ASSESSMENT OF RIPARIAN VEGETATION AND HYDROLOGIC CONDITIONS WITHIN THE SAN PEDRO RIPARIAN NATIONAL CONSERVATION AREA IN 2023

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EXECUTIVE SUMMARY

Purpose: The purpose of this project was to characterize riparian vegetation condition (**Figure A1**), as quantified through an assessment model, across the San Pedro Riparian National Conservation Area (SPRNCA) and relate riparian health to hydrologic conditions (flow permanence, groundwater depth and variation). Findings will provide a baseline for assessing future trends in riparian ecosystem condition and system hydrology to inform future land and water management decisions in the San Pedro basin.

Methods: From May-July 2023 we collected riparian vegetation data at 25 study sites across the 14 reaches of the SPRNCA using methods described in Lite (2003) and Stromberg et al. (2006a,b). Sampling consisted of characterizing (1) herbaceous wetland vegetation in 1m x 1m quadrats in the streamside zone and (2) floodplain vegetation composition and structure along cross-floodplain transects. The streamside plot sampling was used to collect data for bioindicators 6-9 in the riparian assessment model, whereas the floodplain transect sampling was used to collect data for bioindicators 1-5 (**Table A1**). Based on scores assigned to different values of the bioindicator values, we classified sites and reaches into three different condition classes: wet (class 3), intermediate (class 2), and dry (class 1) (**Figure A1**).

We compiled recent hydrologic data for sites and reaches within the SPRNCA from several sources, including groundwater and flow permanence data from the San Pedro Web-based Hydrologic Information Portal (WHIP, https://uppersanpedrowhip.org/), flow data from USGS streamflow gaging stations, and June wet-dry mapping data from The Nature Conservancy of Arizona. These hydrologic data were summarized relative to the condition class assigned by the vegetation bioindicator values.

Findings: Fremont cottonwood was the most frequent woody dominant species in the floodplain. Most cottonwood and willow patches are composed of older trees, with very few young patches, suggesting that little recruitment of new forests has occurred in the last 30 years or more. Terrace patches were predominantly covered by patches dominated by velvet mesquite (56%) or non-woody species (33%), with coverage of mesquite increasing from upstream to downstream. Signs of recent cattle presence were ubiquitous across the SPRNCA, occurring on 20 of the 25 study sites.

The riparian assessment model, based on the nine vegetation bioindicators, scored thirteen of the 25 sites in the SPRNCA as condition class 3 (wet) and twelve as condition class 2 (intermediate). At the reach-level, five reaches were classified as wet and eight as intermediate (**Figure A2**). We did not assign a condition class to reach 14. No sites or reaches were classified as condition class 1 (dry). Lewis Springs, on reach 5, that had a lower than expected condition class, based on the vegetation bioindicators, and has shown some signs of decreased wetted river length in the annual June wet-dry mapping. Differences between our findings and previous work may be affected, in part, by maturation of the vegetation and slight differences in field methods. Summaries of hydrologic conditions (groundwater, flow permanence) by 2023 condition class designations are shown in **Table A2**, and percentage of each reach with surface water in June of 2022 and 2023 is shown in **Figure A3**.

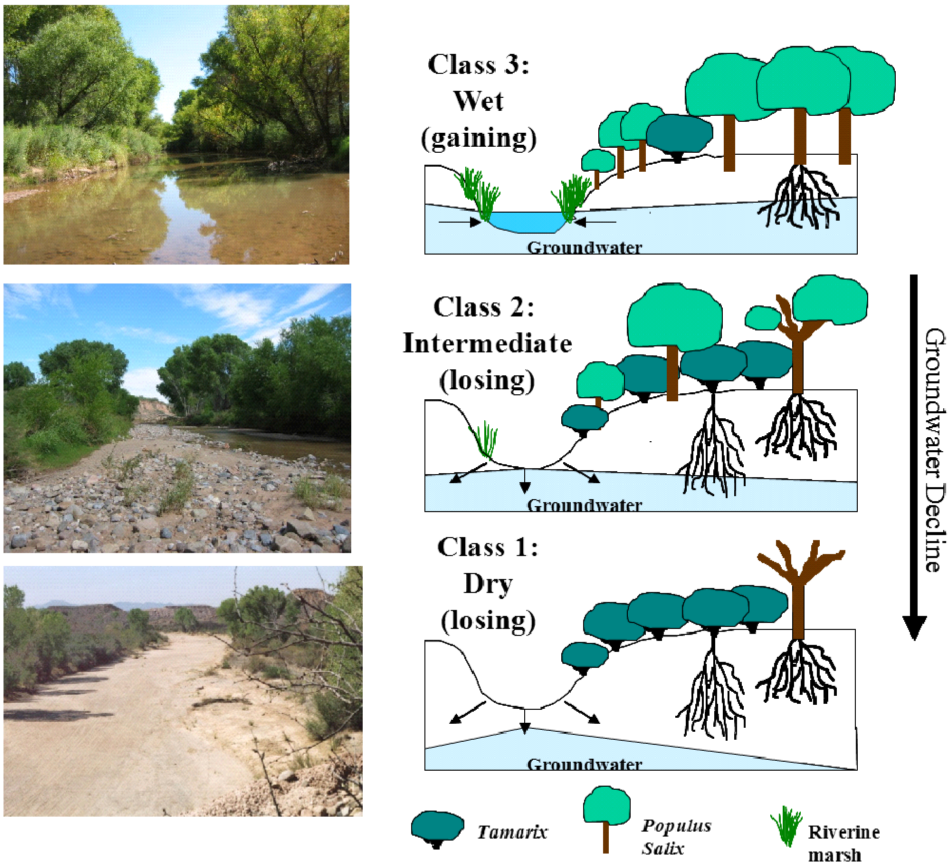

Figure A1. Schematic and site photographs of condition classes from the riparian assessment model.

Table A1. Bioindicators for riparian assessment model (Stromberg et al. 2006a,b).

		Score			
Bioind. #	**Bioindicator variable**	**1**	**1.5**	**2.5**	**3**
1	# 10-cm Cottonwood + Willow size classes in floodplain	≤ 3		> 3	
2	Cottonwood + Willow basal area (m^2/ha)	≤ 4.7		> 4.7	
3	Cottonwood + Willow relative basal area (%)	≤ 21		> 21	
4	Maximum vegetation height in floodplain (m)	≤ 15		> 15	
5	Relative (%) coverage of shrubland patches in floodplain	≥ 35		< 35	
6	Absolute cover of streamside hydric perennial herbs (%)		≤ 5		> 5
7	Relative cover of streamside hydric perennial herbs (%)		≤ 14		> 14
8	Absolute cover of streamside hydric herbs (%)		≤ 29		> 29
9	Relative cover of streamside hydric herbs (%)		≤ 24		> 24

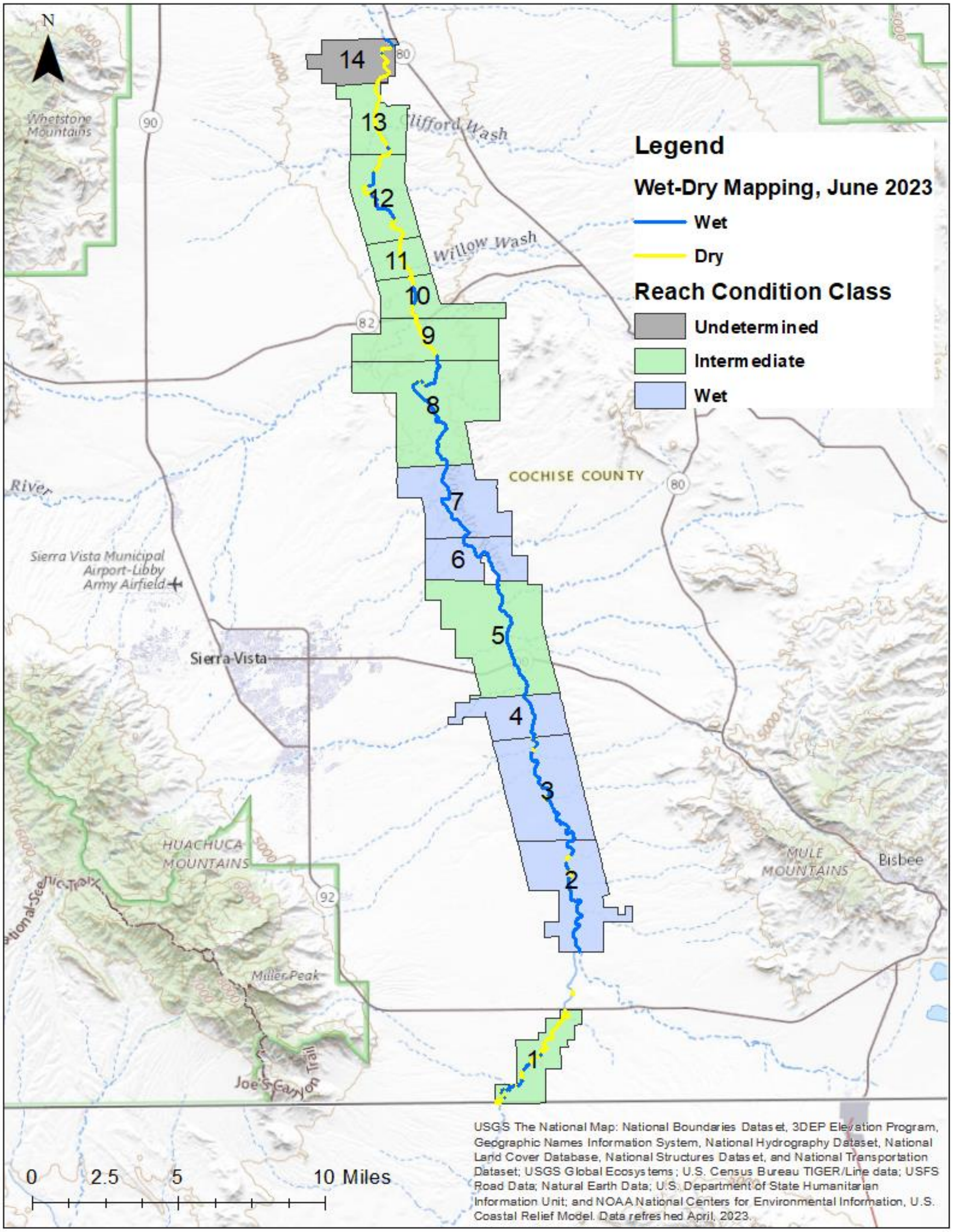

Figure A2. Map of the SPRNCA, with condition classes of reaches, based on 2023 vegetation sampling. Wet and dry river reaches are based on June 2023 wet-dry mapping.

Table A2. Mean values (and SD) for mean, maximum, minimum, and annual fluctuation in groundwater depths for 2022/2023, multi-year (2014-2023 for most sites) flow permanence, and 2023 flow permanence across vegetation sites in each condition class and overall. There were no sites scored as condition class 1, based on vegetation bioindicators.

Condition Class	GW Mean Depth (m)	GW Max Depth (m)	GW Min Depth (m)	Annual GW Flux (m)	% Flow 2023	Mean % Flow multi-year
2	1.95 (0.72)	2.85 (1.23)	1.36 (0.58)	1.49 (0.93)	53.5 (11.3)	66.8 (19.9)
3	1.87 (0.34)	2.14 (0.36)	1.70 (0.37)	0.45 (0.32)	88.1 (17.8)	96.7 (7.2)
All	1.91 (0.56)	2.52 (0.97)	1.52 (0.51)	1.00 (0.87)	69.5 (22.8)	79.3 (21.7)

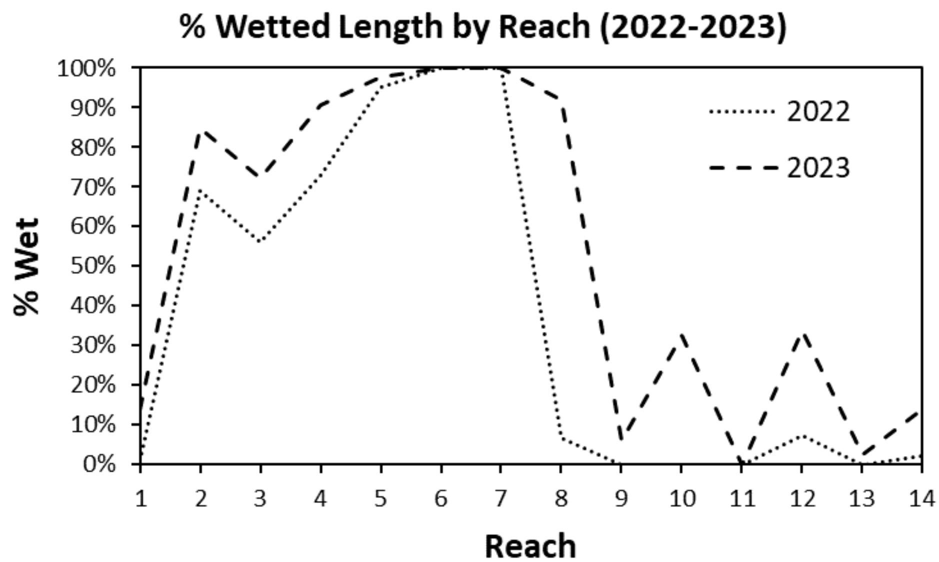

Figure A3. Percentage wetted channel length during June wet-dry mapping by SPRNCA reach in 2022 and 2023.

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Lite, S. J., 2003. *San Pedro River Riparian Vegetation across Water Availability and Flood Disturbance Gradients*. Ph.D. Dissertation. Arizona State University, Tempe, AZ, USA.

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Stromberg, J.C., Lite, S.J., Dixon, M., Rychener, T., and Makings, E., 2006b. Relations between streamflow regime and riparian vegetation composition, structure and diversity within the San Pedro Riparian National Conservation Area, Arizona. Chapter C, pp. 57-106, In: J.M. Leenhouts, J.C. Stromberg, and R.L. Scott (eds.), *Hydrologic Requirements of and Consumptive Ground-water Use by Riparian Vegetation along the San Pedro River, Arizona*. U.S. Geological Survey Scientific Investigations Report 2005-5163.

ASSESSMENT OF RIPARIAN VEGETATION AND HYDROLOGIC CONDITIONS WITHIN THE SAN PEDRO RIPARIAN NATIONAL CONSERVATION AREA IN 2023

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INTRODUCTION

The purpose of this project was to characterize riparian vegetation condition, as quantified through a riparian assessment model (Lite 2003, Stromberg et al. 2006a,b), along the San Pedro River within the San Pedro Riparian National Conservation Area (SPRNCA) and relate riparian health to hydrologic conditions (streamflow permanence, groundwater depth and variation) at 25 study sites spread throughout the 14 reaches that compose the SPRNCA (**Table 1**). Findings from field work conducted in 2023 provide a baseline for assessing future trends in riparian ecosystem condition and system hydrology, which will help guide future land and water management decisions in the San Pedro basin.

The riparian assessment model was developed for the San Pedro River by Lite (2003) and Stromberg et al. (2006a,b). The model is composed of nine hydrologically sensitive vegetation bioindicators, with four of these bioindicators related to herbaceous wetland plant abundance in the streamside zone, and the other five describing characteristics of floodplain land cover and the abundance, stem size distribution, and dominance of groundwater-dependent (phreatophytic) tree species (Fremont cottonwood, Goodding's willow) in the floodplain (**Table 2**). Individual bioindicators are assigned scores between 1 and 3, based on hydrologically sensitive threshold values of cover or other criteria, and then averaged, to provide a composite score for each site. Site scores are then scaled up to the reach level, with 14 reaches defined in the upper San Pedro River that correspond to spatial differences in sinuosity, floodplain width, and streamflow intermittency (Stromberg et al. 2006a,b, Brand et al. 2011).

Based on these composite scores, sites or reaches are classified into three condition classes, which have been shown to be associated with different levels of riparian "health" and hydrologic conditions (**Figure 1**). Sites scored as class "3" (wet) are considered to be of highest quality, with gallery forests of Fremont cottonwood (*Populus fremontii*) and Goodding's willow (*Salix gooddingii*) dominating the floodplain and riverine marsh plants (particularly perennial hydric herbaceous plants) abundant along the channel. Hydrologically, these sites are typically associated with "gaining" river reaches with perennial or nearly perennial streamflows, shallow maximum groundwater depths (e.g., <2.5 m), and little (<0.5 m) annual variation in groundwater levels. Sites scored as class "2" (intermediate) are considered of intermediate quality. They still contain forests dominated by cottonwood and willow in the floodplain but often have lower abundances of riverine marsh plants (particularly perennial species) along the channel. These often occur on "losing" reaches in which streamflow ceases for part of the year (e.g., flow permanence is 60-95% of the year), deeper maximum depth to groundwater (e.g., 2.5-3.5 m), and higher annual fluctuation in groundwater levels (0.5-1 m). Finally, on sites scored as class "1" (dry), saltcedar (*Tamarix ramosissima*) shrublands have generally replaced cottonwood-willow forests in the floodplain and riverine marsh plants are sparse or absent. These sites have lower-frequency intermittent streamflow (e.g., <60% of the year), deeper maximum groundwater levels (e.g., >3.5 m), and greater annual fluctuation (>1 m) in groundwater levels (Stromberg et al. 2006a,b, Brand et al. 2011).

METHODS

We conducted fieldwork within the SPRNCA in May-July 2023 to collect riparian vegetation data at 25 study sites (**Table 1**) using the methods described in Lite (2003) and Stromberg et al. (2006a,b). The sampling sites were located using geographic coordinates provided in Leenhouts et al. (2006: Table 2) and the RFP, using GPS-enabled field tablets. These GPS coordinates corresponded to the location of a monitoring well on or near each site. Using maps and GPS on our tablets, we chose a sampling location on the river that was closest to or perpendicular to (if the well coordinates were in the upland) the GPS coordinates for that site. Sampling consisted of two main stages: (1) characterizing herbaceous wetland vegetation in 1m x 1m quadrats in the streamside zone and (2) characterizing floodplain and terrace vegetation composition and structure along cross-floodplain transects. The streamside plot sampling was used to collect data for bioindicators 6-9 in the riparian assessment model, whereas the floodplain transect sampling was used to collect data for bioindicators 1-5 (**Table 2**). Note that numeric order of the bioindicators is different in the original paper by Stromberg et al. (2006a).

Streamside Plot Sampling

We conducted the streamside plot sampling early in the season (May 26-June 9) to complete it before the onset of the summer monsoon (i.e., before June 30, as required by contract), when site differences in hydrology might be masked by wetter conditions and vegetation might be disturbed by flood flows.

Streamside sampling was conducted near the central (“GPS-middle”) transect on each site (with the exception of Tombstone South, where it was closer to the north transect), which corresponded to the nearest location on the river to the site GPS coordinates (**Table 1**). After navigating to this location on the river, we used flagging tape to provide a reference for our sampling. As specified by Stromberg et al. (2006a,b) and Bagstad (2002) for the assessment protocol, we sampled herbaceous vegetation in at least five 1m x 1m square quadrats within the streamside zone of each site. We considered “streamside” to include channel bars, the side of the channel bank, vegetation growing directly adjacent to the low-flow channel, and other landforms occurring within the bankfull channel of the river. We chose sampling locations with a stratified random procedure, using random numbers generated from an application on the tablet or based on tenths and hundredths of seconds on a digital stopwatch. Typically, we sampled 2-3 plots on each side (east/west) of the river but sometimes added additional plots to better capture variation in site conditions (e.g., additional channels or landforms). On a given side of the river, we typically chose one plot on or adjacent to the central transect location (that is, in line with where we had flagged the site), with additional plots upstream and downstream within 10-25 meters. Hence, although the Stromberg protocol specified at least five plots, we usually sampled six or more plots at a site (range of 5-9, mean = 6.4, standard deviation = 0.97 SD), so as to achieve balanced representation of sides of the river and landform diversity on a given site. The sides of the square sampling frames were oriented so as to be parallel (and perpendicular) to the river channel or the slope of the channel bank.

Within each plot, we identified each vascular plant species present within the 1 x 1 m quadrat and estimated the percentage of the plot area occupied by its foliage using Domin-Krajina cover classes (0, <1%, 1-5%, 5-10%, 10-25%, 25-33%, 33-50%, 50-75%, 75-99%, 100%) (Bagstad 2002). We later calculated midpoints of each class for data summarization and bioindicator calculations. In most cases, we also took a photograph of each sampled quadrat. Plants were identified to species based on descriptions provided in *Flora Neomexicana IIIa: Field Keys, 2nd edition* (Allred and Jercinovic 2020), regional field guides, and other sources. We also used the *Flora of the San Pedro Riparian National Conservation Area* by Elizabeth

Makings (Makings 2006) and the USDA Plants Database (https://plants.usda.gov) as references to help determine which species were likely to be in the area. When we were not able to identify a species in the field, we collected the plant and identified it later in the laboratory using the above noted reference materials (especially *Flora Neomexicana*). In a few cases (e.g., young seedlings), we could not identify individual plants to species and had to list them as “unknowns” (e.g., unknown forb, unknown sedge, etc.).

To document general conditions within the stream channel and the gallery riparian community, we used our tablet to take a photograph looking upstream and one looking downstream from the streamside zone at the central transect within each site. We also took additional photographs to document sampling protocols and interesting site features. The required site photographs and selected additional photographs are included in **Appendix A** at the end of this report.

Transect Sampling

Consistent with the protocols described by Lite (2003) and Stromberg et al. (2006a,b), we characterized vegetation structure and composition within the riparian corridor (streamside, floodplain, and terrace) using cross-floodplain transects from May 26 - July 26, 2023. In most cases (Tombstone South is the only exception), we established a central (“GPS-middle”) transect that coincided with the streamside plot locations and the site GPS coordinates provided in the RFP and Water Needs Report (**Table 1**) and then established additional transects approximately 100 m upstream (south) and downstream (north) from the central one. In the case of Tombstone South, the north transect corresponded most closely to the streamside plot locations. In the case of Escalante, we added an additional (4th) transect approximately 125 m upstream (south) of the original south transect. In each case, we established the transect starting location at the river and then chose an azimuth that was roughly perpendicular to the direction of the river course at that point. On each side of the river, we continued the transect until it reached the floodplain-terrace boundary (that is, the edge of the pre-entrenchment surface).

The terrace boundary was usually distinguishable by a sharp topographic divide (e.g., a steep bank 2-5 meters high) and a change in the vegetation from hydromesic species (e.g., cottonwood, willow) to dominance by mesic or xeric species (e.g., mesquite or xeric shrubs). However, deciding what truly represented the pre-entrenchment terrace vs. upper post-entrenchment floodplain was not always obvious. Because of this, we used a GIS shapefile of the floodplain-terrace boundary as a rough guide to where the floodplain ended, and the terrace began. This shapefile, created about 20 years ago by the Stromberg lab, used a combination of digitized maps of historical channel locations derived from Hereford (1993) and topographic changes interpreted from LiDAR to define the floodplain-terrace boundary (Stromberg et al. 2006a, 2010, Brand et al. 2011).

We delineated patch types by vegetation structure (e.g., open, grassland, herbland, shrubland, woodland, and forest) and dominant plant species within 10 m of the transect for the streamside and floodplain zones and the first 100 m of the terrace zone on each side of the river, using protocols established by Lite (2003) and Stromberg et al. (2006a,b). The patch type was defined by the estimated % live cover of vegetation within three height strata: canopy, >5 m; mid-stratum, 1-5 m; and ground, <1 m. Patches designated as forest had estimated cover of ≥60% in the canopy (> 5 m) layer and woodlands had canopy cover of 25-60%. Patches with <25% canopy cover, but >25% cover by woody plants in the mid-stratum (1-5 m) were considered shrublands. Those patches with <25% cover in the canopy and mid-stratum and >25% vegetative cover in the ground layer were considered grasslands or herblands (depending on whether a grass species was one of the dominant or subdominant species or not). Those patches with

<25% live vegetative cover in all layers were called "open." Dominant species were those that composed at least half of the cover within a particular stratum, subdominants were others that occupied at least 20% of the cover within a stratum, and other notable species were noted as "abundant, but not dominant." Cover values and species dominance were defined by overhead cover over the patch, regardless of whether or not the dominant woody plants were rooted within the patch or were overhanging from an adjacent patch (e.g., a streamside patch with a large overhanging cottonwood from an adjacent patch could still be considered a woodland or forest patch, even if no trees were rooted within it). The common and scientific names for all dominant and subdominant woody plant species recorded in the patches are included in **Table 3**.

We also measured the basal diameters of the largest two individuals of the most abundant (or dominant) canopy species in each patch. For patches with cottonwood, willow, or saltcedar as the dominant species, these diameters were used to define forest age classes according to the following classes and cut-offs: young (<20 cm for cottonwood and willow, <5 cm for saltcedar), mature 1 (20-50 cm for cottonwood and willow, 5-20 cm for saltcedar), mature 2 (50-90 for cottonwood and willow, 20-35 cm for saltcedar), and old (≥90 cm for cottonwood and willow, ≥35 cm for saltcedar). These diameter classes correspond approximately to plants <11 years old for young, 11-30 years for mature 1, 31-50 years for mature 2, and >50 years old for old (Stromberg et al. 2006b).

We measured the beginning and end of each patch along each transect using 100-m survey tapes or Garmin GPS units. Any signs of recent disturbance from fire, flooding, channel shifting, cattle, or clearing were noted in each patch. Each patch was scored with a 0 (for no evidence) or a 1 (for evidence of a particular disturbance factor). Site scores were calculated for each disturbance factor by summing the relative widths of patches on the site that contained evidence for that disturbance. Evidence for fires – all fires and recent, within five years – included charred trunks of trees or other burned foliage. Flood disturbance was noted for patches with significant flood debris. Evidence for cattle included manure, hoof prints, or sightings of cattle during our visits. Evidence of channel shifting included meander migration (e.g., eroding into the terrace) and channel avulsion. Disturbance from clearing was evidenced by cut stumps, roads or railroad embankments, and other signs of vegetation management. We also inspected saltcedar plants, when encountered, for any signs of defoliation or presence of live tamarisk leaf beetles (*Diorhabda* spp.), as beetles have recently been observed impacting saltcedar patches on the lower San Pedro and Gila Rivers.

We measured the height (to nearest 0.5 m) of the tallest tree within 10 meters of each floodplain transect using a digital rangefinder (Nikon Forestry Pro II Laser Rangefinder) with a three-point height measurement function or, for a few trees, estimated the height using a manual clinometer.

Within streamside and floodplain patches (but not the terrace), we tallied basal stem diameters and densities of woody stems within one or more rectangular plots that were randomly located along the transect in each patch. A second plot was added for some patches >50 m in width. Plots were typically 10 m x 20 m, with the long axis parallel to the river. However, plot width along the transect direction was limited by patch width, so that it was shorter on patches <10 m wide (e.g., 4 m x 20 m for a 4-m wide plot). In plots with very high densities of woody stems (e.g., young mesquite or seep-willow), particularly in patches lacking cottonwood and willow on the outer parts of the floodplain, we often narrowed plot width in the lateral direction from the transect to 10 m (or occasionally narrower) to reduce sampling time. Prior to analysis, woody stem counts and basal area estimates in each plot were divided by plot area and then converted to stem density or basal area (m^2) per hectare to standardize for the different plot sizes. These values were then weighted by the relative width of the patch within the transect and summed up to scale to the entire streamside-floodplain transect length.

Stem diameters (cm) of all woody plants in the plot were tallied or measured at ankle height using diameter tapes or calipers. If a tree was split into two or main trunks close to the ground, however, then each stem was measured separately, instead of measuring the diameter of the basal trunk. Stems <2 cm in diameter were separated into those < 1 cm and 1-2 cm. Stems >2 cm in basal diameter were measured to the nearest 0.5 or 1 cm. On our first transect (GPS-middle at Lewis Springs), we initially also estimated % shrub cover, by woody species, on two short line transects that ran the length of the plot parallel to the main transect (e.g., at 5 m on either side of the central transect). We decided, however, that this was largely redundant with the woody stem sampling and was not required for calculation of bioindicator metrics for the assessment model. Hence, we discontinued the shrub cover sampling.

During the first part of the field season, we entered all data in the field on digital forms in the Survey 123 app using rugged field tablets and uploaded the data to cloud-based storage at the end of each field day. The tablets automatically collected GPS coordinates for observer locations during field data entry. Later in the season, because of malfunctions in Survey 123 for some of the forms, we recorded data manually on paper data sheets and entered them into excel spreadsheets in the lab at a later time.

Calculation of Vegetation Bioindicators

Streamside Herbs (Bioindicators 6-9): We used the data collected from the streamside herbaceous quadrats for calculating bioindicators 6-9 (**Table 2**). For calculating absolute and relative cover values, we used the midpoint of each Domin-Krajina cover class (e.g., 0.5% for <1%, 3% for 1-5%, 7.5% for 5-10%, etc.), averaged absolute cover values (i.e., for all herbaceous plants, all hydric plants, all hydric perennials) across quadrats within each site, and then calculated relative cover based on the site averages. Lifespan (annual, biennial, perennial) and wetland indicator status (for the Arid West Region) of each sampled species were determined from the USDA Plants Database (https://plants.usda.gov). USDA plants did not include wetland indicator status for a few species. For those, we obtained information on wetland status for the Arid West (or Western Mountains, Valleys, and Coast) or Region 7 (for older lists) from previous National Wetland Plants lists (https://wetland-plants.usace.army.mil/) or from Lichvar and Dixon (2007) for plant species characteristic of specialized habitats in the region. For a few species, we revised our wetland indicator and lifespan designations to match those provided in Stromberg et al. (2006b, Digital Appendix 7D). Hydric species were those with wetland indicator values of OBL (obligate) or FACW (facultative wet). Non-hydric species and those for which wetland status could not be determined were included in total herbaceous cover, but not in the hydric or hydric perennial totals. Although we often encountered woody plant seedlings (e.g., seep-willow, cottonwood, saltcedar) or saplings in our plots, these were excluded from the streamside bioindicator calculations. Only herbaceous species were included in the calculations.

A few quadrat locations were selected subjectively in the field, in order to capture distinct site conditions or patches of streamside vegetation that were not sampled through the stratified random selection procedure. We calculated bioindicator values both with and without those supplemental quadrats, but only include those for the randomly chosen quadrats in this report.

<u>Transect Sampling (Bioindicators 1-5):</u> We used data collected from the streamside-floodplain transect sampling and woody basal diameter plots for calculating bioindicators 1-5 (**Table 2**). For bioindicator 1 (# of 10-cm cottonwood and willow size classes), we tallied the number of cottonwood or willow basal diameter classes across the plots in each transect (both sides of the river combined) and then averaged across the transects to compute the site-level mean number of classes. Cottonwood and willow seedlings and saplings tallied within the 0-1 cm and 1-2 cm diameter classes, as well as those measured with basal diameter <10 cm, were included in the 0-10 cm diameter class.

For bioindicator 2 (cottonwood and willow basal area), we calculated basal area values for each woody species in each basal diameter plot. For stems in the 0-1 cm and 1-2 cm classes, we used the class midpoint (e.g., 0.5 and 1.5 cm diameters) for calculating basal area. For each stem, basal area was calculated as pi (3.14159) times the stem radius (half the diameter) squared, and then converted to square meters. These were summed for each woody species in each plot and converted to m^2/ha by dividing by the plot dimensions in square meters (e.g., 200 m^2 for a 10 m x 20 m plot) and then multiplying by 10,000 to convert it to basal area per hectare (m^2/ha). The total and basal area values for each species in each plot were then multiplied by the relative width (proportion of the sum of all streamside and floodplain patches on that transect) of the patch within which the plot occurred and then summed across all patches on a given transect (both sides of the river combined), creating a patch-weighted average basal area overall and for each species for the entire transect. These transect values were then averaged to calculate the site-average basal area values. Only the cottonwood, willow, and saltcedar basal area values are included in this report, as only these are used to compute the bioindicators, but values for other species can also be calculated from the data.

For bioindicator 3 (cottonwood and willow relative basal area), we added the mean patch-weighted basal area values for cottonwood and willow, divided this by the sum of the cottonwood, willow, and saltcedar basal areas on each site, and expressed it as a percentage. Note that this value uses only these three species to computer relative basal area, not the total basal area of all woody species.

For bioindicator 4 (maximum vegetation height on the floodplain), we averaged the heights of the tallest trees across the three (or four) transects to calculate the site-level mean value.

For bioindicator 5 (relative % coverage of shrubland in the floodplain), we added up the widths of all shrubland patches (patches with canopy cover <25% and mid-stratum cover >25%) on each transect, divided by the total width of all streamside and floodplain patches on the transect, and then averaged across all transects on the site. The stream channel was not included in the computation of total streamside and floodplain width.

<u>Condition Class Calculations</u>: The site-level riparian condition class was calculated by (1) assigning the condition score of each bioindicator, based on its value (**Table 2**), (2) summing up all nine bioindicator scores, and (3) dividing the total by nine. A site with a composite indicator score of <1.5 would be classified as condition class 1 (dry), one with a score of ≥1.5 but <2.5 would be classified as condition class 2 (intermediate), and one with a score ≥2.5 would be classified as condition class 3 (wet). Reach-level condition scores were the average of the site-level scores of the sites within each reach (if there is more than one site per reach).

Hydrologic Data Compilation

We compiled recent hydrologic data for sites and reaches within the SPRNCA from several sources, including groundwater and flow permanence data from the San Pedro Web-based Hydrologic Information Portal (WHIP, https://uppersanpedrowhip.org/), flow data from USGS streamflow gaging stations (i.e., San Pedro River at Palominas, 9470500; Charleston, 09471000; and Tombstone, 09471550), and June wet-dry mapping data from The Nature Conservancy of Arizona (Turner and Richter 2011, TNC 2023: https://azconservation.org/project/wet_dry_mapping/).

Groundwater Data and Calculations: For groundwater dynamics, we used the "Near-stream alluvial-aquifer water levels" dataset from WHIP. This dataset contains historical groundwater measurements for 54 different USGS monitoring wells in or adjacent to the riparian corridor along the upper San Pedro River. Of the available wells, we selected fifteen (**Appendix B: Table**) that coincided with our study sites, with a preference for wells that are located on the post-entrenchment alluvial surface (floodplain) based on Leenhouts et al. (2006: Digital Appendix 1C). We converted the depth to groundwater values from feet to meters and subtracted them from the land surface elevation at the well (Leenhouts et al. 2006: Digital Appendix 1C) to compute groundwater elevation. We then computed depth to groundwater for the floodplain by calculating approximate floodplain elevation for the study site from Leenhouts et al. (2006: Digital Appendix 1) and subtracting the groundwater elevation from it. These estimates of depth to groundwater for the floodplain should be considered approximate, as they are based on only a single well per study site and a single mean elevation for the floodplain. Hence, they do not account for possible gradients in the groundwater surface and different depths to groundwater across the floodplain. In addition, both land surface elevations for the wells and floodplain elevations may have changed since 2006 due to sedimentation. Hence, we recommend a more systematic and detailed approach, potentially with new topographic surveys, be used for calculating these depths for future reference. We also did not include data from the nine federal reserved water rights wells that are monitored by BLM (with the exception of our SUM-LI site). It may be desirable to include these wells in future analyses.

We plotted these estimated depths to groundwater from the floodplain for the entire record in the WHIP dataset for each study site (**Appendix B: Graphs**) but only used the data from calendar years 2022 and 2023 in our other analyses. For each year, for sites with at least three different measurement dates, we computed the maximum, minimum, and mean depth to groundwater, and subtracted the minimum from the maximum to estimate the annual change (flux) in groundwater level. We then also computed the average of each of these values across the two years. The well at Summers (SUM-LI) had only one depth to groundwater measurement in 2022 (June 22), so we were only able to compute groundwater metrics for 2023 for that site. For future analyses, we may want to summarize groundwater depth statistics based on the water year (Oct. 1 - Sept. 30), rather than the calendar year, to be more consistent with Stromberg et al. (2006a,b).

Flow Permanence Data and Calculations: We used the "Streamflow permanence" dataset from WHIP to compute the percentage of days per calendar year with measurable streamflow at twelve (later updated to fifteen) study sites on the upper San Pedro River within the SPRNCA. These data were originally compiled based on a combination of camera station records and (for some sites) flow data from USGS gaging stations. Statistics reported for each year in the dataset include days with no data, days when the river was dry, days with no flow (but possibly ponded water), days when the river was flowing, and total observations (total days). There was also a variable called "percent flowing." However, the percent flowing calculation did not subtract the "no data" days from the total observations, in essence assuming that "no data" signified days in which there was no streamflow. We did not want to make that assumption. For our analysis we recalculated the percent flowing by subtracting the "no data" days from the total, so that our calculations show the percentage of days of flow relative to the total number of days with data in each calendar year.

Records for all sites in the database began in 2007 or earlier and continued until part-way through 2021, with the exception of Lewis Springs DCP, which ended in 2013, and Hereford, which ended in 2019 (**Appendix C**). From correspondence with the USDA Agricultural Research Service (David Goodrich and Jason Wong, personal communication), we were able to obtain recent camera station data to complete the 2021 data and extend the record to Oct. 2023 for seven of the sites (Hunter, Moson, Charleston Mesquite, Boquillas, Fairbank, Contention, and St. David). For three other sites (Palominas Gage, Charleston Gage, and Tombstone Gage), we used discharge data from the USGS gages at those sites to extend the record to December 2023, based on the assumption that days with estimated discharge of 0 cfs constituted "no flow" days, while those with discharge >0 were "flowing." Finally, we obtained data from new camera stations installed at three additional sites (Cottonwood, Fairbank North, Escalante) beginning in fall of 2022, bringing the total number of sites to fifteen. Because monitoring for those three new sites included only 26-57 days in 2022, we combined the 2022 data with the more complete 2023 data to compute a single flow permanence value based on both years for those sites. When more recent (after October 2023) data have been downloaded from all camera stations, then the records for all active stations can be updated through the end of 2023. To our knowledge, however, new data on streamflow permanence are not available for Hereford (last records in 2019) or Lewis Springs (last records in 2013). For Lewis Springs, it may be possible to estimate the number of flowing and non-flowing days from the active USGS gage there (USGS 09470920, San Pedro at Lewis Springs), although only stage data (no daily discharge calculations) are available.

Wet-Dry Mapping Data: We obtained data from the wet-dry channel mapping program of The Nature Conservancy (TNC) for the reaches of the SPRNCA for 1999-2023 (TNC 2023: https://azconservation.org/project/wet_dry_mapping/). These data, compiled through field visits by citizen scientists and natural resource professionals, record channel locations along the San Pedro (and elsewhere) with surface water present (wetted length) during the low-flow period in June (pre-monsoon) of each year (Turner and Richter 2011). Arizona TNC (Lisa McCauley, pers. comm.) provided summaries of wetted length and total surveyed length of the San Pedro River channel, by reach, for each year of the program, as well as a statistical analysis of temporal trends in those data using a Mann-Kendall trend test (Turner and Richter 2011) (see **Appendix E**). We used these data to compute the percentage of surveyed channel length in each reach that had surface water during the June survey period in each year (**Appendix D**) and also mapped wet and dry sections of the San Pedro River across the SPRNCA for 2023.

RESULTS AND DISCUSSION

Streamside Quadrat Sampling (Bioindicators 6-9)

We identified 56 vascular plant taxa in the streamside quadrats (**Table 4**). 52 of the 56 species were herbaceous. The only woody species were seep-willow, cottonwood, saltcedar, and mesquite, and these were excluded from the analysis. Of the herbaceous species, 20 were hydric (wetland indicator status of OBL or FACW), and 12 of these hydric herbaceous species were perennial.

Total mean herbaceous cover ranged from 5.7% at Palominas to 108.3% at Hunter (**Table 5**). Totals can exceed 100% because they are the sum of the cover of individual species, which may overlap in their ground coverage. The lowest hydric herb cover (bioindicator 8) was 2.1% at Palominas, and four sites (Palominas South, Palominas, Tombstone, and Contention) averaged less than 10% hydric herb cover among plots (**Table 5**). The highest values were for sites in reaches 2 and 3, with 87.9% hydric herb cover at Hereford and 69% or greater at Kolbe, Hunter, and Hunter South. Overall, ten sites had % hydric herb cover values <29%, receiving a bioindicator 8 score of 1.5, whereas fifteen sites had values >29%, for bioindicator 8 scores of 3 (**Table 6**). Relative cover of hydric herbs (bioindicator 9) was very high (over 90%) at Kolbe, Hereford, and Escalante and was only <24% on one site, Tombstone (**Table 5**). Hence, only Tombstone received a score of 1.5 for bioindicator 9, whereas the other 24 sites received scores of 3 for this bioindicator (**Table 6**).

The average cover of perennial hydric herbs varied from <1% at five sites (Palominas, Tombstone, Contention, St. David, and St. David North) to more than 40% (Kolbe, Hunter South, and Charleston Bridge) (**Table 5**). In general, cover of perennial hydric herbs was lowest in reach 1 and in the more northern reaches, with values less than 2% in the two Tombstone sites (reach 11), at Contention (reach 12), and at the two St. David sites (reach 13). Overall, twelve sites had cover values for perennial hydric herbs <5%, which corresponds to bioindicator 6 scores of 1.5, whereas thirteen sites had values >5%, corresponding to scores of 3 (**Table 6**). Relative cover by perennial hydric herbs was also lowest, at <2%, at Palominas, Tombstone, Contention (0% at Contention), St. David, and St. David North, and highest (>60%) at Kolbe, Charleston Bridge, and Escalante (**Table 5**). Ten sites had relative cover of perennial hydric herbs below the 14% threshold, corresponding to bioindicator 7 scores of 1.5, whereas 15 sites had cover values above the threshold, with bioindicator 7 scores of 3 (**Tables 5, 6**).

Averaging across the four bioindicator (6-9) scores based on streamside herbs, eleven sites had perfect scores of 3, including Kolbe, Hereford, Hunter South, Hunter, Cottonwood, Moson, Charleston South, Charleston Bridge, Boquillas, Boquillas North, and Escalante (**Table 6**). Reach 5, represented by Lewis Springs, is in a section of the river that has generally had perennial flows and high condition class scores in the past (Stromberg et al. 2006a,b). However, the two bioindicators related to cover of perennial hydric herbs both scored low at this site, contributing to lower composite scores than the sites on adjacent reaches upstream and downstream. Similarly, Charleston Mesquite (in reach 8) had low scores for three of the four streamside bioindicators (for all but relative cover of hydric herbs), for a composite score of 1.875, whereas adjacent sites upstream (Moson, Charleston South, Charleston Bridge) and downstream (Boquillas and Boquillas North) had perfect high condition scores. Tombstone had the lowest composite score of streamside bioindicators, with low scores for all four of them, for a site average of 1.5 (lowest possible score). The adjacent upstream (Tombstone South) and downstream (Contention) sites had low scores for three of the four bioindicators, yielding average scores of 1.88 for each site, based on the four streamside bioindicators.

Reach averages of the streamside scores retain similar geographic patterns, with the lowest composite score in reaches 12 (1.69), 11 (2.06), and 1 (2.06); high scores in reaches 2, 3, 4, 6, 7, and 14; and intermediate scores in the others (e.g., 5, 8, 9, 10, 13) (**Table 6**). Reaches 8 and 9 are interesting, in that each has one site with a low score (Charleston Mesquite and Fairbank, respectively, each had 1.88) and one site with a perfect high score (Boquillas and Boquillas North, both had scores of 3), resulting in a large standard deviation in composite scores and suggesting high spatial variability in hydrologic conditions within these reaches (**Table 6**).

Transect Sampling

<u>Site Disturbance Scores</u>: As noted in the methods, floodplain site disturbance scores are based on the relative widths (vs. the total surface width) of all patches in the site showing evidence of that disturbance. This was recorded in binary fashion, as a 0 or 1 for the entire patch, rather than scaling by the proportion of the patch affected. Hence, the scores should not be taken to mean that that percentage of the entire floodplain was affected by a particular disturbance.

The most widespread kind of recent disturbance was presence of cattle (**Table 7**). Twenty of the 25 sites showed at least some signs of cattle having been present recently in some of the streamside or floodplain patches. Evidence of cattle having been present in the channel and streamside zone was often noted during the streamside quadrat sampling, and other evidence was noted on floodplain patches on many sites. The two Palominas sites, Cottonwood North, and Charleston Bridge were the only sites where we did not record evidence of cattle on any patch or the streamside quadrats.

Evidence for past fire was recorded at five sites (**Table 7**), with some evidence for recent fire (within last five years) recorded at four of them (Kolbe, Hunter South, Lewis Springs, and Escalante). Only on Kolbe, however, was there evidence of recent fire on a large percentage of the patches. Based on our field visit, vegetation on parts of Kolbe showed strong effects of very recent fire, probably from earlier in the spring of 2023.

Several (four) sites showed some evidence of vegetation clearing (Contention, Escalante), road or railroad embankment construction (e.g., Tombstone), or other kinds of human-caused disturbance of the vegetation in the floodplain (**Table 7**). On the west side of the river along the central transect at Contention, cut stems and downed woody debris indicated that mesquite and other midstratum shrubs or small trees had been cleared in the narrow floodplain patch immediately adjacent to the river. At Escalante, the midstratum (e.g., mesquite and saltcedar) and understory of significant portions of the floodplain (and terrace) on the north and central transects had been cleared, and portions of the transects could not be sampled because they were on private property.

Eleven of the sites showed some evidence of flood disturbance, as indicated by flood debris, with this affecting a fairly large proportion of the patches at Hunter (**Table 7**). Five sites showed some evidence of significant meander migration and channel avulsion and abandonment. The patch percentage values were small, suggesting an influence primarily on the patches immediately adjacent to the channel. Although not indicated by a high % channel shifting score, the channel at Hereford was notable in showing a major channel avulsion that occurred sometime in the last decade or so, with a new channel cut across the floodplain on the east side of the original river channel and portions of the old channel abandoned.

Although we inspected saltcedar patches for presence of tamarisk leaf beetles (*Diorhabda* spp.), we never detected any beetles or noted any evidence of defoliation from them. However, recent observations of beetles impacting saltcedar patches on the lower San Pedro and Gila rivers suggest that they are likely to spread to saltcedar patches on northern portions of the SPRNCA in the near future.

We also computed disturbance scores for the patches sampled on the terrace on each site (**Table 8**). As with the streamside-floodplain disturbance scores, several sites showed signs of past fires on terrace patches, but only Kolbe and Lewis Springs showed significant recent evidence, with fire affecting most of the terrace patches at Kolbe. In comparison with the streamside-floodplain scores, fewer terrace sites showed evidence of cattle presence (6 terrace vs. 20 floodplain sites) but more showed disturbance to vegetation via clearing (8 vs. 4). As with the floodplain, a large proportion of the terrace showed evidence of vegetation clearing at Escalante.

Floodplain Patch Widths and Types (includes Bioindicator 5: % shrubland): Average total streamside-floodplain widths (excluding channel) varied considerably across sites, ranging from less than 60 m on Tombstone, Depot, Fairbank, Charleston, and Charleston South to over 300 m at Cottonwood, Contention, and St. David North, and averaging approximately 158 m (**Table 9**).

Overall, mean values of coverage by different structural vegetation types were relatively evenly split among grassland (28%), forest (27%), and woodland (23%), with smaller amounts of shrubland (13%), open (8%), and herbland (1%) (**Table 9**, **Figure 2**). However, these varied considerably among sites. Coverage of shrubland, on which bioindicator 5 is based, exceeded 35% only at Contention. This means that Contention is the only site with a low condition score (1) for bioindicator 5, with the other 24 sites receiving high scores (2.5).

Fremont cottonwood was the most frequent woody dominant species in the floodplain, averaging 33% of the floodplain patch width overall, ranging from 1.5% at Contention to 72.5% at Palominas (**Figure 3**). Goodding's willow and velvet mesquite were also frequent dominant woody species, with mesquite more common from Charleston South (reach 7) to farther downstream. Saltcedar was a frequent dominant species on patches of the last three sites, St. David, St. David North, and Escalante.

Based on stem diameter, the cottonwood and willow patches are primarily in the old (>90 cm, estimated >50 years old) and mature 2 (50-90 cm diameter, estimated 31-50 years old) age classes, with very few patches in the young (<20 cm, <11 years old) age class. Across sites, on average 57% of the cottonwood and willow patch area is in the old-growth class, 28% in the mature 2 class, 14% in the mature 1 class, and only 1.4% in the young class (**Figure 4**). For just cottonwood patches, an average of 66.5% of the patch area is in the old-growth class, 26.9% in mature 2, 5.4% in mature 1, and only 1.1% in the young class. These values suggest that the SPRNCA is dominated by older age classes of Fremont cottonwood and Goodding's willow, with very little successful recruitment over the last 30 years or more.

Terrace Patch Widths and Types: On the portions of the terrace that we sampled, average proportional coverage of vegetation structural types was nearly evenly split among shrubland (27%), woodland (25%), and grassland (24%), with lesser amounts of forest (13%), herbland (6%), and open (4%) (**Table 10**, **Figure 5**). Terrace vegetation types showed a more distinctive spatial pattern than floodplain vegetation types, with grassland and herbland dominating the terrace of sites in reaches 1-5, forest and woodland being most abundant in middle reaches (reaches 6-10, in part), and sites farther downstream (reaches 10-14, in part) having greatest coverage by shrubland or woodland. Shrubland had the greatest proportional coverage, at around 70%, in the terrace of three consecutive sites in reaches 10-11: Tombstone South, Tombstone, and Contention.

Terrace patches were predominantly covered by patches with either velvet mesquite (56% on average) or non-woody species (33% on average) as dominants, with coverage of mesquite increasing (and non-woody patches decreasing) from upstream to downstream (**Figure 6**). A handful of terrace patches with very large, old-growth Fremont cottonwoods as dominants occurred at Hunter, Cottonwood, Moson, Boquillas, Boquillas North, and Escalante.

Tallest Tree (Bioindicator 4): The height of the mean tallest tree per transect varied from 14 m (Contention) to 30 m or more (Summers, Moson, and Kolbe). Mean tallest tree height was less than 20 m at Contention, Tombstone South, Charleston South, and Hereford (**Figure 7**, **Table 11**). However, only Contention had an average tallest tree height less than 15 m, receiving a low (1.5) score for bioindicator 4, while all other sites had high (2.5) scores (**Table 12**). We suspect that at least some of our tree heights may have been overestimated, as we recorded heights as tall as 36-36.5 m (118-120 ft) for a few individual cottonwood trees at Kolbe, Cottonwood North, Boquillas, and Tombstone. It may be worth rechecking some of these measurements by field visits or LiDAR in 2024.

Number of Cottonwood and Willow Diameter Classes (Bioindicator 1): The mean number of 10-cm diameter classes for cottonwood or willow varied considerably among sites, from 2.3 at Tombstone South to 10.3 at Moson (**Figure 8**, **Table 11**). Tombstone South, St. David, Contention, and Cottonwood North all averaged <4 diameter classes per transect. The threshold value for separating high (2.5) and low (1) scores for bioindicator 1 is 3 diameter classes. Of the 25 sites, only Tombstone South received a score of 1 (mean # of diameter classes ≤3), whereas the other 24 sites had scores of 2.5 for bioindicator 1 (mean # of diameter classes >3) (**Table 12**).

Cottonwood and Willow Basal Area (Bioindicators 2 and 3): The mean total basal area of cottonwood and willow by transect ranged from only 2.2 m^2/ha at Contention to more than 60 m^2/ha at Tombstone and Charleston Mesquite (**Figure 9**, **Table 11**). These very high values at Tombstone and Charleston Mesquite reflect dominance by very large, old-growth cottonwood trees on very narrow floodplains, although some other sites with narrow floodplains (e.g., Fairbank, Depot, Charleston South, Tombstone South) had much lower basal area totals. Contention had low cottonwood and willow abundance and a very wide floodplain. Saltcedar occurred at some sites, with greatest basal area in the more downstream sites (Tombstone South, Contention, St. David, St. David North, Escalante). Except for Contention, the total basal area values of Fremont cottonwood and Goodding's willow exceeded the 4.7 m^2/ha threshold for bioindicator 2, meaning that Contention received a score of 1, and all other sites received a score of 2.5, for this bioindicator (**Table 12**).

Although saltcedar was common on northern segments of the river, its basal area was considerably smaller than cottonwood (or cottonwood plus willow) on all sites except Contention (**Figure 9**, **Table 11**). Relative basal area of cottonwood and willow (divided by the sum of the basal areas of cottonwood, willow, and saltcedar) was lowest, at 37.5% at Contention (**Figure 10**, **Table 11**). This, however, was the only site on which relative basal area of cottonwood and willow was less than 66%. It was 100% or nearly so on the first 18 sites, including all of reaches 1-10, and was less than 90% only on Contention, St. David, St. David North, and Tombstone South. Even on Contention, where the lowest value occurred, the relative basal area of cottonwood and willow still exceeded the threshold score (21%) for high (2.5) scores of bioindicator 3. Hence, all sites scored 2.5 for bioindicator 3 (**Table 12**).

<u>Site and Reach Condition Class Values:</u> Average scores for the nine bioindicators classified twelve sites as condition class 2 (scores 1.72-2.39) and thirteen as condition class 3 (scores 2.56-2.72) (**Table 12**, **Figure 11**). The lowest individual score was for Contention (1.72) and the next two lowest were the two Tombstone sites (2.06 each). Except for Contention, most sites had high scores for the floodplain indicators (bioindicators 1-5) but had variable scores for the streamside indicators (bioindicators 6-9). These high floodplain scores for nearly all sites contributed to somewhat higher scores than we had expected for the northern tier of sites, including St. David and St. David North, with no sites that scored as condition class 1 (mean score ≤ 1.5).

At the reach level, five reaches scored as condition class 3 (scores 2.64-2.72) and eight as condition class 2 (scores 2.06-2.48) (**Table 12, Figure 11**). Reach 1, with the two Palominas sites, was scored as condition class 2 (intermediate) based entirely on low scores for some of the streamside bioindicators, including low values for hydric herbaceous cover overall and hydric perennial herbs specifically. Reaches 2 and 3 were scored as condition class 3 (wet), with perfect high scores for every bioindicator. This was somewhat surprising for reach 3, which historically has had spatially and/or temporally discontinuous flow. Reaches 4, 6, and 7 all scored as condition class 3 as well. Somewhat surprisingly, reach 5, which has only the Lewis Springs site in it, was scored as condition class 2. This is a reach with historically perennial streamflow, but the Lewis Springs site scored low for the two bioindicators (6 and 7) based on absolute and relative cover of hydric perennial plant species.

Reaches 8-10 were scored as condition class 2 but had composite scores that were just barely below the threshold score (2.5) for condition class 3 (**Table 12**, **Figure 11**). Each of these reaches had two sites, with one site in each scoring as condition class 3 (Boquillas, Boquillas North, Depot) and one scoring as condition class 2 (Charleston Mesquite, Fairbank, Fairbank North). In the case of reaches 8 and 9, the contrast between the two sites in each reach is reflected in a high standard deviation in the reach score. In each case, the sites with the lower overall scores had low scores for absolute and relative cover of hydric perennial herbs (bioindicators 6 and 7) and absolute cover of hydric herbs in general (bioindicator 8). The high variability in site scores in these reaches likely reflects spatial variability in hydrologic conditions within each reach. Each reach has spatially discontinuous flow during the June low-flow period, although this varies considerably among years, especially for reach 8 (see hydrologic findings later in this report, **Figure 12**).

All sites in reaches 11, 12, and 13 scored as condition class 2, with the lowest reach scores in reaches 11 and 12 (**Table 12**, **Figure 11**). In reach 11, both Tombstone sites have identical composite scores, reflecting generally low streamside herbaceous scores (bioindicators 6-9), and in the case of Tombstone South, a small number of cottonwood-willow size classes in the floodplain (bioindicator 1). In reach 12, low scores for most bioindicators at Contention are partially counterbalanced by high scores for all bioindicators except the absolute cover of hydric herbs in general (bioindicator 8) and hydric perennial herbs in particular (bioindicator 6) at Summers. The strong differences in conditions between the two sites (Contention and Summers) are reflected in a high standard deviation for the reach score. The two St. David sites, with identical bioindicator scores, composed reach 13. Both sites had perfect high scores for all bioindicators except for low scores for the streamside hydric perennial herbs (bioindicators 6 and 7). The high scores for the floodplain bioindicators at these two sites, which occur in historically the driest reach (13) in the SPRNCA, was somewhat of a surprise.

We were unable to confidently assign a condition class to reach 14. The only site that we sampled there, Escalante, had high scores for all bioindicators, yielding a perfect high composite score (**Table 12**). However, this site occurs on one of the few "wet" sections of an otherwise mostly intermittent reach (**Figure 11, Table 16, Appendix D**). Previous assessments have also sampled a second site, Escalante South, which occurs on a drier portion of the reach. No unique geographic coordinates were available for Escalante South (Leenhouts et al. 2006 and the RFP provide identical coordinates for Escalante and Escalante South), however, so we did not establish and sample a site there. Establishing and sampling a second site, to the south of the current Escalante site, will be important for more accurately assessing the condition of the entire reach in the future.

Hydrologic Data

Groundwater: Based on USGS well data from the Web-based Hydrologic Information Portal, we computed changes in depth to groundwater relative to mean floodplain elevation across the available record for fifteen study sites across all reaches but 10 and 14 (**Appendix B: Table and Graphs**). For 2022-2023, we computed mean, maximum, and minimum depths to groundwater and annual change (flux) in groundwater level and averaged these values for each site across the two years (**Table 13**). Mean depths to groundwater varied from 0.92 m (Lewis Springs) to 2.85 m (Contention) and average maximum depths across the two years ranged from less than 2 m (Kolbe, Lewis Springs, Moson) to more than 4 m (Tombstone and Contention). Annual groundwater fluctuation was less than 0.5 m at six sites (Kolbe, Cottonwood, Lewis Springs, Moson, Charleston Bridge, and Boquillas), between 0.5-1.0 m at three sites (Hereford, Hunter, Fairbank), between 1-2 m at four sites (Palominas South, Palominas, Summers, St. David), and >2 m at two sites (Tombstone and Contention) (**Table 13**).

Flow Permanence: We computed the percentage of days of surface flow in calendar year 2023 for twelve sites, including all reaches except 2 and 5 (**Table 13**). Most sites were temporally intermittent, with only four sites with flow on >90% of the days (Moson in reach 6, Charleston Bridge in reach 7, Boquillas in reach 8, and Escalante in reach 14). The other nine sites had surface flow less than 71% of the time, with lowest flow permanence at Palominas in reach 1 (34.8%) and in the northern tier of sites (aside from Escalante) in reaches 9-13 (Fairbank, Fairbank North, Tombstone, Contention, and St. David). Flow permanence in 2023 tended to be lower than the multi-year (2014-2023 for most) average for most sites and reaches, with the exception of the perennial sites in reaches 6-8 (Moson, Charleston Bridge, and Boquillas) and the intermittent site at St. David.

Hydrologic Variables and Condition Classes: We also computed average values of groundwater metrics and flow permanence across sites assigned to each condition class value (**Table 14**). Condition class 3 ("wet") and class 2 ("intermediate") sites had similar mean groundwater depths (1.87 and 1.95, respectively) but differed more strongly in maximum and minimum groundwater depths and annual groundwater fluctuation. Maximum groundwater depth averaged 2.14 for wet (class 3) sites and 2.85 for intermediate (class 2) sites. Annual groundwater fluctuation averaged 0.45 m for wet sites and averaged three-fold greater, at 1.49 m, at intermediate sites. In terms of flow permanence, sites classified as condition class 3 tended to be perennial or nearly so, with an average of 97% of the days in a year with flow over a multi-year period, whereas class 2 sites averaged 67%, with higher variability. Flow permanence values for each condition class were somewhat drier in 2023, with class 2 sites averaging surface flow on only 53.5% of the days, and class 3 sites averaging 88%.

Groundwater and flow permanence values for the two condition classes in 2023 (**Table 14**) were roughly similar to patterns observed by Stromberg et al. (2006b) in 2002-2003 (**Table 15**), although streamflow permanence averaged a bit lower for both classes in 2023 and annual groundwater fluctuation averaged higher, particularly for intermediate (class 2) sites. On an individual basis, two adjacent sites that scored as "wet" (condition class 3) based on vegetation indicators (Hunter in reach 3 and Cottonwood in reach 4) had flow permanence values in 2023 (60.4% and 70.6%, **Table 13**) that were more consistent with intermediate class (2) sites in 2002-2003 (**Table 15**). On the other hand, Lewis Springs was scored as intermediate condition based on its low abundance of hydric perennial herbs in 2023 (**Table 12**), despite having groundwater conditions and a history of flow permanence (although data were unavailable after 2013) that should support wet condition class vegetation (**Table 13**). None of the 2023 sites were scored as condition class 1 (dry) based on vegetation indicators, although Tombstone (reach 11) and Contention (reach 12) both had annual groundwater change of >2.5 m and maximum depth to groundwater of >4 m (**Table 13**), which are more consistent with hydrologic values for sites classified as dry by Stromberg et al. in 2002-2003 (**Table 15**). Vegetation indicators, particularly those based on the composition and abundance of woody plants in the floodplain (bioindicators 1-5), may integrate hydrologic conditions over multiple years (Stromberg et al. 2006a,b), so that condition scores may remain higher despite individual years with drier conditions. The streamside bioindicators (6-9), however, should be more sensitive to short-term hydrologic conditions.

Wet-Dry Mapping: Wet-dry mapping illustrated spatial intermittency patterns across the reaches of the SPRNCA (**Table 16, Figures 11-12, Appendix D, E**). Reaches 5-7 had nearly continuous surface water in June of both 2022 and 2023 (**Table 16**), which is consistent with multi-year patterns. However, small lengths of dry channel have appeared in reach 5 in the wet-dry surveys of some recent years (**Appendix D**) and (as noted above) the reach received an intermediate (class 2) condition score in 2023 because of low cover of hydric perennial herbs at Lewis Springs. Reach 1 and the northern tier or reaches (9-14) had the lowest percentages of wetted stream length in June 2022 and 2023, with all of these reaches averaging <40% across the two years, including <10% in reaches 1, 9, 11, 13, and 14 (**Table 16**). Long-term patterns (**Appendix D, E**) suggest that reach 1 may be showing a trend of decreasing wetted length with time over the last 20 years. Reaches 2-4 had intermediate values (average of 64%-82%) across 2002-2023, similar to multi-year patterns. Most reaches, aside from those with nearly continuous surface water, had lower percent wetted length in 2022 than 2023. Reach 8 was particularly striking in this regard, with nearly continuous surface water in June 2023 (92%) and very little wetted length in 2022 (6.5%). Of all the reaches, this one has been the most variable across years in the percentage length of surface water (**Figure 12, Appendix D, E**).

Analysis by Arizona TNC (Lisa McCauley, pers. comm.) suggests statistically discernable negative trends in wetted length for reaches 1 and 5 ($p<0.001$) over the period of record, a significant positive trend for reach 14 ($p=0.005$), and no significant trend for the other reaches ($p>0.20$ for each) based on Mann-Kendall tests (**Appendix E**). The Mann-Kendall trend test is a non-parametric statistical approach that assesses whether there is a consistent directional (monotonic) change in a variable, in this case, the length of wetted channel.

Consistency of Field Methods and Vegetation Change

Growth of vegetation over the last 20 years and some minor differences in field methods could have influenced vegetation bioindicator values, particularly for the floodplain, irrespective of hydrologic changes. We noticed several differences between floodplain vegetation values computed in our work from 2023 compared to those by Stromberg et al. (2006a,b) from 2001-2004.

First, our floodplain width measurements (transect lengths) were often narrower – sometimes by 40% or more – than those for the 20 sites recorded in Stromberg et al. (2006b: Digital Appendix 7B) (**Figure 13**). Differences in estimates of floodplain width may affect computation of other variables, such as % of the floodplain in shrubland (bioindicator 5) and basal area of cottonwood and willow per unit area (bioindicator 2). Our floodplain widths were >10% narrower for ten sites, >10% wider for four sites (Hereford, Hunter, Boquillas North, Escalante), and differed by 10% or less from Stromberg et al. for six sites (Cottonwood, Charleston South, Charleston Bridge, Charleston Mesquite, Summers, Contention). Floodplain widths were strikingly greater in the Stromberg data set for the two Palominas sites, Depot, and St. David, but considerably greater in our data at Hereford.

Some of these discrepancies in floodplain width may simply reflect slight differences in transect placement or azimuth. However, it is also possible that we defined the floodplain-terrace boundary differently from Stromberg et al. on some of the sites. Although we used vegetation and topographic cues in the field to help determine the floodplain-terrace boundary, we also relied on a GIS shapefile of the SPRNCA floodplain to determine where the floodplain ended, and the terrace began. This floodplain map was derived by Stromberg et al. (2006a) by digitizing historical channel maps from Hereford (1993) and topographic breakpoints from LiDAR to define the boundary between the post-entrenchment floodplain and the pre-entrenchment surface (terrace). Based on visual comparisons using GIS, our floodplain widths appeared to match the floodplain-terrace shapefile very well, suggesting that past field sampling by Stromberg et al. may have extended beyond this boundary on some sites.

Second, the proportion of the floodplain in shrubland patches (bioindicator 5) was usually lower and the proportion of forest was usually higher in our data than in Stromberg et al. (2006b: Digital Appendix 7B) (**Figures 14 and 15**). Shrubland averaged 21% across the 20 sites in Stromberg's dataset, but only averaged 12% in our dataset, while the combined width of forest and woodland averaged 30% in Stromberg's dataset and 53% in ours. For 16 of the 20 sites in common between the two datasets, % shrubland patch width was greater in Stromberg's dataset, and combined woodland and forest coverage was greater in our study for 17 of the 20 sites. These differences directly affected the scoring of bioindicator 5. In Stromberg's dataset, four sites in the northern tier or reaches (Depot, Summers, Contention, St. David) would have received scores of "1" for bioindicator 5, as they had % shrubland coverage of at least 35% in 2001-2004 (**Table 2**). Three of these sites (Depot, Summers, St. David), however, received a bioindicator score of "2.5" in 2023, as all except Contention had <35% shrubland coverage in the floodplain.

The reasons for the difference in shrubland coverage in the floodplain between our study and Stromberg et al. are unknown. Narrower floodplain measurements in our data could have contributed to this, if the longer transects of Stromberg intersected more shrubland in what we called terrace. However, another possibility is simply that woody vegetation, particularly mesquite, may have matured (if it was mostly young vegetation in the earlier surveys) and grown in stature from shrubland (<5 m tall) in 2001-2004 to woodland or forest (>5 m tall) in 2023. Comparison of mesquite stem diameters in our 2023 dataset vs. the 2001-2004 data of Stromberg et al., if the data are available, could shed more light on this issue.

Third, our estimates for bioindicator 4, maximum vegetation height, were often much larger than Stromberg's (**Figure 16**). In Stromberg's dataset, the mean height of the tallest tree per transect was 19.5

m vs. 25.9 m in ours, and tree height was greater in our dataset for all 20 sites. In Stromberg's data, the mean tallest tree was 15 m tall or less for four sites (Depot, Contention, St. David, and Charleston Bridge), resulting in a low bioindicator 4 score (1) for those sites. However, in our data, all of those sites except Contention had tree heights >15 m, resulting in Depot, St. David, and Charleston Bridge each receiving a score of 2.5 instead of 1 for bioindicator 4. These differences in our tallest tree data vs. that of Stromberg et al. may, in part, have to do with growth of the vegetation (particularly cottonwood) over the last 20 years. However, as noted earlier, we suspect that some of our tree height measurements may have been overestimates, as our measurements included multiple cottonwood trees over 30 m tall and even as large as 36.5 m (120 feet). We recommend rechecking and possibly remeasuring the maximum tree heights in the field or via using LiDAR to confirm these estimates.

Finally, although there were not systematic differences across all sites in cottonwood and willow absolute (bioindicator 2) and relative basal area (bioindicator 3), some individual sites differed considerably between our dataset and that of Stromberg et al. Using the Stromberg dataset, only the St. David site in reach 13 would have received a low (dry) score for both cottonwood and willow basal area variables, with basal area less than 4.7 m^2/ha and relative basal area <21% (**Figures 17 and 18**). In our dataset, none of the sites had relative basal area of cottonwood and willow <21%, and only one site had cottonwood-willow basal area <4.7 m^2/ha, but this time it was Contention rather than St. David. Cottonwood-willow basal area was more than eight-fold higher in our dataset than the Stromberg dataset at St. David (**Figure 17**) and the number of cottonwood-willow 10-cm diameter classes (bioindicator 1) (**Figure 8**) also appears higher than previously (e.g., Stromberg et al. 2006a: Figure 5).

The net effect of improved values for all of the floodplain bioindicators at St. David (from all scoring as "1" in Stromberg to all scoring as "2.5" in our dataset) is that the site and reach now are classified as intermediate condition (class 2), rather than being the sole dry condition (class 1) site and reach in the SPRNCA in Stromberg's original surveys (Stromberg et al. 2006a,b). Scores for the streamside bioindicators 8 (absolute cover of hydric herbs) and 9 (relative cover of hydric herbs) also were higher in our study (**Tables 6 and 12**) than in the original Stromberg study, further contributing to the improvement in condition score at St. David. Whether these changes are related to maturation of the vegetation, some differences in transect placement, hydrologic changes, or some combination of these reasons is unknown.

CONCLUSIONS AND RECOMMENDATIONS

The riparian assessment model, based on the nine vegetation bioindicators, scored thirteen of the 25 sites in the SPRNCA as condition class 3 (wet) and twelve as condition class 2 (intermediate). In contrast to previous years, no sites were classified as condition class 1 (dry). At the reach-level, five reaches were classified as condition class 3 and eight as condition class 2. None were classified as condition class 1. We did not assign a condition class to reach 14. The only site sampled there (Escalante) occurs on a small section with perennial streamflow, whereas most of the reach is intermittent. To properly account for the diversity of flow conditions in the reach, a second site should be added on an intermittent section of the reach. Then the condition scores for the two sites can be averaged to provide a more representative composite score for the reach.

The vegetation on some sites and reaches (e.g., reach 3) had higher condition scores (wet instead of intermediate) than expected from past sampling and from recent groundwater and streamflow permanence conditions. Reach 13, with the two St. David sites, scored higher in 2023 than in the original riparian assessment 20 years ago, largely because of floodplain bioindicator values (# of cottonwood-willow diameter classes, cottonwood-willow absolute and relative basal area, maximum vegetation height, and % shrubland) in 2023 that were characteristic of intermediate or wet conditions in the assessment model. This reach had formerly been classified as the driest reach in the SPRNCA. It is unknown to what extent these higher scores are the result of vegetation growth over the last 20 years, differences in sampling approach or floodplain definition, changes in hydrology, or other factors. The extent to which floodplain bioindicator values might be sensitive to maturation of the vegetation with time, to slight differences in protocol, or in response to other non-hydrological factors, should be investigated.

Lewis Springs, the only site in reach 5, was classified as condition class 2 (intermediate) on the basis of low cover of hydric perennial herbs. This score does not seem to be consistent with the history of perennial flow and shallow groundwater at the site. The streamside bioindicators (6-9) in the assessment model are meant to serve as an indicator of short-term hydrologic conditions. Hence, additional years of streamside monitoring would help determine whether these lower scores at Lewis Springs simply reflect short-term drier conditions in 2022 and 2023 or are symptomatic of longer-term trends. The wet-dry mapping data also showed that small portions of reach 5 have been dry in June during some recent years, and analysis suggests that this represents a statistically discernable negative trend in wetted length. Unfortunately, no camera stations are in operation at Lewis Springs to assess flow permanence, and data based on a stream flow gage have not been updated to assess flow permanence since 2013. Given these possible warning signs from the riparian assessment model and the wet-dry mapping, it may be beneficial to increase the hydrologic monitoring effort at Lewis Springs or elsewhere on reach 5. Besides Lewis Springs, hydrologic monitoring could also be augmented on reaches 2, 10, and 14. It may be useful to reinitiate camera station (or other) monitoring of streamflow permanence at Hereford (ended in 2019) or elsewhere (Kolbe) on reach 2, as none currently exists to our knowledge. Groundwater monitoring could also be expanded to reaches 10 and 14, as no wells from those reaches are available in the WHIP database.

Evidence of different kinds of site disturbances (e.g., fire, vegetation clearing, channel shifting, cattle) were observed across multiple sites in the SPRNCA. Kolbe was the only site that appeared to be strongly affected by recent fire. Some of the Escalante (reach 14) sampling transects were truncated because of private land or have been significantly altered by understory and mid-story vegetation management, and other sites in the northern tier of reaches (e.g., Depot, Contention, Tombstone) also showed some evidence of vegetation alteration. Evidence of cattle was ubiquitous across the SPRNCA, with at least some signs of recent cattle presence on 20 of the 25 sites, including in the channel and streamside zones. The extent to which disturbance by cattle may affect streamside (or other) bioindicator scores is unknown.

Although Fremont cottonwood and Goodding's willow, foundational species in the riparian corridor, occupy considerable areas of forest within the SPRNCA, the forests are strongly dominated by trees greater than 30-50 years old. Trees less than about 30 years old (and even fewer that are less than 11 years old) constitute only a small percentage of the forest area, suggesting that current forests are largely a legacy of past geomorphic dynamics, with few opportunities for recruitment of new forests under the current regime of the river.

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Figure 5. Relative widths of different vegetation structural types in the terrace of each study site.

Figure 6. Proportion of terrace patch width by dominant species. Other riparian includes seep-willow, net-leaf hackberry, and velvet ash. Desert shrubs include whitethorn acacia, catclaw acacia, rubber rabbitbrush, four-wing saltbush, and creosote.

Figure 7. Mean height (and standard deviation) for the tallest tree per transect on each site.

Figure 8. Mean (and standard deviation) of the number of 10-cm basal diameter classes of Fremont cottonwood and Goodding's willow per transect on each study site.

Figure 9. Mean absolute basal area (m^2/ha) for Fremont cottonwood, Goodding's willow, and saltcedar per transect on each study site.

Figure 10. Relative basal area for Fremont cottonwood, Goodding's willow, and saltcedar (% of each, relative to the sum of the three species) on each study site.

Table 11. Vegetation values by site for the five floodplain bioindicators based on 2023 sampling data.

Table 12. Individual and composite (mean) bioindicator scores per site and reach based on 2023 data.

Table 13. Hydrologic conditions at vegetation study sites. Groundwater (GW) mean, maximum, minimum, and flux correspond to mean values for 2022-2023, except for Summers, which only had data from 2023. Multi-year mean flow permanence (%) is for 2014-2023, except for Lewis Springs (2006-2013) and Hereford (2014-2019). Flow permanence % in 2023 includes records only up until October or December, depending on the site. For Cottonwood, Fairbank North, and Escalante, flow permanence for 2023 also includes some dates in fall-winter 2022.

Figure 11. Map of the SPRNCA, with condition classes of vegetation sites and reaches, based on 2023 vegetation sampling. Wet and dry river reaches are based on June 2023 wet-dry mapping.

Table 14. Mean values (and SD) for mean, maximum, minimum, and annual fluctuation in groundwater depths for 2022/2023, multi-year (2014-2023 for most sites) flow permanence, and 2023 flow permanence across vegetation sites in each condition class and overall. There were no sites scored as condition class 1, based on vegetation bioindicators.

Table 15. Hydrologic variables (mean and standard deviation) for sites sampled and classified into condition classes in 2002-2003. Modified from Stromberg et al. (2006b). Stromberg et al. did not report minimum groundwater levels.

Table 16. Percentage of surveyed San Pedro River length that had surface water during annual June wet-dry mapping in 2022-2023 and over previous multi-year periods, by reach. At the bottom of the table, means are for reaches classified in condition classes 2 and 3 in 2023 (reach 14 is excluded).

Figure 12. Percentage wetted channel length during June wet-dry mapping by SPRNCA reach in 2022 and 2023 (top) and 10-year (2014-2023) average and standard deviation by reach (bottom).

Figure 13. Comparison of mean (and standard deviation) floodplain width measurements between this study and Stromberg et al. (2006b).

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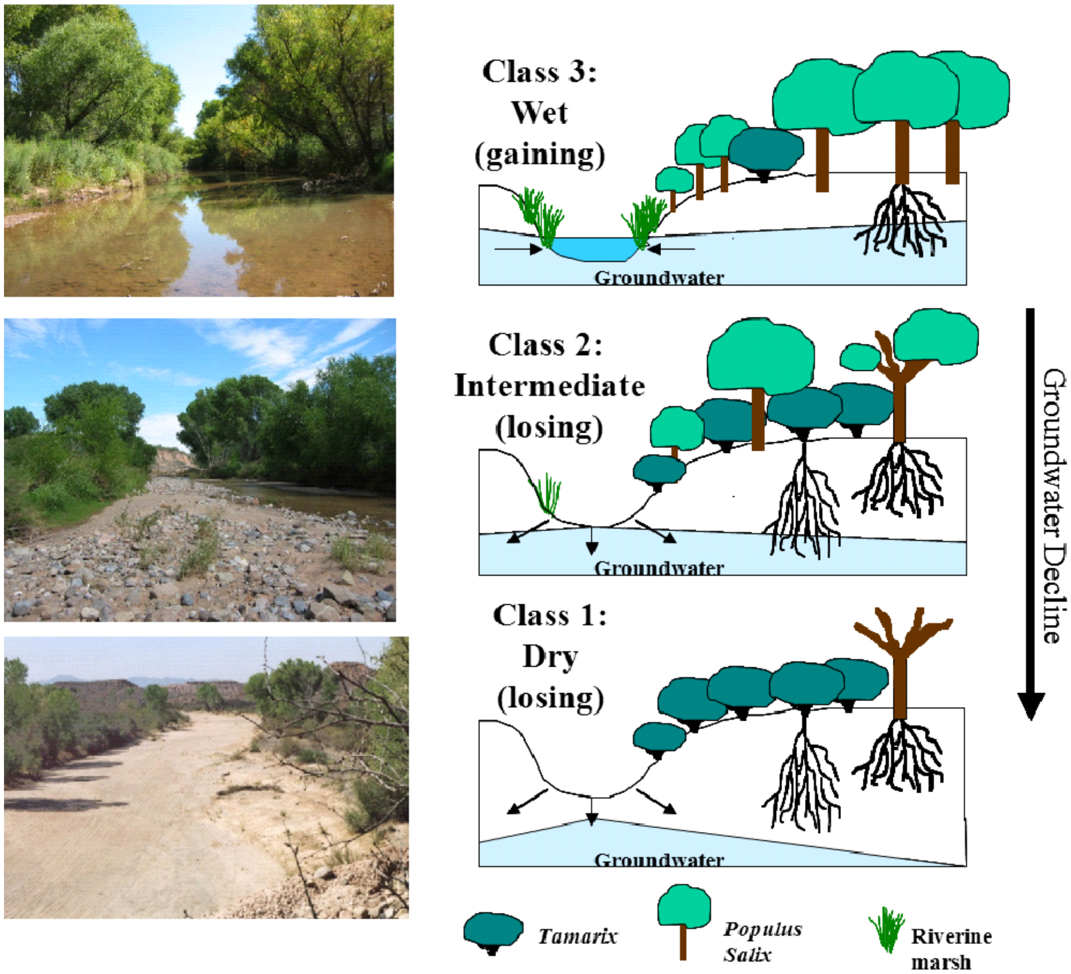


Figure 1. Schematic and site photographs of condition classes from the riparian assessment model.

Table 1. Study sites from south to north within the San Pedro Riparian National Conservation Area (SPRNCA). UTM coordinates are for monitoring well for each site. Site codes are used in the graphs.

Reach #	Site #	Site name	Site code	UTM Coordinates (Zone 12N) Northing (m)	Easting (m)
1	1	Palominas South	PLS	3469500	583000
1	2	Palominas	PAL	3470900	583800
2	3	Kolbe	KOL	3475900	585100
2	4	Hereford	HER	3480300	584600
3	5	Hunter South	HUS	3492100	584500
3	6	Hunter	HUN	3483500	583800
4	7	Cottonwood	COT	3487500	582600
4	8	Cottonwood North	CTN	3488700	582500
5	9	Lewis Springs	LS	3491700	581600
6	10	Moson	MOS	3497700	579000
7	11	Charleston South	CHS	3498600	578700
7	12	Charleston Bridge	CHB	3499500	578100
8	13	Charleston Mesquite	CHM	3503700	577900
8	14	Boquillas	BOQ	3506400	577300
9	15	Boquillas North	BON	3507500	577600
9	16	Fairbank	FAI	3509900	576400
10	17	Depot	DEP	3510800	575700
10	18	Fairbank North	FAN	3511900	576700
11	19	Tombstone South	TOS	3513000	575700
11	20	Tombstone	TOM	3513200	575700
12	21	Contention	CON	3514900	575400
12	22	Summers	SUM	3517800	574000
13	23	St. David	STD	3520300	574300
13	24	St. David North	SDN	3520800	573800
14	25	Escalante	ESC	3525200	574700

Table 2. Bioindicators for riparian assessment model (Stromberg et al. 2006a,b). Cottonwood refers to Fremont cottonwood (*Populus fremontii*), willow refers to Goodding's willow (*Salix gooddingii*). For bioindicator 3, cottonwood and willow basal area is expressed relative to the sum of cottonwood, willow, and saltcedar (*Tamarix ramosissima*) basal area. "Floodplain" includes both streamside and floodplain (but excludes terrace). For bioindicator 5, the direction of greater/less than symbols were incorrectly reported (switched) in Stromberg et al. (2006b) but are correctly reported here.

		Score			
Bioind. #	**Bioindicator variable**	**1**	**1.5**	**2.5**	**3**
1	# 10-cm Cottonwood + Willow size classes in floodplain	≤ 3		> 3	
2	Cottonwood + Willow basal area (m^2/ha)	≤ 4.7		> 4.7	
3	Cottonwood + Willow relative basal area (%)	≤ 21		> 21	
4	Maximum vegetation height in floodplain (m)	≤ 15		> 15	
5	Relative (%) coverage of shrubland patches in floodplain	≥ 35		< 35	
6	Absolute cover of streamside hydric perennial herbs (%)		≤ 5		> 5
7	Relative cover of streamside hydric perennial herbs (%)		≤ 14		> 14
8	Absolute cover of streamside hydric herbs (%)		≤ 29		> 29
9	Relative cover of streamside hydric herbs (%)		≤ 24		> 24

Table 3. Common and scientific names of woody plants species (sub-shrubs, shrubs, vines, trees) recorded during field sampling.

Common Name	**Scientific Name**	**Scientific Name (USDA Plants)**
Whitethorn acacia	*Acacia constricta*	*Vachellia constricta*
Sweet acacia	*Acacia farnesiana*	*Vachellia farnesiana*
Catclaw acacia	*Acacia greggii*	*Senegalia greggii*
Viscid acacia	*Acacia neovernicosa*	*Vachellia vernicosa*
Fourwing saltbush	*Atriplex canescens*	*Atriplex canescens*
Seep-willow	*Baccharis salicifolia**	*Baccharis salicifolia*
Coulter brickellbush	*Brickellia coulteri*	*Brickellia coulteri*
Bird of paradise	*Caesalpinia gilliesii*	*Caesalpinia gilliesii*
Spiny hackberry	*Celtis pallida*	*Celtis ehrenbergiana*
Net-leaf hackberry	*Celtis reticulata*	*Celtis laevigata* var. *reticulata*
Buttonbush	*Cephalanthus occidentalis*	*Cephalanthus occidentalis*
Desert willow	*Chilopsis linearis*	*Chilopsis linearis*
Coulter's wrinklelfruit	*Clerodendrum coulteri*	*Tetraclea coulteri*
Cane cholla	*Cylindropuntia spinosior*	*Cylindropuntia spinosior*
Ephedra	*Ephedra trifurca*	*Ephedra trifurca*
Rubber rabbitbrush	*Ericameria nauseosa*	*Ericameria nauseosa*
Tarbush	*Flourensia cernua*	*Flourensia cernua*
Velvet ash	*Fraxinus velutina*	*Fraxinus velutina*
Threadleaf snakeweed	*Gutierrezia microcephala*	*Gutierrezia microcephala*
Burrobush	*Hymenoclea monogyra*	*Hymenoclea monogyra*
Burroweed	*Isocoma tenuisecta*	*Isocoma tenuisecta*
Arizona walnut	*Juglans major*	*Juglans major*
Allthorn	*Koeberlinia spinosa*	*Koeberlinia spinosa*
Creosote	*Larrea tridentata*	*Larrea tridentata*
Redberry desert-thorn	*Lycium andersonii*	*Lycium andersonii*
Pale desert-thorn	*Lycium pallidum*	*Lycium pallidum*
Horehound	*Marrubium vulgare*	*Marrubium vulgare*
Catclaw mimosa	*Mimosa aculeaticarpa* var. *biuncifera*	*Mimosa aculeaticarpa* var. *biuncifera*
Texas mulberry	*Morus microphylla*	*Morus microphylla*
Fremont cottonwood	*Populus fremontii*	*Populus fremontii*
Velvet mesquite	*Prosopis velutina*	*Prosopis velutina*
Little-leaf sumac	*Rhus microphylla*	*Rhus microphylla*
Skunkbush sumac	*Rhus trilobata*	*Rhus trilobata*
Goodding's willow	*Salix gooddingii*	*Salix gooddingii*
Black elderberry	*Sambucus nigra*	*Sambucus nigra*
Soapberry	*Sapindus saponaria*	*Sapindus saponaria*
Saltcedar	*Tamarix ramosissima*	*Tamarix ramosissima*
Arizona grape	*Vitis arizonica*	*Vitis arizonica*
Graythorn	*Ziziphus obtusifolia*	*Ziziphus obtusifolia*

*May include Emory baccharis, *Baccharis emoryi*. The two species were not distinguished during field sampling.

Table 4. Plant taxa encountered in streamside quadrat sampling. Asterisk indicates non-native species. WIS is wetland indicator status. Hydric species (OBL and FACW) are in **bold**. Longevity is perennial (P) and non-perennial (NP). In Herb/Woody, H denotes herbaceous and W, woody. [1]Denotes modified from original hydric or longevity designation to better match Stromberg et al. (2006b: Digital Appendix 7D).

Scientific Name	Common Name	WIS	Longevity (P/NP)	Herb/ Woody (H/W)
Ambrosia artemisiifolia	annual ragweed	FACU	NP	H
Ambrosia confertiflora	weakleaf bur ragweed	UPL	P	H
Ambrosia psilostachya	cuman ragweed	FACU	P[1]	H
Ambrosia trifida	great ragweed	FAC	NP	H
Baccharis salicifolia	**seep-willow**	**FACW**	**P**	**W**
Castilleja minor	**lesser Indian paintbrush**	**OBL**	**P[1]**	**H**
Chenopodium berlandieri	pitseed goosefoot	FACU	NP	H
Chenopodium fremontii	Fremont's goosefoot	FACU	NP	H
*Cirsium arvense**	Canada thistle	FACU	P	H
Conyza canadensis	Canadian horseweed	FACU	NP	H
Cryptantha sp.	*Cryptantha* sp.	Unknown	NP	H
*Cynodon dactylon**	Bermudagrass	FACU	P	H
Descurainia pinnata	western tansymustard	UPL	NP	H
Echinochloa crus-galli*	**barnyard grass**	**FACW**	**NP**	**H**
Eleocharis palustris	**common spikerush**	**OBL**	**P**	**H**
Eleocharis rostellata	**beaked spikerush**	**OBL**	**P**	**H**
Equisetum laevigatum	**smooth horsetail**	**FACW**	**P**	**H**
Erigeron divergens	spreading fleabane	UPL	P[1]	H
Eriogonum trichopes	little deserttrumpet	Unknown	NP	H
Halimolobos pubens	spreading fissurewort	Unknown	P	H
Helenium thurberi	**Thurber's sneezeweed**	**OBL**	**NP**	**H**
Helianthus sp.	sunflower sp.	Unknown	NP	H
Juncus balticus	**mountain rush**	**FACW**	**P**	**H**
Juncus interior	inland rush	FAC	P	H
Juncus torreyi	**Torrey's rush**	**FACW**	**P**	**H**
Laennecia coulteri	**Coulters horseweed**	**FACW[1]**	**NP**	**H**
Lepidium thurberi	Thurber's pepperweed	FACU	NP	H
Lesquerella fendleri	Fendler's bladderpod	Unknown	P	H
*Melilotus alba**	white sweetclover	FACU	NP	H
*Melilotus indicus**	annual yellow sweetclover	FACU	NP	H
Melilotus sp.*	sweetclover	FACU	NP	H
Myosurus minimus	**tiny mousetail**	**OBL**	**NP**	**H**
Nama hispidum	bristly nama	UPL	NP	H
Nasturtium officinale*	**watercress**	**OBL**	**P**	**H**
Oenothera rosea	**rose evening primrose**	**FACW**	**P**	**H**
Oxalis stricta	common yellow oxalis	FACU	P	H

Persicaria lapathifolia	**curlytop knotweed**	**FACW**	**NP**	**H**
*Phalaris minor**	littleseed canarygrass	Unknown	NP	H
Polypogon monspeliensis*	**annual rabbitsfoot grass**	**FACW**	**NP**	**H**
Populus fremontii	**Fremont cottonwood**	**FACW**	**P**	**W**
Prosopis velutina	velvet mesquite	FACU	P	W
Pseudognaphalium stramineum	cottonbatting plant	FAC	NP	H
Ranunculus sceleratus	**cursed buttercup**	**OBL**	**NP**	**H**
Schoenoplectus acutus	**hardstem bulrush**	**OBL**	**P**	**H**
Schoenoplectus americanus	**chairmaker's bulrush**	**OBL**	**P**	**H**
Sonchus sp.*	sow-thistle	FACU	NP	H
*Sorghum halepense**	Johnsongrass	FACU	P	H
Sunflower sp.	sunflower sp.	Unknown	NP	H
Tagetes sp.*	marigold	Unknown	NP	H
*Tamarix ramosissima**	saltcedar	FAC	P	W
Typha domingensis	**southern cattail**	**OBL**	**P**	**H**
Verbesina encelioides	golden crownbeard	FACU	NP	H
Veronica anagallis-aquatica	water speedwell	OBL	P[1]	H
Veronica peregrina	**neckweed**	**FACW[1]**	**NP**	**H**
Xanthium strumarium	rough cocklebur	FAC	NP	H
Zannichellia palustris	**horned pondweed**	**OBL**	**P**	**H**

Table 5. Site-level summary of streamside herbaceous cover data (non-random plots excluded).

Reach #	Site Name	# plots	Total herb cover (%)	Hydric herb cover (%) (Bio 8)	Rel. cover hydric herbs (%) (Bio 9)	Hydric per. herb cover (%) (Bio 6)	Rel. cover hydric per. herbs (%) (Bio 7)
1	Palominas South	6	9.9	8.5	85.7	2.2	21.8
1	Palominas	7	5.7	2.1	36.3	0.1	1.3
2	Kolbe	5	78.8	73.7	93.5	53.5	67.9
2	Hereford	6	94.3	87.9	93.3	36.0	38.2
3	Hunter South	5	89.3	69.0	77.3	46.9	52.5
3	Hunter	5	108.3	73.6	68.0	23.1	21.3
4	Cottonwood	6	86.3	60.6	70.2	25.0	29.0
4	Cottonwood North	6	43.8	20.5	46.8	9.5	21.7
5	Lewis Springs	5	65.5	32.1	49.0	4.3	6.6
6	Moson	6	59.2	39.4	66.6	26.7	45.1
7	Charleston South	6	49.1	33.4	68.1	19.1	38.9
7	Charleston Bridge	6	68.8	54.6	79.3	43.8	63.7
8	Charleston Mesquite	6	47.2	27.5	58.3	1.9	4.1
8	Boquillas	6	47.8	40.1	83.8	10.2	21.3
9	Boquillas North	6	45.4	29.8	65.5	14.8	32.5
9	Fairbank	6	49.4	24.2	48.9	2.3	4.7
10	Depot	6	35.3	25.2	71.2	9.6	27.1
10	Fairbank North	6	51.1	31.0	60.7	2.8	5.5
11	Tombstone South	8	32.9	20.1	61.0	1.3	4.0
11	Tombstone	7	41.9	9.7	23.2	0.5	1.2
12	Contention	6	11.9	8.6	72.0	0.0	0.0
12	Summers	6	12.7	10.8	85.5	3.1	24.3
13	St. David	6	60.0	37.7	62.8	0.5	0.8
13	St. David North	6	56.8	38.4	67.6	0.1	0.1
14	Escalante	6	51.0	49.9	97.9	32.5	63.7

Table 6. Site- and reach-level summary of streamside herbaceous bioindicator scores (6-9).

Reach #	Site Name	Bio 6	Bio 7	Bio 8	Bio 9	Site Mean (Bio 6-9)	Reach Mean (Bio 6-9)	Reach SD (Bio 6-9)
1	Palominas South	1.5	3	1.5	3	2.25	2.06	0.27
1	Palominas	1.5	1.5	1.5	3	1.88		
2	Kolbe	3	3	3	3	3	3	0
2	Hereford	3	3	3	3	3		
3	Hunter South	3	3	3	3	3	3	0
3	Hunter	3	3	3	3	3		
4	Cottonwood	3	3	3	3	3	2.81	0.27
4	Cottonwood North	3	3	1.5	3	2.63		
5	Lewis Springs	1.5	1.5	3	3	2.25	2.25	-
6	Moson	3	3	3	3	3	3	-
7	Charleston South	3	3	3	3	3	3	0
7	Charleston Bridge	3	3	3	3	3		
8	Charleston Mesquite	1.5	1.5	1.5	3	1.88	2.44	0.80
8	Boquillas	3	3	3	3	3		
9	Boquillas North	3	3	3	3	3	2.44	0.80
9	Fairbank	1.5	1.5	1.5	3	1.88		
10	Depot	3	3	1.5	3	2.63	2.44	0.27
10	Fairbank North	1.5	1.5	3	3	2.25		
11	Tombstone South	1.5	1.5	1.5	3	1.88	1.69	0.27
11	Tombstone	1.5	1.5	1.5	1.5	1.5		
12	Contention	1.5	1.5	1.5	3	1.88	2.06	0.27
12	Summers	1.5	3	1.5	3	2.25		
13	St. David	1.5	1.5	3	3	2.25	2.25	0
13	St. David North	1.5	1.5	3	3	2.25		
14	Escalante	3	3	3	3	3	3	-

Table 7. Floodplain site disturbance scores, based on the relative width (% of total streamside-floodplain width) of patches that contained some evidence of each kind of disturbance. % Fire (All) represents evidence of fire at any time in the past, whereas % Fire (New) represents evidence of fire in the last five years.

Reach #	Site Name	% Fire (All)	% Fire (New)	% Cattle	% Clearing	% Flood	% Chan Shift
1	Palominas South	8.2	0	0	0	0	0
1	Palominas	0	0	0	0	0	0
2	Kolbe	68.8	68.8	5.9	0	7.8	1.9
2	Hereford	0	0	21.4	0	10.1	0.3
3	Hunter South	17.0	2.0	18.8	0	0	0
3	Hunter	0	0	15.6	0	30.5	0.5
4	Cottonwood	0	0	8.8	0	9.4	0
4	Cottonwood North	0	0	0	0	3.7	0
5	Lewis Springs	20.6	4.1	8.6	0	16.1	0
6	Moson	0	0	0	0	4.5	4.5
7	Charleston South	0	0	2.2	0	0	0
7	Charleston Bridge	0	0	0	0	0	0
8	Charleston Mesquite	0	0	40.8	0	0	0
8	Boquillas	0	0	27.7	0	0	0
9	Boquillas North	0	0	8.8	0	2.5	0
9	Fairbank	0	0	30.0	0	0	0
10	Depot	0	0	41.4	9.9	0	0
10	Fairbank North	0	0	72.8	0	0	0
11	Tombstone South	0	0	22.3	0	10.4	0
11	Tombstone	0	0	32.9	12.6	0	0
12	Contention	0	0	6.4	13.1	0	0
12	Summers	0	0	39.0	0	5.2	0.6
13	St. David	0	0	10.9	0	9.1	0
13	St. David North	0	0	7.2	0	0	0
14	Escalante	4.4	4.4	5.4	23.1	0	0

Table 8. Terrace site disturbance scores, based on the relative width (% of total sampled terrace width) of patches that contained some evidence of each kind of disturbance. % Fire (All) represents evidence of fire at any time in the past, whereas % Fire (New) represents evidence of fire in the last five years. Terrace patches were not significantly affected by flood disturbance or channel shifting.

Reach #	Site Name	% Fire (All)	% Fire (New)	% Cattle	% Clearing
1	Palominas South	0	0	0	0
1	Palominas	0	0	0	10.8
2	Kolbe	83.3	83.3	0	0
2	Hereford	0	0	16.7	0
3	Hunter South	16.7	0	0	0
3	Hunter	33.3	0	7.5	9.2
4	Cottonwood	0	0	0	0
4	Cottonwood North	0	0	0	0
5	Lewis Springs	55.2	35.0	0	0
6	Moson	0	0	0	0
7	Charleston South	0	0	0	12.0
7	Charleston Bridge	0	0	0	20.7
8	Charleston Mesquite	0	0	0	0
8	Boquillas	1.2	0	16.1	4.3
9	Boquillas North	0	0	0	0
9	Fairbank	0	0	0	0
10	Depot	0	0	5.5	0
10	Fairbank North	0	0	0	0
11	Tombstone South	0	0	0	26.1
11	Tombstone	0	0	0	4.1
12	Contention	0	0	10.5	0
12	Summers	0	0	0	0
13	St. David	0	0	0	0
13	St. David North	0	0	0	0
14	Escalante	0	0	10.3	34.7

Table 9. Total mean width of floodplain (includes streamside) and % of floodplain width in different structural vegetation types per site.

Reach #	Site Name	Total Width Mean (m)	Total Width SD (m)	% OPEN	% HERB LAND	% GRASS LAND	% SHRUB LAND	% WOOD LAND	% FOREST
1	Palominas South	122.5	34.2	0.0	0.0	57.9	0.0	9.3	32.8
1	Palominas	115.2	33.4	0.0	0.0	23.4	8.8	9.7	58.1
2	Kolbe	103.3	14.5	9.7	0.0	31.9	0.0	41.0	17.4
2	Hereford	251.5	112.1	0.0	3.6	42.7	24.3	6.0	23.4
3	Hunter South	179.3	29.0	0.0	1.0	55.5	17.2	10.1	16.1
3	Hunter	206.3	36.2	0.5	0.0	11.0	34.6	9.9	43.9
4	Cottonwood	321.7	29.3	23.1	0.0	26.5	14.9	11.7	23.7
4	Cottonwood North	198.7	69.0	0.0	0.0	35.4	21.8	18.6	24.2
5	Lewis Springs	135.8	25.7	0.0	0.0	73.8	0.0	7.4	18.8
6	Moson	220.0	97.1	4.8	0.0	32.0	5.9	32.4	24.9
7	Charleston South	50.7	2.3	0.0	0.0	4.8	2.1	50.7	42.4
7	Charleston Bridge	73.0	11.1	17.1	9.7	24.1	0.0	39.9	9.2
8	Charleston Mesquite	59.0	10.8	15.1	0.0	21.1	0.0	16.9	46.9
8	Boquillas	120.3	44.7	10.3	0.0	21.4	17.6	26.0	24.7
9	Boquillas North	119.7	11.9	15.9	0.0	28.4	16.2	4.7	34.7
9	Fairbank	50.7	22.0	0.0	0.0	37.1	0.0	21.6	41.3
10	Depot	56.7	6.5	16.0	0.0	18.5	2.7	47.2	15.6
10	Fairbank North	78.0	43.6	23.7	0.0	36.1	1.8	29.1	9.2
11	Tombstone South	68.3	13.9	17.1	0.0	27.3	17.5	38.2	0.0
11	Tombstone	47.8	17.9	18.5	0.0	8.5	15.6	25.5	31.9
12	Contention	340.3	52.7	2.7	0.0	36.1	55.4	4.4	1.4
12	Summers	296.3	132.8	0.0	0.0	0.9	17.8	25.9	55.4
13	St. David	155.3	38.2	23.2	0.0	5.9	26.2	27.5	17.2
13	St. David North	391.7	18.6	4.8	0.0	37.0	23.5	28.2	6.6
14	Escalante	182.1	86.3	0.0	8.3	3.2	1.6	36.5	50.5
	MEAN	**157.8**	**99.5**	**8.1**	**0.9**	**28.0**	**13.0**	**23.1**	**26.8**

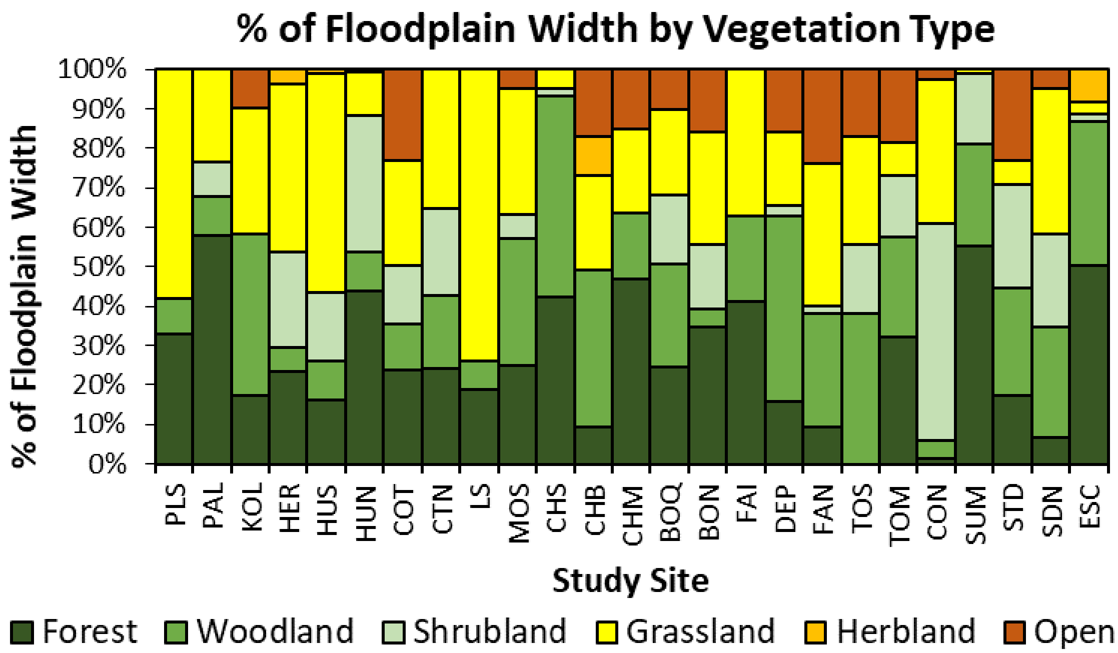


Figure 2. Relative widths of different vegetation structural types in the floodplain of each study site.

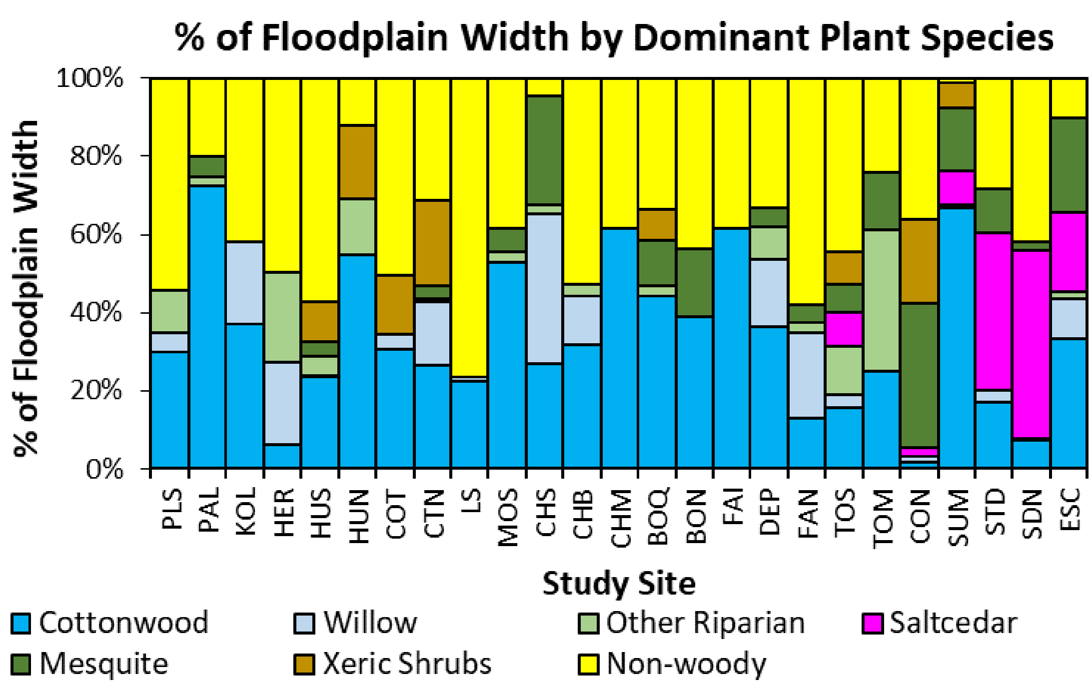


Figure 3. Proportion of floodplain patch width by dominant species. Willow is Goodding's willow. Other riparian includes seep-willow, net-leaf hackberry, and velvet ash. Xeric shrubs include rubber rabbitbrush, burrobrush, catclaw mimosa, four-wing saltbush, and catclaw acacia.

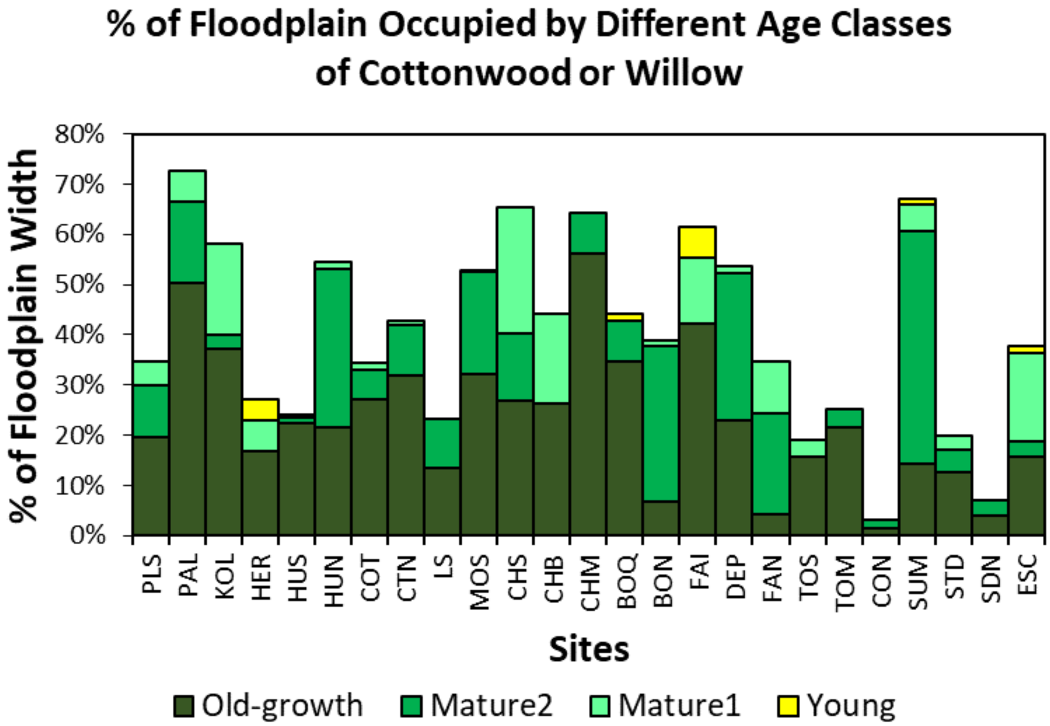


Figure 4. Percentage of the floodplain width composed of Fremont cottonwood or Goodding's willow patches, by age class, at each study site.

Table 10. Total mean width of sampled terrace and % of terrace width in different structural vegetation types per site.

Reach #	Site Name	Total Width Mean (m)	Total Width SD (m)	% OPEN	% HERB LAND	% GRASS LAND	% SHRUB LAND	% WOOD LAND	% FOREST
1	Palominas South	188.0	20.8	13.0	38.4	48.6	0.0	0.0	0.0
1	Palominas	212.0	20.8	26.3	36.0	9.2	28.5	0.0	0.0
2	Kolbe	200.0	0.0	0.0	50.0	50.0	0.0	0.0	0.0
2	Hereford	201.7	2.9	0.0	0.0	53.7	29.7	16.7	0.0
3	Hunter South	200.0	0.0	0.0	0.0	95.8	4.2	0.0	0.0
3	Hunter	200.0	0.0	0.0	0.0	56.5	20.3	15.7	7.5
4	Cottonwood	232.7	58.3	0.0	0.0	56.4	7.5	35.0	1.1
4	Cottonwood North	166.7	57.7	1.7	0.0	41.7	49.2	7.5	0.0
5	Lewis Springs	200.0	0.0	0.0	0.0	86.0	12.3	1.7	0.0
6	Moson	200.0	0.0	0.0	12.8	26.7	0.0	49.7	10.8
7	Charleston South	142.0	41.3	0.0	0.0	9.6	37.8	22.2	30.4
7	Charleston Bridge	166.7	95.4	0.0	0.0	20.7	44.0	8.5	26.9
8	Charleston Mesquite	200.0	0.0	0.0	0.0	0.0	16.7	50.0	33.3
8	Boquillas	186.7	32.1	0.0	1.2	4.3	0.0	44.7	49.8
9	Boquillas North	200.0	0.0	0.0	6.5	0.0	0.0	35.2	58.3
9	Fairbank	200.0	0.0	3.3	0.0	10.2	32.3	25.0	29.2
10	Depot	200.0	0.0	11.8	0.0	3.3	23.2	33.2	28.5
10	Fairbank North	172.8	50.1	0.0	0.0	28.1	38.0	27.2	6.7
11	Tombstone South	114.7	91.7	24.7	0.0	0.0	68.4	6.9	0.0
11	Tombstone	133.0	59.8	4.1	0.0	0.0	70.4	25.5	0.0
12	Contention	233.3	57.7	8.5	0.0	0.0	74.8	16.7	0.0
12	Summers	186.7	23.1	0.0	0.0	8.0	18.3	49.5	24.2
13	St. David	200.0	0.0	0.0	0.0	0.0	23.2	76.8	0.0
13	St. David North	233.3	57.7	0.0	0.0	0.0	25.6	50.0	24.4
14	Escalante	205.0	120.5	3.4	0.0	0.0	56.6	38.1	1.9
	MEAN	**191.0**	**28.9**	**3.9**	**5.8**	**24.4**	**27.2**	**25.4**	**13.3**

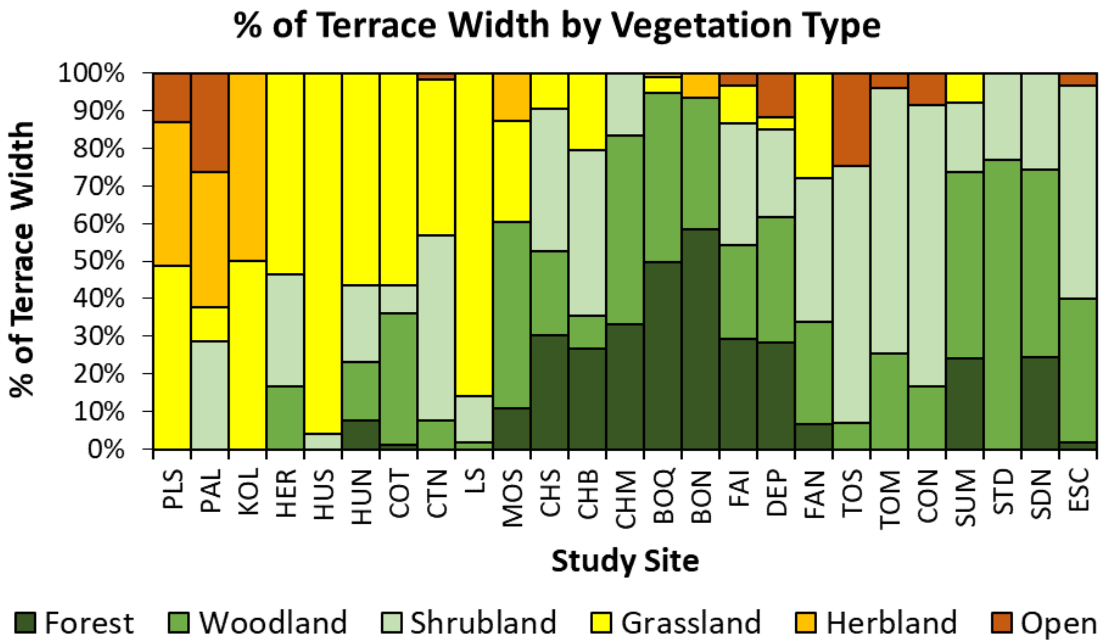


Figure 5. Relative widths of different vegetation structural types in the terrace of each study site.

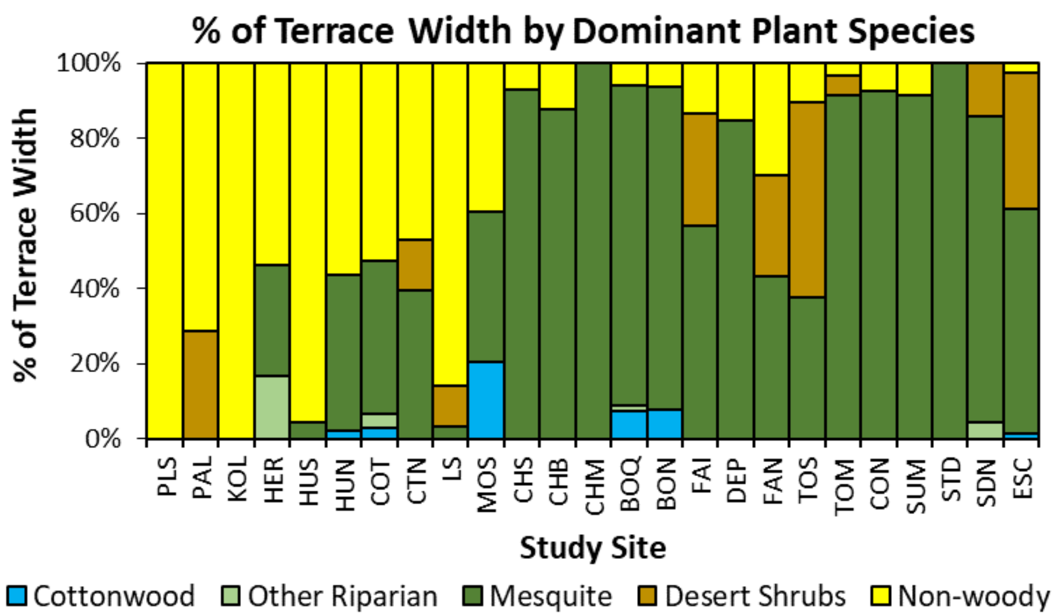


Figure 6. Proportion of terrace patch width by dominant species. Other riparian includes seep-willow, net-leaf hackberry, and velvet ash. Desert shrubs include whitethorn acacia, catclaw acacia, rubber rabbitbrush, four-wing saltbush, and creosote.

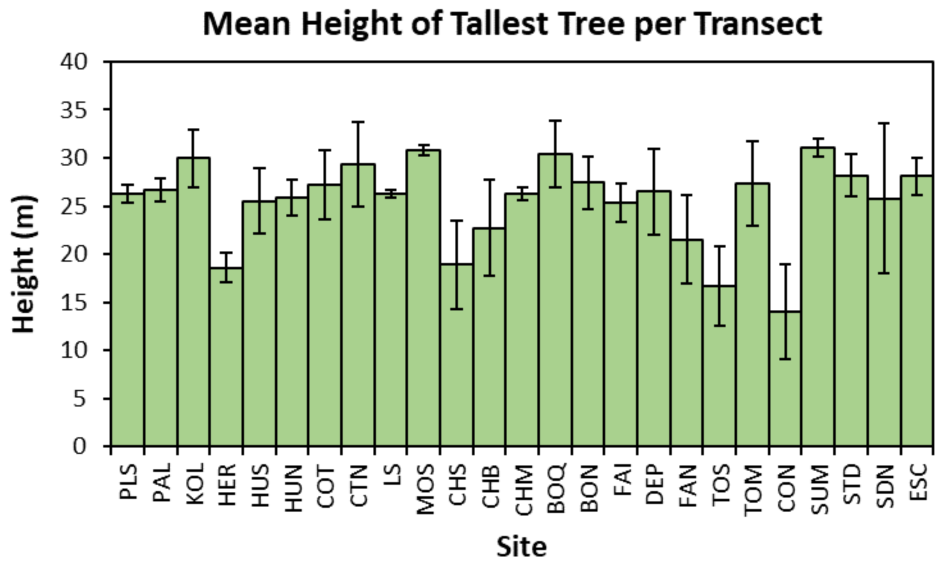


Figure 7. Mean height (and standard deviation) for the tallest tree per transect on each site.

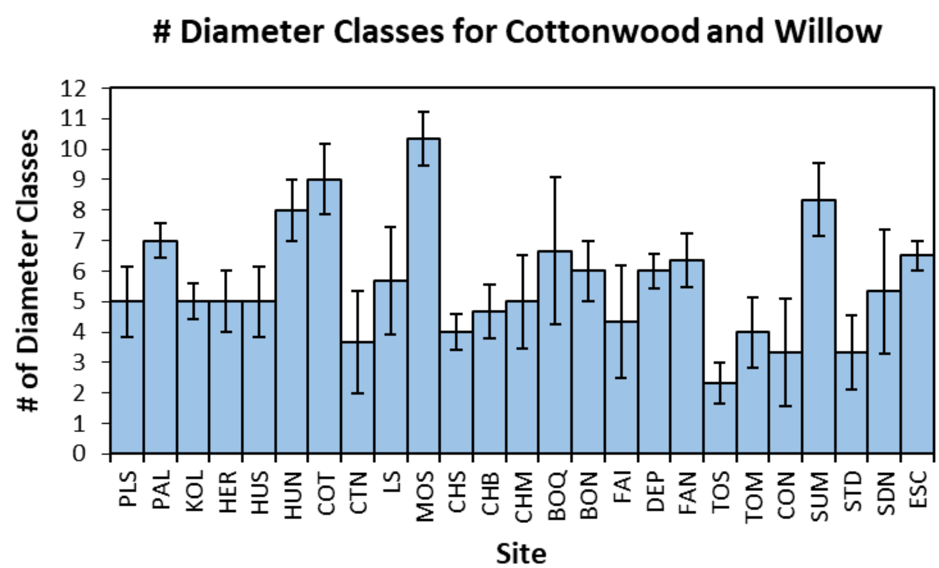


Figure 8. Mean (and standard deviation) of the number of 10-cm basal diameter classes of Fremont cottonwood and Goodding's willow per transect on each study site.

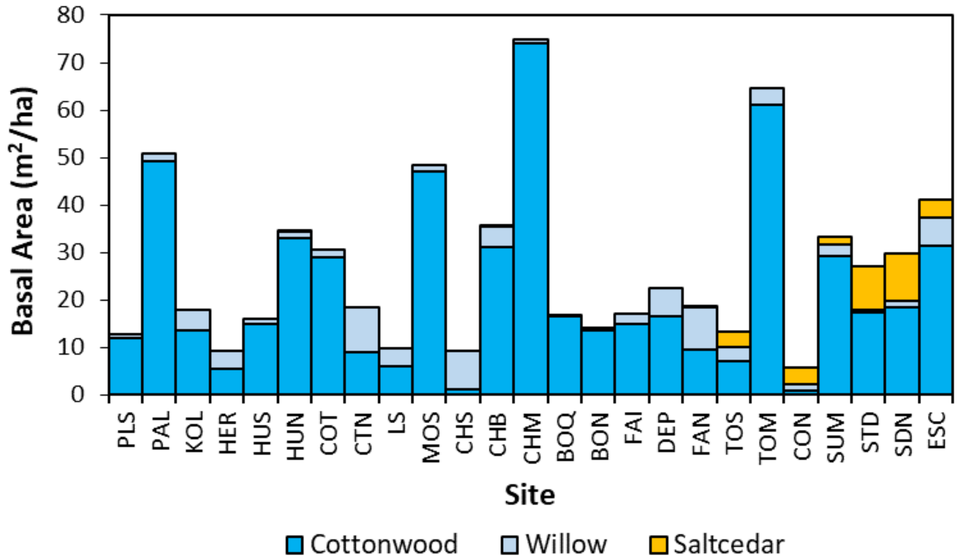


Figure 9. Mean absolute basal area (m^2/ha) for Fremont cottonwood, Goodding's willow, and saltcedar per transect on each study site.

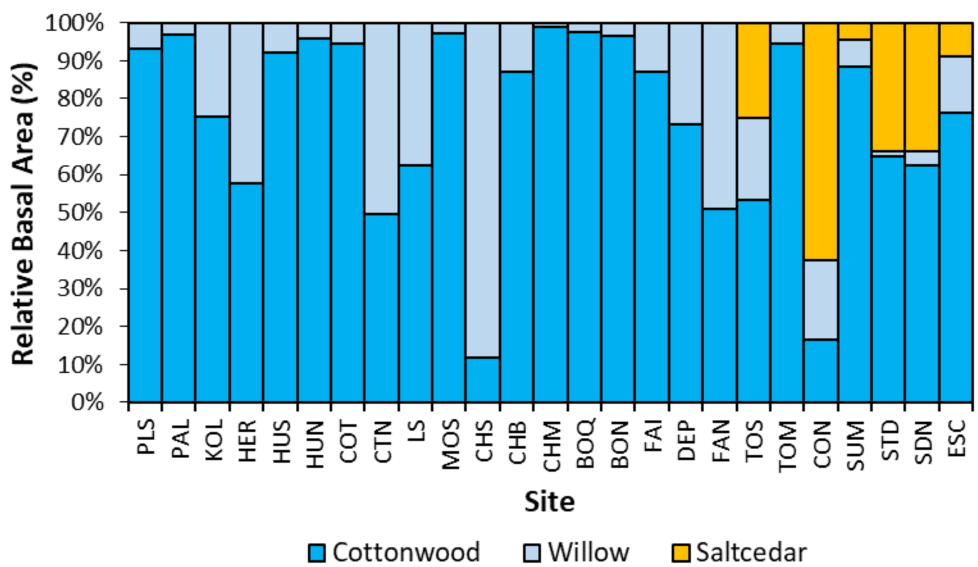


Figure 10. Relative basal area for Fremont cottonwood, Goodding's willow, and saltcedar (% of each, relative to the sum of the three species) on each study site.

Table 11. Vegetation values by site for the five floodplain bioindicators based on 2023 sampling data.

Reach #	Site Name	Mean # CW-WI Diam. Classes (Bio 1)	CW-WI Basal Area (m^2/ha) (Bio 2)	CW-WI Relative Basal Area (%) (Bio 3)	Max Tree Height (m) (Bio 4)	% SHRUBLAND (Bio 5)
1	Palominas South	5.0	12.8	100	26.3	0.0
1	Palominas	7.0	50.9	100	26.7	8.8
2	Kolbe	5.0	17.9	100	30.0	0.0
2	Hereford	5.0	9.3	100	18.6	24.3
3	Hunter South	5.0	16.0	100	25.5	17.2
3	Hunter	8.0	34.5	100	25.9	34.6
4	Cottonwood	9.0	30.6	100	27.2	14.9
4	Cottonwood North	3.7	18.4	100	29.3	21.8
5	Lewis Springs	5.7	9.8	100	26.3	0.0
6	Moson	10.3	48.4	100	30.8	5.9
7	Charleston South	4.0	9.3	100	18.9	2.1
7	Charleston Bridge	4.7	35.6	99.9	22.7	0.0
8	Charleston Mesquite	5.0	74.8	100	26.2	0.0
8	Boquillas	6.7	16.9	100	30.4	17.6
9	Boquillas North	6.0	14.0	100	27.4	16.2
9	Fairbank	4.3	17.1	100	25.3	0.0
10	Depot	6.0	22.5	100	26.5	2.7
10	Fairbank North	6.3	18.6	100	21.5	1.8
11	Tombstone South	2.3	9.9	75.0	16.7	17.5
11	Tombstone	4.0	64.6	100	27.3	15.6
12	Contention	3.3	2.2	37.5	14.0	55.4
12	Summers	8.3	31.7	95.4	31.1	17.8
13	St. David	3.3	17.9	66.2	28.2	26.2
13	St. David North	5.3	19.7	66.3	25.8	23.5
14	Escalante	6.5	37.4	91.2	28.1	1.6

Table 12. Individual and composite (mean) bioindicator scores per site and reach based on 2023 data.

Reach #	Site Name	Bio 1	Bio 2	Bio 3	Bio 4	Bio 5	Bio 6	Bio 7	Bio 8	Bio 9	Site Mean Score	Reach Mean Score	Reach Score SD
1	Palominas South	2.5	2.5	2.5	2.5	2.5	1.5	3	1.5	3	2.39	2.31	0.12
1	Palominas	2.5	2.5	2.5	2.5	2.5	1.5	1.5	1.5	3	2.22		
2	Kolbe	2.5	2.5	2.5	2.5	2.5	3	3	3	3	2.72	2.72	0
2	Hereford	2.5	2.5	2.5	2.5	2.5	3	3	3	3	2.72		
3	Hunter South	2.5	2.5	2.5	2.5	2.5	3	3	3	3	2.72	2.72	0
3	Hunter	2.5	2.5	2.5	2.5	2.5	3	3	3	3	2.72		
4	Cottonwood	2.5	2.5	2.5	2.5	2.5	3	3	3	3	2.72	2.64	0.11
4	Cottonwood North	2.5	2.5	2.5	2.5	2.5	3	3	1.5	3	2.56		
5	Lewis Springs	2.5	2.5	2.5	2.5	2.5	1.5	1.5	3	3	2.39	2.39	-
6	Moson	2.5	2.5	2.5	2.5	2.5	3	3	3	3	2.72	2.72	-
7	Charleston South	2.5	2.5	2.5	2.5	2.5	3	3	3	3	2.72	2.72	0
7	Charleston Bridge	2.5	2.5	2.5	2.5	2.5	3	3	3	3	2.72		
8	Charleston Mesquite	2.5	2.5	2.5	2.5	2.5	1.5	1.5	1.5	3	2.22	2.47	0.35
8	Boquillas	2.5	2.5	2.5	2.5	2.5	3	3	3	3	2.72		
9	Boquillas North	2.5	2.5	2.5	2.5	2.5	3	3	3	3	2.72	2.47	0.35
9	Fairbank	2.5	2.5	2.5	2.5	2.5	1.5	1.5	1.5	3	2.22		
10	Depot	2.5	2.5	2.5	2.5	2.5	3	3	1.5	3	2.56	2.48	0.12
10	Fairbank North	2.5	2.5	2.5	2.5	2.5	1.5	1.5	3	3	2.39		
11	Tombstone South	1	2.5	2.5	2.5	2.5	1.5	1.5	1.5	3	2.06	2.06	0
11	Tombstone	2.5	2.5	2.5	2.5	2.5	1.5	1.5	1.5	1.5	2.06		
12	Contention	2.5	1	2.5	1	1	1.5	1.5	1.5	3	1.72	2.06	0.47
12	Summers	2.5	2.5	2.5	2.5	2.5	1.5	3	1.5	3	2.39		
13	St. David	2.5	2.5	2.5	2.5	2.5	1.5	1.5	3	3	2.39	2.39	0
13	St. David North	2.5	2.5	2.5	2.5	2.5	1.5	1.5	3	3	2.39		
14	Escalante	2.5	2.5	2.5	2.5	2.5	3	3	3	3	2.72	-	-

Table 13. Hydrologic conditions at vegetation study sites. Groundwater (GW) mean, maximum, minimum, and flux correspond to mean values for 2022-2023, except for Summers, which only had data from 2023. Multi-year mean flow permanence (%) is for 2014-2023, except for Lewis Springs (2006-2013) and Hereford (2014-2019). Flow permanence % in 2023 includes records only up until October or December, depending on the site. For Cottonwood, Fairbank North, and Escalante, flow permanence for 2023 also includes some dates in fall-winter 2022.

Reach #	Site Name	Cond. Class	GW Well	GW Mean Depth (m)	GW Max Depth (m)	GW Min Depth (m)	Annual GW Flux (m)	% Flow multi-year mean	% Flow 2023
1	Palominas South	2	PLS-LI	2.23	2.81	1.71	1.10	--	--
1	Palominas	2	PAL-LD	1.77	2.34	1.34	1.01	49.0	34.8
2	Kolbe	3	KOL-LI	1.70	1.81	1.63	0.18	--	--
2	Hereford	3	HER-LD	1.64	2.14	1.36	0.78	100.0	--
3	Hunter South	3	--	--	--	--	--	--	--
3	Hunter	3	HUN-LO	1.71	2.33	1.34	0.98	83.8	60.4
4	Cottonwood	3	COT-LD	2.43	2.68	2.27	0.41	--	70.6
4	Cottonwood North	3	--	--	--	--	--	--	--
5	Lewis Springs	2	LSPLED	0.92	1.08	0.79	0.29	99.3	--
6	Moson	3	MOSLND	1.56	1.65	1.49	0.16	100.0	100.0
7	Charleston South	3	--	--	--	--	--	--	--
7	Charleston Bridge	3	CHB-LI	1.80	2.00	1.65	0.35	100.0	100.0
8	Charleston Mesquite	2	--	--	--	--	--	81.9	70.1
8	Boquillas	3	BOQ-LI	2.27	2.39	2.15	0.25	99.6	97.8
9	Boquillas North	3	--	--	--	--	--	--	--
9	Fairbank	2	FBK-LI	2.53	3.14	2.24	0.89	75.9	56.8
10	Depot	3	--	--	--	--	--	--	
10	Fairbank North	2	--	--	--	--	--	--	57.8
11	Tombstone South	2	--	--	--	--	--	--	--
11	Tombstone	2	TOM-LI	2.65	4.25	1.58	2.66	64.8	48.2
12	Contention	2	CONLID	2.85	4.89	1.82	3.07	51.7	47.3
12	Summers	2	SUM-LI	1.28	2.27	0.85	1.42	--	--
13	St. David	2	STD-LO	1.36	2.03	0.57	1.47	45.3	59.6
13	St. David North	2	--	--	--	--	--	--	--
14	Escalante	3	---	--	--	--	--	--	100.0

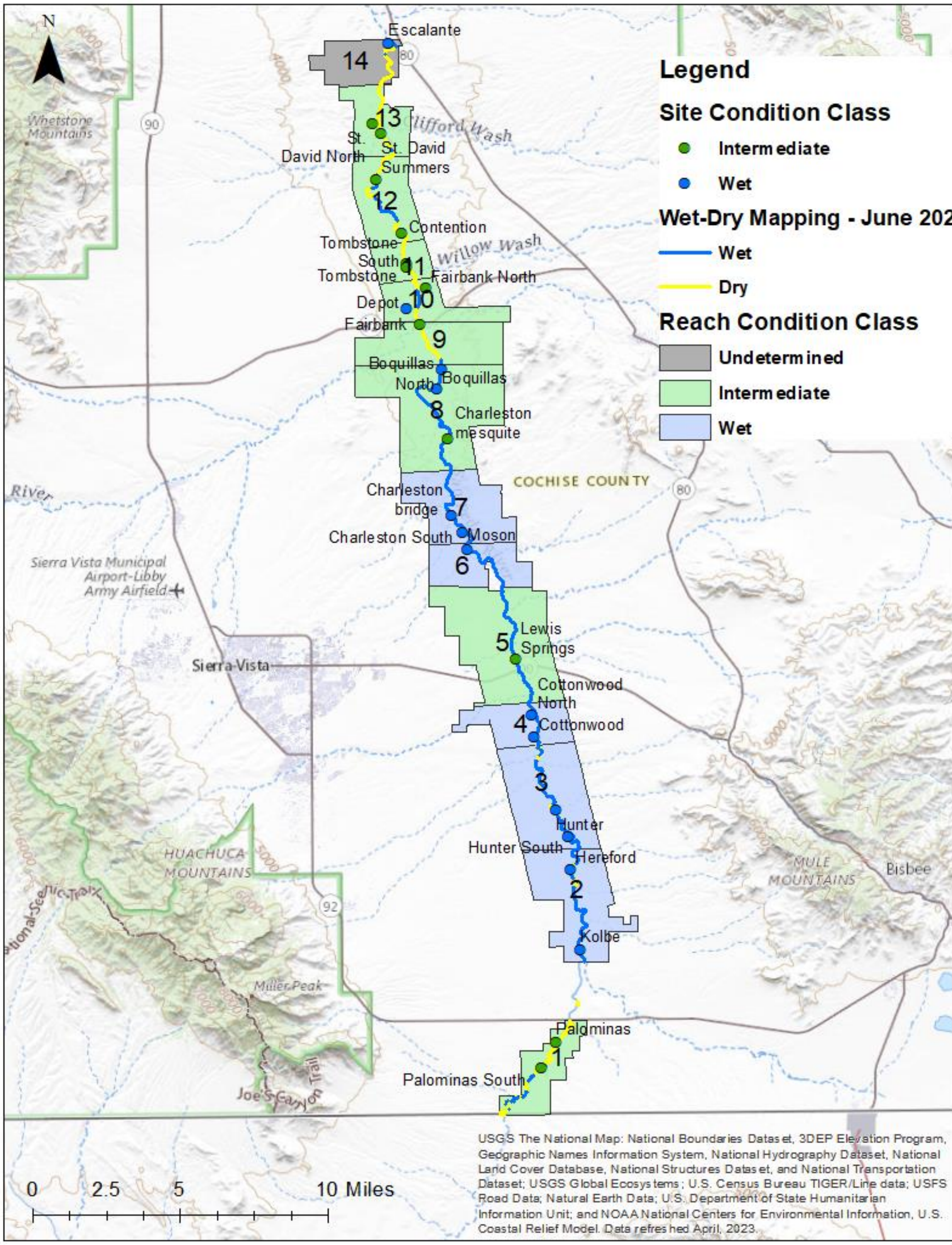


Figure 11. Map of the SPRNCA, with condition classes of vegetation sites and reaches, based on 2023 vegetation sampling. Wet and dry river reaches are based on June 2023 wet-dry mapping.

Table 14. Mean values (and SD) for mean, maximum, minimum, and annual fluctuation in groundwater depths for 2022/2023, multi-year (2014-2023 for most sites) flow permanence, and 2023 flow permanence across vegetation sites in each condition class and overall. There were no sites scored as condition class 1, based on vegetation bioindicators.

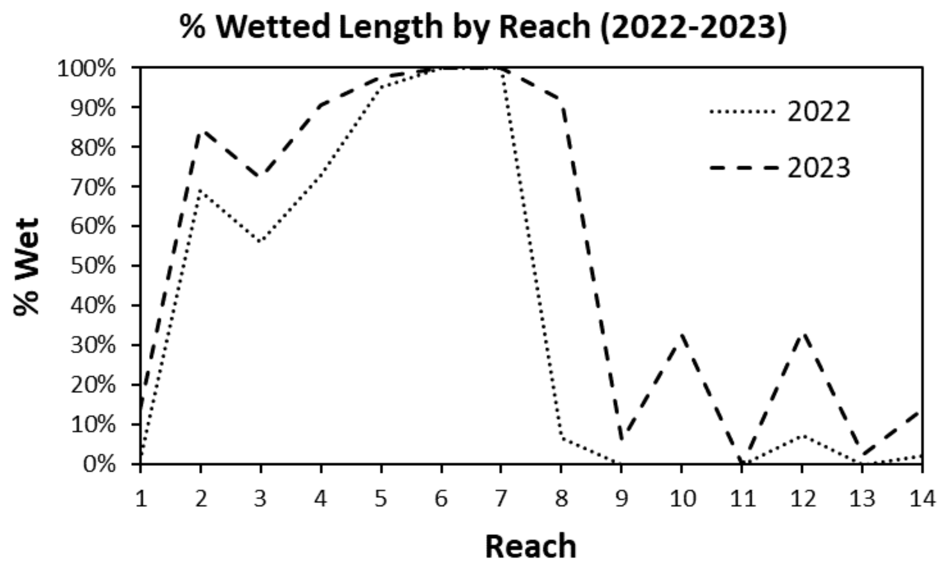
Condition Class	GW Mean Depth (m)	GW Max Depth (m)	GW Min Depth (m)	Annual GW Flux (m)	% Flow 2023	Mean % Flow multi-year
2	1.95 (0.72)	2.85 (1.23)	1.36 (0.58)	1.49 (0.93)	53.5 (11.3)	66.8 (19.9)
3	1.87 (0.34)	2.14 (0.36)	1.70 (0.37)	0.45 (0.32)	88.1 (17.8)	96.7 (7.2)
All	1.91 (0.56)	2.52 (0.97)	1.52 (0.51)	1.00 (0.87)	69.5 (22.8)	79.3 (21.7)

Table 15. Hydrologic variables (mean and standard deviation) for sites sampled and classified into condition classes in 2002-2003. Modified from Stromberg et al. (2006b). Stromberg et al. did not report minimum groundwater levels.

Condition Class	# Sites	GW Mean Depth (m)	GW Max Depth (m)	Annual GW Flux (m)	% Flow 2002	% Flow 2003
1	1	2.5	3.5	1.8	48	17
2	9	2.5 (0.6)	3.0 (0.9)	0.9 (0.7)	78 (15)	63 (21)
3	6	1.6 (0.5)	1.7 (0.5)	0.3 (0.0)	100 (0)	98 (4)

Table 16. Percentage of surveyed San Pedro River length that had surface water during annual June wet-dry mapping in 2022-2023 and over previous multi-year periods, by reach. At the bottom of the table, means are for reaches classified in condition classes 2 and 3 in 2023 (reach 14 is excluded).

Reach #	Condition Class (2023)	% Wet 2022	% Wet 2023	% Wet 2022-2023		% Wet 2019-2023		% Wet 2014-2023	
				Mean	SD	Mean	SD	Mean	SD
1	2	0.8	13.6	7.2	9.1	5.8	5.4	10.7	10.9
2	3	69.1	85.0	77.0	11.2	81.4	9.1	85.8	8.8
3	3	56.1	72.1	64.1	11.3	64.2	9.8	66.8	10.5
4	3	72.8	90.5	81.7	12.5	80.2	13.0	80.8	11.0
5	2	95.1	97.8	96.4	1.9	96.0	3.0	96.7	2.5
6	3	100.0	100.0	100.0	0.0	100.0	0.0	100.0	0.0
7	3	100.0	100.0	100.0	0.0	98.8	2.7	99.4	1.9
8	2	6.5	91.8	49.2	60.3	49.4	38.3	51.0	33.2
9	2	0.0	5.9	2.9	4.2	5.4	9.1	10.7	22.1
10	2	0.0	32.5	16.3	23.0	11.6	14.2	15.1	21.7
11	2	0.0	0.0	0.0	0.0	0.0	0.0	0.8	2.5
12	2	7.4	33.7	20.6	18.6	24.3	22.4	25.1	21.4
13	2	0.0	2.5	1.2	1.7	2.7	4.6	3.0	5.4
14	--	2.1	13.7	7.9	8.2	7.5	5.7	6.7	4.5
Mean	2	13.7	34.7	24.2	33.3	24.4	33.1	26.6	32.5
Mean	3	79.6	89.5	84.6	15.5	84.9	14.9	86.6	13.9



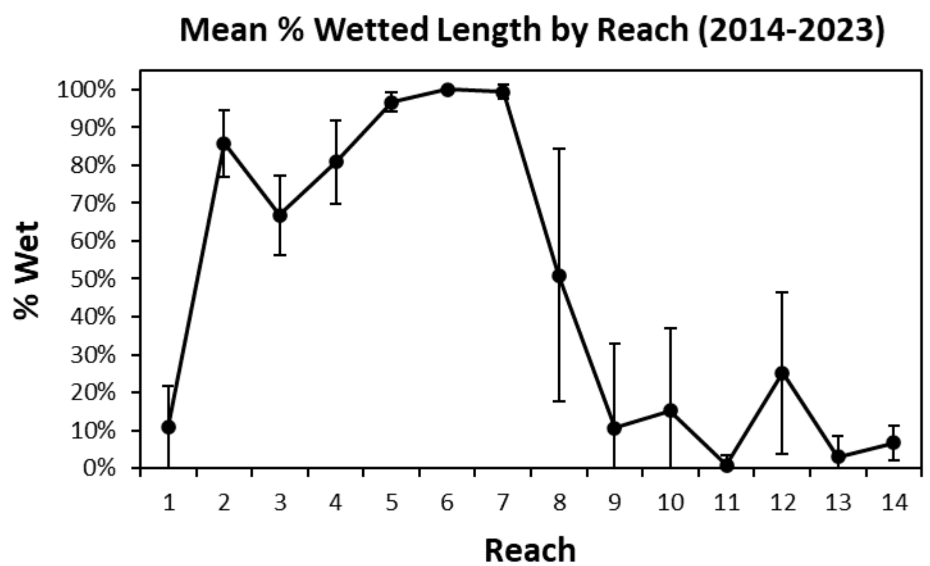


Figure 12. Percentage wetted channel length during June wet-dry mapping by SPRNCA reach in 2022 and 2023 (top) and 10-year (2014-2023) average and standard deviation by reach (bottom).

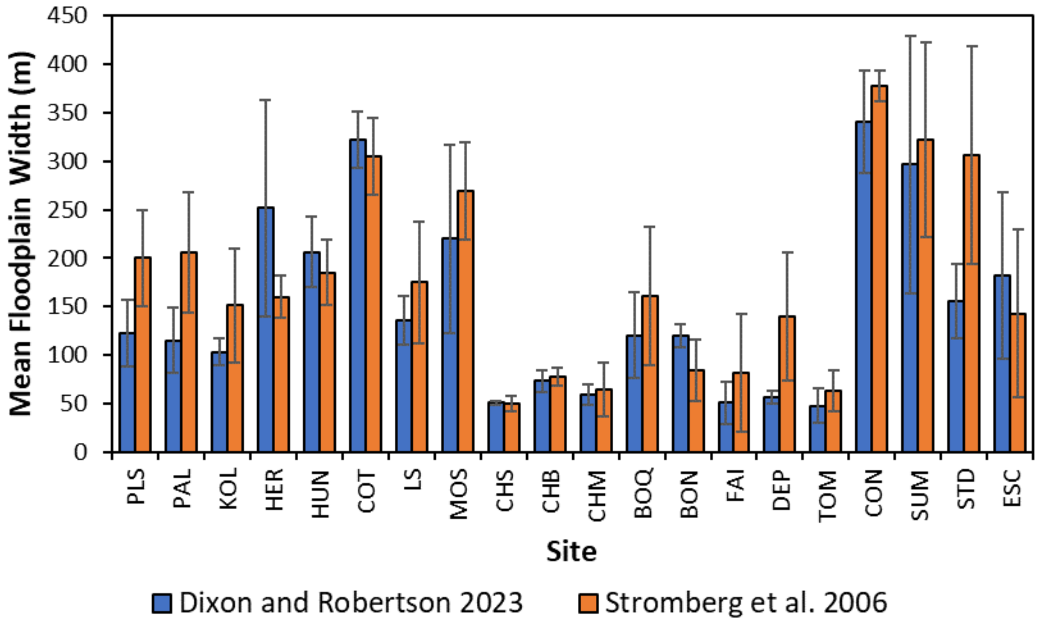


Figure 13. Comparison of mean (and standard deviation) floodplain width measurements between this study and Stromberg et al. (2006b).

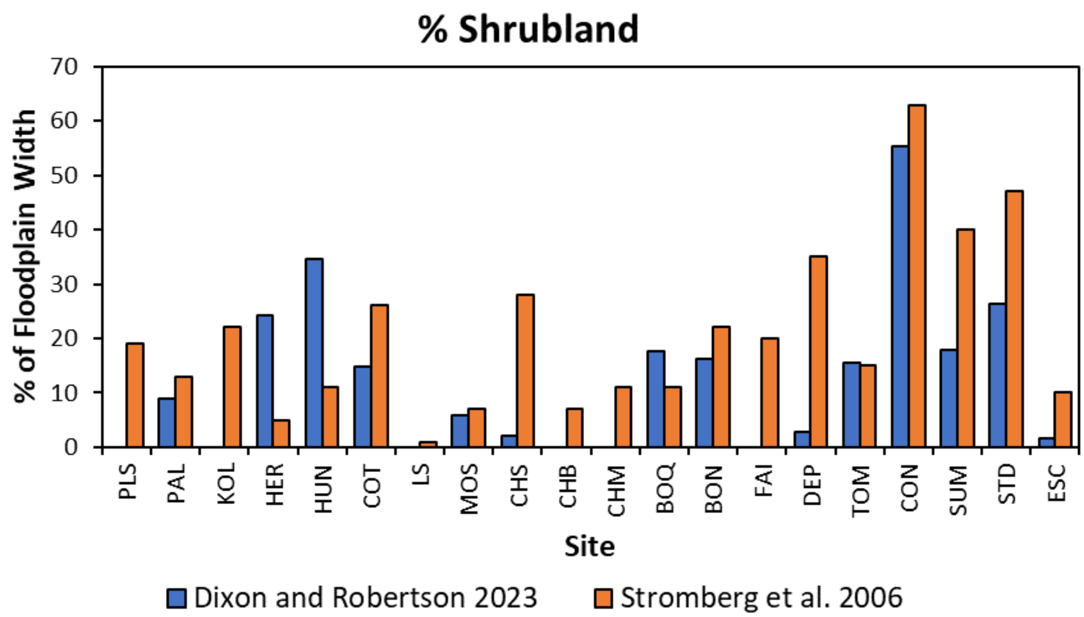


Figure 14. Comparison of percentage of floodplain width composed of shrubland patch types, by site, between this study and Stromberg et al. (2006b).

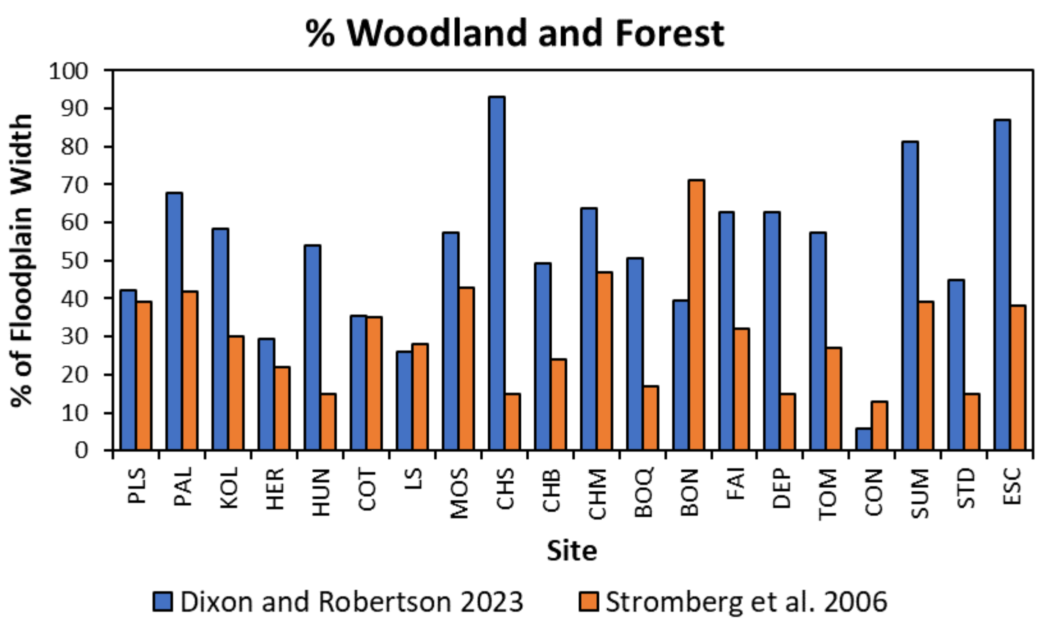


Figure 15. Comparison of percentage of floodplain width composed of woodland or forest patch types, by site, between this study and Stromberg et al. (2006b).

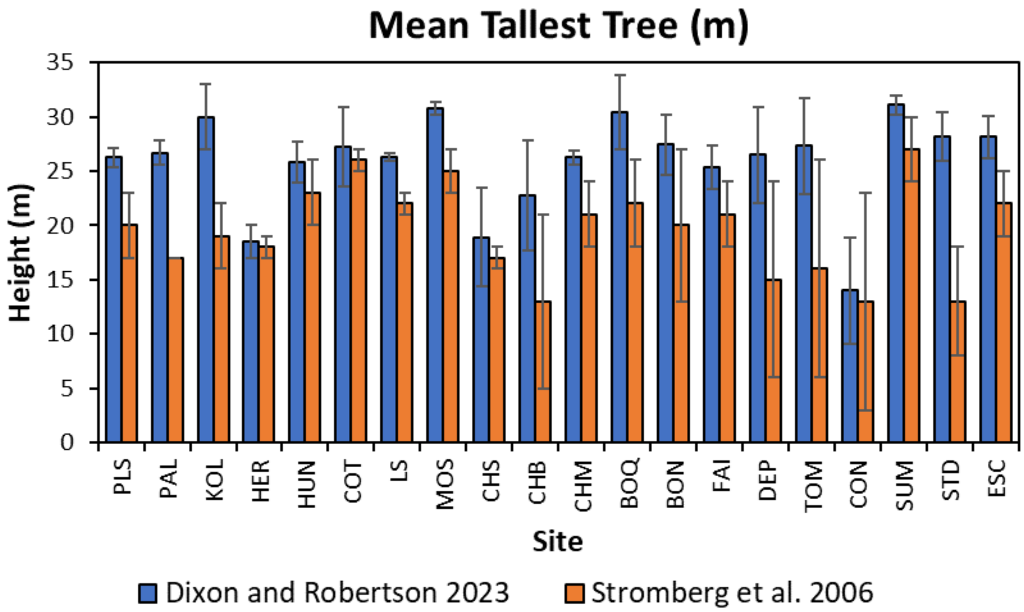


Figure 16. Comparison of mean (and standard deviation) height of tallest tree per site between this study and Stromberg et al. (2006b).

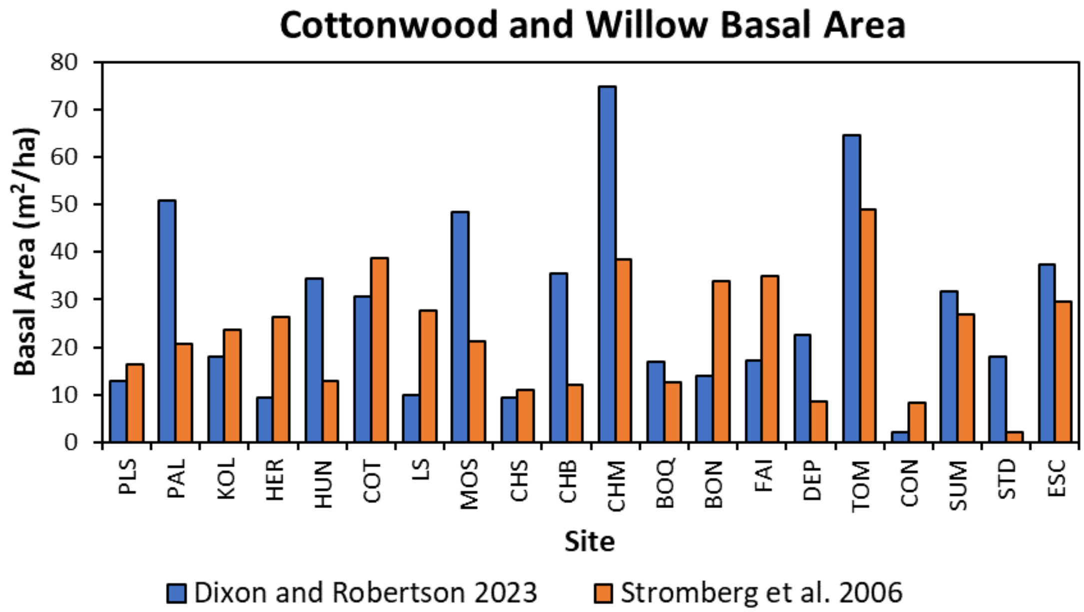


Figure 17. Comparison of mean total basal area (m^2/ha) of cottonwood and willow by site between this study and Stromberg et al. (2006b).

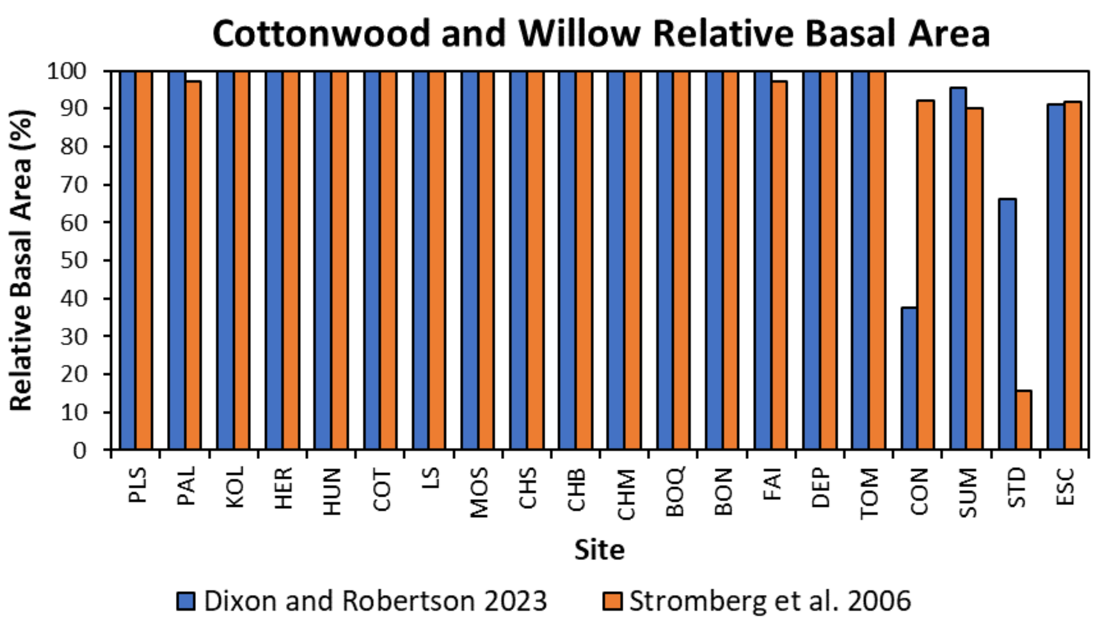


Figure 18. Comparison of relative basal area (%) of cottonwood and willow by site between this study and Stromberg et al. (2006b).