat type, several efforts are already underway.

HTH is studying the hybridization between California sycamore and London plane tree. Funded by the SCVWD, HTH is in the midst of a genetics study designed to develop a better understanding of the nature of hybridization between California sycamore and London plane tree in southern Santa Clara County and to locate California sycamore individuals that can be used as propagule sources for propagation studies and restoration projects. The genetics study involves analyzing leaf samples from a combination of California sycamore, London plane tree, and potential hybrids to determine the ancestry fraction (percent native California sycamore) in each tree sampled and to identify genetically pure California sycamore "mother" trees. The results of SFEI's tree coring and the genetic analysis will help determine approximately when hybridization began to occur in southern Santa Clara County. If a point in time can be identified before which hybridization did not occur, then we will identify the minimum tree size (diameter at breast height) that can be used as a "rule of thumb" to select pure California sycamore trees as source materials for propagation. Such a short cut would be a significant advantage for future sycamore restoration projects.

HTH is leading a propagation study to advance the science of vegetative propagation of California sycamore and improve the cost-effectiveness of vegetative propagation of California sycamore. Funded by SCVWD project funds and a SCVWD grant, the propagation experiment will test a number of treatments, including: cutting material (basal sprouts and stems), cutting preparation (simple cut and heal cut), willow water presoak, rooting media, and cutting season (spring, fall). Response variables for assessing California sycamore cutting success will include: survival, growth, and vigor. A report will be prepared that will provide clear direction to the reader regarding the most promising techniques that can be used. It also will include clear recommendations concerning further studies that could be performed based on knowledge gained from this study.

A study will be designed for a pilot restoration project to test different techniques that could be used to establish California sycamore. Funded by a SCVWD grant, the experimental design will involve biological, geomorphic, and cartographic work that will build on the knowledge gained from this habitat mapping and regeneration study. Using existing data, HTH and SFEI will continue their investigation of the relationship between flows, geomorphic features, and SAW stand age and establishment at Upper Coyote Creek and Pacheco Creek. The pilot restoration project design will potentially include elements such as planting sycamore trees in different geomorphic zones, planting at different distances from the main creek channel, and planting with different soil and vegetation types. We also will experiment with planting California sycamore cuttings directly into the ground and will compare the results with those obtained from planting container stock. The study will measure signs of establishment and growth, such as survival, canopy spread, diameter, height, health, and vigor.

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