Monitoring impacts of *Tamarix* leaf beetles (*Diorhabda elongata*) on the leaf phenology and water use of *Tamarix* spp. using ground and remote sensing methods


Photo: Greg Joder

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ABSTRACT

Tamarix leaf beetles (*Diorhabda elongata*) have been released in several locations on western U.S. rivers to control the introduced shrub, *Tamarix ramosissima* and related species. As they are expanding widely throughout the region, information is needed on their impact on *Tamarix* leaf phenology and water use over multiple cycles of annual defoliation. We used networked digital cameras (phenocams) and ground surveys to monitor the defoliation process from 2008-2010 at multiple sites on the Dolores River, and MODIS satellite imagery from 2000 to 2009 to monitor leaf phenology and evapotranspiration (ET) at beetle release sites on the Dolores, Lower Colorado, Carson, Walker and Bighorn Rivers. Enhanced Vegetation Index (EVI) values for selected MODIS pixels were used to estimate green foliage density before and after beetle releases at each site. EVI values were transformed into estimates of ET using an empirical algorithm relating ET to EVI and potential ET (ETo) at each site. Phenocam and ground observations show that beetle damage is temporary, and plants regenerate new leaves following an eight week defoliation period in summer. The original biocontrol model predicted that *Tamarix* mortality would reach 75-85% over several years of defoliation due to progressive weakening of the shrubs each year, but over the early stages of leaf beetle-*Tamarix* interactions studied here (3-8 years), our preliminary findings show actual reductions in EVI and ET of only 13-15% across sites due to the relatively brief period of defoliation and because not all plants at a site were defoliated. Also, baseline ET rates varied across sites but averaged only 329 mm yr-1 (23% of ETo), constraining the possibilities for water salvage through biocontrol of *Tamarix*. The spatial and temperol resolution of MODIS imagery were too coarse to capture the details of the defoliation process, and high-resolution imagery or expanded phenocam networks are needed for future monitoring programs.

Rationale for Study

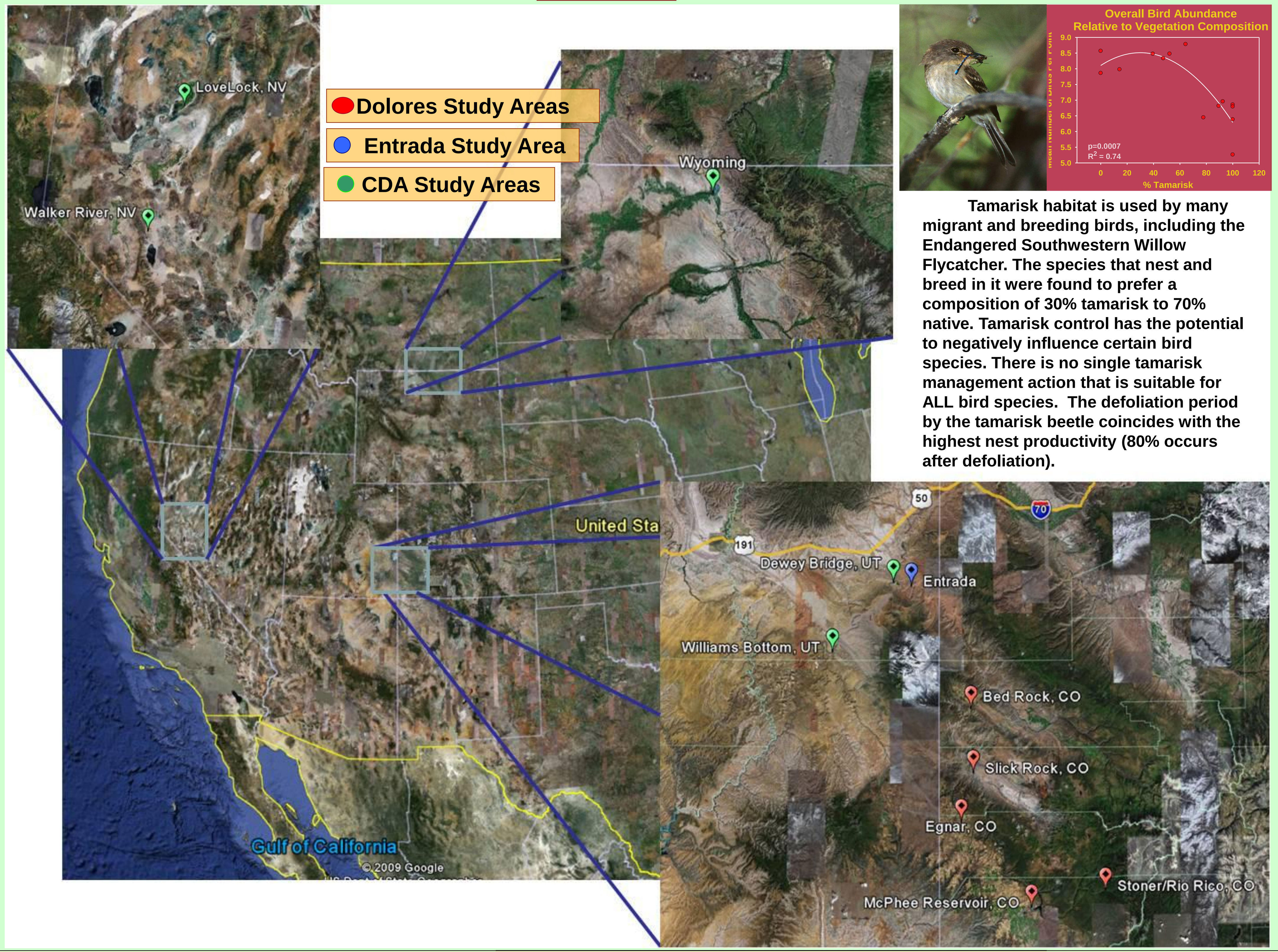
The control of tamarisk (*Tamarix* spp) trees and shrubs near rivers, streams, and wetlands in the western US is now a high priority among many local, state, and federal agencies. Recent releases of the saltcedar leaf beetle have shown considerable promise for controlling tamarisk over large areas, but may also have many unintended negative impacts on highly valued riparian ecosystems. Intensive monitoring of ecosystem services in these riparian zones, including sediment & nutrient export, water usage, distribution of noxious weeds, habitat quality, and socioeconomic factors, to improve remediation efforts in tamarisk-invaded riparian ecosystems is needed. Restoration and future control efforts would benefit from the timely establishment of a comprehensive policy and research framework to address potential impacts of biocontrol agents, through collaborations with scientists, land managers, and stakeholders.

Objectives

- To determine baseline values of riparian evapotranspiration (ET) for each river reach
- To estimate the percent reduction in ET that can be attributed to defoliation of Tamarisk by beetles.

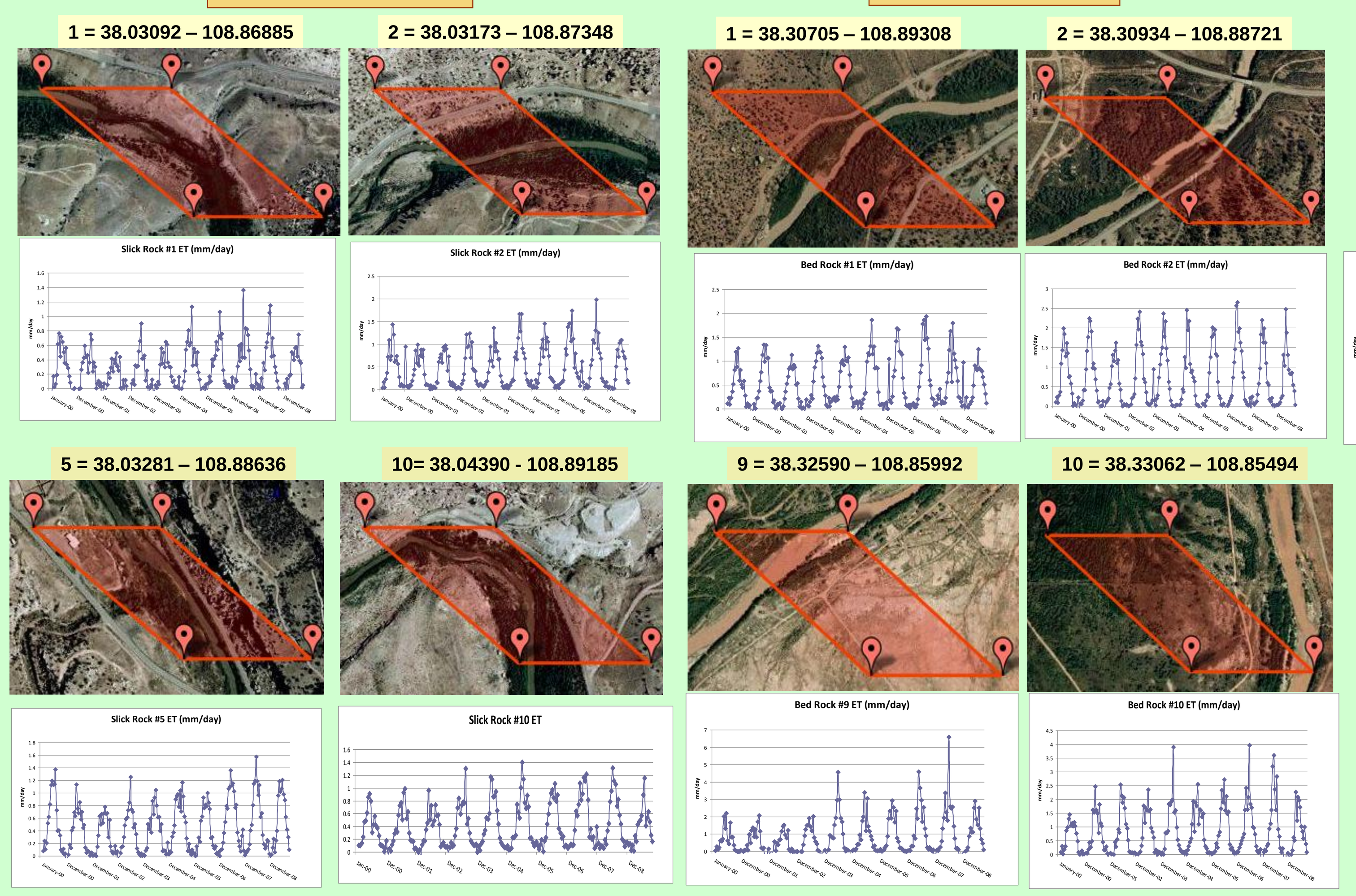
Tamarisk stand on the Dolores River, near Moab, UT,
(a) before and (b) after defoliation by the saltcedar leaf beetle *(Diorhabda elongata)*.

Methods



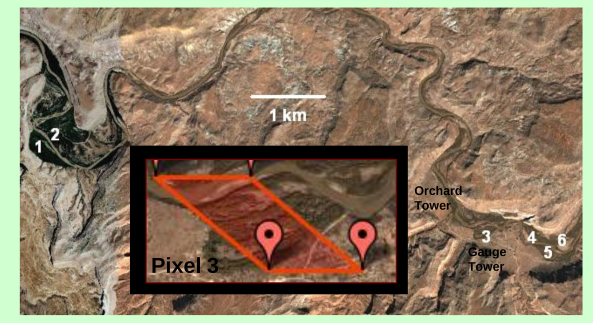
Tamarisk habitat is used by many migrant and breeding birds, including the Endangered Southwestern Willow Flycatcher. The species that nest and breed in it were found to prefer a composition of 30% tamarisk to 70% native. Tamarisk control has the potential to negatively influence certain bird species. There is no single tamarisk management action that is suitable for ALL bird species. The defoliation period by the tamarisk beetle coincides with the highest nest productivity (80% occurs after defoliation).

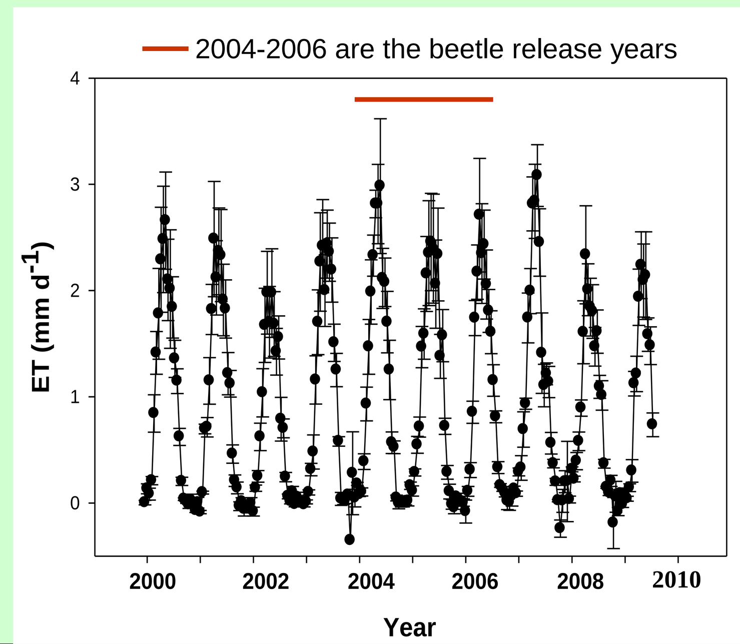
Dolores Study Areas



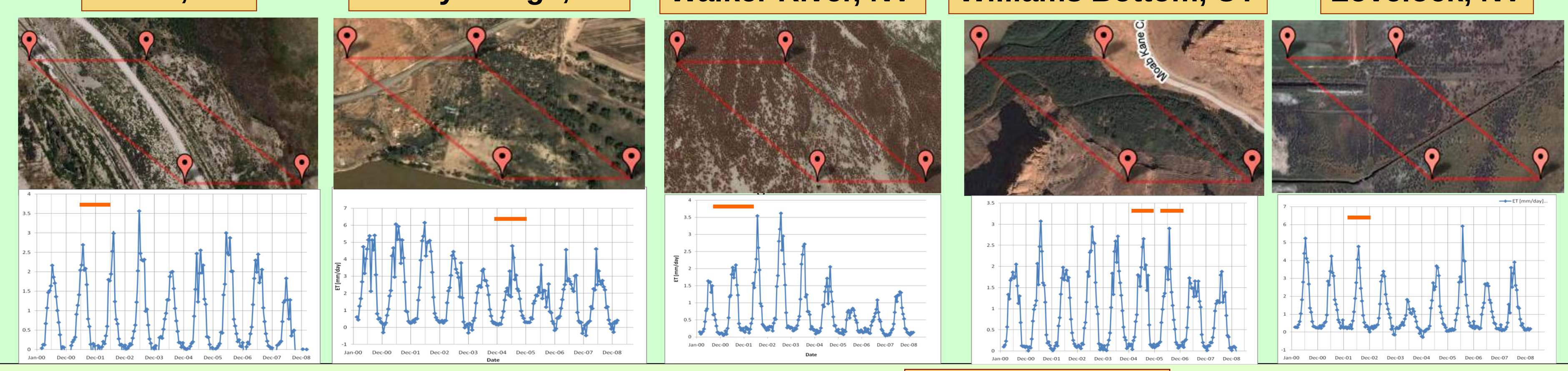
We used MODIS imagery to attempt to quantify potential water savings through defoliaiton of Tamarisk. We obtained before-beetle-release and after-beetle release imagery for sixteen sites where ground surveys have confirmed that beetles have established and are actively defoliating Tamarisk. The sites represent seven river reaches on the Upper Colorado, Walker, Upper Dolores, Lower Dolores, Wyoming, and Humbolt rivers.

Entrada Study Area





CDA Study Areas



RESULTS

ET in mm d-1 was calculated for each site from MODIS Enhanced Vegetation Index (EVI) values and potential ET for each site using methods described in Nagler et al. (2009). The figures above show 16-day composite ET values for each site from 2000 to 2009, with an indication of when beetles were released and noted to be active at each site. Baseline ET values differed among sites, with peak summer values ranging from < 1 to 6 mm d^{-1}. Values at some sites were artificially low because the MODIS pixel footprint encompassed adjacent sparse vegetation as well as riparian vegetation. For those pixels that fell completely within the riparian zone, mean ET was 3.7 mm d^{-1} in summer, about 60% of potential ET of 6.6 mm d^{-1} across these sites.

Location	ET Before (mm yr^{-1})	ET After (mm yr^{-1})	F	P
Lower Dolores R. UT	359 (28)	347 (42)	0.051	0.822
Upper Dolores R. UT	181 (14)	206 (26)	0.909	0.341
Walker R. NV	306 (38)	254 (24)	1.428	0.233
Upper Colorado R. At Dewey Bridge UT	849 (70)	560 (49)	10.7	0.001**
Wyoming R. At Lovell WY	290 (42)	224 (29)	0.006	0.937
Humbolt R. At Lovelock NV	537 (69)	412 (38)	2.911	0.089
Upper Colorado R. At Williams Bottom UT	371 (27)	272 (34)	3.81	0.052
All Sites	400 (17)	340 (14)	7.402	0.007**

Annual evapotranspiration (ET) before and after beetle release for riparian sites on western U.S. rivers. ** Denotes significant difference between before and after means at P < 0.01. Numbers in parentheses after means are standard errors. Mean values across sites within a reach were used so that each reach had equal weight in the statistical analysis. Release years were counted in the Before (pre-release) group because there was a lag of 1-2 years following release before defoliation was noted in ground surveys.

Annual ET rates before beetle release ranged from 290 to 840 mm yr^{-1}, and from 224 to 560 mm yr^{-1} post-release. When analyzed separately, only the Dewey Bridge site showed a significant reduction in ET following beetle release. When all sites were combined, ET decreased significantly, from 400 mm yr^{-1} to 340 mmyr^{-1} (P < 0.01), a 15% reduction following beetle release. This results in a net reduction of 60 mm yr^{-1} of water use. However, this is an underestimate because some pixels were not totally within the riparian zone and contained sparse adjacent vegetation. Based on analyses of landcover classes within individual pixels, riparian vegetation represented 60% of pixel contents across sites. Hence, the potential ET reduction in the riparian zone was about 100 mm yr^{-1}. As noted, results varied among sites, with no significant reduction observed at most sites.

Conclusions

Based on these results, the potential water savings from Tamarisk defoliation appear to be limited. Several factors contribute to the minimal reduction in ET noted at these sites: (i) Defoliation is temporary, affecting shrubs for 6-8 weeks over their 30 week growing season. (ii) Defoliation is patchy within an affected river reach. Dennison et al. (2009) reported that about 25% of riparian areas showed defoliation on the Lower Dolores River. Tamarisk only accounted for 40% of land cover in those Tamarisk-dominated riparian zones, due to the presence of bare soil and other vegetation types, and beetles did not attack all Tamarisk plants within a reach. (iii) Base levels of riparian ET are relatively low, no greater than 60% of potential ET, which limits the maximum possible ET reduction even if defoliation was to be complete.

However, this situation could change in the future. Beetles are still increasing their range, and it is possible that as niches become full, they will more effectively defoliate Tamarisk stands at a given location. Tamarisk stands might also be weakened and eventually killed through repeated years of defoliation. At present, Tamarisk is thought to dominate some 400,000 to 640,000 ha of western U.S. riparian habitat. Based on a projected water savings of 100 mm yr^{-1}, beetles might eventually result in an ET reduction of 4 – 6.4 x 10^8 m^3 yr^{-1} (340,000 – 544,000 acre-ft) of water if it spreads to all possible locations and its pattern of defoliation remains the same. Actual water savings would be less because the beetle might not be adapted to the climatic extremes in the southwestern U.S., and because the calculation assumes no replacement vegetation with defoliated reaches. Now that it is part of the riparian ecosystem, careful monitoring will be needed to detect effects of the beetle on riparian hydrology and ecology.

References

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