Velvet mesquite thinning to improve riparian forests

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Abstract--*Velvet mesquite (*Prosopis velutina*) in riparian settings is known for developing bosques, stands of mature trees with an open understory that supports other native plants and wildlife. Many historic mesquite bosques in the Madrean Archipelago have been cleared to allow farming on river floodplains. In some cases, cultivation of those farm fields was later abandoned, leading to a rapid recolonization by mesquite. The result has been dense stands of small mesquites, all competing for limited soil moisture and groundwater supply. We looked at the possibility of advancing one of those stands toward the structure of a mature community by an experimental thinning program. A treatment plot was thinned from 2,683 to 542 trees ha^{-1} (1086 to 219 trees ac^{-1}). During the first two years, stem diameters increased 67% faster in the thinned area than an adjacent control plot. After 19 years, the thinned plot still showed a more open stand structure and had a taller canopy than the control plot. However, resprouting of some cut trees affected results in basal area and area at breast height, so success of the effort would likely have been greater with some follow-up treatment. Based on these results, it appears that thinning dense sapling stands can produce significantly higher growth rates in the remaining trees, accelerating the transition to open stands of large trees that might provide better habitat for other species.*

INTRODUCTION

Velvet mesquite (*Prosopis velutina*) evolved within the Sonoran Desert and Madrean Archipelago regions of North America. It grows in a variety of geomorphic settings and can be part of very different biotic communities, largely dependent on access to water. In riparian contexts with relatively shallow groundwater, they can grow quite large and form closed-canopy forests known as bosques (Minkley and Clark 1981). Similar communities with the same common name are also formed by honey mesquite (*P. glandulosa* var. *glandulosa*) and western honey mesquite (*P. glandulosa* var. *torreyana*). Mesquite bosques were formerly abundant along low-elevation (below 1,200 m) rivers in the southwestern U.S. and northwestern Mexico, but they have been reduced to small remnant stands due to land clearing for agriculture and declining water tables. Virtually none remain in pristine condition, suggesting a need for both protection and restoration efforts (Brown 1982; Shreve and Wiggins 1964; Stromberg 1993; Szaro 1989).

Large velvet mesquite bosques were historically common along the San Pedro River in Sonora and Arizona, and small bosques remain common there as patch communities (Minkley and Clark 1981, Stromberg 1993). These bosques along the San Pedro River in Arizona were historically common only in entrenched reaches or along reaches where the flow was intermittent. After entrenchment spread during floods of 1890-1926, much of the river had suitable groundwater conditions to develop bosques. These were subsequently reduced by human activities, and small bosques remain common there as patch communities (Hereford and Betancourt 2009; Stromberg 1993; Stromberg et al. 2009).

Mature bosques were historically described as having dense canopies with a low density of large, single-trunked trees (Table 1). They tend to be strongly dominated by mesquite, with less than 25% of other tree species, and typically have a low-density understory of shrubs, vines, and seasonal herbaceous plants (Stromberg 1993).

Bosques are known to support diverse wildlife communities. Breeding bird species richness in riparian mesquite forests is equal to that found in cottonwood forests, and these riparian forest types support different suites of species (Brand et al. 2008). Bosques are particularly important for birds such as Abert's towhee (*Melozone aberti*) and Lucy's warblers (*Vermivora luciae*), and historically were important for Yellow-billed cuckoo (*Coccyzus americanus*) and Cactus ferruginous pygmy-owl (*Glaucidium brasilianum cactorum*)(Arnold 1940; Gavin 1973; Johnson et al. 1997; Johnson et al. 2000; Marshall 1960; Phillips et al. 1964). They were also the primary habitat for Merriam's mesquite mouse (*Peromyscus merriami*) (Arnold 1940; Hoffmeister 1986).

This study began with the observation that multiple sites along the San Pedro River had inactive farm fields, previously cleared of mesquite, that were displaying substantial recruitment of young mesquite. That recruitment appeared to be mediated by cattle which ate mesquite pods under nearby trees and deposited seed in their dung on the farm fields. The result was growth of mesquite seedling or sapling stands that appear dense enough to have intraspecific water competition.

Table 1—Structure of mature mesquite bosques. Values are reported as ranges or as means $\pm$ 1 SE.

Area	Density Trees Trees/ha (trees/ac)	Basal Area m^2/ha (ft^2/ac)	Canopy Height m (ft)	N	Reference
Arizona	736 $\pm$ 158 (298 $\pm$ 64)	39.8 $\pm$ 5.6 (173.4 $\pm$ 24.4)		4	Szaro 1989
Location:					
San Pedro River, Hassayampa River, Tanque Verde Creek		28.2 $\pm$ 1.6 (22.8 $\pm$ 7.0)	10.3 $\pm$ 0.5 (33.8 + 1.6)	10	Stromberg et al. 1993
Gila River	256 $\pm$ 86 (104 $\pm$ 35)		2-12 (6.6-39.4)	4	Minckley and Clark 1981
Sonoran Desert			15-18 (49.2-59.1)		Shreve and Wiggins 1964
Salt River	85 (35)				Douglas 1938
Lower Salt and Verde Rivers	200 trees >3m (81 trees >10 ft)			4	Higgins and Ohmart 1981
Salt River	260-530 (105-214)				Turner 1983
Hassayampa River	375-500 >1 cm dbh (148-197 >0.4 in dbh)				J. Stromberg unpubl. data

Our goal was to determine whether thinning of a dense stand of young velvet mesquite can speed the development of mature mesquite bosque community characteristics.

Silvicultural research on other tree species has clearly demonstrated that individual trees in dense stands will grow faster when released from intraspecific competition for resources (e.g., Roberts and Harrington 2008; Ronco et al. 1985; Stoneman et al. 1997). Several studies on upland stands of honey mesquite in Texas found that thinning dense sapling stands produced significantly higher growth rates in the remaining trees and inhibited establishment of new seedlings, leading to open stands of large trees (Cornejo-Oviedo et al. 1991; Felker et al. 1990; Patch and Felker 1997). A regression line of stand density against biomass/ha indicated that about 100 trees ha^{-1} (40 trees ac^{-1}), or 10 m (33 ft) spacing between trees, would produce the greatest volume of timber in honey mesquite stands. That regression had a slope that differed from the commonly reported -3/2 which might lead to full site occupancy without canopy closure, apparently due to the extensive root system of honey mesquite (Felker et al. 1990). We are not aware of previous comparable studies for velvet mesquite or other mesquite species in riparian settings.

METHODS

This study was conducted at Bingham Cienega Natural Preserve, a 115-ha (284 ac) site on the San Pedro River owned by the Pima County Flood Control District (32.458056°N, 110.483033°W). An analysis of 1879 General Land Office surveys of the area described a cienega (wetland) with adjacent sacaton grasslands, deciduous riparian forests, and mesquite bosques, along with some cultivated fields (Fonseca 1998). Much of the area around the cienega was cleared for agriculture soon after that. The agricultural fields on the Preserve were last cultivated in 1987, and grazing was eliminated in 1990.

Study plots were established on the Preserve in 1998, with a 0.34 ha (0.83 ac) treatment plot and an adjacent 0.18 ha (0.43 ac) control. Study plots were initially designed as adjacent rectangles, but the reference plot was clipped along one margin to avoid a layer of gypsum soils that clearly affected tree height and density. Initial density in the control plot was 2,683 trees ha^{-1} (1,086 trees ac^{-1}).

Mesquite stems on the treatment plot were thinned in April, 1998, so that adjacent individuals were 5-6 m (16.4-19.7 ft) apart, with a density of 542 trees ha^{-1} (219 trees ac^{-1}). This value was determined by literature densities for mature mesquite forests (Table 1). Trees were cut by hand, the cut stumps were treated with herbicide (Garlon™; Dupont de Nemours, Inc.), and the remaining trees were counted. We tagged 58 mesquite saplings in the thinned plot and 50 in the control plot and measured their stem diameter and maximum height in June 1998 and May 2000.

We revisited the plots on December 12, 2017. After relocating and marking boundaries, all mesquite trees were counted on each plot. A tree with more than one stem emerging from the trunk (main stem) or from the root crown was counted as a single individual. We also counted all understory shrubs by species on each plot. Tags from the initial study had been removed, so we were unable to identify previously tagged individuals. For 20 randomly chosen mesquite trees on each plot, we measured basal diameter at ground level, diameter at breast height (1.37 m high, 4.5 ft high) of all stems, and counted stems. Measurements were compared using two-sample t-tests assuming unequal variances.

To compare current tree heights, we obtained Lidar data for the area from Pima County, with data acquired from flights on February 20-26, 2015. Absolute vertical accuracy for the data was verified at 10.3 cm (4.1 in) for the raw LAS files. For the study area, the data had an average point density of 1.3 points m^{-2} (0.1 points ft^{-2}). It was collected in late winter, and thus at the time least likely to produce return data from leaf surfaces. There was no field verification of individual tree height and no attempt to correlate with basal diameter for a weighted canopy average, so the values used here provide a useful comparison between plots but cannot be assumed as a value comparable to other sites. Canopy top height was determined from the highest 10% of Lidar returns for each plot (reference plot n= 239, treated plot n=430). The mean ground surface elevation for each plot was subtracted from every canopy value, giving a canopy height above ground. Height values for the two plots were compared with a two-sample t-test assuming unequal variances. We used a significance value of p=0.05 with a two-tail probability.

RESULTS

Two years after thinning, there was a significantly greater increase in diameter among mesquites in the thinned plot, which increased an average of 2.5 cm (means of 4.6 and 7.1 cm in 1998 and 2000, respectively) compared to 1.5 cm in the control plot (4.5 and 6.0 cm)($p<0.005$, 105 df). This corresponds to a 67% increase in tree growth due to thinning in only two years. There was no significant difference in the change in tree height from 1998 to 2000. Trees in the thinned plot increased from 2.31 to 2.94 m (7.58 to 9.65 ft) compared to 2.19 to 2.95 m (7.19 to 9.68 ft) in the control (p=0.17, df=104). Most trees in the thinned and control plots had only a single stem. In 2000, 56 of the 58 trees in the thinned plot (97%) had a single stem or trunk, compared to 45 out of 50 trees in the control plot (90%); the remaining trees in both plots had two stems.

Measurements in 2017 showed that mesquite tree density increased on the thinned plot, from 542 to 1,363 trees ha^{-1} (219 to 552 trees ac^{-1}), between 1998 and 2017, through a combination of cut trees that resprouted and recruitment of new individuals. In contrast, the unthinned control plot showed a decrease, from 2,683 to 1,975 trees ha^{-1}. Trees on the thinned plot grew significantly taller than on the control plot, with mean top heights of 5.49 m (18.02 ft) in the thinned plot and 5.34 m (17.54 ft) in the unthinned plot (two-tailed p=0.005, df=420).

Mean basal area of trees was slightly greater on the thinned than the control plot (0.06 vs. 0.04 m^2, 0.67 vs. 0.38 ft^2), but the difference was not statistically significant (p=0.38). When considering only those trees with one or two stems at ground level (13 of the 20 measured on thinned plot, 19 of 20 on the control plot), basal area was almost identical between thinned and control plots (0.03 vs. 0.04 m^2, 0.33 vs. 0.38 ft^2).

Resprouted stems were conspicuous and significantly more abundant on the thinned plot. The sampled trees on the thinned plot had a mean of 5.2 live stems at breast height (range 1-13), twice the density on the control plot (mean 2.7 live stems at breast height, range 1-5; p=0.009) indicating a shift to a more shrub-like growth form. Understory shrubs found on the plots in 2017 showed differences in population density between plots. Graythorn (*Zizyphus obtusifolia*) had 122 plants ha^{-1} (49 plants ac^{-1}) on the thinned plot and 341 plants ha^{-1} (138 plants ac^{-1}) on the control plot, and hackberry (*Celtis* sp.) had 24 plants ha^{-1} (10 plants ac^{-1}) on the thinned plot and 205 plants ha^{-1} (83 plants ac^{-1}) on the control plot. Desert broom (*Baccharis sarothroides*) had 21 plants ha^{-1} (8 plants ac^{-1}) on the thinned plot and none on the control plot. Wolfberry (*Lycium* sp.) had one plant on each plot. A vine component was also present but leafless, and the herbaceous component was dormant during the field visit in 2017.

DISCUSSION

These results demonstrate that thinning a dense stand of young velvet mesquite can result in faster growth rates. It is possible that the effect would have been stronger if the area had been retreated at least once to eliminate root sprouts from cut trees. Despite the return of some cut trees and recruitment of new trees, the treated plot maintained a lower tree density than the control plot 19 years after treatment.

The decrease in tree density on the control plot supports the concept of self-thinning in mesquites, whereby higher density stands will cause enough competition to encourage natural mortality (Felker et al 1990). Despite that, density in the thinned stand remained 2-10 times higher than in mature mesquite reference sites.

The shrubs found on the plots are among those characteristic of mature mesquite bosques (Stromberg 1993). While there were differences in population density of shrub species between plots, mosty of the shrubs counted were very small individuals, not reproductive plants. Thus, these differences are not conclusive but a recommended subject for further study.

While mesquite trees in any context provide habitat value for wildlife, the value of mature mesquite bosques is largely due to the composition and structure of the plant community. High foliage density in multiple height strata supports diversity and abundance among birds, while the understory shrub component supports frugivorous birds (Stromberg 1993). This study suggests that thinning can accelerate development of wildlife habitat in young mesquite stands.

These results may be useful to inform management decisions at Bingham Cienega and at other sites with similar conditions along the San Pedro River and elsewhere, including the San Pedro Riparian National Conservation Area (managed by BLM), Three Links Farm (TNC), and 7B Ranch (Resolution Copper).

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