Big Lake *Lythrum salicaria* Mitigation and Kanab Creek *Tamarix ramosissima, Elaeagnus angustifolia* Removals and Habitat Restoration: 2018-2023

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A Kanab Creek Watershed CRMP Partner

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INTRODUCTION

In 2014-2015 the major land managers and users within the Kanab Creek watershed participated in developing the Kanab Creek Watershed Coordinated Resource Management Plan (CRMP). An important group in the CRMP planning process is the Citizen's Advisory Committee (CAC), which is comprised of private citizens and non-profit organizations. Because Best Friends Animal Society (BFAS) is one of the largest non-profit land users in Kane County, many of their employees have contributed to the CAC. The role of CAC members was to review treatment goals outlined by the Steering and Technical Advisory Committees throughout the planning process. Whereas SAC and TAC members are managers or technical experts from federal, state, national, tribal and municipal organizations.

One of the categories of the CRMP was the control and eradication of invasive plant species. During the planning process, CAC members described an infestation of *Lythrum salicaria* (purple loosestrife) at Big Lake, a reservoir located on a terrace northwest of the Kanab Creek arroyo. Filled by several springs and seeps (Stevens, L) and contained by an earthen dam, or dyke. For many years, the *L. salicaria* infestation had received only bi-monthly mowing treatments throughout the entire growing season.

During a site assessment in 2016, these treatments proved to be insufficient as *L. salicaria* had created a monoculture that extended around the periphery of Big Lake and into adjacent wetlands. Additional break-out populations were also found in the drainage that flows from a southeastern section of the dam into a tributary below the Honeybee pasture. These discoveries initiated a collaboration between Best Friends Animal Society, Kane County and the Color County Central Weed Management Area (CWMA) for a Utah Dept. of Agriculture and Food Invasive Species Mitigation Grant (ISM).

HISTORY OF THE GRANT AND ISM FUNDING

In February 2018, BFAS received ISM funding to control the spread of *L. salicaria* at Big Lake, drainages leading into to Kanab Creek, wetlands, and mitigation treatments for woody invasive species. Table 1 and 2 summarizes project completion dates, equipment for biological, chemical, and mechanical treatments, botanical inventories, administration, and contractors. The following year another ISM grant proposition was submitted to UDAF with the Color Country CWMA. While the project wasn't funded, support was given by the CWMA members and agencies during revegetation workdays. Since receiving the original ISM grant in 2018, the restoration funding has been exclusively provided by BFAS. Their commitment to invasive species management, and habitat restoration, as outlined in the Kanab Creek CRM, has ensured the continued success of *L. salicaria* and woody invasive species within their stewardship boundaries.

Treatment Protocols	Contributors	Completion Dates
Biological Control Releases Site 1,4,8, Honeybee	BFAS, Amber Mendenhall (2018), NREC, Kane County (2018)	2018-2019
Biological Control Releases Site 1,4,8, (2 and 12 added 2021)	BFAS, NREC, Paul Fuhrman-Naturalist, Kane County (2023)	2020-2023
Big Lake Botanical Inventory I	Jason Baker Botanical Consulting, NREC	2018
Standardize Impact Monitoring Protocol (SIMP)	Amber Mendenhall (2018), NREC, BFAS monitoring teams	2018-2023
Lythrum salicaria: Chemical Treatments Big Lake Periphery	American Conservation Experience (ACE)	2018
Kanab Creek *Tamarix ramosissima* and *Elaeagnus angustifolia* Removal Stage I	BFAS, ACE	2018-2019
Ecological Survey and Kanab Amber Snail Field Studies	Dr. Larry Stevens, NAU Springs Institute	2021
GIS Mapping	BFAS, NREC, Dr. Larry Stevens	2018-2022
Habitat Restoration: *Salix exigua* and *Populus fremontii* plantings	BFAS, Color Country CWMA Members, NREC	2018-2019, 2023
Kanab Creek *Tamarix ramosissima* an *Elaeagnus angustifolia* Removal II	ACE	2021-2023
Populus fremontii removal Big Lake Earthen Dam	ACE	2022
Stand 12 Wetland habitat restoration	BFAS, NREC, P. Fuhrman-Naturalist	2023

Table 1: Summary of treatment and monitoring completion dates.

TREATMENT PROTOCOLS 2018-2023

Generalized vegetation categories were developed because specific taxonomic botanical knowledge varies (Table 2). The annual review of designated stands documents population changes and facilitates the types of treatment and restoration actions needed throughout the mitigation sites. In addition, more ecological and botanical surveys were completed every three years. In 2018, Jason Baker, a plant taxonomist, did the first in-depth botanical survey, followed by Dr. Larry Stevens, who finished an ecological and water quality assessment in 2021.

The Standardized Impact Monitoring Protocol (SIMP) is a nationally recognized platform that has been adopted to capture data and perform analysis on biocontrol release sites. Each permanent site included a 100 ft. line transect, GPS points, and rebar set for each vegetative survey. The percent of vegetation and other

categories that are captured along the line-transects used a 0.25 m square placed at 10.0 ft. increments. All data is recorded as a percent and includes: target weeds, other weed species, forbs or shrubs, perennial or annual grasses, bare ground or open water, leaf or woody litter, and moss species. These SIMP guidelines, were developed by the University of Georgia. In addition to a database that assists with the analysis and tracking of the released biocontrol agents.

COMPARISON OF BIO-CONTROLS 2018-2023

After the introduction of biocontrols, most of the infestation decreased in both stand density and height. An exception are 0.5 -3.5 m^2 islands of purple loosestrife communities located on the eastern bank of the dam (Stand 12) and along the southwestern shoreline adjacent to Stand 1 and 2. While bio-controls have been released nearby there is minimum herbivory and standing water all year. The lack of overwintering habitat may be contributing to the persistent robustness of *L. salicaria*. Species that have been released include: *Galerucella calmariensis* (defoliating beetle), and *Nanophyes marmoratus* (flower bud/foliar weevil) that were provided by Integrated Weed Control, Bozeman, MT. *Hylobius transversovittatus* (root mining beetle) was donated by Amber Mendenhall from Utah Weed Supervisor Association.

Landowner & Location Best Friends Animal Society-Big Lake Kanab Creek Watershed	Release Date: 2018-2023				Amount Released Total:			
Permanent Site Yes	2018	2021	2022	2023	2018	2021	2022	2023
Biological Control Agents Name-Stage								
Galerucella calmariensis defoliating beetle-adult	1,4,8, HB*	1,2,4,1 2,HB	1,2,4,8 12	2,4,12	5,000	850	525	645**
Nanophyes marmoratus flower bud/foliar weevil-adult	1,4,8, HB	1,2,4, HB			2,000	150	150	0
Hylobius transversovittatus root mining beetle-adult	1,4	0			300	0	0	0
Location Lat/Long: N 37.15797 W -112.54431	Site Size 20 acres							

*Table 2: Big Lake biological release summary 2018-2023. *HB (Honeybee monitoring site). In May of 2023 a Galerucella insectary was established in a BFAS greenhouse. On August 1, 2023 approximately 40-50 beetles were raised and then released at Stand 12.*

COMPARISON OF VEGETATIVE SURVEYS 2018-2023

A comparison of the percent cover of purple loosestrife and vegetative diversity prior to the first control releases in May 2018 through 2023 quantifies a decrease in purple loosestrife (*Lythrum salicaria*) stand density, height, and robustness. One exception to this trend is Stand 12 where adequate overwinter habitat is limited. Furthermore, the vegetative survey data also shows an increase in vegetative diversity of cattail (*Typha* spp), common spike rush (*Eleocharis palustris*), duckweed (*Lemna* spp), sedges (*Carex* spp*),* willow (*Salix exigua)*

and soft-stemmed bulrush (*Schoenoplectus tabernaemontani).* The following graphs illustrates stand density and vegetation changes between 2018 and 2023.

A benefit of completing the species level botanical survey in conjunction with the SIMP was that it provided guidance for future mitigation efforts. For example, although not as invasive as the ever-present *L. salicaria*, other potentially invasive species were observed: red top (*Agrostis stolonifera*), a spreading perennial grass, Canada bluegrass (*Poa compressa*), a perennial similar to Kentucky bluegrass, and narrowleaf dock (*Rumex stenophyllus*) were identified on Stand 8, 4 and 1. While these species don't pose the same threat to the ecosystem as Purple Loosestrife, they need regular monitoring (Baker, J).

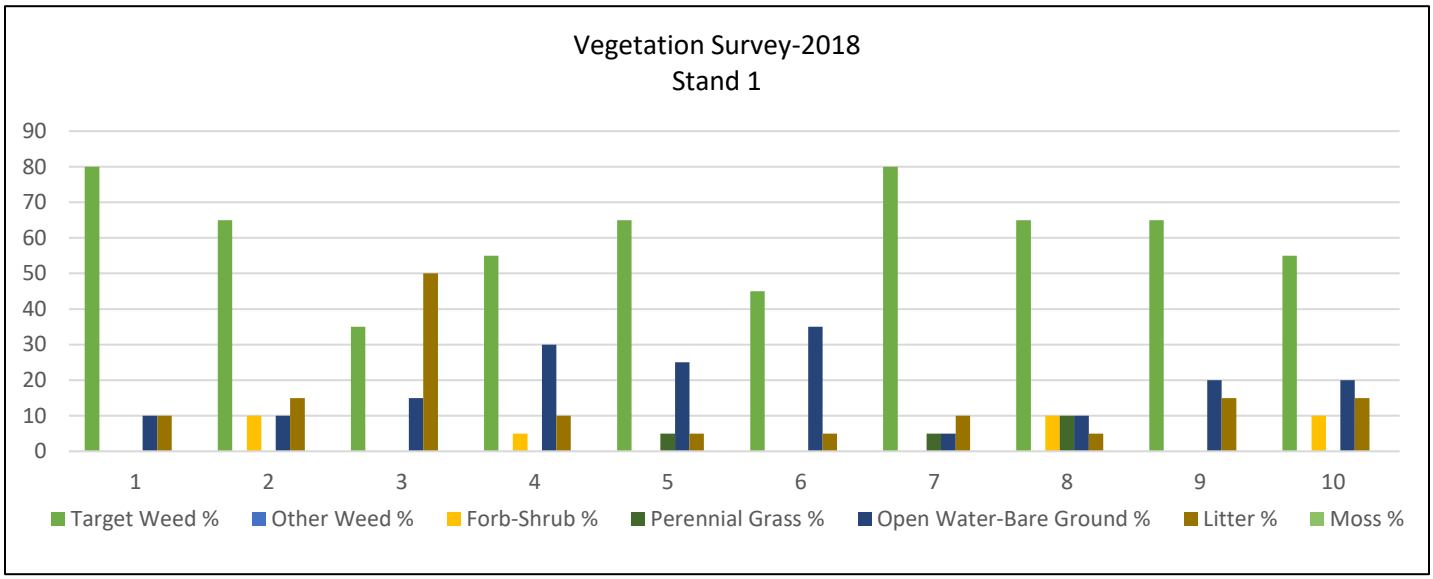


Figure 1: Vegetative survey Stand 1 prior to biological control release.

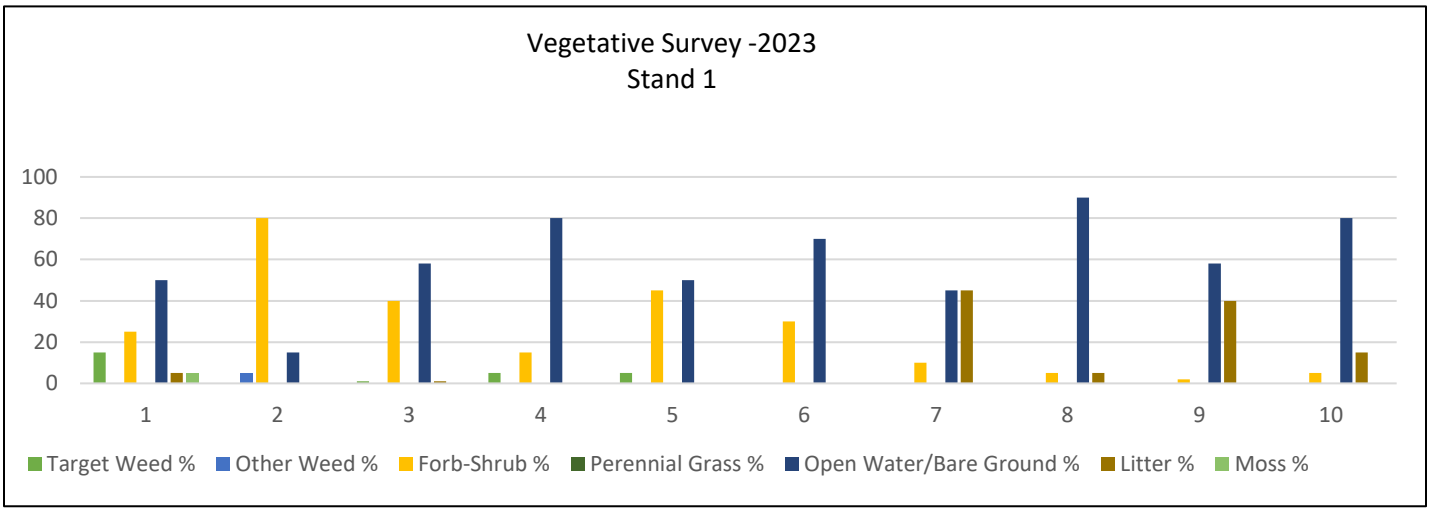


Figure 2: Biological controls were placed in Stand I from 2018-2023. SIMP vegetative survey results show an 80% reduction in purple loosestrife, and significant increases in area hydrology.

Appendix B contains a table of native and non-native species that were identified on transect 1, 4 and 8 during the general SIMP vegetative surveys. This does not include the entire botanical inventory conducted but

only species observed in the 0.25 m quadrats. The entire inventory is documented within Big Lake-Kanab Creek Purple Loosestrife ISM Botanical Survey (Baker, J).

STAND 2: COMPARISON OF VEGETATIVE SURVEYS 2018-2023

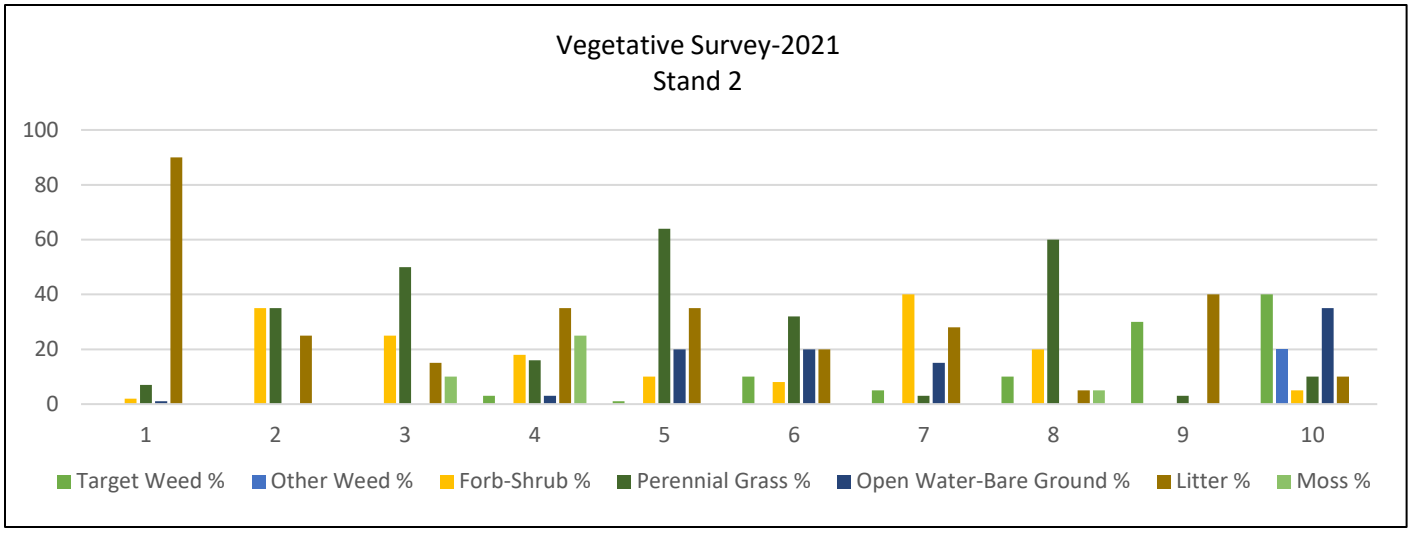


Figure 3: Stand 2 initial vegetative cover evaluation in 2021.

Figure 4: Adjacent to the eastern boundaries of Stand 2 line transect are islands of L. salicaria. A total of 600 Galerucella calmariensis (defoliating beetle-adults) have been released from 2021-2023.

In May 2021, Stand 2 was added to monitor populations of purple loosestrife adjacent to the western shorelines of Big Lake and southern edge of the cliffs. While evidence of herbivory from the released biocontrol's was observed during the 2022-2023 field studies, many vigorous (100+ stem) clumps continue to thrive with limited foliar damage.

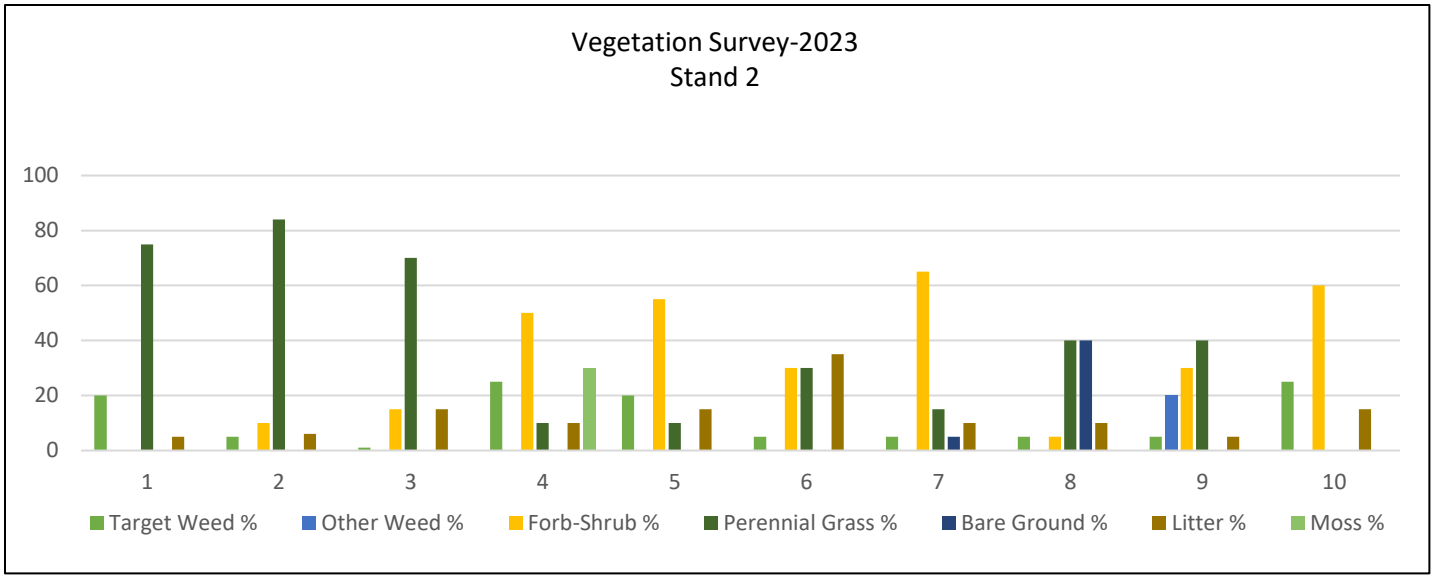


Figure 5: Vegetative survey line transect data of Stand 2, 2023.

STAND 4: COMPARISON OF VEGETATIVE SURVEYS AND DENSITY 2018-2023

Both quantitative and qualitative data collected from Site 4 (2018-2023) revealed a decrease in *L.* salicaria that corresponds with an increase in botanical diversity. This included: larger percentages of perennial grasses (*Bromus* spp.), willow (*Salix exigua*) monkey flower (*Mimulus* spp.), reeds (*Carex* spp.), duck weed (*Lemma* spp.), cattail (*Typha* spp.) and rush (*Juncus* spp.).

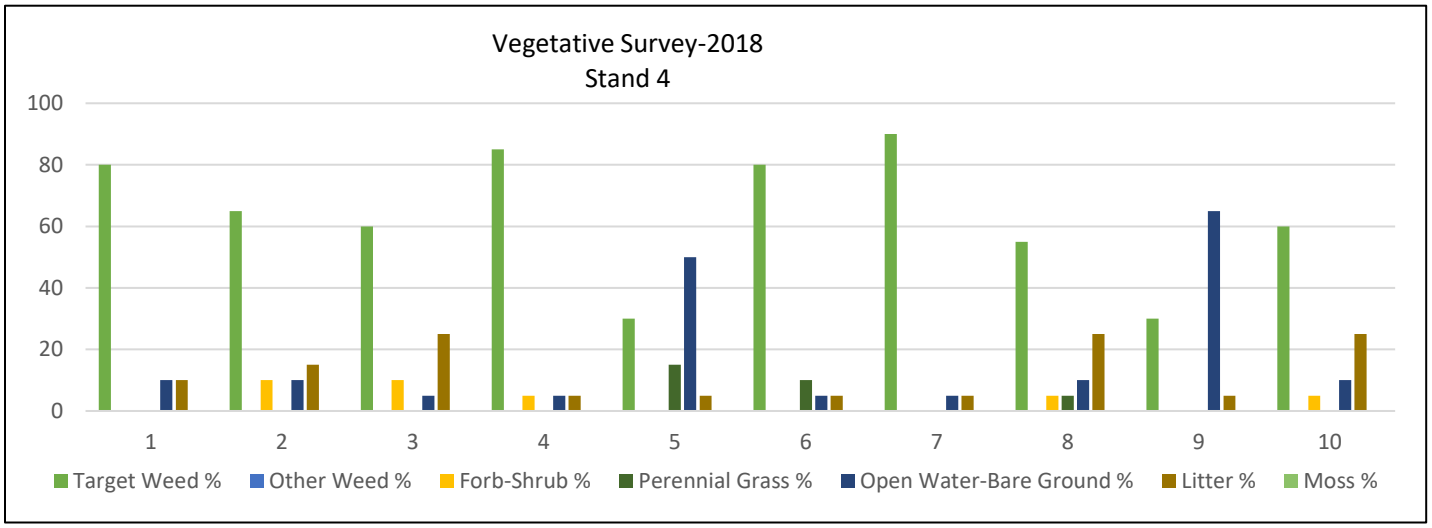


Figure 6: Vegetative survey line transect data of Stand 4, 2018. An average of 65% of purple loosestrife was measured along within the transect.

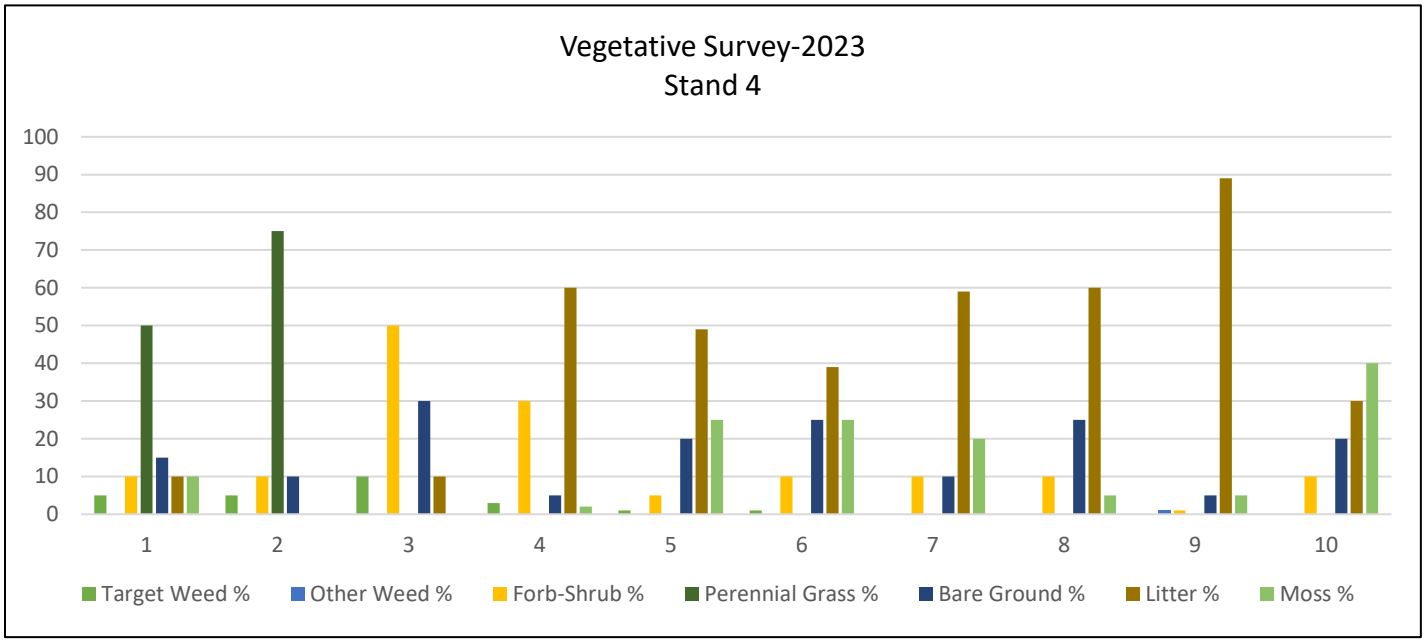


Figure 7: Vegetative survey results from 2023 after two years of the biocontrol impacts on L. salicaria frequency along the transect-line. The populations' density deceased an average of 60%.

Figure 8: (L) Biocontrol releases Stand 4 May 2021. Figure 9: (R) Delightful appearance of Kanab Amber-Snail along Stand 4, Big Lake, Best Friends Animal Society. May 2021. Photo-Credit: P. Fuhrmann.

STAND 8: COMPARISON OF VEGETATIVE SURVEYS 2018-2023

Stand 8 line-transect stretches perpendicular along the western shores of a small pond situated west of Big Lake. There are several springs that contribute to the hydrology of Big Lake that created the wetlands and seeps, in addition to the 1980's construction of the earthen dam. Since the introduction of biological controls, there has been a consistent increase in open water. In 2021-2023 the populations of *L. salicaria* showed little vegetative growth, heavy defoliation, and no floral appendages. Whereas the 2018 line-transect data of the vegetation and target weed inventories were opposite (Figure 10 and 11).

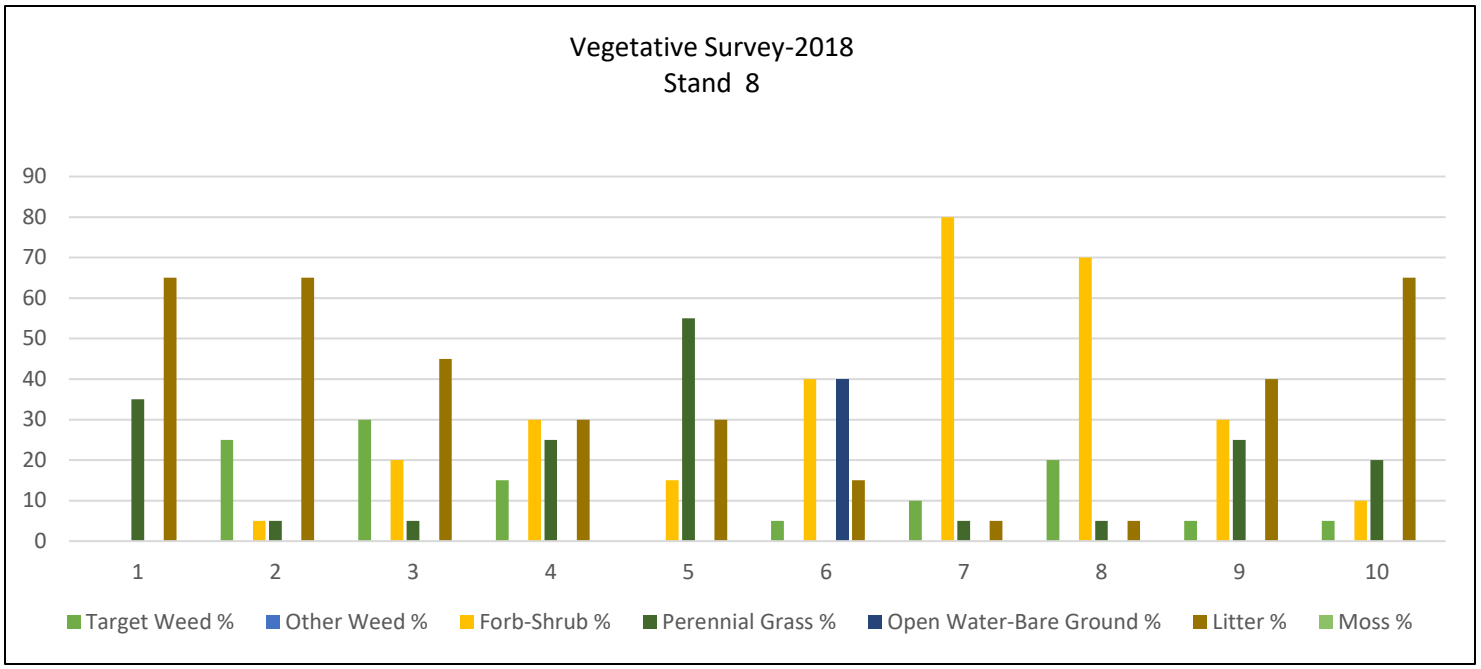


Figure 10: (upper) Illustrates the diversity of the vegetative survey in 2018. Figure 11: (below) Decrease in vegetative abundance due to pronounced increases in hydrology.

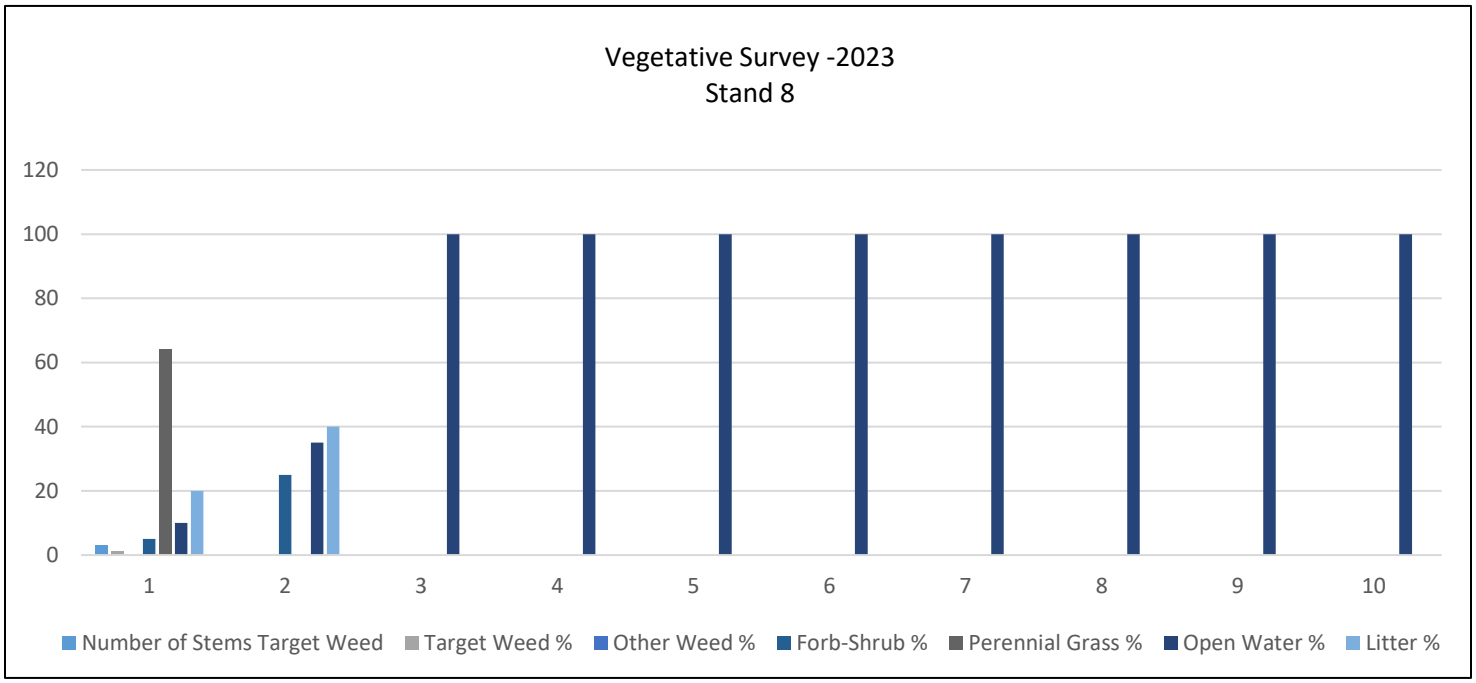


Figure 12: (L) Stand 8 original vegetation populations 2018. Figure 13: (R) Increased hydrology west of transect line.2023. Photo-credit: Goldberry

STAND HONEY BEE- COMPARISON OF VEGETATIVE SURVEYS AND DENSITY 2021:

In 2017 a small outbreak population of *L. salicaria* was observed in a narrow wash on the east side of Big Lake's earthen dam. Due to its proximity to Kanab Creek and continued growth a line transect was established in 2021. The line transect is called Honeybee after a horse pasture located above the drainage. Monitoring in May 2022 yielded no presence of purple loosestrife. A vegetative survey was not conducted in 2022 and 2023 because no purple loosestrife populations were observed. However, continued observations of the drainage is recommended until the infestation along the base of the earthen dam responds to treatments.

SIMP SURVEY CATEGORY	PERCENT COVER %	TARGET WEED STEM #	TARGET WEED cm
Target Weed	4.0	10	26.0
Other Weed	0	-	-
Ford-Shrub	5.0	-	-
Perennial Grass	6.0	-	-
Open Water/Bare Ground	80.0	-	-
Litter	5.0	-	-
Moss	0.0	-	-

Table 3: Honey Bee 2021, SIMP survey results and analysis of density.

STAND 12: COMPARISON OF VEGETATIVE SURVEYS 2018-2023

Due to its proximity to Kanab Creek and heavy growth, when a large population of *L. salicaria* was observed along the east side of Big Lake dam in 2020, a new monitoring site was established. *Galerucella calmariensis* (defoliating beetle) was released in June 2021. While moderate defoliation was observed in August 2021, no specimens were collected, and foliar growth continued to be robust. The removal of established cottonwoods (*Populus fremontii*) for dam stability was completed in April 2022. Consequently, the established stands of *L. salicaria* receive almost full sun exposure rather than heavy shade. Research conducted by the NRCS indicates that shade will reduce growth by 50%. After the necessary tree removals the reduction in canopy increased *L. salicaria* density (Figure 15).

The vegetative data analyzed from other stands in the mitigation project in comparison to Stand 12 suggests that a lack of overwintering habitat is contributing to decrease herbivory by *Galerucella calmariensis* and *Nanophyes marmoratus*. Other contributors may be predation on the biocontrol's by avian, or other invertebrate predators. Consequently, habitat restoration efforts to replace the standing water with wetland vegetation began in June 2023. The protocol will mechanically cut down *L. salicaria*, fill the depression with shredded materials from earlier removals of *P. fremontii,* and transplant wetland vegetative mats along the western edge of the depression where biocontrols were released.

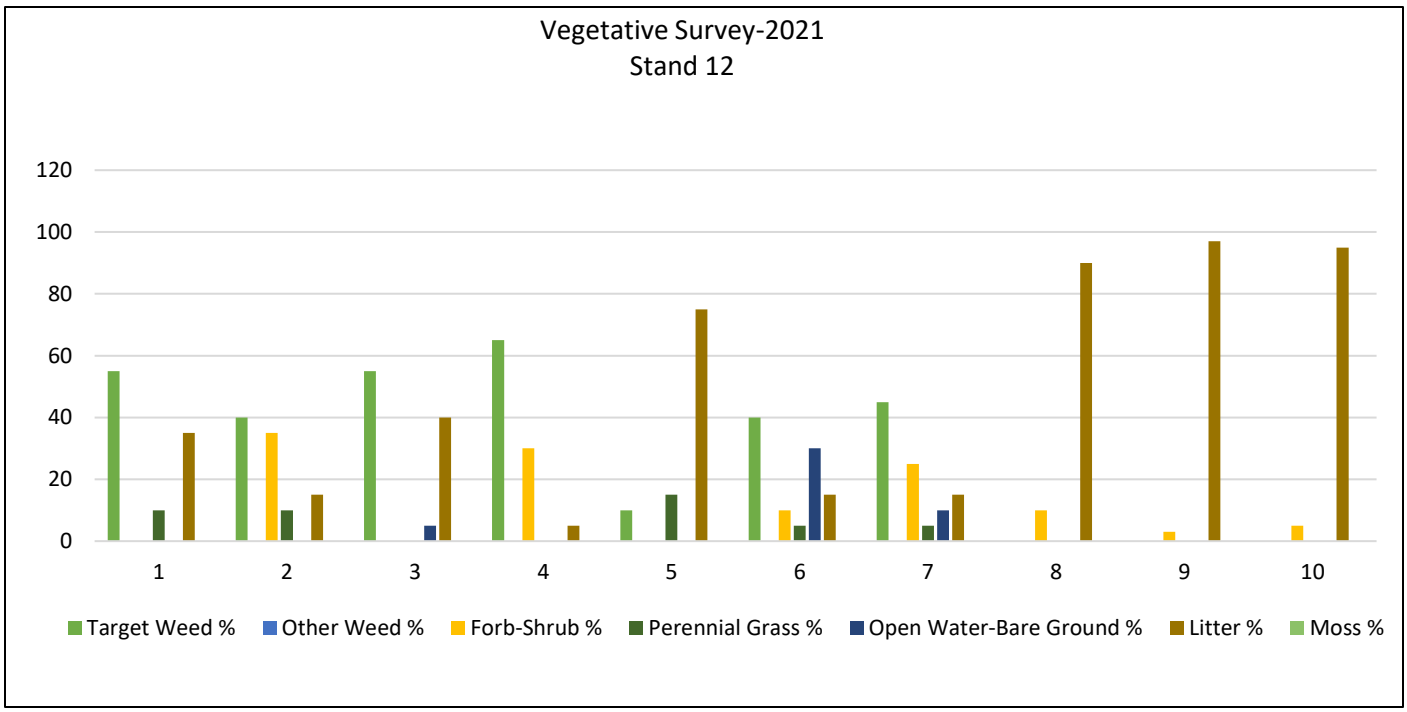


Figure 14: Vegetative survey of L salicaria prior to biological control release in May 2022. BFAS. Purple Loosestrife Mitigation Project

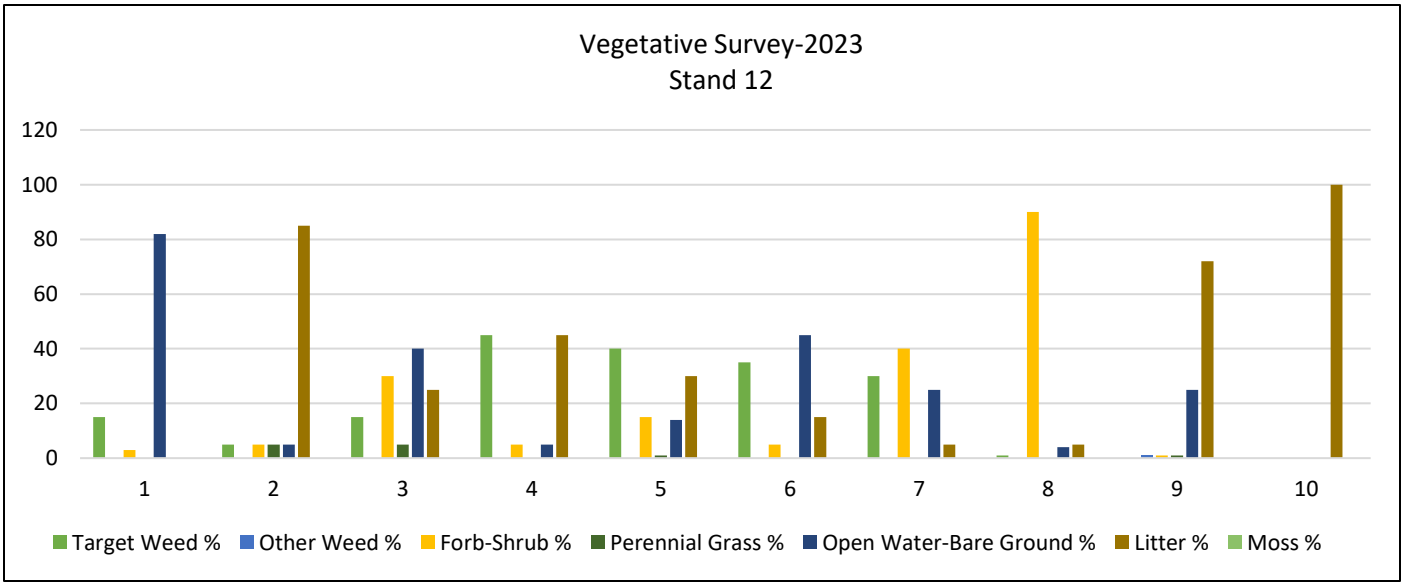
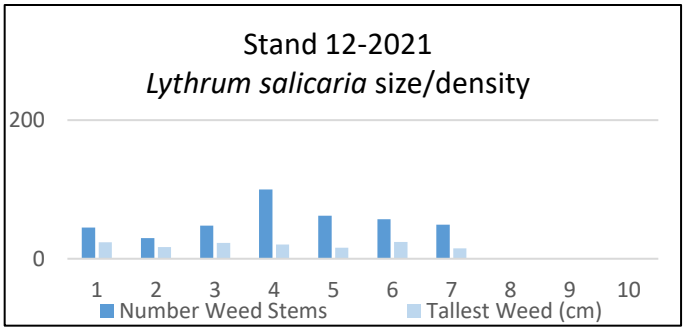


Figure 15: While there has been a reduction in population percentage of purple loosestrife along the transect, there are large staggered clumps of 100+ stems located in depressions of standing water along the majority of the earthen dams length.



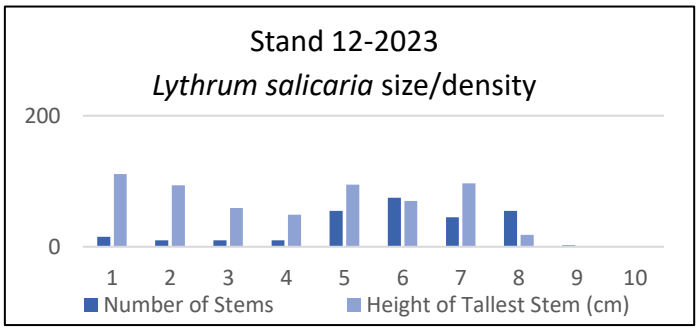


Figure 16: Since the removal of the cottonwood canopy in 2022, there has been an increase in L. salicaria density. Figure 17: Stand 12 density in 2023.

Figure 18: Stand 12 density timeline prior and after biocontrol releases and cottonwood removal. Images I (NW), III (W), IV (W), are prior to cottonwood removal. II post cottonwood removals (broken cottonwood branch-S). Photo credits: P. Furhmann, S. Goldberry.

COMPARISON OF STAND DENSITY 2018-2023

A comparison of the stand density of pre-biocontrol releases in May 2018 to the current survey results illustrates a decrease in purple loosestrife (*Lythrum salicaria*) stand density, height, and robustness at all permanent sites, except Stand 12 and 2 (Figure 17). Furthermore, the botanical survey conducted in 2018, in addition to the SIMP vegetative survey data illustrates that vegetative diversity was dependent on location (Baker, J).

In 2021, both the SIMP and Dr. Larry Steven's ecological survey supported the positive correlation between the decrease *of L. salicaria* and increase in plant and animal species diversity (Steven, L.). A temporary decrease in project funding, changes in BFAS management, and the COVID-19 global pandemic contributed to the mitigation data gaps from 2019-2020. While *Galerucella calmariensis* was released on Stand 2 in 2022, the increased density may be attributed to several factors including an adjacent infestation of *Onopordum ancanthium* (scotch thistle), changes in soil moisture, predation, and increased populations of shrub species: *Ribes aureum*, *Amelanchier utahensis* var*. utahensis, and Rosa woodsii.*

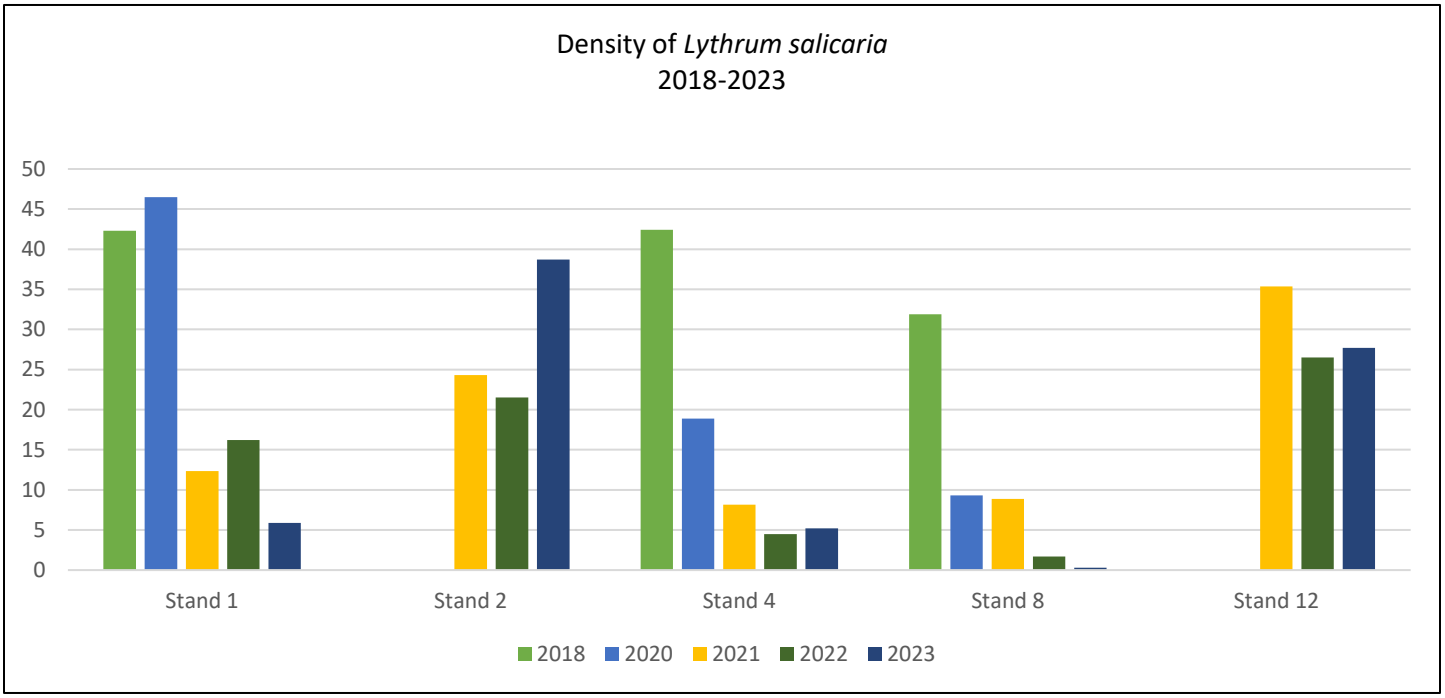


Figure 19: Evaluation of purple loosestrife population density throughout the total mitigation site 2018-2023.

KANAB AMBER SNAIL ECOLOGICAL SURVEY

During the 2020 vegetative survey's specimens of the Kanab Amber Snail (*Oxyloma haydeni kanabensiswas*) were discovered at Stand 4. In 2021, ecological surveys were conducted by Dr. Larry Stevens on all transects within the mitigation site and random root samples were harvested from transects where *Hylobius transversovittatus* had been released. His sampling efforts during the purple loosestrife control

monitoring on 2 August 2021 revealed a grand mean density >21.2/m2 of living *Oxyloma*, and 0.5 dead shells/m2, for a total detection density of 22.8 snails/m2 (Appendix B).

Figure 20: Kanab Amber Snail (Oxyloma haydeni kanabensiswas) Stand 4. 2021. Photo credit: P. Fuhrmann

CONCLUSION & RECOMMENDATIONS

Successful mitigation projects make adjustments in response to new information and changes in context. Throughout the project treatment many integrated weed management standards were used: mechanical, chemical, biological and habitat restoration efforts. While there has been a significant reduction in *L. salicaria* throughout the original polygon the new outbreaks need continued treatment and monitoring. Moreover, the continued integration of adaptive management protocols is recommended and includes:

1) Conduct annual vegetative surveys of the established stands within the polygon of Big Lake and drainages leading to Kanab Creek.
2) Establish qualitative and quantitative appraisal of all biocontrol species released into Big Lake.
3) Monitor and continue the removal of invasive woody species: *Tamarix ramosissima* and *Elaeagnus ramisomossa* within Kanab Creek and associated tributaries.
4) Integrate late fall or early spring riparian revegetation regime in woody species removal areas.
5) Continue water quality monitoring protocols at Big Lake.

6) Establish protocols for ecological evaluations of the Kanab Amber Snail with Dr. Larry Stevens and Springs Steward Institute.
7) Initiate partnership opportunities with Color Country Coordinated Weed Management Area partners, Kane County Conservation District, Kane County Extension, Kane County School District, Natural Resource Conservation Service, university and colleges, and others when applicable.
8) Develop a GIS or non-GIS based data base to ensure continuity, and credibility of restoration and monitoring decisions (Stevens, L).

ACKNOWLEDGEMENTS

The success of the Big Lake Purple Loosestrife Project and Woody Invasive Species Mitigation Project are due to the innumerable hours of professional expertise, care and labor of individuals and organizations. Without these many contributions the project would not have achieved this level of success. Many thanks and appreciation to: American Conservation Experience, Kane County Conservation District, Tyce Palmer, Utah Department of Agriculture and Food, Aaron Eagar, Jared Brinkerhoff, Chris Young, Chris Courville, Jordan Moody, Bambi Skrzynski, Color Country Cooperative Weed Management Area members, Vicky Tyler, Bert Harris, Kane County Weeds and Roads, Kanab Creek Coordinated Resource Management Steering, Technical and Citizen Advisory Committee members, Kaibab Band of Paiute Indians, D'On and Gary Pearce, NRCS offices in Fredonia, AZ and Panguitch, UT, Kane County Administration, Amber Mendenhall, Cyndi Crayton-Integrated Weed Control, Jason Baker, Josh Buck, Dr. Larry Stevens, Jeri Ledbetter, Andrea Hazelton, Paul Fuhrmann, Dr. Ben Everitt, Cyndi Everitt, Kanab City Library staff, Santa Clara Library staff, Best Friends Animal Society cafeteria, shipping, media, grounds maintenance and administration staff, and all life within the Kanab Creek Watershed.

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APPENDIX A

Oxyloma density was non-linearly (unimodally) influenced by the extent of soil saturation and negatively influenced by the depth of leaf litter (Figs 3, 4). Other noteworthy observations included detection of many snails 0.25 m or higher on cattail stems above the ground, or water surface. Also, open wounds on cattail stems broken by trespass cattle the previous day were occupied by feeding *Oxyloma* snails. A plant feeding behavior not previously observed by us within this genus. (L. Stevens 2021).

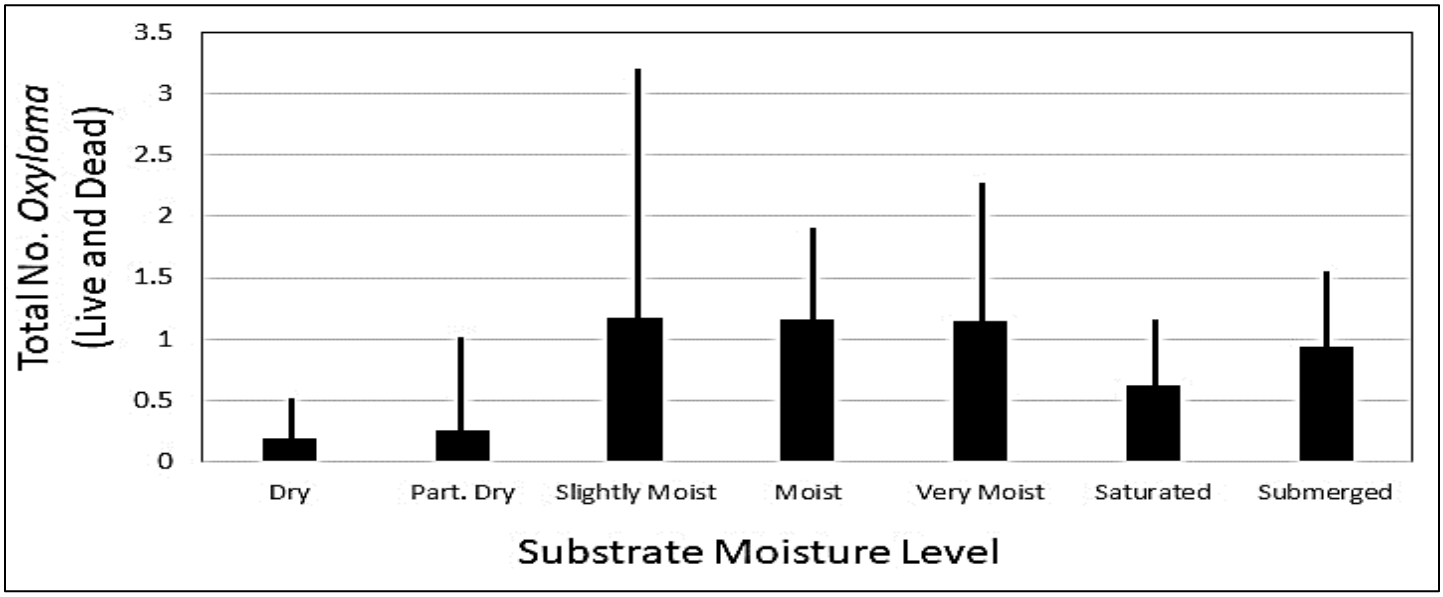

Figure 21: Oxyloma density/m2 in relation to substratum moisture on Best Friends Animal Sanctuary in August 2021. N = 122 20 cm diameter circles, and error bars are 95% confidence intervals.

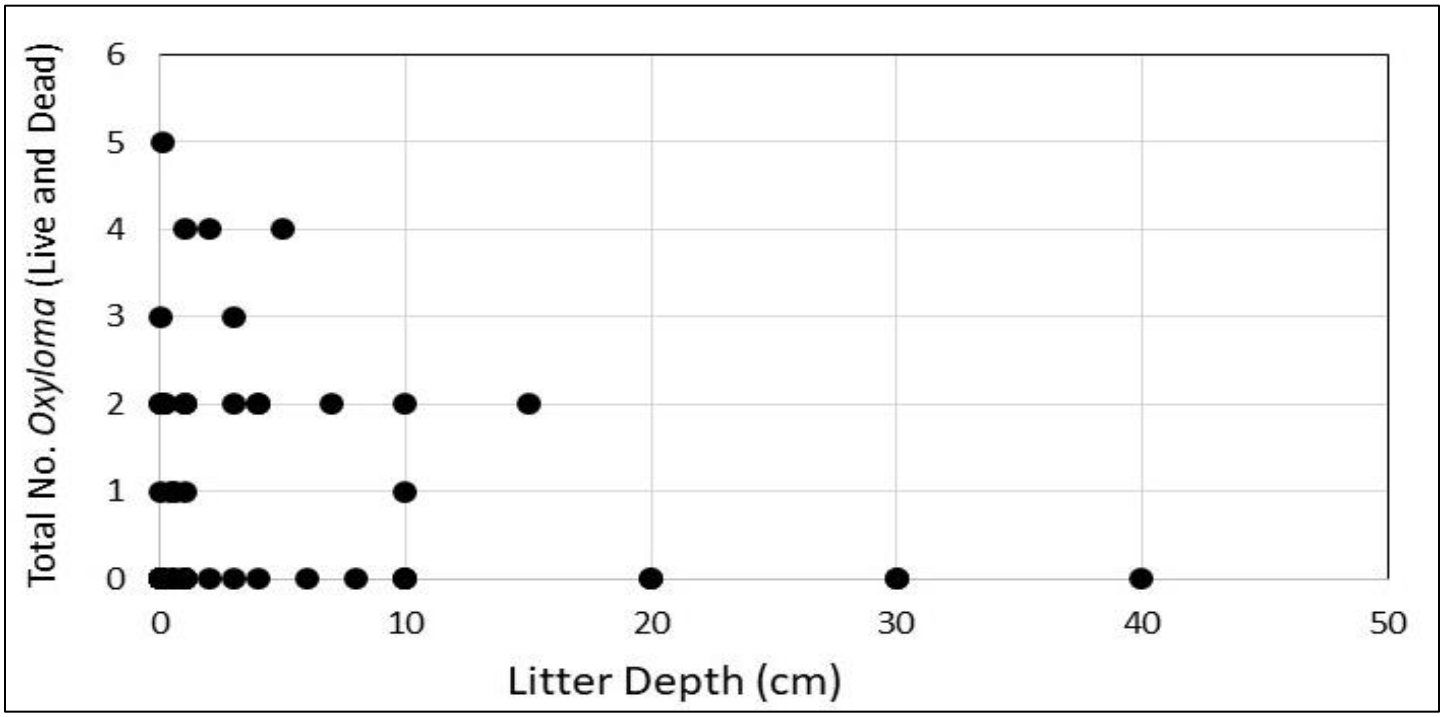

Figure 22: Total number of live and dead Oxyloma / plot in relation to leaf litter depth (cm) at Upper Three Lakes on the Best Friends Animal Sanctuary on 28 August 2021. N = 62 20 cm diameter circle samples.

APPENDIX B

Family	Botanical Name	Common Name	Status
Poaceae	*Agrostis stolonifera*	Red Top	Non-native
Cyperaceae	*Carex hystericina*	Bottlebrush Sedge	Native
Cyperaceae	*Carex praegracilis*	Field Sedge	Native
Cyperaceae	*Eleocharis palustris*	Common Spike Rush	Native
Rubiaceae	*Galium trifidum*	Three-petal Bedstraw	Native
Juncaceae	*Juncus balticus*	Baltic Rush	Native
Araceae	*Lemna minor*	Duckweed	Native
Lythraceae	*Lythrum salicaria*	Purple Loosestrife	Non-native
Scrophulariaceae	*Mimulus guttatus*	Monkeyflower	Native
Poaceae	*Phalaris arundinacea*	Reed Canary Grass	Native
Poaceae	*Poa compressa*	Canada Bluegrass	Non-native
Polygonaceae	*Rumex stenophyllus*	Narrowleaf Dock	Non-native
Salicaceae	*Salix exigua*	Sandbar Willow	Native
Cyperaceae	*Schoenoplectus tabernaemontani*	Softstem Bulrush	Native
Typhaceae	*Typha domingensis*	Cattail	Native
Plantaginaceae	*Veronica anagallis-aquatica*	Water Speedwell	Native

Table 4: Plant species observed along transects 1,4 and 8 during the 2018 field studies with Jason Baker and other field technicians. This list is not inclusive, and only reflects the species observed within the 1.0 m square samples.

APPENDIX C

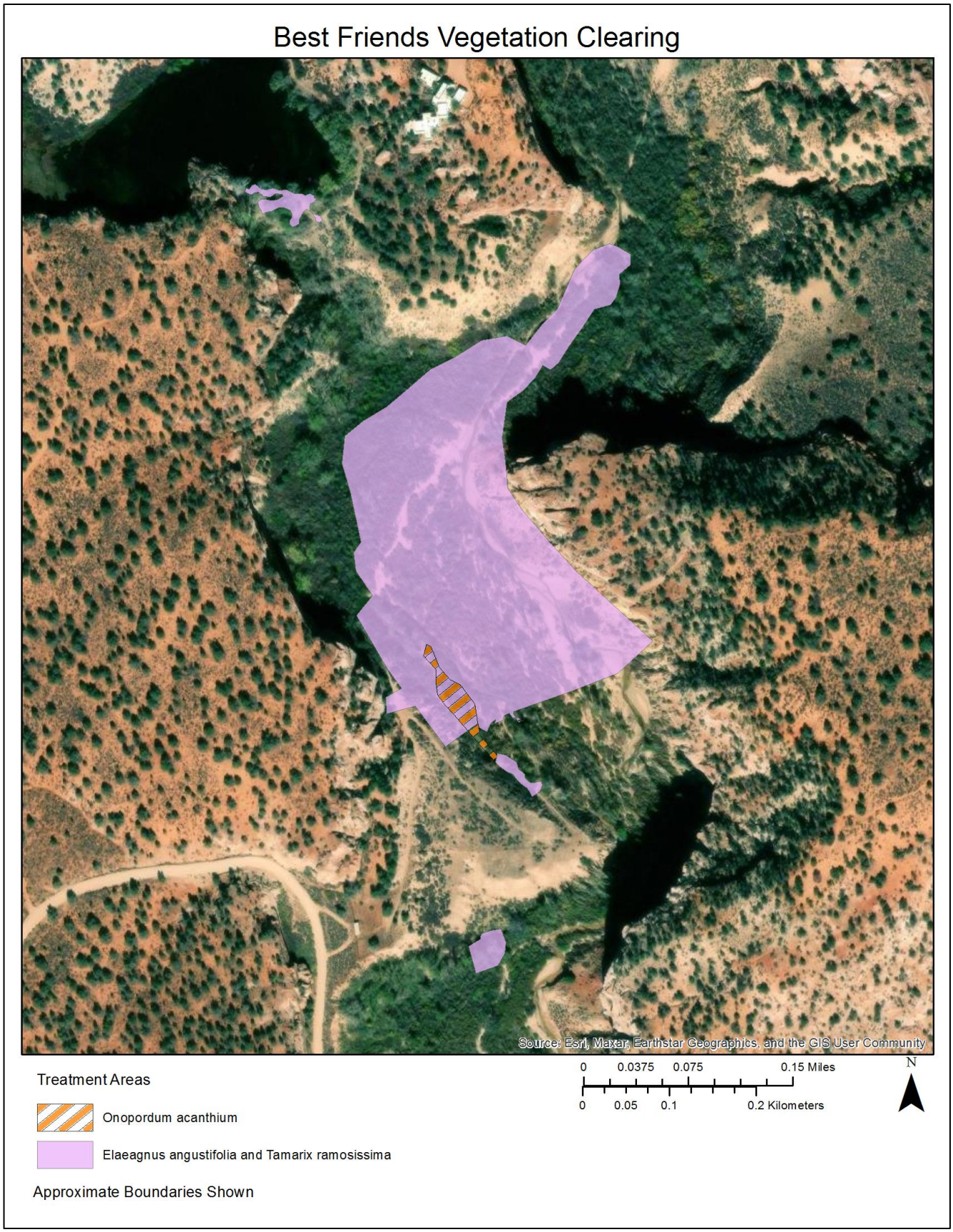

Figure 23: Woody invasive (Tamarix and Elaegnus) and non-invasive (Populus dam removals) treatment areas completed by ACE crews 2018-2022.

A.C.E. Big Lake and Kanab Creek Treatment Analysis								
Year	**Acreage**	**Plant and Treatment Type**				**Treatments Per Type**		**Project Total**
		Russian Olive		*Tamarisk*		*Russian Olive*	*Tamarisk*	
		CS	FC	CS	FC	CS	FC	
2019	8.42	2031	1879	431	8151	3910	8482	12,392
2021	7.15	262		2231		-	-	2,493

Big Lake Cottonwood Earthen Dam Removal			
	Trees Felled by Chainsaw	Acres of Area Chipped	Acres treated with Herbicide
2022	14	0.167	0.085

Table 5: Summary of ACE Big Lake and Kanab Creek treatments from 2019-2022. Treatment type abbreviations CS: cut stump, and FC: frill cut.