Task 4.5 Final Sampling/Monitoring Report
Arizona Water Protection Fund Grant; Inventory of Tamarisk Leaf Beetle and Effects on Riparian Habitat in the Colorado, Verde, Salt and Tonto Rivers, 2011, 2012 and 2013

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Arizona Water Protection Fund Grant #11-179WPF: Inventory of Tamarisk Leaf Beetle and Effects on Riparian Habitat in the Colorado, Verde, Salt and Tonto Rivers.

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Table of Contents

Abstract

Tamarisk beetles, *Diorhabda spp.,* were introduced as a biocontrol agent on tamarisk (*Tamarix spp.*) in 2000 in Utah and Colorado. Tamarisk beetles defoliate the leaves of tamarisk and reduce the plant's ability to photosynthesize resulting in reduced flowering and seed production. Since its introduction, its range has expanded to include Nevada, Texas, and New Mexico, and it is now in the Colorado River in Arizona. Because tamarisk is a component of much of the riparian ecosystem in the southwestern United States and provides critical habitat for some endangered riparian bird species, the effect of defoliation by the beetle is likely to include associated elements of riparian habitat beyond tamarisk such as ecosystem processes and wildlife population dynamics, and plant community structure. For example, defoliation will affect microclimate variables (temperature, humidity, light availability) of riparian habitats. Each of these parameters plays a role in nesting environments by possibly increasing temperatures and understory plant assemblages by changing light availability. The goal of this project is to provide resource managers with information about beetle advancement along Arizona watersheds, identify potential effects of defoliation on microsite variables within riparian ecosystems, and provide recommendations for approaches that may be used to mitigate the effects of defoliation by the beetle.

This final report covers results from 2011, 2012 and 2013 tamarisk leaf beetle sampling along the Colorado River (Lee's Ferry – Glen Canyon Dam), Lower Verde River, lower Tonto Creek, and Upper and Lower Salt Rivers. We sampled each site three times from June through August. We followed the sampling protocol recommended by the USDA. The only site we detected beetles during all three years was at the Colorado River site (Lee's Ferry – Glen Canyon Dam). We compared 2011, 2012 and 2013 tamarisk leaf beetle abundance and distribution results on the Colorado River and found that tamarisk leaf beetle numbers had declined dramatically in 2012 and 2013 among early larvae, late larvae and adults, when compared to 2011. In 2011, 2012 and 2013 we observed higher defoliation rates by the leaf beetle throughout all Colorado River site during each of the three visits with the highest defoliation rate occurring in July.

During tamarisk leaf beetle surveys we also sampled all arthropods detected, which including the Splendid tamarisk weevil (*Coniatus splendidulus*), a tamarisk obligate arthropod that was accidently released in the Phoenix, AZ area in 2010 and was detected at most sites we sampled each year.

In 2011, 2012 and 2013, we also collected microclimate data at sites along the Colorado River, Tonto Creek and upper and lower Salt River sites. We found that mean temperatures were highest at the Colorado River sites (river mile -6 = 32.3 degrees C; river mile -12 = 32.1) during 2013, followed by the upper Salt River Rafters Takeout site (31.8 degrees C) during 2012. The Phon D Sutton site on the lower Salt River was one of the sites with the lowest mean temperatures in 2012 (28.4 degrees C) and 2013 (28.3 degrees C), which is one of our most southern sites. We also compared temperatures and relative humidity at the Colorado River site and found that there was no correlation with increased temperature, lower relative humidity and defoliation by the beetle. This may change as the beetle continues to defoliate tamarisk trees at this site, which ultimately results in tamarisk mortality. Since the tamarisk leaf beetle is not currently present at our other monitoring sites along the Verde River, Tonto Creek and the upper

and lower Salt River sites, this microclimate data will represent baseline data to compare to when the beetle does invade these sites, therefore we highly recommend continuing monitoring microclimate at these sites.

We also monitored vegetation at the Colorado River, Verde River, Tonto Creek and upper and lower Gila River sites. During the three years of this study we found that average cover for tamarisk (*Tamarix spp.*) was greater than 20% for each site over the three years of this study. For eight of the 10 sites, tamarisk was the species with the greatest cover at the initiation of this project in June 2011, which was also observed for 2012 and 2013. Though the tamarisk beetle was present at the Colorado River Sites, cover values for tamarisk at these sites were within the range of cover values recorded for all other sites along the Verde River and upper and lower Salt River watersheds.

The results of this study clearly indicate that the beetle is present along the Colorado River from Lee's Ferry to Glen Canyon Dam, but absent from the sites along Verde River, Tonto Creek and upper Salt River and lower Salt River. As noted in 2011, the north rim drainages of Grand Canyon may be a source for these beetle population expansions along the Colorado River sites, particularly the Paria Canyon drainage. The Little Colorado River within the Navajo Reservation, which includes; northern tamarisk leaf beetle (*Diorhabda carinulata*) and the Rio Grande River in Texas and New Mexico which includes; Mediterranean tamarisk leaf beetle (*Diorhabda elongata*), larger tamarisk leaf beetle (*Diorhabda carniata*) and subtropical tamarisk leaf beetle (*Diorhabda sublineata*) may all be the sources of this population expansion into the central and southern Arizona sites. Tamarisk leaf beetle expansion into central and southern Arizona (Verde River, Tonto Creek, upper and lower Salt River), where this study was conducted, is expected for 2017 (Tracy et al. 2014). The reduction in tamarisk cover in riparian areas, by beetle defoliation will pave the way for changes in plant community composition and structure, with consequent effects on wildlife populations and ecosystem processes (such as wildfire, hydrological dynamics, and sediment dynamics).

Background

Tamarisk (*Tamarix spp.*) is an invasive riparian shrub that has spread extensively in the southwestern U.S. since its introduction in the late 19th Century. Tamarisk occupies approximately 600,000 ha of riparian habitat in the southwestern region, and it is the second most common woody species in riparian zones in the western United States (Friedman et al., 2005; DiTomaso 1998). Though occurring in both regulated and free flowing river systems (Birken and Cooper 2006; Stromberg 1998), tamarisk is particularly successful at propagation under regulation (Beauchamp and Stromberg 2007, Stromberg et al. 2007). The plant affects native plant diversity, wildlife habitat, and poses an increased wildfire risk where dense stands occur (Fleishman et al. 2003; Beauchamp et al. 2005; Busch and Smith 1993; Busch and Smith 1995). In spite of its effect on community and ecosystem processes, the plant provides critical habitat for animals within the southwest including endangered species such as the southwestern willow flycatcher (*Empidonax traillii extimus*), and the Yellow-billed Cuckoo (*Coccyzus americanus occidentalis*). Within the Colorado Plateau region of Arizona, it is a dominant constituent of the Colorado River in Grand Canyon (Ralston et al., 2008), and is a component of riparian habitats along the Verde River (Johnson et al. 2010, Stromberg 1998, Beauchamp and Stromberg 2007, Stromberg et al. 2007).

With increasing emphasis by public and private sectors to control tamarisk in the western United States, the Department of Agriculture explored identifying a biocontrol agent for tamarisk. By 2000, specialist herbivore beetles in the genus *Diorhabda*, from Eurasia, were identified as potential biocontrol agents. Experimental field trials of the tamarisk beetle determined that these beetles caused substantial defoliation and mortality of tamarisk (DeLoach et al. 2000, Dudley et al. 2001). The release of several species of *Diorhabda* in western U.S. river systems to control tamarisk began in 1999 and has resulted in reduction of tamarisk cover along the Colorado and Green Rivers in Utah (Dennison et al. 2009). Though introductions of this biocontrol agent were stopped in 2009, the beetle continues to spread within the Upper Colorado River watershed, and is well established in parts of Texas, New Mexico, Wyoming, Utah and Nevada (Figures 1a, 1b, and 1c). Ground surveys in 2011, 2012 and 2013 for the beetle have identified beetles as far south as northern Arizona and New Mexico and as far east as eastern Colorado, it is expected to colonize the lower Colorado River and the entire Rio Grande River systems in the next couple years. Beetle expansion into central and southern Arizona (Verde River, Tonto Creek, upper and lower Salt River), where this study was conducted, is expected for 2017 (Tracy et al. 2014). The reduction in tamarisk cover in riparian areas, by beetle defoliation, pave the way for changes in plant community composition and structure, with consequent effects on wildlife populations and ecosystem processes (such as wildfire, hydrological dynamics, and sediment dynamics).

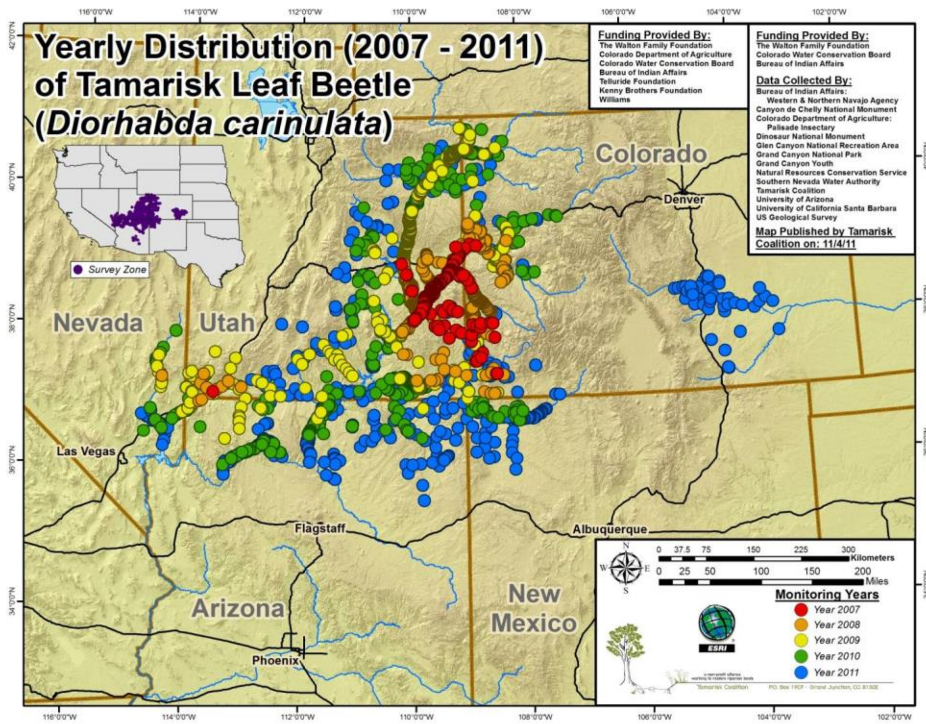


Figure 1a. 2007- 2011 tamarisk leaf beetle distribution in Utah, Colorado, and Arizona (from tamarisk coalition http://www.tamariskcoalition.org).

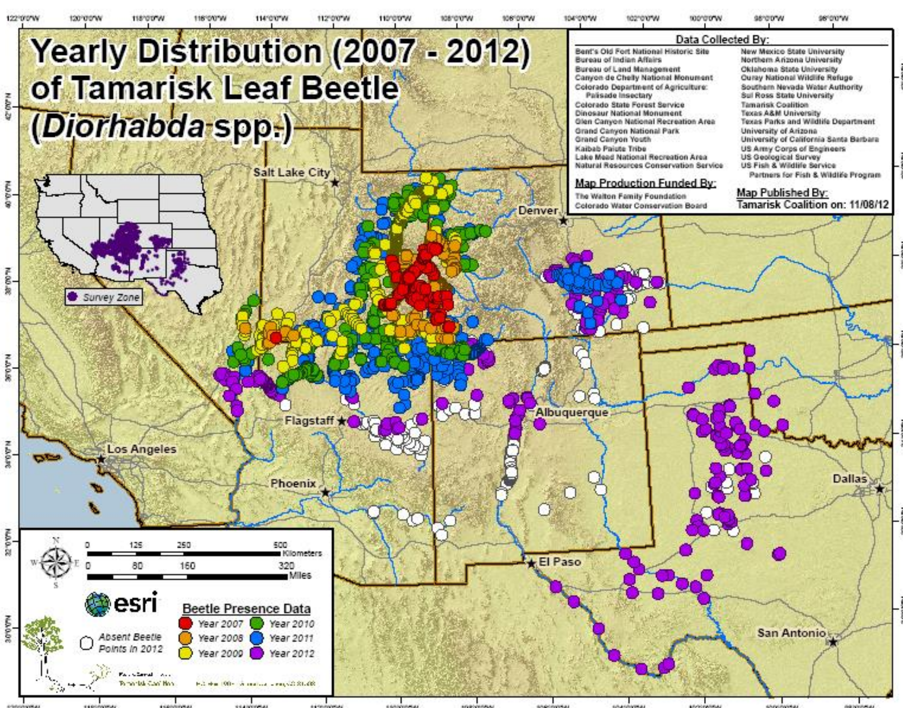


Figure 1b. 2007- 2012 tamarisk leaf beetle distribution in Utah, Colorado, and Arizona (from tamarisk coalition http://www.tamariskcoalition.org).

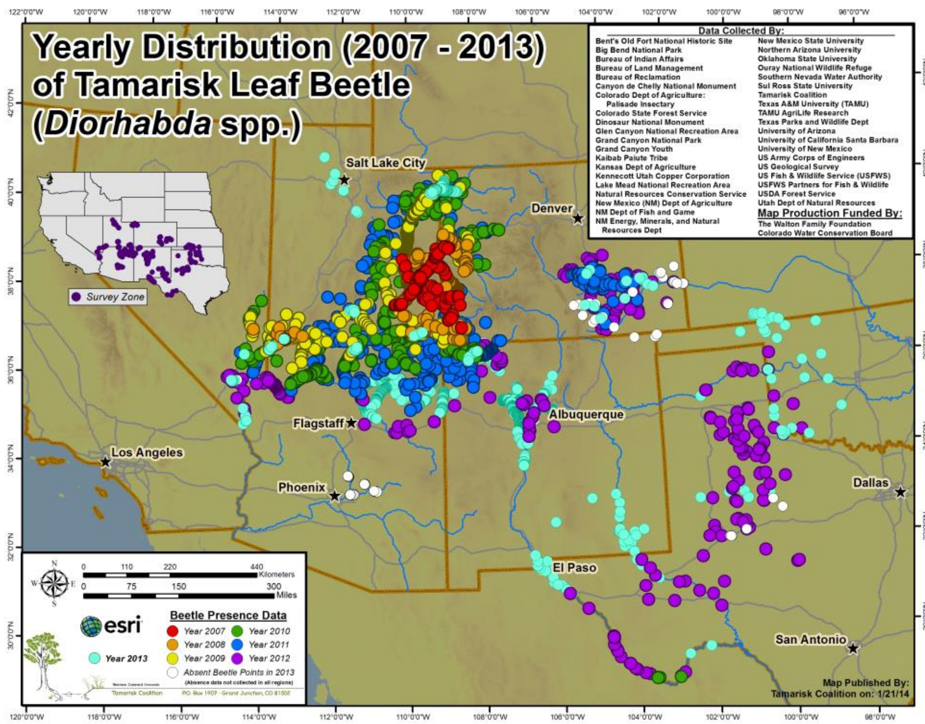


Figure 1c. 2007- 2013 tamarisk leaf beetle distribution in Utah, Colorado, and Arizona (from tamarisk coalition http://www.tamariskcoalition.org).

The rates at which vegetation changes in composition will occur, and the resultant effects on riparian-dependent fauna and birds that breed in tamarisk are presently unknown. Effects on riparian vegetation communities will likely include changes in plant biomass, microclimate changes, and plant species diversity (Busch and Smith 1995). These changes could potentially affect migratory and breeding birds within riparian corridors throughout the southwest (Van Riper et al. 2008, Hultine et al. 2009) and particularly in those areas where tamarisk is the dominant overstory plant. Central questions about the ecosystem effects of tamarisk defoliation exist and need to be addressed including

- *What is the beetle distribution and directionality of their spread in Arizona?*
- *How does defoliation affect microhabitat parameters such as temperature and light availability in riparian understory?*

Answering these questions requires ground surveys to sample for the presence and identification of beetle species, and collection of baseline microhabitat data prior to beetle infestation. A secondary activity involves using field observations of defoliation rates and microhabitat variables to estimate resultant effects on riparian fauna and understory plant communities. The information gained can be used by resource managers to mitigate the effects of beetle defoliation if beetles do infest critical habitat of endangered riparian birds.

Project Goals

The goal of this project is to provide resource managers with information about beetle advancement along Arizona watersheds, identify potential effects of defoliation on microsite variables within riparian ecosystems, and provide recommendations for approaches that may be used to mitigate the effects of defoliation by the beetle.

-Objectives

Objective 1
Identifying the directionality and extent of beetle distributions in three watersheds across three ecotones in Arizona.
Statement of Problem: *Beetles may disperse differently within watersheds and under variable tamarisk densities. The three study areas are of different stream orders with variable densities of tamarisk. These surveys may inform managers about potential dispersal patterns by the beetle in other stream channels.*

Objective 2
Establish baseline microhabitat and plant diversity data prior to beetle infestation using thermistors that record temperature and humidity values, and ground surveys to establish types of understory cover.
Statement of Problem: *Defoliation may increase temperatures, reduce relative humidity, and increase light availability to understory plants. Each of these changes in microhabitat variables may affect nesting success by riparian bird species, and understory plant diversity. Defoliation effects has repercussion in ecosystem services associated with riparian habitat as refugia for resident and transient populations and the effect of habitat change on this function/service*.

Objective 3
Use data from objectives 1 and 2, published estimates of defoliation rates as well as from field observations to estimate how defoliation might change microhabitat variables (temperature and light availabilities), identify which understory plant species may benefit following defoliation and provide potential approaches that may mitigate beetle defoliation affects.
Statement of Problem: *Light availability affects temperature and relative humidity values, which affect nesting success in riparian birds. Light availability also affects seedling establishment in the understory. The baseline data will provide information about existing variability and potential seed sources for understory plants. Publish information or field observations on percent defoliation can be used to establish percent cover/light availability.*

Methods

Sampling Tamarisk Leaf Beetles

We sampled tamarisk leaf beetles (TLB) using the survey methods based on those established by the USDA and Tamarisk Coalition during June, July and August 2011, 2012 and 2013. Using standard 38 cm diameter cloth insect sweep nets, we conducted 1 m sweeps through the tamarisk foliage for a total of 25 sweeps per sampling location. Between every 5 sweeps the contents of the net we recorded, every set of 5 sweeps roughly 5 m apart (Appendix 1). At each site, we sampled at least 4 locations resulting in 100 sweeps in an area.

Surveys were conducted along riparian zones of the principal rivers and streams, within a minimum of 1.5 km between sites. We also sampled critically important sites such as springs and wetlands where high levels of biodiversity occur. At each site, the number of different instars, adults, ant *spp.*, lady bug *spp*. and spider *spp.* were tallied for each set of sweeps. Eggs were documented as either present or absent. Tamarisk Leaf Beetles were also collected and placed in vials with alcohol for taxonomic species identification. Other site data were also collected including; dominant vegetation community, percent defoliation of tamarisk, aspect, substrate, elevation, location, and other relevant variables. For each survey we documented type of survey, location (UTM), date, surveyor name, temperature, wind speed, and precipitation (see table 1).

Defoliation was also categorized for each sampling location as the average level of defoliation within the sample location (~0.25 km^2) and recorded as a percentage in 10% increments. Percent defoliated was defined as % of canopy currently brown from tamarisk leaf beetle damage.

In concurrence with defoliation, refoliation was only recorded as "present/or absent," this is to avoid confusing partially defoliated trees as fully defoliated trees or partially refoliated. Refoliation is best noticed by the "fireworks puffs" that is the signature of tamarisk re-sprouting on the stems and branches. Note that refoliation does not occur until after Mid-July, and without previous records it can be hard to truly validate. We also revisited a site multiple times in a season so valid identification of refoliation is ensured, refoliation was recorded as a percentage similar to defoliation. Thus the average % of refoliation within ~0.25 km^2 (recorded in 10% increments) could be recorded.

Photos of the sampling area were taken at the GPS point location and recorded by their respective ID number with a compass bearing for the direction of the shot.

Deployment of Thermistors (Microclimate)

In each riparian system we deployed thermistors to collect data on temperature and relative humidity and conduct understory plant surveys where thermistors are deployed. Loggers were placed in the field during the first week of May and removed in mid-September 2011, 2012, and 2013 (see Appendix 1 for data forms). Date, time, location and thermistor number were recorded when deployed and retrieved. Each logger was programmed to record an event (T/RH reading) every 30 minutes for 150 days. Temperature (T) and relative humidity (RH) were recorded with HOBO Pro RH/Temp data loggers (Onset Computer Corporation, Pocasset, MA). HOBO loggers were programmed to collect T (–30°C to 50°C; accurate to ± 0.2° C at 21° C; -22°F to 122°F) and RH (0–100 percent, accurate to ± 3 percent) data. To protect each data logger from direct solar radiation, HOBOs were deployed in the field using a small, inverted plastic container with a sheet of shade cloth covering the top. The open bottom of the bowl was covered with shade cloth to ensure that the HOBO is sampling free-flowing air, and thus can accurately measure T/RH. We deployed a minimum of three thermistors within each drainage. Thermistors were placed within tamarisk patches following our criteria of 25 m area of continuous tamarisk habitat. Each thermistor was deployed within vegetation on a tamarisk tree branch at 2-m high.

Plant Cover Surveys and Microclimate Sampling

Sampling for plant cover took place in early June and late August 2011, 2012 and 2013. We sampled vegetation cover at each thermistor location and five randomly selected sites within each drainage.

Plant cover surveys consisted of a minimum of 5 - 25-m^2 quadrats. Nested within the larger quadrats were 3 subsections of the plot sampled with 1m^2 plots to sample herbaceous cover along each river drainage. The 25m^2 quadrates provide a general cover value for shrubs. Cover in the 25m^2 plots was assigned a categorical cover class. Cover classes incorporated a range of cover values; (1 (0-5% cover); 2 (6-25%; cover); 3 (26-50% cover); 4 (51-75% cover); 5 (76-95% cover); 6 (96-100% cover; see Appendix 1 for data forms). The smaller, 1m^2 plots had an absolute percent cover assigned for each species recorded (the 1m^2 quadrat was divided into 10 cm segments on a side that permit easy assessment of total cover for a species within a plot). Percent overstory cover was also determined from the plots, as well as species diversity and identification of nonnative species. To determine overstory cover we measured leaf area index (Appendix 1). We also measured leaf area using the AccuPar ceptometer model LP-80. The accuPAR ceptometer measures photosynthetically active radiation, which can invert these reading resulting in Leaf Area Index for plant canopy. To calibrate the instrument, 5 readings were taken outside the habitat. After calibration is accomplished, 10 readings were conducted within the habitat along 25-m^2 quadrate at 2.5 m increments. We also measured the overstory cover associated with tamarisk defoliation where the beetle currently exists (e.g., Colorado River in Glen Canyon), which will be determined in a similar manner.

Microclimate – Mean, max and minimum for temperature and relative humidity for each sampling site were determined and compared across months.

Vegetation survey plots -*25m^2 plots* **–** The cover categories assigned to the shrubs found within each large plot were averaged for each species. Mean total cover was determined by summing cover categories and dividing by the total number of plots sampled.

1m^2 plots **–** Mean herbaceous cover for each species encountered were determined by summing values and dividing by total number of encounters. Mean herbaceous cover for plots was determined by summing the total herbaceous cover and dividing the total by 3. Each sub-sampled plots associated with the larger 25m^2 plots were evaluated separately. These values were tested for significant differences among plots. If plots are not significantly different, then cover values from all plots were combined to determine the mean herbaceous cover for each drainage. *Species analysis* – The number and type of native and nonnative species were identified based on the species listed in the data sheets. Richness was compared among sites. The number and type of native and nonnative species were also identified based on the species listed in the data sheets.

For the final report, species richness, diversity and indicator species analysis will be determined using PC-ORD software. Indicator species analysis was used to determine if there were herbaceous plants that are associated with particular drainages or mean cover values. These analysis may identify likely species that may expand following defoliation.

Metrics of Success – In 2011, 2012 and 2013, success was measured by providing a list of species occurrence; identifying those species that may benefit from decreased cover associated with beetle defoliation; and the identification of approaches that may be taken to reduce associated adverse impacts to the habitat as the result of an undesirable plant species thriving in the changed environment.

Materials and equipment list - 50 meter vinyl tape, 1-m^2 collapsible plot frame delineated at 10 cm increments, AccuPar ceptometer model LP-80 Leaf-area index meter.

Discussion of quality assurance/quality control – Training for field sampling occurred during the first sampling trips in the spring 2011, 2012 and 2013. Field technicians were instructed on how to lay out the larger quadrats and how to assess and assign cover classes for shrubs. Plots were done by trainer and technicians to calibrate cover estimates. Subsequent sampling was done such that each field technician developed a cover estimate independently of each other. Subsequent discussion about agreed to cover category assigned occurred if the assigned values differed. All plants that were not identified in the field were brought back to the lab for identification. Plants were identified as native or nonnative using the national plant database (*http://plants.usda.gov/*).

Site Selection

In May of 2011, 2012 and 2013, we evaluated available tamarisk habitat along the Colorado River (Lee's Ferry- Glen Canyon Dam), and the Verde, Tonto and upper and lower Salt River Watersheds (Appendix 2). In order to sample for tamarisk leaf beetles and evaluate the effects they may have on the vegetation and microclimate, ultimately affecting riparian bird habitat, we established a criteria of a 25 m area of continuous tamarisk habitat as minimum area that would be sampled. Additional plots were sampled if available tamarisk habitat (25 m area of continuous habitat) exists within each sampling drainage. The 25 m area was based on the tamarisk leaf beetle sampling method that is required to conduct 5 sweeps on 5 random tamarisk trees 5 m apart. During 2011, 2012 and 2013 each site was sampled at a minimum of 3 visits. The following sampling site evaluation was summarized according to drainage.

Colorado River (Lee's Ferry-Glen Canyon Dam)

In 2011, 2012 and 2013, site evaluation of the Colorado River between Lee's Ferry to Glen Canyon Dam found that the tamarisk habitat along this section of the Colorado River continued to meet our minimum criteria and were re-established as our Colorado River sites (Table 1; Appendices 3 and 4). Due to the available tamarisk habitat along this section of the Colorado River, we continued to sample approximately every mile from Lee's Ferry to 1 mile south of Glen Canyon Dam. The 1 mile buffer from Glen Canyon Dam was initiated by the Bureau of Reclamation based on security measures. In order to sample both sides of the river we alternated between sides if the minimum criteria of 25 m of continuous tamarisk habitat existed. We established 16 tamarisk sampling sites between Lee's Ferry – 1 mile south of Glen Canyon Dam (Table 1). A minimum of three 25 m sampling plots were established within each site, additional sampling plots were established depending on the availability of tamarisk at the site. Sampling occurred 100 m from each sampling plot. Of the 14 sampling sites we selected along this section of the Colorado River, three sites were selected for placement of temperature and relative humidity data loggers and as our vegetation plots.

Table 1. Selected sites for tamarisk leaf beetle sampling, microclimate and vegetation sampling along the Colorado River, AZ (Lee's Ferry – Glen Canyon Dam) 2011, 2012, and 2013.

	UTM Location	
Site Name	**Start E**	**Start N**
Colorado River – 0 (Lee's Ferry)	447196	4080214
Colorado River - River Mile -3.0	450434	4077576
Colorado River - River Mile -4.0	451357	4078268
Colorado River - River Mile -5.0	450231	4079734
Colorado River - River Mile -6.0	449878	4081197
Colorado River - River Mile -7.0	451348	4080648
Colorado River - River Mile -8.0	452532	4081576
Colorado River - River Mile -9.0	454072	4081609
Colorado River - River Mile -10.0	452885	4082396
Colorado River - River Mile -11.0	453231	4083253
Colorado River - River Mile -12.0	454130	4083930
Colorado River - River Mile -13.0	455331	4084985
Colorado River - River Mile- 14.0	456234	4085911
Colorado River - River Mile -15.0	456857	4086295

Verde River Watershed

In May 2011, 2012 and 2013, we re-evaluated sites in proximity of Horseshoe Reservoir that met our minimum criteria and re-established this area as our Verde River Watershed sites (Table 2, Appendices 2 and 3). A minimum of three 25 m sampling plots were established within each site, additional sampling was established depending on the availability of tamarisk at the site. Sampling occurred 100 m from each sampling plot. Of the sampling sites we selected within the Verde River Watershed, three sites were selected for placement of temperature and relative humidity data loggers and as our vegetation plots.

Table 2. Selected sites for tamarisk leaf beetle sampling, microclimate and vegetation measurements along the Verde River Watershed 2011, 2012 and 2013.

	UTM Location	
Site Name	**Start E**	**Start N**
Verde River - Catfish Point	434020	3760056
Verde River - Dam Vista	434352	3760240
Verde River - Horseshoe Lake 1	433428	3759005
Verde River - Horseshoe Lake 2	433635	3759671
Verde River - Old Corral	435542	3757954

Upper and Lower Salt River Watershed

In May 2011, 2012 and 2013, we visited sites within the Salt River Watershed to re-evaluate tamarisk habitat in order to identify sites to sample for tamarisk leaf beetles. The sites within the upper Salt River Watershed were identified in our original proposal. Within the upper Salt River Watershed we also included Tonto Creek and all the sites that were sampled within this drainage.

Tonto River (Tamarisk Island)

In May 2011, 2012 and 2013, we visited sites within the Tonto River Watershed to re-evaluate tamarisk habitat in order to identify sites to sample for tamarisk leaf beetles. The sites within the Tonto River Watershed were identified in our original proposal. The sites in the proposal were evaluated and in 2012 continued to meet our minimum criteria and were established as our Tonto River Watershed sites (Table 3; Appendices 2 and 3). A minimum of three 25 m sampling plots were sampled within each site; additional sampling plots were established depending on the availability of tamarisk at the site. Sampling occurred 100 m from each sampling plot. Of the sampling sites selected, three sites were selected for placement of our temperature and relative humidity data logger and as our vegetation plots.

Table 3. Selected sites for tamarisk leaf beetle sampling, microclimate and vegetation measurements along the Tonto River Watershed, 2011, 2012 and 2013.

	UTM Location	
Site Name	**Start E**	**Start N**
Tonto Creek – Tamarisk Island 1	476034	3738595
Tonto Creek – Tamarisk Island 2	476054	3738568
Tonto Creek – Tamarisk Island 3	476080	3738518
Tonto Creek – Tamarisk Island 4	476106	3738497
Tonto Creek – Tamarisk Island 5	475934	3738926
Tonto Creek – Tamarisk Island 6	475970	3739154
Tonto Creek – Tamarisk Island 7	476327	3739380
Tonto Creek – Tamarisk Island 8	476370	3739420

The sites in our proposal met our minimum criteria and were re-established as our upper Salt River Watershed sites in 2012 (Table 4; Appendices 2 and 3). We also re-evaluated sites on the lower Salt River near Mesa, Arizona, which met our minimum criteria in 2012 sampling and monitoring schedule (Table 5; Appendices 2 and 3), these sites were continued to meet our minimum criteria in the 2013 sampling and monitoring schedule. A minimum of three 25 m sampling plots were sampled within each site; additional sampling plots were established depending on the availability of tamarisk habitat at the site. Sampling occurred 100 m from each sampling plot. Of the sampling sites selected, three sites were selected for placement of our temperature and relative humidity data loggers and as our vegetation plots.

Table 4. Selected sites for tamarisk leaf beetle sampling, microclimate and vegetation measurements along the upper Salt River Watershed, 2011, 2012 and 2013

	UTM Location	
Site Name	**Start E**	**Start N**
Salt River - Eads Wash	503889	3720091
Salt River - Eads Wash	503842	3720115
Salt River - Eads Wash	503941	3720029
Salt River - Eads Wash	503894	3720038
Salt River - Eucalyptus	505290	3720959
Salt River - Eucalyptus	505337	3720930
Salt River - Eucalyptus	505582	3720842

	UTM Location	
Site Name	**Start E**	**Start N**
Salt River - HZ Wash	505940	3720702
Salt River - HZ Wash	505900	3720687
Salt River - HZ Wash	506013	3720662
Salt River - HZ Wash	505979	3720638
Salt River - Rafters Takeout	507133	3719956
Salt River - Rafters Takeout	507051	3719949
Salt River - Rafters Takeout	507167	3719945
Salt River - Rafters Takeout	507221	3719943
Salt River - Schoolhouse	500074	3721678
Salt River - Schoolhouse	499984	3721695
Salt River - Schoolhouse	499939	3721782
Salt River - Schoolhouse	500030	3721740
Salt River- Eucalyptus	505608	3720770

Table 5. Selected sites for tamarisk leaf beetle sampling, microclimate and vegetation measurements along the lower Salt River Watershed, 2011, 2012 and 2013.

	UTM Location	
Site Name	**Start E**	**Start N**
Salt River - Blue Point	446682	3713096
Salt River - Coon Bluff	439989	3712188
Salt River - Coon Bluff	440138	3712241
Salt River - Pebble Beach	446793	3712360
Salt River - Pebble Beach	446932	3712352
Salt River - Phon D. Sutton	438773	3712072
Salt River - Phon D. Sutton	438672	3712034
Salt River - Phon D. Sutton	438960	3712143
Salt River - Phon D. Sutton	439048	3712177
Salt River - Sheep’s Crossing	446590	3713061
Salt River - Sheep’s Crossing	446572	3712986
Salt River - Water Users	449563	3712876
Salt River - Water Users	449436	3712810

RESULTS

Colorado River, Verde River, Tonto Creek and Salt River Tamarisk Leaf Beetle Survey Effort, Distribution and Abundance, 2011, 2012 and 2013.

In 2011, 2012 and 2013, we completed three sampling visits along the Colorado, Verde, Tonto and Salt Rivers (Tables 1-5, Appendices 2 and 3). During each year, we sampled 14 sites along the Colorado River from Lee’s Ferry – Glen Canyon Dam. Along the Verde River we re-evaluated 16 sites in 2011, but only sampled three sites below Horseshoe Dam due to the limited amount of tamarisk trees, which included the Catfish Point, Horseshoe Camp and Old Corral sites. For the upper Salt River watershed we included Tonto Creek in this watershed and we sampled three sites within Tonto Creek, which included Tamarisk Island and two unnamed sites upstream and downstream of Tamarisk Island that enters Roosevelt Lake. Along the upper Salt River, we also sampled Schoolhouse Wash and four sites downstream of Schoolhouse Wash, which included Ead's Wash Eucalyptus, HZ Wash and Rafters Takeout, which was a new site in 2012 and 2013. For the lower Salt River, we sampled six sites just upstream of the confluence of the Salt and Verde Rivers, which included; Phon D Sutton, Coon Bluff, Goldfield, Blue Point/Sheep's Crossing, Pebble Beach and Water Users.

In 2011, 2012 and 2013, we detected tamarisk leaf beetles only at our Colorado River sites and did not detect tamarisk leaf beetles at any of the other sites (Verde River, upper and lower Salt River watersheds) throughout our sampling periods (June, July, and August). Since the Colorado River site was our only site where beetles were detected, distribution and abundance of beetles for 2011, 2012 and 2013 will be summarized only for the Colorado River. For all watersheds, we also summarized specified arthropods (ants, ladybugs, spiders) detected during beetle sampling, including the Splendid tamarisk weevil (*Coniatus splendidulus*), which is a tamarisk tree obligate that was accidently released in the Phoenix, AZ area in 2010 and was detected at most sites we sampled each year.

Colorado River Mainstem (Lee's Ferry – Glen Canyon Dam) Tamarisk Leaf Beetle Abundance and Distribution 2011, 2012, 2013

Abundances of tamarisk leaf beetles during 2011 were highest during the early larvae (x = 9.4), late larvae (x = 33.9) and adult stages (x = 24.7), while in 2012 significantly few early larvae (x = 0.8), late larvae (x = 1.0) and adults beetles (x = 3.6) and were detected during this year (Figures 2). During 2013, we observed and increase in early larvae (x = 2.0), late larvae (x = 4.0) and adult beetles (x = 5.8), yet were all well below the 2011 observations.

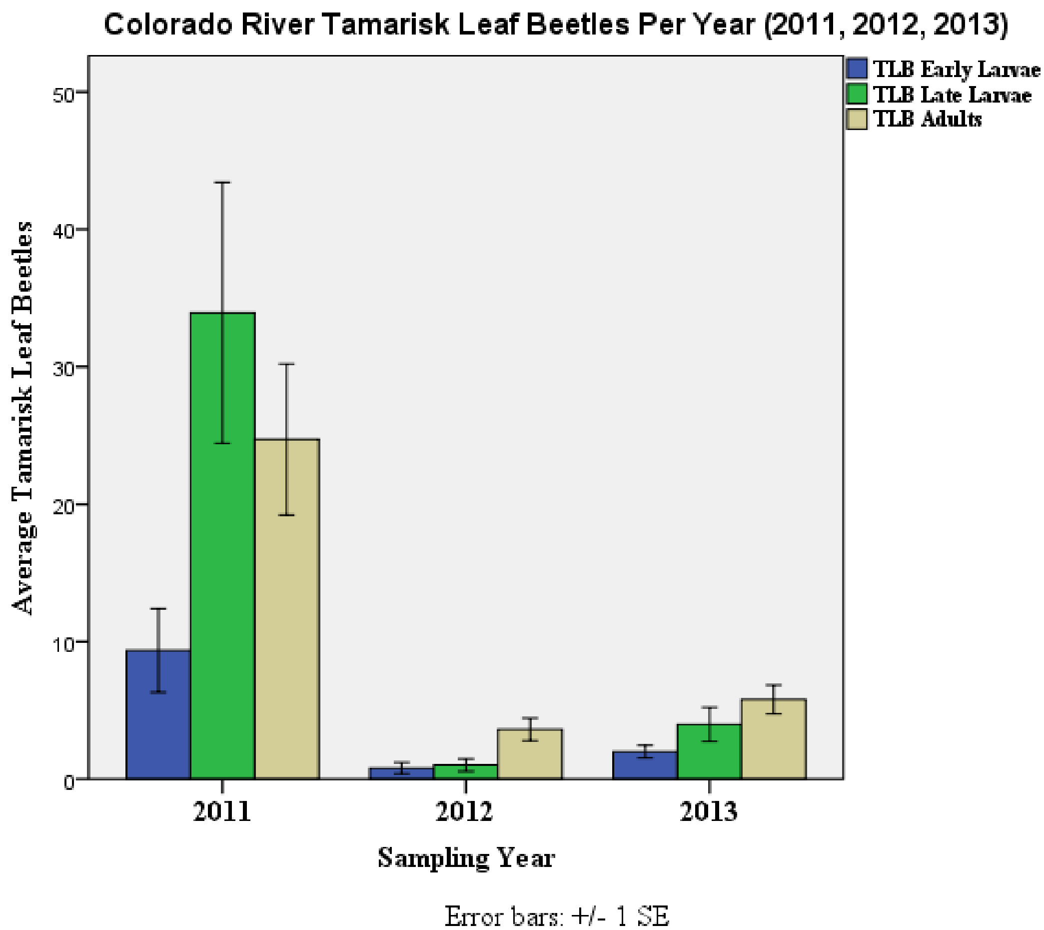


Figure 2. Mean number of tamarisk leaf beetles (early stage larvae, late stage larvae, and adults) per survey year during 2011, 2012 and 2013 tamarisk leaf beetle surveys. Error bars represent +/- 1SE.

Examining beetle abundance by year and month we found that in June 2011 average early larvae (x = 20.8) and late larvae (x = 89.5) were more abundant than any month or year we sampled (Figure 3). Average adult beetles were significantly more abundant in July (x = 43.8) and August 2011 (x = 24.9) than any other month or year (Figure 3). Average number of beetles declined dramatically during each month in 2012 and 2013, however, in 2013 we saw and increase of adult beetles in June (x = 7.8) and July 2013 (x = 6.3) and an increase of late larvae in August (x = 3.4) increased, but again were well below the 2011 observations.

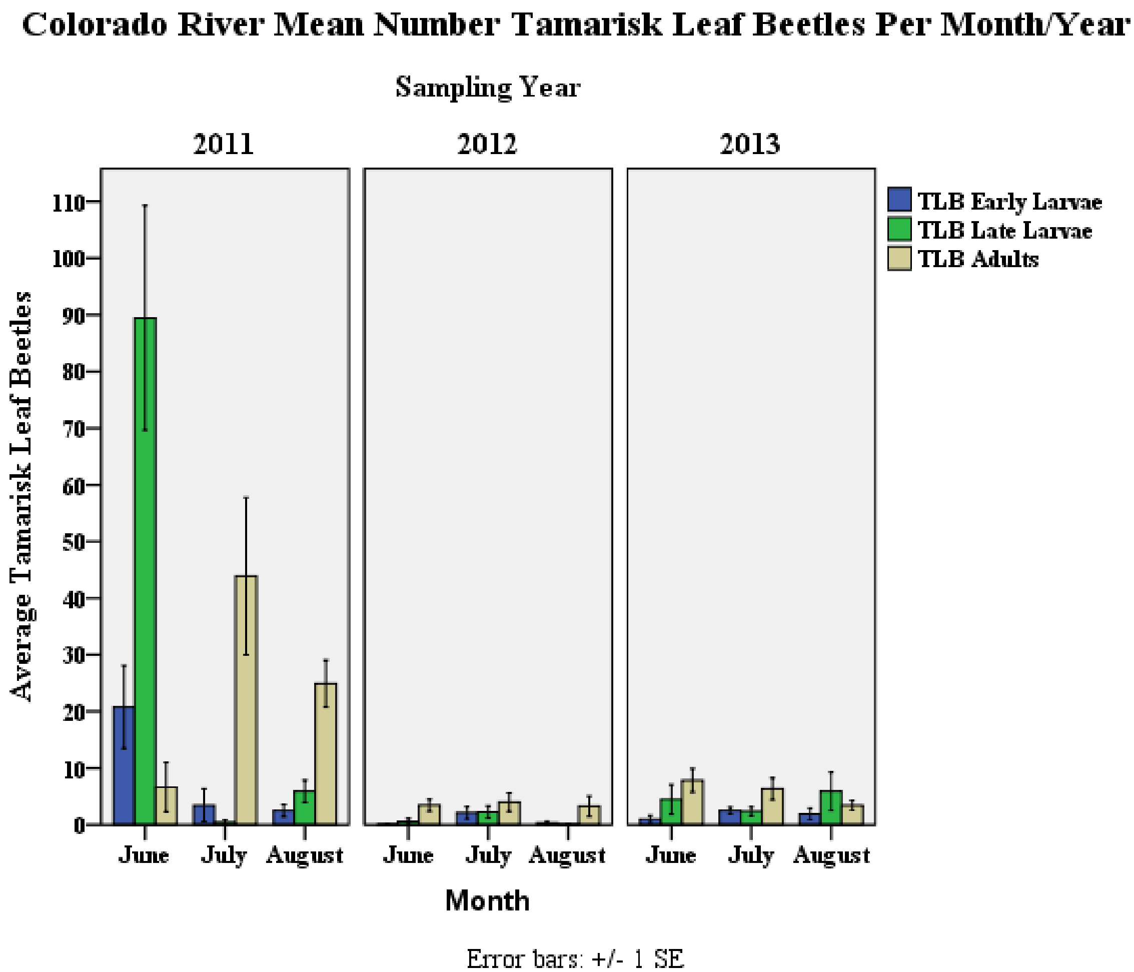


Figure 3. Mean number of tamarisk leaf beetles (early stage larvae, late stage larvae, and adults) per survey month/year during 2011, 2012 and 2013 tamarisk leaf beetle surveys. Error bars represent +/- 1SE.

Combining all tamarisk leaf beetle detections for 2011, 2012 and 2013 we found that beetles were distributed throughout the Colorado River site where we detected the highest average number of early larvae at river mile -10 (x = 15.3) followed by river mile -7 (x = 7.9), while the highest mean number of late larvae was detected at river mile -15 (x = 31.2) followed by river mile -2 (x = 23), which was only sampled in 2011 due to access, and therefore river mile -11 (x = 19.9) was the second highest (Figure 4). The highest average number of adult beetles were detected at river mile -6 (x = 26.6) followed by river mile -2 (x = 15.5), again was only sampled in 2011 and therefore river mile -9 (x = 17.5) was the second highest.

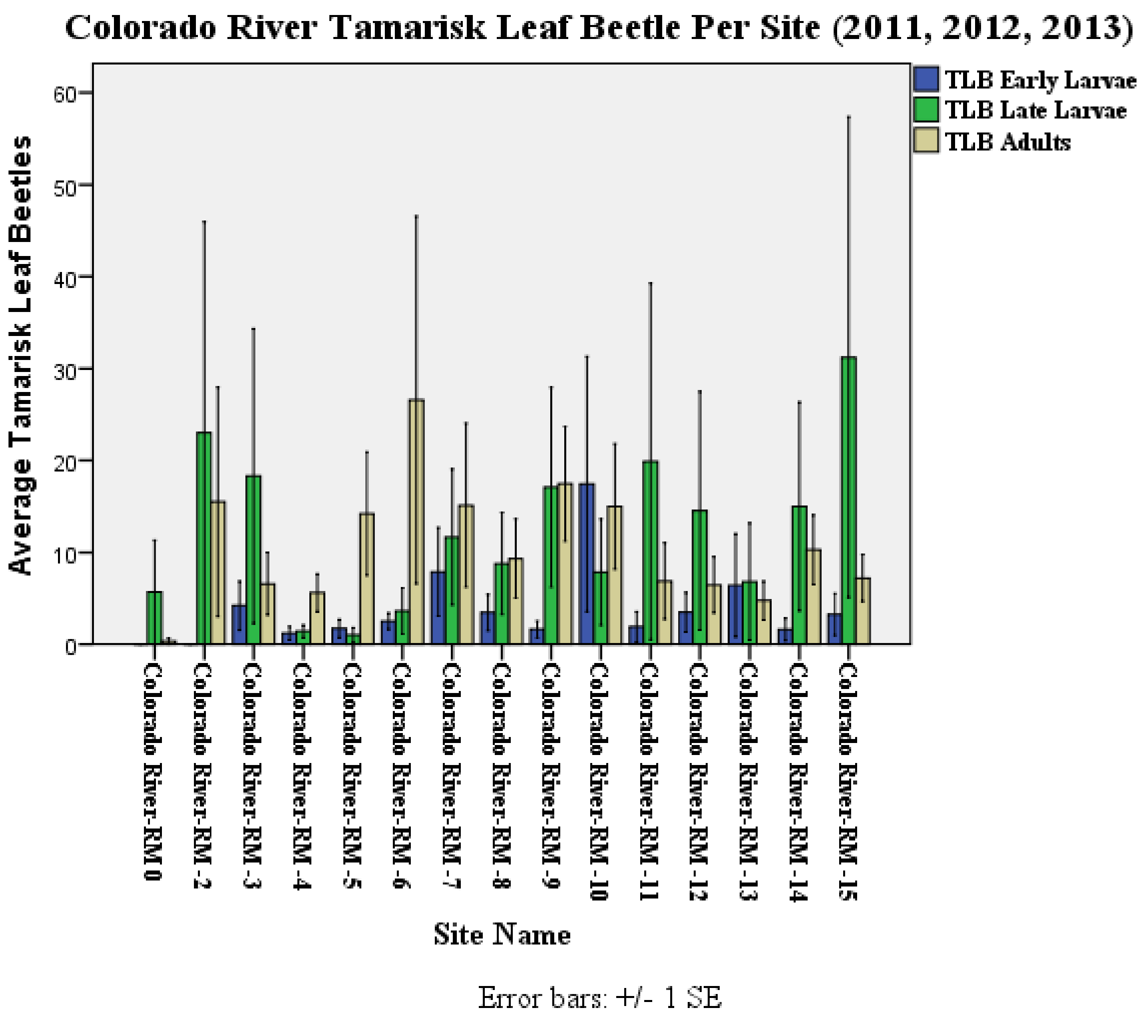


Figure 4. Mean number of tamarisk leaf beetles (early stage larvae, late stage larvae, and adults) by river mile along the Colorado River combining the years 2011, 2012 and 2013 tamarisk leaf beetle surveys. Error bars represent +/- 1 SE.

Distribution of tamarisk leaf beetles by year, we found that in 2011, early and late larvae and adults were distributed throughout the Colorado River sites with the highest number of early larvae abundant at river mile -10 (x = 38) and -7 (x = 27.3) in 2011 (Figure 5), while late larvae abundance was highest at river mile -15 (x = 81.3) followed by river mile -12 (x = 69.3). During 2011, adults were abundant at river mile -6 (x = 79. 3) and -9 (x = 42). Numbers at each site in 2012 and 2013 declined dramatically during each year (Figure 5).

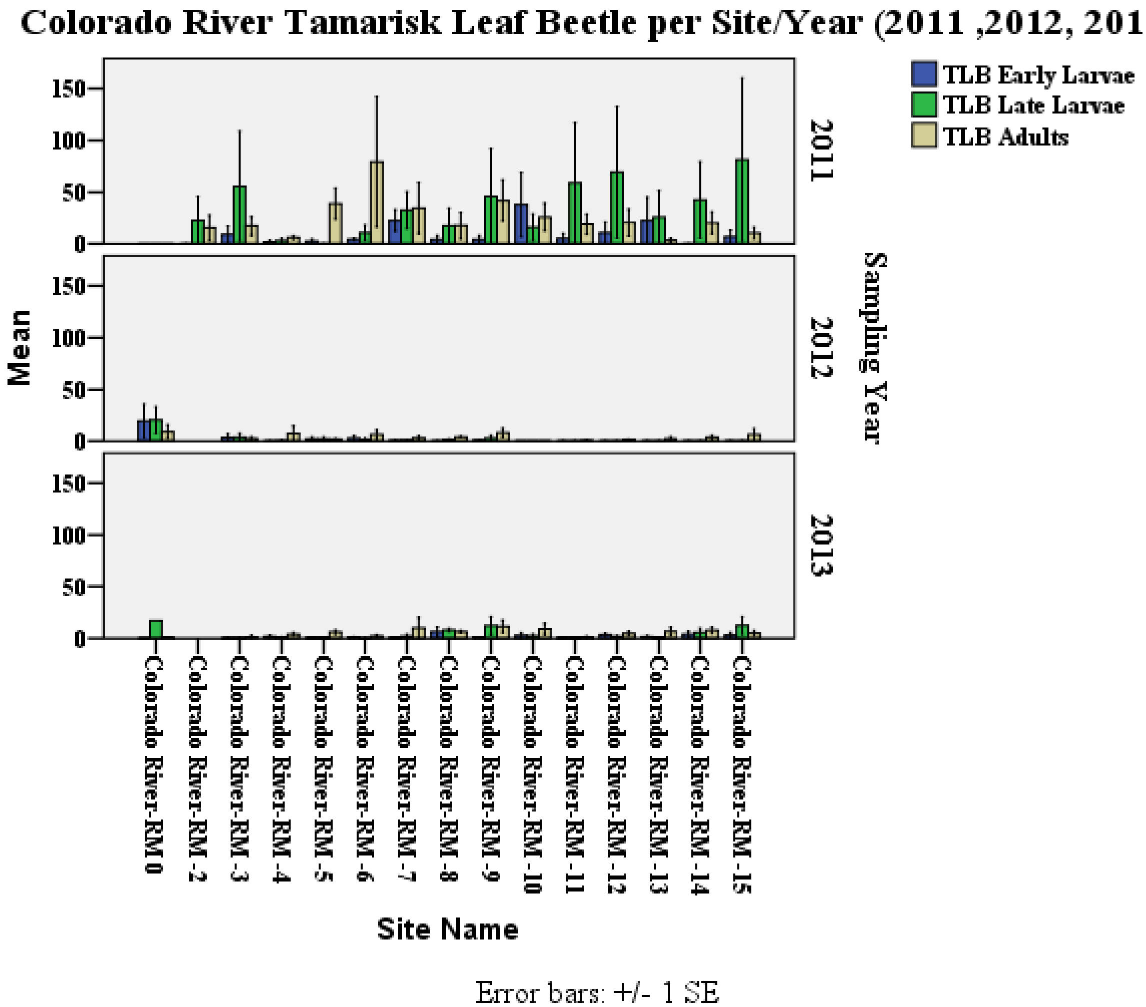


Figure 5. Tamarisk Leaf Beetle (early/late larvae and adults) detections per year during 2011, 2012 and 2013 per sampling months of June, July and August along the Colorado River (Lee's Ferry - Glen Canyon Dam).

Distribution of beetle by month, combining 2011, 2012 and 2013, we detected the highest average number of early larvae were also detected in June at river mile -10 (x = 48.3) and -13 (x = 24.4 and late larvae in June at river mile -15 (x = 89.3), -11 (x = 87.5; Figures 6).). The highest mean number of adults were in July at river mile -6 (x = 56) followed by August at river mile -10 (x = 45; Figure 6).

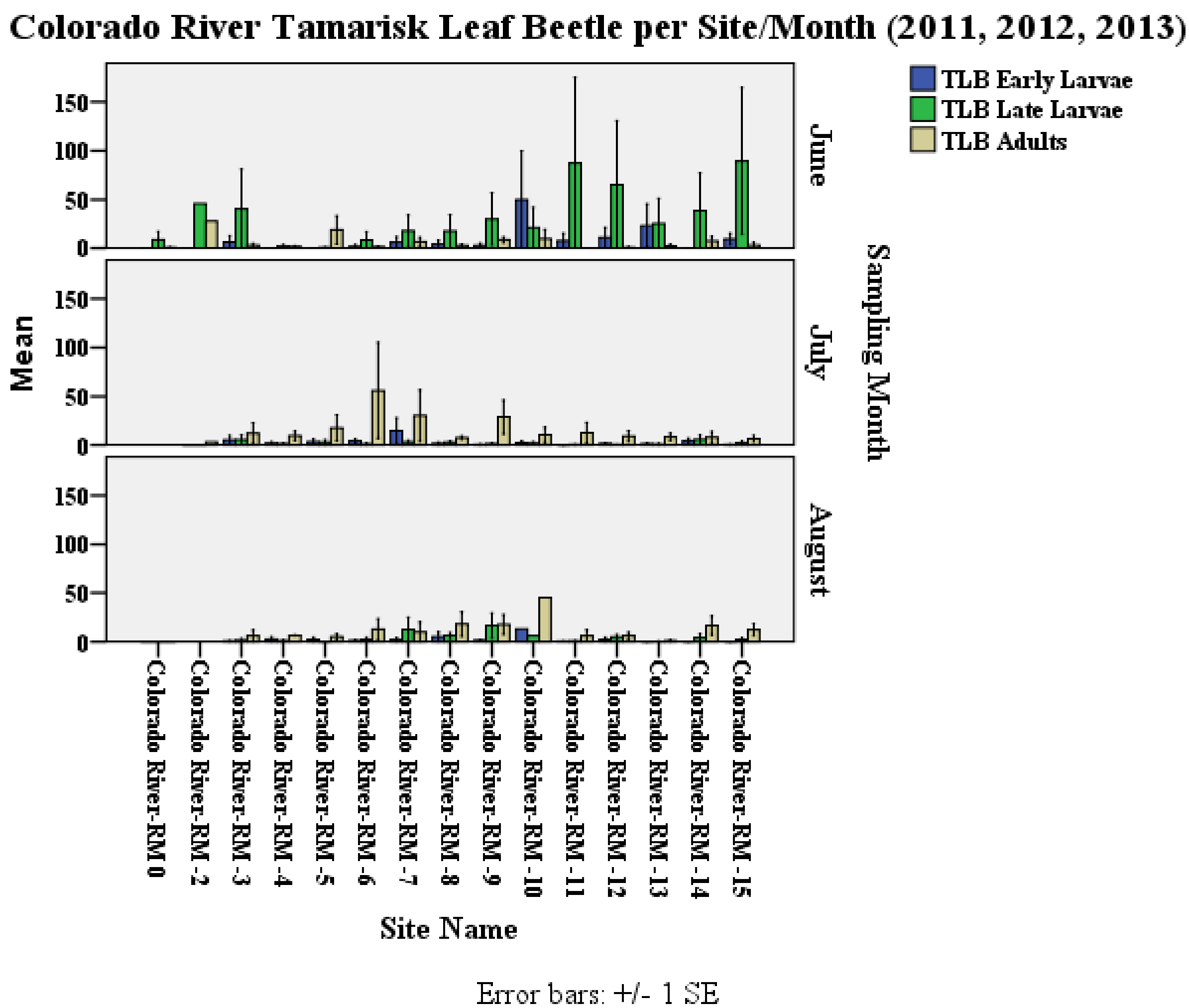


Figure 6. Tamarisk Leaf Beetle (early/late larvae and adults) detection per site during June, July and August combining 2011, 2012, 2013 along the Colorado River (Lee's Ferry - Glen Canyon Dam).

In Summary, during 2011 the average number of early larvae late larvae and adult beetles detected at all Colorado River sites were the highest numbers over the three years we sampled (Figures 2, 3, 4, 5, and 6). During 2012 and 2013, we observed similar numbers for each year, but observed a dramatic decline in beetle presence at all Colorado River sites for those two years.

Colorado River Tamarisk Leaf Beetle Defoliation and Refoliation, 2011, 2012 and 2013

In 2011, defoliation by the tamarisk leaf beetles was observed during all three months (June, July and August) surveys were conducted in (Figures 7). During June 2011 (44%), we observed moderate levels of defoliation by tamarisk leaf beetles. During July 2011, defoliation was at its peak, averaging 84% throughout all Colorado River sites but declined in August (53%). We observed tamarisk refoliate after defoliation occurred in July (17%) and August (27%; Figure 7).

During June 2012, we observed low defoliation rates (9%) by tamarisk leaf beetles (Figures 7), while during July 2012, defoliation was averaging 40% throughout all Colorado River sites and peaked in August (67%). We observed tamarisk refoliate after defoliation occurred in June (6%), July (20%) and August 2012 (19%; Figure 7).

During June 2013, we observed high defoliation rates (70%) by tamarisk leaf beetles (Figures 7), while during July 2013, defoliation was averaging 50% throughout all Colorado River sites and in August we observed an increase in defoliation rates (67%). We observed tamarisk refoliate in 2012 after defoliation occurred in June (6%), July (16%) and August (7%; Figure 7).

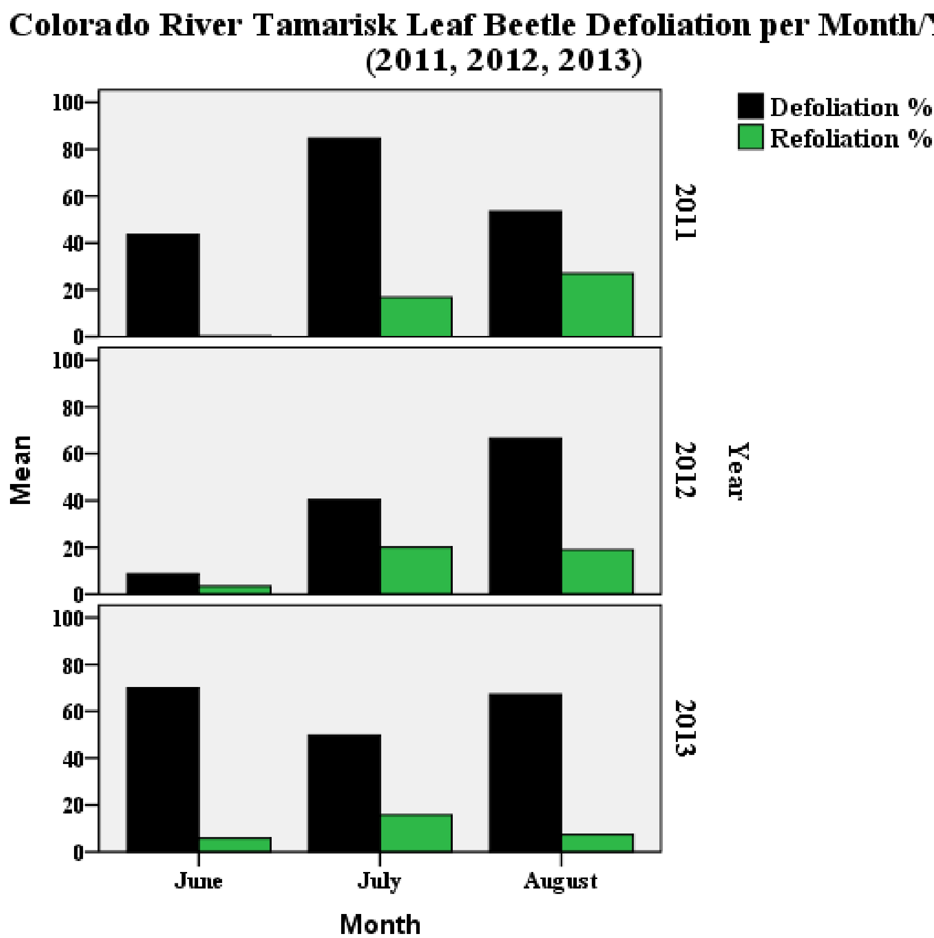


Figure 7. Average tamarisk cover defoliated by tamarisk leaf beetle and tamarisk refoliation by survey date along the Colorado River (Lee's Ferry – Glen Canyon Dam) during June, July and August for 2011, 2012 and 2013 tamarisk leaf beetle surveys. Error bars represent +/- 1SE.

Average defoliation by tamarisk leaf beetles at the Colorado River sites in 2011 were highest at river mile 0 (95%) followed by river mile -12 (87%), with average defoliation for all sites in 2011 at 60% (Figure 8). In 2012, we observed lower defoliation rates at each site with the highest at river mile -11 (70%) and overall defoliation rates at 33% for 2012. In 2013, we observed high rates of defoliation at river miles -6 (88%), -7 (95%) and -5 (85%). Overall defoliation was 59% in 2013, very similar to 2011. Refoliation was highest in 2012 at river mile -9 (29%) followed by river mile -6 (27%) in 2011 and in 2013 at river mile -9 (26% Figure 8).

Average defoliation by tamarisk leaf beetles by river mile when we combined all three years (2001, 2012, 2013) were greatest at river mile -11(67%) and river mile -10 (66%) where defoliation occurred earlier in the year (Figure 8). The least amount of defoliation was observed at river mile 0 (38%) and river mile -3 (41%) where defoliation occurred later in the season. Tamarisk refoliation was observed higher at river miles -9 (26%), -13 (16%) and -7 (14%) when we combined all three years.

In 2013, we also observed higher tamarisk mortality at river miles 0, -10 and -11, which was the first year we observed mortality since the beetle arrived on the Colorado River in 2010.

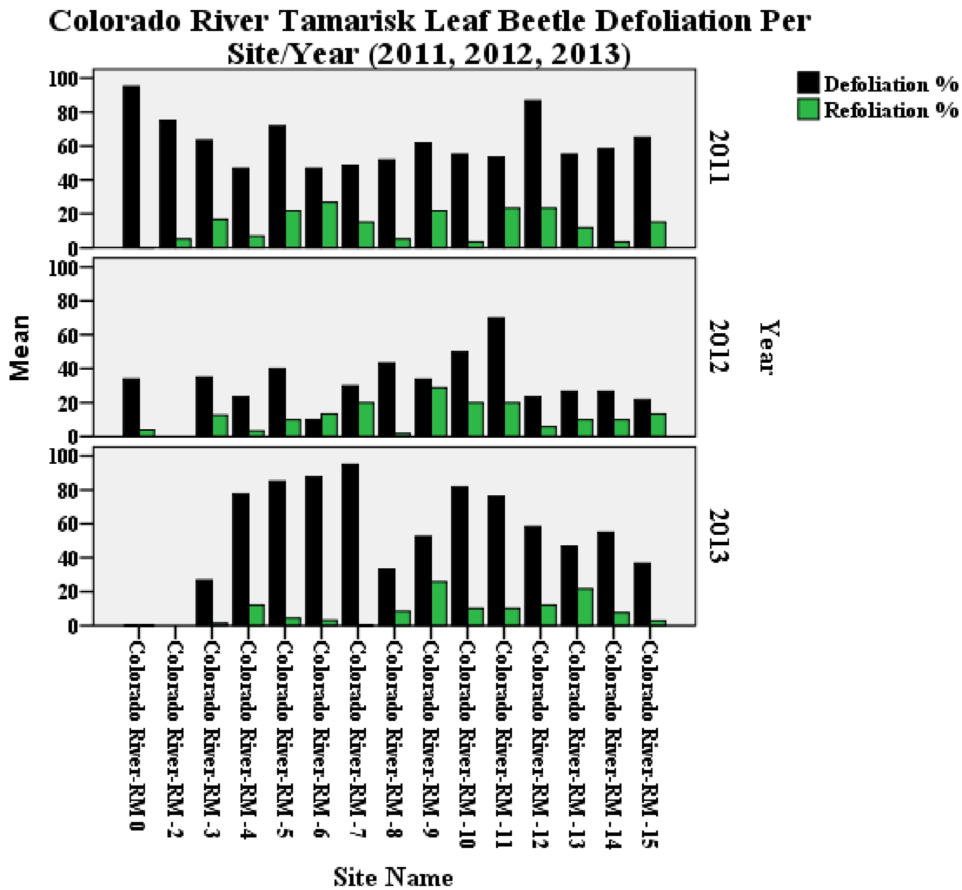


Figure 8. Average tamarisk cover defoliated by tamarisk leaf beetle and tamarisk refoliation by river mile along the Colorado River (Lee's Ferry – Glen Canyon Dam) during 2011 tamarisk leaf beetle surveys. Error bars represent +/- 1SE.

Colorado River Arthropod Abundance and Distribution

In 2011, 2012 and 2013, we also collected data on other arthropods while we sampled for tamarisk leaf beetles, which were mainly abundance and distribution of predators of tamarisk leaf beetles that included ants, ladybugs and spiders. We also included the splendid tamarisk weevils (*Coniatus splendidulus*) which are not predators, but are also a tamarisk obligate arthropod accidently released in 2010 that eat the young leaf shoots of tamarisk trees, yet it is unknown what their impact on tamarisk tree growth is. In 2011, the most common arthropod detected were spiders (x = 11.14) followed by ants (x = 2.8) and tamarisk weevils (x = 0.7; Figure 9). In 2012 and 2013 Spiders, ants, tamarisk weevils and ladybugs followed the same abundance trends respectively as 2011. Spiders were by far more abundant in 2011 than in 2012 and 2013. Spider abundance always increased after defoliation of the tamarisk trees by the tamarisk leaf beetle (Figure 9). Why this occurred we are still uncertain. We also observed an increase in tamarisk weevil in 2012, but then dropped in 2013. Combining all years, spiders were more abundant in June (x = 8.2) than July and August, while ants were more abundant in July (x = 2.2) than the other sampling months. Tamarisk weevils were more abundant in June and July and declined in August, while ladybugs were more abundant in June, but were relatively low in numbers during all sampling months (Figure 9).

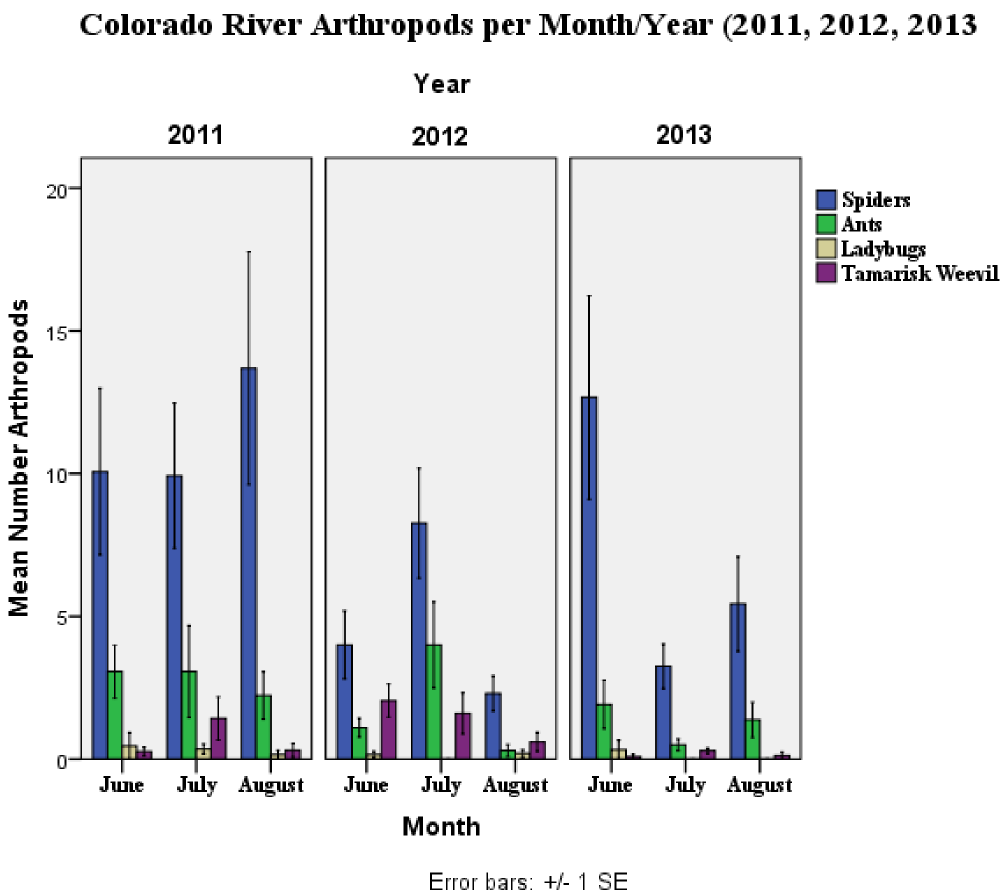


Figure 9. Average arthropods per month and year sampled during tamarisk leaf beetle surveys at Colorado River sites for June, July and August 2011, 2012 and 2013.

Distribution of arthropods at the Colorado River sites in 2011, particularly spiders, were at sites where we observed high defoliation rates, which were high in numbers at river mile sites -13 (x =

36), -9 (x = 23) and -8 (x = 20); Figure 10). In 2012, spider mean numbers were high at river mile -10 (x = 24) and in 2013 at river mile -15 (x = 22.7). Ants, which are a predator of tamarisk leaf beetles, were distributed at higher numbers in 2011 at river mile -4 (x = 11), river mile -9 (x = 5.1) and river mile -10 (x = 3.1), which followed no real pattern of defoliation or tamarisk leaf beetle abundance. During 2012, ant numbers decreased at all sites with river mile -4 (x = 5.3) the highest number detected and in 2013, ants were noted at fewer sites and at relative lower numbers (Figure 10). Ladybugs were only detected at half the sites during each year with high numbers at river mile 0 (x = 7.1) in 2011 but were low in abundance at all sites where we detected them during each year (Figure 10). Tamarisk weevil distribution was observed at four sites in 2011 at relative low numbers at river miles -7 (x = 2.9), -10 (x = 1.7). In 2012, we observed weevils at 9 sites with the highest numbers at river mile -4 (x = 5.3) and -7 (x = 4.9), while in 2013, we observed weevils at six sites but were detected at very low numbers (Figure 10).

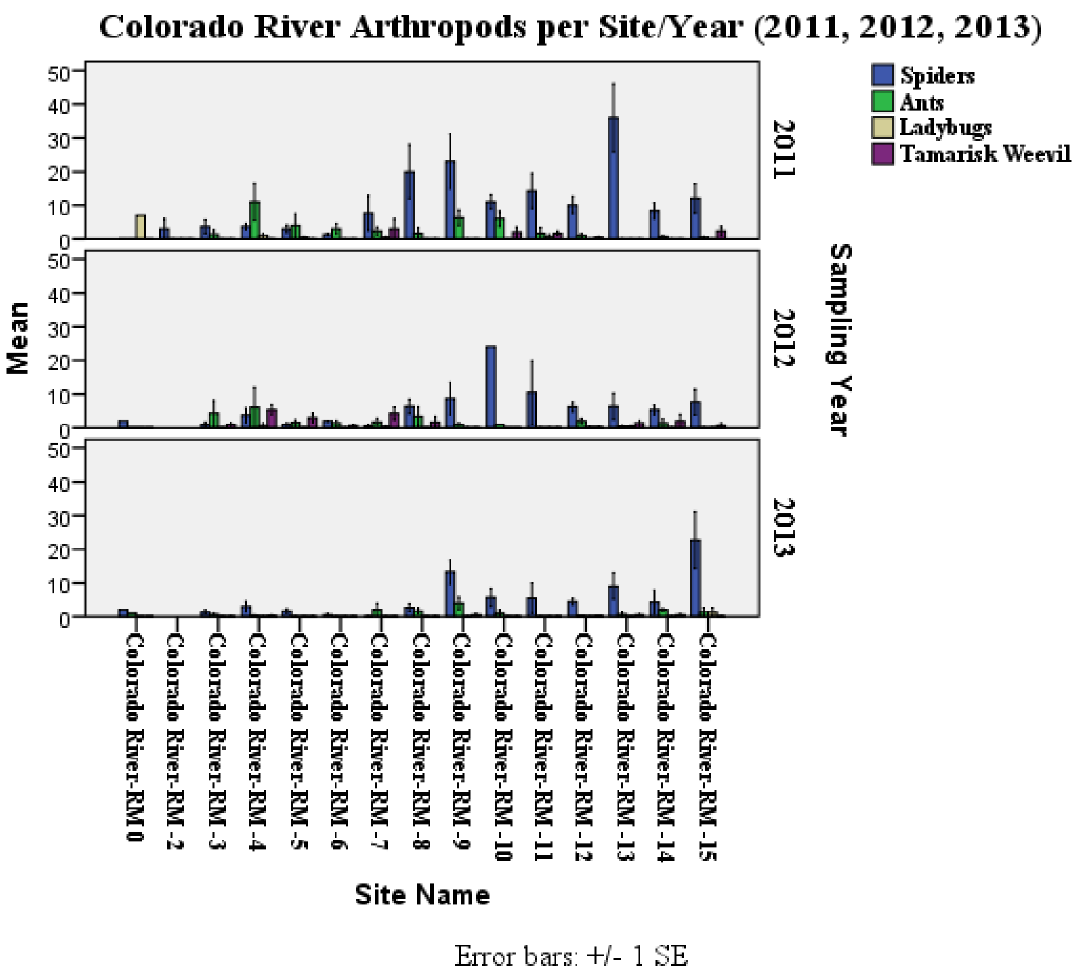


Figure 10. Average arthropods per site sampled during tamarisk leaf beetle surveys at Colorado River sites for June, July and August 2011, 2012 and 2013.

Verde River, Tonto Creek, Upper and Lower Salt River Watershed Arthropod Abundance and Distribution

In 2011, 2012 and 2013, we did not detect tamarisk leaf beetles at any of the sites surveyed within the Verde River, Tonto Creek, and upper and lower Salt River watersheds. However, we detected other arthropods while sampling for beetles. Arthropod abundance varied from year to year, but during each year (2011-2013) ants were the most common arthropod detected (Figure 11), particularly in August 2012 (x = 11.15) followed by June 2011 (x = 7.8) yet in August 2013 (x = 7.5) spiders were more common arthropod detected. Ladybugs were present during each year and month but abundance of this arthropod was relatively low with the highest numbers in June 2011 (x = 0.5) and August 2011 (x = 0.4); Figure 11)

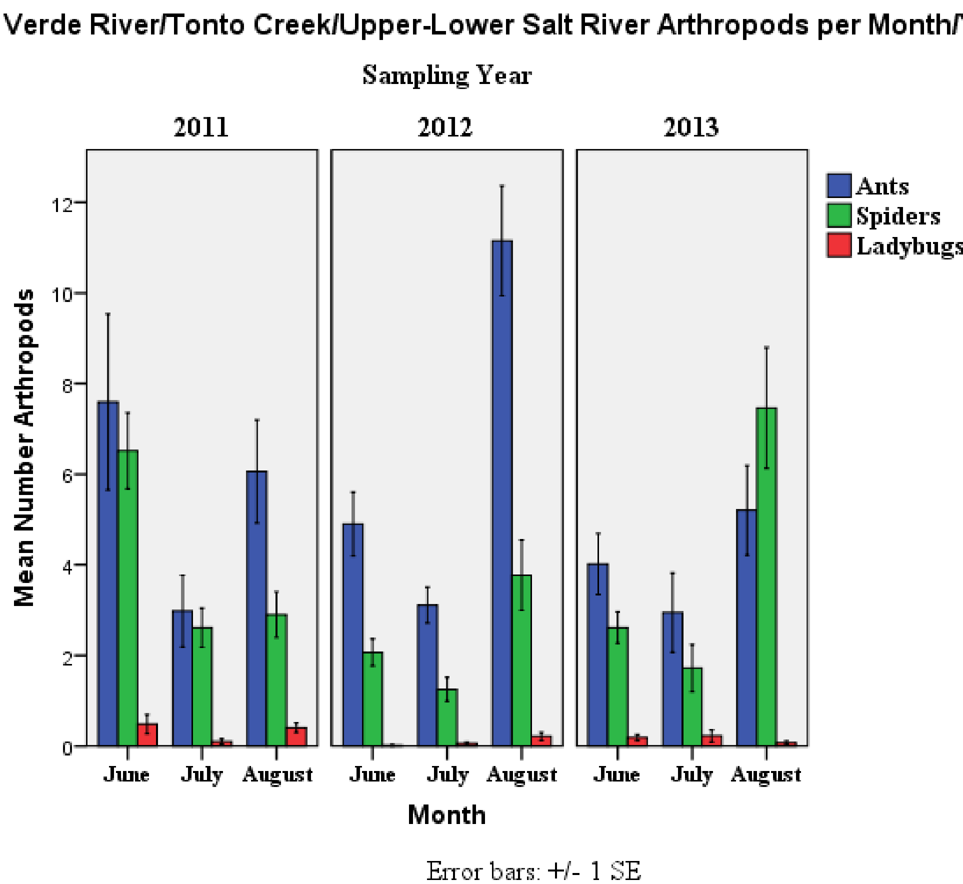


Figure 11. Average arthropods per month and year sampled during tamarisk leaf beetle surveys at Verde River/Tonto Creek and upper and lower Salt River sites during June, July and August 2011, 2012 and 2013.

In 2011, 2012 and 2013, ants, spiders and ladybugs were distributed at all sites sampled in the Verde River, Upper and lower Gila River Watersheds. During this sampling periods, we found that most common arthropod detected were spiders at the lower Gila River Water Users site (x = 12. 9) followed by ants at the lower Gila River Goldfield site (x = 8.8). Ladybugs were most common at lower Gila River Sheep's Crossing site (x = 0.8), but again were relatively low at most sites. Combining all sites for all years, ants (x = 5.4) were the most common arthropod followed by spiders (x = 3.5), with ladybugs present at each site, but low in numbers at each site during each year.

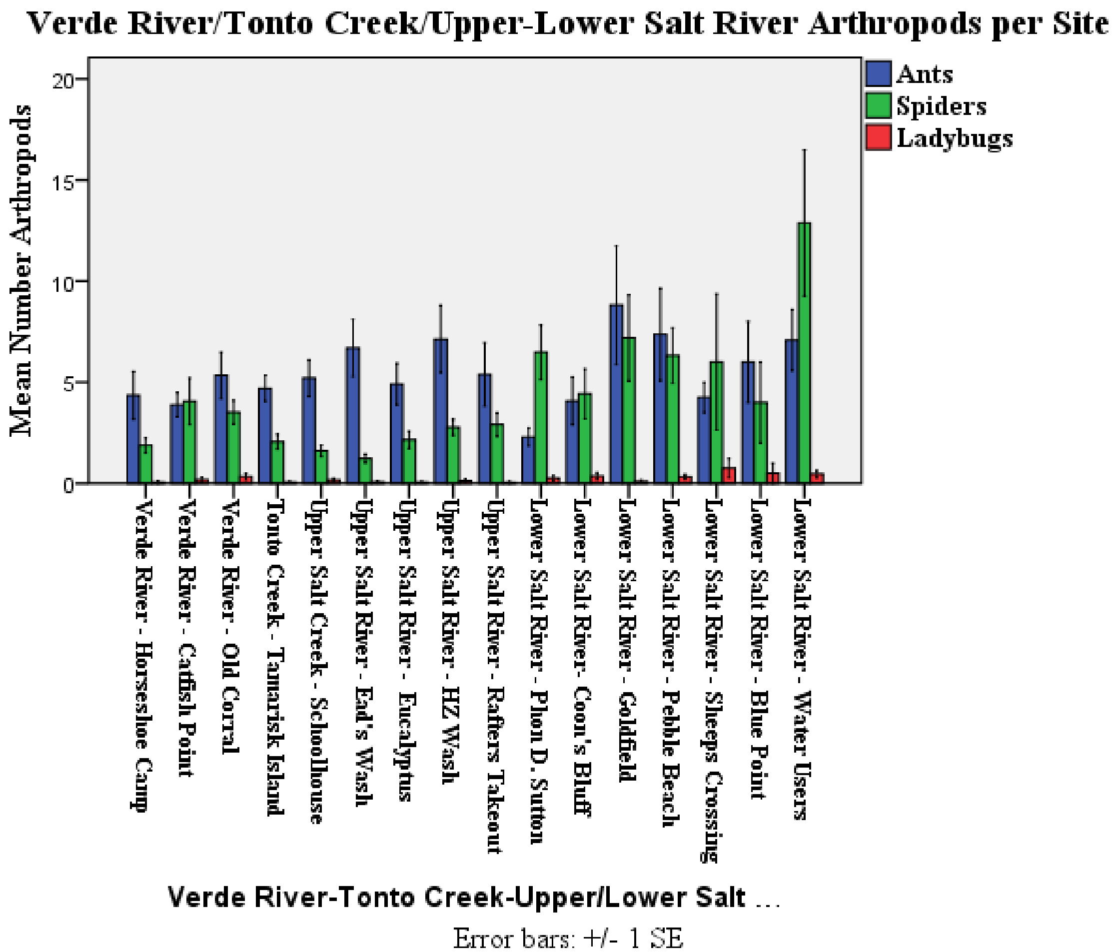


Figure 12. Average arthropods per site sampled during tamarisk leaf beetle surveys at Verde River, Tonto Creek and upper and lower Salt River sites during June, July and August 2011, 2012 and 2013.

We singled out Splendid tamarisk weevils (*Coniatus splendidulus*) since it's a tamarisk obligate arthropod at sites we did not detect tamarisk leaf beetle since it may have impact on tamarisk tree growth due to it eating the young leaf shoots of tamarisk trees, yet it is still unknown what their impact on tree growth is. This arthropod was common in August 2013 (x = 5.6) and in June 2011 (x = 5.1; Figure 13). Abundance was usually higher in June of each year (2011 – 2013) but declined in July and August of 2011 and 2012. In 2013, abundance increased during each sampling month when compared to the previous two years (Figure 13).

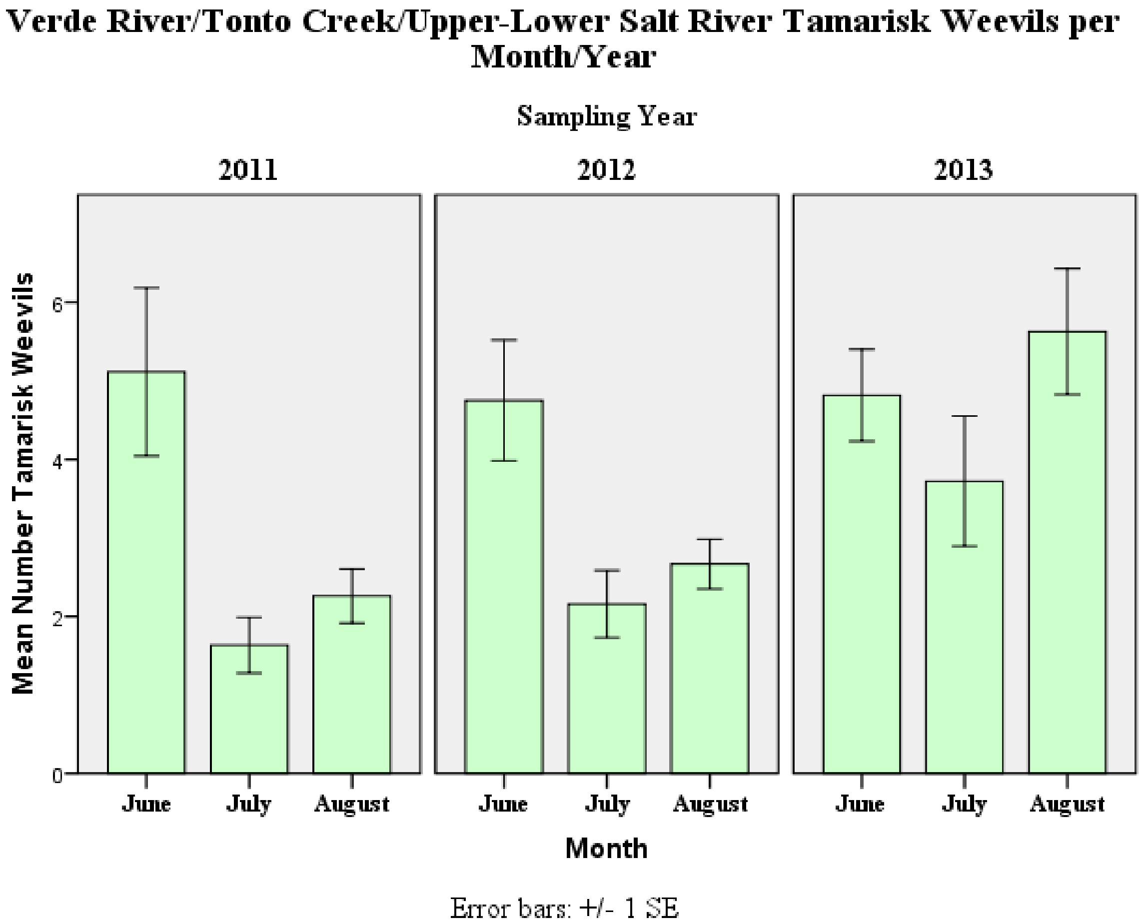


Figure 13. Average tamarisk weevils per month and year sampled during tamarisk leaf beetle surveys at Verde River/Tonto Creek and upper and lower Salt River sites during June, July and August 2011, 2012 and 2013.

During 2011, 2012 and 2013, tamarisk weevils were distributed throughout the Verde River, Tonto Creek and the upper and lower Salt River Watersheds and detected at each site we sampled (Figure 14). Tamarisk weevils were most common at the lower Salt River Goldfield site (x = 6.4) followed by the lower Salt River Water Users site (x = 5.8). The lowest numbers were at the Verde River sites (Horseshoe; x = 1.9 and Catfish Point (1.6; Figure 14).

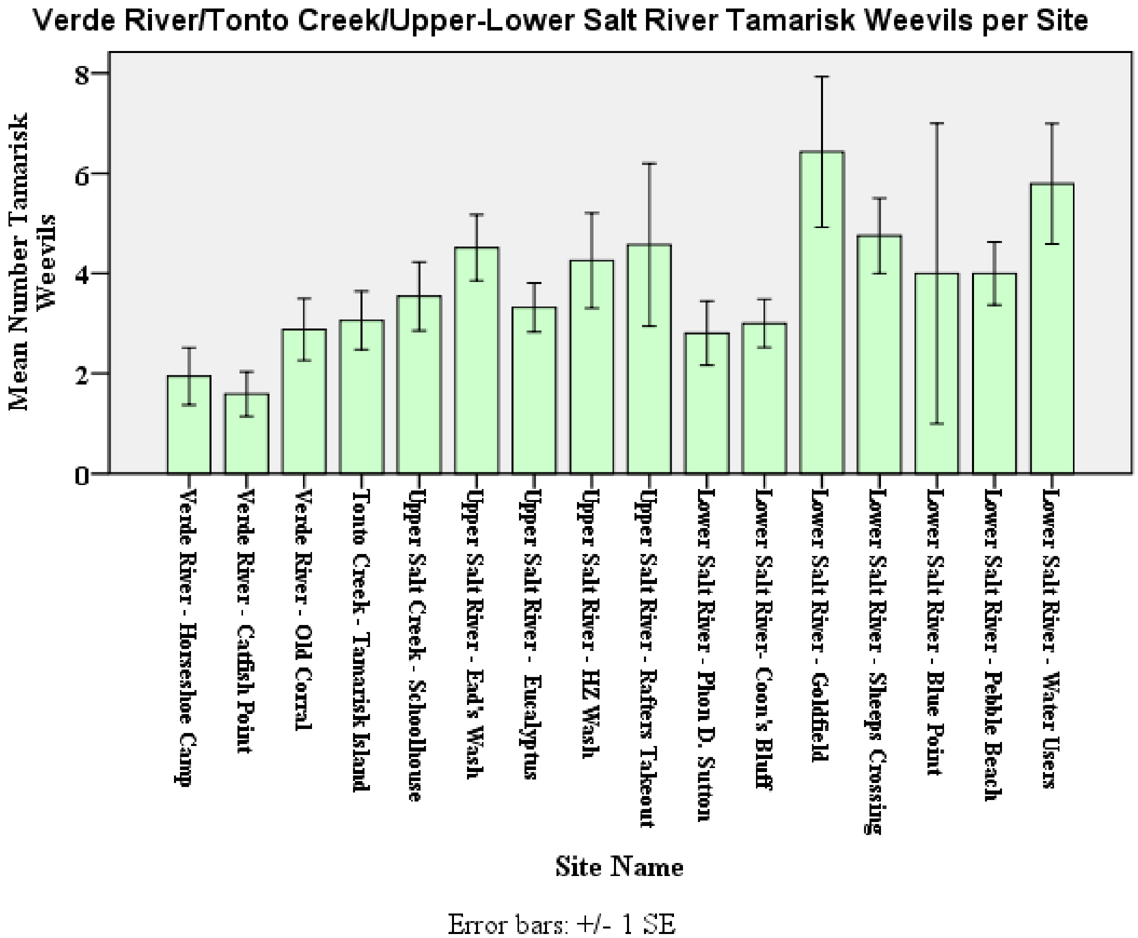


Figure 14. Average tamarisk weevils per site sampled during tamarisk leaf beetle surveys at Verde River, Tonto Creek and upper and lower Salt River sites during June, July and August 2011, 2012 and 2013.

Microclimate Measurements (Temperature/Relative Humidity) (Colorado River, Verde River, Upper and Lower Salt River Watershed), 2011, 2012, 2013

To examine the changes in tamarisk habitat that maybe occurring where the tamarisk leaf beetle exists due to defoliation and ultimately tamarisk mortality we measured microclimate (temperature and relative humidity) in 2011 2012 and 2013 at sites along the Colorado River (Lee's Ferry-Glen Canyon Dam) and along the Verde River, Tonto Creek and upper and lower Salt River Watersheds where the beetle does not exist. The latter sites, where the beetle does not exist will be valuable base line information for when the beetle does arrive at these sites.

During this study we examined microclimate at each site and looked at differences that maybe occurring between the years 2011, 2012 and 2013. We felt it would be difficult to compare each site and the impact of the beetle may have on habitat and microclimate since each site is unique in it's geographic location, vegetation composition and structure and therefore we compared monthly (June, July and August) difference between each year (2011, 2012 and 2013).

Average 2012 June temperatures (minimum and mean) at the Colorado River -6 site were higher when compared to 2011 and 2013 (Figure 15), however, the maximum temperatures were higher in June 2013. During July, mean and maximum temperatures were higher in 2013, while the minimum was higher in 2011. During August, the mean and maximum temperatures were higher in 2012, while the minimum high was in 2011 (Figure 15). The higher microclimate temperatures in June and July maybe due to the higher defoliation rates that occur from tamarisk leaf beetle during this time period while during August, refoliation occurs, which may provide more cover and lower the temperatures. We had higher defoliation rates occur in July 2011 (85%) and June 2013 (70%), which does not reveal a clear pattern correlating defoliation with microclimate temperature, and therefore additional data will be required, particularly when tamarisk mortality occurs that may dramatically change microclimate temperature at this site.

Mean relative humidity (minimum, mean and maximum) at the Colorado River -6 site were lower in June 2011, 2012 and 2013, and higher in July and August 2011, 2012 and 2013, which correlates with the monsoon season that occurs in July in August (Figure 16). Lower relative humidity (maximum) in June 2012 may correlate with the higher temperature observed in June of 2013, but does not reveal a clear pattern related to relative humidity microclimate and defoliation at this site, which again will require additional data to relate tamarisk defoliation and mortality to microclimate.

Colorado River (Glen Canyon Sites -6 and -12) Temperature and Relative Humidity

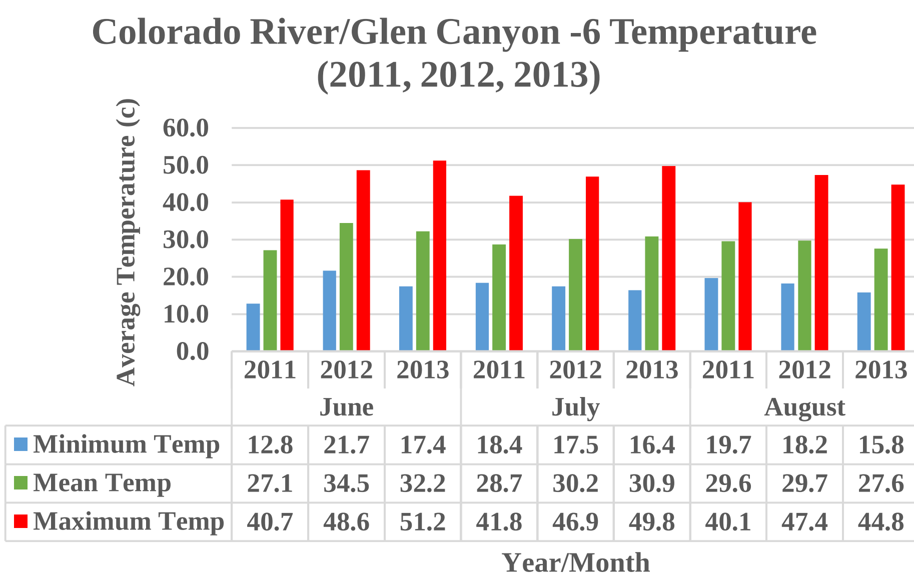
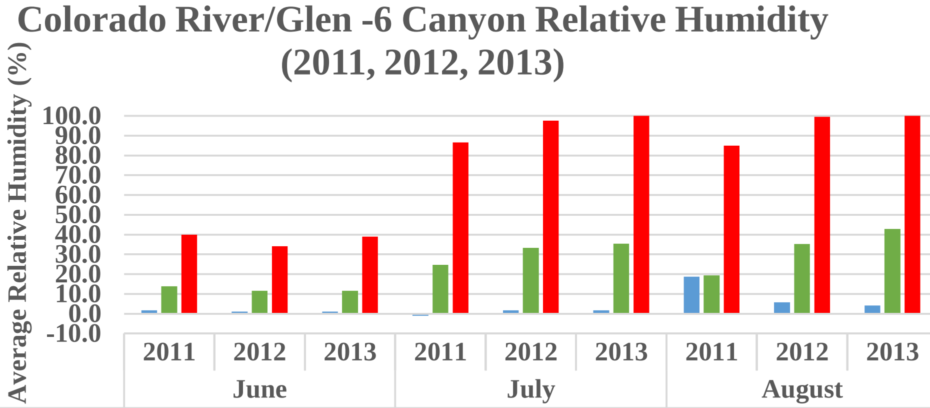


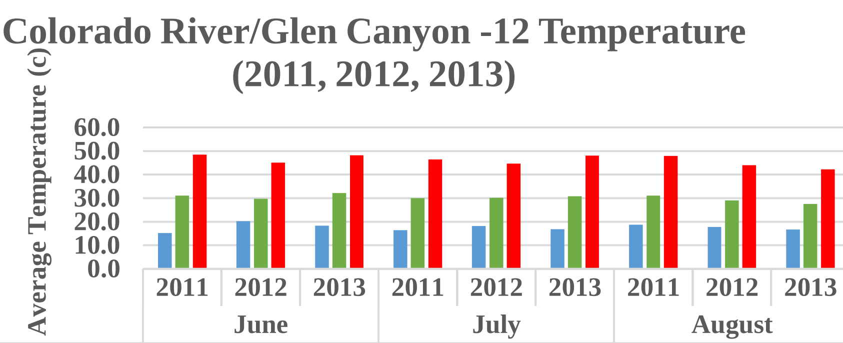
Figure 15. Mean, maximum mean and minimum mean monthly air temperatures for June, July and August along the Colorado River between Lees Ferry and Glen Canyon Dam at monitoring site -6 during 2011, 2012 and 2013 tamarisk leaf beetle surveys.



	June			July			August		
	2011	2012	2013	2011	2012	2013	2011	2012	2013
Minimum RH	1.7	1.0	1.0	-1.1	1.8	1.7	18.7	5.8	4.1
Mean RH	13.8	11.6	11.6	24.7	33.2	35.4	19.4	35.2	42.8
Maximum RH	40.0	34.0	38.9	86.6	97.6	100.0	84.9	99.5	100.0

Figure 16. Mean maximum mean and minimum mean relative humidity for June, July and August along the Colorado River between Lees Ferry and Glen Canyon Dam at monitoring site -6 during 2011, 2012 and 2013 tamarisk leaf beetle surveys.

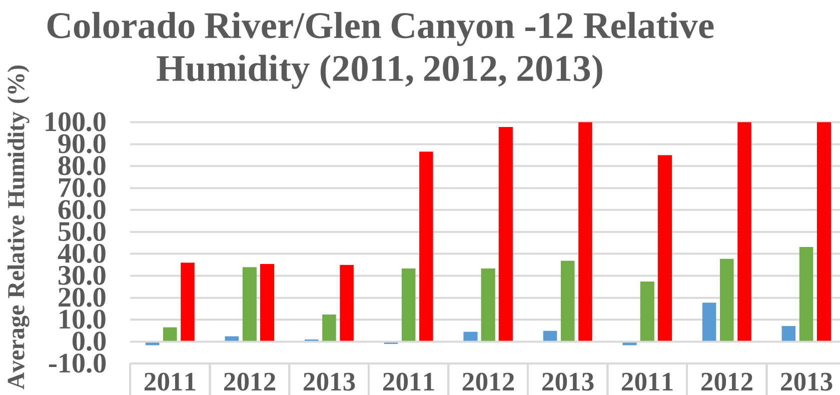
Average mean and maximum temperatures at the Colorado River -12 site were higher during June 2013, while the average minimum temperatures were higher in June 2012 (Figure 17). The maximum mean temperature in July were higher in 2013, while the mean and minimum average temperatures were relatively the same. In August, we observed higher minimum, mean and maximum temperatures in 2011. These microclimate temperatures don't correlate well with defoliation rates at this Colorado River site, yet again we will need additional microclimate data, particularly when tamarisk mortality occurs.



	June			July			August		
	2011	2012	2013	2011	2012	2013	2011	2012	2013
Minimum Temp	15.2	20.2	18.3	16.4	18.2	16.8	18.7	17.8	16.7
Mean Temp	31.0	29.7	32.2	30.0	30.1	30.8	31.1	29.0	27.5
Maximum Temp	48.5	45.0	48.1	46.4	44.7	48.1	48.0	44.0	42.1

Figure 17. Mean, maximum mean and minimum mean monthly air temperature for June, July and August along the Colorado River between Lees Ferry and Glen Canyon Dam at monitoring site -12 during 2011, 2012 and 2013 tamarisk leaf beetle surveys.

Mean relative humidity (minimum, mean and maximum) at the Glen Canyon -12 site were lower in June 2011, 2012 and 2013, and higher in July and August 2011, 2012 and 2013, which correlates with the monsoon season that occurs in July in August (Figure 18). This again does not reveal a clear pattern related to relative humidity microclimate at this site and defoliation, which will require additional data to relate tamarisk defoliation and mortality to microclimate.



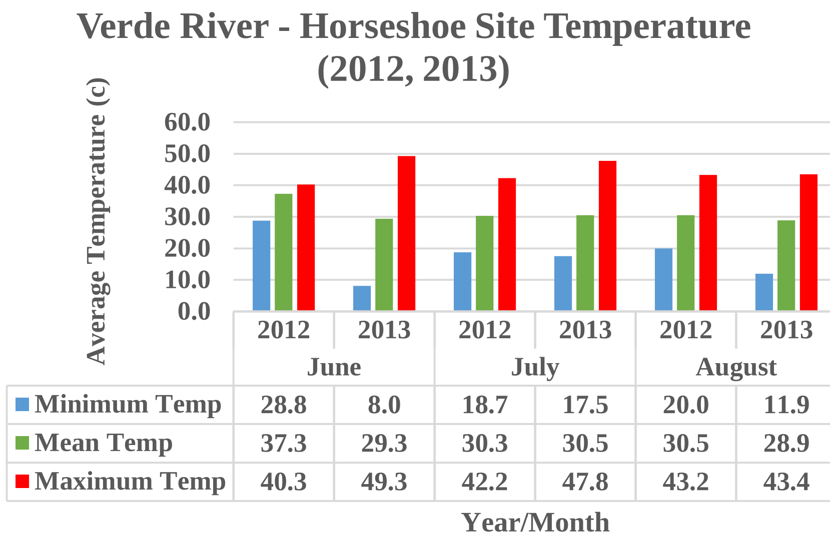
	June			July			August		
	2011	2012	2013	2011	2012	2013	2011	2012	2013
Minimum RH	-1.6	2.4	1.0	-1.1	4.4	4.9	-1.6	17.8	7.1
Mean RH	6.6	33.9	12.3	33.4	33.3	36.8	27.4	37.8	43.1
Maximum RH	36.0	35.4	34.9	86.6	97.8	100.0	84.9	100.0	100.0

Figure 18. Mean, maximum mean and minimum mean monthly air relative humidity for June, July and August along the Colorado River between Lees Ferry and Glen Canyon Dam at monitoring site -12 during 2011, 2012 and 2013 tamarisk leaf beetle surveys.

Verde River (Horseshoe and Old Corral sites) Microclimate Temperature and Relative Humidity

The Verde River watershed microclimate results included Horseshoe and the Old Corral sites. (Figure 4). Microclimate sampling at the Verde River sites only included 2012 and 2013, in 2011 we did not include these sites due to logistical complications. We did not detect tamarisk leaf beetles at any of the sites within the Verde River watershed and therefore did not document any tamarisk defoliation. We did observe discoloration of many tamarisk trees that had high densities of tamarisk leafhoppers, another tamarisk obligate, which were not sampled during this study and should be in the future. Leafhoppers may also affect tamarisk habitat and microclimate within riparian habitat.

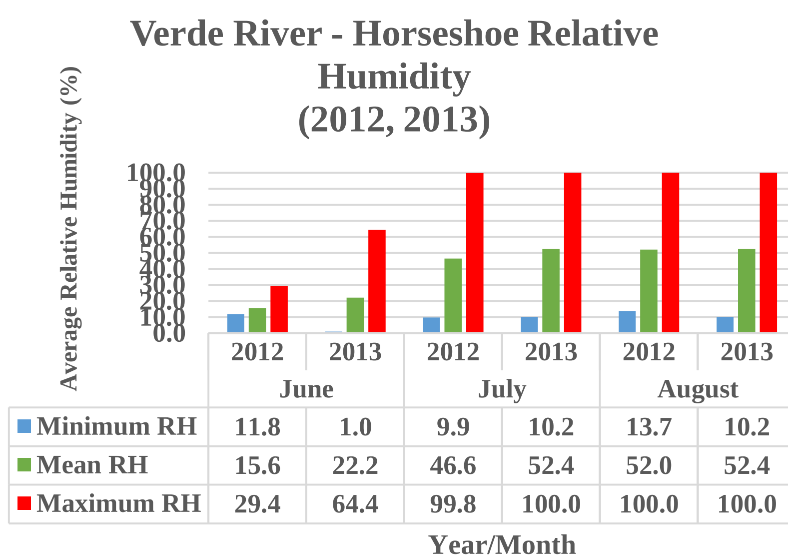
Microclimate patterns within the Verde River Horseshoe site found mean temperatures 8 degrees higher in June 2012 when compared to 2013, while the maximum temperature was 9 degrees higher in June 2013 than 2012 (Figure 19). During July, maximum temperatures were 5 degrees higher in 2013 at the Horseshoe site than 2012, while the minimum and mean temps were relatively the same. In August, mean and maximum temperatures were relatively the same between years, with the exception of minimum average temperatures that were 8 degrees warmer in 2012. These microclimate temperatures are baseline results and will be valuable data upon the arrival of the tamarisk leaf beetle, which will alter the habitat through tamarisk defoliation and mortality.



	June 2012	June 2013	July 2012	July 2013	August 2012	August 2013
Minimum Temp	28.8	8.0	18.7	17.5	20.0	11.9
Mean Temp	37.3	29.3	30.3	30.5	30.5	28.9
Maximum Temp	40.3	49.3	42.2	47.8	43.2	43.4

Figure 19. Mean, maximum mean and minimum mean monthly air temperatures for June, July and August along the Verde River Watershed at the Horseshoe monitoring site during 2012 and 2013 tamarisk leaf beetle surveys

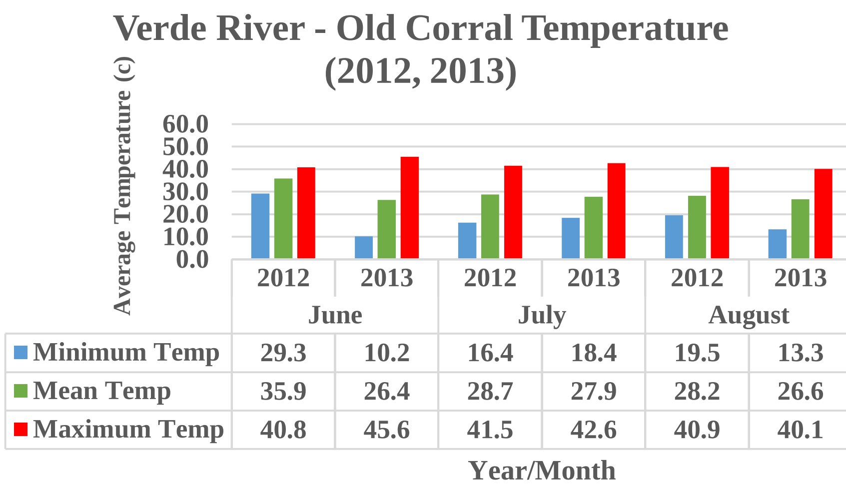
Mean and maximum relative humidity at the Horseshoe site were higher in June 2013, where the maximum was 34% higher than 2012 (Figure 20). During July and August 2012 and 2013, minimum, mean and maximum relative humidity levels were relatively the same, with no real extremes during either year, which correlates with the monsoon season that occurs in July in August. The relative humidity microclimate at this site will again require additional data to habitat and microclimate change upon the arrival of the tamarisk leaf beetle.



	June 2012	June 2013	July 2012	July 2013	August 2012	August 2013
Minimum RH	11.8	1.0	9.9	10.2	13.7	10.2
Mean RH	15.6	22.2	46.6	52.4	52.0	52.4
Maximum RH	29.4	64.4	99.8	100.0	100.0	100.0

Figure 20. Mean maximum mean and minimum mean relative humidity for June, July and August along the Verde River Watershed at the Horseshoe monitoring site during 2012 and 2013 tamarisk leaf beetle surveys.

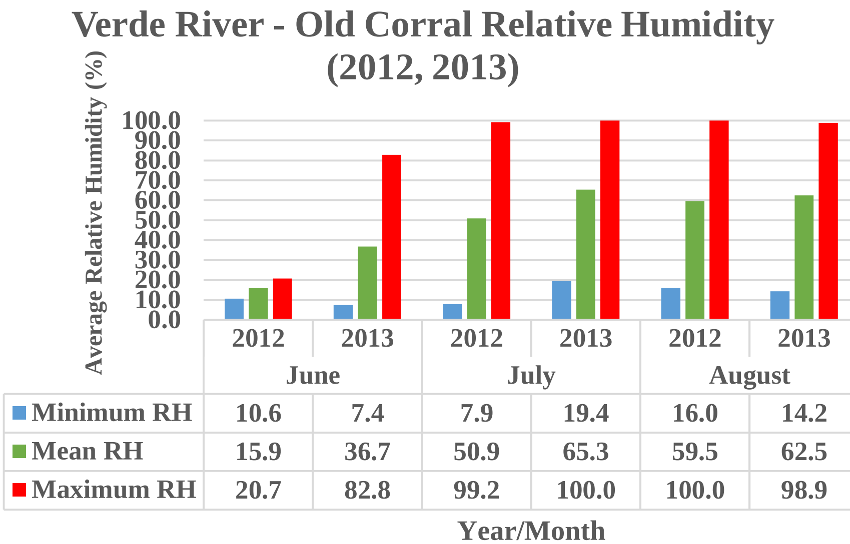
Microclimate patterns at the Verde River Old Corral site detected mean temperatures of 9.5 degrees higher in June 2012 when compared to 2013, while the maximum temperature was 5 degrees higher in June 2013 than 2012 of that month (Figure 21). During July and August 2012 and 2013, mean and maximum temperatures at the Old Corral site were relatively the same, yet the minimum average temperatures were 6 degrees higher in August 2012 than 2013. These microclimate temperatures at the Old Corral site are again baseline results and will be valuable data upon the arrival of the tamarisk leaf beetle.



	June 2012	June 2013	July 2012	July 2013	August 2012	August 2013
Minimum Temp	29.3	10.2	16.4	18.4	19.5	13.3
Mean Temp	35.9	26.4	28.7	27.9	28.2	26.6
Maximum Temp	40.8	45.6	41.5	42.6	40.9	40.1

Figure 21. Mean, maximum mean and minimum mean monthly air temperatures for June, July and August along the Verde River Watershed at the Old Corral monitoring site during 2012 and 2013 tamarisk leaf beetle surveys.

Relative humidity (mean and maximum) at the Old Corral site were much higher in June 2013, where mean relative humidity was over 21 percent higher than June 2012 and maximum humidity was over 60 percent higher in 2013 than 2012 (Figure 22). During July and August 2012 and 2013 minimum and maximum relative humidity percentages were relative the same except mean humidity rates were 15 percent higher in July 2013 than 2012. The relative humidity microclimate at this site will again require additional data upon the arrival of the tamarisk leaf beetle.



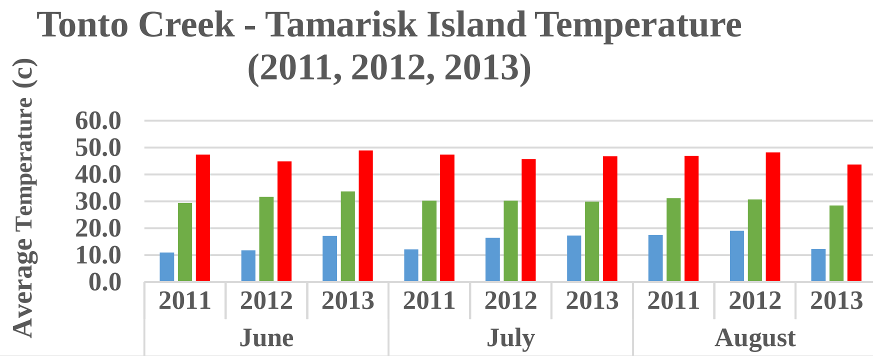
	June 2012	June 2013	July 2012	July 2013	August 2012	August 2013
Minimum RH	10.6	7.4	7.9	19.4	16.0	14.2
Mean RH	15.9	36.7	50.9	65.3	59.5	62.5
Maximum RH	20.7	82.8	99.2	100.0	100.0	98.9

Figure 22. Mean maximum mean and minimum mean relative humidity for June, July and August along the Verde River Watershed at the Old Corral monitoring site during 2012 and 2013 tamarisk leaf beetle surveys.

Upper Salt River Watershed Microclimate Temperature and Relative Humidity

The upper Salt River watershed microclimate results included Tonto Creek (Tamarisk Triangle) Schoolhouse Wash, Ead's Wash, HZ Wash and Rafters Takeout. The Tonto Creek sites are located in the vicinity of the Salt River watershed sites (Figure 4), and therefore included in this watershed. We did not detect tamarisk leaf beetles at any of the sites within the upper Salt River Watershed, and therefore did not document any tamarisk defoliation. Again, we did observe discoloration of many of the tamarisk trees that had high densities of leafhoppers, which may affect microclimate within the habitat and should be further examined in the future.

Microclimate minimum, mean and maximum temperatures at Tonto Creek, Tamarisk Island were higher in June 2013 when compared to June 2011 and 2012 (Figure 23). In July, mean temperatures were relatively the same for all three years, with minimum higher in 2013 and maximum higher in 2011. In August, mean temperatures were relatively the same with minimum mean and maximum temperatures slightly lower in 2013.

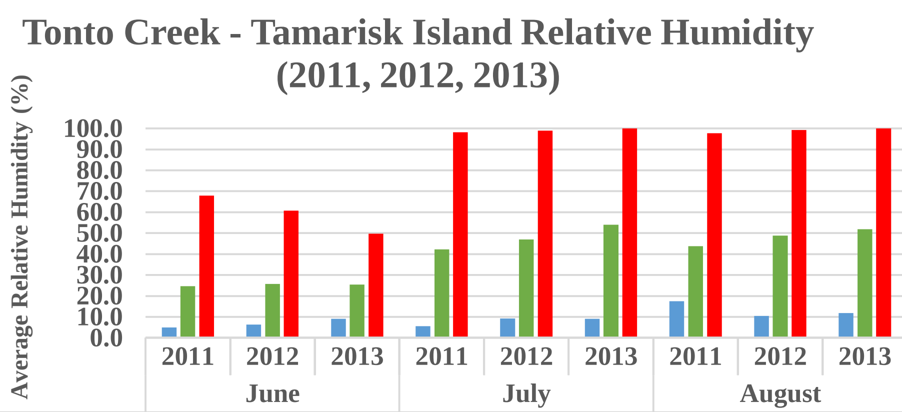


	June 2011	June 2012	June 2013	July 2011	July 2012	July 2013	August 2011	August 2012	August 2013
Minimum Temp	11.0	11.8	17.2	12.2	16.4	17.2	17.5	19.1	12.3
Mean Temp	29.4	31.7	33.7	30.3	30.3	29.9	31.2	30.7	28.5
Maximum Temp	47.4	44.9	49.0	47.4	45.7	46.8	46.9	48.3	43.6

Year/Month

Figure 23. Mean, maximum mean and minimum mean monthly air temperatures for June, July and August along the upper Salt River Watershed on Tonto Creek at the Tamarisk Island monitoring site during 2011, 2012 and 2013 tamarisk leaf beetle surveys.

Minimum relative humidity microclimate at Tonto Creek (Tamarisk Island) during June was slightly higher in 2013, while the mean was relatively the same for each year and the maximum relative humidity in 2011 was 8 percent higher than 2012 and 18 percent higher than 2013 (Figures 24). During July, the mean humidity was higher in 2013 and the maximum were relatively the same for all three years. During August, minimum relative humidity was highest in 2011, the mean highest in 2013 and the maximum were relatively the same for all three years.

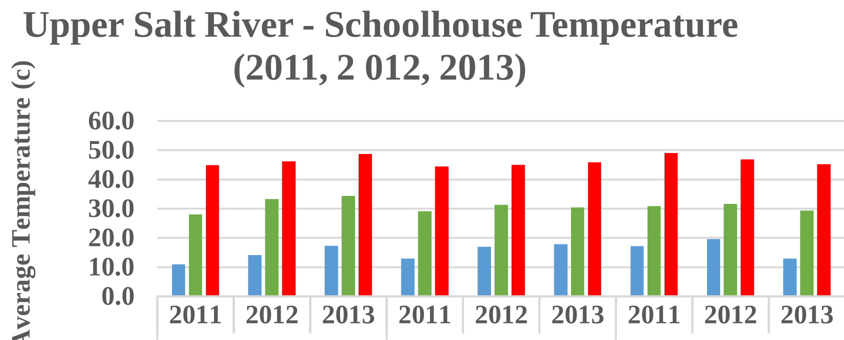


	June 2011	June 2012	June 2013	July 2011	July 2012	July 2013	August 2011	August 2012	August 2013
Minimum RH	5.0	6.3	9.1	5.6	9.3	9.1	17.5	10.5	11.8
Mean RH	24.7	25.8	25.4	42.2	46.9	54.1	43.8	48.9	52.0
Maximum RH	68.0	60.7	49.8	98.2	99.0	100.0	97.8	99.2	100.0

Year/Month

Figure 24. Mean, maximum mean and minimum mean monthly air temperatures for June, July and August along the upper Salt River Watershed on Tonto Creek at the Tamarisk Island monitoring site during 2011, 2012 and 2013 tamarisk leaf beetle surveys.

Microclimate minimum, mean, maximum temperatures during June at Schoolhouse Wash were progressively higher from 2011 to 2013 (Figure 25). In July, minimum, mean and maximum temperatures at Schoolhouse wash revealed the same pattern as June where temperatures were progressively higher each year. During August, minimum and mean temperatures were higher in 2012 than both 2011 and 2013 and maximum were higher in 2011 (Figure 25).

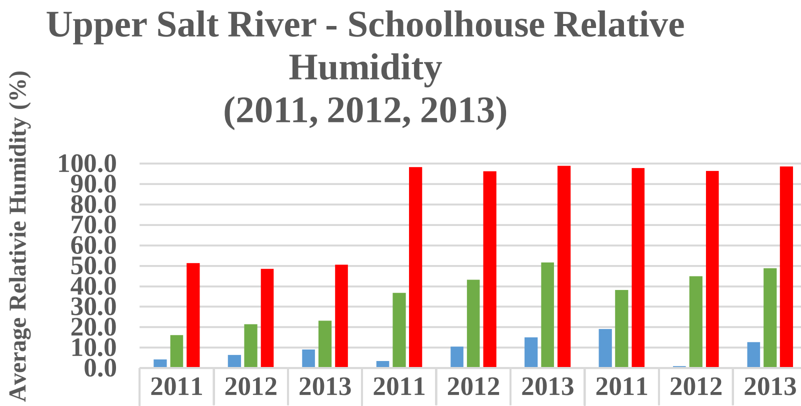


	June 2011	June 2012	June 2013	July 2011	July 2012	July 2013	August 2011	August 2012	August 2013
Minimum Temp	11.0	14.1	17.3	12.9	17.0	17.9	17.1	19.6	12.9
Mean Temp	28.0	33.3	34.4	29.2	31.3	30.5	30.9	31.6	29.3
Maximum Temp	44.9	46.2	48.7	44.4	45.0	45.9	49.0	46.8	45.2

Year/Month

Figure 25. Mean, maximum mean and minimum mean monthly air temperatures for June, July and August along the upper Salt River Watershed at Schoolhouse Wash monitoring site during 2011, 2012 and 2013 tamarisk leaf beetle surveys.

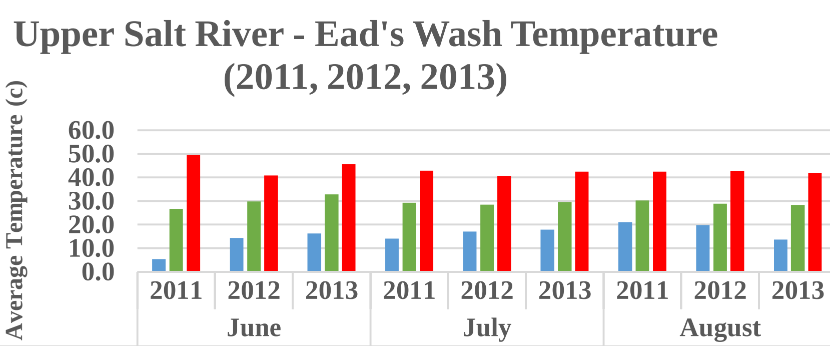
Minimum and mean relative humidity microclimate at Schoolhouse Wash during June was higher in 2013 while the maximum was slightly higher in 2011 (Figures 26). During July, minimum and mean relative humidity was higher in 2013, while maximum were relatively the same for all three years. During August, minimum relative humidity was highest in 2011, by 18 percent over 2012, while the mean humidity was higher in 2013 than 2011 and 2012. The maximum in August at Schoolhouse Wash were relatively the same for all three years (Figure 26).



	June 2011	June 2012	June 2013	July 2011	July 2012	July 2013	August 2011	August 2012	August 2013
Minimum RH	4.2	6.4	9.1	3.4	10.5	15.0	19.0	1.0	12.7
Mean RH	16.1	21.5	23.2	36.9	43.1	51.7	38.2	44.9	48.9
Maximum RH	51.3	48.5	50.5	98.3	96.2	99.0	97.9	96.5	98.6

Figure 26. Mean, maximum mean and minimum mean monthly air temperatures for June, July and August along the upper Salt River Watershed at Schoolhouse Wash monitoring site during 2011, 2012 and 2013 tamarisk leaf beetle surveys.

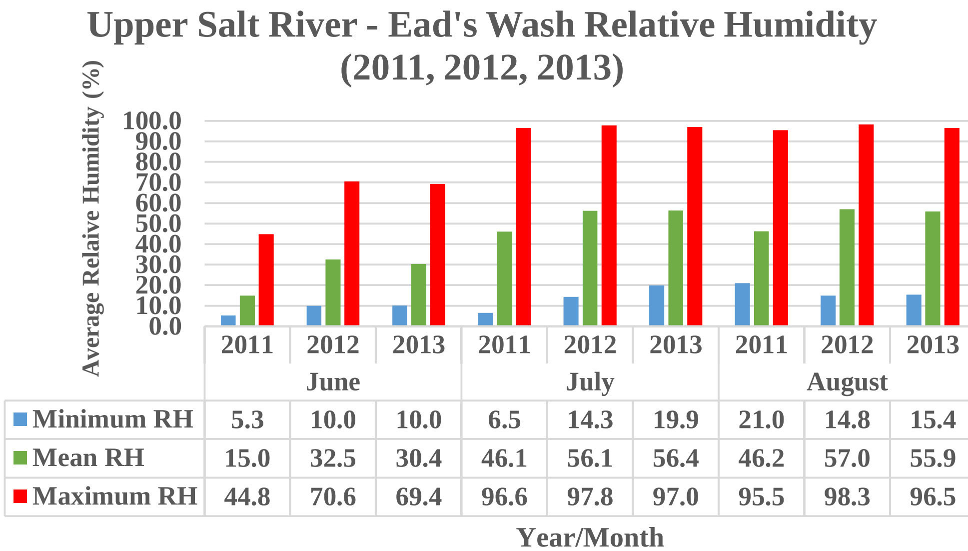
Microclimate patterns at Ead's Wash during June revealed lower minimum and mean temperatures in 2011 and higher maximum temperatures during 2011 when compared to 2012 and 2013 (Figure 27). During July, minimum and mean temperatures were higher in 2013, while maximum temperatures were slightly higher in 2011. During August, minimum and mean temperatures were all higher in 2011, with minimum between 6 and 7 degrees lower in 2013 than 2012 and 2011 respectively. Maximum temperatures were relatively the same during all three years in August.



	June 2011	June 2012	June 2013	July 2011	July 2012	July 2013	August 2011	August 2012	August 2013
Minimum Temp	5.4	14.4	16.2	14.1	17.1	17.9	21.0	19.8	13.7
Mean Temp	26.8	29.8	32.9	29.3	28.4	29.6	30.3	28.9	28.3
Maximum Temp	49.6	40.8	45.7	42.9	40.6	42.4	42.5	42.8	41.9

Figure 27. Mean maximum mean and minimum mean relative humidity for June, July and August along the upper Salt River Watershed at Ead's Wash monitoring site during 2011, 2012 and 2013 tamarisk leaf beetle surveys.

Minimum relative humidity microclimate at Ead's Wash during June was almost 5 percent higher in 2012 and 2013 while the mean was 17 to 15 higher respectively than 2011 and same, the maximum was almost 26 percent higher in 2012 and 2013 (Figures 28). During July, minimum and mean relative humidity were higher in 2013, while maximum were relatively the same for all three years. During August, minimum relative humidity was highest in 2011, while the mean humidity was almost 11-12 percent higher in 2013 and 2012 respectively. The maximum in August at Schoolhouse Wash were relatively the same for all three years (Figure 28).



	June			July			August		
	2011	2012	2013	2011	2012	2013	2011	2012	2013
Minimum RH	5.3	10.0	10.0	6.5	14.3	19.9	21.0	14.8	15.4
Mean RH	15.0	32.5	30.4	46.1	56.1	56.4	46.2	57.0	55.9
Maximum RH	44.8	70.6	69.4	96.6	97.8	97.0	95.5	98.3	96.5

Figure 28. Mean maximum mean and minimum mean relative humidity for June, July and August along the upper Salt River Watershed at Ead's Wash monitoring site during 2011, 2012 and 2013 tamarisk leaf beetle surveys.

Microclimate minimum and mean temperatures at HZ Wash during June were much lower in 2011, while maximum temperatures were higher in 2011 (Figure 29). During July, minimum, mean and maximum temperatures were higher in 2013, while in August, minimum temperatures were higher in 2011, mean and maximum temperatures were higher in 2012.

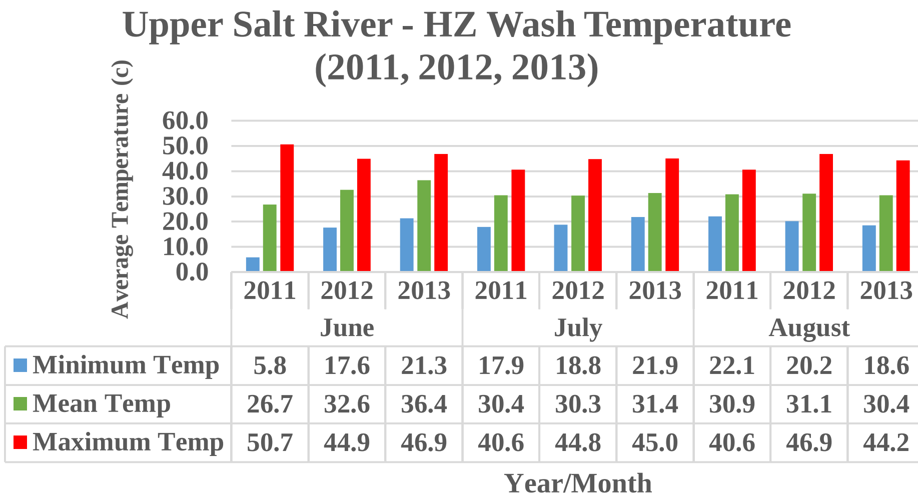


Figure 29. Mean maximum mean and minimum mean temperature for June, July and August along the upper Salt River Watershed at HZ Wash monitoring site during 2011, 2012 and 2013 tamarisk leaf beetle surveys.

Minimum relative humidity microclimate at HZ Wash during June was higher in 2013 while the mean was higher in 2012 and 2013 respectively, the maximum was almost 20 percent higher in 2012 than 2011 and 2013 (Figures 30). During July, minimum relative humidity were higher in 2013, while mean was higher in 2012 and the maximum were 6 percent lower in 2013. During August, minimum relative humidity was highest in 2011, while the mean humidity was relatively the same. The maximum in August at Ead's Wash were relatively the same for all three years, with the exception of 2012 which was higher 10 percent higher than 2013 and 7 percent higher that 2012 (Figure 30).

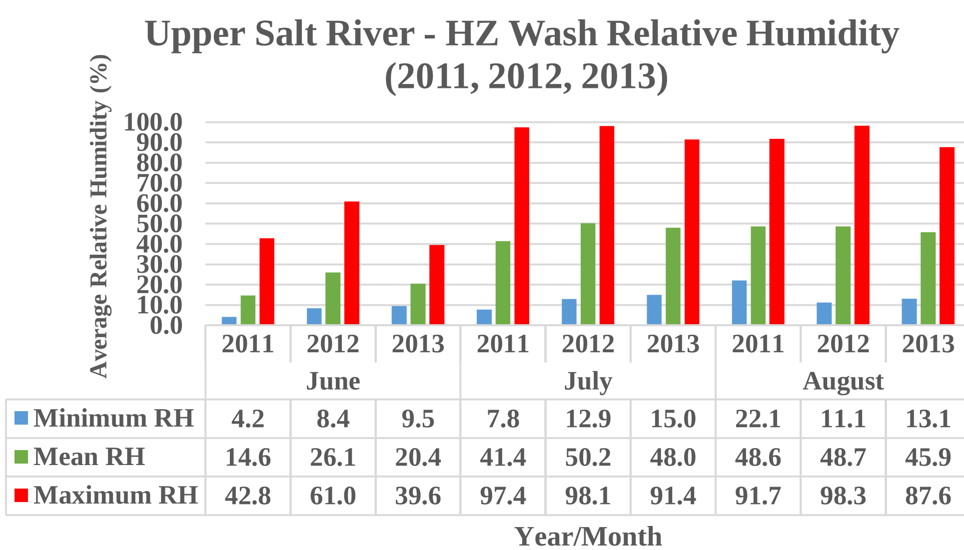


Figure 30. Mean maximum mean and minimum mean relative humidity for June, July and August along the upper Salt River Watershed at HZ Wash monitoring site during 2011, 2012 and 2013 tamarisk leaf beetle surveys.

Microclimate measurements at Rafters takeout were only observed in 2012 and 2013. During June, minimum and mean temperatures at Rafters takeout were higher in 2012, with minimum temperatures almost 6 degrees higher, while maximum temperatures were almost 6 degrees higher in 2013 (Figure 31). During July, minimum and maximum were higher in 2013, while mean temperatures were higher in 2012. During August, minimum, mean and maximum temperatures were all slightly higher in 2012.

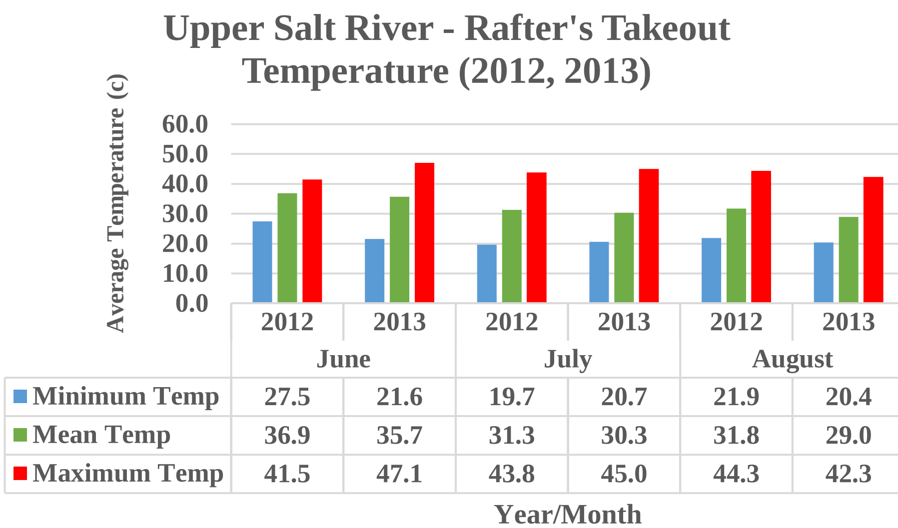


Figure 31. Mean maximum mean and minimum mean temperature for June, July and August along the upper Salt River Watershed at Rafter's Takeout monitoring site during 2012 and 2013 tamarisk leaf beetle surveys.

Minimum relative humidity microclimate during June at Rafters Takeout was the same for both 2012 and 2013, while the mean and maximum were higher in 2013. (Figures 32). During July, minimum and mean relative humidity were higher in 2013, while maximum were relatively the same for both years. During August, minimum and mean relative humidity was highest in 2013, while the maximum relative humidity was 5 percent higher in 2012.

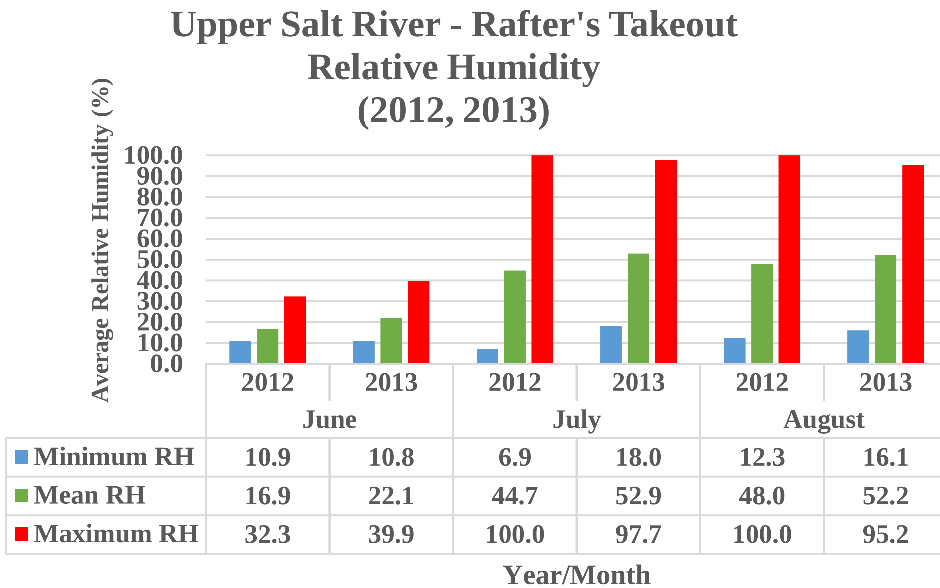
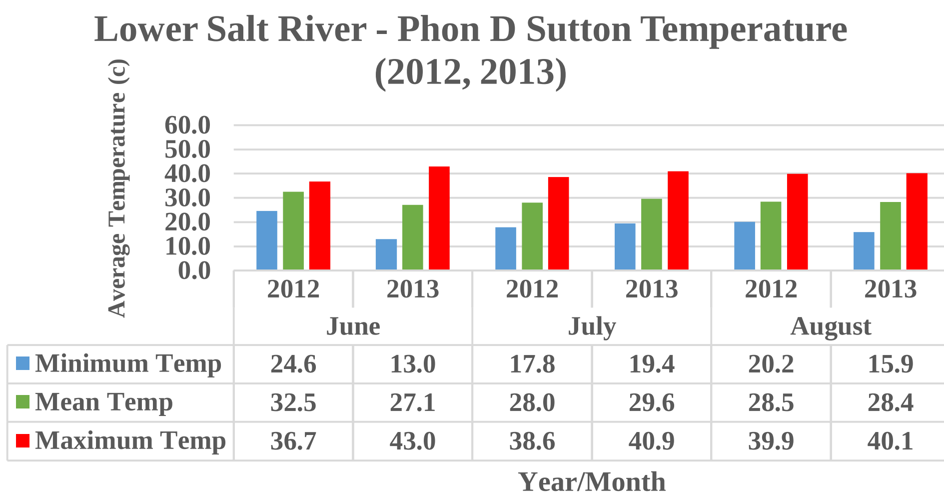


Figure 32. Mean maximum mean and minimum mean relative humidity for June, July and August along the upper Salt River Watershed at Rafter's Takeout monitoring site during 2012 and 2013 tamarisk leaf beetle surveys.

Lower Salt River Watershed Microclimate Temperature and Relative Humidity

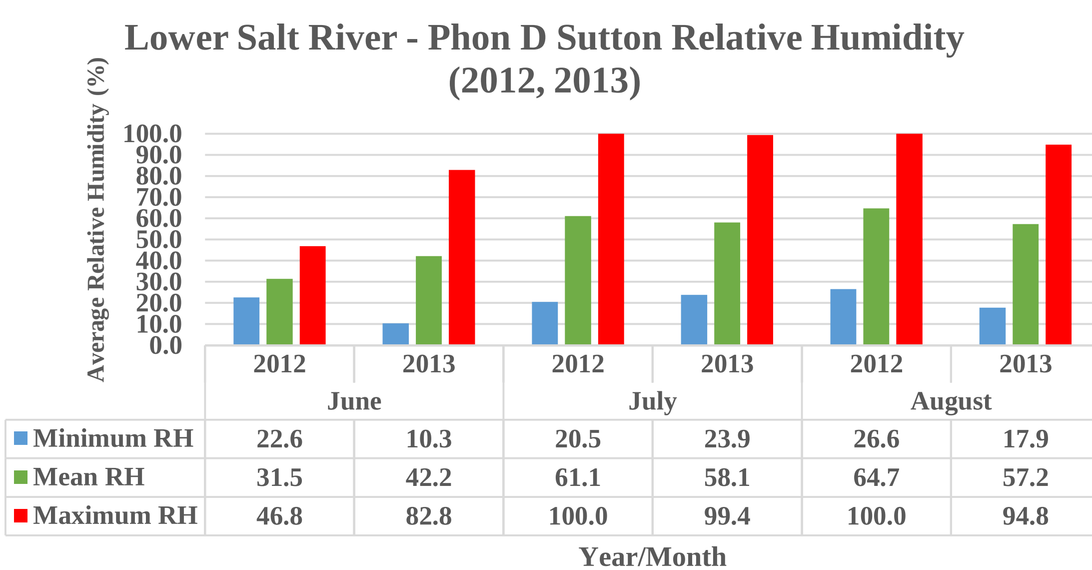
The Salt River watershed microclimate results included Phon D. Sutton and Water User's sites. Microclimate data for the lower Salt River sites were only observed in 2012 and 2013. Microclimate patterns at Phon D. Sutton during June revealed higher minimum and mean temperatures in 2012 with minimum temperatures 11 degrees higher in June, and higher maximum temperatures nearly 6 degrees higher during 2013 (Figure 33). During July, minimum mean and maximum temperatures were higher in 2013 than 2012. During August, minimum temperatures were all higher in 2012 and mean maximum temperatures were relatively the same during all both years in August.



	June 2012	June 2013	July 2012	July 2013	August 2012	August 2013
Minimum Temp	24.6	13.0	17.8	19.4	20.2	15.9
Mean Temp	32.5	27.1	28.0	29.6	28.5	28.4
Maximum Temp	36.7	43.0	38.6	40.9	39.9	40.1

Figure 33. Mean maximum mean and minimum mean temperature for June, July and August along the lower Salt River Watershed at Phon D Sutton monitoring site during 2012 and 2013 tamarisk leaf beetle surveys.

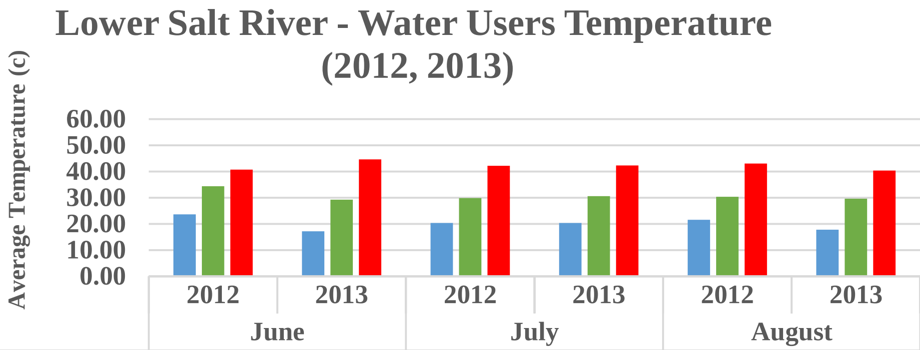
Minimum relative humidity microclimate at Phon D Sutton during June were 12 percent higher in 2012 while the mean and maximum were higher in 2013, with the mean nearly 11 percent higher and maximum 36 percent higher in 2013 (Figures 34). During July, minimum relative humidity were higher in 2013, while the mean was higher in 2012 and the maximum were relatively the same for all both years. During August, minimum, mean and maximum relative humidity were all higher in 2012.



	June 2012	June 2013	July 2012	July 2013	August 2012	August 2013
Minimum RH	22.6	10.3	20.5	23.9	26.6	17.9
Mean RH	31.5	42.2	61.1	58.1	64.7	57.2
Maximum RH	46.8	82.8	100.0	99.4	100.0	94.8

Figure 34. Mean maximum mean and minimum mean relative humidity for June, July and August along the lower Salt River Watershed at Phon D Sutton monitoring site during 2012 and 2013 tamarisk leaf beetle surveys.

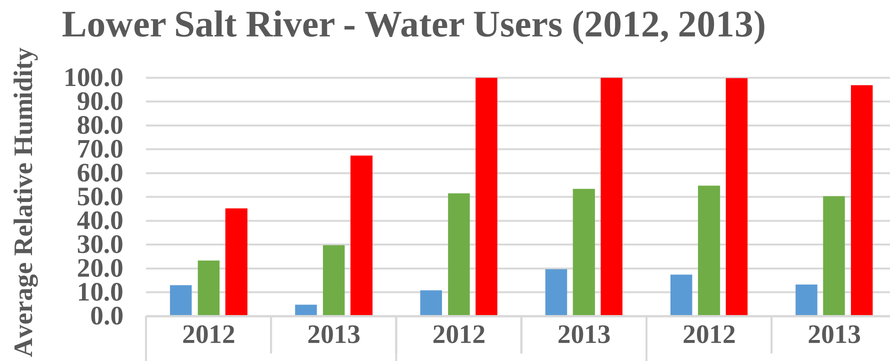
Microclimate patterns at the Water Users site during June revealed higher minimum and mean temperatures in 2012, with the minimum 6 degrees higher and the mean 5 degrees higher while the maximum were 4 degrees higher in 2013 (Figure 35). During July, minimum mean and maximum temperatures were all slightly higher in 2013 than 2012. During August, minimum mean and maximum temperatures were all higher in 2012.



	June 2012	June 2013	July 2012	July 2013	August 2012	August 2013
Minimum Temp	23.64	17.13	20.32	20.37	21.53	17.75
Mean Temp	34.4	29.3	29.8	30.6	30.3	29.6
Maximum Temp	40.7	44.6	42.1	42.3	43.0	40.4

Figure 35. Mean maximum mean and minimum mean temperature for June, July and August along the lower Salt River Watershed at Water Users monitoring site during 2012 and 2013 tamarisk leaf beetle surveys.

Minimum relative humidity microclimate at Water Users was 8 percent higher during June 2012, while mean percent relative humidity was 6 percent higher in 2013 and maximum was 22 percent higher (Figures 36). During July, minimum and mean percent relative humidity were higher in 2013 while the maximum were the same for 2012 and 2013 at 100 percent. During August, minimum, mean and maximum relative humidity were higher in 2012 than 2013.



	2012	2013	2012	2013	2012	2013
	June		July		August	
Minimum RH	13.0	4.8	10.8	19.6	17.4	13.3
Mean RH	23.3	29.7	51.6	53.3	54.7	50.3
Maximum RH	45.2	67.3	100.0	100.0	99.9	96.9

Year/Month

Figure 36. Mean maximum mean and minimum mean relative humidity for June, July and August along the lower Salt River Watershed at Water Users monitoring site during 2012 and 2013 tamarisk leaf beetle surveys.

These microclimate temperatures and relative humidity percentages are baseline results and will be valuable data once the tamarisk leaf beetle arrives in this area and alters the habitat through tamarisk defoliation and mortality.

Vegetation Plots, 2011, 2012 and 2013 (Colorado River and Upper Salt and Lower Salt Rivers)

The vegetation results included Colorado River/Glen Canyon sites -6 and -12, upper Salt River sites Tamarisk Island, Schoolhouse Wash, Ead's Wash, HZ Wash and Rafters Takeout, lower Salt River sites included Phon D Sutton and Goldfield.

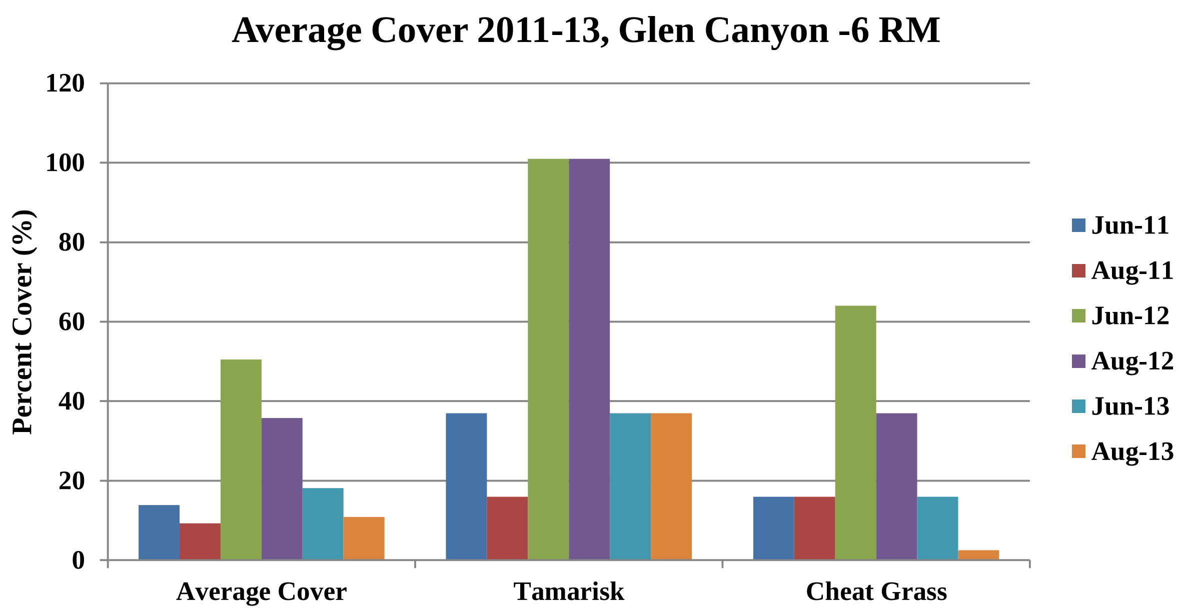
Vegetation Species Patterns (2011, 2012, and 2013)

Low average vegetation cover was associated with a low abundance of individual plants at any site (Figures 37-45). A few species at each site accounted for the greatest values observed for cover. For example, average cover for Tamarisk (*Tamarix spp.*) was greater than 20% for each site among the three years of study. For eight of the 10 sites tamarisk was the species with the greatest cover at the initiation of this project in June 2011 (Figures 37-45). A similar pattern was observed for subsequent years. Though the tamarisk beetle was present at the Glen Canyon Sites, cover values for tamarisk at these sites were within the range of cover values recorded for other sites (Figure 37-38).

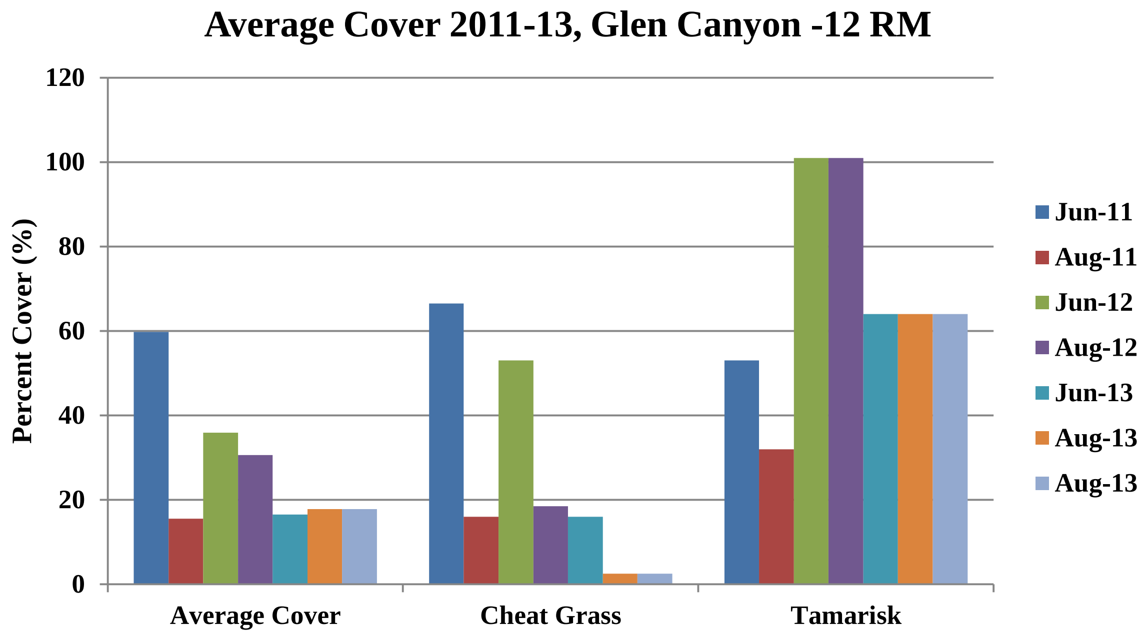
Multiple woody riparian species co-occurring at a site was rare among the sites. HZ Wash, Rafters Takeout and Phon D. Sutton were three sites where native and nonnative woody vegetation dominated the sample areas (Figures 42, 43, 44). At other sites, tamarisk and annual warm-season grasses such as cheat grass (*Bromus tectorum*) or red brome (*Bromus rubens*) were often co-dominant species (figures 37-41). Other species cover values ranged from 1-3%. These species were not included in the figures. The low average cover values is a reflection of the low species presence at sites where native woody species were present in higher numbers (e.g., HZ Wash, Phon D. Sutton; Figures 42 and 44), annual grass cover was either similar to or lower than that of the native woody species. The Tamarisk Island Site (Figure 39) had low native species number and high cover values of both tamarisk and cheat grass.

General Vegetation Cover (2011, 2012, 2013)

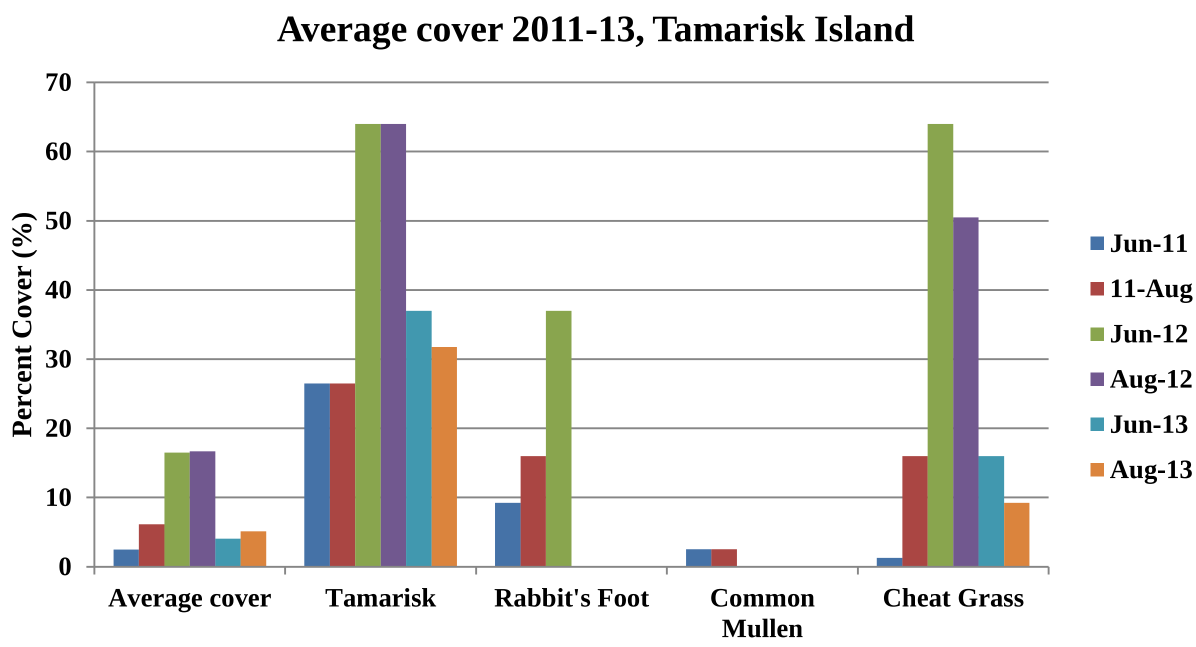
Average vegetation cover was low across most sites (<30%; Figures 37-45). The Phon D Sutton site (Figure 44) was an exception with average cover values exceeding 30% each year (June mean cover = 35%, 54%, 44%). The greatest average cover was recorded in 2012 for most sites, and particularly in the June sampling period. The Phon D. Sutton site exhibited the greatest variability in cover across years (Figure 44). Cover values between sampling times for a single year varied little for woody species, but showed greater declines for annual species, as would be expected.



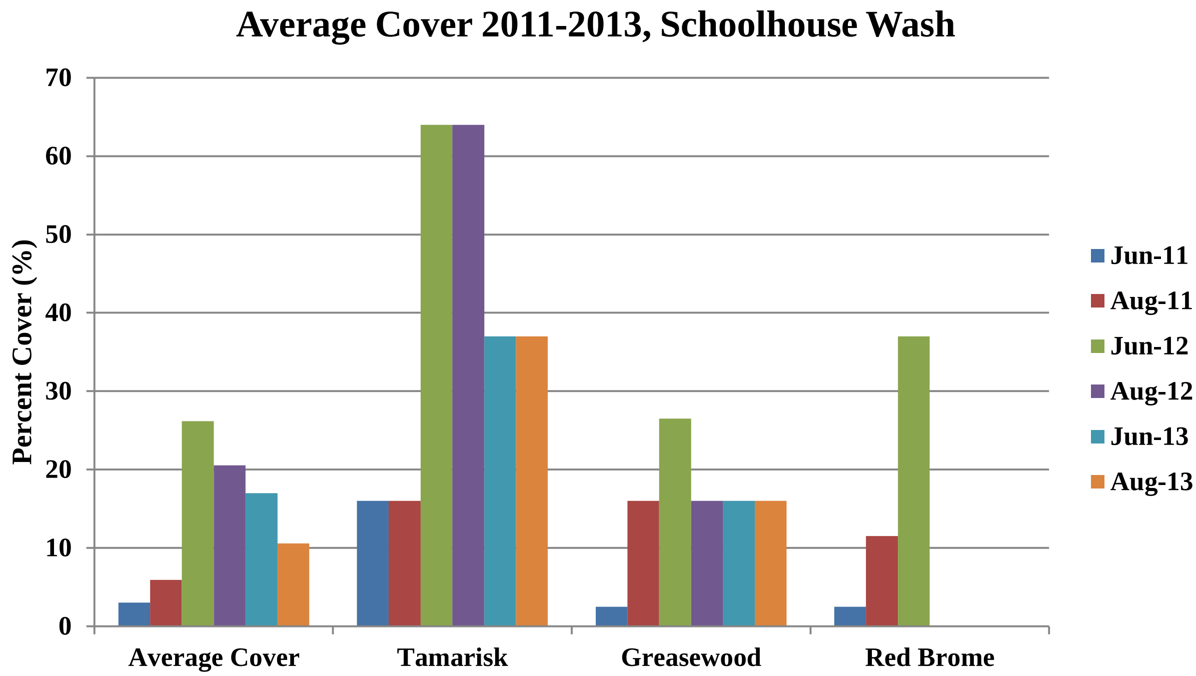
Figures 37. Percent cover of plant species found in 50 m^2 and 1m^2 plots in June and August, 2011, 2012 and 2013 along Colorado River in Glen Canyon at river mile -6 during 2011, 2012 and 2013 tamarisk leaf beetle sampling and vegetation surveys.



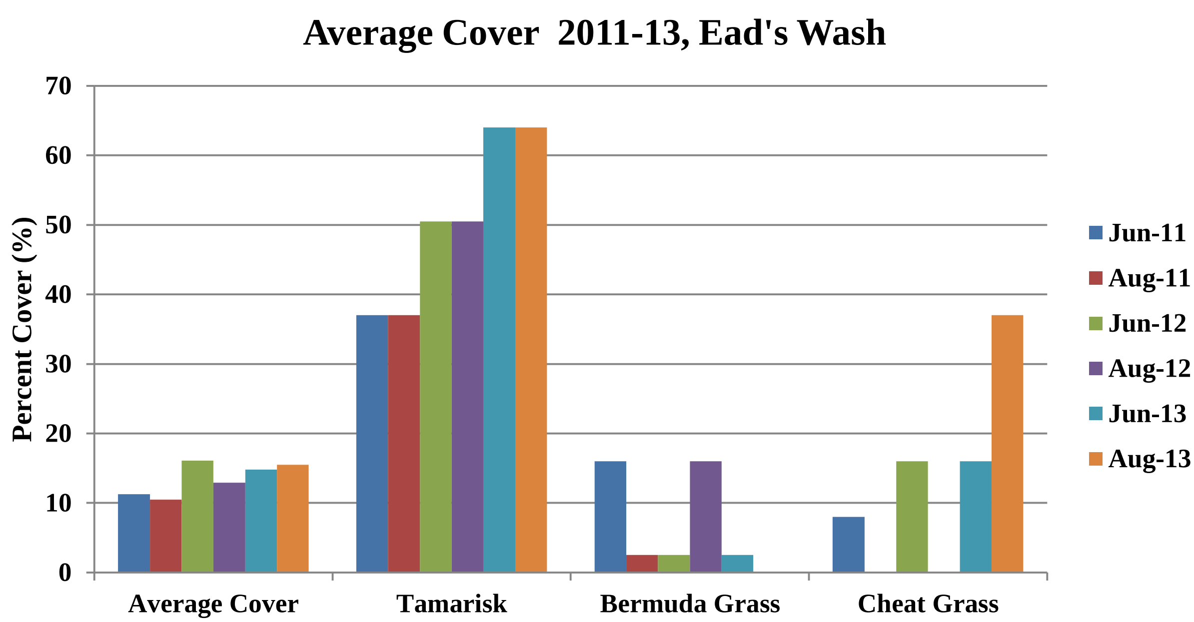
Figures 38. Percent cover of plant species found in 50 m^2 and $1m^2$ plots in June and August, 2011, 2012 and 2013 along Colorado River in Glen Canyon at river mile -12 during 2011, 2012 and 2013 tamarisk leaf beetle sampling and vegetation surveys.



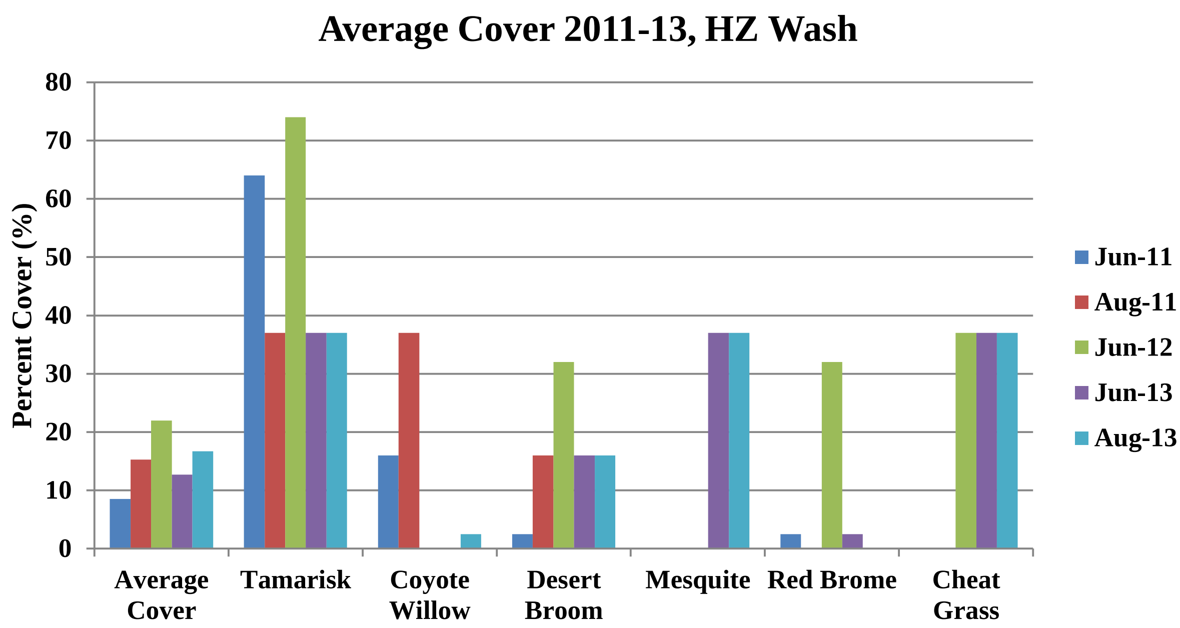
Figures 39. Percent cover of plant species found in 50 m^2 and $1m^2$ plots in June and August, 2011, 2012 and 2013 along Tonto Creek at Tamarisk Island during 2011, 2012 and 2013 tamarisk leaf beetle sampling and vegetation surveys.



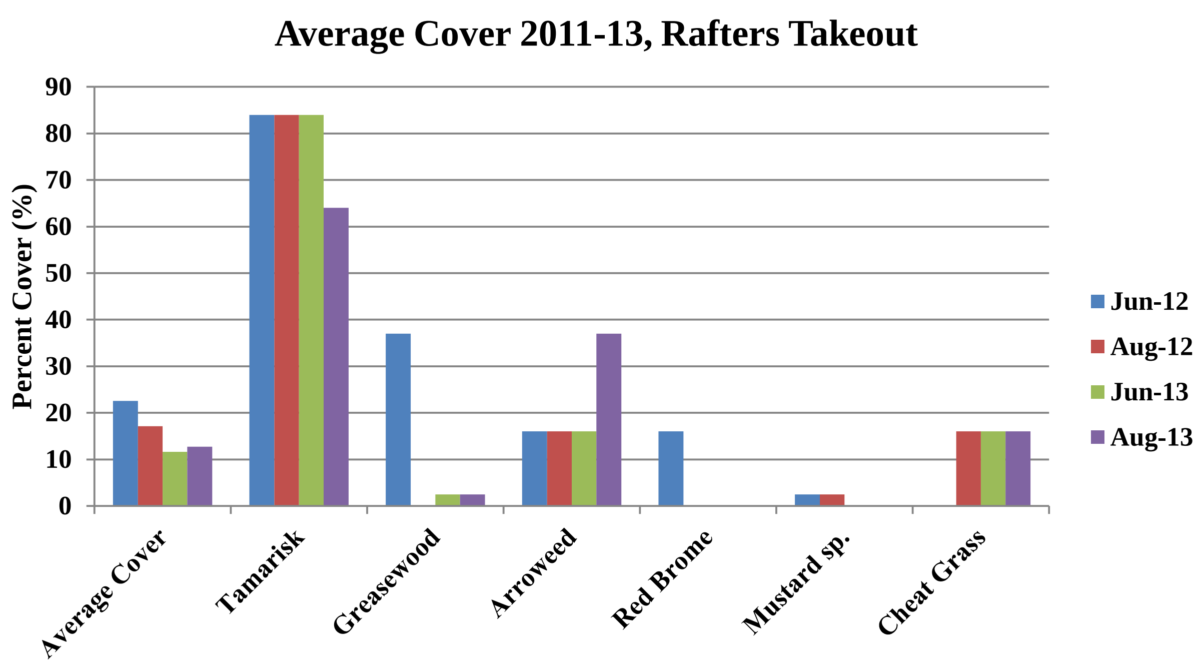
Figures 40. Percent cover of plant species found in 50 m^2 and 1m^2 plots in June and August, 2011, 2012 and 2013 along upper Salt River at Schoolhouse Wash during 2011, 2012 and 2013 tamarisk leaf beetle sampling and vegetation surveys.



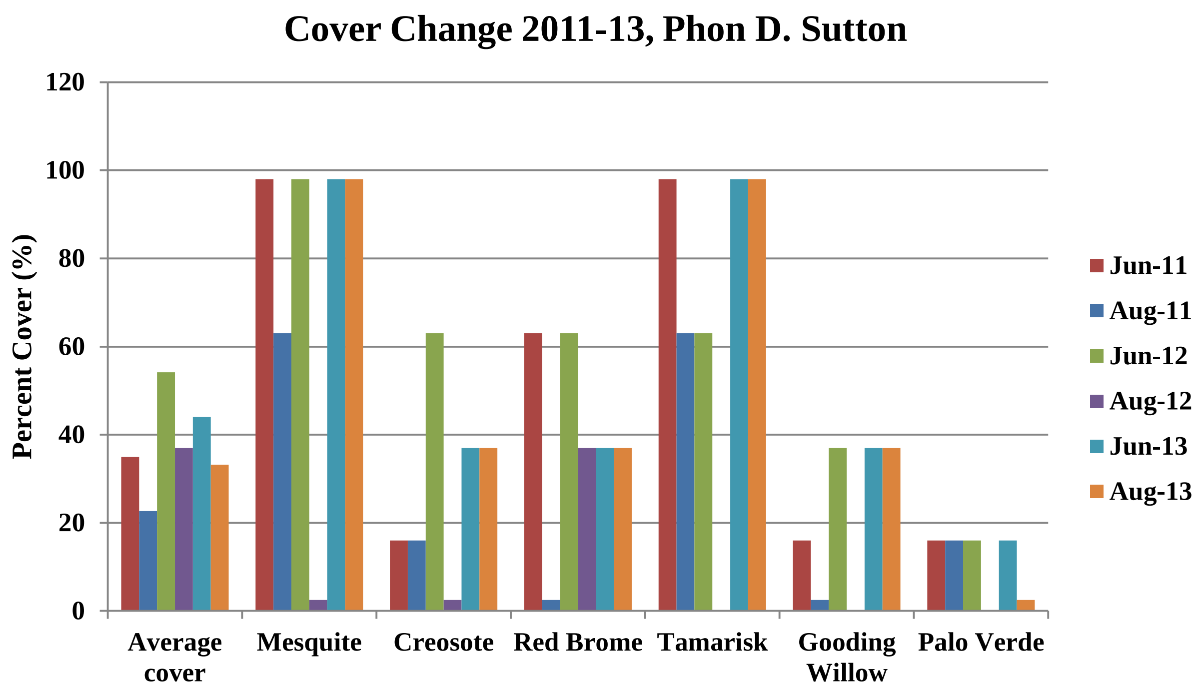
Figures 41. Percent cover of plant species found in 50 m^2 and 1m^2 plots in June and August, 2011, 2012 and 2013 along upper Salt River at Ead’s Wash during 2011, 2012 and 2013 tamarisk leaf beetle sampling and vegetation surveys.



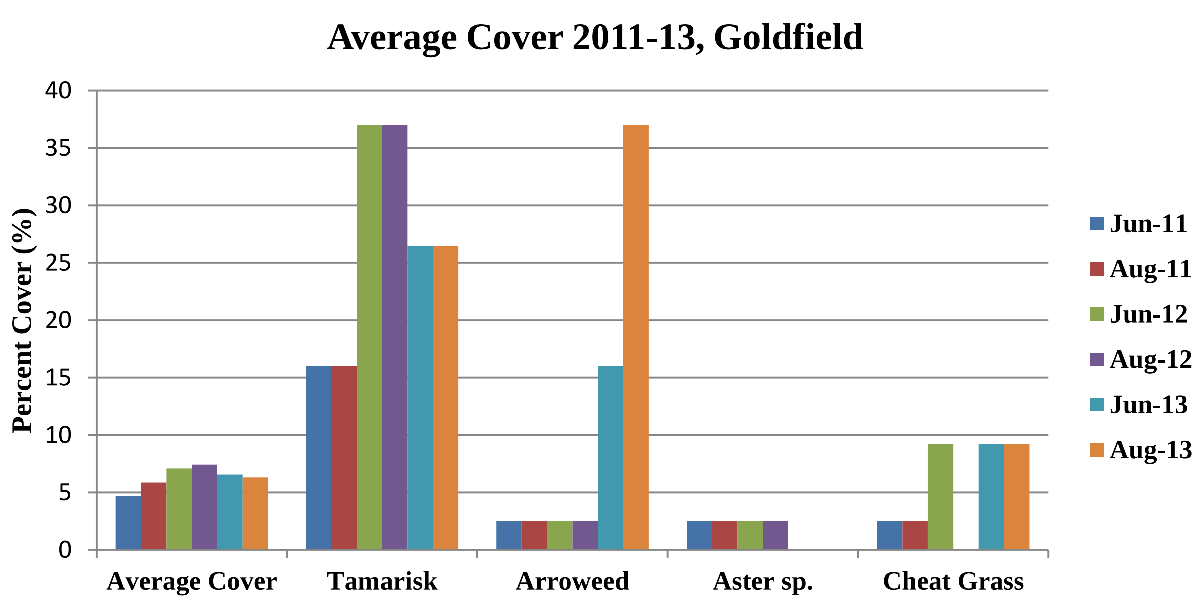
Figures 42. Percent cover of plant species found in 50 m^2 and $1m^2$ plots in June and August, 2011, 2012 and 2013 along upper Salt River at HZ Wash during 2011, 2012 and 2013 tamarisk leaf beetle sampling and vegetation surveys.



Figures 43. Percent cover of plant species found in 50 m^2 and $1m^2$ plots in June and August, 2011, 2012 and 2013 along upper Salt River at Rafters Takeout during 2011, 2012 and 2013 tamarisk leaf beetle sampling and vegetation surveys.



Figures 44. Percent cover of plant species found in 50 m^2 and 1m^2 plots in June and August, 2011, 2012 and 2013 along lower Salt River at the Phon D. Sutton site during 2011, 2012 and 2013 tamarisk leaf beetle sampling and vegetation surveys.



Figures 45. Percent cover of plant species found in 50 m^2 and 1m^2 plots in June and August, 2011, 2012 and 2013 along lower Salt River at the Goldfield site during 2011, 2012 and 2013 tamarisk leaf beetle sampling and vegetation surveys.

Sampling/Monitoring Summary, 2011, 2012 and 2013

This summary discusses that sampling/monitoring strategy and how we implemented it during our 2011, 2012 and 2013 field seasons and what worked each year and what we suggest to do differently in the future.

Site Selection

Our evaluation of the areas we sampled for tamarisk leaf beetles was selected on the basis that a 25 m area of continuous tamarisk habitat as minimum area would have to exist in order for the site be part of our sampling regime. The 25 m area is based on the tamarisk leaf beetle sampling method that is required to conduct 5 sweeps on 5 random tamarisk trees 5 m apart.

In 2011, 2012 and 2013, we sampled tamarisk leaf beetles, vegetation and microclimate along the Colorado River between Lee's Ferry - Glen Canyon Dam. This sampling area complied according to our sampling strategy. During each year we sampled for tamarisk leaf beetles at 14 sites (approximately 1 site per mile) and vegetation/microclimate at two of the 14 sites (Table 1, Appendix 2). The Colorado River area was the only area we found tamarisk leaf beetles and determined that the number of sampling plots for each variable was an adequate sample size for this area.

In 2011, 2012 and 2013 we sampled for tamarisk leaf beetles within the Verde River Watershed in proximity of Horseshoe Reservoir, which also complied according to our sampling strategy (Table 2, Appendix 2). During 2012 and 2013, we sampling vegetation at 2 sites. We did not collect information on microclimate in 2011 but collected this data in 2012 and 2013.

In 2011, 2012 and 2013 we sampled for tamarisk leaf beetles, vegetation and microclimate within the Tonto River watershed at Tamarisk Island, which was part of the upper Salt River Watershed, which complied according to our sampling strategy. During each year, we sampled for tamarisk leaf beetles at eight sampling sites and vegetation and microclimate at three of those sites (Table 3, Appendix 2). We did not detect tamarisk leaf beetles within the Tonto River Watershed, but we feel that the number of plots sampled for each variable was an adequate sample size for this area.

In 2011, 2012 and 2013, we sampled for tamarisk leaf beetles, vegetation and microclimate within the upper and lower Salt River Watershed, complying according to our sampling strategy. We sampled for tamarisk leaf beetles at 11 sites. We sampled vegetation and microclimate at three of the four sites along the upper Salt River (Table 4, Appendix 2). Along the lower Salt River, we sampled for tamarisk leaf beetles at 13 sites and vegetation and microclimate at two of those sites (Table 5, Appendix 2). We did not detect tamarisk leaf beetles within the upper or lower Salt River Watershed, but we feel that the number of plots sampled for each variable was an adequate sample size for this drainage.

Tamarisk Leaf Beetle Sampling

In 2011, 2012 and 2013 we sampled for tamarisk leaf beetles using the survey method based on those established by the USDA and Tamarisk Coalition. This method was adequate in detecting tamarisk leaf beetles where beetles were well established at our Colorado River Site. We also think that this method was adequate for sites where beetles are not established within the Verde, Tonto and Salt River Watersheds. In 2012 and 2013, we increased our sampling effort in sites where tamarisk leaf beetles were not established. Researchers working in areas entirely outside of the known area of beetle colonization have found that more intensive sampling at sites is more effective in detecting tamarisk leaf beetles at low density, low pheromone levels, and with no aggregation (T. Dudley, pers. comm.). This Intensive Survey Method consists of a minimum of 100 (average 300) "haphazard" sweeps made throughout a site. In addition to our regular protocol of sampling for tamarisk leaf beetles, we employed this Intensive Survey Method at all sites.

Plant Cover Surveys

In 2011, 2012 and 2013, we sampled vegetation cover at two sites within each area of the Colorado River, five sites along the upper Salt River including one site at Tonto Creek and two sites along the lower Salt River. The only area not sampled in 2011 was the Verde River Watershed sites which not sampled in 2012 or 2013 because of the current ongoing restoration occurring in this drainage.

According to our analysis, the number of areas sampled, the methods (cover classes and overstory) and sampling periods (June and August) we employed for vegetation cover was sufficient to examine what vegetation cover currently exists during early growing season growth (reflecting winter precipitation) and late growing season growth (reflecting monsoon precipitation). The vegetation cover of sites affected by the mortality of tamarisk could be replaced by other exotics or native vegetation dependent upon active restoration of these sites.

Microclimate

In 2011, 2012 and 2013, our analysis of microclimate also reflected that measuring temperature and relative humidity every 30 minutes for 150 days and the number of data loggers deployed (2-3 at each area) were sufficient to examine the microclimate of a site where tamarisk leaf beetle exist and where they don't presently exist. The microclimate of these sites could change dramatically due to defoliation by the beetle. This could open up canopy cover, affecting wildlife (i.e. nesting birds) and drying out understory vegetation cover. The microclimate could greatly be affected if tamarisk trees die off due to repeated defoliation within these areas. Replacement of tamarisk in these areas again will be dependent upon active restoration of these sites.

Data Entry, Verification, Validation and Metadata

In 2011, 2012 and 2013, data entry, verification and validation were performed by the project manager and field crew. The overall goal was to check 10% of the records. We would then correct and track any errors and enforce a threshold for an acceptable error rate. We found that the error rate for records we checked was less than 3% and felt that this was well below our 10% error rate and therefore did not need to review all records with the 2012 dataset.

Crew and Staff

The field crew hired for this project completed all the required objectives of this project and was very enthusiastic about the project. We were very pleased with the quality of work the crew performed for all three years of this project.

Quality Assurance/quality Control (Tamarisk Leaf Beetle and Plant Cover Sampling)

In 2011, 2012 and 2013 we held extensive field crew training on both identification of tamarisk leaf beetles and plants. The training of the crew lasted a week and was well received by the field crew. Any questions on identification of beetles and all other insects were brought back to the lab and identified by experts at Northern Arizona University and Dr. Thomas Dudley with University of California at Santa Barbara. Tom is an entomologist and has done extensive research on the tamarisk leaf beetle. Any questions on plants were directed toward Barbara Ralston.

Final Report Summary

In 2011 2012 and 2013, three tamarisk leaf beetle sampling trips were conducted to survey for tamarisk leaf beetle. Sampling results indicate that the beetle is present along the Colorado River from Lee’s Ferry to Glen Canyon Dam, but absent from the sites along Tonto Creek, Verde River, Upper Salt River and Lower Salt River. As noted in 2011, the north rim drainages of Grand Canyon may be a source for these beetle population expansions along the Colorado River sites, particularly the Paria Canyon drainage. The Little Colorado River within the Navajo Reservation, which includes; northern tamarisk leaf beetle (*Diorhabda carinulata*) and the Rio Grande River in Texas and New Mexico which includes; Mediterranean tamarisk leaf beetle (*Diorhabda elongata*), larger tamarisk leaf beetle (*Diorhabda carniata*) and subtropical tamarisk leaf beetle (*Diorhabda sublineata*) may all be the sources of this population expansion into the central and southern Arizona sites. Tamarisk leaf beetle expansion into central and southern Arizona (Verde River, Tonto Creek, upper and lower Salt River), where this study was conducted, is expected for 2017 (Tracy et al. 2014). The reduction in tamarisk cover in riparian areas, by beetle defoliation will pave the way for changes in plant community composition and structure, with consequent effects on wildlife populations and ecosystem processes (such as wildfire, hydrological dynamics, and sediment dynamics).

Avifauna Response and Implications to Tamarisk Leaf Beetle

Extensive defoliation of tamarisk caused by tamarisk leaf beetles and the resulting widespread loss of riparian vegetation may have a considerable impact on birds that breed in riparian regions dominated by tamarisk. In St. George, UT, Southwestern Willow Flycatchers demonstrated lowered site fidelity the year after tamarisk defoliation from the tamarisk leaf beetle negatively impacted flycatcher nesting success (Dobbs et al. 2012, Johnson and Nowak 2014). Along the

Virgin River at Mesquite, both reduced site fidelity and lower numbers of resident flycatchers were recorded in response to reduced nest success and habitat quality as the result of poor habitat conditions due to the beetle (McLeod and Pellegrini 2013). A similar pattern of reduced site fidelity and lower numbers of breeding flycatchers at Mormon Mesa, Nevada in 2013 was also observed in response to the poor reproductive success and lower habitat quality due to the beetle documented in both 2012 and 2013 (McLeod and Pellegrini 2013).

Due to the habitat changes from the tamarisk leaf beetle many bird species may attempt breeding, possibly in reduced quality habitat; or they could spend the breeding season as non-breeding residents, ultimately affecting overall populations.

Herpetofauna Response and Implications to Tamarisk Leaf Beetle

Many herpetofauna species may decline in tamarisk that are defoliated region-wide as a result of localized changes in microclimate, (i.e. increased maximum active-season temperatures and decreased relative humidity in defoliated stands; Bateman et al. 2013, 2014). The near-term trophic effects on lizard communities in response to defoliation may be mixed, including both positive (expanded diet) and negative (decreased abundance and/or activity) outcomes. Longer-term, removal of tamarisk may provide opportunities for native re-vegetation (Shafroth et al. 2005, Bateman et al. 2008), so the changes in lizard communities seen as a result of defoliation in areas such as Virgin River drainage may be temporary. If native or non-native forbs, shrubs, and trees recolonize defoliated areas, we would expect corresponding increases in relative humidity and decrease maximum temperatures, potentially increasing habitat suitability for lizards that had previously declined.

Microclimate and Tamarisk Leaf Beetle Effects on Avifauna and Herpetofauna

In the future, vegetation density and canopy cover may be more important to avian communities in southwestern riparian forests (Paxton et al. 2011). In the low-elevation deserts where tamarisk now dominates, vegetation cover it likely plays an important role in ameliorating the microclimate at the nest of many species (e.g., Tieleman et al. 2008). Currently, many areas in the southwest reach or exceed ambient air temperatures lethal to eggs (43–44 °C; Webb 1987), and high summer daytime temperatures and aridity can quickly stress birds' ability to dissipate heat and balance their water demands (Wolf and Walsberg 1996), which will ultimately worsen as tamarisk defoliation and tamarisk mortality continue due to the persistence and spread of the tamarisk leaf beetle.

Decreases in herpetofauna activity and species richness could also be a response by herpetofauna to changes in microclimate in defoliated stands as a result of the tamarisk leaf beetle (Bateman et al. 2014). Temperature influences development and survival of embryos (Shine and Harlow 1996; Angilletta et al. 2009) and daily activity patterns (Rouag et al. 2006). Changes in the thermal environment could result in lizards retreating to refuges to avoid overheating. Other research has found that in response to temperature increases, lizards reduce activity, which can result in less time dedicated to foraging, undermining metabolic maintenance, reproduction, and ultimately population growth (Sinervo et al. 2010).

Future Monitoring and Research

Continuing monitoring of the established tamarisk leaf beetle vegetation and microclimate plots on the Colorado River, Verde River, Tonto Creek, upper and lower Salt River would be highly recommended. Long term monitoring of these plots will provide valuable data at the Colorado River sites that have been impacted by the beetle and will likely see major changes to riparian habitat. These changes will likely be from repeated defoliation of the tamarisk trees and ultimately mortality. The Verde River, Tonto Creek and Salt River sites do not currently have tamarisk leaf beetles and therefore continued monitoring at these sites will provide valuable baseline data upon the arrival of the beetle.

Organisms inhabiting riparian woodlands of the southwest United States are species likely tolerant of habitat changes following decades of tamarisk establishment. Because long-term effects of tamarisk biocontrol (i.e. tamarisk leaf beetle) could depend on geographic extent and on how quickly various species of plants establish after defoliation (Shafroth et al. 2005; Sogge et al. 2008), we also suggest future monitoring the effects of tamarisk leaf beetles include sites in Arizona with greater proportions of native riparian trees and across the geographic range of tamarisk. As other vegetation establishes and increases, foliar cover may recover to pre-biocontrol conditions, therefore, long-term studies of flora (vegetation plots) and fauna (avian fauna and herpetofauna) following biocontrol establishment could provide a more complete view of indirect effects of tamarisk biocontrol.

Restoration through tamarisk biocontrol can represent an alternative to more costly management efforts, such as mechanical removal or herbicide use. But, the long-term trend for understanding how biocontrol affects ecosystem function (e.g., vegetation growth and structure) will be critical to managing habitats and wildlife impacted by biocontrol. The availability of native habitat and the degree to which wildlife use exotic habitats, such as those dominated by tamarisk, should be considered when managing using biocontrol (Paxton et al. 2011). And therefore we suggest incorporating restoration activities to increase native tree cover in areas likely to be affected by tamarisk biocontrol.

Acknowledgements

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Appendix 1. Data forms for tamarisk leaf beetle and vegetation sampling along the Colorado River (Lee's Ferry-Glen Canyon Dam), Lower Verde River, Tonto Creek and the Upper and Lower Salt River, 2012.

Table 1. 2012, Tamarisk Leaf Beetle Monitoring data from; Tamarisk Leaf Beetle Sampling Plan; Arizona Water Protection Fund Grant; Inventory of tamarisk beetle and monitoring effects on riparian bird habitat in the Colorado, Verde, Salt and Tonto Rivers.

Tamarisk Beetle Monitoring Data Form 2012

Check if same as previous site ☐ Check after in database ☐ **Date of Survey** ______________________________

Observer 1 ___________________ **Observer 2** ________________ **Park Area/Canyon** ______________________________

River Mile________**River Side?** R L **Revisit?** Y N **Trip #**____ **Hobo?** Y N

Point Name____**(Area + RM + RS + Survey #. Ex: GLCA15L1)**

UTM Easting ___ ___ ___ ___ ___ ___ **UTM Northing** ___ ___ ___ ___ ___ ___ ___ (in NAD83)

GPS Accuracy (m) ____________

Associated Tree Species ____

Associated Shrub Species ____

Associated Grass/ForbSpecies____

____

	Adult (#)	Early Larvae (#)	Late Larvae (#)	Ants (#)	Ladybugs (#)	Spiders (#)	Weevils (#)	Egg clusters (#)	Defoliation (%)	Branches (%)	Refol. (%)
Set 1											
Set 2								Picture Taken? (Number/Camera)			
Set 3											
Set 4											
Set 5											
Total											
Total # beetles											

Site Notes/Comments____

____

____

____

(Appendix 1 cont.)

Sampling Instructions:

- Conduct 5 sets of 5 sweeps, each roughly 5 meters apart per sampling location/GPS point: 25 sweeps total done per sampling location/ GPS point
- Conduct 1 m sweeps in upward movement through foliage
- Record contents of the net after every 5 sweeps (1 set). Count the number of adult beetles, the number of Early Larvae (1st and 2nd instars: small & black with no yellow stripe), and the number of Late Larvae (2nd & 3rd instars: larger body with a noticeable yellow stripe). Also record the number of spiders, ants, ladybugs and weevils in each set of sweeps.
- Record % Defoliation: Record the % of green leaves that turned brown due to defoliation this year. Avg. level at each sample location (roughly $0.25km^2$) recorded in 10% increments. In the fall, be sure not to confuse the yellow tinge on the tamarisk that is a result of Leaf Hopper damage with the browning from defoliation. Total brown leaves (defoliation) + Total green leaves = 100%.
- Record the % of Branches that are dead: Avg. the % of dead branches at sample location (i.e.: $0.25km^2$); record in 10% increments. The goal of this is to get a visual of the exposed branches that should be leafed out but are not due to continued defoliation. This number aims to get at tree mortality and what percentages of the branches are dying each year. Total leaves (green or brown) + Total Branches = 100%.
- Record Refoliation: % of the branches that show refoliation (fireworks puffs? After mid-June?)
- Record the number of egg clusters observed in a 30 second window. Scan the canopy for creamy pink/white clusters of eggs
- While on the river aim to sample every 1.5 km (1 mile) and conduct sweeps within 50 meters of landing point: 25 m upstream and downstream

Tamarisk Beetle Notes:

- Early larvae: 1st and 2nd Instars: small and black with no yellow stripe
- Late larvae: 2nd and 3rd Instars: larger body with noticeable yellow stripe
- Egg clusters: creamy pink/white

Data Notes:

Point Name: Area + RM + RS ex: GLCA-15-L

- **River Mile:** leave it blank in the field (don't guess) but fill it in once back in the office using the UTMS
- **Associated tree, shrub, grass and forb species**: Do not include tamarisk, we know it's there. Use capitalized 6 letter species codes: (first 3 letters of genus: first 3 letters of species) • Example: *Tamarisk ramosissima* = TAMRAM; *Diorhabda carinulata* = DIOCAR; • Use the cheat sheet or the plant book to make sure the codes are correct. • If you are unsure of the species, use a 5 letter code for the genus and include *spp*. at the end. If you are unsure of the genus, code it as a grass, forb or shrub with *spp.* at the end. • Example: Baccharis of unknown species= BACCHSPP or Grass of unknown genus= GRASSSPP .

(Appendix 1 cont.)

Table 2. 2012, Microclimate thermistor (HOBO) datasheet; Tamarisk Leaf Beetle Sampling Plan; Arizona Water Protection Fund Grant; Inventory of tamarisk beetle and monitoring effects on riparian bird habitat in the Colorado, Verde, Salt and Tonto Rivers.

Location/Site Name:____

Biologist(S)____

HOBO Serial Number:____________________

HOBO Point Name:______________________

UTM E:_______________________________

UTM N:_______________________________

Type of Point (circle one): Beetle Present / Beetle Not Present

Date Deployed:_________________________

Time Deployed:_________________________

Date Retrieved:_________________________

Time Retrieved:_________________________

Height HOBO is hung (m):_________________

Tree Species hung in:_____________________

GPS#____________

Directions to HOBO:____

____

____

____

____

____

Site Description/ General Comments:____

____

____

____

____

____

(Appendix 1 cont.)

Table 3. 2012, Tamarisk leaf beetle plant cover form; Tamarisk Leaf Beetle Sampling Plan; Arizona Water Protection Fund Grant; Inventory of tamarisk beetle and monitoring effects on riparian bird habitat in the Colorado, Verde, Salt and Tonto Rivers.

<table>
<tr><td colspan="2">Date</td><td colspan="3">Location and sample number</td><td colspan="2">UTM (N)</td><td colspan="2">UTM (E)</td></tr>
<tr><td colspan="2">Recorder</td><td colspan="4">Observer #1</td><td colspan="3">Observer #2</td></tr>
<tr><td colspan="2">Dominant Plant Species</td><td>#1</td><td colspan="2">#2</td><td colspan="2">#3</td><td colspan="2">#4</td></tr>
<tr><td colspan="4">Soil Substrate
silt sand gravel cobble</td><td colspan="5">Litter depth (range)</td></tr>
<tr><td colspan="9">Description: General site description (tree distribution (patchy, equally dispersed), all understory plot, 1/2 understory, 1/2 open)</td></tr>
<tr><td colspan="9">Other overstory plants. Near water? Near dry wash? Near road? Evidence of human activity/visitation adjacent?</td></tr>
</table>

(Appendix 1, Table 3 cont.)

Plot 1 (1m sq plot).		**Plot 2 (1m sq plot)**		**Plot 3 (1 m sq plot)**	
Species list	% Cover	**Species list**	% Cover	**Species list**	% Cover

(Appendix 1, Table 3 cont.)

Plot 4 (50 m sq plot)					
	T (<1%); 1 (1-5%); 2 (5-25%); 3 (25-50%); 4 (50-75%); 5 (75-90%); 6 (>90%)				
Species list	% Cover	**Species list**	% Cover	**Plants outside plot**	

(Appendix 1, Table 3 cont.)

Description of unknown plants					
Unknown # from plot #					
Unknown # from plot #					
Unknown # from plot #					
Unknown # from plot #					
Unknown # from plot #					
Unknown # from plot #					

(Appendix 1 cont.)

Table 4. 2012, Leaf area index datasheet (LAI); Tamarisk Leaf Beetle Sampling Plan; Arizona Water Protection Fund Grant; Inventory of tamarisk beetle and monitoring effects on riparian bird habitat in the Colorado, Verde, Salt and Tonto Rivers.

Site Name____

Biologist(s)____

Date_________________________

CONTROL LAI (Outside Habitat, No Cover) - 5 Readings total

Point Name	LAI

HABITAT LAI (Inside Habitat) - 10 Readings total

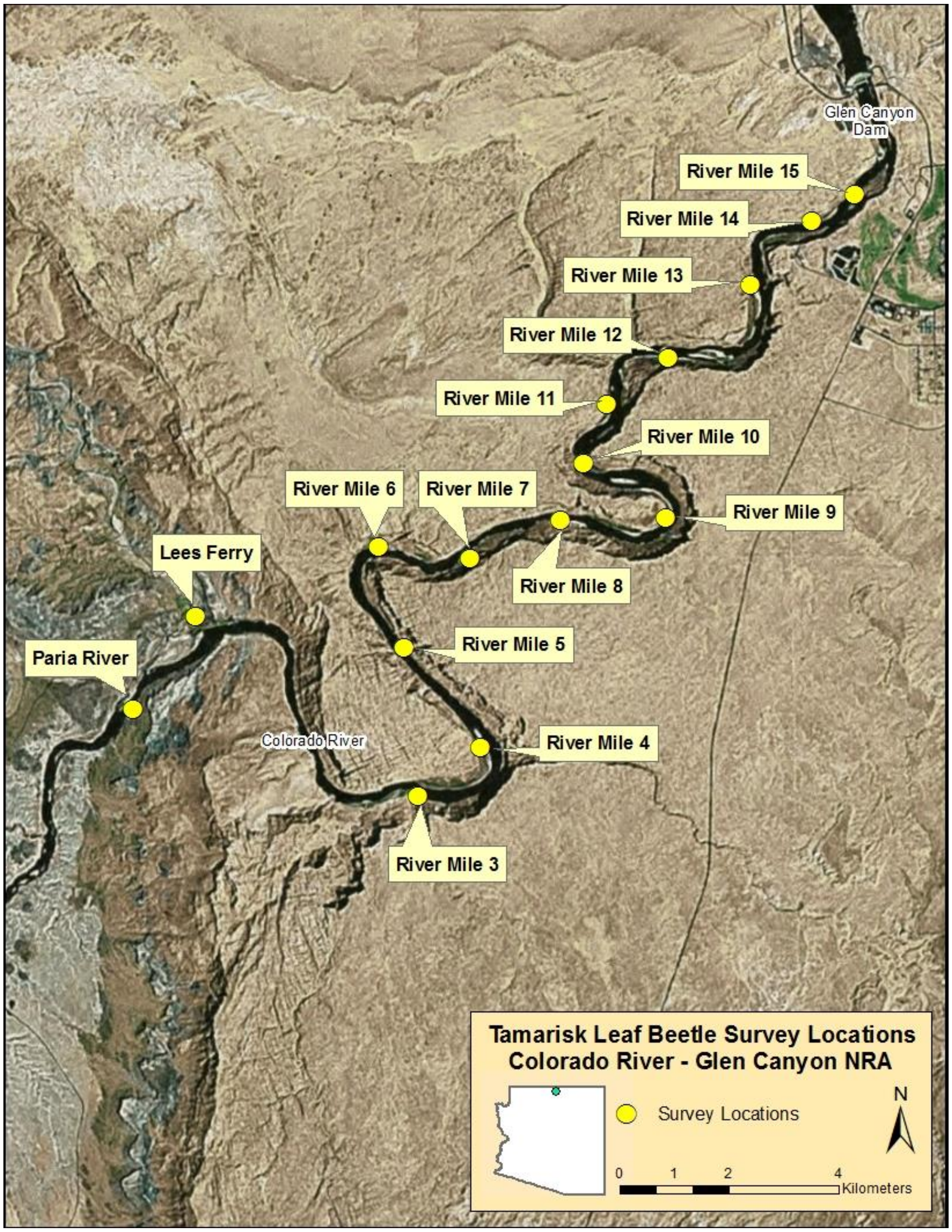
Point Name	LAI

Comments:

____
____
____
____
____
____
____

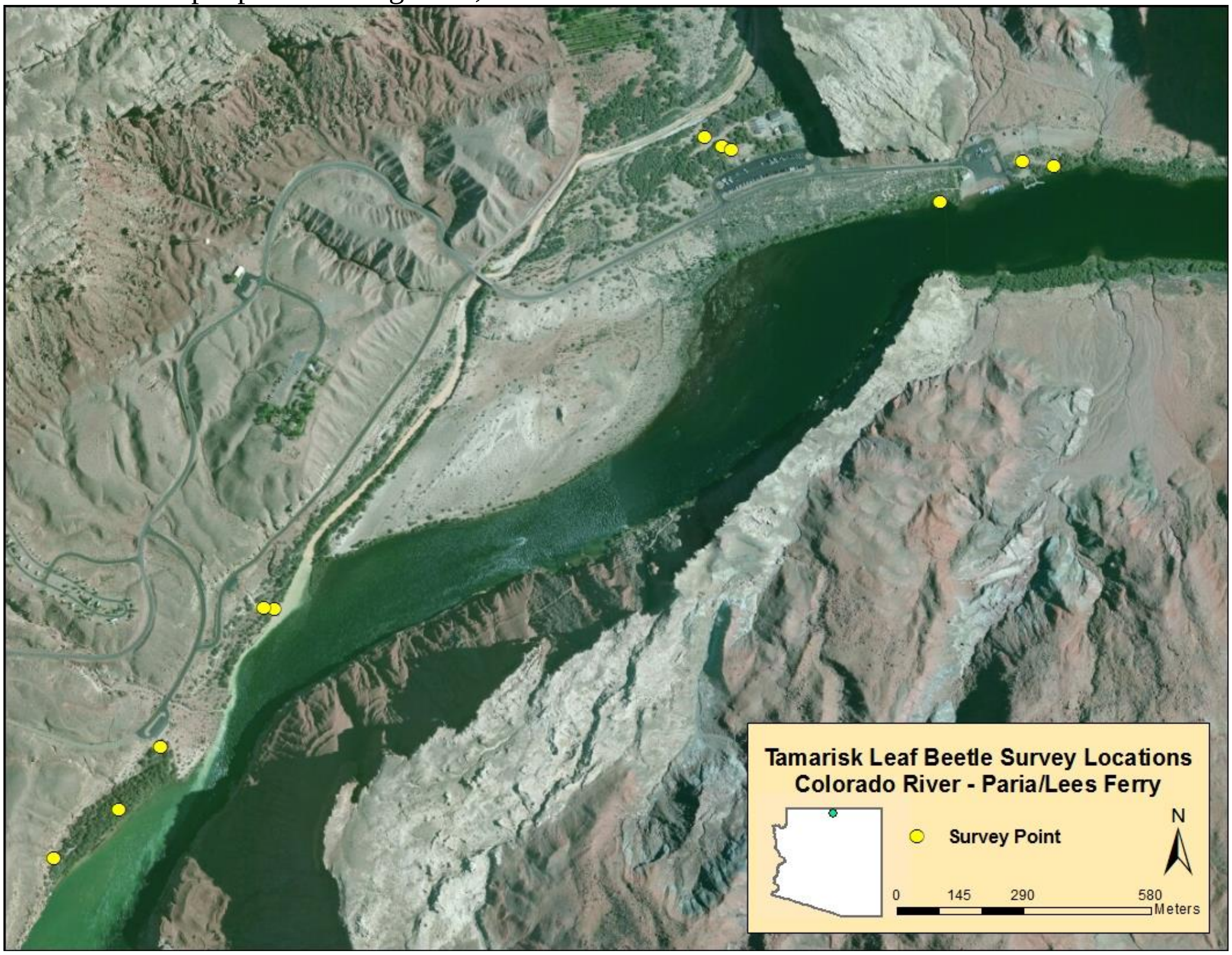
Appendix 2. The following maps are the locations where sampling tamarisk leaf beetles occurred along sections of the Colorado, Verde, Tonto, and Salt Rivers in 2011, 2012 and 2013.

The following map displays tamarisk leaf beetle sampling points within Glen Canyon Recreation Area from Lee's Ferry-Glen Canyon Dam, AZ. These sites start at Lee's Ferry (RM 0) and are located approximately every mile to mile -15. Points shown represent the specific area where sampling occurred at each sampling point. Additional plots (not shown) were also sampled throughout the sampling area where tamarisk was present.



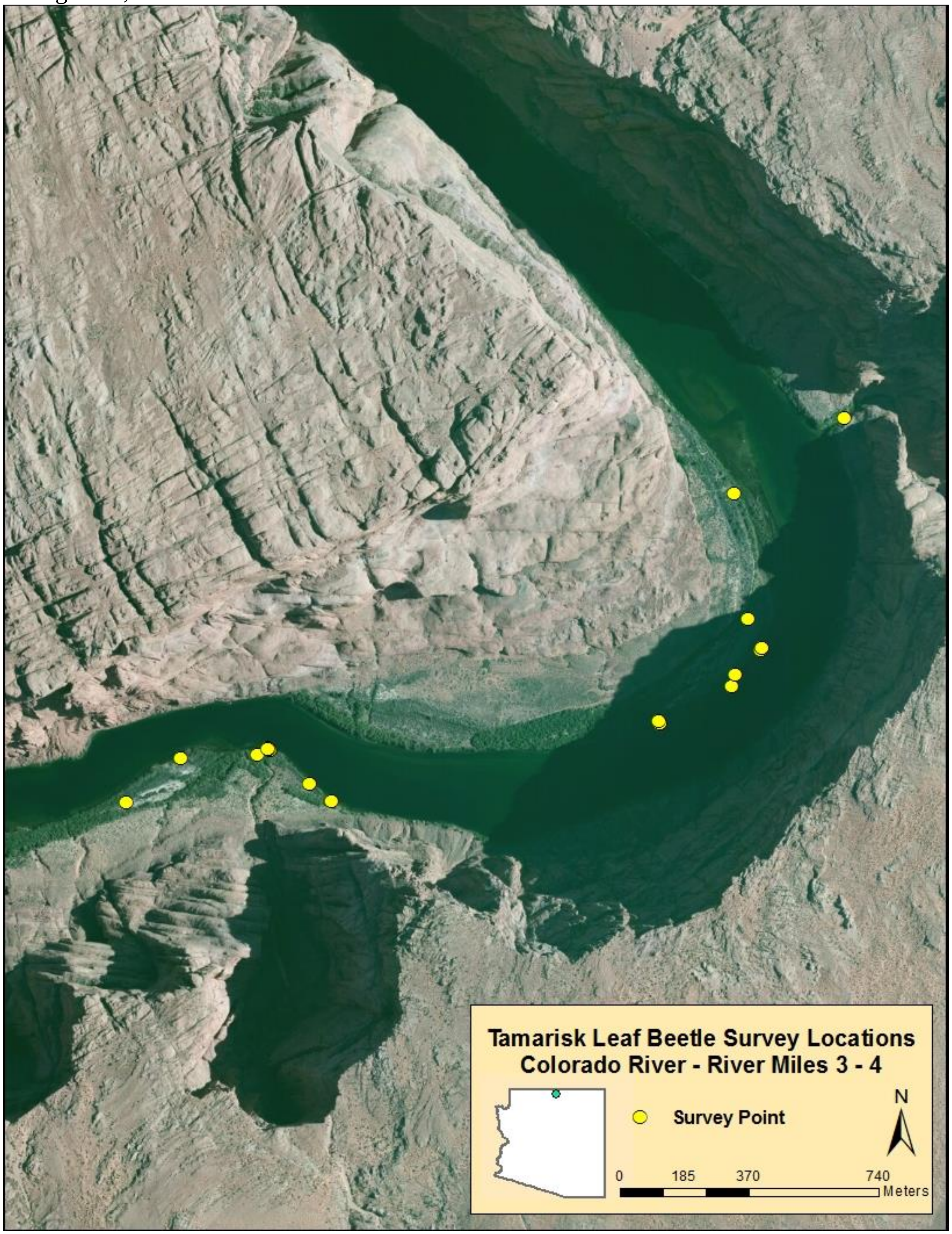
Appendix 2 cont.)

Colorado River (Lee's Ferry – Glen Canyon Dam; RM –Lee's Ferry - River Mile 0) tamarisk leaf beetle sample points during 2011, 2012 and 2013.



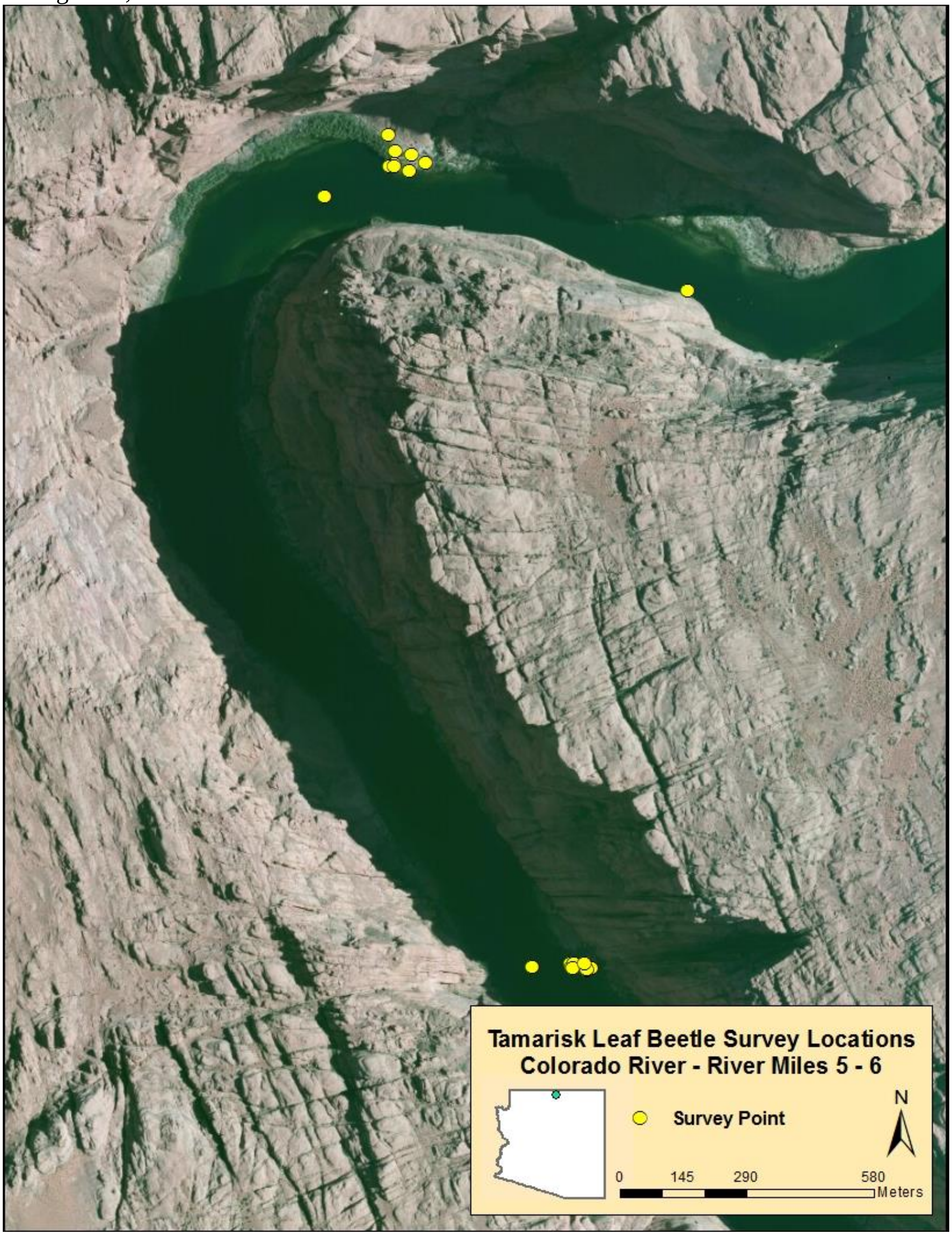
(Appendix 2 cont.)

Colorado River (Lee's Ferry – Glen Canyon Dam; RM -3_-4) tamarisk leaf beetle sample points during 2011, 2012 and 2013.



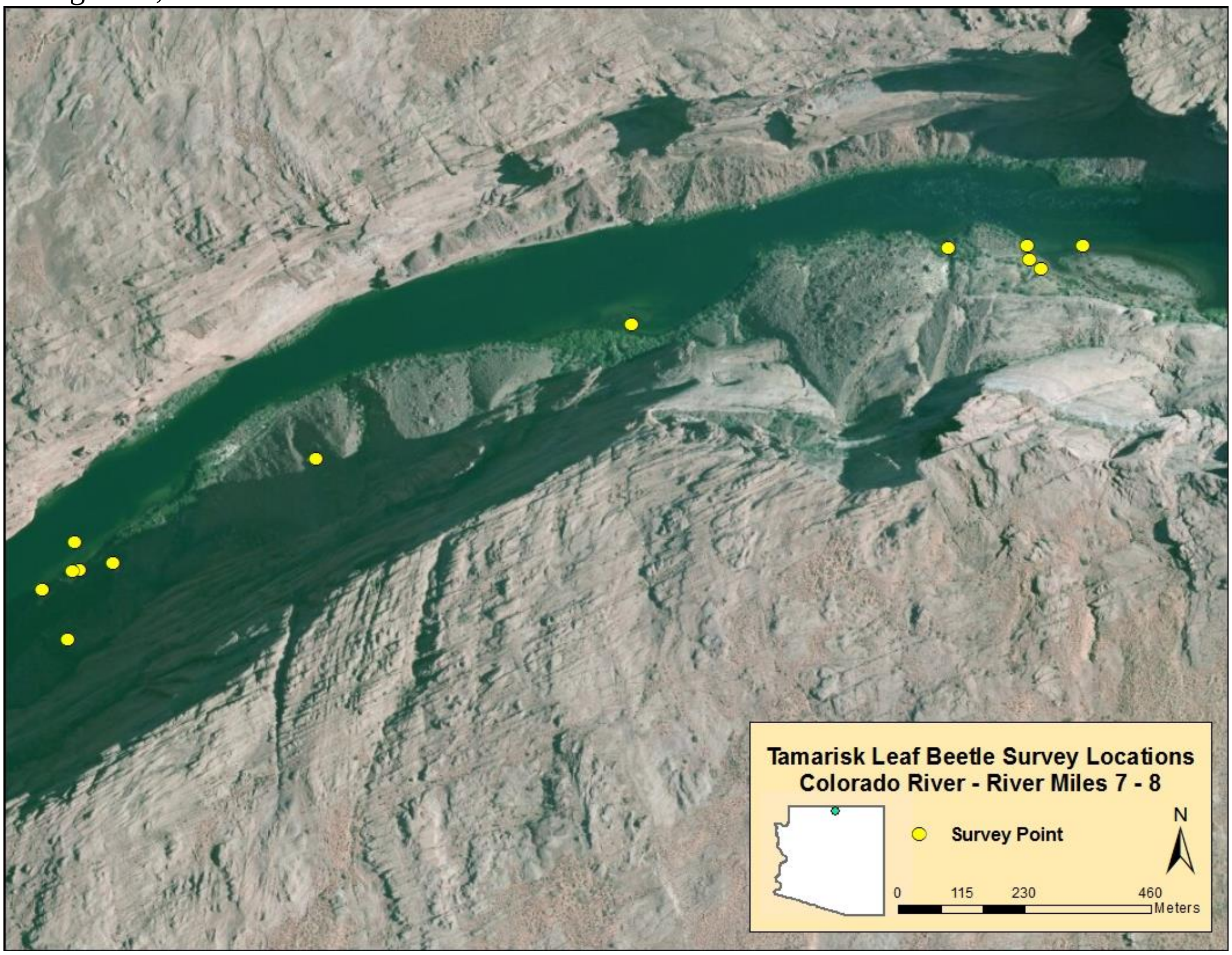
(Appendix 2 cont.)

Colorado River (Lee's Ferry – Glen Canyon Dam; RM -5_-6) tamarisk leaf beetle sample points during 2011, 2012 and 2013.

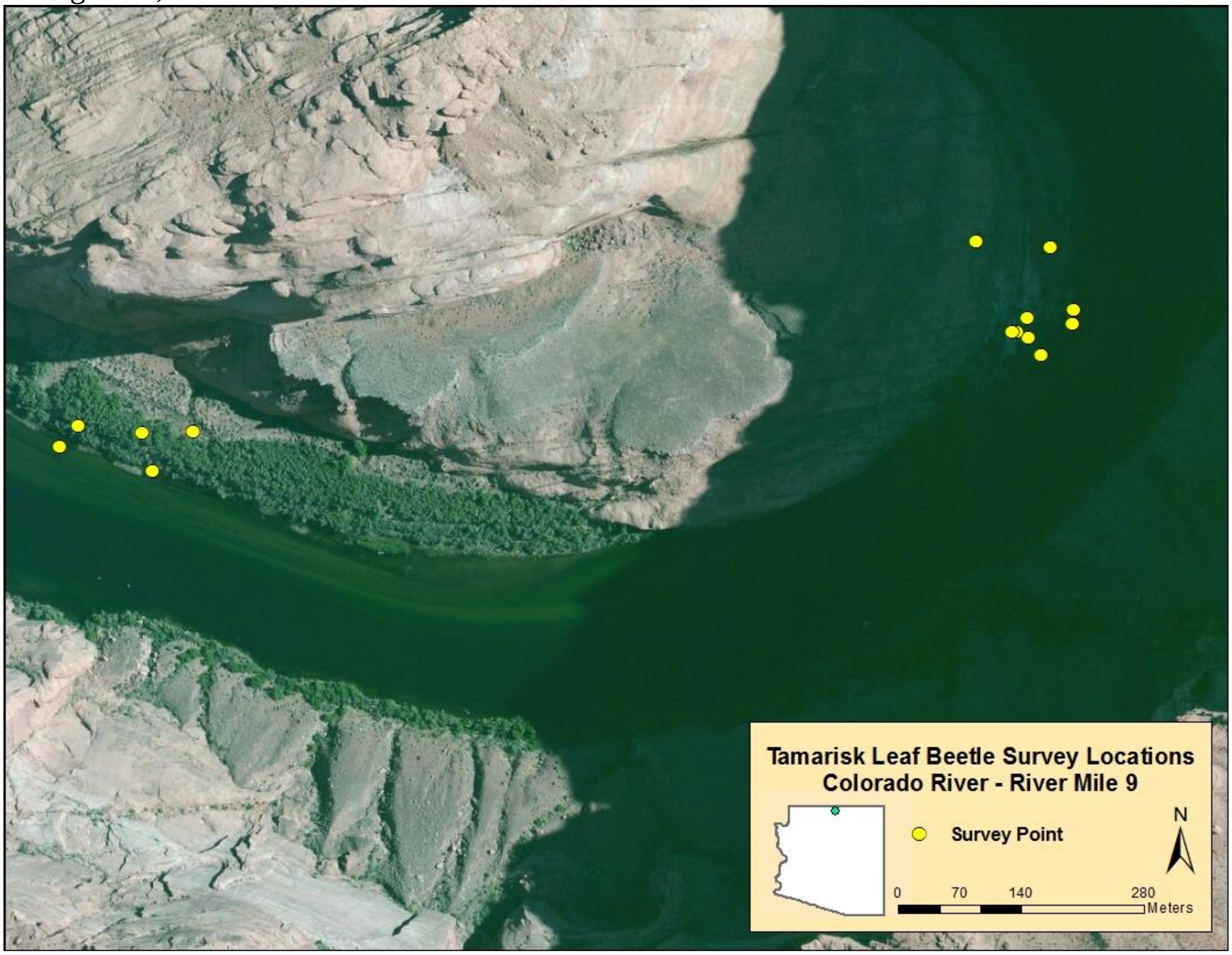


(Appendix 2 cont.)

Colorado River (Lee's Ferry – Glen Canyon Dam; RM -7_-8) tamarisk leaf beetle sample points, during 2011, 2012 and 2013.



(Appendix 2 cont.)
Colorado River (Lee's Ferry – Glen Canyon Dam; RM -9) tamarisk leaf beetle sample points, during 2011, 2012 and 2013.

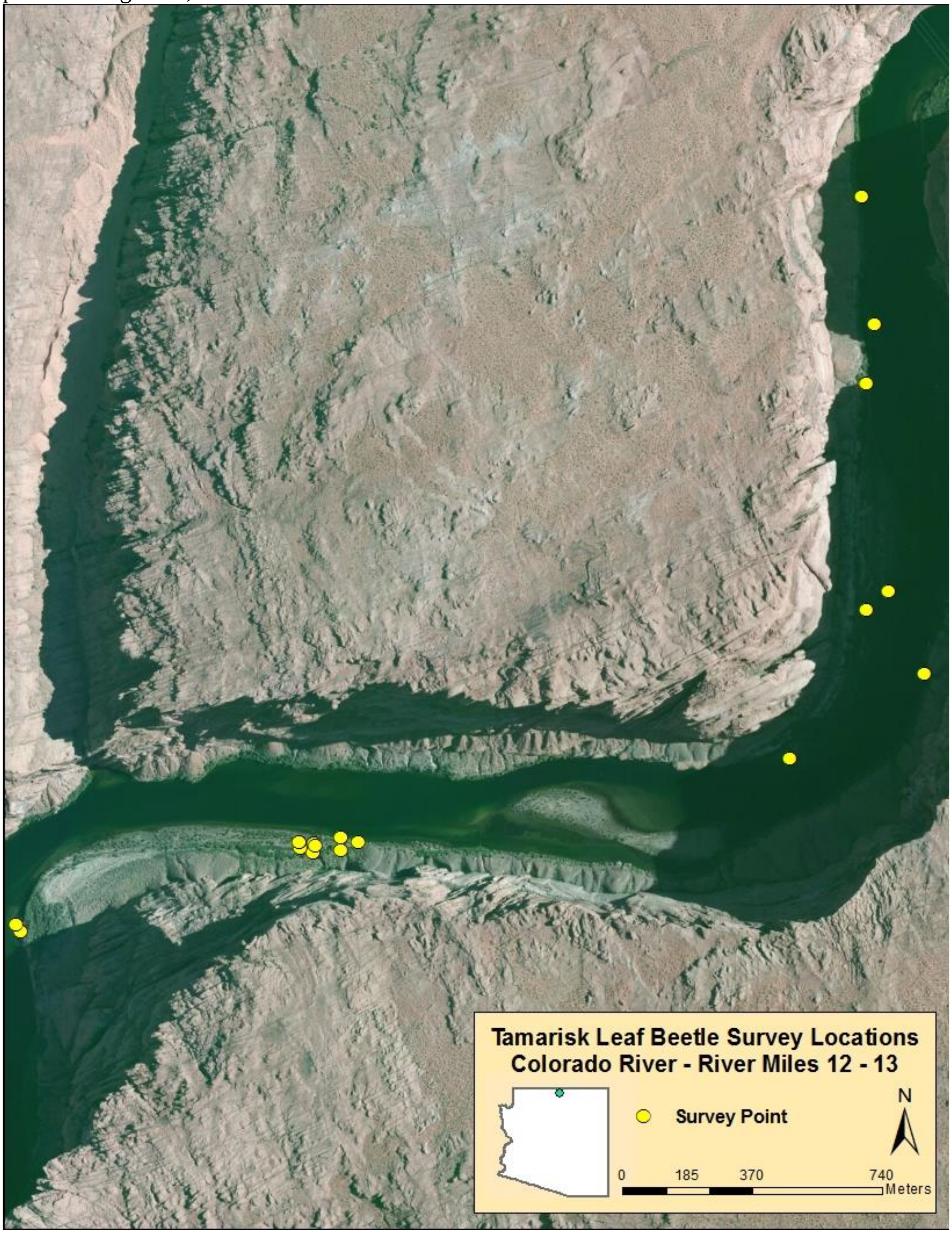


(Appendix 2 cont.)

Colorado River (Lee's Ferry – Glen Canyon Dam; RM -10_-11) tamarisk leaf beetle sample points during 2011, 2012 and 2013.

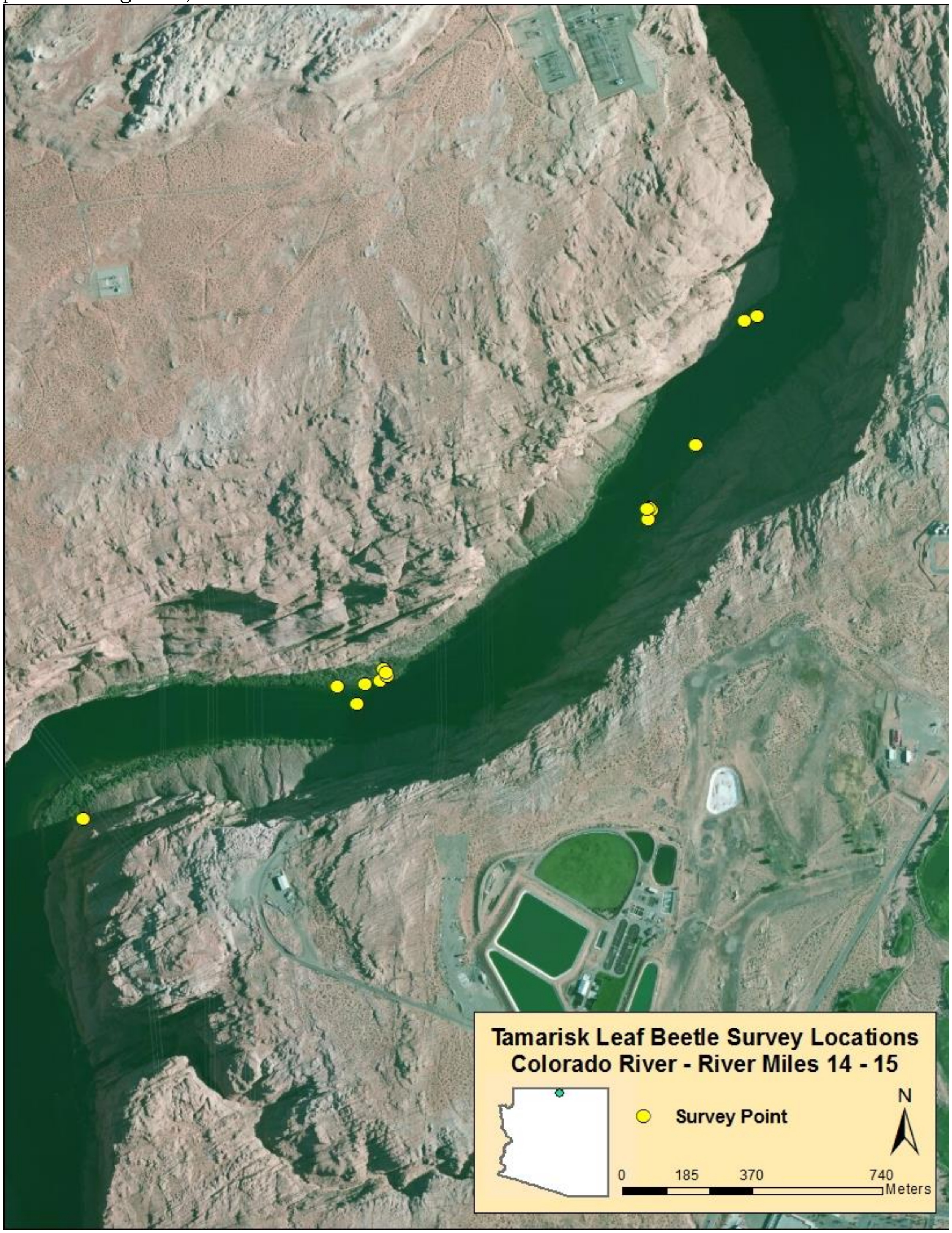
(Appendix 2 cont.)

Colorado River (Lee's Ferry – Glen Canyon Dam; RM -12_-13) tamarisk leaf beetle sample points during 2011, 2012 and 2013.



(Appendix 2 cont.)

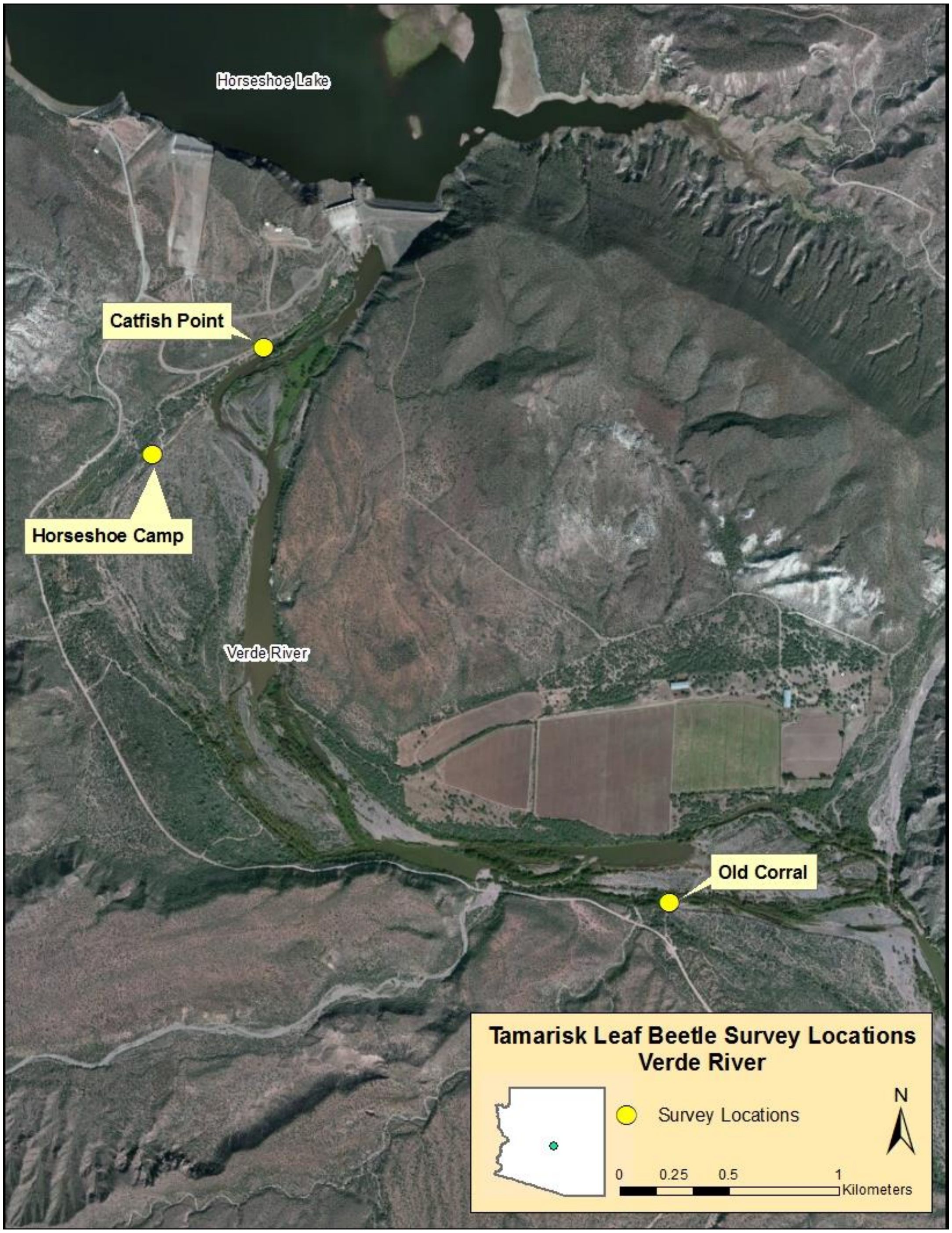
Colorado River (Lee's Ferry – Glen Canyon Dam; RM -14, -15) tamarisk leaf beetle sample points during 2011, 2012 and 2013.



(Appendix 2 cont.)

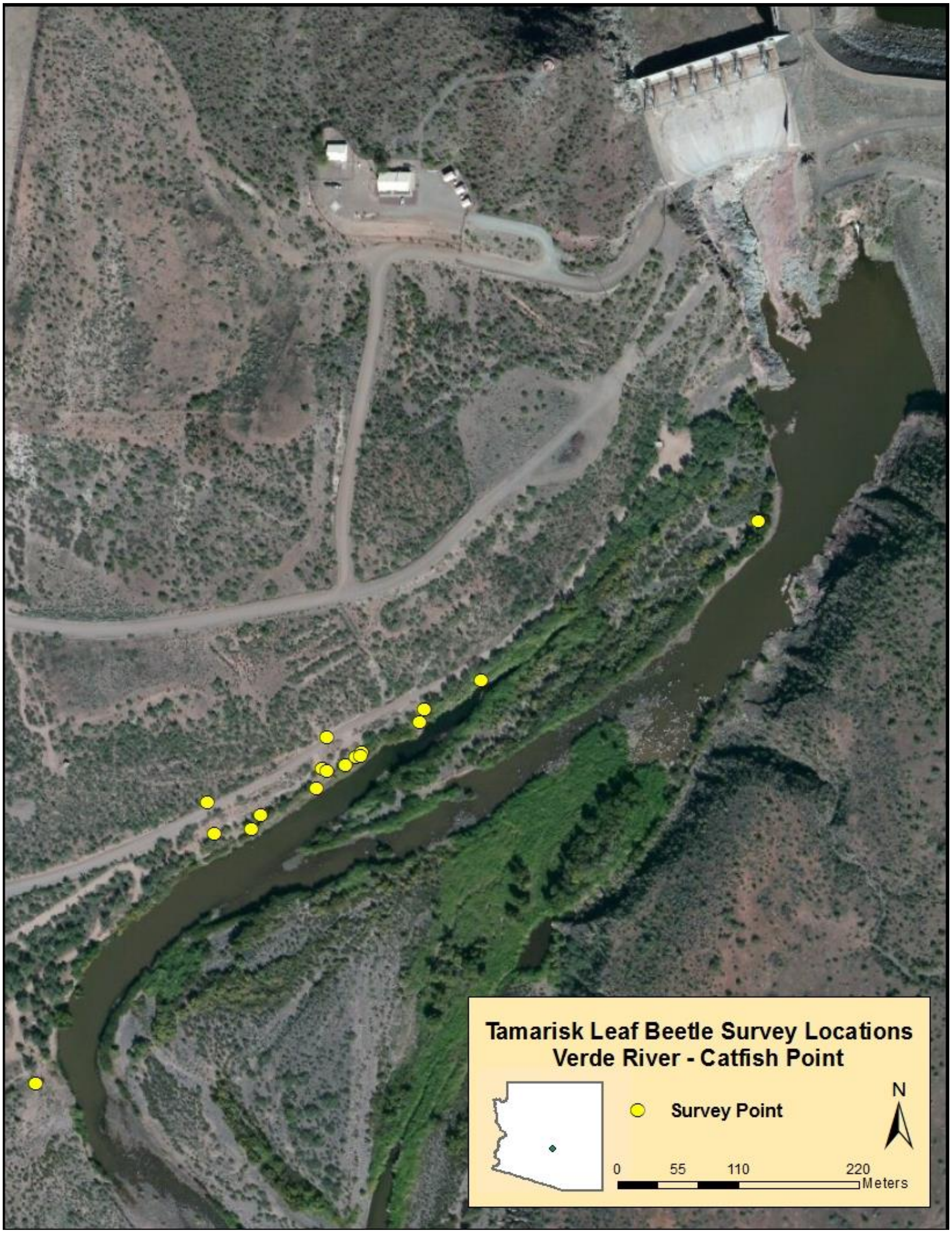
Verde River Watershed, AZ

The following map displays tamarisk leaf beetle sampling points within the Verde River Watershed, AZ. These sites are downstream from the Horseshoe Dam, and are referenced as the Dam Vista, Catfish Point, Horseshoe Lake and Old Corral sites, 2011, 2012 and 2013. Points shown represent the specific area where sampling occurred. Additional plots (not shown) were sampled throughout the sampling area where tamarisk was present. Tamarisk leaf beetles were not detected at any of the Verde River sites in 2011, 2012 or 2013.



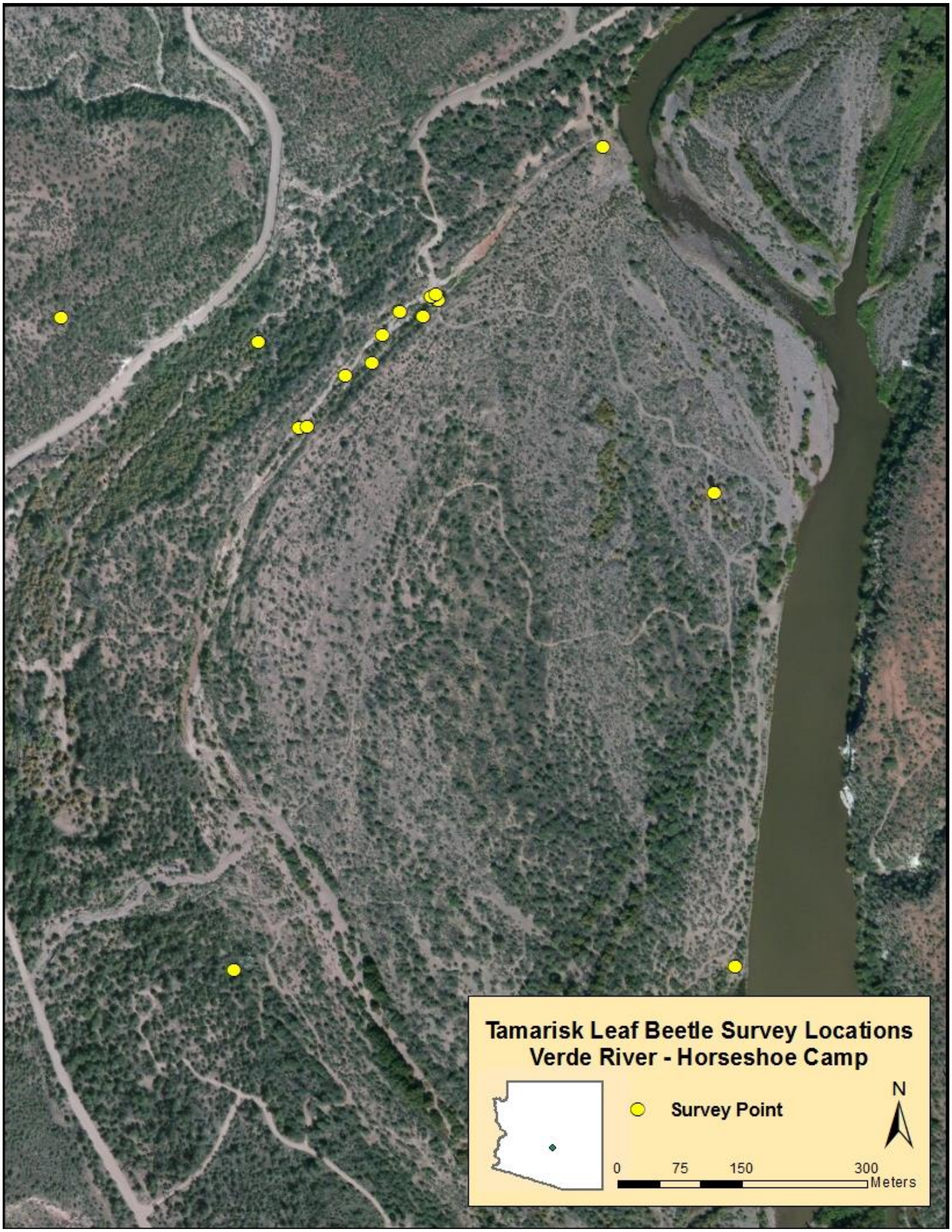
(Appendix 2 cont.)

Catfish Point (Verde River, Arizona) s tamarisk leaf beetle sampling points during 2011, 2012 and 2013.



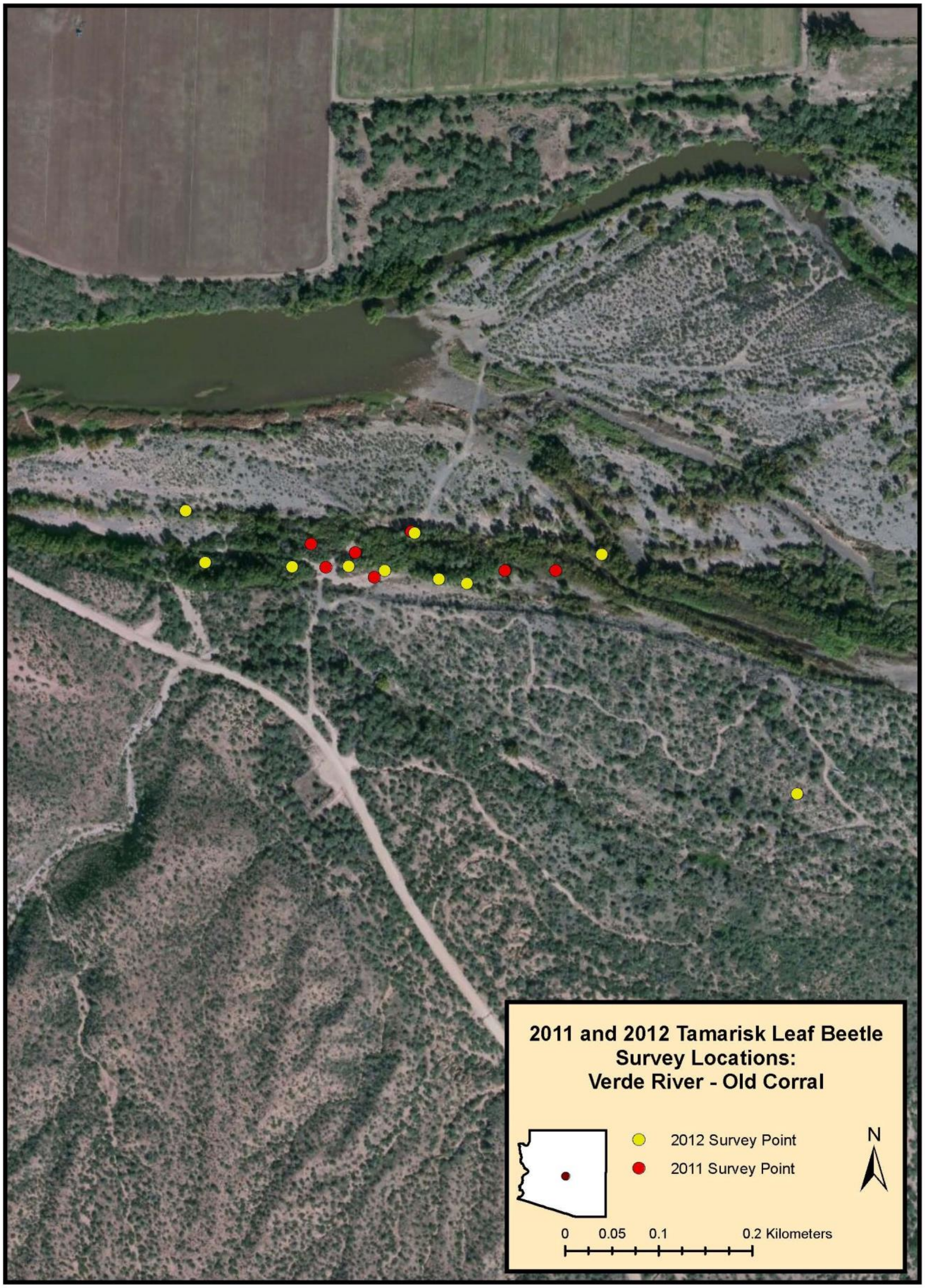
(Appendix 2 cont.)

Horseshoe Camp (Verde River, Arizona) tamarisk leaf beetle sampling points during 2011, 2012 and 2013.



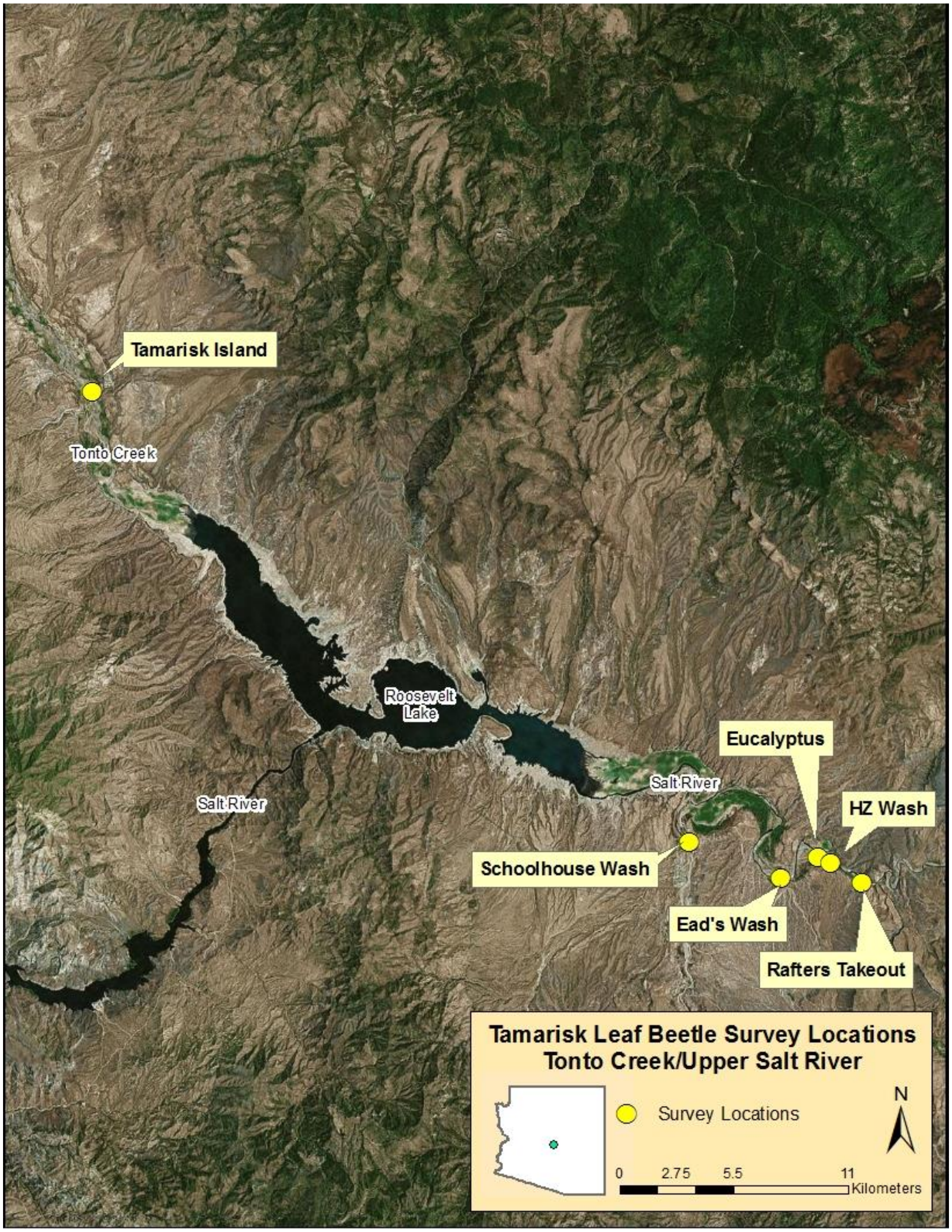
(Appendix 2 cont.)

Old Corral (Verde River, Arizona) tamarisk leaf beetle sampling points during 2011, 2012 and 2013.



Upper Salt River Watershed, AZ cont.

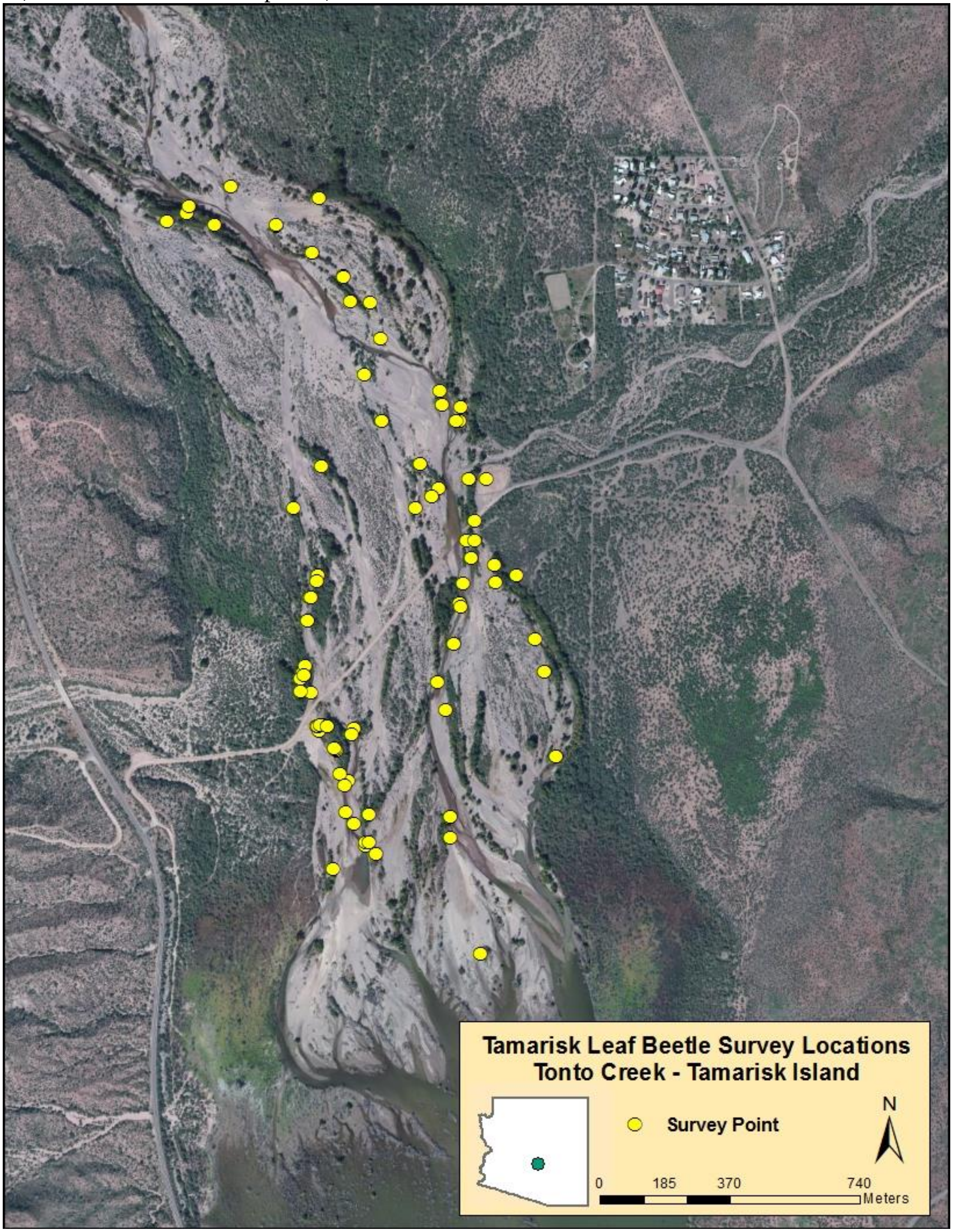
The following map displays tamarisk leaf beetle sampling points along the Salt River Watershed, AZ within the Upper Salt River Recreation Area, at Tamarisk Island on Tonto Creek, Schoolhouse, Eucalyptus site, Ead's Wash site, Rafters Takeout site, HZ Wash site, 2011 and 2012. Points shown represent the specific area where sampling occurred. Additional plots (not shown) were sampled throughout the sampling area where tamarisk was present. Tamarisk leaf beetles were not detected at any of the Upper Salt River sites in 2012.



(Appendix 2 cont.)

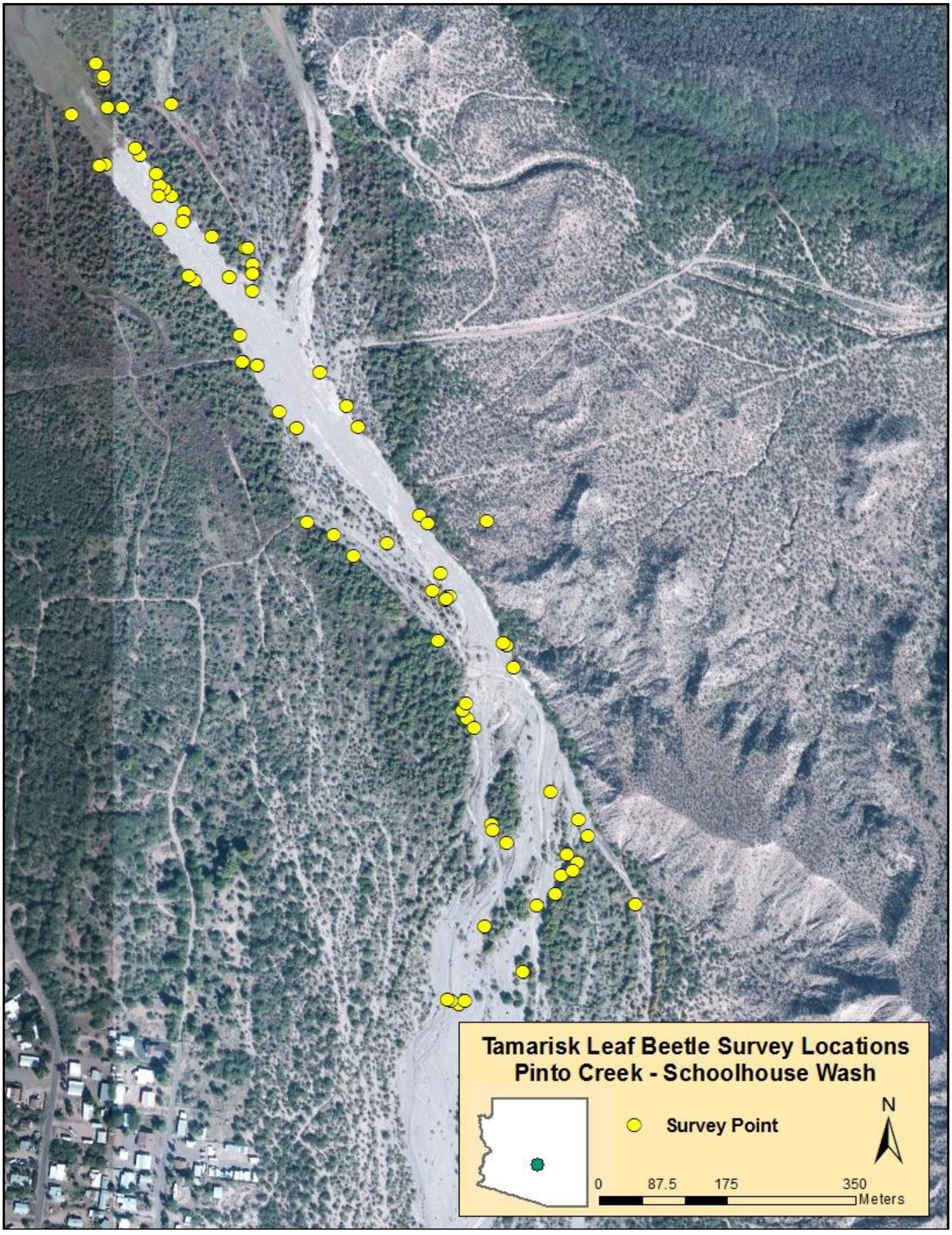
Tamarisk Island, Tonto Creek, AZ

The following map displays tamarisk leaf beetle sampling points along Tonto Creek Watershed, AZ, at the Tamarisk Island points, 2011 2012.



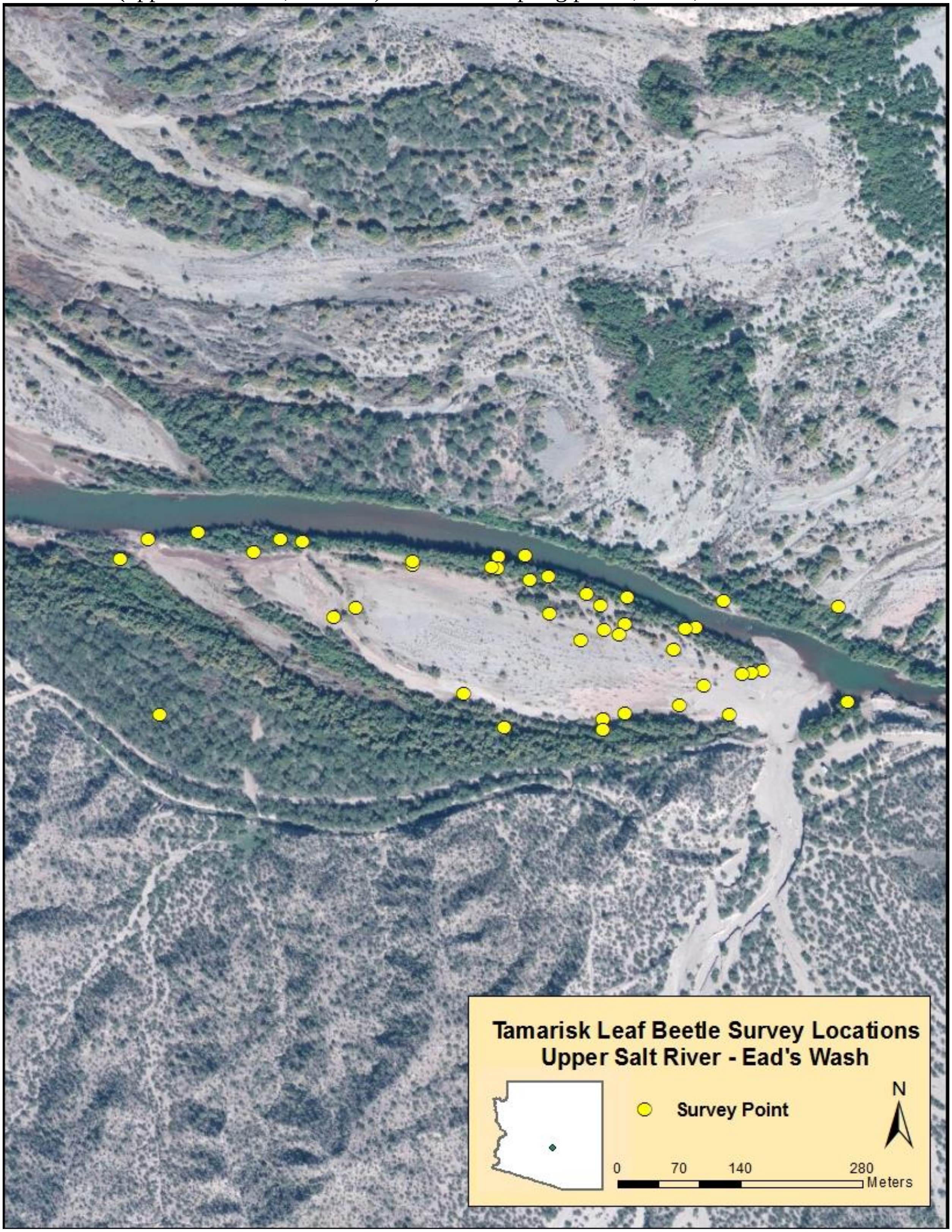
(Appendix 2 cont.)

Schoolhouse (Upper Salt River, Arizona) tamarisk leaf beetle sampling points, 2011, 2012 and 2013.



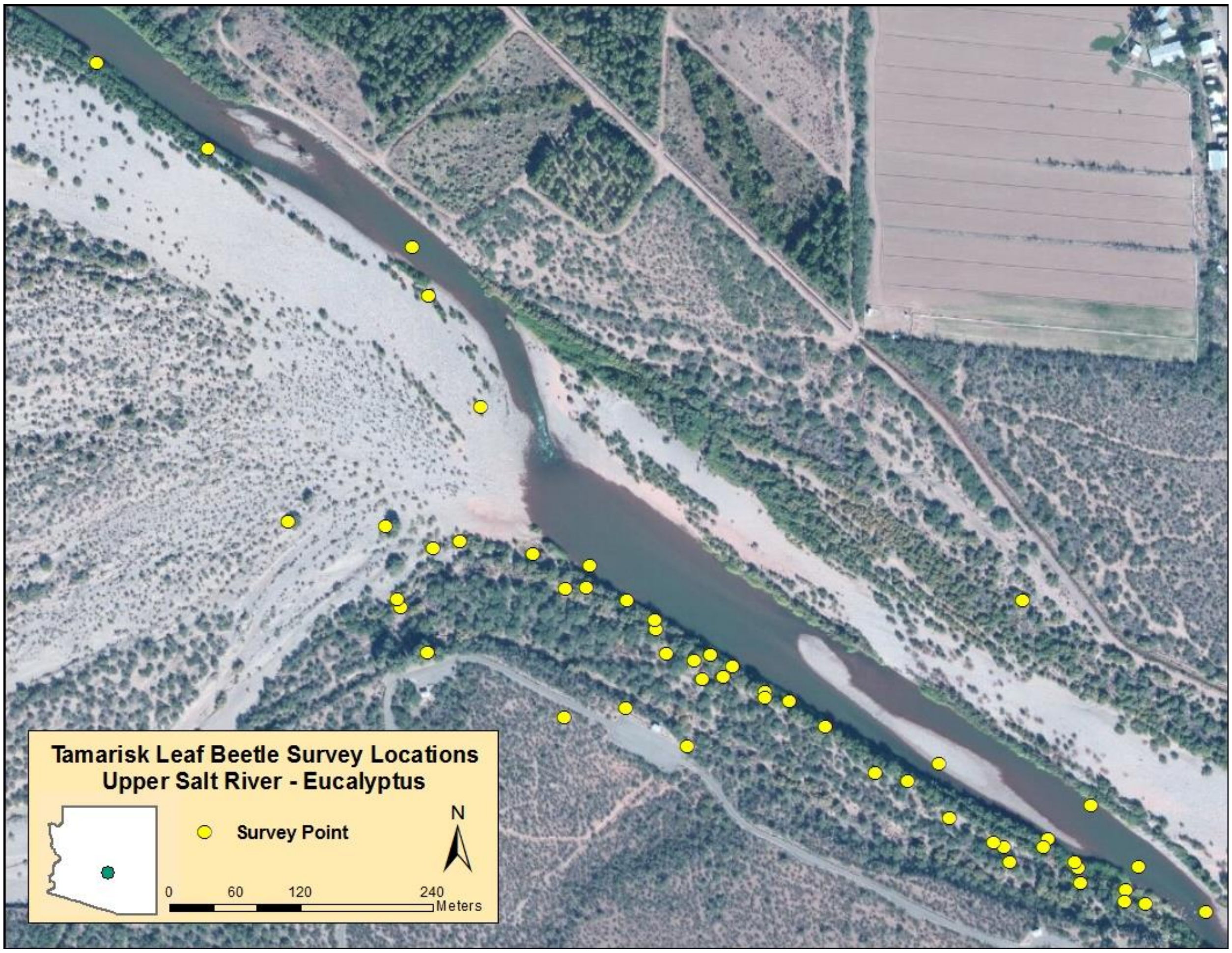
(Appendix 2 cont.)

Eads Wash (upper Salt River, Arizona) tamarisk sampling points, 2011, 2012 and 2013.



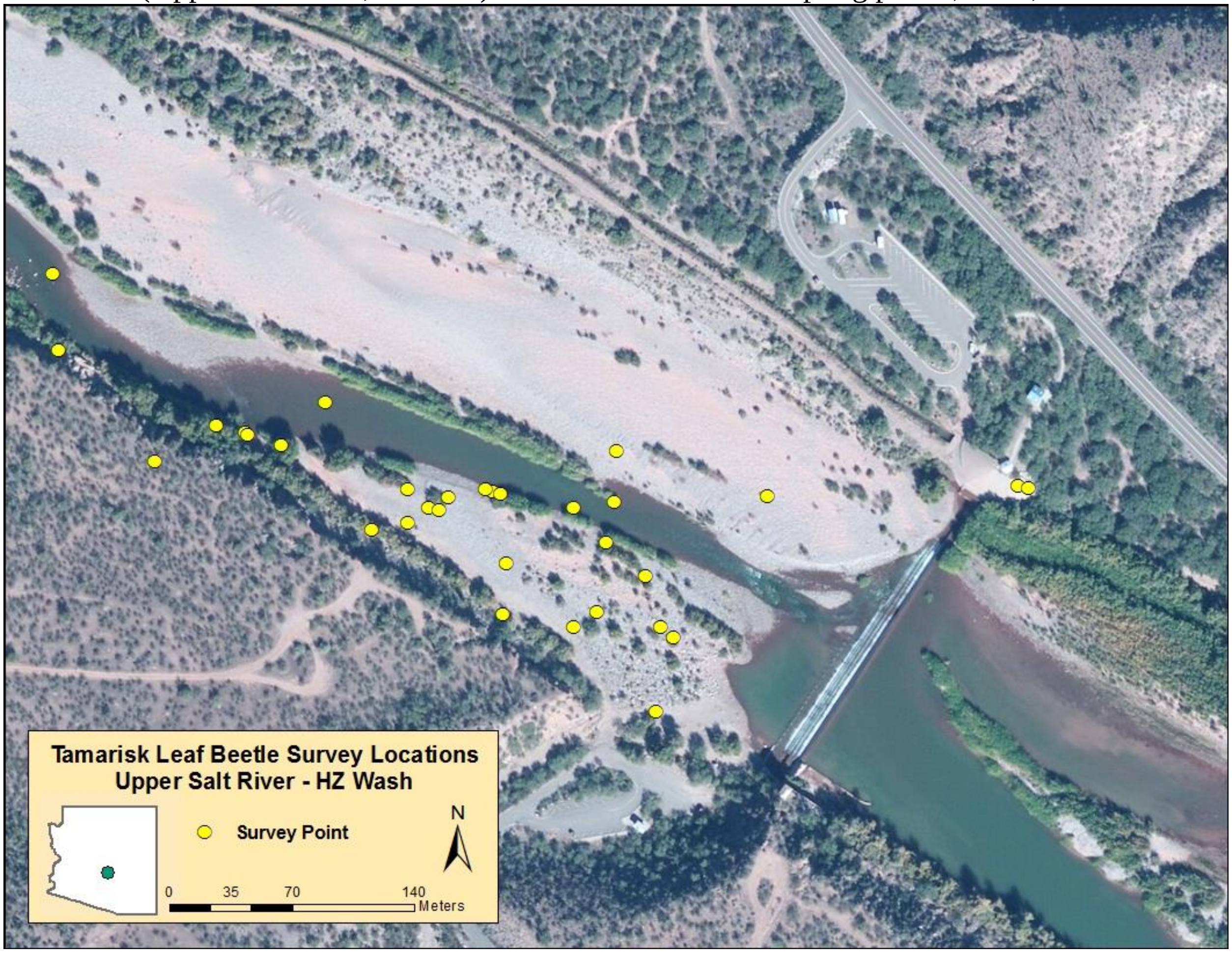
(Appendix 2 cont.)

Eucalyptus (Upper Salt River, Arizona) tamarisk leaf beetle sampling points, 2011, 2012 and 2013.



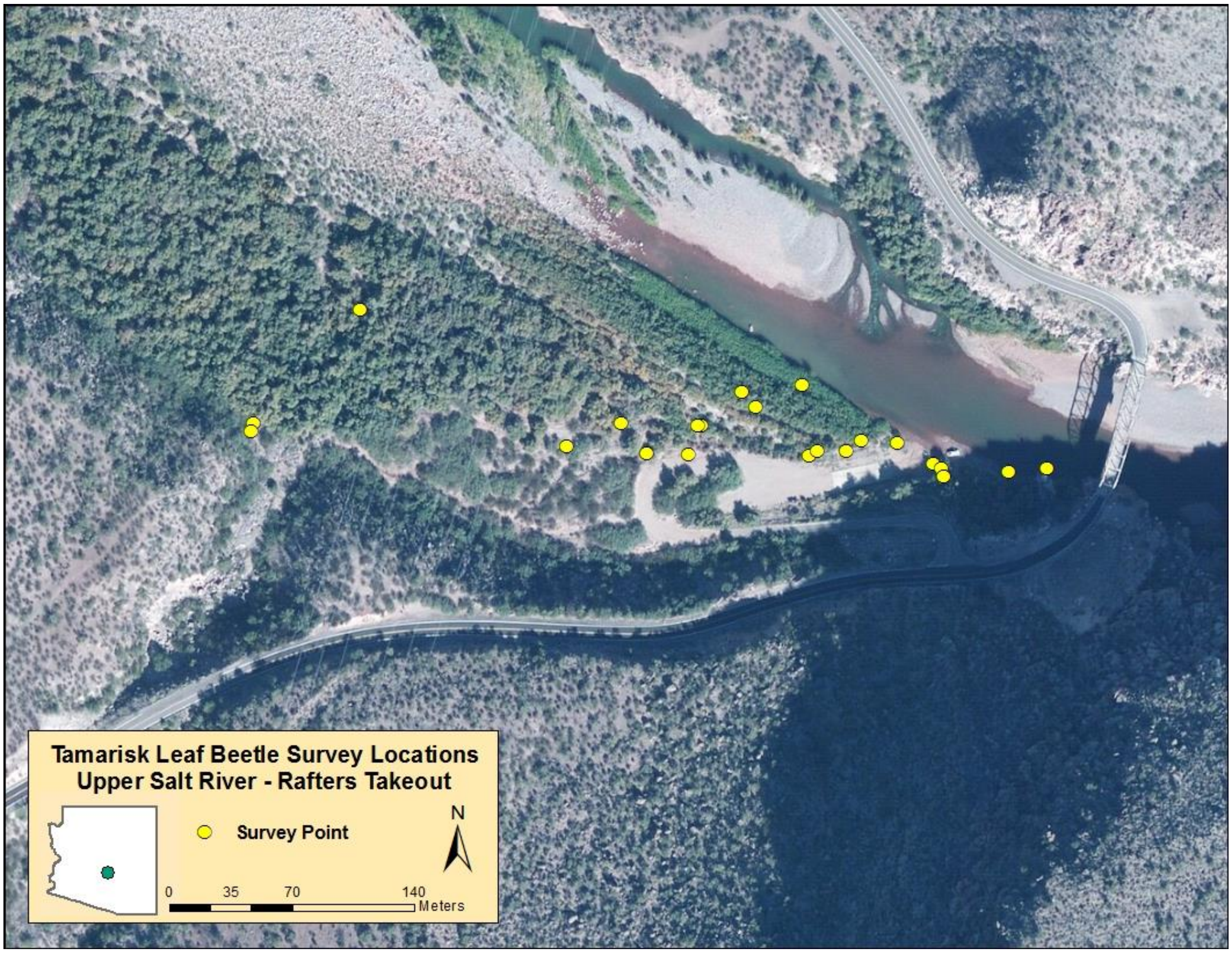
(Appendix 2 cont.)

HZ Wash (Upper Salt River, Arizona) tamarisk leaf beetle sampling points, 2011, 2012 2013.



(Appendix 2 cont.)

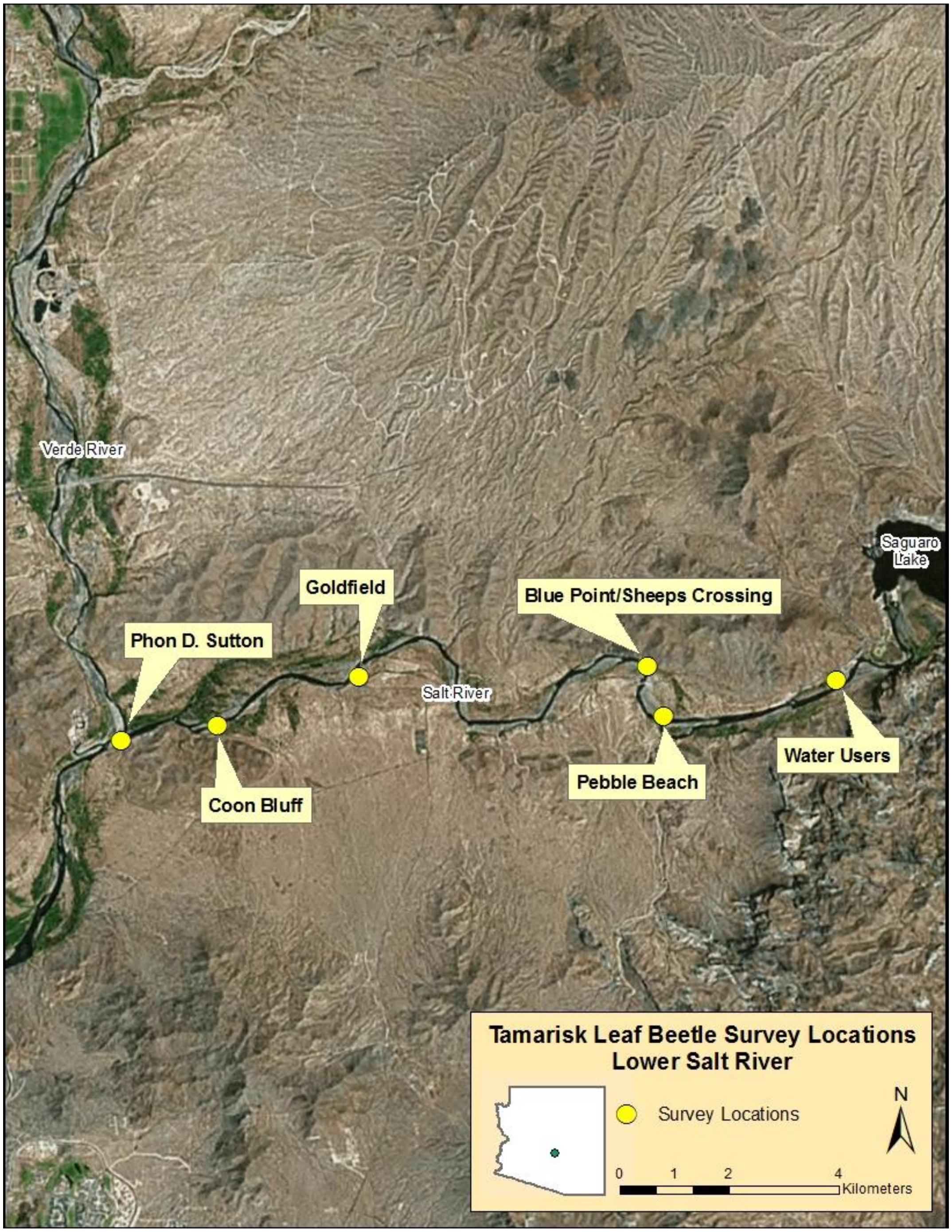
Rafter's Takeout (Upper Salt River, Arizona) tamarisk leaf beetle sampling points, 2011, 2012 and 2013.



(Appendix 2 cont.)

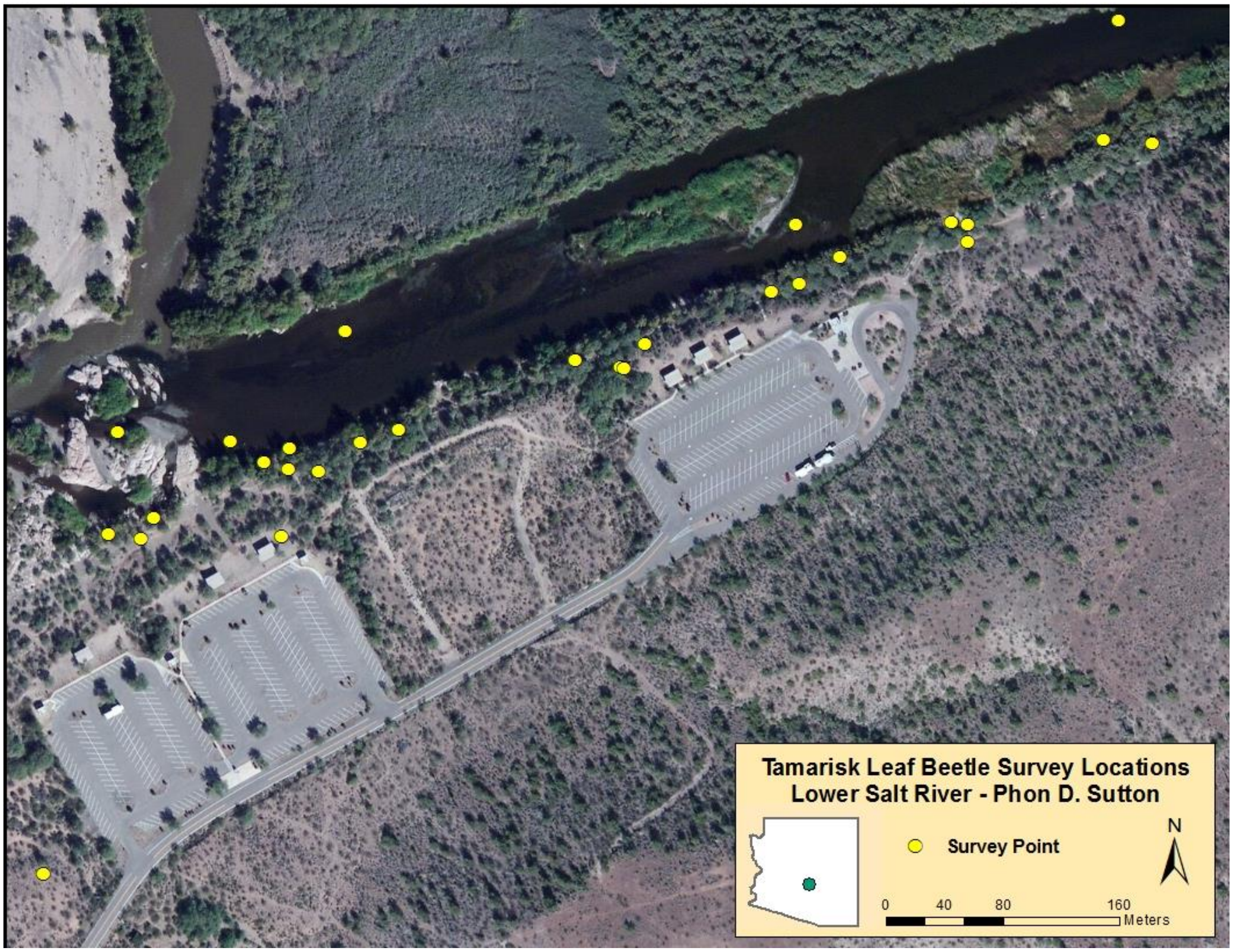
Lower Salt River Watershed, AZ

The following map displays tamarisk leaf beetle sampling points along the Salt River, AZ within the Lower Salt River Recreation Area, at the Goldfield, Coon Bluff and Phon D. Sutton sites Water Users, Pebble Beach, Blue Point, and Sheep Crossing sites, 2011, 2012 and 2013. The points shown represents the specific area where sampling occurred. Additional plots (not shown) were sampled throughout the sampling area where tamarisk is present. Tamarisk leaf beetles were not detected at any of the Lower Salt River sites in 2012.



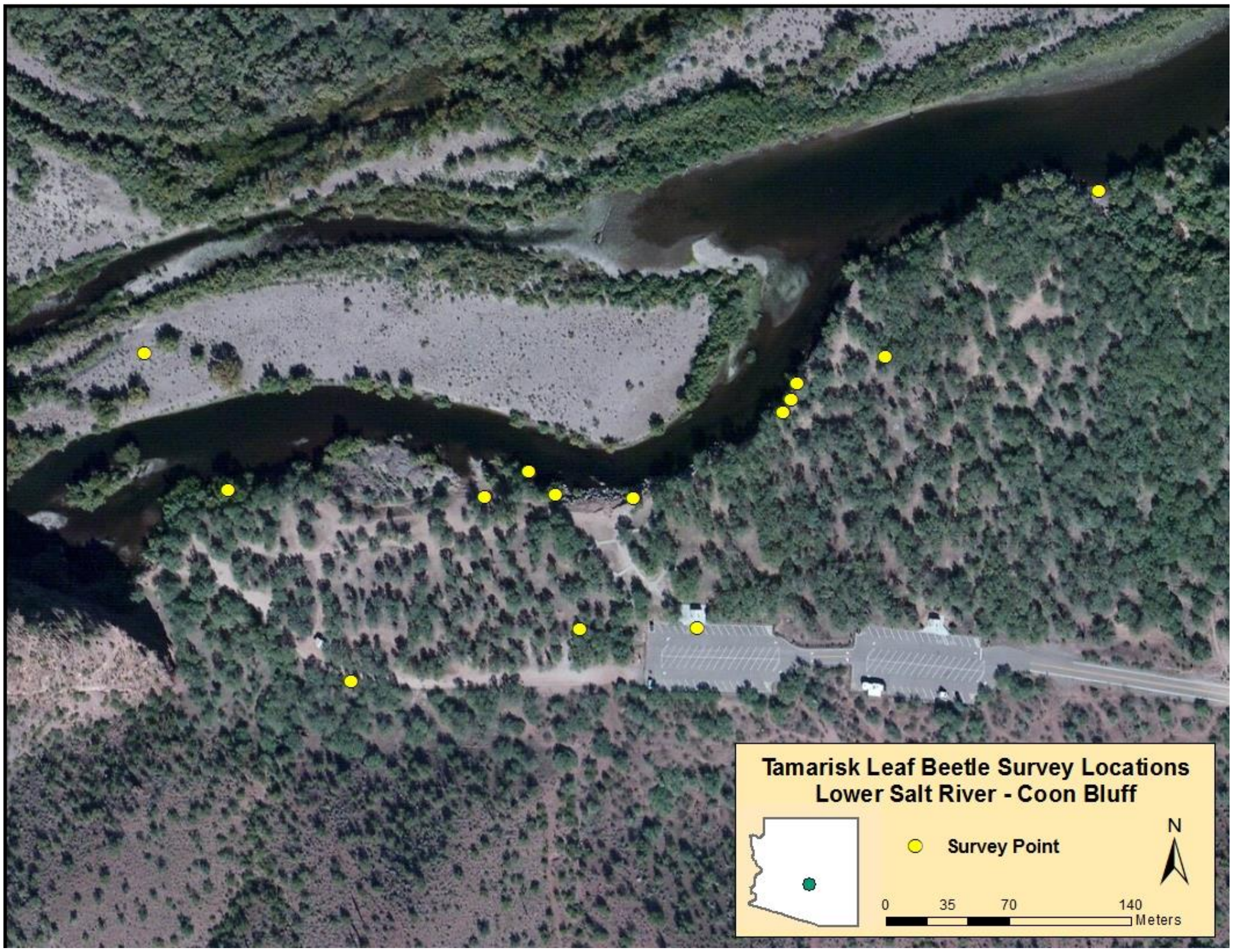
(Appendix 2 cont.)

Phon D Sutton (Lower Salt River, Arizona) tamarisk leaf beetle sampling points during 2011, 2012 and 2013.



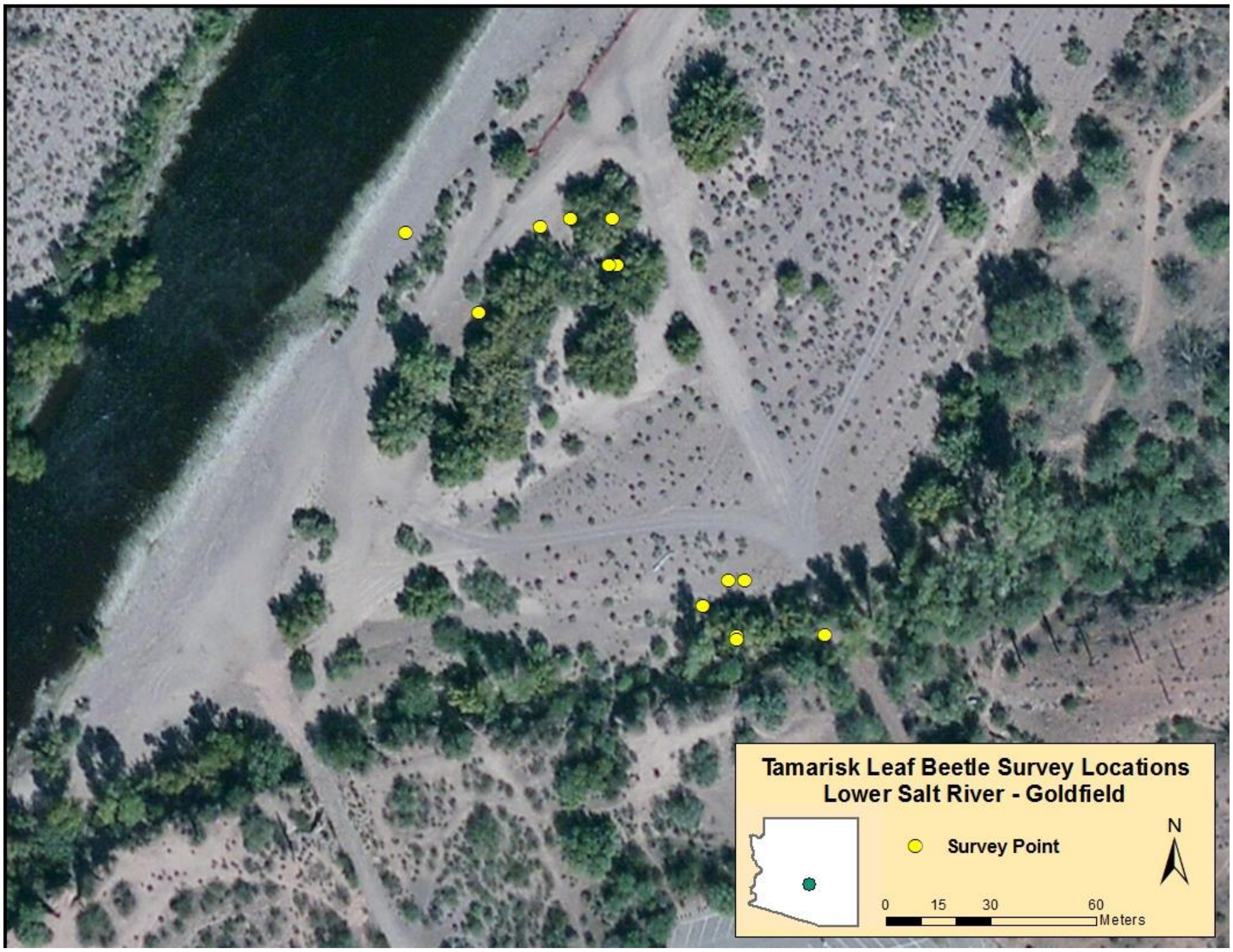
(Appendix 2 cont.)

Coon Bluff (Lower Salt River, Arizona) tamarisk leaf beetle sampling points during 2011, 2012 and 2013.



(Appendix 2 cont.)

Goldfield (Lower Salt River, Arizona) tamarisk leaf beetle sampling points during 2011, 2012 and 2013.

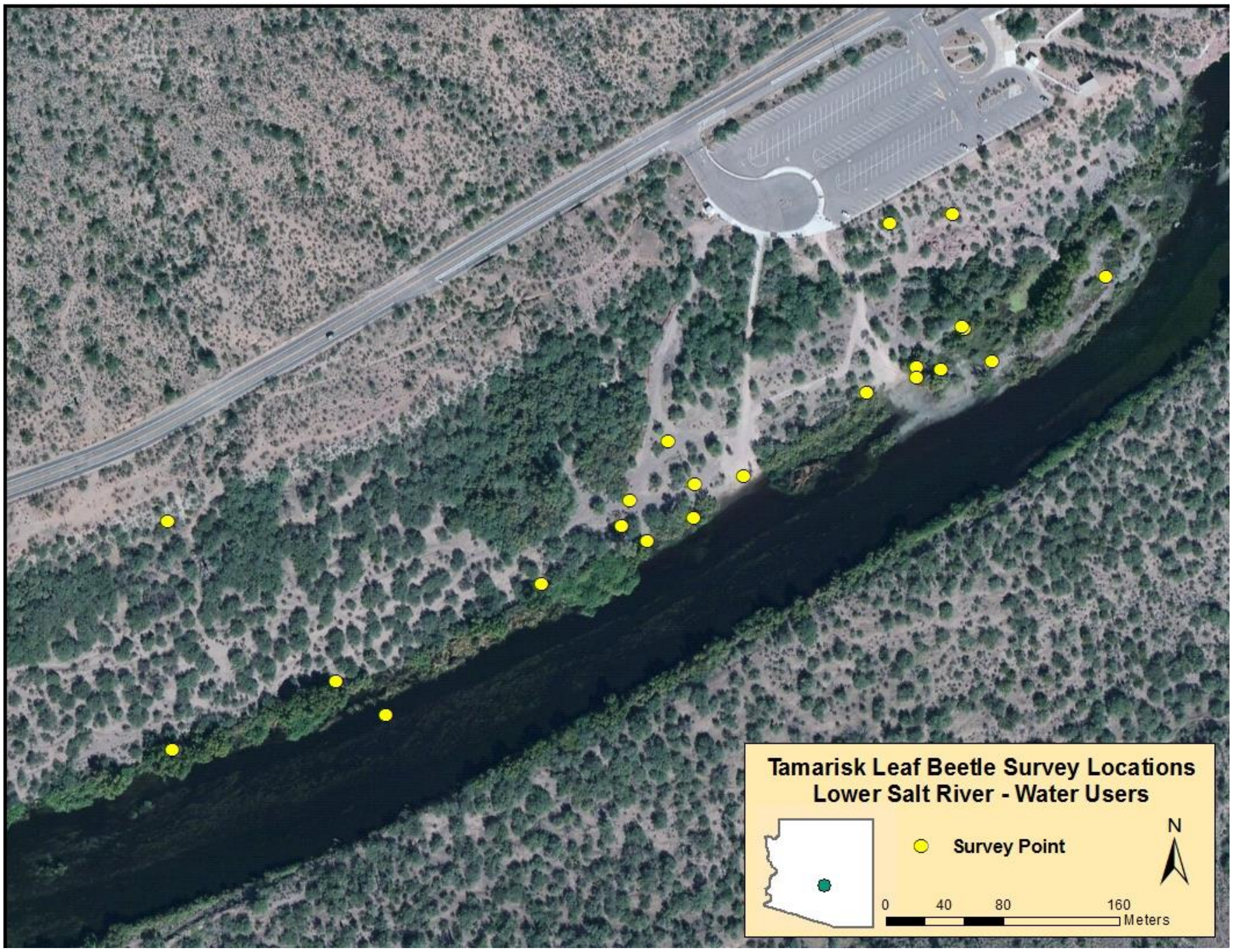


(Appendix 2 cont.)

Blue Point/Sheep's Crossing/Pebble Beach (Lower Salt River, Arizona) tamarisk leaf beetle sampling points during 2011, 2012 and 2013.

(Appendix 2 cont.)

Water Users (Lower Salt River, Arizona) tamarisk leaf beetle sampling points during 2011, 2012 and 2013.



Appendix 3. 2012 Habitat photos of tamarisk leaf beetle sampling areas along the Colorado River (Lee's Ferry-Glen Canyon Dam), Lower Verde River, Tonto Creek and the Upper and Lower Salt River. Listed with each photo, area name, site name and if defoliation occurred.

Glen Canyon National Recreation Area (NRA), AZ - Colorado River - River Miles 0_-15

Glen Canyon NRA-Colorado River Lee's Ferry Boat Ramp River Mile 0

Glen Canyon NRA-Colorado River Lee's Ferry Boat Ramp River Mile 0

Glen Canyon NRA-Colorado River Mile -3 (defoliated)

Glen Canyon NRA-Colorado River Mile -3 (defoliated)

(Appendix 3 cont.)
Glen Canyon NRA, AZ - Colorado River - River Miles 0_-15

Glen Canyon NRA- Colorado
River Mile -4 (defoliated)

Glen Canyon NRA-Colorado
River Mile –4 (defoliated)

Glen Canyon NRA–Colorado
River Mile -5 (defoliated)

Glen Canyon NRA- Colorado
River Mile -5 (defoliated)

Glen Canyon NRA-Colorado
River Mile -6 (defoliated)

Glen Canyon NRA-Colorado
River Mile -6 (defoliated)

(Appendix 3 cont.)

Glen Canyon NRA, AZ - Colorado River - River Miles 0_-15

Glen Canyon NRA-Colorado
River Mile -7 (defoliated)

Glen Canyon NRA-Colorado
River Mile -7 (defoliated)

Glen Canyon NRA-Colorado
River Mile -8 (defoliated)

Glen Canyon NRA-Colorado
River Mile -8 (defoliated)

Glen Canyon NRA-Colorado
River Mile -9 (defoliated)

Glen Canyon NRA-Colorado
River Mile -9 (defoliated)

(Appendix 3 cont.)
Glen Canyon NRA, AZ - Colorado River - River Miles 0_-15

Glen Canyon NRA-Colorado
River Mile -10 (defoliated)

Glen Canyon NRA-Colorado
River Mile -10 (defoliated)

Glen Canyon NRA-Colorado
River Mile -11 (defoliated)

Glen Canyon NRA-Colorado
River Mile -11 (defoliated)

Glen Canyon NRA-Colorado
River Mile -12 (defoliated)

Glen Canyon NRA-Colorado
River Mile -12 (defoliated)

(Appendix 3 cont.)
Glen Canyon NRA, AZ - Colorado River - River Miles 0_-15

Glen Canyon NRA-Colorado
River Mile -13 (defoliated)

Glen Canyon NRA-Colorado
River Mile -13 (defoliated)

Glen Canyon NRA-Colorado
River Mile -14 (defoliated)

Glen Canyon NRA-Colorado
River Mile -14 (defoliated)

Glen Canyon NRA-Colorado
River Mile -15 (defoliated)

Glen Canyon NRA-Colorado
River Mile -15 (defoliated)

(Appendix 3 cont.)
Horseshoe Lake, AZ - Verde River

Verde River - Old Corral

Verde River - Old Corral

Verde River - Catfish Point

Verde River - Catfish Point

Verde River - Horseshoe Campground

Verde River - Horseshoe Campground

(Appendix 3 cont.)
Tonto Creek and Upper Salt River, AZ

Tonto Creek - Tamarisk Island

Tonto Creek - Tamarisk Island

Tonto Creek - Tamarisk Island

Upper Salt River/Pinto Creek - Schoolhouse Wash

Upper Salt River/Pinto Creek - Schoolhouse Wash

Upper Salt River/Pinto Creek - Schoolhouse Wash

(Appendix 3 cont.)
Upper Salt River, AZ

Upper Salt River - Rafter's Takeout

Upper Salt River - HZ Wash

Upper Salt River - HZ Wash

Upper Salt River - Eucalyptus

Upper Salt River - Ead's Wash

Upper Salt River - Ead's Wash

(Appendix 3 cont.)
Lower Salt River Recreation Area, AZ

Lower Salt River - Water Users

Lower Salt River - Pebble Beach

Lower Salt River - Goldfield

Lower Salt River - Goldfield

Lower Salt River - Coon Bluff

Lower Salt River - Coon Bluff

(Appendix 3 cont.)
Lower Salt River Recreation Area, AZ

Lower Salt River - Phon D. Sutton

Lower Salt River - Phon D. Sutton

Lower Salt River - Phon D. Sutton

Lower Salt River - Phon D. Sutton