Abundance and Distribution of Blue Elderberry (*Sambucus nigra* ssp. *caerulea*) on Lower Cache Creek, Yolo County, CA

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Prepared for:

Yolo County Administrator's Office

Attn: Elisa Sabatini

625 Court St.

Woodland, CA 95695

Prepared by:

Andrew Rayburn, Ph.D., Certified Ecologist (ESA)

Cache Creek Technical Advisory Committee Riparian Biologist

Executive Summary

Blue elderberry is a native shrub commonly found in cottonwood forests, mixed riparian forests, and associated open savannas in California's Great Central Valley. As the sole host for the federally-threatened Valley elderberry longhorn beetle (VELB), blue elderberry is a protected plant species in California. Mitigation for impacts to blue elderberry and VELB is regulated by the U.S. Fish and Wildlife Service, and a variety of regulations have been established to protect the two species from further declines in the Central Valley. Blue elderberry is a common component of riparian ecosystems along lower Cache Creek in Yolo County, including the region encompassed by the Cache Creek Area Plan (CCAP).

The CCAP was adopted by the County in 1996 to regulate mining, protect groundwater, restore riparian habitat, create open space and recreation areas, and to preserve agriculture along lower Cache Creek. A significant component of the CCAP was the elimination of in-channel commercial aggregate mining in exchange for the establishment of off-channel aggregate mining operations. Among other things, this enabled the County to begin the process of stabilization and restoration of lower Cache Creek including enhancement and re-establishment of riparian habitat. The purpose of the study was to complete a comprehensive blue elderberry survey as a checkpoint for the success of the program after 20 years of implementation and to provide important information about elderberry abundance and distribution to support the County's requested reissuance of federal and state permits that are necessary for continued implementation of the CCAP.

From 2015–2016, the locations and size classes of all blue elderberry shrubs were mapped within the Cache Creek Resources Management Plan (CCRMP) area, a portion of the CCAP area that includes the creek channel and associated riparian areas. An estimated 10,296 blue elderberry shrubs spanning small, medium, and large size classes were mapped within the CCRMP area, including 4,712 individual shrubs and another 5,584 shrubs comprising 1,056 patches. The estimated 2,650 small shrubs mapped during this study strongly suggested an increasing population that has directly and indirectly benefitted from CCAP implementation, especially cessation of in-channel mining and intensive control of invasive species. While blue elderberry shrubs were widely distributed throughout the CCRMP area, analysis of shrub distribution relative to the seven reaches of lower Cache Creek, floodplain inundation zones, topographic

position, and associated vegetation strongly suggested a non-random distribution influenced by slope, the presence of other woody vegetation, and exposure to flooding among other factors.

Both the current abundance and distribution of blue elderberry have important implications for continued CCAP implementation and adaptive management of lower Cache Creek. Continued treatment of invasive species and implementation of habitat restoration projects will further create favorable conditions for blue elderberry expansion, which could also be directly planted during restoration. Channel maintenance and bank stabilization projects are also critical components of the CCAP, and reissuance of programmatic permits for these management actions is underway. The results of this study support permit reissuance from the perspective of blue elderberry as a protected species that could potentially be impacted by continued program implementation. Given the abundance (> 10,000 shrubs) and widespread distribution of elderberry shrubs within the CCRMP area, as well as the thousands of small shrubs that suggest favorable conditions for establishment and an increasing population, potential impacts from continued program implementation to a relatively small number of elderberry shrubs should have a negligible impact on the overall population along lower Cache Creek. Furthermore, in addition to ensuring flood safety and creating public recreation opportunities, continued program implementation will facilitate further habitat preservation and restoration that will provide long-term benefits for the local elderberry population.

Introduction

Blue elderberry (*Sambucus nigra* ssp. *caerulea*; hereafter referred to as elderberry) is a drought-deciduous native shrub typically < 8 m. in height that is a common component of cottonwood forests, mixed riparian forests, and associated open savannas in California's Central Valley (Vaghti and Greco 2007; Vaghti et al. 2009). Mirroring broader trends across the Western U.S., riparian habitat in the Central Valley has been reduced by approximately 95% with remaining habitat highly fragmented and often degraded (Katibah 1984; Golet et al. 2013). Riparian restoration has been widely implemented as a management practice to reconnect fragmented patches and to enhance habitat for both common and protected species (Golet et al. 2013).

The value of elderberry for wildlife and invertebrates in the Central Valley has been widely recognized. Numerous species of mammals and birds are known to consume its fruit or foliage (Martin et al. 1951; Vaghti et al. 2009). For example, elderberry is important source of food for mammals such as the Columbian black-tailed deer (*Odocoileus hemionus columbianus*) and numerous native songbirds including western bluebird (*Sialia mexicana*), ash-throated flycatcher (*Myiarchus cinerascens*), white-crowned sparrow (*Zonotrichia leucophyrys*), and California thrasher (*Toxostoma redivivum*) (Martin et al. 1951; Vaghti et al. 2009). In addition, songbirds utilize larger elderberry shrubs for nesting sites (Vaghti et al. 2009), while deer and other mammals also frequently seek shade under elderberry canopies in hot summer months (A.P. Rayburn, personal observation).

Elderberry also supports various spider and insect species, including native bees and other pollinators that provide key ecosystem services in Central Valley agricultural landscapes (Allen-Wardell et al. 1998; Neal 1998; Vaghti et al. 2009). However, elderberry is most widely known as the sole host plant of the Valley elderberry longhorn beetle (VELB; *Desmocerus californicus dimorphus*), a federally-listed threatened insect species that occupies elderberry at all stages of its life cycle (USFWS 1980; Barr 1991; Collinge et al. 2001). The VELB is endemic to riparian woodlands along rivers and streams in the lower Sacramento and upper San Joaquin Valley of California. The insect spends most of its life in a larval stage within the stems of elderberry shrubs, emerging via an exit hole from February–June. Exit holes are often the only exterior evidence of VELB presence on an elderberry shrub. The beetle can be locally common, although they typically have a patchy distribution, low dispersal distances, and tend to occur at very low densities (Barr 1991; Collinge et al. 2001; Talley et al. 2007). Factors leading to the listing of VELB included widespread loss of Central Valley riparian habitat, as well as use of insecticide and herbicide (Stevens and Nesom 2006). The species was proposed for delisting in 2012, but the proposal was withdrawn in 2014 based on a re-evaluation of historical and present occurrence and a more detailed assessment of current threats (USFWS 2012, 2014).

As the sole host for VELB, elderberry is a protected species in California. Proposed project sites that are within the VELB range and that have elderberry shrubs with stems ≥ 1.0 in. (2.54 cm.) diameter at ground level must be surveyed by a qualified biologist prior to the initiation of any projects that might directly or indirectly impact shrubs and associated VELB. Elderberry with stems ≥ 1.0 in. that will be left in place on project sites require the establishment of buffers, commonly 100 ft. (30.5 m.), fencing, and other protective measures. Shrubs that are removed must be transplanted, or if transplantation is infeasible, require compensatory mitigation based on the size and number of stems and other factors. Mitigation for VELB habitat loss, considered a taking under the Endangered Species Act, is regulated by the U.S. Fish and Wildlife Service (USFWS 1999). Blue elderberry shrubs are important components of many riparian restoration projects in the Central Valley, primarily due to the need to restore VELB habitat (River Partners 2004; Holyoak and Koch-Munz 2008; Golet et al. 2013).

Among the waterways along which elderberry occurs is Cache Creek, an 87 mi. (140 km.) stream spanning Lake, Colusa, and Yolo counties in north-central California, the name of which comes from Hudson’s Bay Company trappers who cached furs along tributaries of the Sacramento River (NHC 1995). The climate of the Cache Creek basin is characterized by cool, moist winters and warm, dry summers. Most precipitation is rain, with 85% of the annual total occurring between November and March (KHE 2010). The Cache Creek watershed is divided into the upper watershed above Capay Dam, and the lower watershed below Capay Dam to the Cache Creek Settling Basin (WRAYC 2007).

Cache Creek is one of six principle environmental water resources in Yolo County, which also includes Putah Creek, Willow Slough, the Colusa Basin Drain, the Yolo Bypass, and the Sacramento River, in addition to numerous smaller waterways (WRAYC 2007). These waterways, along with interconnected groundwater resources, are characterized by a complex mosaic of aquatic and riparian ecosystems that support an array of terrestrial and aquatic species. However, like most other California waterways, Cache Creek and associated habitat has been significantly altered over the past 150 years by anthropogenic activities including in-channel gravel mining, dams, transportation and utility infrastructure (e.g., roads, bridges, gas lines, and power lines) and diversions for agriculture and urban use.

In-channel gravel mining began along lower Cache Creek soon after settlement by eastern U.S. emigrants in the mid-1800s and accelerated during the 20th century (NHC 1995; WRAYC 2007). In 1996, Yolo County adopted the innovative Cache Creek Area Plan (CCAP) to regulate mining, protect groundwater, restore and enhance riparian habitat, create open space and recreation areas, and preserve agriculture along lower Cache Creek. The CCAP is comprised of the Off-Channel Mining Plan (OCMP) and the Cache Creek Resources Management Plan (CCRMP), each of which have non-overlapping spatial extents (Fig. 1).

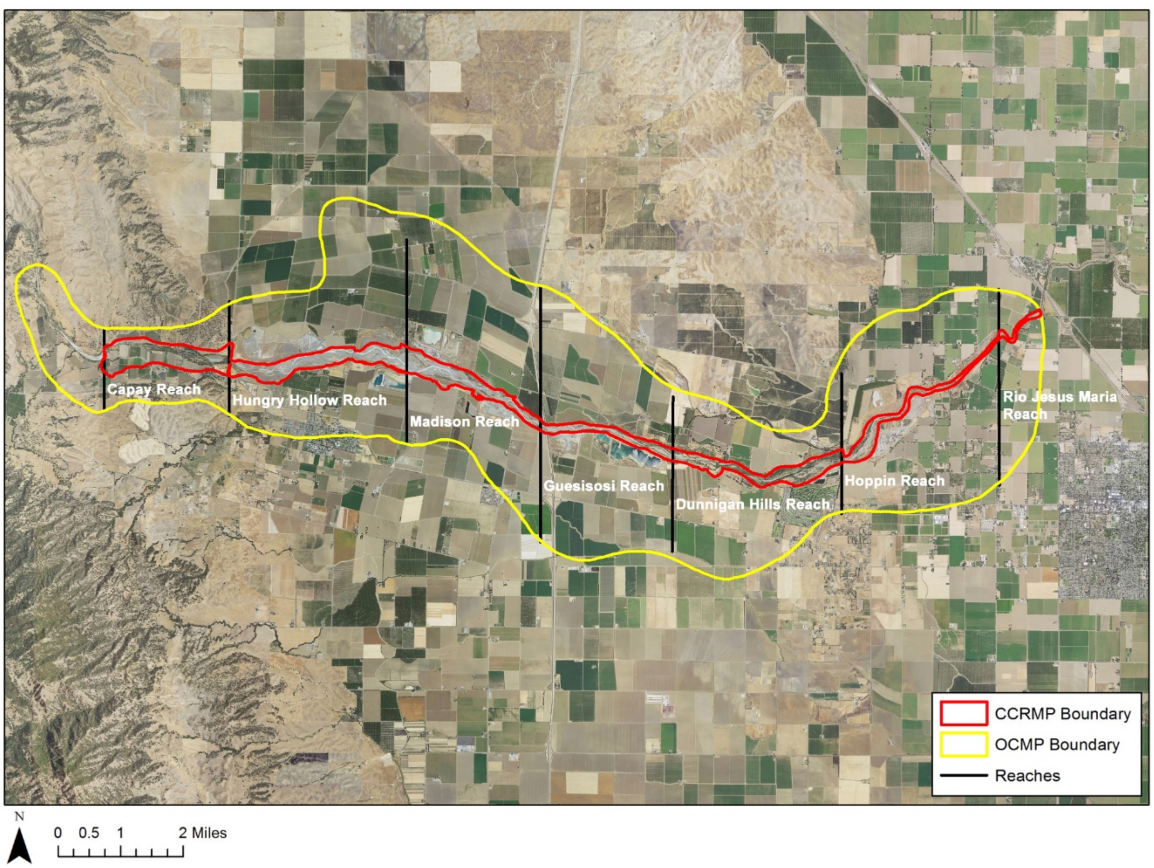

Figure 1. Boundaries of the Cache Creek Resources Management Plan (CCRMP) and Off-Channel Mining Plan (OCMP) areas, which together comprise the footprint of the Cache Creek Area Plan (CCAP).

The CCRMP eliminated in-channel commercial mining and established the Cache Creek Improvement Program (CCIP) to guide the implementation of bank stabilization, channel maintenance, and habitat improvement projects on lower Cache Creek. The CCRMP encompasses seven reaches (Capay, Hungry Hollow, Madison, Guesisosi, Dunnigan Hills, Hoppin, and Rio Jesus Maria) that are geomorphically and hydraulically distinct based on factors including bedrock, flow volume, and anthropogenic alterations (Fig. 1).

Curtailment of in-channel mining has substantially affected riparian vegetation dynamics in the planning area (WRAYC 2007; Rayburn 2016). Both natural regeneration and active restoration of riparian forest, willow scrub, and herbaceous vegetation has occurred in some areas, offset to a degree by vegetation losses to scour during high flow years and recent die-back due to California's prolonged drought. Changes in vegetation have also occurred due to intensive treatment of invasive species including arundo (*Arundo donax*), ravennagrass (*Saccharum ravennae*), and tamarisk (*Tamarix* spp.), although other invasive species have established and spread including Himalayan blackberry (*Rubus armeniacus*) and perennial pepperweed (*Lepidium latifolium*). Additional factors influencing vegetation dynamics in the CCRMP area include high year-to-year variability in climate, surface flows, groundwater, channel meander, sediment deposition, unregulated OHV use, agriculture and other land uses, fires, and implementation of bank stabilization measures.

Prior to this study, elderberry was known to be relatively common along lower Cache Creek based on observations by landowners, gravel operators, County staff, and academic researchers (e.g., Fremier and Talley 2009; Vaghti et al. 2009). The presence of this important riparian species has consistently been viewed as beneficial from the perspective of native vegetation, VELB conservation, and resources for wildlife and other invertebrate species. However, the actual abundance and distribution of elderberry within the CCRMP area was unknown, as was the status of the population. Given the conservation importance of the species, the significant changes in land management associated with the adoption of the CCAP, and the need for the County to plan and implement riparian and river management projects including habitat restoration, invasive species control, channel maintenance, and bank stabilization, data were needed on the abundance and distribution of elderberry along lower Cache Creek. In 2015, the TAC Riparian Biologist was tasked with conducting a comprehensive field survey to map the locations and size classes of all elderberry shrubs within the CCRMP area. Specific objectives were to 1) evaluate the distribution and status of elderberry as a component of the biological resources covered by the framework of the CCAP, and 2) infer the degree to which adoption of the CCAP has increased elderberry abundance, and 3) provide quantitative data to support the County's requested reissuance of programmatic permits to facilitate continued implementation of the CCAP.

Methods

Field surveys were conducted in spring–summer 2015 and spring 2016 to map all elderberry shrubs within the CCRMP area using mobile mapping software (ArcGIS Collector) with an approximate spatial precision of ± 6.6 ft. (2.0 m.). Specific phenological and morphological characteristics were used to aid in elderberry identification relative to other riparian vegetation. For example, elderberry shrubs are among the first species to leaf out in the early spring, and also have large, white clusters of flowers that are visually distinct compared to other riparian trees and shrubs. Elderberry shrubs were mapped as individual points, and as patches when discrete individuals could not be easily identified. All individual shrubs (points) were assigned an approximate size class based on visual estimates of height: small (< 5 ft.), medium (5-15 ft.), and large (> 15 ft.). Patches were classified as small (3 shrubs), medium (5 shrubs), and large (approximately 7 shrubs), and the approximate mix of shrub size classes was noted. Patch size was conservatively estimated due to plant density, and in some instances the actual number of plants in a patch may have been higher than the approximation. Points and patches were visualized in ArcGIS 10.1, and stored as shapefiles that were provided to the County.

These data were analyzed in ArcGIS 10.1 to estimate density and to examine elderberry distribution in relation to associated vegetation, slope, aspect (compass direction that the slope faces), and floodplain inundation zones. Elderberry distribution was also visualized via Kernel density estimation (10 ft. cell size, 150 ft. search radii, and the CCRMP boundary as the raster analysis mask) using *Spatial Analyst* tools in ArcGIS 10.1. For estimating density, points were treated as individual shrubs while patches were treated as 3, 5, or 7 individuals (representing small, medium, and large patches respectively). A five-bin, green-to-red classification scheme was used to visualize the density raster with the following classes: ≤ 5.0 shrubs/ac.; 5.1–10.0 shrubs/ac.; 10.1–50.0 shrubs /ac., 50.1–100.0 shrubs/ac., 100.1–251.4 shrubs/ac. This raster layer was also provided to the County.

In order to estimate the broader vegetation class associated with elderberry plants and patches, a vegetation layer created in 2016 based on manual classification of 2015 high-resolution aerial photography (see Rayburn 2016 for details) was joined with both the point and patch data. Vegetation classes (riparian forest, dense scrub, scattered scrub, herbaceous, and a "bare ground" class that represented areas with no significant vegetation) were then extracted for each point and patch.

The topographic position of elderberry plants and patches was also analyzed in terms of slope, aspect, and floodplain inundation zones. Slope and aspect layers were derived from a 2011 LiDAR dataset with a resolution of approximately 1 m^2 using *Spatial Analyst* tools in ArcGIS. Slope and aspect values were extracted from each raster for each elderberry plant and patch. The percentage of total CCRMP area represented by 0–10°, 10–20°, 20–30°, 30–40°, and >40° slope classes was 85.5%, 9.0%, 3.2%, 1.4%, and 0.5% respectively. The percentage of total CCRMP area represented by the 8 aspect classes was 10.5% (NW), 18.7% (N), 14.0% (NE), 9.3% (E), 11.9% (SE), 18.1% (S), 11.0% (SW), and 6.7% (W). Elderberry plants and patches were then overlain with polygons representing the estimated 2-yr., 5-yr., 10-yr., and 100-yr. floodplain inundation boundaries derived from a 2016 HEC-RAS 2D model using 2011 LiDAR, 2015 land cover, and historical flood frequency data as inputs. The 2-yr. inundation boundary represented the "active channel," i.e., the portion of the CCRMP that is most frequently wetted including the low-flow channel. The 5-yr. and 10-yr. inundation boundaries were included to examine elderberry distribution on the active floodplain. The 100-yr. inundation boundary represented a reasonable "maximum extent" of potential high flows that would occur during extreme precipitation events. The percentage of total CCRMP area represented by the 2-yr., 5-yr., 10-yr., and 100-yr. inundation boundaries was 44.0% (983.2 ac., or 397.9 ha.), 59.3% (1325.2 ac., or 536.3 ha.), 62.8% (1403.6 ac., or 568.0 ha.), and 65.8% (1470.0 ac., or 594.9 ha.) respectively (Table 1). The 21.8% of the CCRMP area (764.8 ac. or 309.5 ha.; Table 1) outside of the 100-yr inundation boundary was considered as being disjunct from the active floodplain.

For associated vegetation, slope, and aspect, the number of individual plants observed versus that expected by the percentage of the CCRMP area in each variable class (five vegetation classes, five slope classes, and eight aspect classes) was analyzed using goodness-of-fit statistics (see Appendix 3 for detailed methods and results). This analysis was not conducted for counts of observed versus expected shrubs in the floodplain inundation zones, since observations were not independent (e.g., a shrub occurring within the 10-yr. inundation zone also occurred within the 5-yr. and 2-yr. inundation zones). In addition, this analysis was not performed for elderberry patches, since both the locations and number of individuals within each patch were only approximated in the field.

Finally, elderberry locations were overlain in ArcGIS with the historical extent of in-channel mining operations from 1984–1994, estimated by the TAC Geomorphologist from historical aerial photography and maps from the baseline Technical Study (NHC 1995). Because these areas were stripped of vegetation during intensive mining operations, present-day elderberry located in these areas were assumed to have established after cessation of in-channel mining and CCAP adoption. This analysis provided an additional means of conservatively estimating the benefits of the CCAP for the elderberry population on lower Cache Creek (see *Discussion*). A full comparison of the elderberry dataset collected in this study to baseline elderberry distribution and abundance in 1996 was not possible, as a comparable dataset was not collected at that time due to logistical and technological constraints (e.g., a lack of mobile mapping technology meant that rapid and precise mapping of plants in the field was not possible).

Results

Elderberry Abundance

Including individual shrubs and patches, an estimated 10,296 elderberry shrubs were mapped within the CCRMP area. Additional elderberry shrubs were observed outside of the CCRMP boundary within the OCMP area, but were not mapped in this project due to logistical constraints. Thus, the total number of elderberry shrubs within the broader-scale CCAP area is likely substantially higher since large patches of appropriate habitat exist within the OCMP area, especially in areas closer to the channel (i.e., closer to the CCRMP boundary).

A total of 4,712 individual shrubs were mapped, including 1,194 small shrubs, 2,565 medium shrubs, and 953 large shrubs including some tree-like in form. The percentage of small shrubs (25.3%) observed was slightly more than the 19% of small elderberry shrubs (<0.5 m. in height) observed in plots in a smaller-scale study by Vaghti et al. (2009). An additional 1,056 patches (ca. 5,584 plants) were mapped, including 240 small patches, 424 medium patches, and 392 large patches. For the purpose of estimating how many elderberry have established in the CCRMP area since adoption of the CCAP in 1996 (see above, and *Discussion*), the number of small elderberry shrubs in each patch was estimated from field notes recorded for each patch observation. The number of small elderberry shrubs identified as components of patches in addition to the 1,194 small shrubs mapped as discrete individuals was conservatively estimated at 1,456, for a total of 2,650 small shrubs.

Elderberry Distribution

The distribution of elderberry plants and patches was considered from the perspective of floodplain inundation zones, topographic position (slope and aspect), associated vegetation classes, and the seven reaches within the CCRMP area. The results of this survey strongly suggested that elderberry shrubs are not randomly distributed within the CCRMP area, and instead tend to occur in association with woody riparian vegetation on flat-to-intermediate slopes above the channel floor within the 10-yr floodplain inundation zone (Table 1; see also Appendix 3). In addition, elderberry shrubs tended to be more abundant in reaches where other riparian vegetation was also more widespread (Appendix 1). Elderberry shrubs were also abundant within the areas that were historically mined from 1984–1994 (Appendix 2). These represent general observations as numerous plants and patches were observed in other locations as described below.

Distribution Relative to Floodplain Inundation Zones

Field observations suggested that most elderberry shrubs were found relatively near the channel on terraces, benches, and channel slopes, with only a few scattered shrubs on the channel floor. This observation was reinforced by the examination of elderberry distribution relative to the 2-yr, 5-yr, 10-yr. and 100-yr. floodplain inundation zones: 84.6% of plants and 83.5% of patches occurred within the 100-yr. inundation zone, while 25.0% of plants and 19.2% of patches occurred within the 2-yr. inundation zone, a region representing 44.0% of the study area (Table 1). Plants and patches within this region rarely occurred on the channel floor, instead occurring more often on channel slopes and occasionally on elevated bars. Within the 5-yr. inundation zone, which represented 59.3% of the total CCRMP area, 69.3% of plants and 64.8% of patches occurred, while 77.7% of plants and 75.1% of patches fell within the 10-yr. inundation zone (62.8% of the study area; Table 1). A substantial portion of the study area (34.2%) fell outside of the 100-yr. inundation zone, in which 15.4% of plants and 16.5% of patches occurred (Table 1).

Table 1. Distribution of individual elderberry plants (points) and patches according to estimated floodplain inundation zones, slope, aspect, and associated vegetation. Percent of total CCRMP area for each category included to illustrate point and patch distribution relative to overall extent of each category across the study area. See Appendix 3 for details of statistical analysis.

		% total area	Small plants	Medium plants	Large plants	Subtotal plants	*% total plants*	Small patches	Medium patches	Large patches	Subtotal patches	*% total patches*
Floodplain inundation zone	≤ 2 yr	*44.0*	301	741	139	1181	*25.0*	55	85	63	203	*19.2*
	≤ 5 yr	*59.3*	762	1934	571	3267	*69.3*	178	266	242	686	*64.8*
	≤ 10 yr	*62.8*	874	2117	672	3663	*77.7*	209	308	278	795	*75.1*
	≤ 100 yr	*65.8*	989	2260	741	3990	*84.6*	221	343	319	883	*83.5*
	>100 yr	*34.2*	205	307	213	725	*15.4*	20	81	74	175	*16.5*
	>2 yr and ≤ 100 yr	*21.8*	688	1519	602	2809	*59.6*	166	258	256	680	*64.3*
Slope	0–10.0°	*85.5*	742	1847	665	3254	*69.1*	157	270	288	715	*67.7*
	10.1–20.0°	*9.0*	237	410	169	816	*17.3*	46	76	61	183	*17.3*
	20.1–30.0°	*3.2*	127	153	71	351	*7.4*	17	31	30	78	*7.4*
	30.1–40.0°	*1.4*	60	100	31	191	*4.1*	15	31	7	53	*5.0*
	>40.0°	*0.5*	28	55	17	100	*2.1*	5	16	6	27	*2.6*
Aspect	NW (292.5-337.5°)	*10.5*	245	394	155	794	*16.9*	38	78	59	175	*16.6*
	N (337.5-22.5°)	*18.7*	213	516	195	924	*19.6*	44	93	83	220	*20.8*
	NE (22.5-67.5°)	*14.0*	133	323	125	581	*12.3*	27	57	56	140	*13.3*
	E (67.5-112.5°)	*9.3*	78	183	70	331	*7.0*	16	34	29	79	*7.5*
	SE (112.5-157.5°)	*11.9*	147	298	100	545	*11.6*	31	36	46	113	*10.7*
	S (157.5-202.5°)	*18.1*	197	404	136	737	*15.6*	43	55	53	151	*14.3*
	SW (202.5-247.5°)	*11.0*	96	236	87	419	*8.9*	23	43	34	100	*9.5*
	W (247.5-292.5°)	*6.7*	85	211	85	381	*8.1*	18	28	32	78	*7.4*
Associated vegetation	Riparian forest	*11.3*	504	1121	305	1930	*40.9*	117	188	180	485	*45.8*
	Dense scrub	*7.3*	250	698	338	1286	*27.3*	78	143	155	376	*35.5*
	Scattered scrub	*2.2*	21	71	15	107	*2.3*	2	5	1	8	*0.8*
	Herbaceous	*21.3*	261	445	234	940	*19.9*	37	65	41	143	*13.5*
	Bare ground	*57.8*	158	230	61	449	*9.5*	6	23	15	44	*4.2*

Distribution Relative to Slope and Aspect

Most individual elderberry plants (69.1%) occurred on low-slope areas (0–10°), which represented 85.5% of the total study area (Table 1). However, there was a lower number of individual plants that expected based on the percentage of the study area in this slope class (Appendix 3). For the four other slope classes, a significantly higher number of plants were observed than based on the percentage of the study area in each slope class (Appendix 3). More individual plants were observed in the 10–20° class (816) than in the remaining three classes combined, and only 291 plants were observed on the steepest slopes (>30°) (Table 1). Similar results were observed in terms of elderberry patches, with 67.7% of patches observed on low-slope areas and only 7.6% of patches observed on slopes greater than 30°.

Patterns were less clear in terms of elderberry distribution relative to aspect. For example, more shrubs were observed than expected on northwestern- and western-facing aspects, but fewer than expected on northeastern-, eastern-, southern-, and southwestern-facing slopes ($P<0.001$ for all comparisons; Table 2). Almost half (48.8%) of individual shrubs occurred on more northerly-facing areas (NW, N, NE), while 36.1% occurred on more southerly-facing areas (SW, S, SE). A similar pattern was observed for patches, as 50.7% occurred on northerly-facing areas and 34.5% occurred on southerly-facing areas (Table 1).

Distribution Relative to Associated Vegetation

Field observations suggested that elderberry shrubs were most often found growing within patches of riparian forest and dense scrub in association with other native woody riparian species including Fremont cottonwood (*Populus fremontii*), black walnut (*Juglans hindsii*), Valley oak (*Quercus lobata*), California buckeye (*Aesculus californica*), and willow species such as black willow (*Salix nigra*). For both riparian forest and dense scrub vegetation classes, analysis revealed that almost four times as many elderberry plants (68.2%) were observed than might be expected based on the proportional amount of each vegetation class within the study area (Table 1, Appendix 3). Conversely, approximately four times fewer shrubs were observed on bare ground (9.5%) than would be expected based on percentage of bare ground (57.8%) in the CCRMP area (Table 1, Appendix 3). Fewer individual shrubs (19.9%) were also observed in herbaceous vegetation than expected; however, this difference was only marginally significant

(Table 1, Appendix 3). A similar pattern was observed in terms of elderberry patches, as 81.4% of patches were observed in association with either riparian forest (45.8%) or dense scrub (35.5%) vegetation while only 13.5% and 4.2% of patches were observed in herbaceous vegetation and on bare ground respectively (Table 1).

Reach-Scale and Fine-Scale Distribution

Elderberry were not distributed uniformly by reach, and were more common in reaches with a higher proportion of woody vegetation (especially dense scrub and riparian forest; see Rayburn 2016 for detailed vegetation analysis). The highest density of elderberry shrubs was observed in the Dunnigan Hills, Hoppin, and Rio Jesus Maria reaches; intermediate density was observed in the Capay and Guesisosi reaches, while the lowest density was observed in the Hungry Hollow and Madison reaches (Appendix 1). Even in the latter two reaches, which are characterized by wide, braided, gravelly floodplains with little woody vegetation, dense patches of elderberry were observed in addition to numerous isolated individuals of all size classes. Considering only the historically-mined portion of the CCRMP area, which included large portions of the Hungry Hollow, Madison, and Guesisosi reaches as well as potions of the Dunnigan Hills and Hopping reach (see Appendix 2), 582 individual shrubs were mapped including 54 small shrubs, 390 medium shrubs, and 138 large shrubs. In addition, 123 patches comprising an estimated 691 individual shrubs were also mapped (19 small patches, 47 medium patches, and 57 large patches). Thus, an estimated total of 1,273 elderberry shrubs were mapped in areas previously mined from 1984–1994, most of which occurred in clustered patches separated by open areas with little vegetation (Appendix 2).

A similar fine-scale spatial distribution of shrubs was often observed throughout the CCRMP area, although elderberry shrubs did also occur as isolated individuals and patches (see Appendix 1). This type of patchy distribution has been commonly observed for elderberry in the Central Valley by previous researchers (e.g., Fremier and Talley 2009), and is likely due in part to patterns of seed dispersal (see *Discussion*).

Discussion

Elderberry Distribution

Past studies of elderberry distribution in relation to variables associated with riverine geomorphic processes and flooding (e.g., relative elevation on the floodplain, floodplain age, distance from the river) and physical habitat attributes (e.g., associated vegetation, canopy cover, shading, soil texture) have found some general patterns, but little consistency across Central Valley river systems. While elderberry has been found at varying relative elevations above river channels (e.g., Lang et al. 1989; Talley 2005; Williams 2006; Fremier and Talley 2009), researchers have generally concluded that elderberry presence is most commonly associated with intermediate relative floodplain elevations (e.g., 5–15 ft. above the river), a sort of "goldilocks zone" in which sustained inundation occurs only occasionally but where groundwater is still accessible during warmer parts of the year (Talley 2005; Fremier and Talley 2009). Similar results were found in this study, as most elderberry shrubs were found outside of the 2-yr. floodplain inundation zone, e.g., the most frequently flooded portion of the CCRMP area. Persistence of elderberry shrubs within the 2-yr. inundation zone may be due to the relative flashy nature of high flows on Cache Creek, as floodwaters most often recede rapidly suitable conditions for elderberry survival are reestablished. Of elderberry observed outside of the 2-yr. inundation zone, 44.3% of individual plants and 45.6% of patches fell within the 5-yr. inundation zone, while 52.7% of plants and 55.9% of patches fell within the 10-yr. inundation zone. These shrubs are likely exposed to similar conditions as described above: occasional and survivable inundation, coupled with sufficient access to groundwater.

Little is known about elderberry distribution relative to slope and aspect, although fine-scale topographic variables have been analyzed as potential predictors of VELB occupancy (e.g., Talley et al. 2007). However, Fremier and Talley (2009) combined aspect, slope, and latitude into a local heat index to examine effects of local abiotic variables on elderberry presence, abundance, and condition. They found a weak influence of local topography, which explained only a small portion of variance in elderberry occurrence and condition. This was attributed to the widely-recognized stochasticity in elderberry distribution, data resolution issues which limited analysis of fine-scale topographic patterns, and the overriding effects of more influential variables such as relative elevation and soil texture (Fremier and Talley 2009). In this study, we observed that most elderberry shrubs occurred on flatter portions of the study area, although less than expected based on the percentage of the study area characterized by low slope. This may be due in part to soil moisture limitations on upper benches and terraces that have deeper groundwater, less-frequent inundation, more sun exposure, and less woody vegetation in which seed-dispersing birds perch. More elderberry occurred on intermediate slopes than expected, potentially due to increased moisture availability from occasional inundation and shallower groundwater as a result of being lower in relative elevation relative to the creek. As woody vegetation was generally more common closer to the creek, and thus more common on the steeper slopes of the channel banks, elderberry abundance may have also been higher due to seed dispersal by birds perching on branches. In terms of aspect, we found no clear pattern of elderberry occurrence although our data suggest that elderberry may be more common on more northerly slopes, perhaps due to lower environmental stress (e.g., sun exposure).

Past studies have reported a wide range of vegetation in association with elderberry, including native riparian and upland trees, shrubs, and vines, as well as a wide variety of nonnative and invasive species. In this study, elderberry shrubs were concentrated in areas of riparian forest and dense scrub more so than expected. However, a substantial number of elderberry shrubs were also observed in open, herbaceous areas, and even on bare, gravelly ground with little to no vegetation observable from aerial imagery. However, far fewer elderberry plants were observed in these vegetation classes than expected based on the percent of the CCRMP area composed of these classes, likely due to multiple interacting factors including low rates of seed dispersal by wildlife and the tendency for these vegetation classes to occur on upper terraces and benches with reduced soil moisture.

Elderberry Abundance and Population Status

Numerous factors have likely influenced the elderberry population on lower Cache Creek since adoption of the CCAP in 1996. Program implementation ended in-channel mining, which was likely having a substantial negative impact on elderberry on and near the channel floor. In the subject study, over 1,200 elderberry shrubs of all size classes were mapped in historically-mined areas of the channel, suggesting significant recovery of elderberry as a result of the CCAP. Significant investment in invasive species control has also occurred as part of the CCAP, and removal of invasive arundo, ravennagrass, and tamarisk along the creek most likely benefited elderberry by reducing competition for light, water, and other resources that is known to negatively impact elderberry survival (Baird 1989; Hubbell 1997; Vaghti et al. 2009). Elderberry shrubs were observed growing in some dense patches of aggressive invasive species (the three listed above, as well as Himalayan blackberry, perennial pepperweed, and other species) that have yet to be treated, suggesting that elderberry on lower Cache Creek can tolerate some level of non-native competition. The CCAP was designed to, among other things, create and enhance habitat for wildlife, including native birds which are often assumed to be the primary disperser of elderberry seeds (e.g., Vaghti et al. 2009). Over 140 species of birds have been observed in the CCAP area since the program was implemented (Rayburn 2016), and in the subject study many bird species were observed foraging for berries on mature elderberry shrubs. Elderberry seeds were also observed in bird droppings. While some elderberry seeds may fall directly to the ground under mature shrubs, seed dispersal by birds and other wildlife is likely a critical factor influencing elderberry abundance and distribution. In addition, voluntary elderberry plantings have occurred at several locations along lower Cache Creek, such as Capay Open Space Park in the Hungry Hollow reach and the Harrison Property in the Hoppin Reach.

Additional factors influencing the elderberry population include disturbance, climate, scour from high flows, and mortality due to age. In terms of disturbance, while some impacts to elderberry have likely occurred due to fire and OHV use, elderberry readily resprouts after fire and can tolerate a high degree of physical damage. For example, many elderberry shrubs of all size classes were observed resprouting in burned areas during field work for this study. Regarding climatic effects, especially the prolonged and significant drought that has affected California over the past 5 years, field observations confirmed the general assumption that elderberry shrubs are drought-tolerant riparian species. While drought-stressed elderberry shrubs were observed during this study, no significant mortality was observed and some resprouts were seen at the base of mostly-dead shrubs that likely died back during the drought. Scour from high flows has also likely had a minimal impact on the elderberry population, since elderberry does not tolerate prolonged flooding and relatively few elderberry shrubs occur on the channel floor. In addition, like other flexible-stemmed riparian vegetation, elderberry shrubs can also bend under high-flow conditions without breaking or being uprooted. Evidence of this was observed in the field in the form of near-horizontal, yet otherwise healthy, elderberry shrubs along some portions of the channel. Lastly, elderberry along lower Cache Creek appear to have the potential to live for many years, as some very large individuals were observed that were clearly aged and more tree-like in form.

The results of this study strongly suggest that the local elderberry population has increased substantially over the past 20 years due to the implementation of the CCAP. The lack of a comparable dataset on elderberry distribution and abundance from the time of CCAP implementation precluded a comprehensive assessment of changes in the population (see *Introduction*). However, the estimated 2,650 small shrubs mapped during the project represent new recruits added to the population in recent years. While numerous small shrubs occurred under the canopies of mature trees and shrubs, small shrubs also occurred in the open suggesting that recruitment is being driven by factors other than canopy cover and associated vegetation. Many of the medium-sized shrubs, as well as some of the larger shrubs, also likely established over the past two decades since CCAP adoption. In addition, as previously discussed, many elderberry shrubs from all size classes were observed on historically-mined areas, further supporting the hypothesis of a robust, increasing population. Elderberry appear to be a highly successive native species on lower Cache Creek, which in turn has positive implications for wildlife and invertebrate species that utilize the plant for perching, foraging, nesting, and thermal refugia.

Implications for Adaptive Management of Lower Cache Creek

The results of this study demonstrate the positive impact of the CCAP on the local elderberry population on lower Cache Creek since 1996. Continued implementation of invasive species control and habitat restoration projects will create favorable conditions for further elderberry expansion and benefit native wildlife species that forage on elderberry and subsequently disperse seeds. Restoration projects should consider including elderberry in the species palette to benefit wildlife and VELB, as well as to accelerate continued recover of native vegetation across the CCAP. Elderberry is an appropriate species for riparian areas along the creek, as well as oak woodlands and open grasslands that characterize the upper terraces and portions of the OCMP area further from the channel.

Channel maintenance and bank stabilization projects are also critical components of the CCAP framework. Reissuance of programmatic federal permits for these management actions is being sought to continue implementation of the CCAP. The results of this study support the requests for permit reissuance from the perspective of elderberry as a protected species that could potentially be impacted by such projects. Given the abundance (>10,000 shrubs) and widespread distribution of elderberry shrubs within the CCRMP area, as well as the thousands of small shrubs that suggest an increasing population, potential impacts from these projects to a relatively small number of elderberry shrubs would have a negligible impact on the overall population along lower Cache Creek. Site-specific surveys will be required to verify current elderberry distribution and to determine VELB occupancy of elderberry shrubs on any particular project site; however, if VELB are detected and if elderberry shrubs must be transplanted off the project site, the results of this study can also be used to determine suitable, local sites for replanting transplanted individuals.

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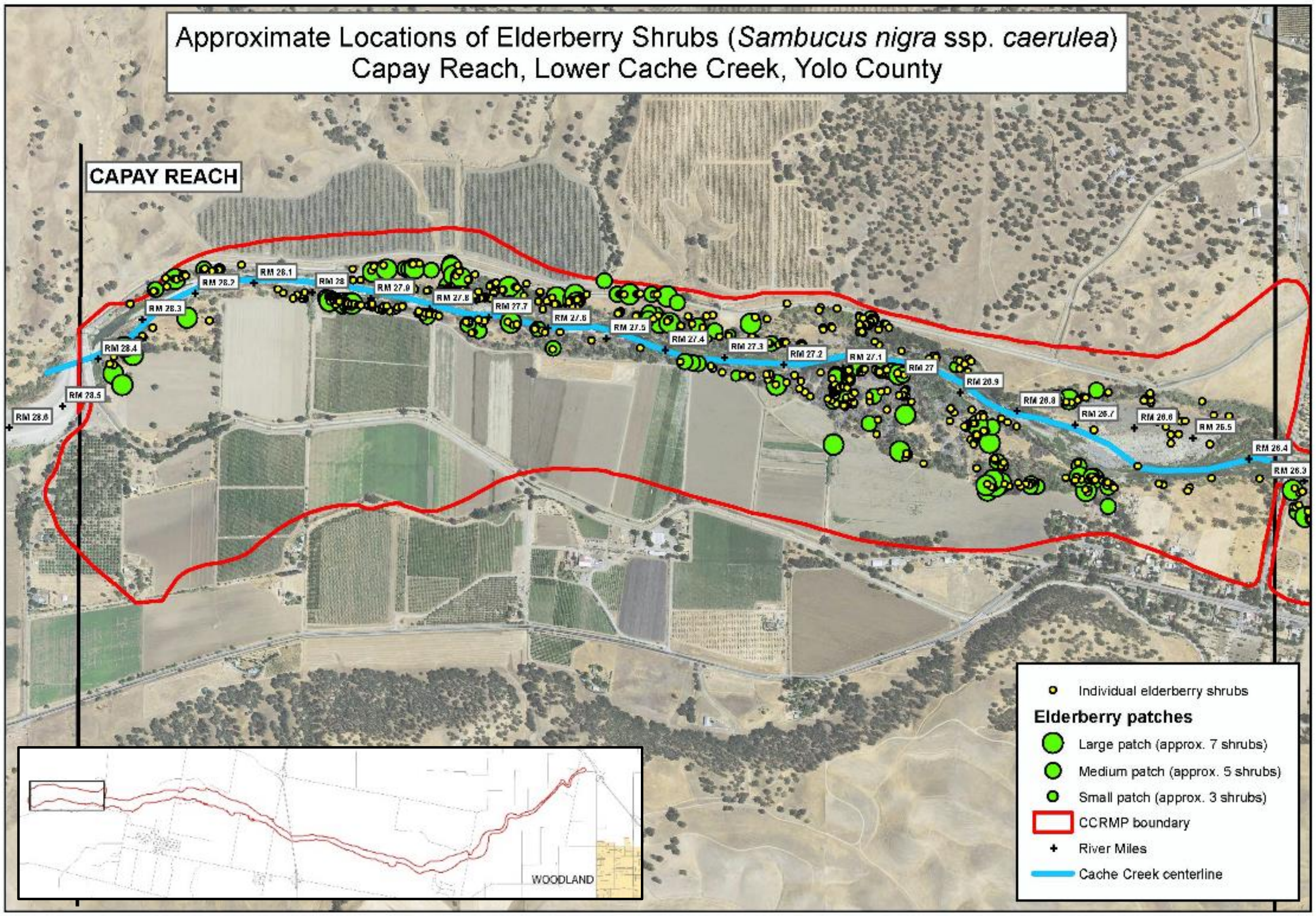
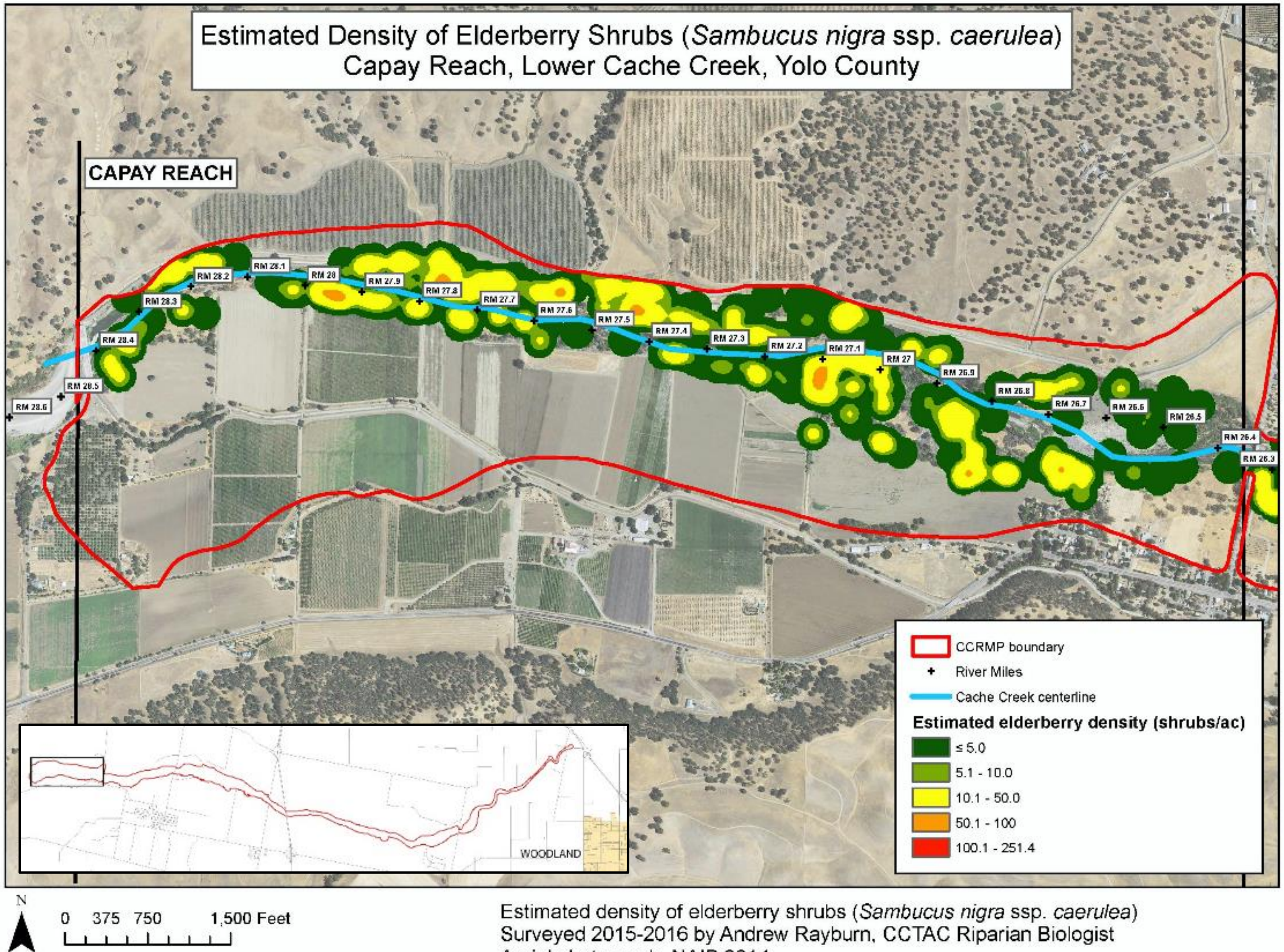
Appendices

Appendix 1. Distribution (points and patches) and estimated density of blue elderberry by reach.

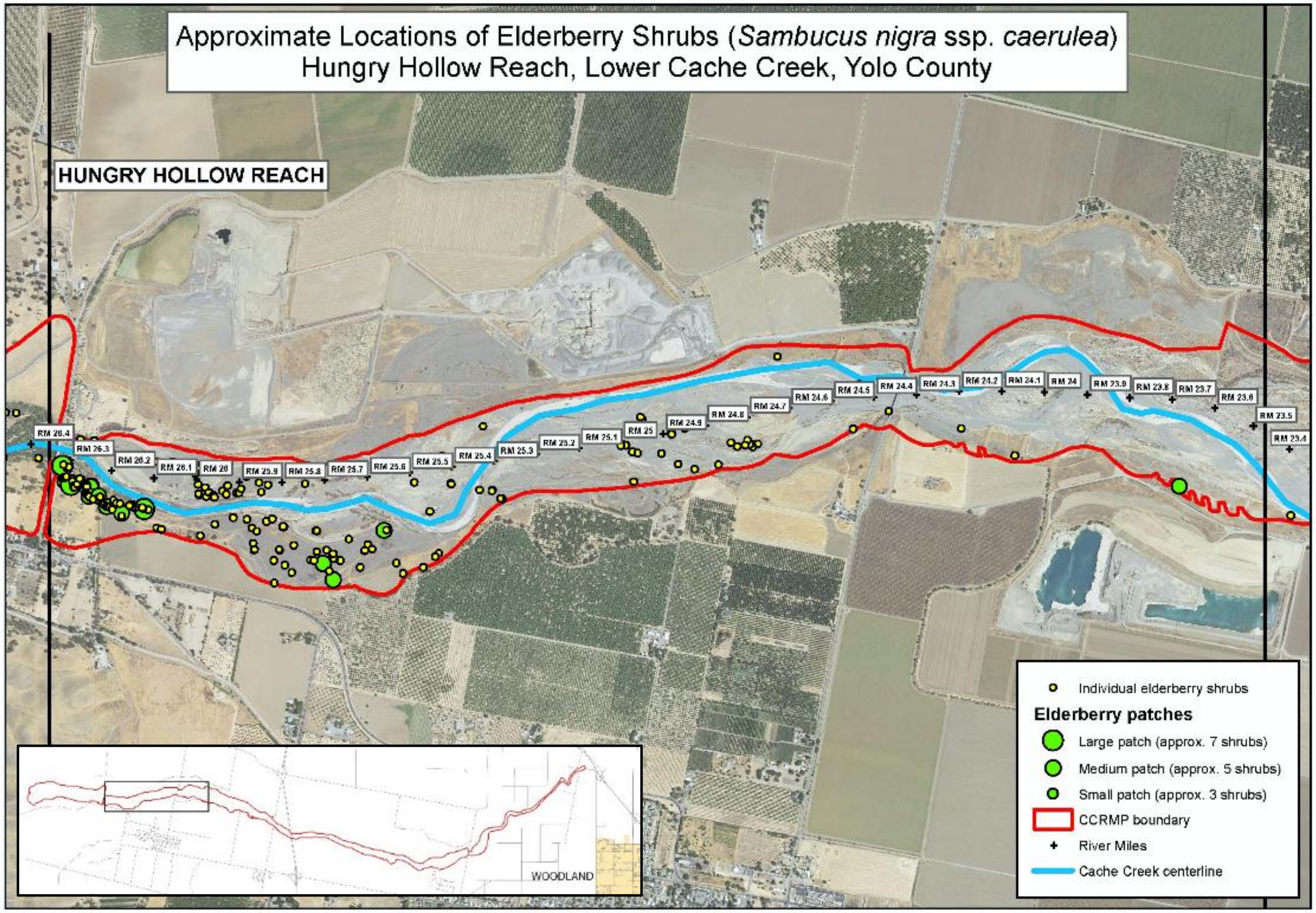


N
0 375 750 1,500 Feet

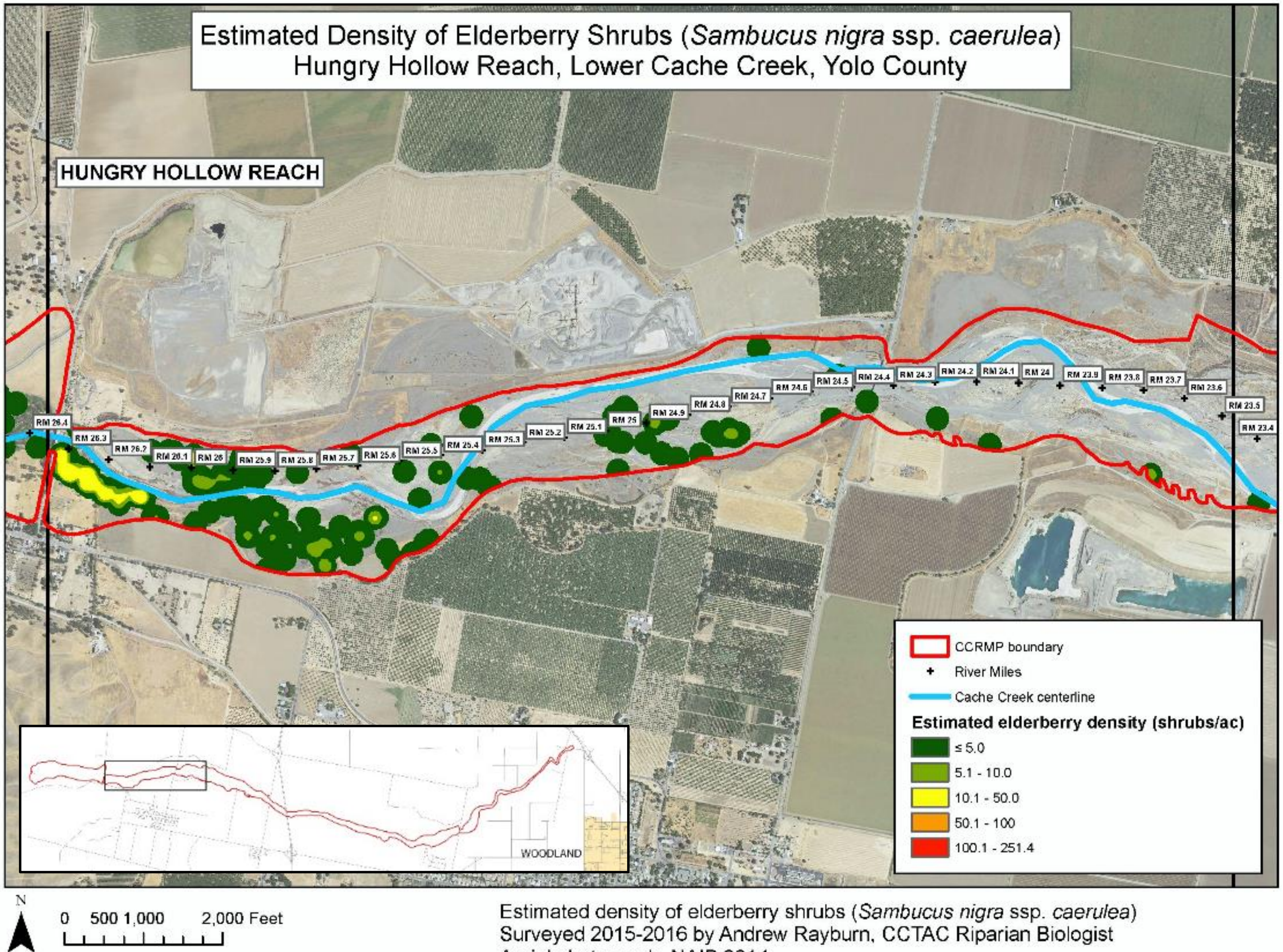
Approximate locations of elderberry shrubs (*Sambucus nigra* ssp. *caerulea*)
Surveyed 2015-2016 by Andrew Rayburn, CCTAC Riparian Biologist
Aerial photograph: NAIP 2014



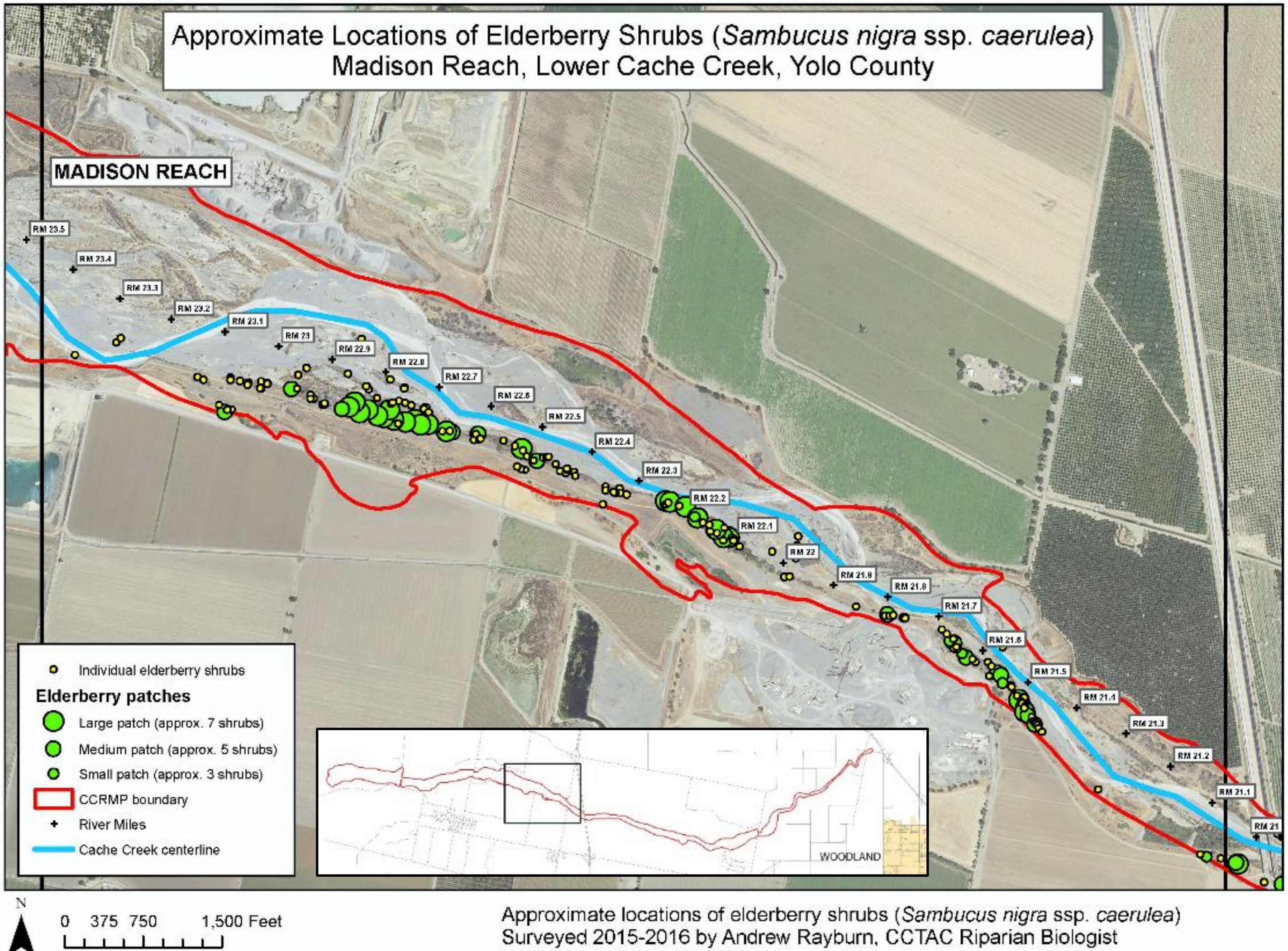
Estimated density of elderberry shrubs (*Sambucus nigra* ssp. *caerulea*)
Surveyed 2015-2016 by Andrew Rayburn, CCTAC Riparian Biologist
Aerial photograph: NAIP 2014



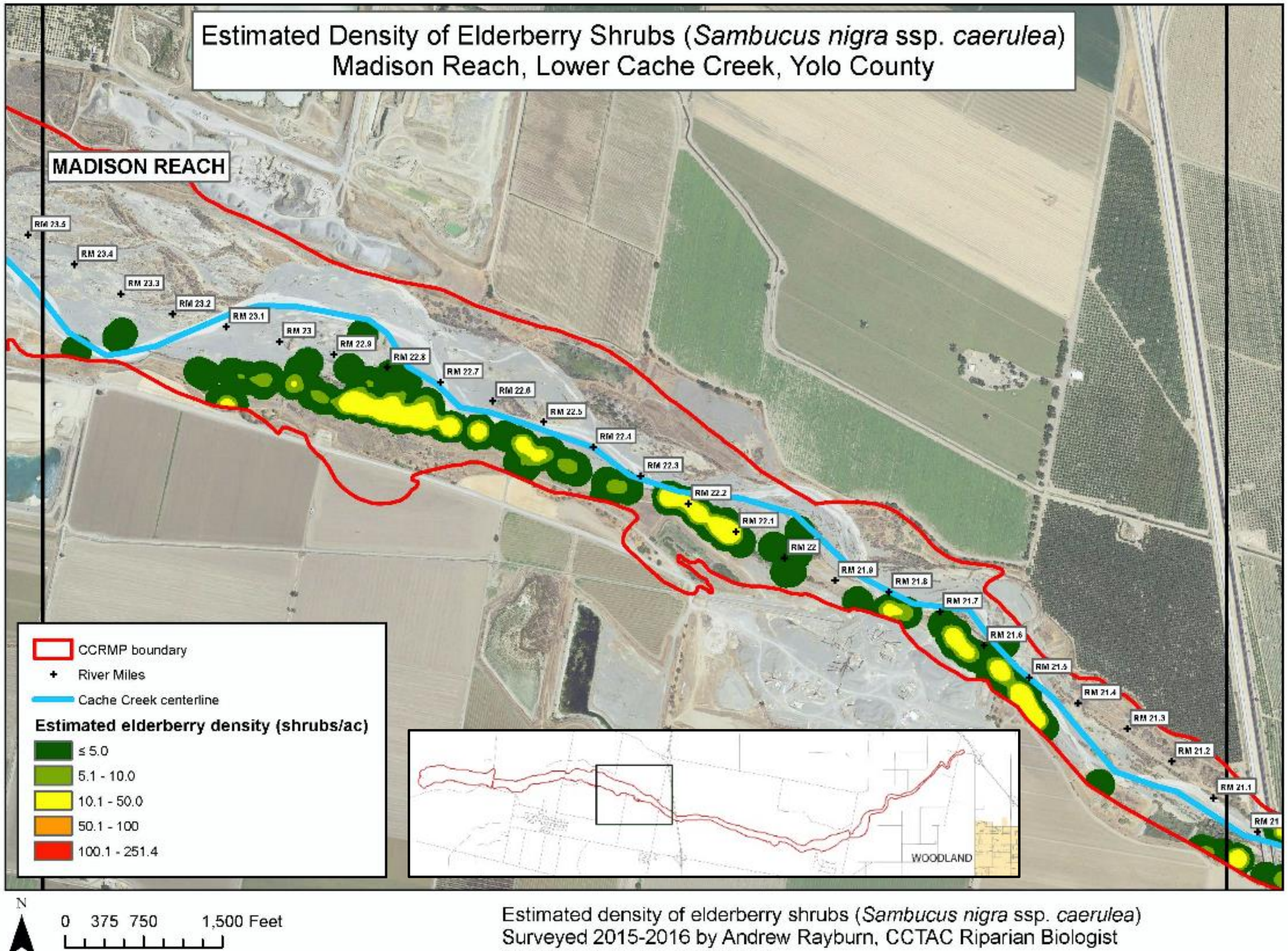
Approximate locations of elderberry shrubs (*Sambucus nigra* ssp. *caerulea*)
Surveyed 2015-2016 by Andrew Rayburn, CCTAC Riparian Biologist
Aerial photograph: NAIP 2014



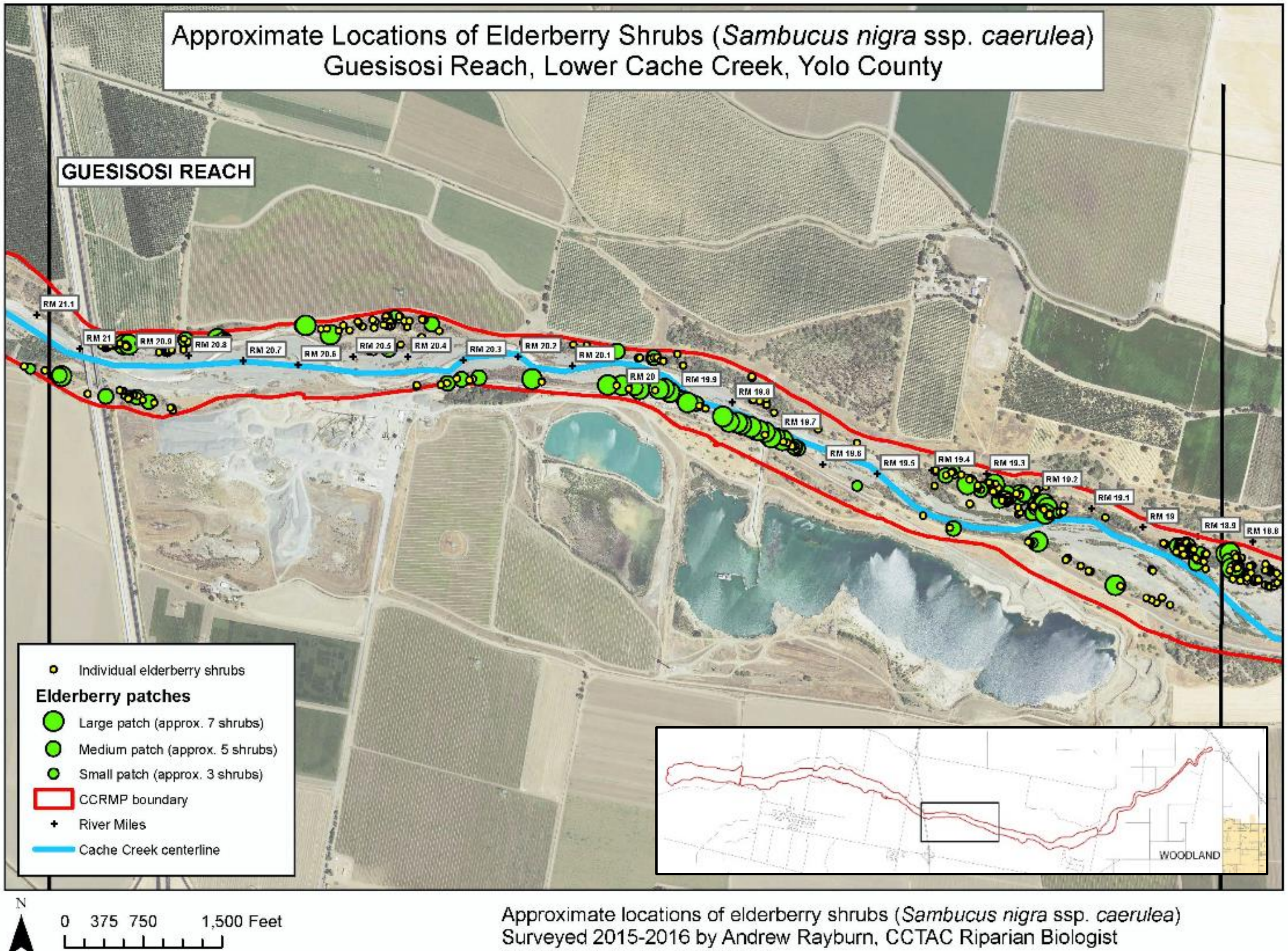
Estimated density of elderberry shrubs (*Sambucus nigra* ssp. *caerulea*)
Surveyed 2015-2016 by Andrew Rayburn, CCTAC Riparian Biologist
Aerial photograph: NAIP 2014



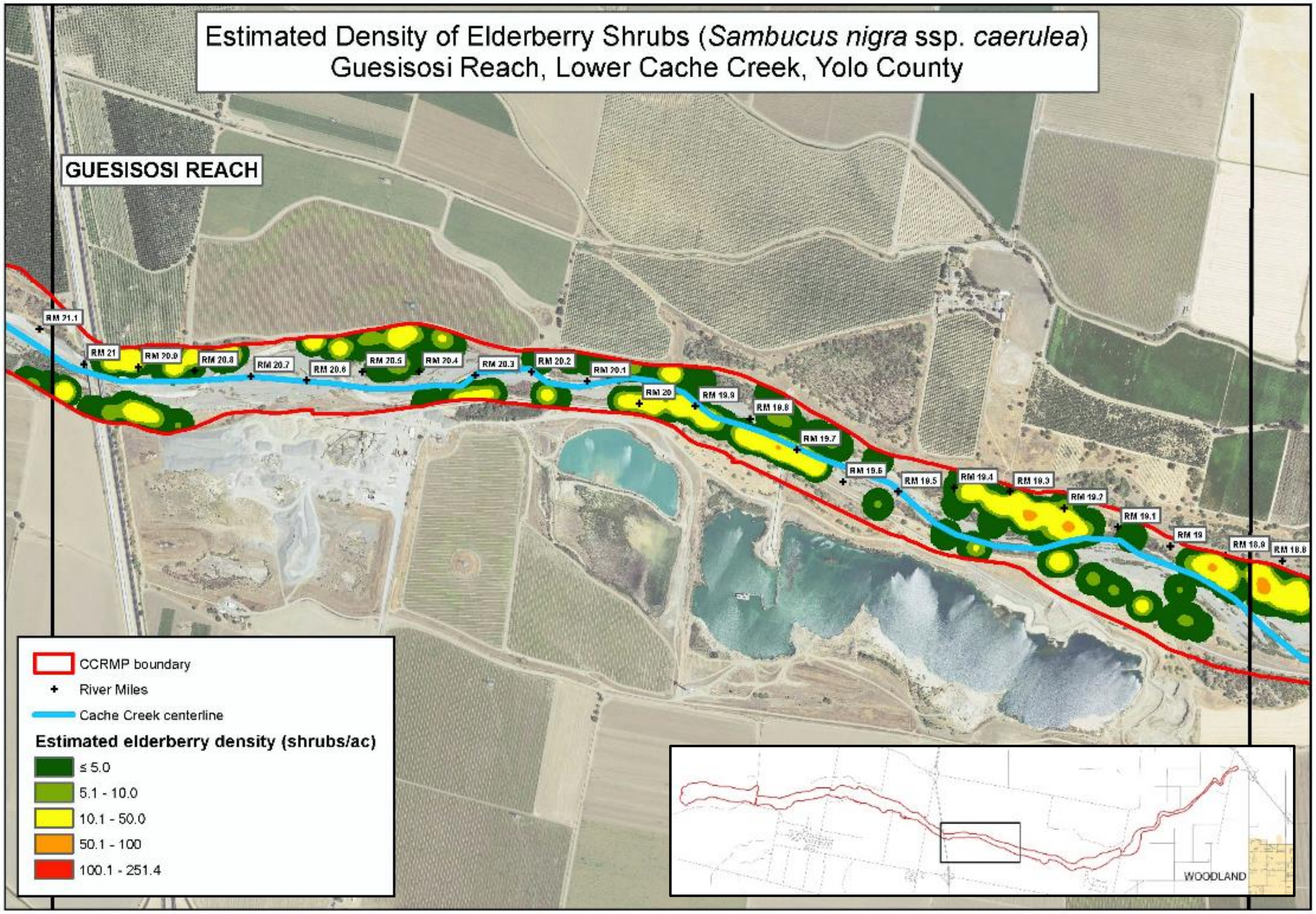
Approximate locations of elderberry shrubs (*Sambucus nigra* ssp. *caerulea*)
Surveyed 2015-2016 by Andrew Rayburn, CCTAC Riparian Biologist
Aerial photograph: NAIP 2014



Estimated density of elderberry shrubs (*Sambucus nigra* ssp. *caerulea*)
Surveyed 2015-2016 by Andrew Rayburn, CCTAC Riparian Biologist
Aerial photograph: NAIP 2014



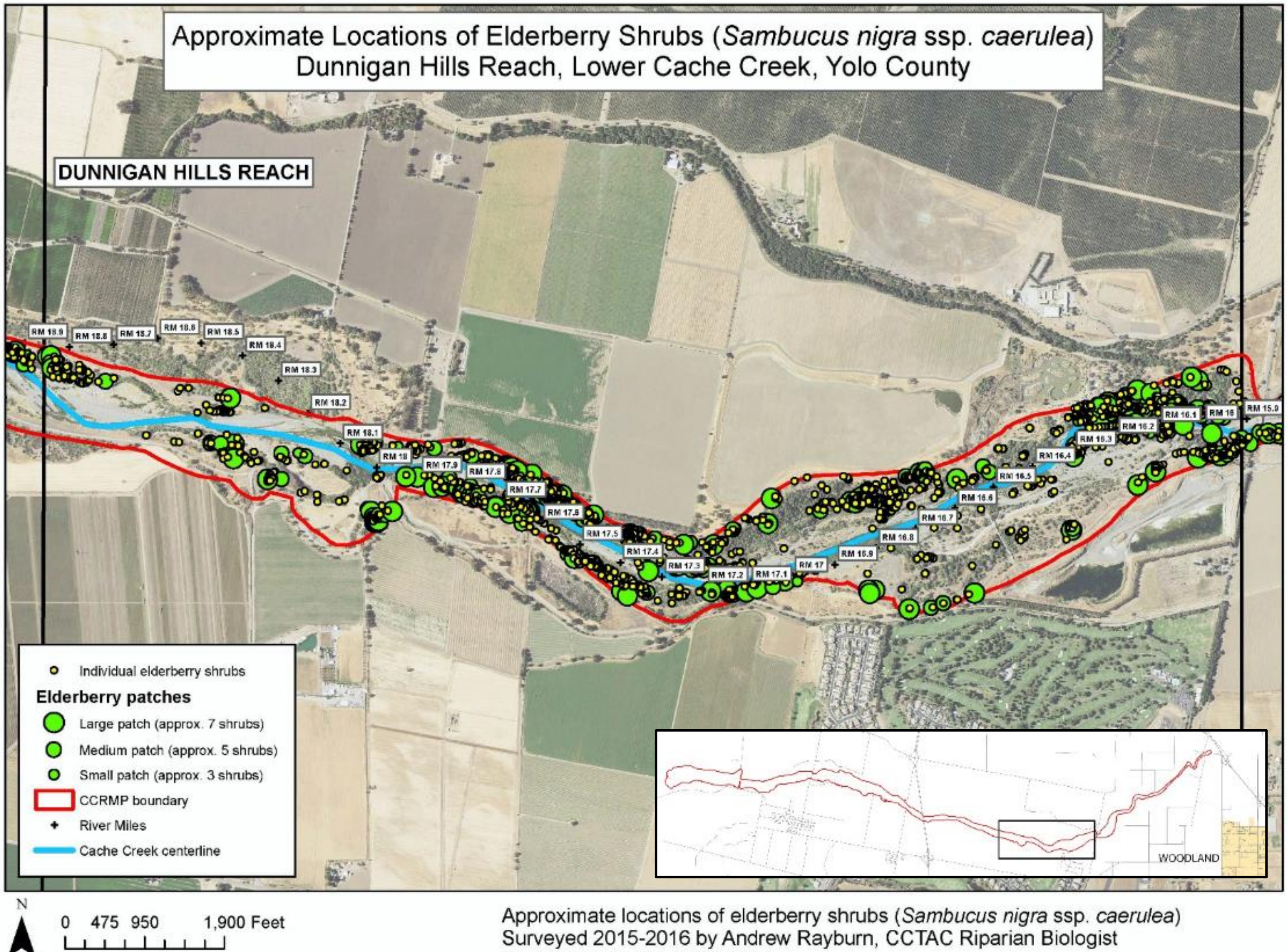
Approximate locations of elderberry shrubs (*Sambucus nigra* ssp. *caerulea*)
Surveyed 2015-2016 by Andrew Rayburn, CCTAC Riparian Biologist
Aerial photograph: NAIP 2014



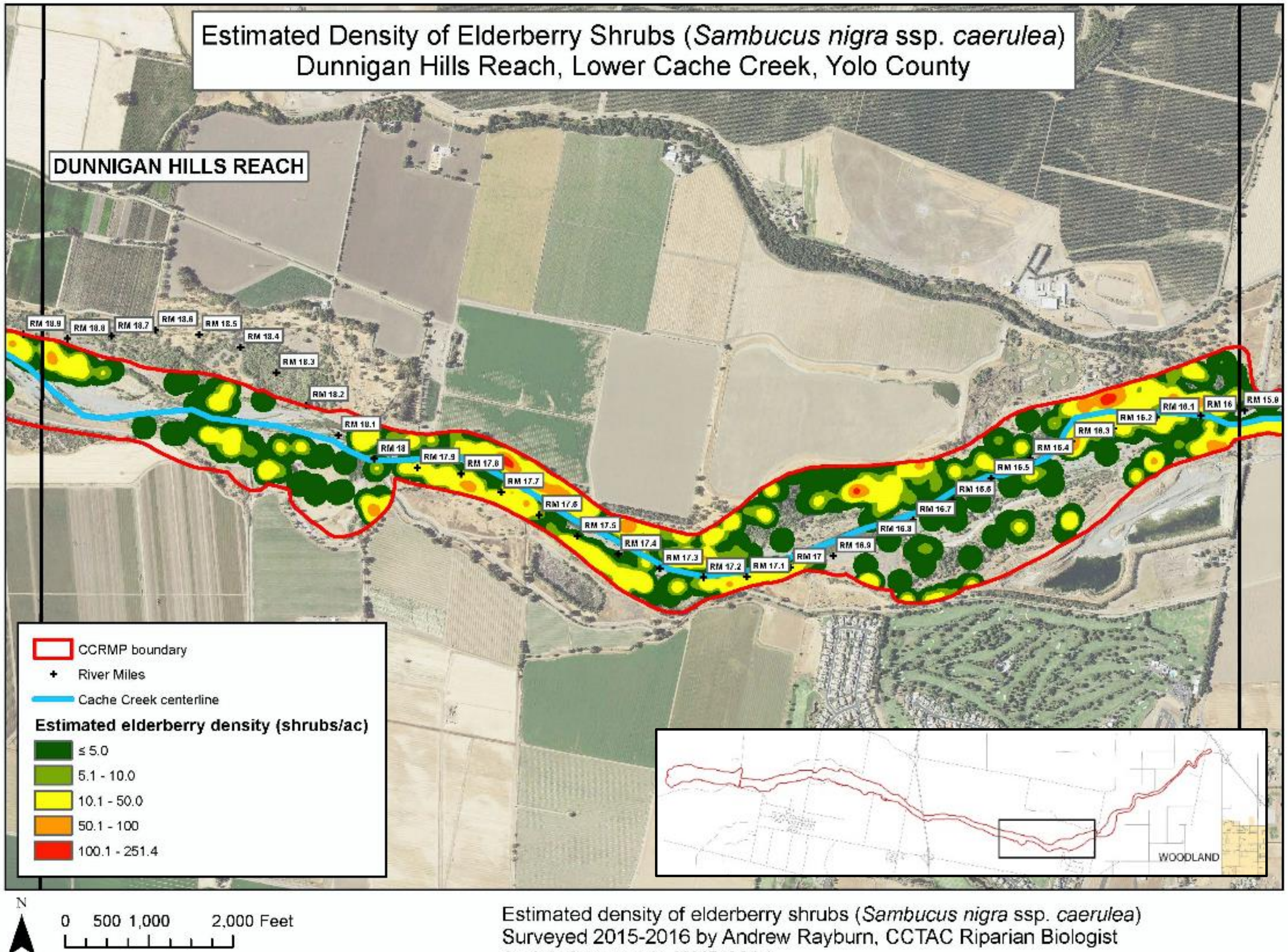
N

0 375 750 1,500 Feet

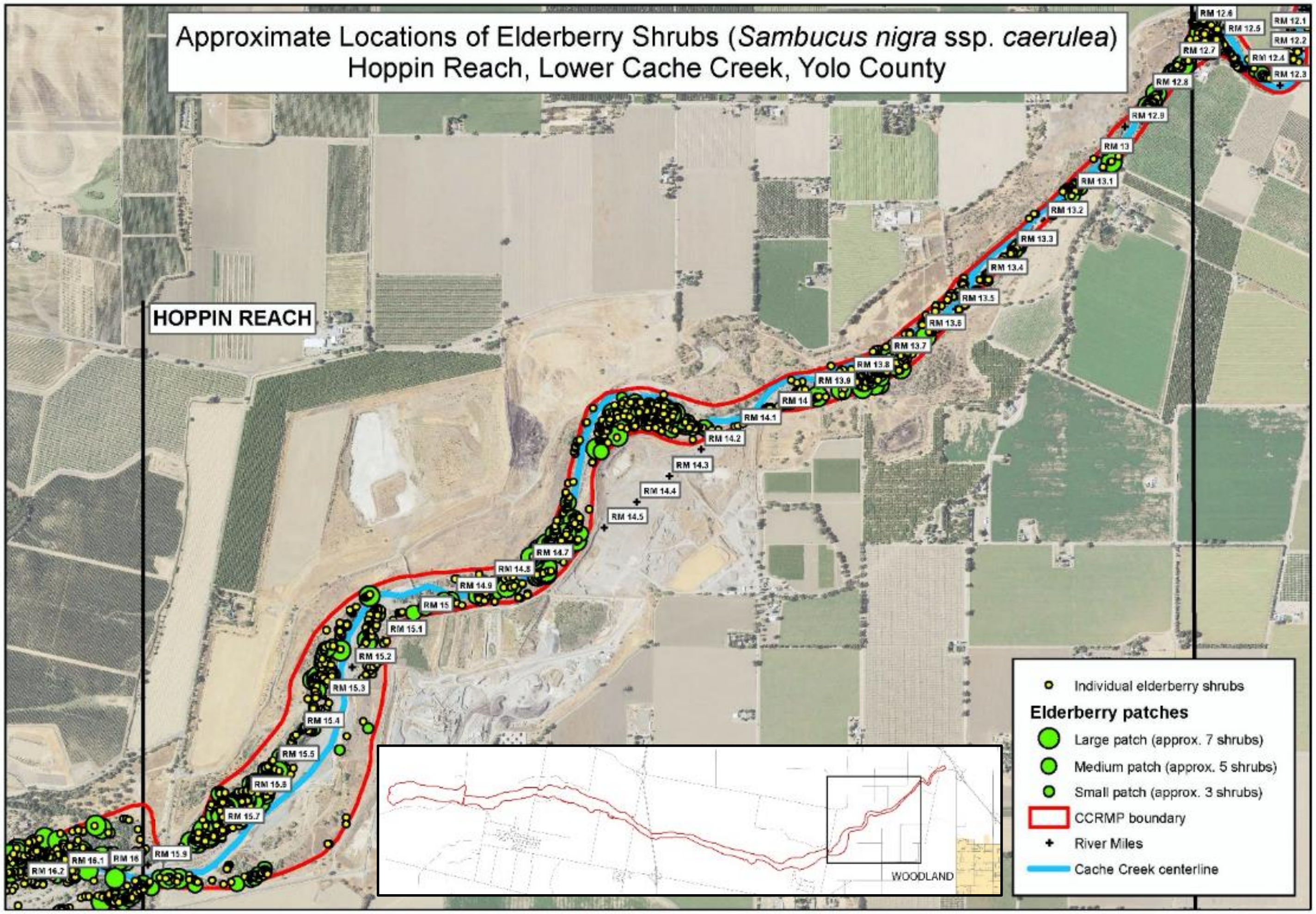
Estimated density of elderberry shrubs (*Sambucus nigra* ssp. *caerulea*)
Surveyed 2015-2016 by Andrew Rayburn, CCTAC Riparian Biologist
Aerial photograph: NAIP 2014



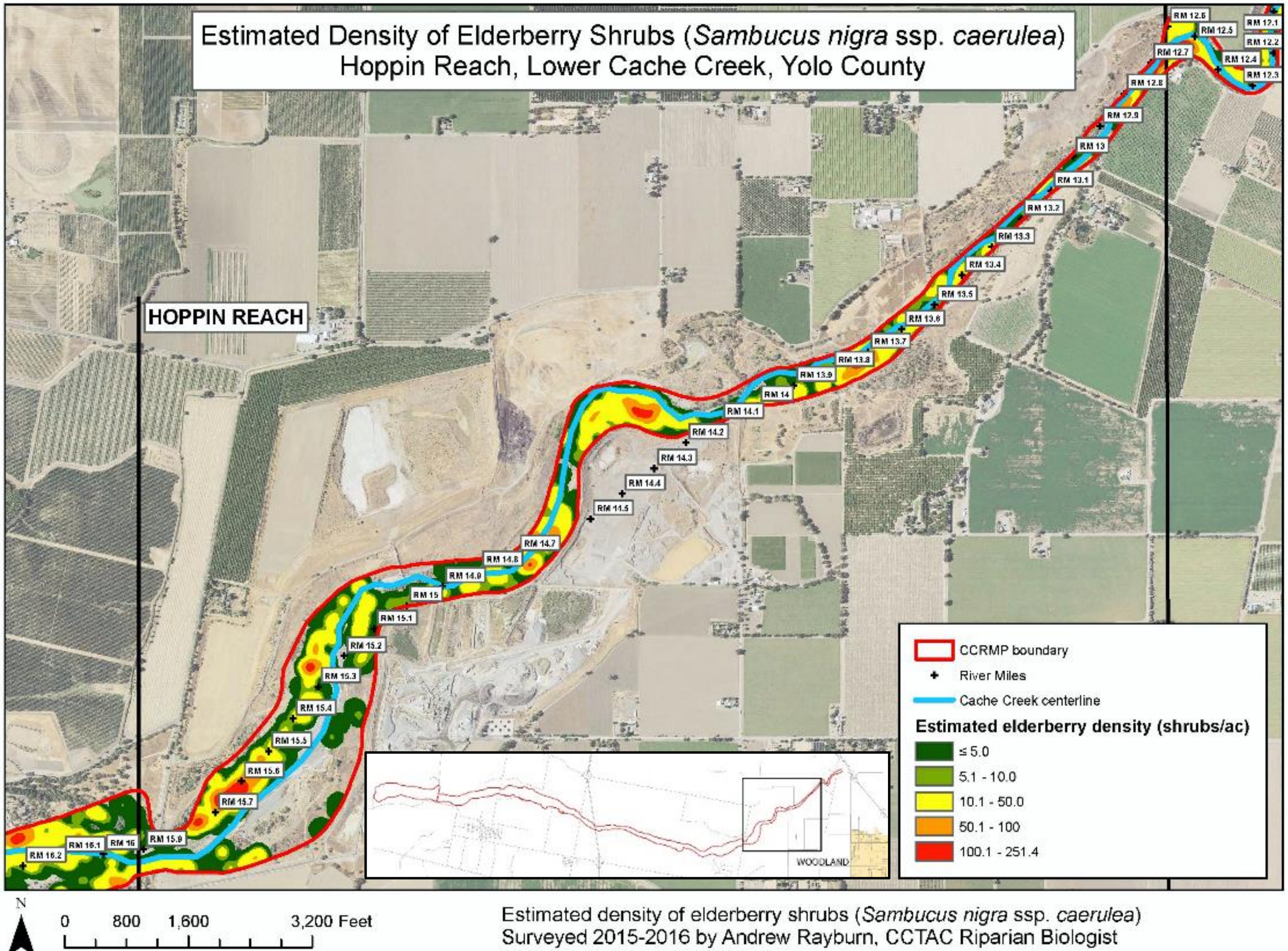
Approximate locations of elderberry shrubs (*Sambucus nigra* ssp. *caerulea*)
Surveyed 2015-2016 by Andrew Rayburn, CCTAC Riparian Biologist
Aerial photograph: NAIP 2014



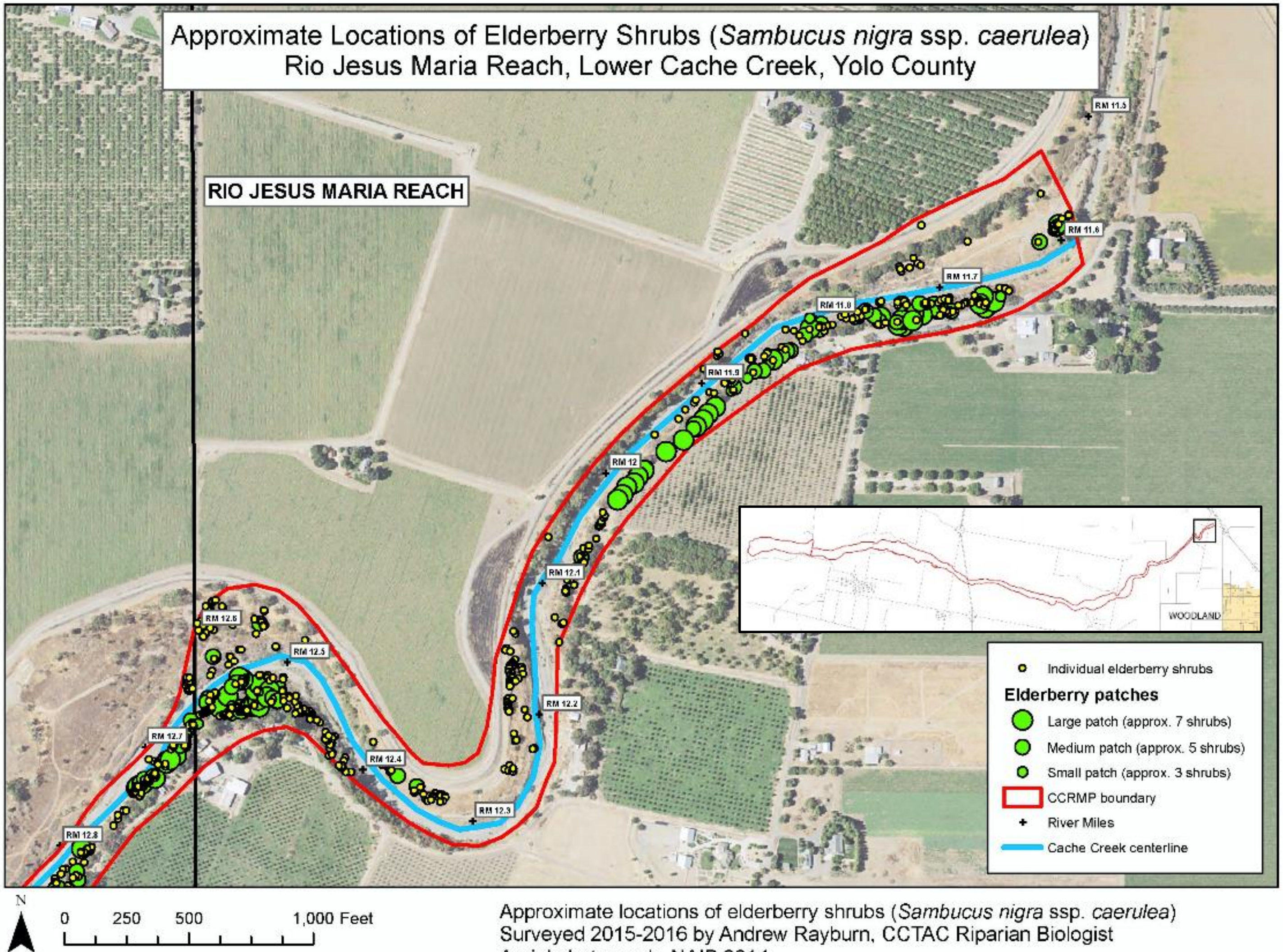
Estimated density of elderberry shrubs (*Sambucus nigra* ssp. *caerulea*)
Surveyed 2015-2016 by Andrew Rayburn, CCTAC Riparian Biologist
Aerial photograph: NAIP 2014



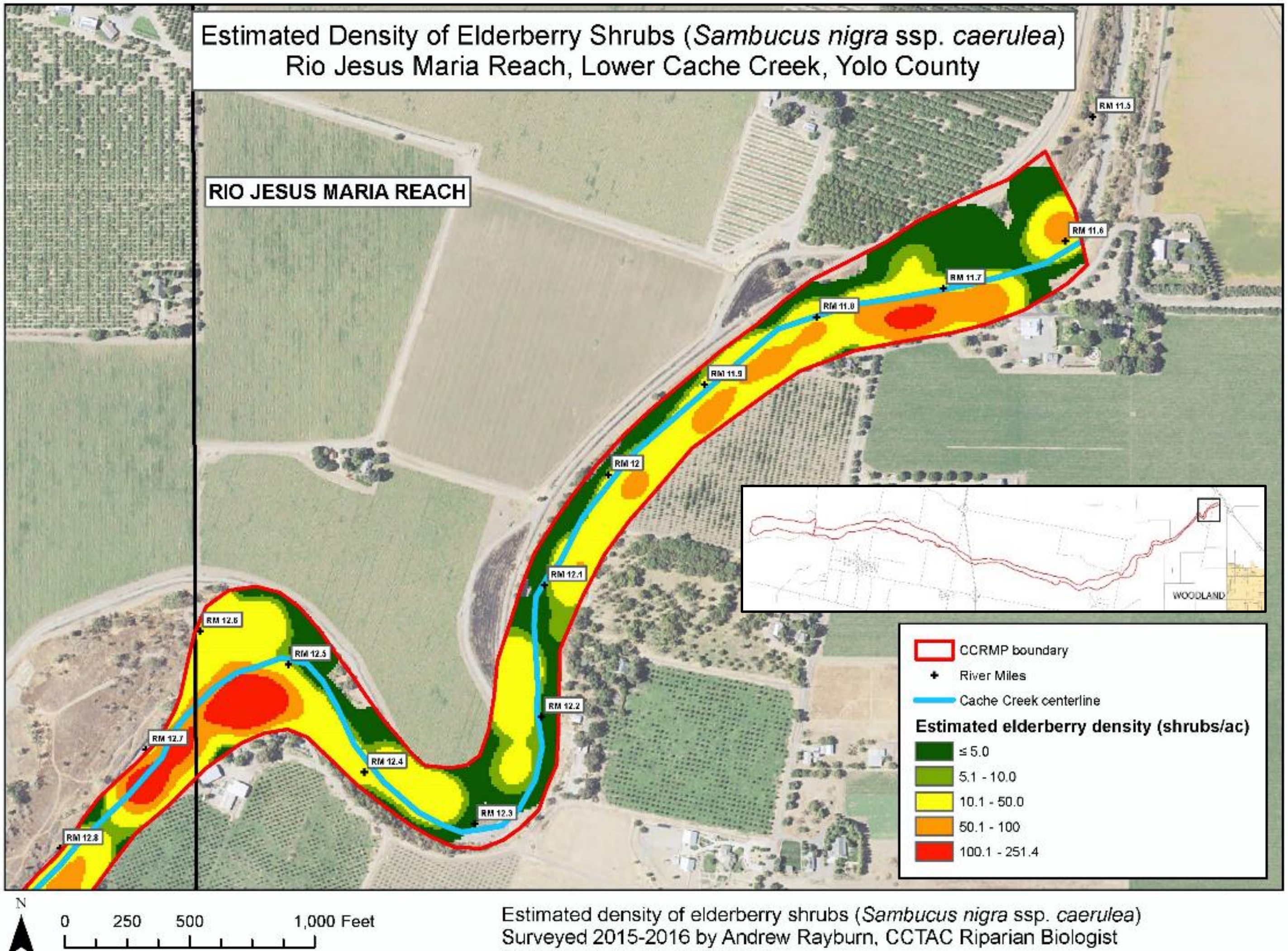
Approximate locations of elderberry shrubs (*Sambucus nigra* ssp. *caerulea*)
Surveyed 2015-2016 by Andrew Rayburn, CCTAC Riparian Biologist
Aerial photograph: NAIP 2014



Estimated density of elderberry shrubs (*Sambucus nigra* ssp. *caerulea*)
Surveyed 2015-2016 by Andrew Rayburn, CCTAC Riparian Biologist
Aerial photograph: NAIP 2014

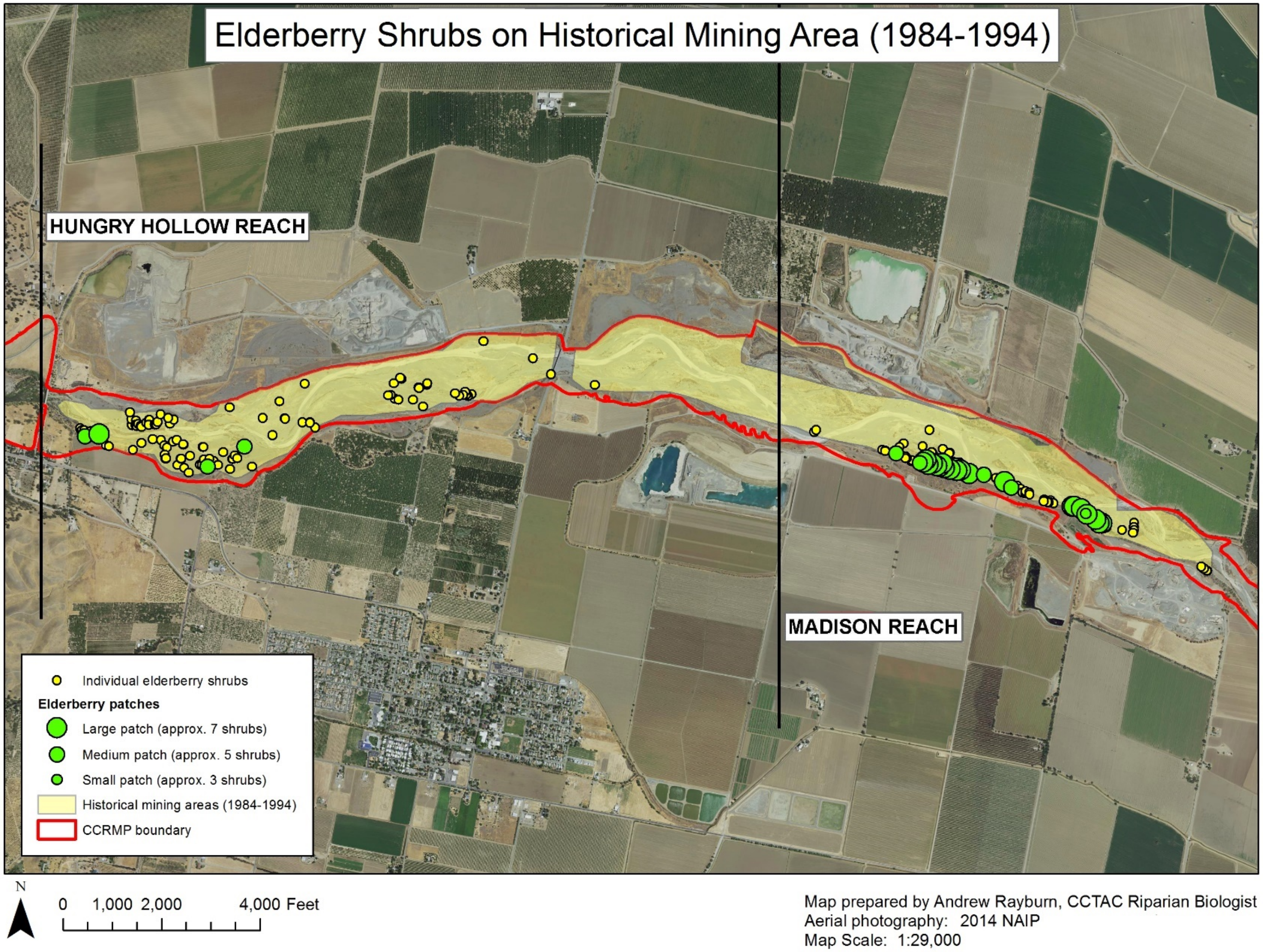


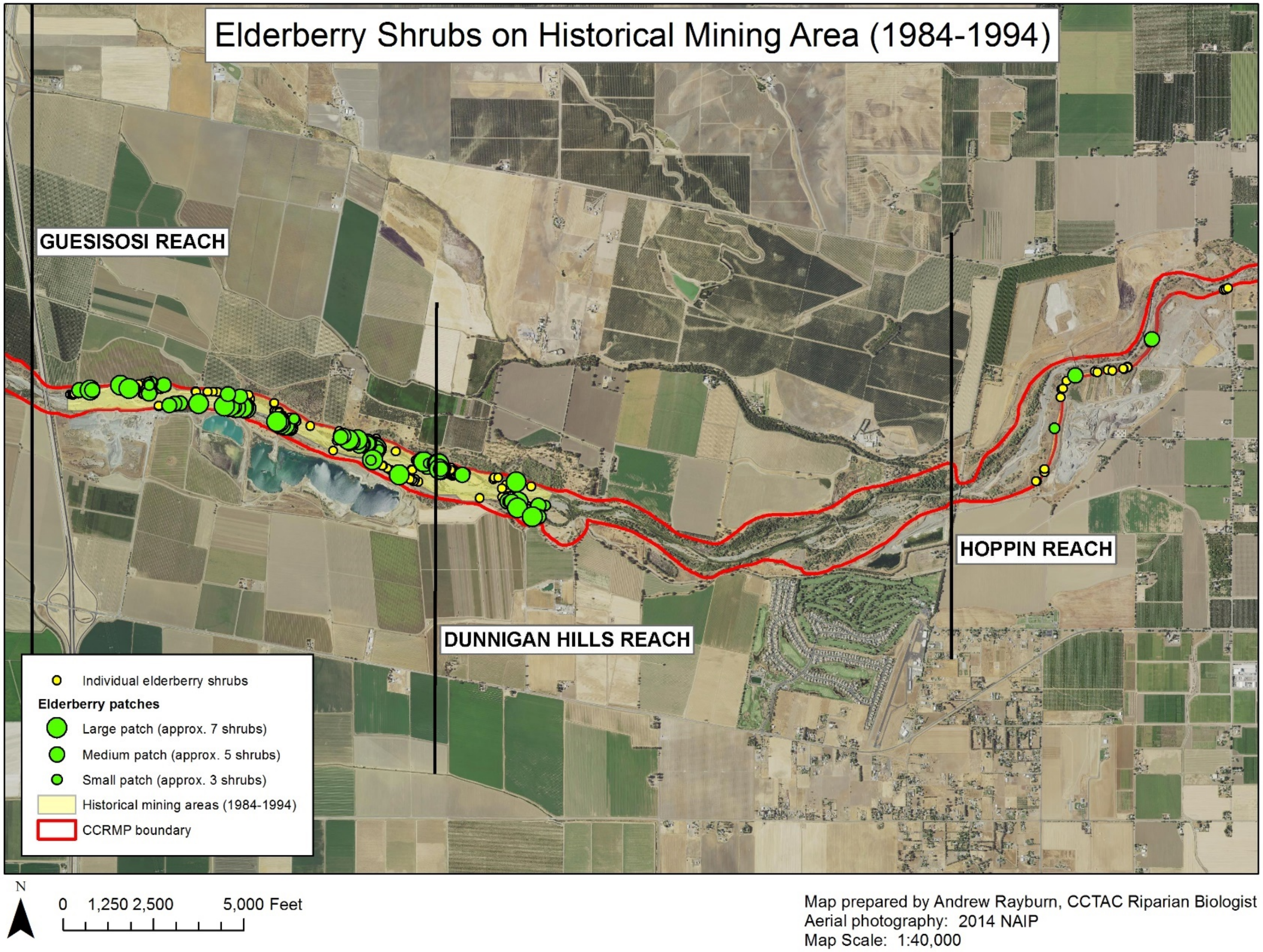
Approximate locations of elderberry shrubs (*Sambucus nigra* ssp. *caerulea*)
Surveyed 2015-2016 by Andrew Rayburn, CCTAC Riparian Biologist
Aerial photograph: NAIP 2014



Estimated density of elderberry shrubs (*Sambucus nigra* ssp. *caerulea*)
Surveyed 2015-2016 by Andrew Rayburn, CCTAC Riparian Biologist
Aerial photograph: NAIP 2014

Appendix 2. Elderberry shrubs (2015–2016) on historically-mined areas (1984–1994) within the CCRMP.




Elderberry Shrubs on Historical Mining Area (1984-1994)
GUESISOSI REACH
DUNNIGAN HILLS REACH
HOPPIN REACH
Individual elderberry shrubs
Elderberry patches
Large patch (approx. 7 shrubs)
Medium patch (approx. 5 shrubs)
Small patch (approx. 3 shrubs)
Historical mining areas (1984-1994)
CCRMP boundary
N
0 1,250 2,500 5,000 Feet
Map prepared by Andrew Rayburn, CCTAC Riparian Biologist
Aerial photography: 2014 NAIP
Map Scale: 1:40,000

Appendix 3. Statistical analysis of elderberry distribution relative to slope, aspect, and associated vegetation (methods and results).

Methods

For associated vegetation, slope, and aspect, the number of individual plants observed versus that expected by the percentage of the study area in each variable class (five vegetation classes, five slope classes, and eight aspect classes) were analyzed using G-tests of goodness of fit (α=0.05). Additional post hoc G-tests using Bonferroni corrections were performed to determine which specific variable classes deviated significantly from expected values; after correction for the number of comparisons, significance levels used for testing were: $\alpha_{vegetation}$=0.01, α_{slope}=0.01, α_{aspect}=0.0071. This analysis was not conducted for counts of observed versus expected shrubs in the floodplain inundation zones, since observations were not independent (e.g., a shrub occurring within the 10-yr. inundation zone also occurred within the 5-yr. and 2-yr. inundation zones). In addition, this analysis was not performed for elderberry patches, since both the locations and number of individuals within each patch were only approximated in the field.

Results

Distribution Relative to Slope and Aspect

The null hypothesis that the number of individual elderberry plants in each slope class would be equal to the amount of the study area in each class was rejected (P<0.0001; Table A1), suggesting a non-random distribution of elderberry shrubs relative to slope. Most elderberry plants (69.1%) occurred on low-slope areas (0–10°), which represented 85.5% of the total study area. However, there was a lower number of individual plants that expected based on the percentage of the study area in this slope class (P<0.0001; Table A1). For the four other slope classes, a significantly higher number of plants were observed than based on the percentage of the study area in each slope class (P<0.0001 in all cases; see Table A1). More individual plants were observed in the 10–20° class (816) than in the remaining three classes combined, and only 291 plants were observed on the steepest slopes (>30°). Similar results were observed in terms of elderberry patches, with 67.7% of patches observed on low-slope areas and only 7.6% of patches observed on slopes greater than 30°.

In terms of aspect, the null hypothesis that the number of individual elderberry plants in each aspect class would be equal to the amount of the study area in each class was also rejected ($P<0.0001$; Table A1), suggesting a non-random distribution of elderberry shrubs relative to aspect. However, results varied widely across the eight aspect classes in terms of significant deviations of observed shrub counts versus expected based on the amount of the study area in each class (Table A1). For example, more shrubs were observed than expected on northwestern- and western-facing aspects ($P<0.001$ for both), but fewer than expected on northeastern-, eastern-, southern-, and southwestern-facing slopes ($P<0.001$ for all comparisons; Table A1). Almost half (48.8%) of individual shrubs occurred on more northerly-facing areas (NW, N, NE), while 36.1% occurred on more southerly-facing areas (SW, S, SE). A similar pattern was observed for patches, as 50.7% occurred on northerly-facing areas and 34.5% occurred on southerly-facing areas.

Distribution Relative to Associated Vegetation

As with slope and aspect, the null hypothesis that the number of individual elderberry plants in each vegetation class would be equal to the amount of the study area in each class was rejected ($P<0.0001$; Table A1), suggesting a non-random distribution of elderberry shrubs relative to associated vegetation. Field observations suggested that elderberry shrubs were most often found growing within patches of riparian forest and dense scrub in association with other native woody riparian species including Fremont cottonwood (*Populus fremontii*), black walnut (*Juglans hindsii*), Valley oak (*Quercus lobata*), California buckeye (*Aesculus californica*), and willow species such as black willow (*Salix nigra*). For both riparian forest and dense scrub vegetation classes, analysis revealed that almost four times as many elderberry plants (68.2%) were observed than might be expected based on the amount of each class across the study area ($P<0.0001$ for both; Table A1). Conversely, approximately four times fewer shrubs were observed on bare ground (9.5%) than would be expected based on percentage of bare ground (57.8%) in the study area ($P<0.0001$; Table A1). Fewer individual shrubs (19.9%) were also observed in herbaceous vegetation than expected; however, this difference was only marginally significant after correcting for multiple comparisons ($P=0.022$; Table A1). A similar pattern was observed in terms of elderberry patches, as 81.4% of patches were observed in association with either riparian forest (45.8%) or dense scrub (35.5%) vegetation while only 13.5% and 4.2% of patches were observed in herbaceous vegetation and on bare ground respectively.

Table A1. Summary of results of statistical analysis. G-tests of goodness of fit, with Bonferroni adjustments for multiple comparisons implemented for pairwise tests for specific classes within variables. See *Materials* for details.

Variable	% Study Area	Observed	Expected[1]	G	P[2]
Slope					
Overall		-	-	928.8	***<0.0001***
0-10°	85.5	3254	4024.74	809.7	***<0.0001***
10-20°	9.0	816	424.08	321.26	***<0.0001***
20-30°	3.2	351	150.78	201.63	***<0.0001***
30-40°	1.4	191	65.97	159.44	***<0.0001***
>40°	0.5	100	23.56	137.50	***<0.0001***
Vegetation					
Overall	-	-	-	6617.93	***<0.0001***
Riparian forest	11.3	1930	532.46	2706.09	***<0.0001***
Dense scrub	7.3	1286	343.98	1727.28	***<0.0001***
Scattered scrub	2.2	107	103.66	0.109	0.74
Herbaceous	21.3	940	1003.66	5.212	0.022
Bare ground	57.8	449	1988.46	2483.7	***<0.0001***
Aspect					
Overall	-	-	-	2922.34	***<0.0001***
NW (292.5-337.5°)	*10.5*	794	494.76	174.42	***<0.0001***
N (337.5-22.5°)	*18.7*	924	881.14	2.53	0.11
NE (22.5-67.5°)	*14.0*	581	659.68	11.3	***0.00078***
E (67.5-112.5°)	*9.3*	331	438.22	31.35	***<0.0001***
SE (112.5-157.5°)	*11.9*	545	560.73	0.51	0.48
S (157.5-202.5°)	*18.1*	737	852.87	19.95	***<0.0001***
SW (202.5-247.5°)	*11.0*	419	518.32	22.71	***<0.0001***
W (247.5-292.5°)	*6.7*	381	315.7	13.63	***0.00022***

[1]Expected values based on percentage of study area in each variable class

[2]After corrections for multiple comparisons, P values used as basis for statistical significance were: 0.01 (slope and vegetation) and 0.007 (aspect)