

# RECLAMATION

*Managing Water in the West*

## Photographic Monitoring of Defoliation by the Tamarisk Beetle

Middle Rio Grande from Belen to Elephant Butte Reservoir, New Mexico



U.S. Department of the Interior  
Bureau of Reclamation  
Fisheries and Wildlife Resources Group  
Denver, Colorado

April 2018

## **Mission Statements**

The U.S. Department of the Interior protects America's natural resources and heritage, honors our cultures and tribal communities, and supplies the energy to power our future.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

# Photographic Monitoring of Defoliation by the Tamarisk Beetle

**Middle Rio Grande from Belen to Elephant Butte Reservoir, New  
Mexico**

*prepared for*

## **Albuquerque Area Office**

555 Broadway NE, Suite 100  
Albuquerque, NM 87102

*by*

## **Technical Service Center Fisheries and Wildlife Resources Group**

Kristen G. Dillon, Wildlife Biologist  
Darrell Ahlers, Wildlife Biologist

Cover Photo: K. Pritchard



**U.S. Department of the Interior  
Bureau of Reclamation  
Fisheries and Wildlife Resources Group  
Denver, Colorado**

**April 2018**



# Contents

*Page*

<b>Executive Summary .....</b>	<b>i</b>
<b>Introduction.....</b>	<b>1</b>
<b>Methods.....</b>	<b>4</b>
Study Area .....	4
Hemispherical Photography.....	9
Landscape Photography .....	9
Microclimate Monitoring.....	10
<b>Results .....</b>	<b>11</b>
Hemispherical Photography.....	11
Landscape Photography .....	19
Microclimate Monitoring.....	21
<b>Discussion.....</b>	<b>24</b>
<b>Conclusions.....</b>	<b>31</b>
<b>Recommendations .....</b>	<b>31</b>
<b>Attachment 1: Photo Station Locations .....</b>	<b>33</b>
Attachment 1A: Hemispherical Photography Station Locations .....	34
Attachment 1B: Landscape Photography Station Locations .....	35
<b>Attachment 2: Canopy Cover by Site Pre- &amp; Post-Colonization by the Tamarisk Beetle.....</b>	<b>36</b>
Sites impacted by the tamarisk beetle in 2017:.....	37
Sites not impacted by the tamarisk beetle in 2017:.....	38
<b>Literature Cited .....</b>	<b>39</b>

## Tables

Table 1. Annual photographic sampling dates by study site. ....	10
Table 2. Tamarisk beetle impact monitoring study design. ....	11

## Figures

Figure 1. Distribution of the tamarisk beetle by species in 2015 (Tracy 2017). ....	3
Figure 2. Hemispherical and landscape photography stations in site BL-10. ....	5
Figure 3. Hemispherical and landscape photography stations in site DL-12. ....	6
Figure 4. Hemispherical and landscape photography stations in site LFCC-5B. ....	7
Figure 5. Hemispherical and landscape photography stations in site EB-15. ....	8
Figure 6. Canopy closure by study site pre- and post-colonization by the tamarisk beetle. ....	12
Figure 7. Percent of vegetation community within 5 m radius of hemispherical photo stations composed of tamarisk. ....	13
Figure 8. Trends in canopy cover at DL-12 pre- and post-colonization by the tamarisk beetle. ....	14
Figure 9. Trends in canopy cover at BL-10 pre- and post-colonization by the tamarisk beetle. ....	14
Figure 10. Canopy cover at EB-15 hemispherical photo stations by sampling occasion. ....	15
Figure 11. Canopy cover at DL-12 hemispherical photo stations by sampling occasion. ....	16
Figure 12. Hemispherical photography at EB-15 point 5 (a, b) and DL-12 point 6 (c, d). ....	17
Figure 13. Canopy cover at DL-12 in the winter (blue) compared to the growing season. ....	18
Figure 14. Canopy cover at BL-10 in the winter (blue) compared to the growing season. ....	19
Figure 15. Seasonal progression of tamarisk browning and defoliation in DL-12 (column a) and EB-15 (column b) in 2017. ....	20
Figure 16. Daily minimum and maximum temperature in EB-15 by hemispherical photo station during 2017 SWFL breeding season. ....	21
Figure 17. Daily minimum and maximum temperature in BL-10 by hemispherical photo station during 2017 SWFL breeding season. ....	22
Figure 18. Daily minimum and maximum percent relative humidity in EB-15 by hemispherical photo station during 2017 SWFL breeding season. ....	23
Figure 19. Daily minimum and maximum percent relative humidity in BL-10 by hemispherical photo station during 2017 SWFL breeding season. ....	24
Figure 20. Percentage of SWFL nests constructed in native willow vs. invasive tamarisk. ....	25
Figure 21. Percentage of SWFL nests constructed in territories dominated by native vs. exotic vs. mixed native and exotic vegetation. ....	25
Figure 22. Number of SWFL territories and mean productivity of successful nests by study site, 2014-2017. ....	28
Figure 23. Outcome of SWFL nests by study site, 2014-2017. ....	29
Figure 24. SWFL nesting substrate use and territory dominance by study site, 2014-2017. ....	30

# Executive Summary

Bureau of Reclamation personnel conducted photographic monitoring of riparian vegetation within occupied Southwestern Willow Flycatcher (*Empidonax traillii extimus*; SWFL) habitat along the Middle Rio Grande, New Mexico from 2015 through 2017. Photographic monitoring was conducted in an effort to quantify the effects of defoliation by the introduced tamarisk beetle (*Diorhabda* spp.). Monitoring consisted of photographs taken at fixed locations within the riparian corridor 1) facing upward into the vegetation overstory (hemispherical photography) and 2) facing inward at the vegetation community (landscape photography). Monitoring was conducted at 35 hemispherical photo stations and 17 landscape photo stations across 4 study sites occupied by SWFLs between Belen, NM and Elephant Butte Reservoir. Photographs were taken between May and August in all years of the study, in order to correspond with tamarisk beetle activity and the Southwestern Willow Flycatcher breeding season. Additionally, hemispherical photographs were taken during the 2017 winter dormant season in order to distinguish woody growth from foliage.

The tamarisk beetle was not detected at any of the photo stations in 2015, and only at one study site in 2016. Thus, 2015 and most of 2016 photography provided baseline data on vegetation structure and canopy closure prior to beetle-induced tamarisk (*Tamarix* spp.) defoliation. Severe defoliation was recorded in two study sites in 2017. Landscape photography revealed notable declines in tamarisk foliage health after the arrival of the tamarisk beetle. Additionally, hemispherical photography suggested a decline in canopy cover associated with tamarisk beetle defoliation, but not to a level outside of the natural range of variation for the study area. Nevertheless, the change in canopy cover was sufficient to result in increased temperature and aridity of the study site. Continued photographic monitoring is recommended as the severity and extent of defoliation by the tamarisk beetle is expected to increase in coming years.





# Introduction

Tamarisk (*Tamarix* spp.; aka salt cedar) is a large woody shrub that was introduced to the United States (U.S.) in the early 1800s for erosion control and horticulture. The species spread rapidly in the 1900s, expanding from 4,000 hectares (ha) in 1920 to more than 500,000 ha by 1970, and is now a dominant plant throughout riparian areas in the southwestern U.S. (Neill 1985, Gay and Fritschen 1979). Tamarisk is highly drought- and salt-tolerant, and the species' rapid expansion in the early 20<sup>th</sup> century is attributed primarily to the alteration of natural, dynamic river flows following construction of large dams and water diversion projects in the western U.S. (Di Tomaso 1998, Everitt 1998). The subsequent drying and salinization of riparian ecosystems, in addition to other disturbances such as grazing, reduced recruitment of native vegetation and created conditions favorable for rapid colonization by tamarisk (Di Tomaso 1998). Tamarisk has a deep tap root, reaches four to eight meters in height, and frequently expands into dense monotypic stands to the exclusion of native vegetation.

The decline of native riparian vegetation and the corresponding loss of biodiversity resulting from tamarisk invasion are two of the factors that prompted the initiation of efforts to eradicate the species (Di Tomaso 1998, Shafroth et al. 2005). Additionally, tamarisk was reported to cause streamflow depletion, increased soil salinization, increased fire severity, and degradation of wildlife habitat (Johnson 1987, Di Tomaso 1998, Shafroth et al. 2005). However, traditional methods to remove tamarisk, such as herbicides, fire, or mechanical treatment, were only marginally successful and often negatively impacted the riparian ecosystem (Shafroth et al. 2005, Harms and Hiebert 2006).

The search for an economical and effective method of controlling and eradicating tamarisk eventually led to the initiation of a biological control program. The tamarisk beetle (*Diorhabda* spp.) defoliates tamarisk, eliminating the plant's ability to photosynthesize, repeatedly over multiple growing seasons. This repeated defoliation can eventually lead to plant mortality. The U.S. Department of Agriculture (USDA) approved the release of the exotic tamarisk beetle in 2001, after laboratory and field testing concluded that the beetle would only defoliate tamarisk and that dispersal would be limited to only 1-2 kilometers (km) per year (yr<sup>-1</sup>) (DeLoach and Tracy 1997, Tracy and Robins 2009). After an initial caged release, the tamarisk beetle was introduced in multiple watersheds throughout the southwestern United States.

Adult tamarisk beetles emerge from diapause in the spring and immediately begin feeding and mating. Females lay 10 to 20 eggs per day on tamarisk foliage, with total production ranging from 300 to 500 eggs per female. Eggs hatch in approximately seven days, and then go through three instar larval stages of approximately four to seven days each. Upon completion of the third instar stage, the larvae drop to the ground where they enter a 7 to 10 day pupal stage and then emerge as adult beetles. Adults live for two to four weeks and typically produce two to five generations per year. All larval and adult stages feed on tamarisk foliage. Adults drop to the ground and burrow into the soil or leaf litter in autumn, enter diapause, and overwinter there (DeLoach et al. 2003; Lewis et al. 2003).

The tamarisk beetle was indeed highly successful at defoliating tamarisk and had limited impact on non-target plant species (Moran et al. 2009). However, the tamarisk beetle spread through riparian systems far more rapidly than predicted, resulting in defoliation of large expanses of tamarisk

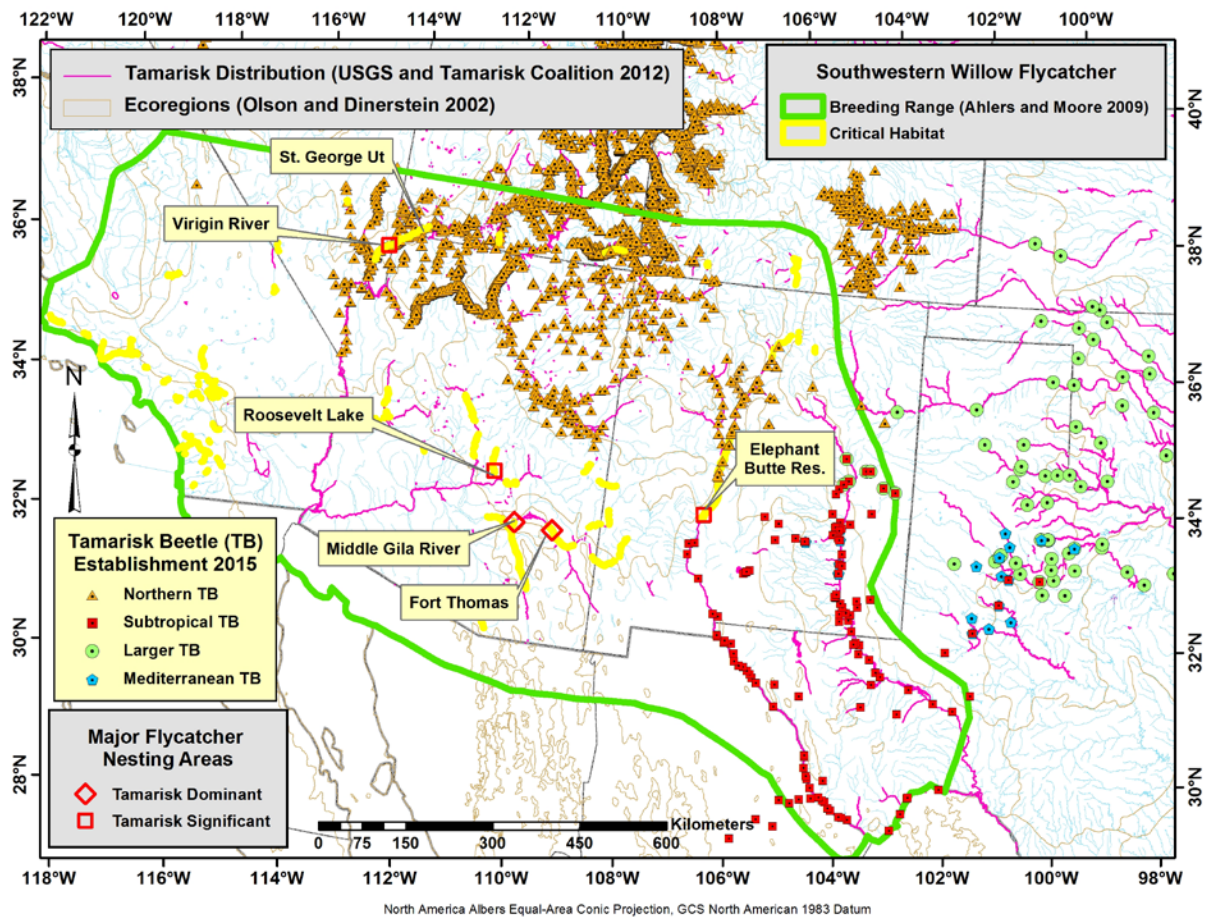
## Introduction

(Dudley and Bean 2012). While this was effective for tamarisk control, there were unforeseen ecological consequences. The pre-release projections of tamarisk beetle dispersal rates led to the belief that native vegetation would replace tamarisk as the beetle slowly defoliated one area and moved along the riparian corridor. Instead, in many instances altered hydrology prevents the immediate re-establishment of native vegetation, or the tamarisk beetle simply defoliates tamarisk much more quickly than native vegetation can regenerate (Paxton et al. 2011). This rapid defoliation of tamarisk without replacement by native vegetation has negatively impacted riparian breeding birds, which are left with drastically reduced or absent nesting habitat, particularly in areas characterized by monotypic tamarisk stands.

The Southwestern Willow Flycatcher (*Empidonax traillii extimus*; SWFL) is one of the most notable avian species to be negatively impacted by tamarisk beetle defoliation, and concern for the species' welfare has led to the cessation of tamarisk beetle releases in many areas (Hultine et al. 2010; Dudley and Bean 2012). Moreover, in August 2017 the U. S. District Court of Nevada ruled that the USDA tamarisk beetle release program is in violation of the Endangered Species Act for its failure to create a concurrent conservation program for the SWFL. The Southwestern Willow Flycatcher is a State- and Federally-listed endangered subspecies of the Willow Flycatcher (*Empidonax traillii*). It is an insectivorous, Neotropical migrant that nests in dense riparian vegetation in the southwestern United States. Southwestern Willow Flycatchers commonly nest in tamarisk, and some SWFL breeding habitat is composed predominately or exclusively of tamarisk. SWFLs typically arrive on their breeding grounds between early May and early June; between late July and mid-August they depart for wintering areas in Mexico, Central America, and northern South America (Sogge et al. 1997, USFWS 2002). The SWFL's brief breeding season coincides with the peak of tamarisk defoliation by the tamarisk beetle.

In October 2005, the United States Fish and Wildlife Service (USFWS) designated Critical Habitat for the SWFL along the Middle Rio Grande between the Isleta Pueblo and Elephant Butte Reservoir (USFWS 2005). The designation was updated in January of 2013 to include the Sevilleta and Bosque del Apache National Wildlife Refuges and a portion of the Elephant Butte Reservoir conservation pool. No critical habitat was designated downstream of Elephant Butte Dam (USFWS 2013), although the SWFL does breed there. The Rio Grande currently supports one of the largest breeding populations of Southwestern Willow Flycatchers in the United States.

Although the tamarisk beetle was not released on the Rio Grande in New Mexico, it was released on the Rio Grande in Texas, the Pecos River in New Mexico, as well as on the San Juan River in Colorado. It is likely tamarisk beetles dispersing from these locations that are now being detected along the Rio Grande in New Mexico. Beginning in 2016, the beetle was detected throughout the river corridor from north of Albuquerque, NM to Texas, following several years of intermittent tamarisk beetle detections along the Rio Grande in New Mexico. Currently, all four tamarisk beetle sub-species have colonized New Mexico, although only one sub-species was intentionally released in the state (Fig. 1). Although the beetle was detected at sample locations throughout the Rio Grande in 2016 and 2017, the population still consisted of multiple, disconnected patches and was not found in all tamarisk continuously throughout the Rio Grande.



**Figure 1.** Distribution of the tamarisk beetle by species in 2015 (Tracy 2017).

Reclamation began a photographic monitoring study of the impacts of the tamarisk beetle on Southwestern Willow Flycatcher habitat in 2015. The objectives of the study were to monitor and quantify defoliation by the tamarisk beetle over time, and the effects of that defoliation on canopy closure and vegetation composition in SWFL breeding habitat.

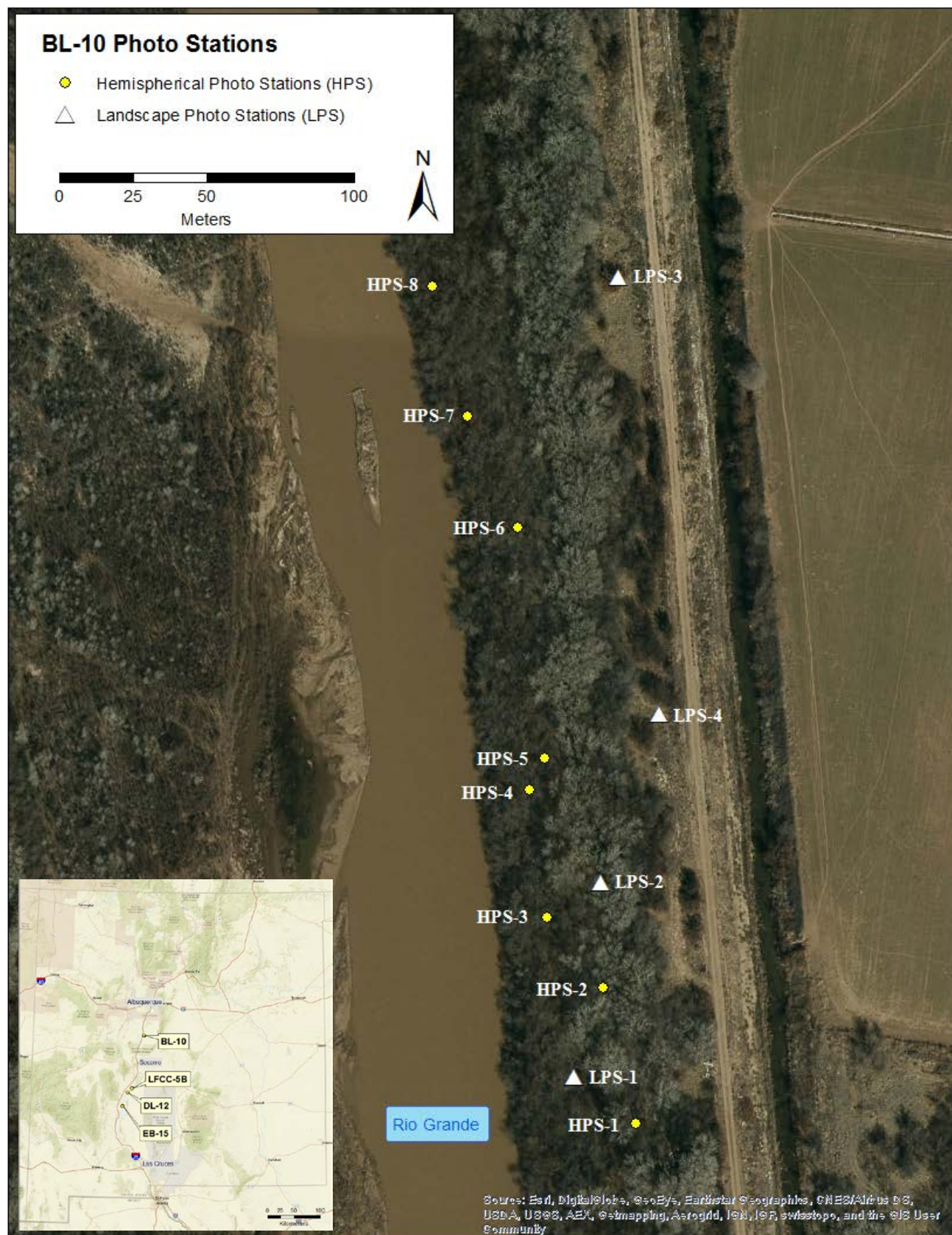
# Methods

## Study Area

Eighteen hemispherical photography stations and 10 landscape photography stations were established at 2 occupied SWFL study sites in the Middle Rio Grande in 2015, one site in the Belen Reach (BL-10) and one site in the San Marcial Reach (DL-12; Fig. 2 and Fig. 3). The study was expanded in 2016 with the addition of eight hemispherical and three landscape photography stations at a third study site (LFCC-5B; Fig. 4), and again in 2017 with the addition of nine hemispherical and four landscape photography stations at a fourth site (EB-15; Fig. 5). However, LFCC-5B was severely burned in late June 2017 in the Tiffany fire, prior to the third sampling period, leaving minimal suitable SWFL habitat.

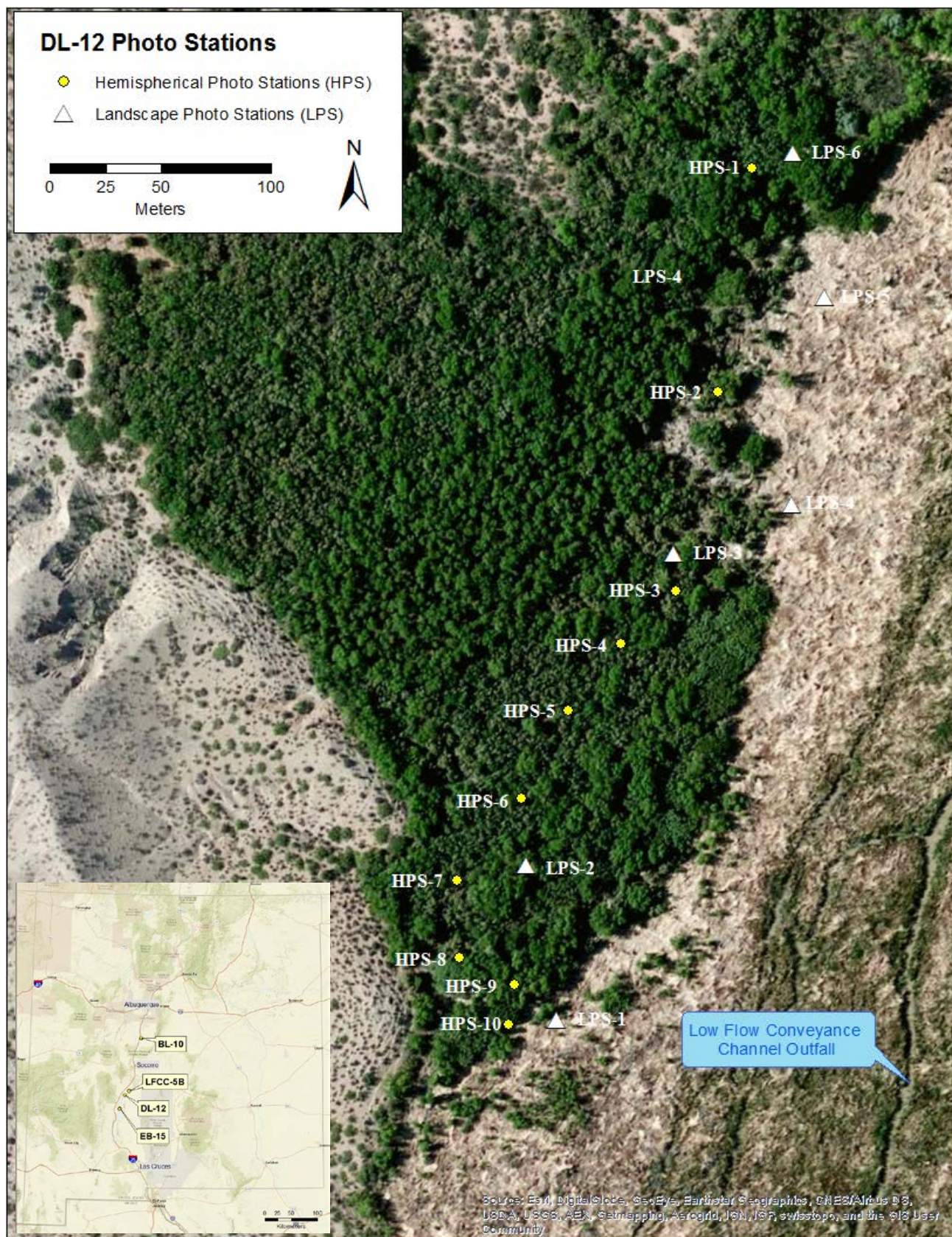
The photo stations in BL-10 and EB-15 were located within the active floodplain of the Rio Grande, and the stations in DL-12 and LFCC-5B were located west of the Low Flow Conveyance Channel (LFCC) and LFCC Outfall. All sites included in this study have consistently supported breeding Southwestern Willow Flycatcher territories throughout many years of SWFL occupancy monitoring (Moore and Ahlers in press).





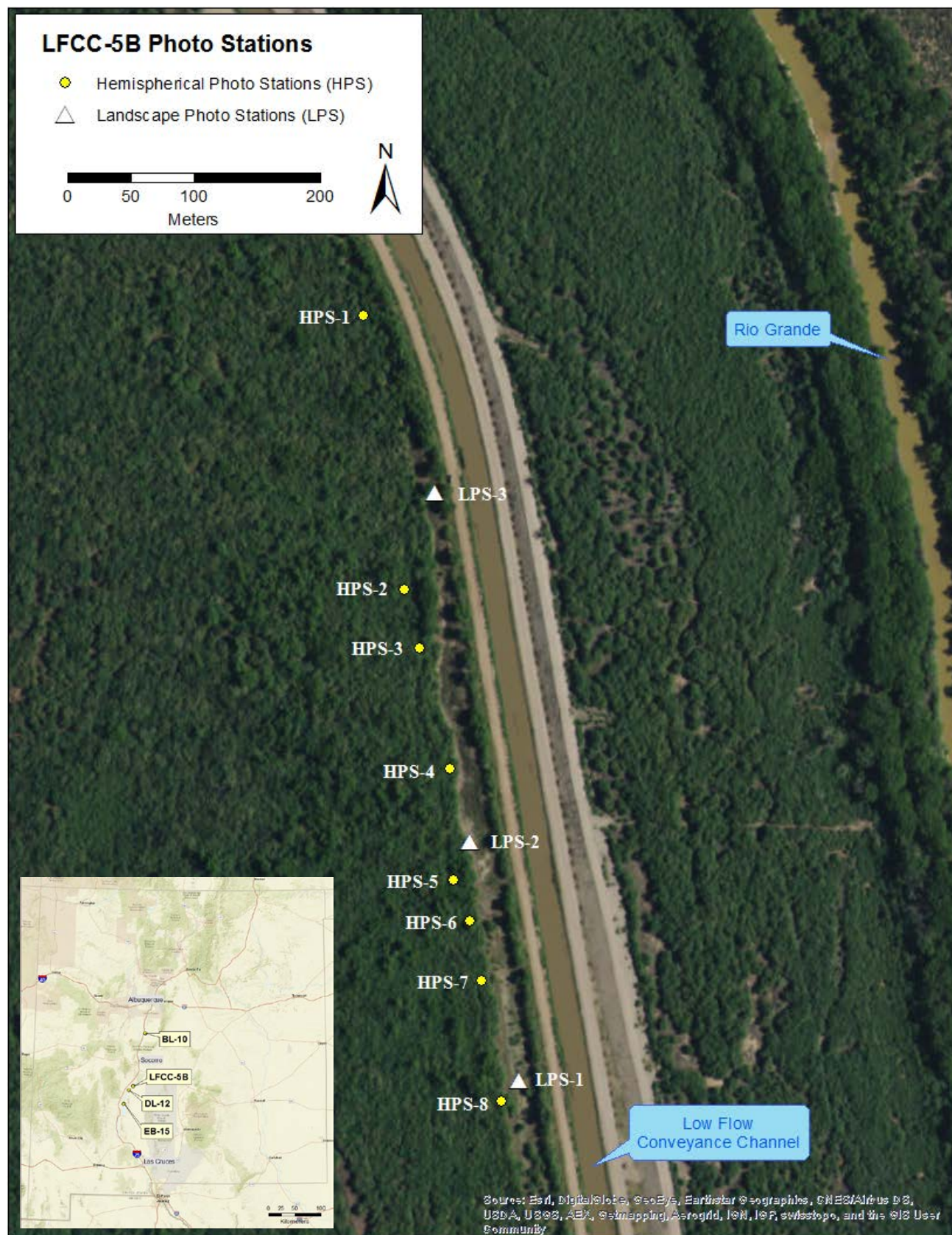
**Figure 2.** Hemispherical and landscape photography stations in site BL-10.





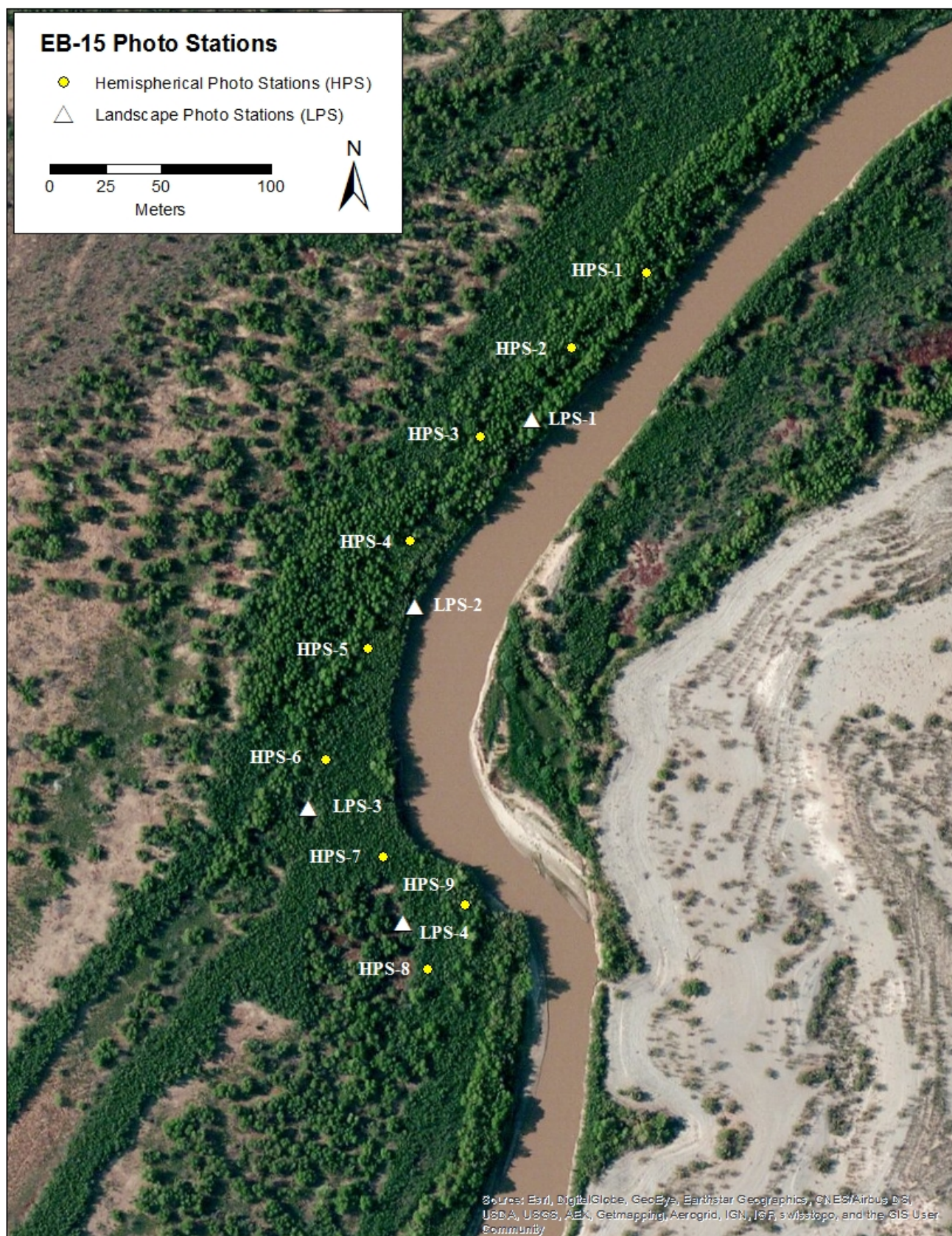
**Figure 3.** Hemispherical and landscape photography stations in site DL-12.





**Figure 4.** Hemispherical and landscape photography stations in site LFCC-5B.





**Figure 5.** Hemispherical and landscape photography stations in site EB-15.



## Hemispherical Photography

Hemispherical photographs were taken with a digital camera fitted with a Sigma EX DC 4.5 millimeter (mm) circular fisheye lens aimed upwards towards the vegetation canopy. A circular fisheye lens is a type of wide-angle camera lens that produces an image with a 180 degree angle of view that is projected as a circle within the image frame. Photographs were taken from a fixed point marked by a T-post. All hemispherical photography stations were established directly below a previously active SWFL nest, or within an active SWFL territory (Attachment 1A).

HemiView software (v.2.1; Delta-T Devices 1999) was used to classify each pixel of the hemispherical images as sky or vegetation. This binary classification was repeated three times for each image, with the data analyst blind to the associated numerical result, to ensure repeatability of results. Photographs were reduced to 40 percent of their original radius for analysis, in an effort to focus only on changes in canopy cover and exclude dense woody substrate captured at the periphery of the fisheye image. All photographs were taken before sunrise, after sunset, or on a cloudy day to eliminate glare caused by the reflection of the sun on foliage that would impede the ability of the HemiView software to distinguish between sky and illuminated vegetation.

HemiView quantifies visible sky on a scale from zero to one. Percent canopy closure was calculated from this value by subtracting the amount of visible sky from 1 and multiplying by 100. Canopy cover was then graphically compared among photo stations, survey sites, and years. However, two years of pre-tamarisk beetle colonization and one year of post-tamarisk beetle colonization data were considered to be insufficient to perform a robust statistical analysis of between-year change in canopy cover.

Vegetation species composition was visually estimated within a five meter (m) radius of every hemispherical photo station in 2016 and 2017. Vegetation species composition was estimated as species-specific percentages that were required to sum to 100 percent. This vegetation species composition estimation was added to our sampling to allow the examination of the impacts of tamarisk beetle defoliation within the context of variation in vegetation community composition, as well as to document changes in vegetation community composition over time.

## Landscape Photography

Landscape photographs were taken with a digital Canon A620 Powershot camera aimed inwards towards the vegetation community. Photographs were taken in a standardized compass direction at each point to ensure the repeatability of photographs. Photographs were taken from a fixed point marked by a metal tag. Landscape photography stations were established in close proximity to the hemispherical photo stations, and within or on the edge of SWFL breeding territories (Attachment 1B). The purpose of the landscape photography was to document changes in vegetation community composition, in association with beetle-induced die-back of tamarisk, as well as to document spatial and temporal variation in defoliation.

Photographs were taken twice at each landscape and hemispherical photography station between May and August in 2015 and 2016, and three times in 2017 (Table 1). Photographic sampling was timed to coincide with the SWFL breeding season and the period of tamarisk beetle activity. Starting in 2017, sampling will occur annually in mid-May, mid-June, and late-July, with sampling date standardized within sites across years. Multiple photographs were taken per year in order to ultimately enable a comparison of the potential impacts of defoliation by the tamarisk beetle within and among years. Additionally, dormant season hemispherical photographs were taken at all sites except EB-15 (not yet established) in March 2017, in order to provide a basis with which to distinguish woody from vegetative cover. Dormant season photographs will be taken annually, if resources allow, in order to document changes in woody substrate.

**Table 1.** Annual photographic sampling dates by study site.

Survey Site	<u>2015</u>			<u>2016</u>		<u>2017</u>		
	Early Season	Mid Season	Late Season	Mid Season	Late Season	Early Season	Mid Season	Late Season
BL-10	14 May	22 June	N/A	8 June	30 July	18 May	8 June	30 July
DL-12	11 May	N/A	7 July	9 June	29 July	20 May	7 June	29 July
LFCC-5B	N/A	N/A	N/A	15 June	27 July	20 May	15 June	28 July
EB-15	N/A	N/A	N/A	N/A	N/A	21 May	11 June	1 August

## Microclimate Monitoring

Loss of canopy cover due to defoliation by the tamarisk beetle could impact breeding willow flycatchers directly, through loss of nest concealment, or indirectly through higher temperatures or lower humidity that lead to higher thermoregulatory demand on adults, offspring, and developing embryos. In an effort to quantify changes in microclimate associated with tamarisk defoliation, Hygrochron™ iButton data loggers were deployed in all four study sites in May 2017. A data logger was affixed at breast height to a tree at all odd-numbered hemispherical photography stations ( $n = 18$ ). Hygrochrons™ were programmed to record ambient temperature and percent relative humidity every 30 minutes for the duration of the SWFL breeding season. They were downloaded and redeployed in August 2017.

# Results

## Hemispherical Photography

Tamarisk beetles were not observed at any hemispherical photo stations in 2015, and were detected at only one site (BL-10) in 2016. Therefore, 2015 and 2016 data (with BL-10 excluded in 2016) were used as baseline “pre-tamarisk beetle colonization” data for comparison to future years in data analysis. Additionally, defoliation was not observed in BL-10 in 2017 and canopy cover rebounded to the normal density and growth pattern for that site, providing acceptable baseline canopy cover data for 2017. When EB-15 was added as a study site in 2017, the tamarisk beetle was already present on the first sampling occasion but browning or defoliation was not yet evident. Therefore, the first sampling period of 2017 in EB-15 was included in analyses of pre-defoliation data as an indicator of baseline (i.e., pre-tamarisk beetle) conditions in that site. Furthermore, baseline canopy closure in EB-15 was found to be very similar to LFCC-5B, and therefore the latter is considered to provide a reasonable pre-defoliation reference for EB-15. Data from 2017 was used to investigate the magnitude of change in canopy cover resulting from tamarisk beetle colonization, i.e., “post-tamarisk beetle colonization”. Defoliation was observed throughout DL-12 and EB-15 in 2017, but not in BL-10 or LFCC-5B. Given this, BL-10 and LFCC-5B served as control sites in 2017 such that they were monitored in the time periods before and after tamarisk beetle arrival but were not impacted in the first year after arrival (Table 2). In Table 2, a site “not impacted” by the tamarisk beetle was never impacted by defoliation either in the years before (‘pre’) or after (‘post’) colonization of the study area as a whole, whereas an “impacted” site was eventually defoliated upon colonization of the study area by the beetle. For example, LFCC-5B was not impacted by tamarisk beetle defoliation in 2016 *or* 2017, even though the majority of the Rio Grande study area was colonized in 2017—thus, LFCC-5B served as a control site. On the other hand, DL-12 was not impacted in 2015 or 2016 (because the study area had not yet been colonized) but *was* defoliated in 2017 upon colonization of the study area by the beetle—thus, DL-12 was an impacted site. In other words, we used a before (pre-colonization)-after (post-colonization)-control (not impacted)-impact (impacted) study design (BACI).

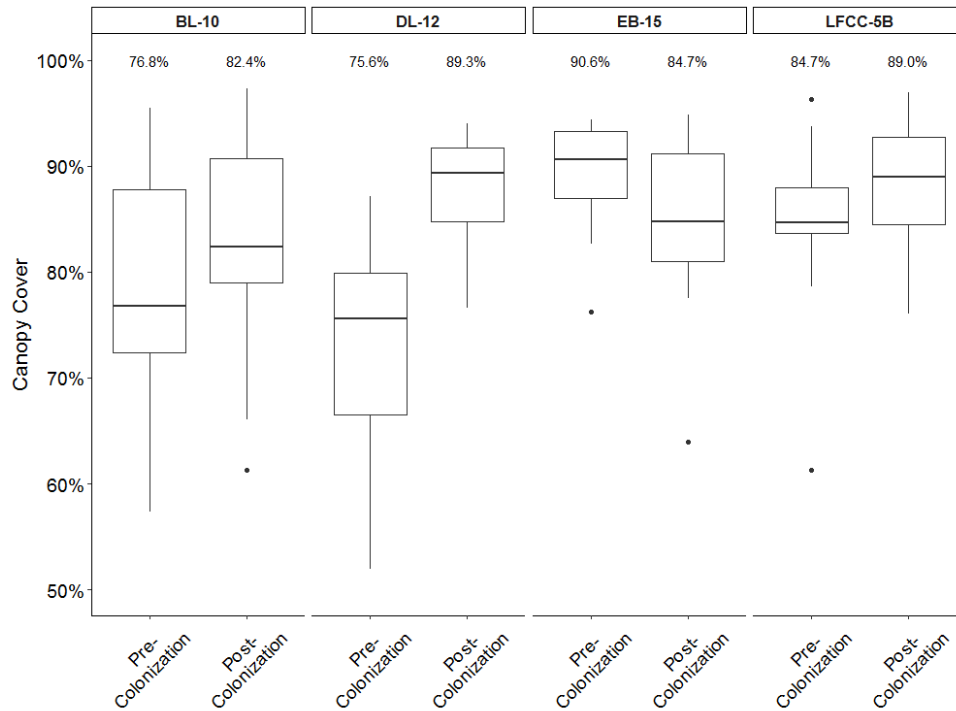
**Table 2.** Tamarisk beetle impact monitoring study design.

	Pre-Tamarisk Beetle Colonization	Post-Tamarisk Beetle Colonization
<b>Not Impacted by Tamarisk Beetle</b>	BL-10*: 2015 LFCC-5B: 2016	BL-10: 2017 LFCC-5B: 2017
<b>Impacted by Tamarisk Beetle</b>	DL-12: 2015, 2016 EB-15: (2017, 1st sample*)	BL-10: 2016 DL-12: 2017 EB-15: 2017

\*EB-15 was first added as a study site in 2017 and therefore the first sample period of that year, prior to tamarisk browning or defoliation, was the only available baseline data from within the site. However, LFCC-5B is a suitable reference site for EB-15 given their baseline similarities in canopy cover. BL-10 was impacted by the tamarisk beetle in 2016 only and had fully recovered in 2017, and therefore provided reference data in 2015 and 2017.

## Results

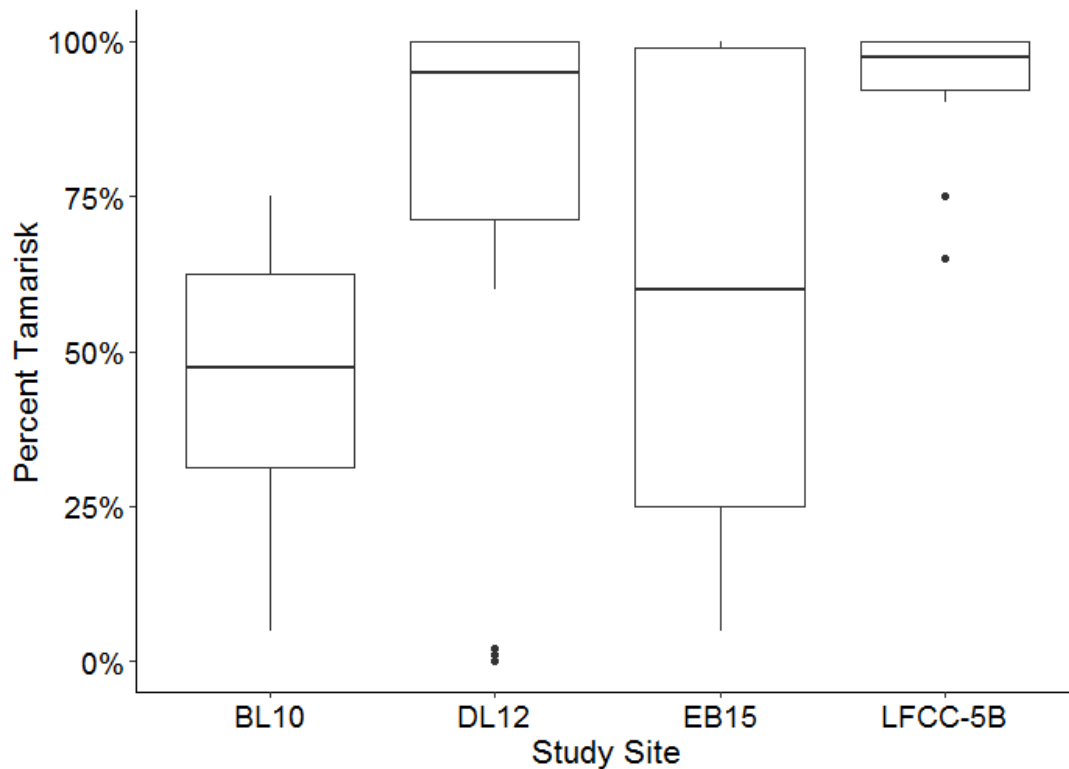
Median site-wide canopy closure prior to the colonization by the tamarisk beetle was highest in EB-15 (91%;  $n = 9$ ) and LFCC-5B (85% %,  $n = 16$ ), when summarized across all pre-tamarisk beetle sampling occasions (Fig. 6). Median canopy closure in BL-10 (77%;  $n = 16$ ) was similar to DL-12 (76%;  $n = 20$ ) prior to colonization by the tamarisk beetle, and both sites exhibited considerably higher variation in canopy closure when compared to the other two study sites.



**Figure 6.** Canopy closure by study site pre- and post-colonization by the tamarisk beetle. Median canopy closure values are listed above each boxplot.

Median site-wide canopy closure after colonization by the tamarisk beetle in 2017 was approximately 82 to 89 percent in all sites, regardless of whether the tamarisk beetle was present in that site. This represented an increase in canopy closure in DL-12 (impacted) compared to the previous years, and nearly no change in BL-10 (control), LFCC-5B (control), and EB-15 (impacted) (Fig. 6). These data suggest that between-year variations in cover in association with defoliation by the tamarisk beetle were confounded by the inherent increase in canopy cover in all sites in 2017, perhaps due to high and persistent river flows, compared to previous years.

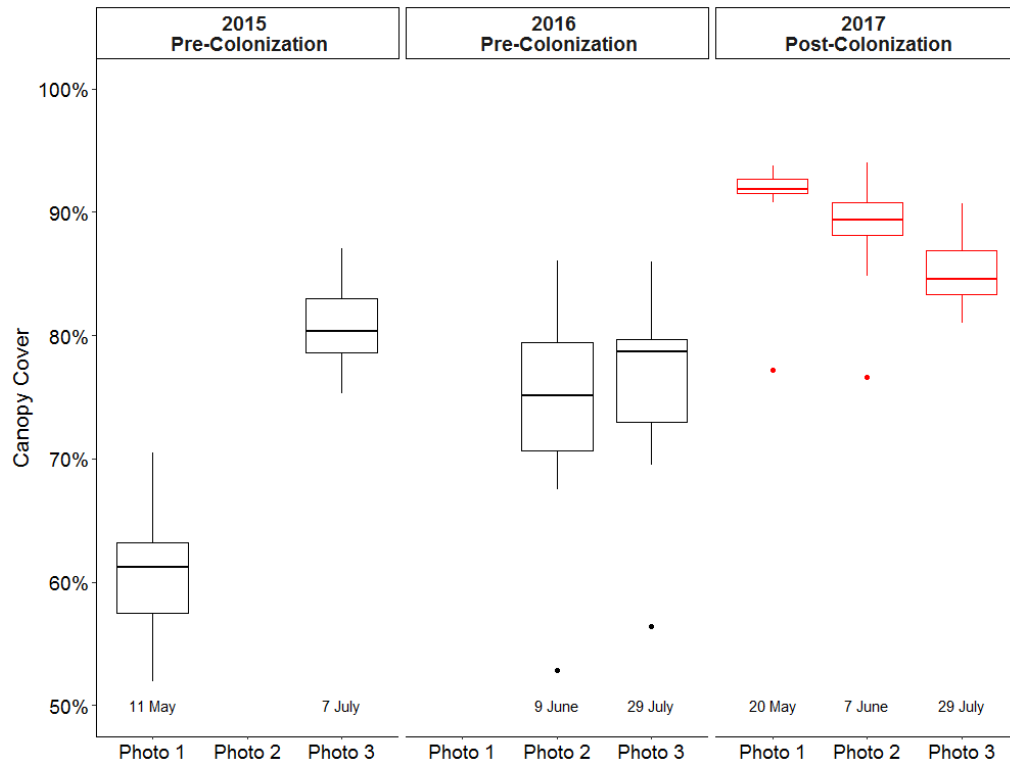
Vegetation composition was estimated at each hemispherical photography station once annually in 2016 and 2017. The median percentage of the vegetation community composed of tamarisk was twice as high in DL-12 (95%) and LFCC-5B (97.5%) as in BL-10 (47.5%; Fig. 7). The majority of the remaining portion of the vegetation community in BL-10 was composed of Russian olive (*Elaeagnus angustifolia*). Tamarisk composed between 5 and 100 percent of the vegetation community at EB-15 photo stations ( $Mdn = 60\%$ ). In general, the proportion of the vegetation community composed of tamarisk increased from north to south in this site, such that stations 1 through 4 were less than 50 percent tamarisk, and stations 5 through 9 were greater than 50 percent tamarisk.



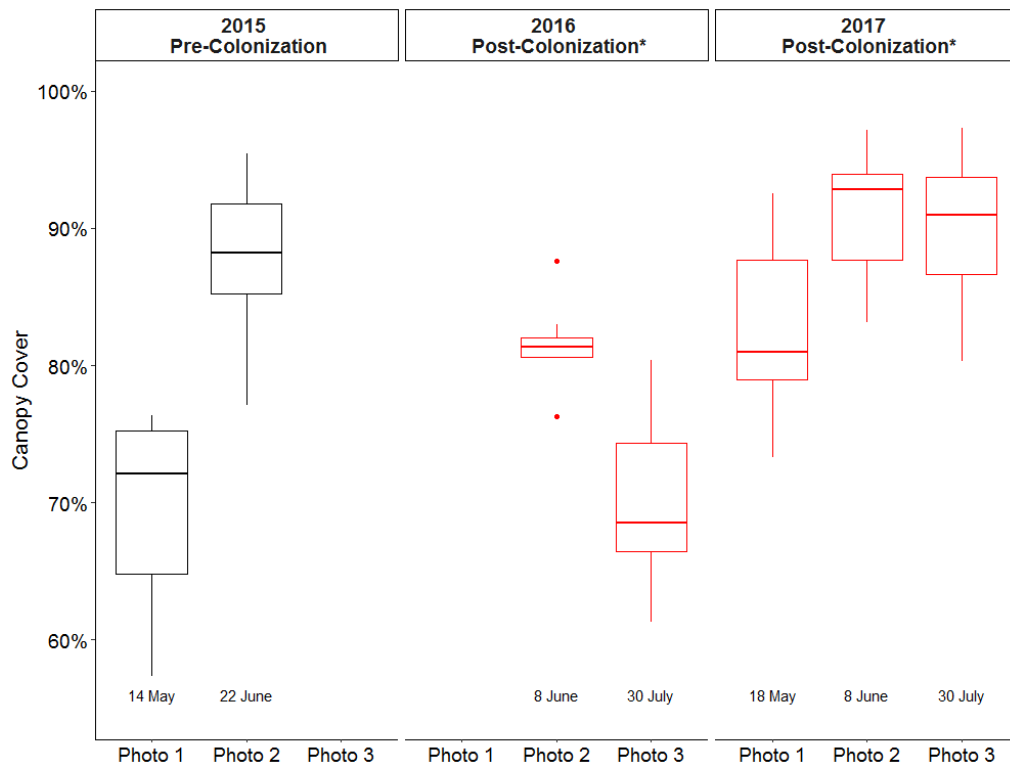
**Figure 7.** Percent of vegetation community within 5 m radius of hemispherical photo stations composed of tamarisk.

Hemispherical photos were taken in DL-12 and BL-10 in all three years of this study (Table 1). Canopy cover in the years prior to colonization by the tamarisk beetle followed a similar trend of increasing canopy cover between May and July, such that canopy cover was highest in June and July, in both sites regardless of between-year variation in absolute cover. However, in the years that each site was defoliated by the tamarisk beetle (BL-10 in 2016 and DL-12 in 2017) canopy cover steadily declined from May to July, rather than increasing. BL-10 was not impacted by the tamarisk beetle in 2017 and canopy cover increased during those same months, as had been observed prior to tamarisk beetle colonization (Fig. 8 & Fig. 9). Nevertheless, although severe tamarisk foliage death and defoliation was recorded in DL-12 in 2017 and a notable decline in canopy cover was observed, canopy cover remained within the apparent normal range of variation for both BL-10 and DL-12 during the year that they were impacted by the tamarisk beetle. The same patterns were observed in the other two study sites, such that canopy cover declined between May and July in EB-15 (impacted by the tamarisk beetle) but increased in LFCC-5B (not impacted; Attachment 2).

## Results



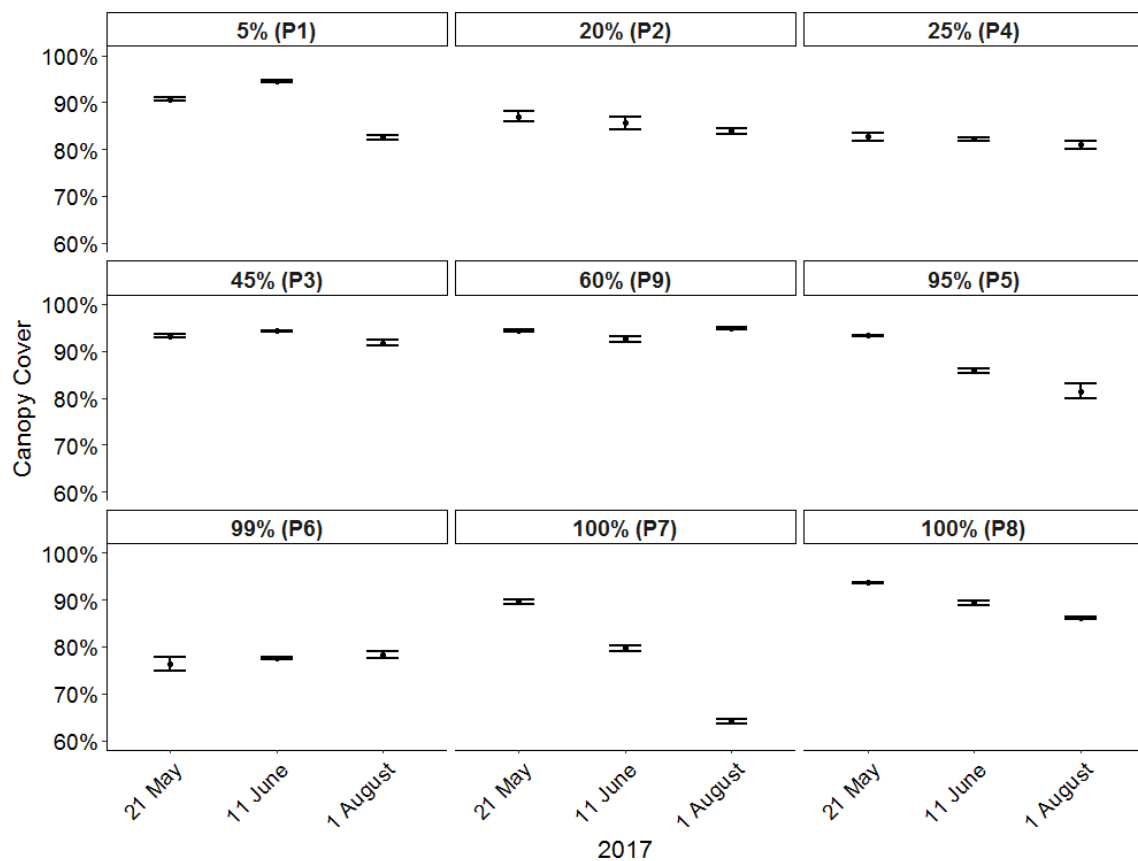
**Figure 8.** Trends in canopy cover at DL-12 pre- and post-colonization by the tamarisk beetle.



**Figure 9.** Trends in canopy cover at BL-10 pre- and post-colonization by the tamarisk beetle.

\*BL-10 was impacted by the tamarisk beetle in 2016, but recovered to pre-colonization canopy cover in 2017.

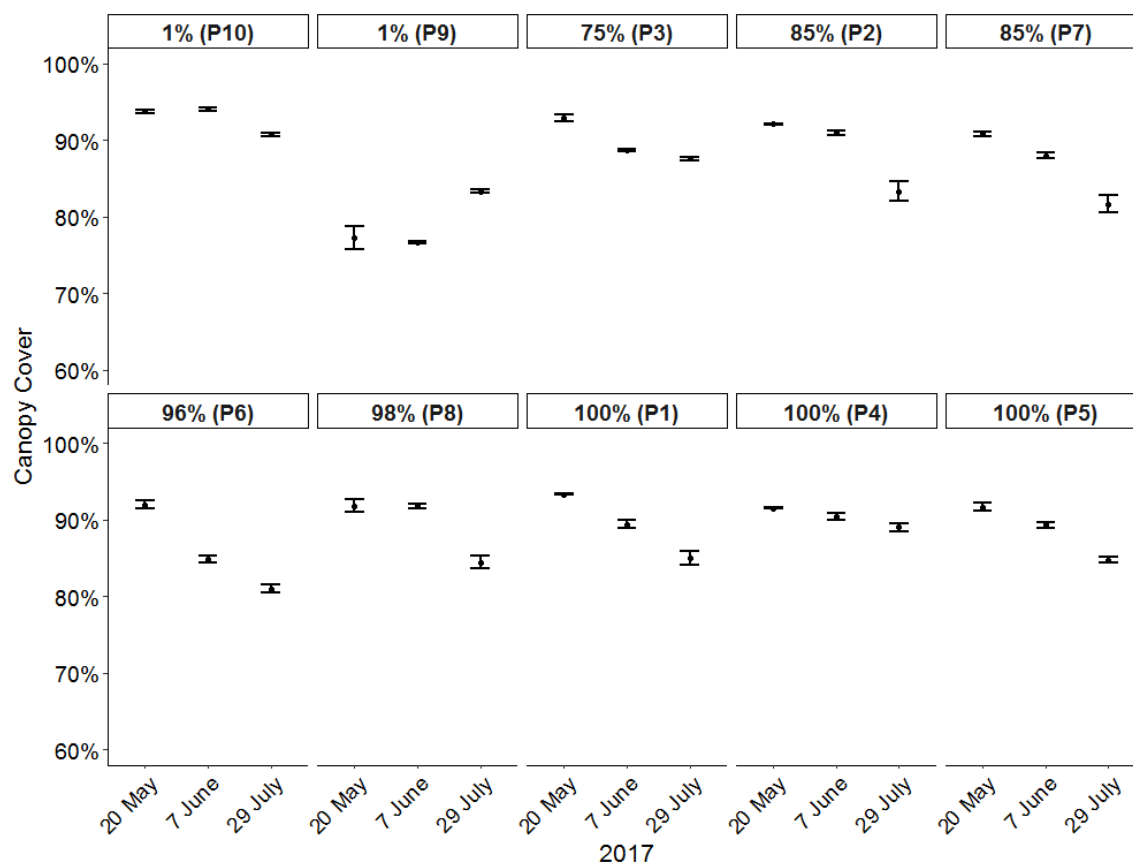
The two study sites impacted by the tamarisk beetle in 2017, DL-12 and EB-15, both exhibited extensive foliage death and defoliation. The impacts of tamarisk beetle defoliation were evident throughout EB-15 by the second sampling period in that site, and throughout DL-12 by the third sampling period. A plot of canopy cover by sample point within each site illustrates the loss of cover as the impact of the tamarisk beetle increased throughout the season (Fig. 10 & Fig 11). Sample points are plotted in order of increasing tamarisk dominance. Variation in the magnitude of canopy cover loss or, in some cases, the lack of apparent loss of cover between points generally reflects variation in tamarisk dominance between sample points. For example, points one through four and nine in EB-15 have a lower percentage of tamarisk compared to other species, whereas points five through eight are primarily tamarisk (Fig. 10). Similarly, canopy cover at point 9 in DL-12 increases rather than decreases over the sampling period—the vegetation community at that point is comprised of nearly 100 percent Goodding’s willow (Fig. 11). Sample points with lesser tamarisk dominance provide a reference for comparison of the effects of defoliation within a site. Canopy cover decreased by approximately 10 percent at tamarisk-dominated sample points in both study sites between May and July 2017, but a loss of 30 percent was documented at point 7 in EB-15 (Fig. 10, Fig. 11, Fig. 12).



**Figure 10.** Canopy cover at EB-15 hemispherical photo stations by sampling occasion.

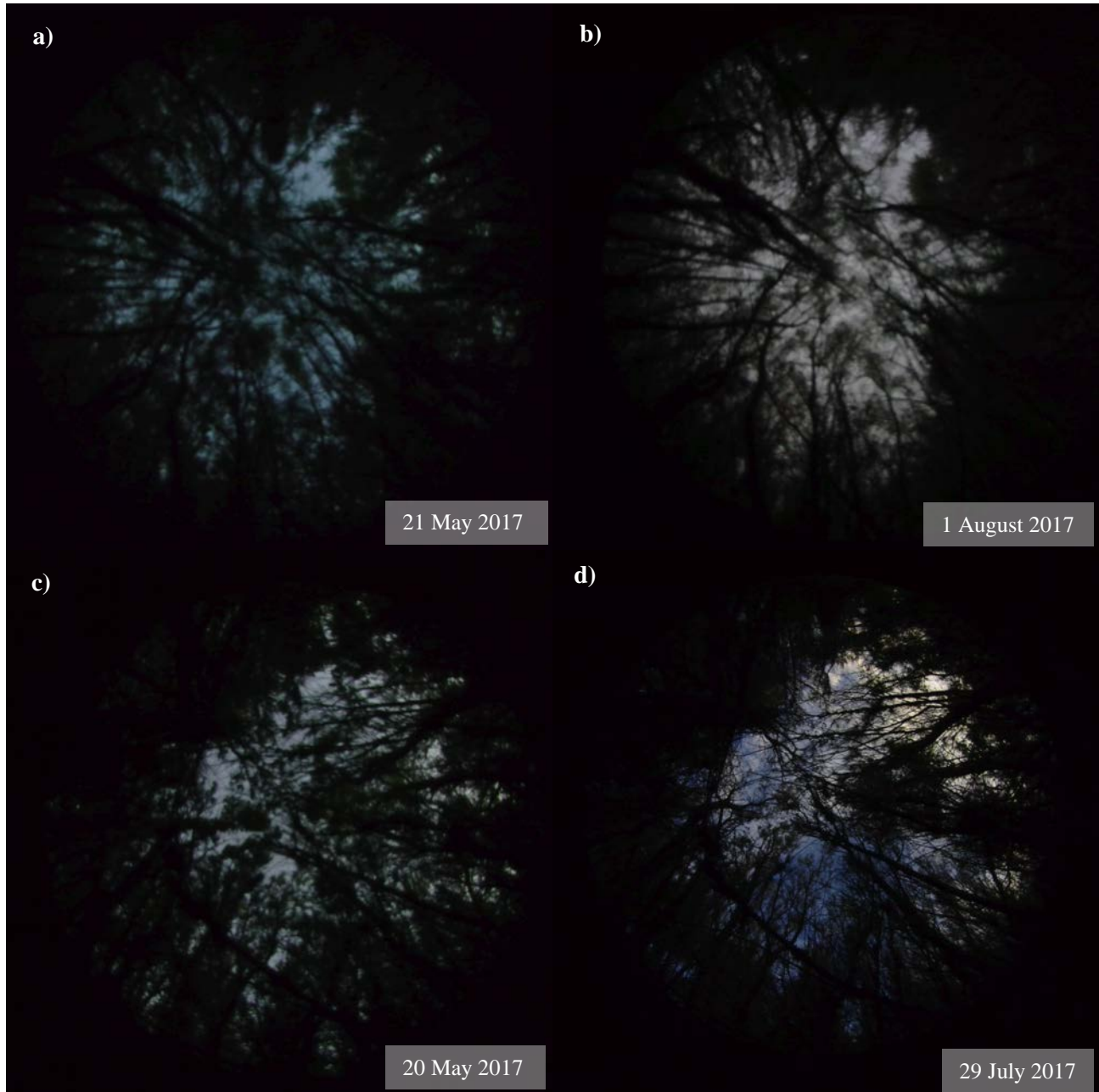
Subplot titles indicate the percentage of vegetation within a five meter radius of the point comprised of tamarisk, with the point number in parentheses. Error bars represent standard error of canopy cover calculated from three repeat classifications of each hemispherical photo.

## Results



**Figure 11.** Canopy cover at DL-12 hemispherical photo stations by sampling occasion. Subplot titles indicate the percentage of vegetation within a five meter radius of the point comprised of tamarisk, with the point number in parentheses. Error bars represent standard error of canopy cover calculated from three repeat classifications of each hemispherical photo.



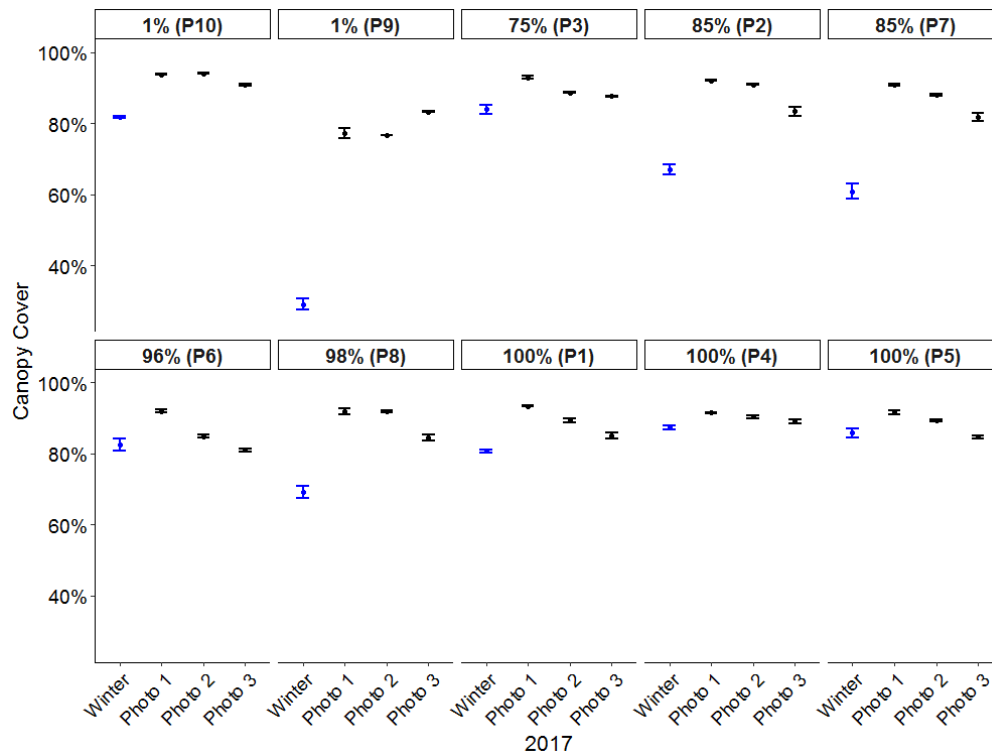


**Figure 12.** Hemispherical photography at EB-15 point 5 (a, b) and DL-12 point 6 (c, d).

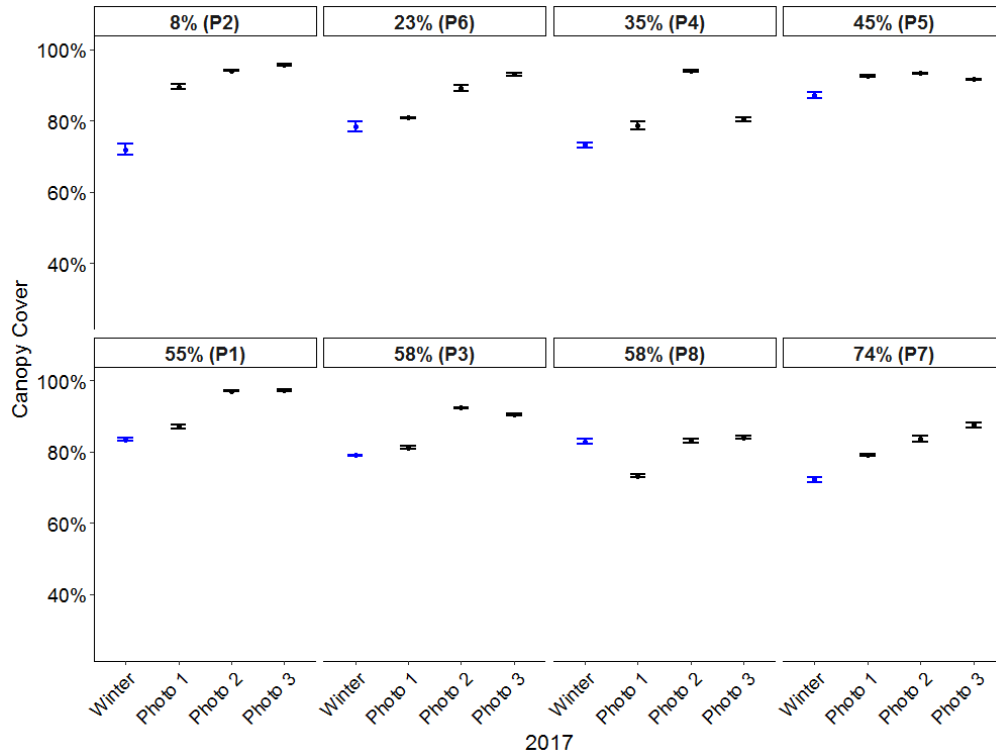
Hemispherical photographs were taken prior to the 2017 growing season (i.e., “winter”) at DL-12, BL-10, and LFCC-5B. A paired t-test found that, as expected, winter canopy cover was significantly lower than June or July 2017 (Photo 2 or Photo 3) canopy cover in all three study sites (Photo 2: BL-10:  $t = 4.8$ ,  $df = 7$ ,  $p = 0.002$ ; LFCC-5B:  $t = 5.8$ ,  $df = 7$ ,  $p = 0.001$ ; DL-12:  $t = 3.4$ ,  $df = 9$ ,  $p = 0.01$ ). However, the difference between winter and July canopy cover in DL-12 was only marginally significant, a testament to the impact tamarisk beetle defoliation had on canopy cover in that site ( $t = 2.3$ ,  $df=9$ ,  $p = 0.05$ ). Indeed, a plot of canopy cover by sample point revealed that canopy cover at several of the most tamarisk-dominant points in DL-12 declined to near winter lows (Fig. 13). When

## Results

the analysis was constrained to include only sample points comprised of greater than 75 percent tamarisk, the difference between winter and July canopy cover in DL-12 was not statistically significant ( $t = 2.3$ ,  $df = 6$ ,  $p = 0.06$ ). On the other hand, canopy cover at all BL-10 points (not impacted by the tamarisk beetle) increased above winter levels throughout the growing season, as would be expected. The relatively small variation in canopy cover between the dormant and growing season in all sites, however, suggests that woody mass comprises a great deal of the overall canopy cover in these densely vegetated riparian study sites. Moreover, 2017 winter canopy cover in BL-10 and DL-12 was higher than growing season canopy cover in those sites in 2015 or 2016, suggesting that significant growth occurred between July 2016 and March 2017 (Attachment 2). The only meaningful comparisons, therefore, were between winter 2017 and growing season 2017 canopy cover.



**Figure 13.** Canopy cover at DL-12 in the winter (blue) compared to the growing season. Subplot titles indicate the percentage of vegetation within a five meter radius of the point comprised of tamarisk, with the point number in parentheses. Error bars represent standard error of canopy cover calculated from three repeat classifications of each hemispherical photo.



**Figure 14.** Canopy cover at BL-10 in the winter (blue) compared to the growing season.

Subplot titles indicate the percentage of vegetation within a five meter radius of the point comprised of tamarisk, with the point number in parentheses. Error bars represent standard error of canopy cover calculated from three repeat classifications of each hemispherical photo.

## Landscape Photography

All landscape photographs were taken on the same dates as the hemispherical photographs in each study site (Table 1). The tamarisk beetle was not recorded at any study site in 2015. Tamarisk browning and defoliation by the tamarisk beetle were recorded at three of four landscape photography stations in BL-10 on the final sampling occasion (30 July) of 2016, but not in any other study site that year. Tamarisk browning and defoliation was observed at all landscape photography stations in DL-12 ( $n=6$ ) and EB-15 ( $n=4$ ) in 2017, and the tamarisk beetle was present in both sites on all three sampling occasions. The tamarisk beetle was present in the interior of EB-15 earlier in the season than in DL-12, and browning and defoliation at landscape photo stations in that site occurred earlier and over a longer time period than in DL-12 (Fig. 15). Indeed, by the third sampling period some foliage resprouting was observed in EB-15, and the tamarisk beetle was present on the resprouting plants. Defoliation was observed at all landscape photography stations in LFCC-5B ( $n=3$ ) during the third sampling period, and at two stations in BL-10 ( $n=4$ ) during the third sampling period. The defoliation in BL-10 was minimal and limited to the outer edge of the study site. The browning and defoliation in LFCC-5B was pervasive, but observed after the site was severely burned in the Tiffany fire leaving little unburned flycatcher habitat. The tamarisk beetle was observed in the scattered remnant patches of unburned tamarisk throughout LFCC-05B. A general pattern was observed in all sites of the tamarisk beetle colonizing the outer edges of the site first, and then moving towards the site interior.



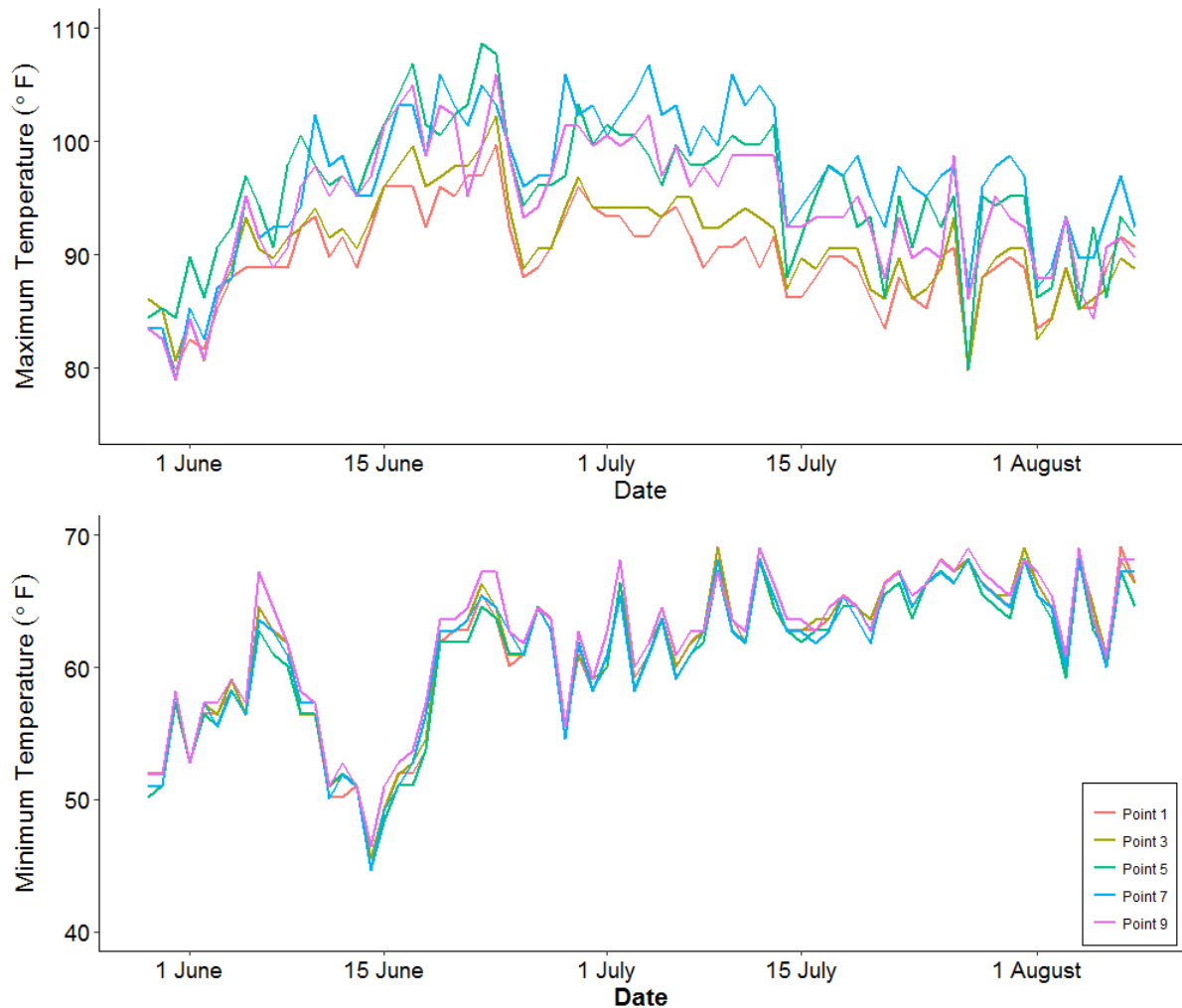
## Results



**Figure 15.** Seasonal progression of tamarisk browning and defoliation in DL-12 (column a) and EB-15 (column b) in 2017.

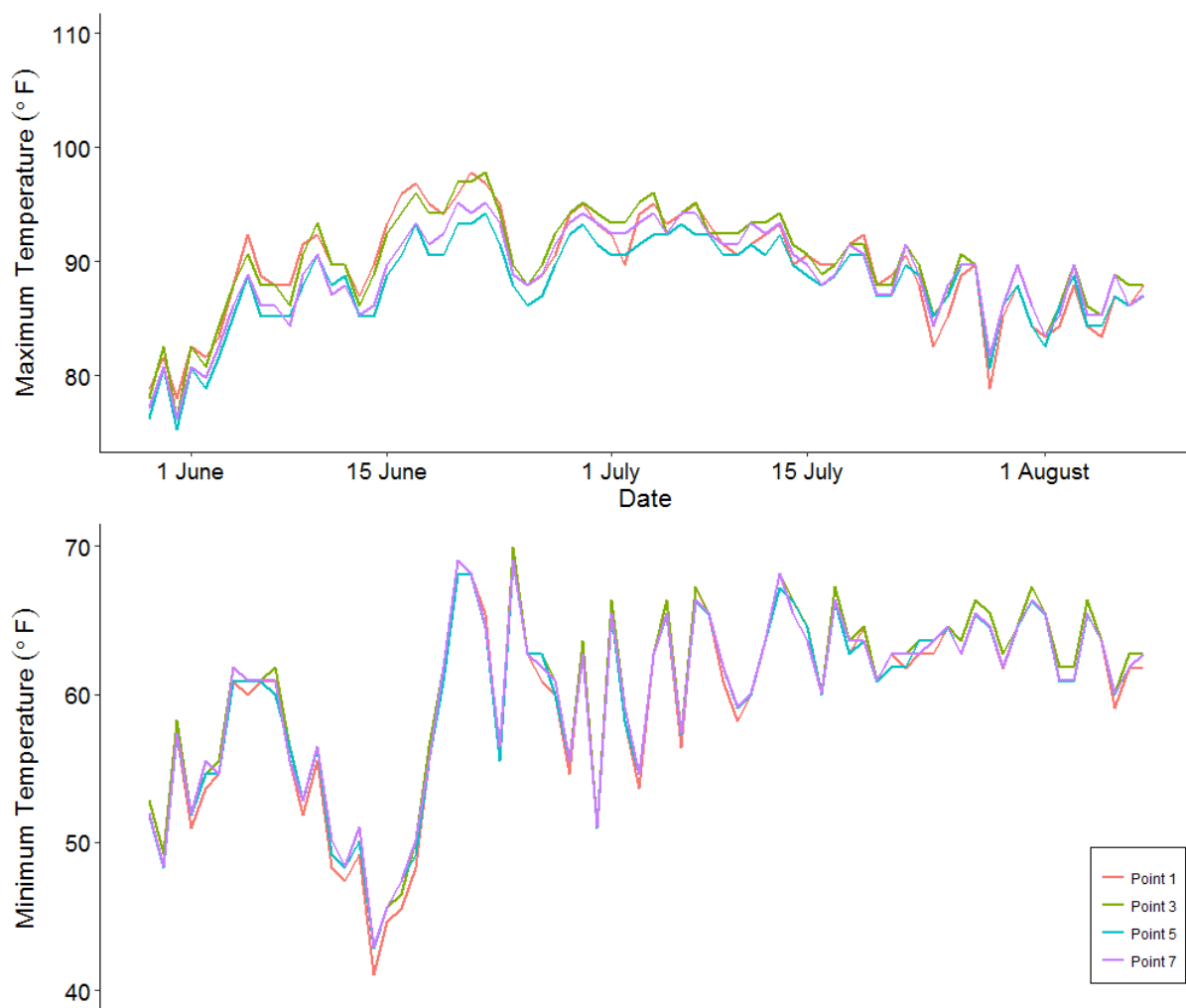
## Microclimate Monitoring

A notable difference in temperature variation was observed at hemispherical photography stations that were impacted by the tamarisk beetle and those that were not, both between and within study sites. Although Hygrochrons™ were deployed in all four study sites, all but one in LFCC-5B was destroyed in the fire and that site was therefore excluded from analysis. There was little variation in daily minimum temperature between hemispherical photography stations at sites that were impacted by the tamarisk beetle. However, daily maximum temperature varied considerably between points (Fig. 16). Similar patterns were observed in both impacted sites (DL-12 and EB-15). Comparison of temperature variation in sites impacted by the tamarisk beetle with BL-10, which was not impacted by the tamarisk beetle, show that large between-point variations in maximum temperature within a study site are not simply typical of a desert riparian ecosystem. Both minimum and maximum temperatures in BL-10 were very similar across sample points within the site throughout the season (Fig. 17).



**Figure 16.** Daily minimum and maximum temperature in EB-15 by hemispherical photo station during 2017 SWFL breeding season.

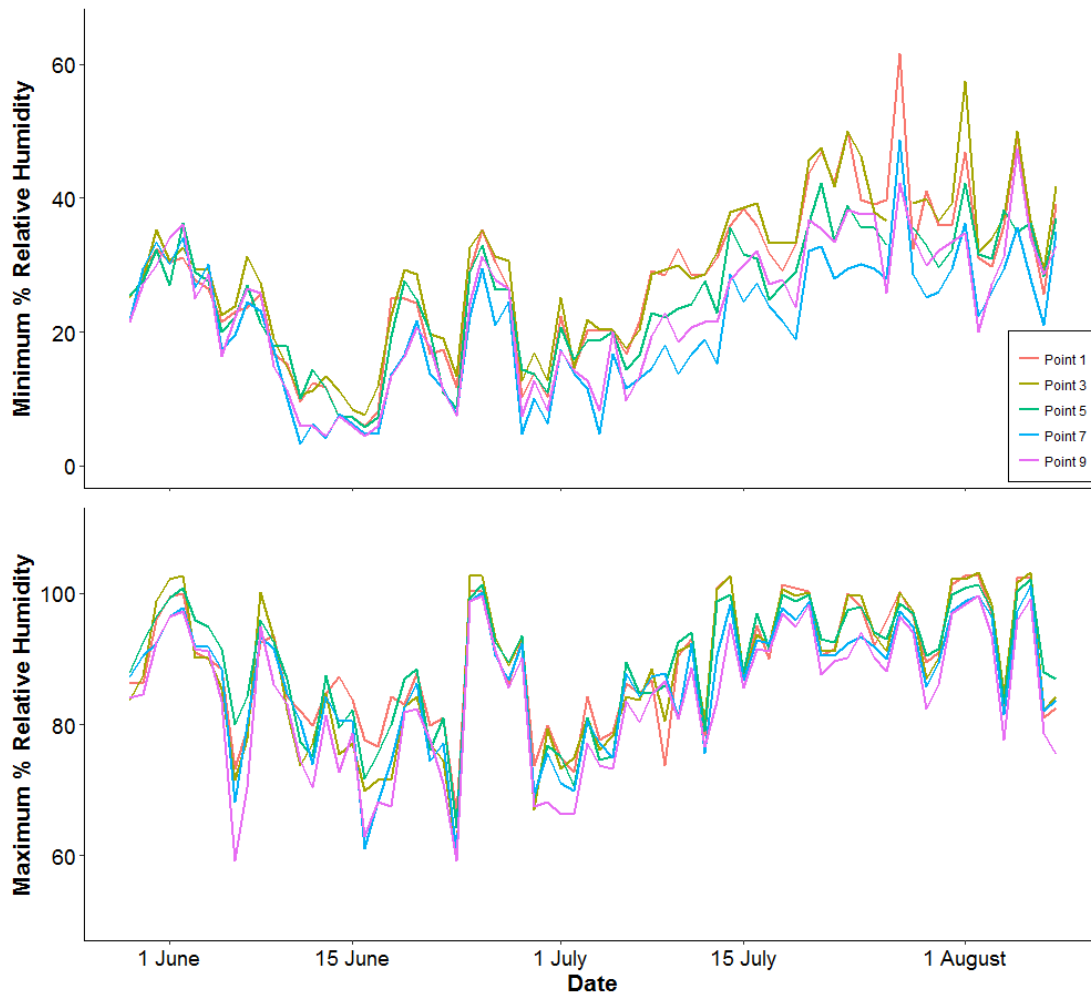
## Results



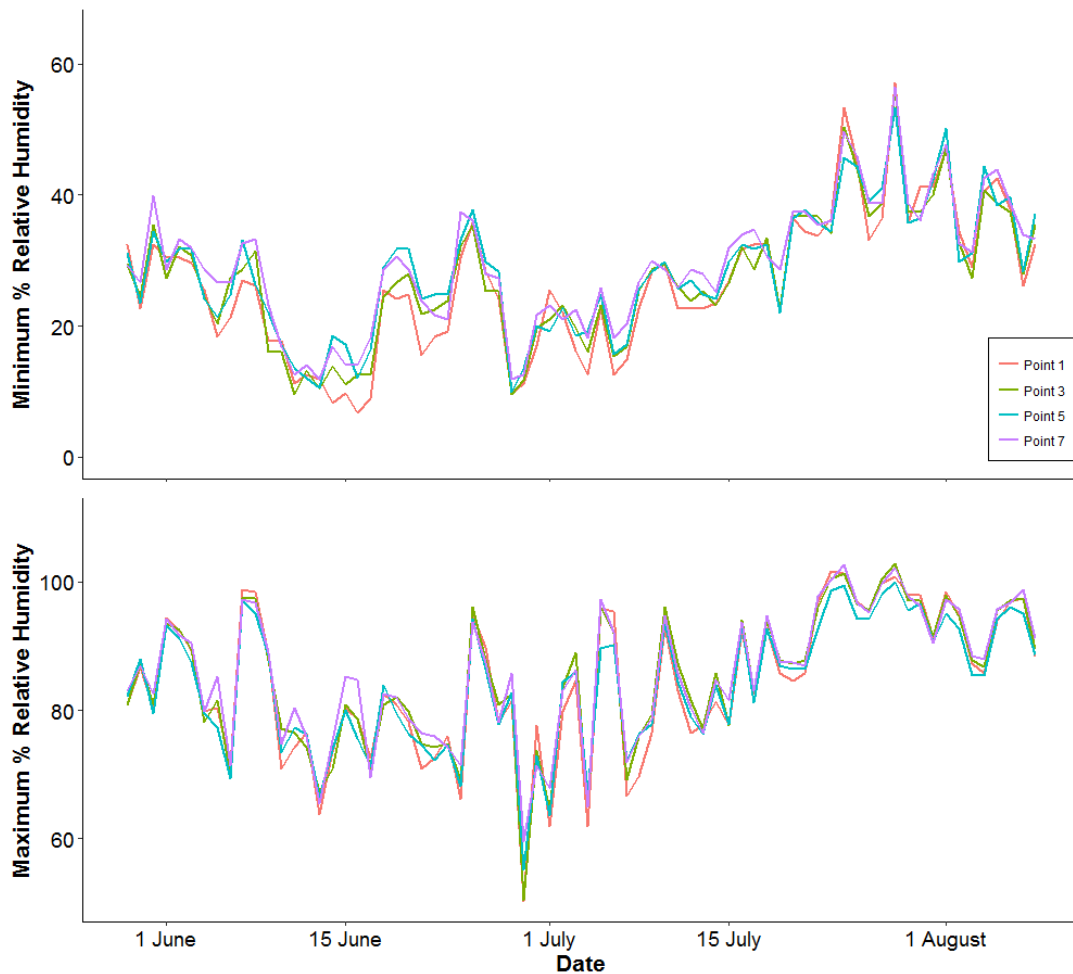
**Figure 17.** Daily minimum and maximum temperature in BL-10 by hemispherical photo station during 2017 SWFL breeding season.



Similar patterns in percent relative humidity were observed within and between study sites. Maximum percent relative humidity was generally consistent between points within a study site, whereas minimum percent relative humidity varied considerably between sample points in sites impacted by the tamarisk beetle (Fig. 18). Percent relative humidity reached the lowest levels at hemispherical photo stations five through nine, where percent tamarisk was the highest. As with temperature, this variation was not observed in the site not impacted by the tamarisk beetle (Fig. 19).



**Figure 18.** Daily minimum and maximum percent relative humidity in EB-15 by hemispherical photo station during 2017 SWFL breeding season.

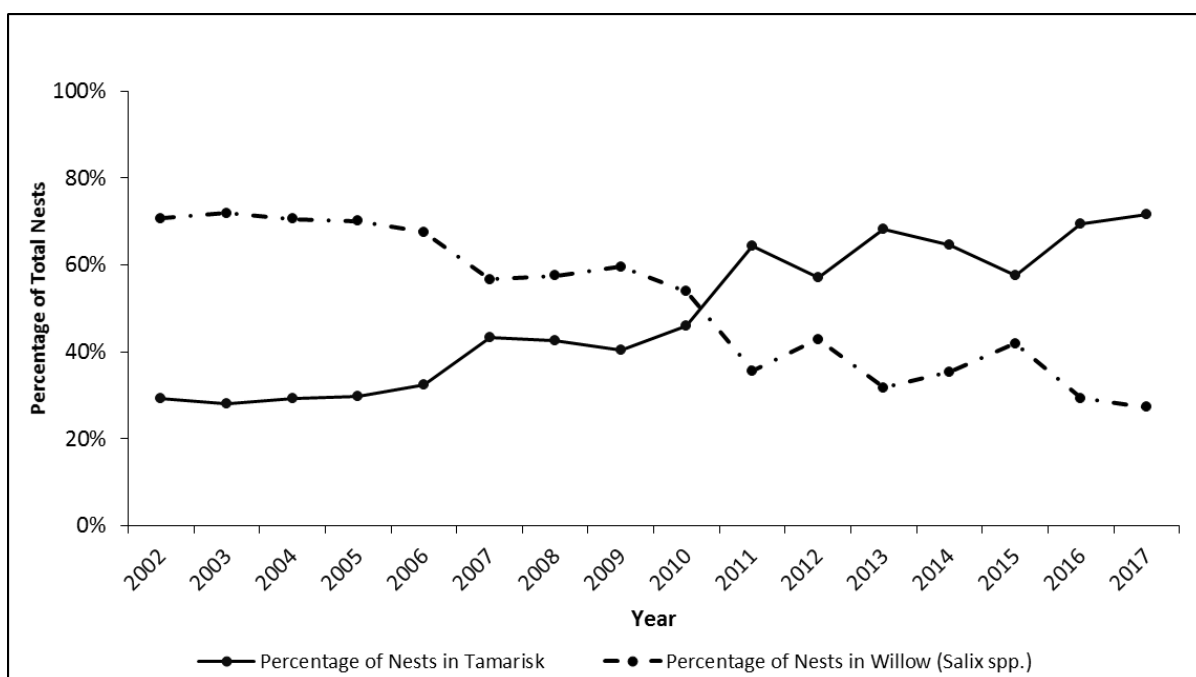


**Figure 19.** Daily minimum and maximum percent relative humidity in BL-10 by hemispherical photo station during 2017 SWFL breeding season.

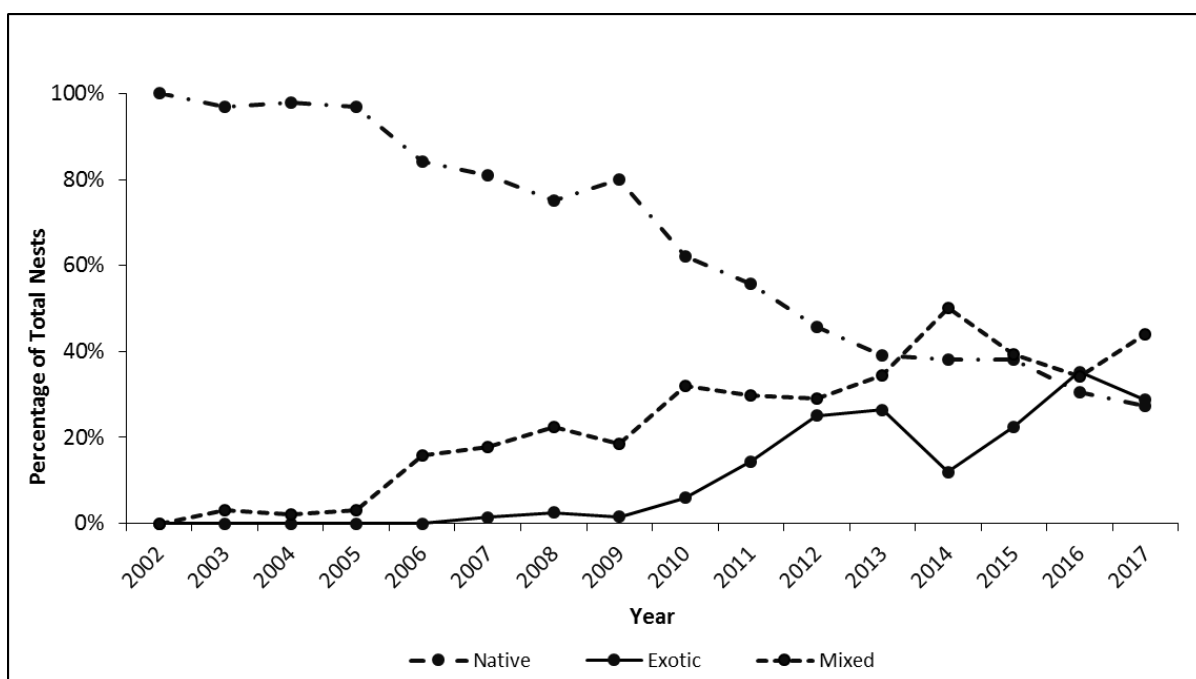
## Discussion

Tamarisk has become an important component of riparian bird habitat as drought and changes in hydrology have prompted the increased abundance of invasive vegetation and the loss of native vegetation in many riparian areas of the southwestern U.S. Indeed, more than 70 percent of SWFL nests located within the receded pool of Elephant Butte Reservoir, which supports the majority of the Middle Rio Grande population, were constructed in tamarisk in 2017 (Fig. 20). This is compared to 70 percent of nests constructed in native willow 15 years ago. Moreover, approximately three quarters of SWFL nests in Elephant Butte Reservoir were in breeding territories that were either dominated by exotic vegetation (primarily tamarisk) or a mix of native and exotic vegetation (Fig. 21). The high use of tamarisk by breeding SWFLs raises many questions regarding how defoliation of SWFL habitat by the tamarisk beetle will ultimately influence the recovery of this endangered species, and makes early and continuous monitoring of these impacts an important aspect of population management.





**Figure 20.** Percentage of SWFL nests constructed in native willow vs. invasive tamarisk. ( $n = 2807$ , range = 65-270 nests per year)



**Figure 21.** Percentage of SWFL nests constructed in territories dominated by native vs. exotic vs. mixed native and exotic vegetation. ( $n = 2807$ , range = 65-270 nests per year)

The tamarisk beetle was documented throughout the entire Rio Grande riparian corridor in 2016 and 2017 (Johnson pers.comm.; Tamarisk Coalition 2016). The subtropical and northern species of the tamarisk beetle were both found on the Middle Rio Grande, with the two populations converging in the vicinity of San Marcial. The northern tamarisk beetle is known to produce three generations in a single season, and the subtropical species produces four to five generations annually (Johnson pers.comm.). The beetle was still found in disconnected sub-populations rather than continuously throughout the riparian corridor, although the population expanded annually throughout this study. Indeed, the tamarisk beetle was not detected at any of the established photo stations in 2015 and only in one study site (BL-10) in 2016. However, the tamarisk beetle was detected at all hemispherical photography stations in two study sites in 2017, and at landscape photography stations in all four study sites.

The 2015 and 2016 data suggested an overall pattern of percent canopy cover reaching a seasonal maximum in approximately late June to early July. This apparent peak of the growing season corresponds with the peak of the Southwestern Willow Flycatcher breeding season on the Rio Grande—at that point in the summer most paired SWFLs have active nests. Canopy cover at all sites typically ranged from 70 to 95 percent throughout the growing season. Mean canopy cover at all sites was notably higher in 2017 than in previous years of the study, averaging approximately 90 percent. The increase may be attributed to unusually high and persistent Rio Grande flow rates throughout the 2017 growing season, which may have led to greater than average vegetation growth.

Two study sites, EB-15 and DL-12, were severely impacted by the tamarisk beetle in 2017. The resulting decline in salt cedar health, foliage density, and cover were evident in landscape photography taken at these sites (Fig. 15). However, hemispherical photography indicated that the observed declines in canopy cover were not outside the natural range of variation for those sites. Indeed, due to overall increases in canopy cover in 2017, canopy cover at most locations defoliated by the tamarisk beetle was still higher than it had been in 2015 or 2016 (Attachment 2).

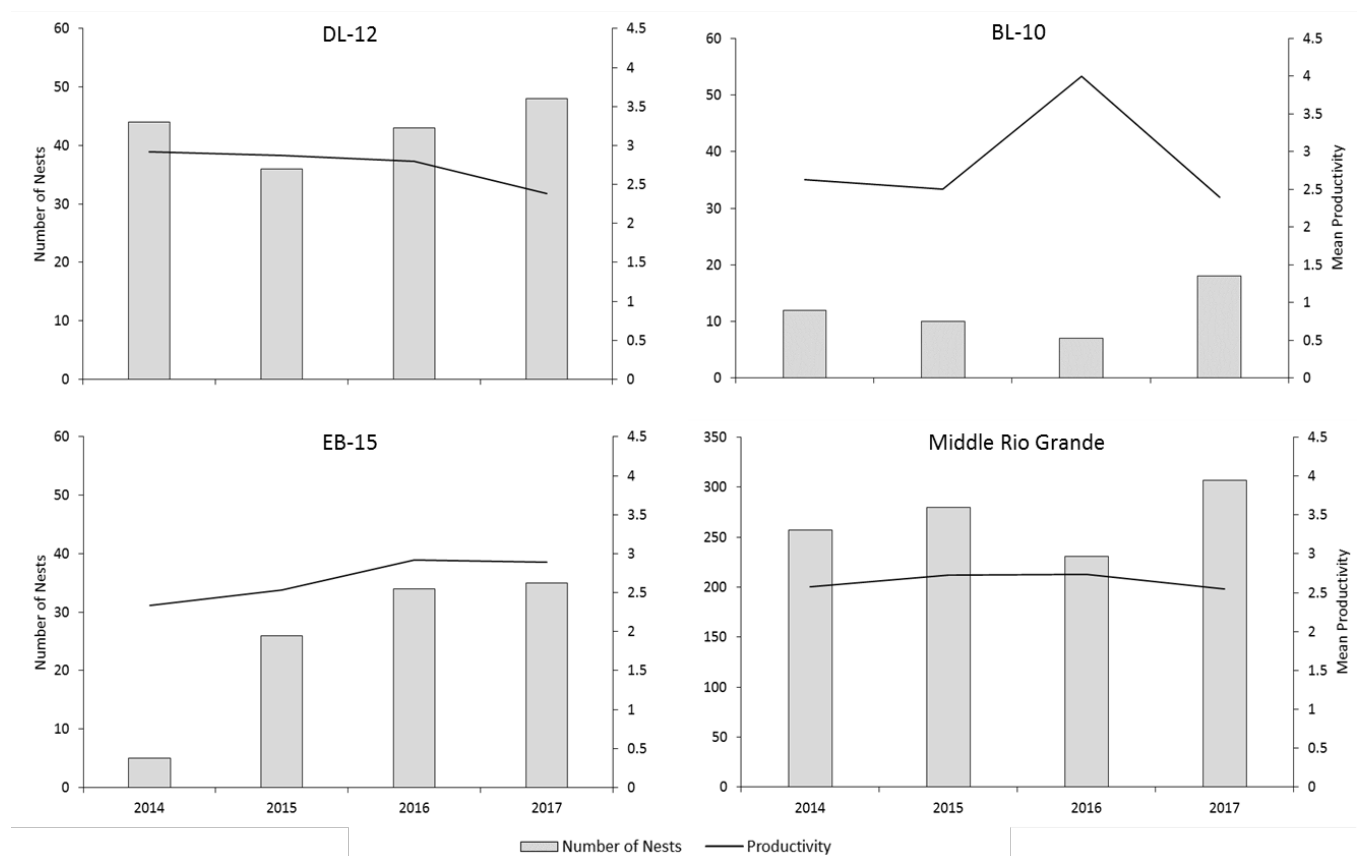
Nevertheless, it is important to note that hemispherical photography cannot distinguish between live and dead foliage, nor between foliage and woody matter. The tamarisk beetle causes “tamarisk browning” prior to defoliation, such that some foliage dies but remains on the tree. Additionally, hemispherical photos taken prior to the 2017 growing season indicated that the majority of canopy closure in this densely vegetated riparian study system can be attributed to non-foliar vegetation (Attachment 2). However, the difference between live foliage cover and dead or woody cover is likely meaningful to a breeding bird that depends on that foliar cover for nest concealment and thermoregulation. Additionally, 2017 was the first year of defoliation by the tamarisk beetle in EB-15 and DL-12. The tamarisk beetle controls tamarisk by repeatedly defoliating the plant over multiple growing seasons, eventually causing it to lose woody mass and vegetation (Dudley 2005). Given this, the impacts of tamarisk beetle defoliation on canopy cover may not be immediate. For example, canopy cover at photo stations impacted by multiple years of defoliation may eventually decline to a value below the 70 to 95 percent natural range of variation in canopy cover currently observed in the study area. Dense canopy cover is a critical component of Southwestern Willow Flycatcher breeding habitat (Stoleson and Finch 2003) and even small decreases in canopy cover can have a strong negative influence on SWFL habitat suitability, nest success, and productivity (Paxton et al. 2011).

Changes in canopy cover can affect breeding flycatchers both directly, through loss of nest concealment, and indirectly through changes in microclimate. Hygrochron™ data indicated that the EB-15 hemispherical photography stations that reached the highest temperature extremes were those with the highest percentages of salt cedar and, therefore, the most severely impacted by the tamarisk beetle. The vegetation community at stations 1 through 4 in EB-15 was less than 50 percent tamarisk, while stations 5 through 9 were greater than 50 percent tamarisk. Maximum temperatures at stations 5 through 9 were approximately 10 degrees Fahrenheit (F) higher than at stations 1 through 4, despite little difference in minimum temperatures (Fig. 16). This is particularly intriguing because although hemispherical photography only detected changes in canopy cover of 10 percent or less at most of those points (Fig. 10), that change was sufficient to result in maximum temperatures approximately 10 degrees warmer than what was recorded a few hundred meters away at stations 1 and 3. Indeed, declines in canopy cover were not detected by hemispherical photography at station 9, despite observed defoliation there, but increases in maximum temperature were detected. This further suggests that woody growth may comprise a great deal of the canopy cover in these dense riparian study sites, but that even a small loss of foliage cover can have significant impacts on habitat characteristics and suitability.

Similar trends in percent relative humidity were observed, such that minimum relative humidity was lowest at the points most severely impacted by tamarisk beetle defoliation. This variation in temperature and humidity was not observed in the study site not impacted by the tamarisk beetle (BL-10). In that site, very little variation in temperature and humidity was observed between sample points, despite large variation in vegetation composition across points. This indicates that the observed variation in microclimate cannot likely be attributed simply to the variation in vegetation composition. Combined, these results suggest that even relatively small losses of canopy cover are leading to hotter and drier flycatcher habitat. Southwestern willow flycatchers are a riparian obligate species that rely on the cooler temperatures and increased humidity of desert riparian areas for cover, a reliable food supply, and to satisfy the thermoregulatory requirements of their eggs and offspring. The loss of canopy cover caused by the tamarisk beetle may negatively impact the suitability of current breeding habitat by causing changes in any of these habitat characteristics.

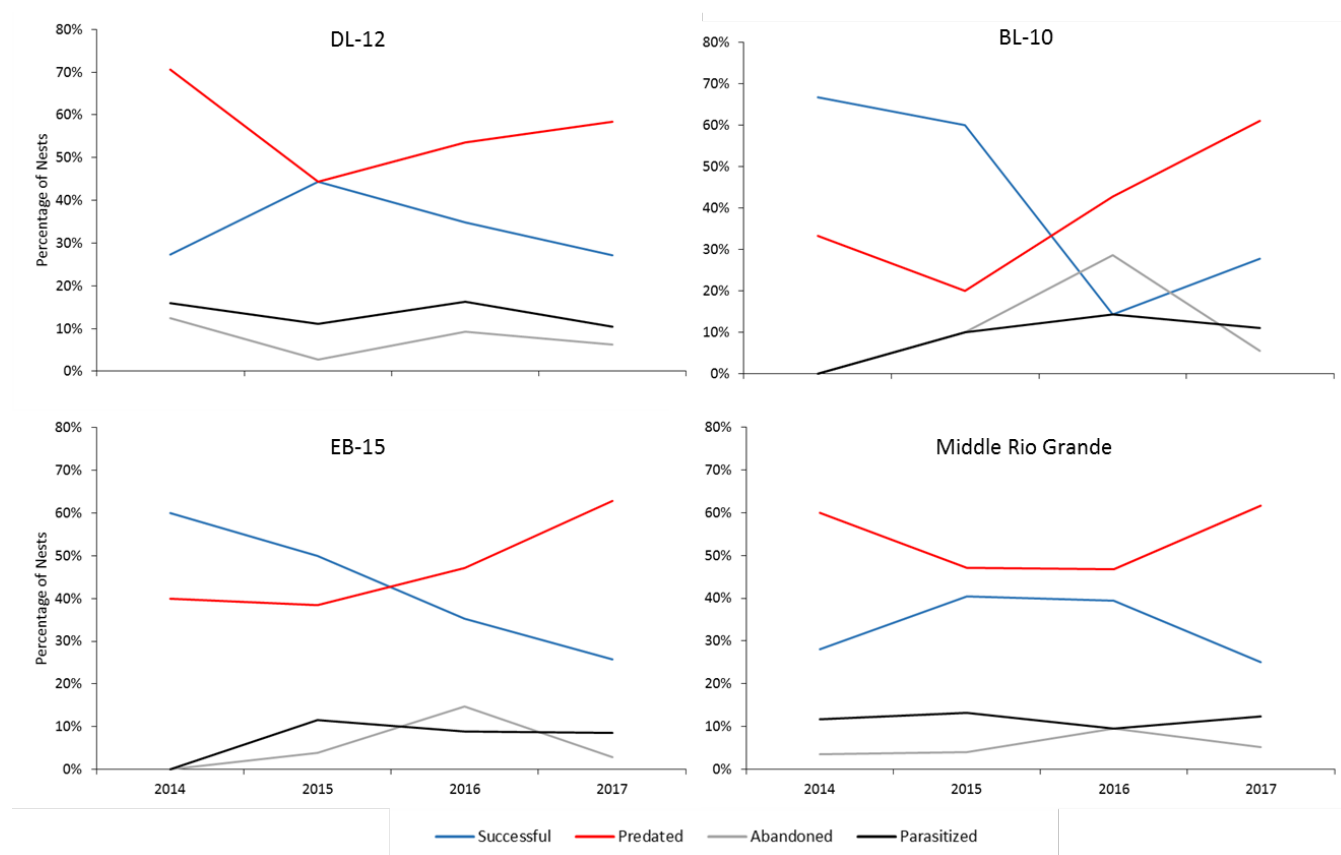
## Discussion

Ultimately, changes in willow flycatcher territory numbers and nest success will be the best indicators of the impacts that the tamarisk beetle has on the willow flycatcher population. If the same study sites are defoliated annually, a gradual decline in nest success and territory numbers might be expected. Willow flycatchers have high site fidelity, so it may take several years of defoliation before adult flycatchers stop establishing breeding territories in an impacted site. Declines in nest success may be observed more quickly. Trends in nesting variables within each study site were plotted for 2014 through 2017, and compared to overall trends in the Middle Rio Grande during that same time period. LFCC-5B was excluded from analysis given that the site was severely burned in 2017 and is not likely to provide suitable SWFL habitat in the near future. Territory numbers in the study sites and the entire Middle Rio Grande were generally stable between 2014 and 2017, with the exception of notable increases in EB-15 as suitable breeding habitat developed in that site (Fig. 22). Nest productivity was also generally stable in the study sites and analogous to the rest of the Middle Rio Grande over the same time period.



**Figure 22.** Number of SWFL territories and mean productivity of successful nests by study site, 2014-2017.

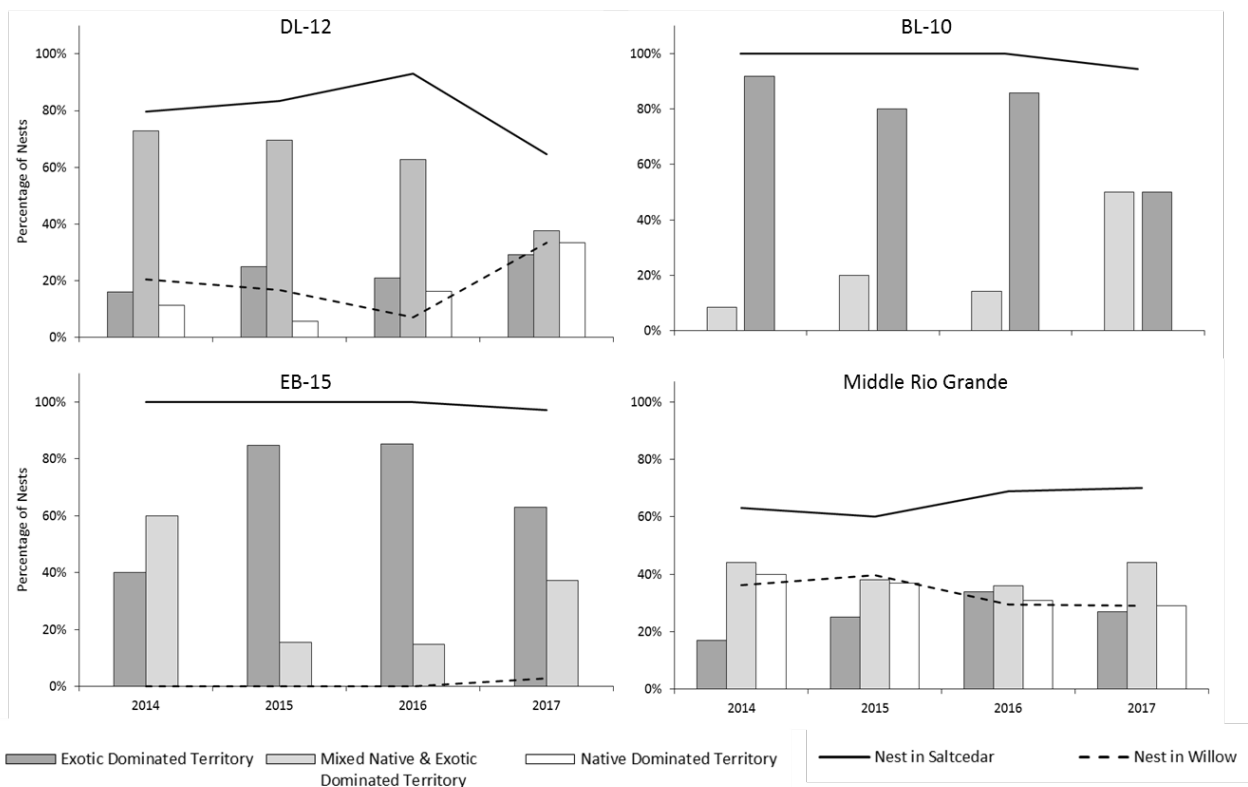
Although nest success was low (25 to 30 percent) in sites impacted by the tamarisk beetle in 2017, nest success was also low in the site not impacted by the tamarisk beetle and throughout the Middle Rio Grande (Fig. 23). Indeed, the 25 percent nest success rate documented on the Middle Rio Grande in 2017 was the lowest observed since nest monitoring began in 1999 (Moore and Ahlers, *In Press*). The vast majority of nest failures were attributed to nest predation. One of the most direct expected effects of browning and defoliation by the tamarisk beetle is the loss of nest concealment, which could lead to increased nest predation or parasitism rates. Initial data suggest that defoliation also results in hotter and more arid habitat conditions, which may in turn lead to increases in nest abandonment or decreased hatching success. If tamarisk beetle defoliation contributes to or exacerbates already low nest success rates observed on the Middle Rio Grande in the coming years, population declines are likely.



**Figure 23.** Outcome of SWFL nests by study site, 2014-2017.

## Discussion

Additionally, shifts in nesting substrate may be observed. The percentage of SWFL nests constructed in tamarisk has increased as willow has declined and tamarisk has become dominant in the Middle Rio Grande riparian vegetation community. The vast majority of nests in these study sites and throughout the Middle Rio Grande are currently constructed in tamarisk (Fig. 24). However, these sites are not monotypic tamarisk and SWFLs are known to nest in coyote willow (*Salix exigua*) as well as Goodding's willow (*Salix gooddingii*), cottonwood (*Populus deltoides*), seep willow (*Baccharis salicifolia*), and Russian olive (*Eleagnus angustifolia*). SWFLs may respond to tamarisk beetle defoliation by increasingly using these other species for nesting. Indeed, SWFLs on the Virgin River, UT shifted from nesting primarily in tamarisk to nesting primarily in coyote willow in the years following acute breeding season defoliation by the tamarisk beetle (Edwards 2017). However, shifts in substrate use would still be limited by availability and would likely not be exclusive from declines in nest success or site-specific territory numbers.



**Figure 24.** SWFL nesting substrate use and territory dominance by study site, 2014-2017.

The timing of tamarisk beetle defoliation in future years will likely be an important factor determining the impact that defoliation has on breeding SWFLs. Severe browning and defoliation was not observed in occupied SWFL territories on the Middle Rio Grande until relatively late in the SWFL breeding season (mid- to late July) in 2016 (pers. obs.). In 2017, defoliation began in EB-15 early in the breeding season, but not until mid-season in DL-12. If defoliation occurs after SWFLs establish territories and are in the early stages of nesting, there is the potential to create an ecological trap in which a bird settles in apparently suitable, foliated vegetation only to have that vegetation defoliated shortly after they begin nesting (Paxton et al. 2011). Ultimately, the timing of defoliation on the Middle Rio Grande will be an important determinant of SWFL nest success and productivity.

## Conclusions

The tamarisk beetle was documented throughout the Rio Grande in the summer of 2017. Although Reclamation biologists had only documented tamarisk beetle defoliation in a small number of occupied SWFL breeding territories late in the breeding season in the previous year, defoliation was pervasive in two of four study sites in 2017. Declines in canopy cover and increases in ambient temperature and aridity were observed in association with tamarisk beetle colonization of these study sites. Ultimately, the timing, severity, and extent of tamarisk beetle defoliation will determine the level of impact on breeding willow flycatchers. Photographic monitoring of changes in canopy cover and vegetation composition in SWFL habitat will provide an important tool to assess the possible need for more active management of the riparian ecosystem. If changes in SWFL productivity and nest success raise concerns about the species' recovery, such modifications of management strategies may be deemed necessary. For example, efforts to mitigate the impact of tamarisk defoliation on the Virgin River watershed SWFL population led to the development of a collaborative riparian restoration plan (Dudley and Bean 2012). Additionally, overbank flooding of the riparian area during the winter is known to kill tamarisk beetle populations, which are in diapause in the soil at that time. Indeed, overbank flooding in BL-10 in 2017 may explain why the tamarisk beetle was not observed at hemispherical photo stations in that site despite initial colonization in late summer 2016. Continued monitoring of beetle-induced changes in riparian vegetation and associated changes in SWFL demographic parameters will provide important data regarding the need, or lack thereof, of these or other management strategies.

## Recommendations

- Continue landscape and hemispherical photography and microclimate monitoring at established sampling locations to quantify impacts of the tamarisk beetle on riparian habitat.
- Take hemispherical photographs once annually during the non-growing (winter) season to determine changes in tamarisk foliage density versus woody mass. Winter measurements of canopy cover, after abscission has occurred for this deciduous shrub, when compared to the preceding summer measurements will enable a calculation of the amount of summer canopy cover comprised of foliage versus woody material - a distinction likely to be important for a breeding bird.
- Expand monitoring to include additional study areas with high Southwestern Willow Flycatcher densities. LFCC-5B was severely burned in the 2017 Tiffany Fire and is not likely to support willow flycatcher habitat in the near future—this study site should be replaced. Control sites should be added to the study that are not likely to be defoliated by the tamarisk beetle, to be used for comparison of trends in habitat quality and flycatcher population demographics. The ability to compare impacted versus non-impacted sites on an annual basis will allow biologists to distinguish between natural annual variation and habitat changes induced by the tamarisk beetle. Additionally, sites with varying degrees of tamarisk-dominated vegetation (and, thus, varying

## Conclusions/ Recommendations

degrees of expected impact) might be added to the study in order to determine what level of impact results in a decline in habitat suitability.

- Further characterize the extent of defoliation and associated changes in habitat structure and suitability by quantifying species composition, tree health, percent defoliation, etc. in a fixed radius plot around each hemispherical photography station. Consideration of the potential mechanistic impacts of the tamarisk beetle on flycatcher habitat suitability would be a useful guide in selecting the most important habitat variables to quantify.
- Analyze satellite imagery to estimate the extent and severity of tamarisk defoliation on the landscape scale in the Middle Rio Grande.



## **Attachment 1: Photo Station Locations**

## Attachment 1A: Hemispherical Photography Station Locations

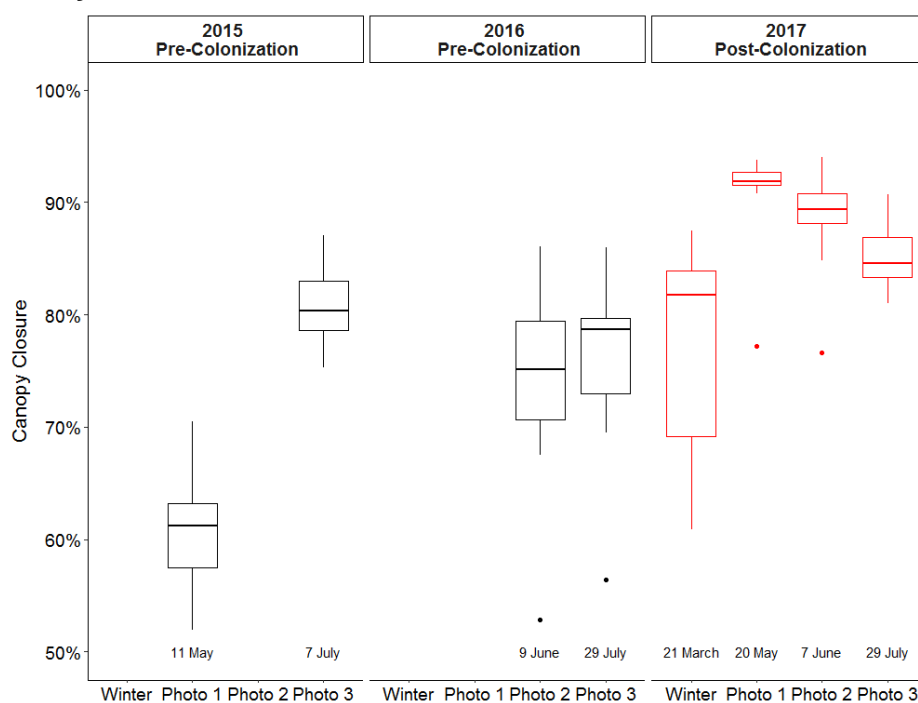
Station Number	Location (UTM NAD 83 Zone 13N)	Distance to Closest 2015/2016 SWFL Pair (m)
BL-10		
HPS-1	338241, 3824809	79
HPS-2	338230, 3824855	31
HPS-3	338211, 3824879	12
HPS-4	338205, 3824922	13
HPS-5	338210, 3824933	15
HPS-6	338201, 3825011	19
HPS-7	338184, 3825049	6
HPS-8	338172, 3825093	16
DL-12		
HPS-1	306804, 3717696	17
HPS-2	306789, 3717595	9
HPS-3	306770, 3717505	6
HPS-4	306745, 3717505	6
HPS-5	306721, 3717451	9
HPS-6	306700, 3717411	3
HPS-7	306671, 3717374	14
HPS-8	306672, 3717339	9
HPS-9	306697, 3717327	10
HPS-10	306694, 3717309	9
LFCC-5B		
HPS-1	314963, 3725319	7
HPS-2	314996, 3725102	6
HPS-3	315008, 3725056	52
HPS-4	315032, 3724960	39
HPS-5	315035, 3724872	11
HPS-6	315048, 3724840	13
HPS-7	315057, 3724793	15
HPS-8	315073, 3724697	15
EB-15		
HPS-1	297104, 3691767	5
HPS-2	297070, 3691733	7
HPS-3	297029, 3691693	25
HPS-4	296997, 3691646	14
HPS-5	296978, 3691597	10
HPS-6	296959, 3691547	27
HPS-7	296985, 3691503	14
HPS-8	297005, 3691452	3
HPS-9	297022, 3691481	30

## Attachment 1B: Landscape Photography Station Locations

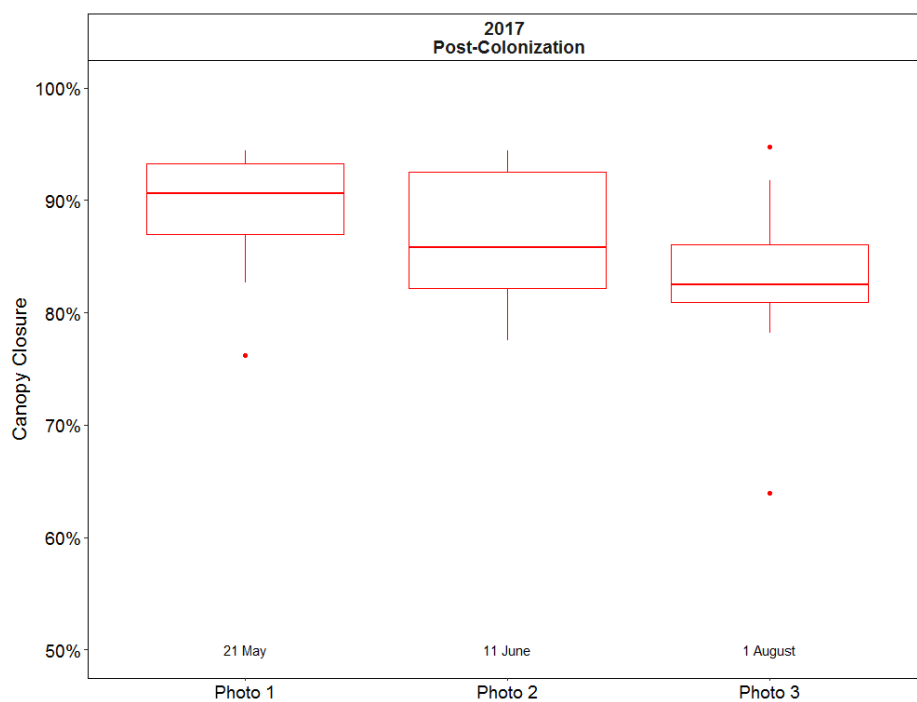
Station Number	Location (UTM NAD 83 Zone 13N)	Bearing (degrees)	Distance to Closest 2015/2016 SWFL Pair (m)
BL-10			
LPS-1	338220, 3824825	20	60
LPS-2	338229, 3824891	260	10
LPS-3	338235, 3825096	170	48
LPS-4	338249, 3824948	180	40
DL-12			
LPS-1	306716, 3717311	220	18
LPS-2	306702, 3717381	350	13
LPS-3	306769, 3717522	195	17
LPS-4	306822, 3717544	210 & 300	28
LPS-5	306837, 3717638	340 & 250	28
LPS-6	306823, 3717703	270	4
LFCC-5B			
LPS-1	315087, 3724714	215	27
LPS-2	315048, 3724903	130	23
LPS-3	315020, 3725179	175	30
EB-15			
LPS-1	297052, 3691701	310 & 230	25
LPS-2	296999, 3691616	294 & 223	33
LPS-3	296951, 3691525	218 & 166	22
LPS-4	338249, 3824948	260 & 196	8

## **Attachment 2: Canopy Cover by Site Pre- & Post-Colonization by the Tamarisk Beetle**

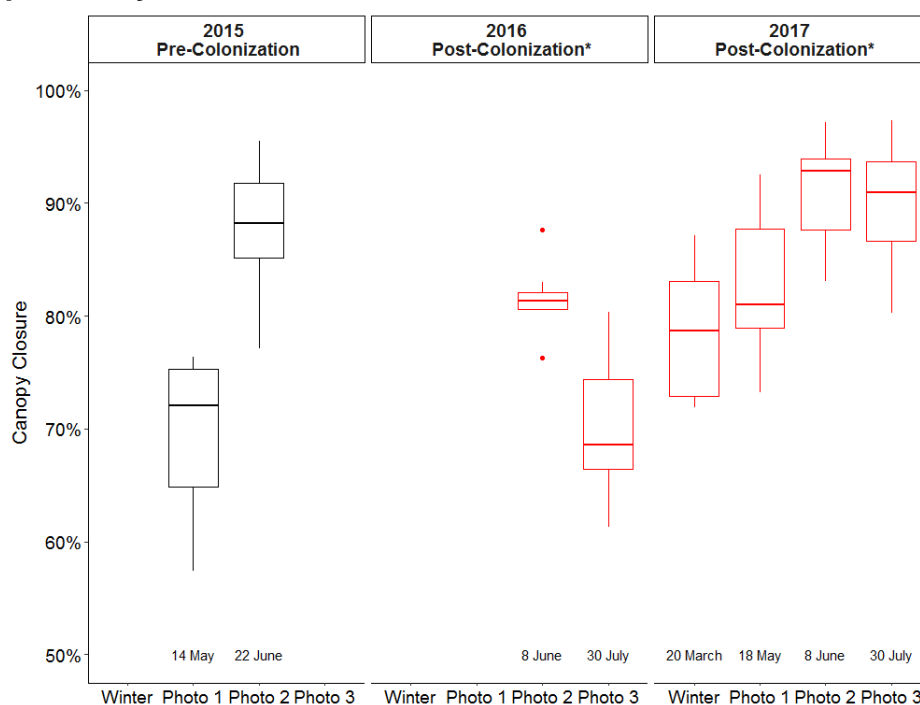
### Sites impacted by the tamarisk beetle in 2017:



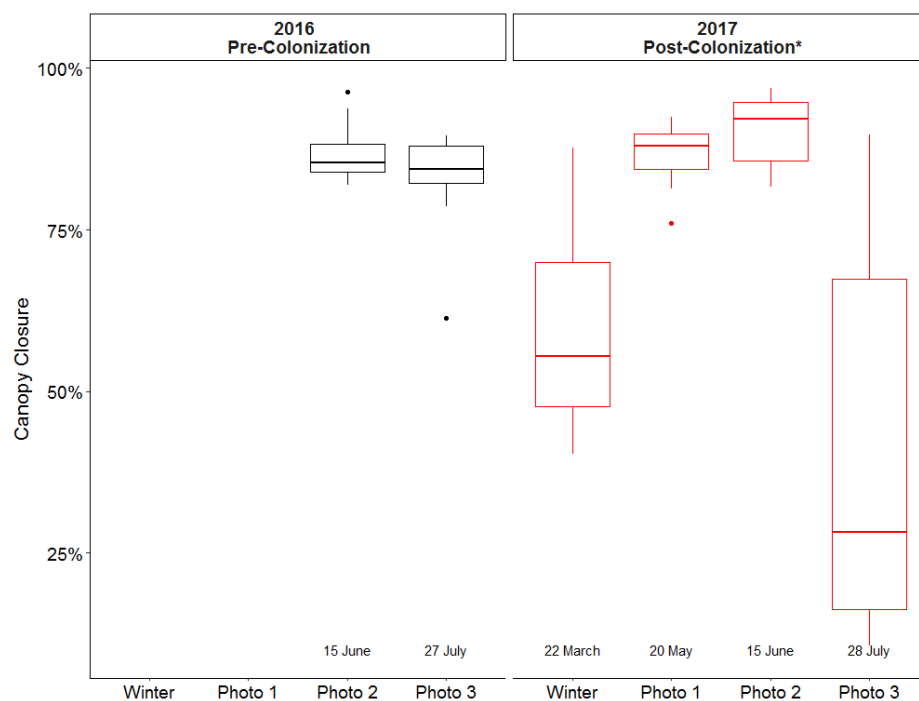
**Figure 1.** Trends in canopy cover at DL-12 pre- and post-colonization by the tamarisk beetle.



**Figure 2.** Trends in canopy cover at EB-15 post-colonization by the tamarisk beetle. EB-15 was not sampled prior to 2017.

**Sites not impacted by the tamarisk beetle in 2017:****Figure 3.** Trends in canopy cover at BL-10 pre- and post-colonization by the tamarisk beetle.

\*BL-10 was a control site that was not impacted by the tamarisk beetle in 2017, however it was the only site in which defoliation was observed in 2016. Canopy cover appeared to recover to pre-defoliation levels the following year.

**Figure 4.** Trends in canopy cover at LFCC-5B pre- and post-colonization by the tamarisk beetle.

\*LFCC-5B was a control site that was not impacted by the tamarisk beetle in 2017. This site was severely burned prior to Photo 3 in 2017.

# Literature Cited

- DeLoach, C. J., & Tracy, J. L. (1997). Effects of biological control of saltcedar (*Tamarix ramosissima*) on endangered species: Draft biological assessment, 17 October 1997. Temple, TX: USDA/ARS (612 pp.).
- DeLoach, C. J., R. I. Carruthers, T. L. Dudley, D. Eberts, D. J. Kazmer, A. E. Knutson, D. W. Bean, J. Knight, P. A. Lewis, L. R. Millbrath, J. L. Tracy, N. Tomic-Carruthers, J. C. Herr, G. Abbott, S. Prestwich, G. Harruff, J. H. Everitt, D. C. Thompson, I. Mityaev, R. Jashenko, B. Li, R. Sobhian, A. Kirk, T. O. Robbins, and E. S. Delfosse. First results for control of saltcedar (*Tamarix* spp.) in the open field in the western United States. *Proceedings of the XI International Symposium on Biological Control of Weeds, Canberra, Australia, 27 April – 2 May 2003*. Ed. J.M. Cullen, D. T. Briesse, D. J. Kriticos, W. M. Lonsdale, L. Morin, and J. K. Scott. Australia: CSIRO Entomology, 2004. 505-513.
- Delta-T Devices, Ltd. 1999. HemiView 2.1 SR4: Canopy Analysis Software [Computer Software]. Cambridge, UK: Delta-T Devices, Ltd.
- Di Tomaso, J. M. 1998. Impact, biology, and ecology of Saltcedar (*Tamarix* spp.) in the Southwestern United States. *Weed Technology* 12: 326-336.
- Dudley, T. L. 2005. Progress and pitfalls in the biological control of saltcedar (*Tamarix* spp.) in North America. *Proceedings 16th U.S. Department of Agriculture interagency research forum on gypsy moth and other invasive species*. GTR-NE-337.
- Dudley, T. L., and D. W. Bean. 2012. Tamarisk biocontrol, endangered species risk and resolution of conflict through riparian restoration. *BioControl* 57: 331-347.
- Edwards, C. 2017. Southwestern willow flycatcher status and habitat restoration efforts on the Virgin River in St. George, Utah. *Colorado River Terrestrial and Riparian Meeting*. January 2017.
- Everitt, Benjamin L. 1998. Chronology of the spread of tamarisk in the central Rio Grande. *Wetlands*. 18: 658-668.
- Gay, L. W. and L. J. Fritschen. 1979. An energy budget analysis of water use by saltcedar. *Water Resour. Res.* 15:1589-1592.
- Hultine, K. R., J. Belnap, C. van Riper III, J. R. Ehleringer, P. E. Dennison, M. E. Lee, P. L. Nagler, K. A. Snyder, S. M. Uselman, J. B. West. 2010. Tamarisk biocontrol in the western United States: ecological and societal implications. *Front. Ecol. Environ.* 8: 467-474.
- Johnson, M. 2017. Personal communication. Northern Arizona University.
- Johnson, S. 1987. Can tamarisk be controlled? *Fremontia* 15: 19-20

## Literature Cited

- Lewis, P. A., C. J. DeLoach, A. E. Knutson, J. L. Tracy, and T. O. Robbins. 2003. Biology of *Diorhabda elongata deserticola* (Coleoptera: Chrysomelidae), and Asian leaf beetle for biological control of saltcedars (*Tamarix* spp.) in the United States. *Biological Control* 27: 101-116.
- Moore, D. and D. Ahlers. 2016. Middle Rio Grande Southwestern Willow Flycatcher Study Results. Bureau of Reclamation, Denver, CO.
- Moore, D. and D. Ahlers. *In Press*. Middle Rio Grande Southwestern Willow Flycatcher Study Results. Bureau of Reclamation, Denver, CO.
- Moran, P. J., C. J. DeLoach, T. L. Dudley, and J. Sanabria. 2009. Open field host selection and behavior by tamarisk beetles (*Diorhabda* spp.) (Coleoptera: Chrysomelidae) in biological control of exotic saltcedars (*Tamarix* spp.) and risks to non-target athel (*T. aphylla*) and native *Frankenia* spp. *Biological Control* 50: 243-261.
- Neill, W. M. 1985. Tamarisk. *Fremontia* 12:22-23.
- Paxton, E., T. Theimer, and M. Sogge. 2011. Tamarisk biocontrol using tamarisk beetles: potential consequences for riparian birds in the Southwestern United States. *The Condor* 113: 255-265.
- Shafroth, P. B., J. R. Cleverly, T. L. Dudley, J. P. Taylor, C. Van Riper III, E. P. Weeks, and J. N. Stuart. 2005. Control of *Tamarix* in the Western United States: Implications for water salvage, water use, and riparian restoration. *Environmental Management* 35: 231-246.
- Stoleson, S. H. and D. M. Finch. 2003. Microhabitat use by breeding southwestern willow flycatchers on the Gila River, New Mexico. *Studies in Avian Biology* 26: 91-95.
- Tamarisk Coalition. "2007-2016 Distribution of tamarisk beetle (*Diorhabda* spp.)" <http://tamariskcoalition.org/events/tamarisk-beetle-maps>. 12 December 2016.
- Tracy, J. L. 2017. Personal communication. Texas A & M University.
- Tracy, J. L. and T. O. Robbins. 2009. Taxonomic revision and biogeography of the *Tamarix*-feeding *Diorhabda elongata* (Brullé, 1832) species group (Coleoptera: Chrysomelidae: Galerucinae: Galerucini) and analysis of their potential in biological control of Tamarisk. Auckland, New Zealand. *Zootaxa*. 152 pp.



## PEER REVIEW DOCUMENTATION

### PROJECT AND DOCUMENT INFORMATION

Project Name Photographic Monitoring of Defoliation by the Tamarisk Beetle WOID FA151

Document Photographic Monitoring of Defoliation by the Tamarisk Beetle: Middle Rio Grande from Belen to Elephant Butte Reservoir, NM

Document Date April 2018

Team Leader Darrell Ahlers, 86-68290, Wildlife Biologist

Document Author(s)/Preparer(s) K. Dillon and D. Ahlers

Peer Reviewer Mike Horn, 86-68290, Fisheries and Wildlife Resources Group Manager

Peer Reviewer \_\_\_\_\_

### REVIEW REQUIREMENT

Part A: Document Does Not Require Peer Review

Explain \_\_\_\_\_

Part B: Document Requires Peer Review: SCOPE OF PEER REVIEW

Peer Review restricted to the following Items/Section(s):

Reviewer:

Complete Document Subject to Review

Mike Horn

### REVIEW CERTIFICATION

Peer Reviewer - I have reviewed the assigned Items/Section(s) noted for the above document and believe them to be in accordance with the project requirements, standards of the profession, and Reclamation policy.

Reviewer: Mike Horn Review Date: April 2, 2018 Signature: 

Reviewer: \_\_\_\_\_ Review Date: \_\_\_\_\_ Signature: \_\_\_\_\_

I have discussed the above document and review requirements with the Peer Reviewer and believe that this review is completed, and that the document will meet the requirements of the project.

Team Leader: Darrell Ahlers Date: April 2, 2018 Signature: 