Prescott Creeks Preservation Association

Watson Woods Riparian Preserve Restoration Project

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Final Report

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PRESCOTT CREEKS

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Prescott Creeks would like to honor Tom Moody, who passed away unexpectedly only days before the implementation of this project. *Tom, Arizona's rivers and friends will always remember you.*

Prescott Creeks 2013 Board of Directors:
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And special appreciation to Doris Cellarius for her dedicated service as Board Chair from 2008 – 2012.

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The views or findings presented are those of Prescott Creeks and do not necessarily represent those of the Commission, the State, or the Arizona Department of Water Resources.

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Executive Summary

Watson Woods Riparian Preserve (Watson Woods/Preserve) is a 126-acre Fremont cottonwood/red willow gallery forest located within the Granite Creek Watershed and larger Upper Verde River Watershed. It is located on Granite Creek northeast of Prescott along the southeast side of State Route 89 approximately 2 miles north of State Route 69. Watson Woods is located within Sections 23, 24 and 26 of Township 14 North, Range 2 West, in Yavapai County, Arizona.

The Preserve was established in 1995, and is managed by Prescott Creeks Preservation Association (Prescott Creeks) through a 25-year renewable lease granted by the City of Prescott. Since that time, Prescott Creeks has developed and implemented a variety of management programs and associated activities designed to improve the functional capacity of Watson Woods as a wetland, riparian, and aquatic ecosystem. Prior to these management programs, Watson Woods was severely degraded from anthropogenic activities associated with natural resource extraction and development (residential, commercial, and industrial). Therefore, in March 2009, Prescott Creeks implemented the "Watson Woods Riparian Preserve Restoration Project (Restoration Project)," a project that included stream channel restoration, hydrologic improvements, vegetative plantings, and a management, maintenance, and monitoring program.

The goals of the Restoration Project are 1) to enhance and restore the Granite Creek channel function and existing riparian habitats and create new riparian habitats and 2) to educate and involve the community in the restoration process. To accomplish these goals multiple scientific disciplines were considered during planning, development and implementation, with the primary areas of focus being geomorphology, botany, macroinvertebrate zoology, herpetology, and ornithology. The Restoration Project has involved the community through volunteer events, outreach, and environmental education programs, along with the construction of an interpretive trail system, as summarized in the *Watson Woods Community Involvement Report*.

Geomorphology
The primary component of the Restoration Project was the functional restoration of the Granite Creek channel. Prescott Creeks identified existing stable segments of the creek and calculated geomorphic dimensions of these segments in order to incorporate those features into a "natural channel" design. Four "reaches" of the creek were restored using a variety of structural practices including channel realignment, off-channel wetlands, toe rock/rock trench sill installation, along with non-structural/bioengineering practices such as seeding/fabric installation, post/pole plantings, bundle plantings, and brush revetment/coir log installation. In total, over 4,100 feet of stream channel were re-aligned, shaped, and planted with native riparian vegetation, over 18 acres was planted with native grass seed, and five off-channel/ephemeral wetlands were constructed. In order to support the initial growth of planted vegetation, an irrigation system was installed and implemented for the first 2-3 growing seasons.

Post-construction monitoring occurred in April 2009, September 2009, October 2010, September 2011, and September 2012 to evaluate the performance of installed structures and bioengineering treatments. Six cross sections of the channel were re-surveyed at each monitoring event to measure channel stability, and six cross sections were re-surveyed to measure bank stability by using the Bank Erodibility Hazard Index (BEHI). Photographs were taken annually at eleven points as well as at each cross-section and BEHI location. Annual stream flow, precipitation data, and groundwater data was also gathered and analyzed to determine the duration, quantity, and force of water that the restoration areas would have experienced that year.

The Granite Creek restoration has resulted in a new channel pattern that has improved stream access to adjacent floodplains and has allowed surface water to spread out over more of the Preserve. This channel alignment has also allowed riparian vegetation to flourish in areas that previously had been spoil areas from gravel mining. Although a major flood event (January 2010) caused significant damage that required supplemental construction activities and repairs, the restored reaches and associated areas appear to be functioning properly, and width/depth ratios have remained within the range of a stable "C" channel type. The BEHI scores at each monitoring location have improved over time. Bioengineering components such as willow clusters/trenches are well established, and cottonwood pole plantings have an 84% survival rate. All structures such as rock plugs, toe rocks, and rock/log sills are intact and functioning properly.

Botany

An analysis of vegetation establishment within Watson Woods was conducted four consecutive years in terms of changes in cover for both woody and herbaceous vascular flora and survivorship of planted species within restored reaches, critical planting areas, and wetlands. A line-intercept method (Bonham 1989) modified to include height estimates was used to sample percent cover in 217 transects, with the purpose of determining performance of the Restoration Project. Baseline data was collected in spring 2009 immediately following initial restoration activities, with subsequent monitoring events in the fall of 2009, 2010, 2011, and 2012.

In fall 2009, overall average percent cover for woody plants was 4.5%, ranging among plots between 0.72% and 10.74%. In fall 2010, overall average percent cover was 15.6%, ranging between 5.0% and 29.7%. In fall 2011, overall average percent cover was 19.0%, ranging between 8.0% and 45.9%. In fall 2012, estimated overall average percent cover for transects along reaches and wetlands were 31.9%, ranging between 10.1% and 48.4%. Between spring 2009 and fall 2012, average height classes among plots increased from 1.0 (< .5m) to 3.5, increased to 3.7 in fall 2011, and to 4.2 in fall 2012. Survivorship was 97.9% by fall 2009 and fell to only 94.6% by 2011, indicating a high overall success rate. By this time, however, estimates were difficult because of flooding events, dead shoot decay, and the sprouting of new shoots from rhizomes and root crowns. In light of these factors, estimates of survivorship were not attempted in 2012. Average herbaceous cover over all plots increased from 34% in fall 2009 to 43% in fall 2010, decreased to 28.1% in fall 2011, and increased to 59% in fall 2012. From fall 2009 to fall 2010 exotic perennials and annuals increased from 44% to 46% of total average herbaceous cover. In fall 2011 exotic perennials and annuals decreased to 37% and to 30% in fall 2012.

In addition to monitoring critical planting areas and restored wetland/riparian areas, the entire Preserve was analyzed using foliar height density (FHD, also referred to as foliar height distribution and foliar height diversity) cover of perennial and annual herbs, and density of trees and shrubs. Vegetation associations were also digitally mapped and a checklist of vascular plant taxa was made. FHD surveys were conducted in 1997, 2005, and 2012 in order to characterize the vegetation within the Preserve and to document progress. Between 1997 and 2012, FHD increased markedly for six species. *Festuca arundinacea*, *Salix exigua, S. lasiolepis*, *Populus angustifolia, P.×hinckleyana,* and *Ulmus pumila*. Estimates for average canopy cover increased between fall 2005 and fall 2012, with riparian species increasing from 25.4% in 2005 to 31.9% in 2012. Similarly, average canopy cover for non-riparian species jumped from 8.4% in 2005 to 20.4% in 2012.

Macroinvertebrate Zoology

Macroinvertebrate bioassessments were conducted in order to assess aquatic conditions within Watson Woods and selected tributaries of Granite Creek. The objectives for this study were to: 1) describe baseline biological conditions for nine sites on Granite Creek and tributaries; 2) utilize ADEQ data and the data from this survey to develop and test metrics and an index for identifying impairment; 3) track macroinvertebrate trends for 2 years following restoration activities within Watson Woods and 4) provide a simplified bioassessment method for use by volunteers that is tailored for intermittent streams.

The bioassessment study consisted of a collection of macroinvertebrates, habitat, and water chemistry sampling at nine intermittent stream sites and the Watson Woods wetland ponds over a 2-year study period (spring 2011 and 2012). Data previously collected by ADEQ from five of these nine stations plus four additional sites (2008-2010) were also utilized to create a larger dataset for the metric testing and Index development analyses. All index development methods followed US Environmental Protection Agency methods for developing and testing a multi-metric bioassessment index.

The streams within the Granite Creek watershed are intermittent, flowing from 4-8 months of the year depending on quantities of winter snowpack and monsoon rain. Althougth these flows cannot sustain many of the typical long-lived macroinvertebrates of perennial streams, these flows are sufficient to support a fairly diverse communitieies of invertebrates. A well developed riparian corridor was evident at most of the study sites with the exception of Granite Creek headwater sites and Manzanita Creek. There were variations in stream bottom habitat and substrate conditions were generally poor at the stressed sites. Since sensitive macroinvertebrate species prefer clean cobble-gravel substrates with open interstitial spaces to colonize, high percentages of fine sediment, high percent embeddedness and high percent run habitat are indicators of a degraded stream channel and poor habitat for macroinvertebrates.

Macroinvertebrate characteristics for these sites include low taxa richness, a lack of EPT taxa, high percent composition by flies (*Diptera*) and a high percentage of the collector-gatherer and filterer functional feeding groups. The metrics selected for the Intermittent Index of Biological Integrity included: total taxa richness, percent composition by stoneflies, percent composition by midges, percent composition by the most dominant taxon, percent collectors and percent filterers. Thresholds for impairment to assess samples were based on the 25th percentile of reference values. This resulted in 8 of 9 sites from 2011 and 7 of 9 sites from 2012 identified as impaired. Interestingly, the Granite Creek @ Watson Woods sample from 2012 was the only site in "good" condition. In 2011, the reference sites upper Miller Creek and upper Butte Creek were in fair condition, whereas the remainder of sites was in poor condition.

Intermittent IBI scores were observed within Watson Woods over the 5-year study period. The samples from 2008 and 2012 were in marginally "good" condition, whereas the 2011 sample was in poor condition, being half the IBI score of the other samples. While the taxa richness was not similar to the reference sites, the percent midges were lower and the percent blackflies (filter feeders) were greater in the 2008 and 2012 samples, resulting in high IBI scores. In addition, the fact that this site is not dominated by midges and worms means that the habitat is not limiting the macroinvertebrate taxa, which is a hopeful step toward recovery of a fully functional aquatic community.

Habitat conditions did improve in the Watson Woods reach. Canopy cover, Habitat index score, Pfankuch channel stability score, riparian PFC score and percent riffle habitat all increased following the channel restoration work, whereas percent embeddedness and the riffle-D50 value decreased; all positive improvements in substrate and channel habitat for aquatic life. It appears that the stream recovery following the channel restoration work was successful not only for restoring the physical integrity and functional riparian community but in creating a stable channel and substrate sufficient for a functional intermittent stream community to develop.

Two bioassessment indexes were developed for use by volunteer groups on macroinvertebrate samples from intermittent streams in Prescott. The first, a Tolerance Index uses order level identification of macroinvertebrates in the field, a simple classification of bugs into three tolerance categories, application of multipliers for each category, and a summed score. The second index is the "Simple Four Metric Index" which also uses Order level identification in the lab and calculation of four metrics in common with the Intermittent IBI (taxa richness at order level, percent composition by stoneflies, percent composition by the dominant taxon, and percent composition by midges). Regression R^2 values and corresponding correlation significance scores between each of the volunteer indexes and the Intermittent IBI were highly significant, indicating that either tool could be used to make accurate bioassessments. The choice of which index to use will depend on the skill level of the volunteers, with the Tolerance Index being easiest to use. With these pieces of a volunteer monitoring program in place, valuable monitoring data can be collected to help track aquatic life condition and stream and watershed health.

Herpetology

Herpetological monitoring was conducted between 2009 and 2012 as part of the Restoration Project. The objectives of the herpetological component of the Restoration Project were to use existing baseline data and standardized survey methods to assess a monitoring program for the herpetofauna of Watson Woods; and to foster public appreciation of the ecological importance of riparian herpetofauna. Survey methods included trapping at pitfall grid and array sites, dip-netting, deployment of box funnel and minnow traps, and two types of visual encounter surveys.

In total, 19 reptile and amphibian species were observed in Watson Woods, including two non-native turtle, one lizard, and three snake species not detected during the previous inventory in 1999. Several mammal, bird, and fish species were also detected; of these, one mammal and all fish species were non-native. Survey methods were not equally likely to detect each species; however, common diurnal lizards were detected during all methods. Plateau Fence Lizard and amphibian larvae constituted the vast majority of detections. Several snake and one lizard species were only detected once or twice; three of these detections were made by volunteers or Prescott Creeks staff, illustrating the important role of citizen scientists. Important amphibian breeding areas include the semi-permanent ponds/ephemeral wetlands (for Tiger Salamanders), and Granite Creek, especially Reaches 2 and 4 and historic channels (Woodhouse's and Southwestern Toads).

Both biodiversity and abundance appears to be increasing in riparian woodlands, likely a function of both previous and current restoration efforts. Although lizards quickly colonized restoration sites, more detailed analyses are needed to ascertain correlation in species population trends with current restoration efforts. Recurring stochastic events occasionally affected trap function and coverboard persistence, illustrating the need to carefully identify and secure traps during long-term monitoring programs, especially in public spaces. Possible conservation concerns include the unknown effects of noise pollution on amphibian breeding success, loss of suitable amphibian breeding habitat due to dense woody vegetation plantings, loss of cover through removal of downed logs, and a projected decrease in abundance and diversity of large-bodied snakes from the area.

Ornithology
Avian monitoring was conducted in order to document bird population and to analyze these results in comparison to the Restoration Project. Surveys were conducted during the months of January, March, April, May, June, July, August, September and November using three survey protocols as designed by the Arizona Important Bird Area (IBA) Program—transect surveys, point count surveys, and census surveys. Point count surveys occurred in March, June, and July, while transect surveys were conducted during the other months as above. Both transect surveys and point count surveys are field sampling surveys which take a sample of avian populations. Transect surveys involve counting the number of individual birds by species along a transect (Granite Creek) within 50 meters of the transect line. Point counts are taken from the same point during each point count survey and individual birds are counted by species within 100 meters of each point. Census surveys are used for water bodies and water body edges, and are designed to count 95% of all the individual birds present on the water body and along the edge.

Results suggest an increased trend in numbers of two neotropic migrant species, common black-hawk and Bullock's oriole. While four years of monitoring may not ascertain clear changes in avian species numbers and diversity that may result from the Restoration Project, it is anticipated that the continued growth of the recently planted vegetation (especially cottonwood and willow trees) will continue to improve avian populations.

Conclusions
The restored reaches of the Granite Creek Channel are stable and functioning properly, and survivorship of planted trees exceeds 80%. In regard to vegetative analyses, overall average percent cover for woody plants increased along with average height classes. In regard to macroinvertebrate studies, results showed habitat improvements within the Preserve, including increased canopy cover, riparian PFC score, and improved riffle habitat, as well as the establishment of a substrate sufficient for a functional intermittent stream community to develop.

While additional studies may be necessary to evaluate the effects of the Restoration Project on Herpetological and Avian Habitat, valuable baseline data was gathered and existing inventories were further expanded. Considering the overall results and analyses of the Restoration Project Professional Team and visible improvements within Watson Woods, Prescott Creeks believes that these goals and objectives were met.

Introduction

Prescott Creeks Preservation Association (Prescott Creeks) is pleased to present this final report summarizing the Watson Woods Restoration Project (Restoration Project). The Restoration Project was made possible due to grants provided by the Arizona Water Protection Fund Commission (#08-158WPF) and the Arizona Department of Environmental Quality Water Quality Improvement Grant Program (#9-0078, #9-008), along with support/funding from the City of Prescott. The project was sponsored by Prescott Creeks, a 501 (c) (3) not-for-profit organization with the mission to achieve healthy watersheds and clean waters in central Arizona for the benefit of people and wildlife through protection, restoration, education, and advocacy.

Watson Woods Riparian Preserve (Watson Woods/Preserve) is in Yavapai County, Arizona. It is located on Granite Creek northwest of downtown Prescott along the southwest side of State Route 89 approximately 2 miles north of State Route 69. The one mile long project is located within Sections 23, 24 and 26 of Township 14 North, Range 2 West (Figure 1).

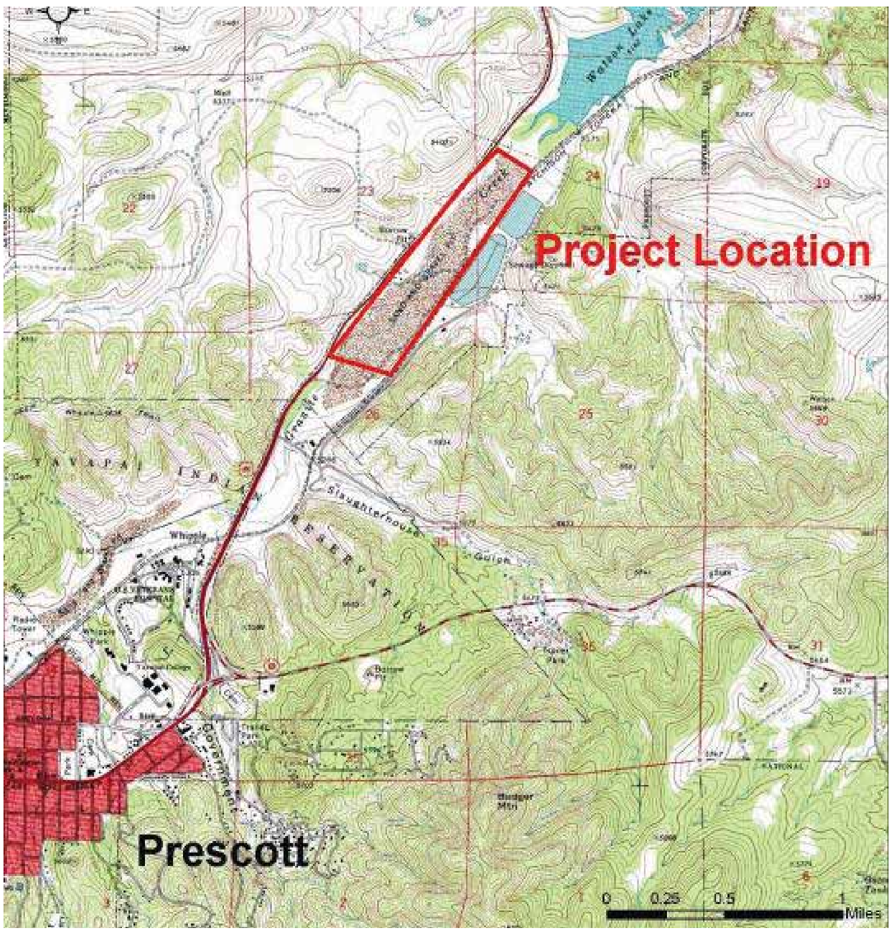


Figure 1-Location of Project Area
Watson Woods Riparian Preserve is located on Granite Creek to the northwest of downtown Prescott

The Preserve was established in 1995 and is managed by Prescott Creeks through a 25-year renewable lease granted by the City of Prescott. Since that time, Prescott Creeks has developed and implemented a variety of management programs and associated activities designed to improve the functional capacity of Watson Woods as a wetland, riparian, and aquatic ecosystem. Prior to these management programs, Watson Woods was severely degraded from anthropogenic activities associated with natural resource extraction and development (residential, commercial, and industrial). Therefore, in March 2009, Prescott Creeks implemented the "Watson Woods Riparian Preserve Restoration Project (Restoration Project)," a project that included stream channel restoration, hydrologic improvements, vegetative plantings, and a management, maintenance, and monitoring program. Figure 2 illustrates a timeline of significant milestones of this project since 2006.

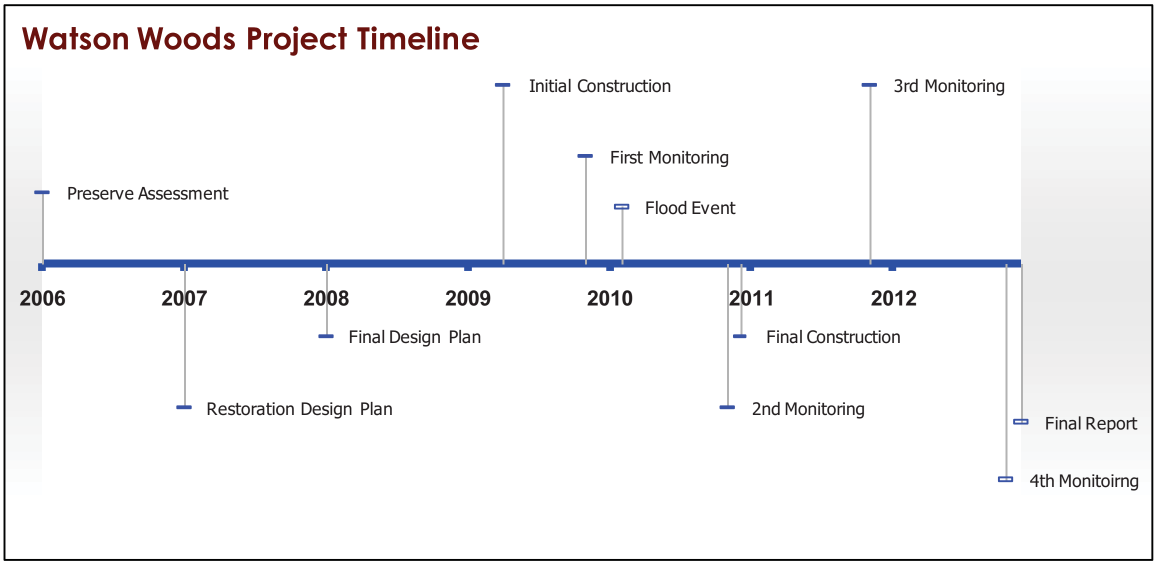


Figure 2-Project Timeline

Goals and Objectives

The goals of this project were to enhance and restore creek function and riparian habitat and create additional riparian habitat. Additionally, the project aims to educate and involve the community in the restoration process of Granite Creek. The results of the education/involvement of the community can be found in Prescott Creeks' *Community Involvement Report* for the Watson Woods Riparian Preserve Restoration Project.

The objectives of the project were to:

- Restore the stability of the Granite Creek stream channel while maintaining natural dynamic stream processes, proper hydrologic conditions and functions, stream morphology and channel characteristics, and floodplain function;
- Enhance, restore, and create riparian vegetation and habitat within the Watson Woods Riparian Preserve;
- Educate and involve community members in the restoration process; and
- Monitor the biotic and abiotic environment to evaluate and communicate project performance.

Granite Creek Restoration

The primary component of the Restoration Project was the restoration of the Granite Creek channel. Prescott Creeks identified existing stable segments of the creek and calculated geomorphic dimensions of these segments in order to incorporate those features into a "natural channel" design. Four "reaches" of the creek were then restored using a variety of structural practices including channel realignment, off-channel wetlands, toe rock/rock trench sill installation, along with non-structural/bioengineering practices such as seeding/fabric installation, post/pole plantings, bundle plantings, and brush revetment/coir log installation. In total, over 4,100 feet of stream channel was re-aligned, shaped, and planted with native riparian vegetation, over 18 acres was planted with native grass seed, and five off-channel ephemeral wetlands were constructed.

Project Planning and Design
The Restoration Project was planned and designed primarily through the 2007 Watson Woods Riparian Preserve – Restoration Plan (Restoration Plan) through a grant awarded by the Arizona Water Protection Fund Commission (#04-122-WPF). The Restoration Plan considered channel geomorphology and function, floodplain function, hydrology, groundwater, stream bank stability, and riparian vegetation, as well as developing a management and monitoring program to ensure project success.

In summary, a geomorphic design approach was utilized, which involved four distinct steps with the intent to improve the physical, biological, and aquatic resources of the riparian corridor and associated wetlands within the Preserve.

1) Characterization of existing physical and biological parameters;
2) Identification and characterization of reference conditions that represent the full potential of the system;
3) Evaluation of existing conditions against reference to determine enhancement needs; and
4) Development of specific design prescriptions to move the system toward the “reference” condition

The project area was divided into four reaches to aid in assessment and design (Figure 3). The reaches vary from 1,200-2,000 feet in length and were selected by considering existing/planned morphology and riparian vegetation.

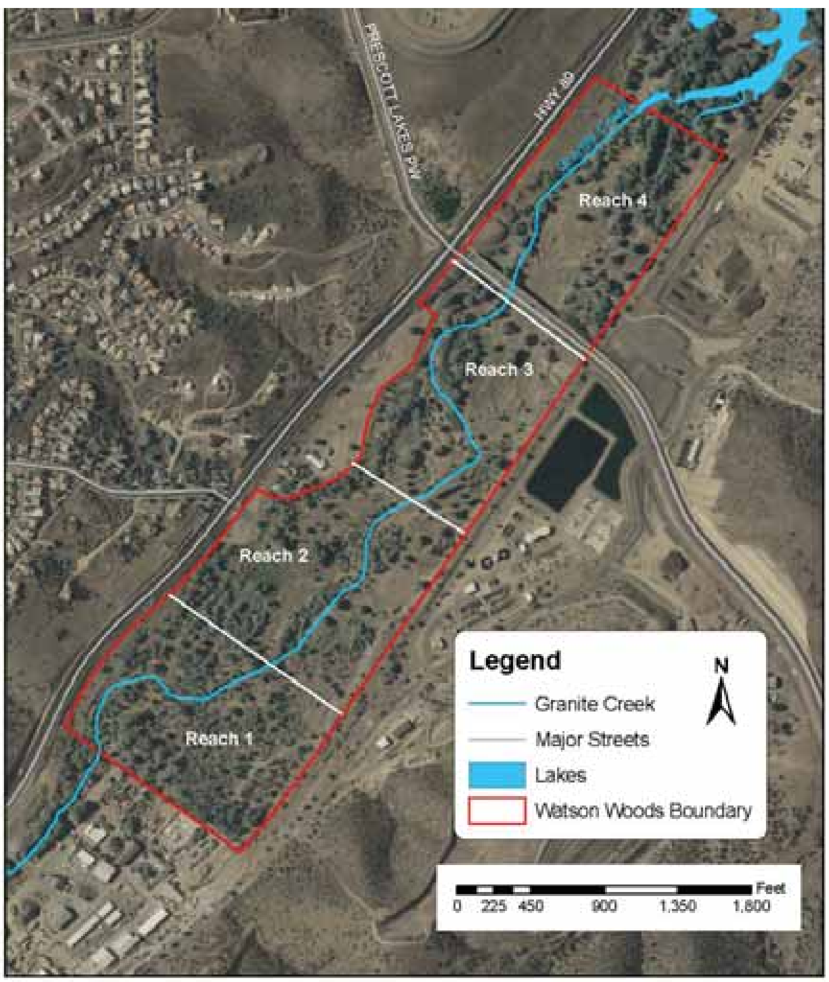


Figure 3-Location of Project Reaches

Construction and Implementation

Initial Construction Efforts (2009)

The initial construction effort took place from March 2nd to April 8th, 2009. Two Natural Channel Design personnel worked as supervisors on the project. Prescott Creeks provided one full time supervisor as well as the Project Manager. Earthwork was sub-contracted to Fann Environmental of Prescott, AZ. Planting labor included two separate 11-person American Conservation Experience (ACE) crews. Volunteers from various local organizations or from personal interest also contributed labor. Equipment utilized included two scrapers, two dozers, a large excavator, a mini-excavator, a loader, a large backhoe, a small Bobcat skid-steer, and a grader.

The following list summarizes the work accomplished during this initial construction effort:

- Stream Channel Excavation — 8,285 cy
- Wetland Excavation — 18,570 cy
- Fill (floodplains) — 14,070 cy
- Road Realignment — 770 cy
- Toe Rock Structure Installation — 420 ft
- TRM Fabric — 70 ft x 8 ft
- Erosion Fabric (Double net straw/coconut) — 54,656 sq ft (61 rolls at 112 ft x 8 ft/roll)
- Erosion Fabric (Single net straw) — 44,800 sq ft (50 rolls at 112 ft x 8 ft/roll)
- Seeding — 17 acres
- Willow Clusters Planted — 1,928 Clusters (~7712 willow stems)
- Willow Vertical Bundles Planted — 365 Bundles (~ 1460 willow stems)
- Cottonwood Post Plantings — 215 Plantings (~645 cottonwood posts)
- Willow Trenches — 17 Trenches (~1267 willow stems)
- Brush Revetment Installation — 615 linear feet
- Coir Log Installation — 540 linear feet

Structural Practices

Channel realignment

The channel was realigned in each of the four reaches in order to restore a more natural meander pattern and increase lateral stability by eliminating sharp bends. In addition, the realignment reconnected the geomorphic floodplain to the stream bed which allows base and flood flows to spread across the entire floodprone area. At each point where the new channel alignment exited the existing channel, excavated material from the new channel was used as a plug to reduce the possibility of the stream returning to its old alignment.

Off-channel wetlands

Three new wetland features were created (wetlands 3, 5 and 6) and two enhanced (wetlands 2 and 4) during initial construction. An outlet channel was constructed to allow any floodwaters which collect in the wetlands to drain back into Granite Creek. Excavated material from the wetland construction was spread out in designated spoil areas.

Wetland 1 was not constructed during the initial construction effort. This wetland was to be located in Reach 2, at the site of an abandoned landfill. Test pits dug at the site indicated the potential for the landfill material to be a greater quantity than originally estimated and thus the cost for cleanup could easily exceed the budget. As a result, this wetland was further reviewed with Water Protection Fund staff and alternatives for relocation considered. Ultimately, Wetland 1 was not included in the restoration project.

Toe Rock with Willow Plantings
This structural bank stabilization practice consists of placing graded angular rock along the plug that is inserted into the existing channel alignment after the new channel alignment has been excavated. The height of rock is 3 ft above the channel bed and extends 2 ft below the channel bed. Planting of willow clusters are placed behind the toe rock. This practice was installed in each reach where a new channel alignment exited the existing channel.

Rock Trench Sills
Rock trenches were installed in two instances where channels were realigned. These sills reduce the risk of stream capture by the previously existing channel during flood periods when overbank flows occur. The trenches were installed at floodplain elevation along the former channel inlet. The trenches are constructed of graded rock.

Temporary Stream Crossing Culverts
Two temporary stream crossings with culverts were constructed so that construction equipment could cross the stream under stable conditions. Both culverts were removed upon completion of earthwork.

Bioengineering Practices

Seeding and Fabric
After the new channel was constructed, the banks were seeded with a native grass and forb mix (Table 1). Then, the banks were covered with erosion control fabric (double and single layer fabrics). The seed was hand broadcast by crewmembers. The fabric was rolled out and staked to the ground to secure it. Stakes were installed approximately every 3 to 4 feet of sloped bank.

Table 1-Native Grass and Forb Mix

Common Name	Latin Name
Purple three-awn	*Aristada purpurea*
Sideoats grama	*Bouteloua curtipendula*
Blue grama	*Bouteloua gracilis*
Bottlebrush squirreltail	*Elymus elymoides*
Blue wildrye	*Elymus glaucus*
Needle and thread	*Hesperostipa comata*
New Mexico feathergrass	*Hesperostipa neomexicana*
Curly-mesquite	*Hilaria belangeri*
Prairie junegrass	*Koeleria macrantha*
Spike muhly	*Muhlenbergia wrightii*
Vine mesquite	*Panicum obtusum*
Western wheatgrrass	*Pascopyrum smithii*
Tobosagrass	*Pleuraphis mutica*
Muttongrass	*Poa fendleriana*
Alkali sacaton	*Sporobolus airoides*
Spike dropseed	*Sporobolus contractus*
Sand dropseed	*Sporobolus cryptandurus*
FORBS/HERBS (WILDFLOWERS)	
Showy goldeneye	*Heliomeris multiflora*
Arroyo lupine	*Lupine succulentus*
Eaton's penstemon	*Penstemon eatonii*
Globe mallow	*Sphaeralcea coccinea*
Yellow evening primrose	*Oenothera elata*

Willow Pole Clusters

Arroyo (*Salix lasiolepis*), coyote willow (*Salix exigua*), and red willow (*Salix lavegata*) were wild-harvested from the immediate surroundings on the Preserve. Each pole cluster planting were placed in an augered hole, watered, and backfilled. To minimize bank disturbance, a 6-inch diameter auger attached to a mini-excavator and small skid-steer was used to create the holes. Clusters were planted approximately every 4-feet. They were planted on all banks that were disturbed by the new channel alignment.

Vertical Bundles

Vertical bundles were planted between cluster plantings.

Willow Trench

This practice was installed in the plugs at each channel re-alignment.

Post Plantings

Cottonwood posts (*Populus fremontii, Populus × Hinckleyana, Populus angustifolia*) were also wild-harvested, and placed in holes excavated to the suggested groundwater depths and backfilled. Willow stems were included in the holes to stimulate cottonwood growth. Post plantings were installed in each Reach along the new channel alignments as well as around the wetlands.

Brush Revetment

Brush revetments were installed in each Reach along banks that were at higher risk of erosion due to the meander radius.

Coir Logs

These 12-inch diameter flexible logs are made of coconut husk, typically 8-10 feet long. They protect the streambank by stabilizing the toe of the slope and by trapping sediment. Logs are secured with 24-inch long wedge-shaped stakes at 5 foot intervals. Stakes are driven through center of log or both sides of log and tied with twine. Coir logs were installed in each Reach along the toe of banks that are at a higher risk of erosion due to the meander radius.

Supplemental Construction Efforts (2010)

Flooding in January 2010 resulted in several impacts to the stream channel and some of the construction practices implemented during the initial construction phase, the most noticeable was the off channel scouring and removal of accumulated biomass along the channel. Direct impacts to the restoration activities were most prominent in the upstream reaches and decreased going downstream. Construction activities in 2010 focused on repairing and enhancing changes brought about by the flood as well as increasing the willow and cottonwood plantings.

The 2010 construction effort took place from November 8 to December 8, 2010. Fann Environmental provided the earthmoving equipment and operators. Project supervision was provided by two Prescott Creeks and one Natural Channel Design, Inc. personnel. Equipment utilized during this phase of construction included an excavator, a loader, large backhoe, a dozer and two dump trucks. Work crews varied depending on the task, but typically included a supervisor/operator, other operators and general laborers. Revegetation efforts were carried out with the use of a 9-person ACE crew along with one to two equipment operators and took ten days to complete. The primary machinery utilized to assist in the plantings was a Bobcat mini-excavator with a 6-inch auger attachment. The auger drilled the holes for the willow clusters while the bucket attachment was used to dig some of the willow trenches. In addition a large backhoe assisted in the excavation of willow trenches.

The following list summarizes the work accomplished during the 2010 construction effort:

• Stream Channel Excavation	260 linear feet
• Stream Channel Sediment Removal	150 linear feet
• Bank Sloping	530 linear feet
• Toe Rock Structure Repair	75 ft (70 cy rock)
• Non-Woven Geotextile Fabric	70 ft x 15 ft
• Double Net Erosion Control Fabric	12,288 sq ft (16 Rolls at 8' x 96' ft/roll)
• Single Net Erosion Control Fabric	19,968 sq ft (26 Rolls at 8' x 96' ft/roll)
• Willow Clusters Planted	391 Clusters (~11732 willow stems)
• Willow Vertical Bundles Planted	11 Bundles (~ 33 willow stems)
• Cottonwood Post Plantings	84 pit plantings (~254 cottonwood posts)
• Willow Trenches	12 Trenches (~1270 willow stems)
• Brush Revetment Installation	40 feet
• Coir Log Installation	150 linear feet
• Native Grass Seed	1.6 Acres

Structural Practices
The following is a summary of activities and practices implemented during the 2010 construction period.

Channel Shaping and Maintenance
The 2010 main channel alignment in Reach 1 had moved away from the 2009 alignment. The decision was made to keep the active channel in this new alignment based on several factors. Since the vegetation planted along the 2009 alignment was established, the new alignment opened up additional areas to expand riparian plantings. The new channel alignment allowed for extending water to previously drier areas while allowing higher water to flow into the 2009 channel. In order to prevent the migration of a headcut through this reach, a new channel was excavated to a more consistent slope and shaped to reconnect the geomorphic floodplain to the stream bed that will allow base and flood flows to spread across the entire floodprone area. The 2009 channel in Reach 1 was cleared of deposited sediment that had filled the channel.

Toe Rock Repair
In Reaches 1 and 2, toe rock that was damaged during the flood was repaired with graded angular rock. After the section of bank needing repairs was resloped, non-woven geotextile was placed on the slope prior to the placement of the rock. The height of rock is 3 ft above the channel bed and extends 2 ft below the channel bed. This rock repair ties into the intact rock still in place.

Log Sills
Log sills were installed in two instances where additional bank stabilization efforts were needed. These sills reduce the risk of stream capture by the historic channel during flood periods when overbank flows will occur. The sills are buried to floodplain elevation. The log sills are an alternative to more expensive rock.

Mound Removal
In Reach 2, a large mound of soil that was a remnant of the gravel mining was removed. This mound located on the adjacent floodplain prevented water from spreading across the floodplain. The result was a concentrated flow in the channel that caused excessive scouring. The removal opens up 100 feet of floodplain width and should allow for a more even flow of water.

Bioengineering Practices

Seeding and Fabric
After any bank was resloped or disturbed, it was seeded with a native grass & forb mix and then covered with erosion control fabric (double and single layer fabrics).

Willow Pole Clusters
Willow pole clusters were planted on all banks that were disturbed and re-sloped during the 2010 construction.

Willow Trench
This practice was installed in areas identified during post flood surveys as needing to have reduced flow velocities to prevent further scour.

Cottonwood Post Plantings
Post plantings were installed in Reaches 1 and 2 along the channel alignments as well as in Critical Planting Area 1.

Brush Revetment
Brush revetments were installed in late winter 2011

Coir Logs
Coir logs were installed in each Reach along the toe of the downstream bank.

Irrigation System
Following the construction and implementation of the Granite Creek restoration, vegetative plantings, and soil stability practices, Prescott Creeks installed a complex irrigation system to provide a regular water supply to native trees, grasses, and forbs planted. The water was supplied by the City of Prescott for 2-3 growing seasons, implemented in 2 different stages.

The first stage consisted of irrigating areas immediately adjacent to the restored reaches of Granite Creek. While successful, this stage was extensively damaged from the January 2010 flood. During post-flood repairs, Prescott Creeks focused on providing irrigation to off-channel areas (critical planting areas and wetlands), which represents the second stage of the system. Figures 4 and 5 illustrate both stages of irrigation within the Preserve.

The system consisted of a series of 2” main lines (PVC), ¾” flex tubes, and “spaghetti” tubes, all of which was automatically operated through a control unit/valve box. The irrigation system operated from approximately May-October, and planting areas were typically watered for 4 hours 2-3 times per week on a staggered schedule. Prescott Creeks considers this system to be beneficial to the restoration project, particularly due to the relatively dry conditions in 2011 and 2012.

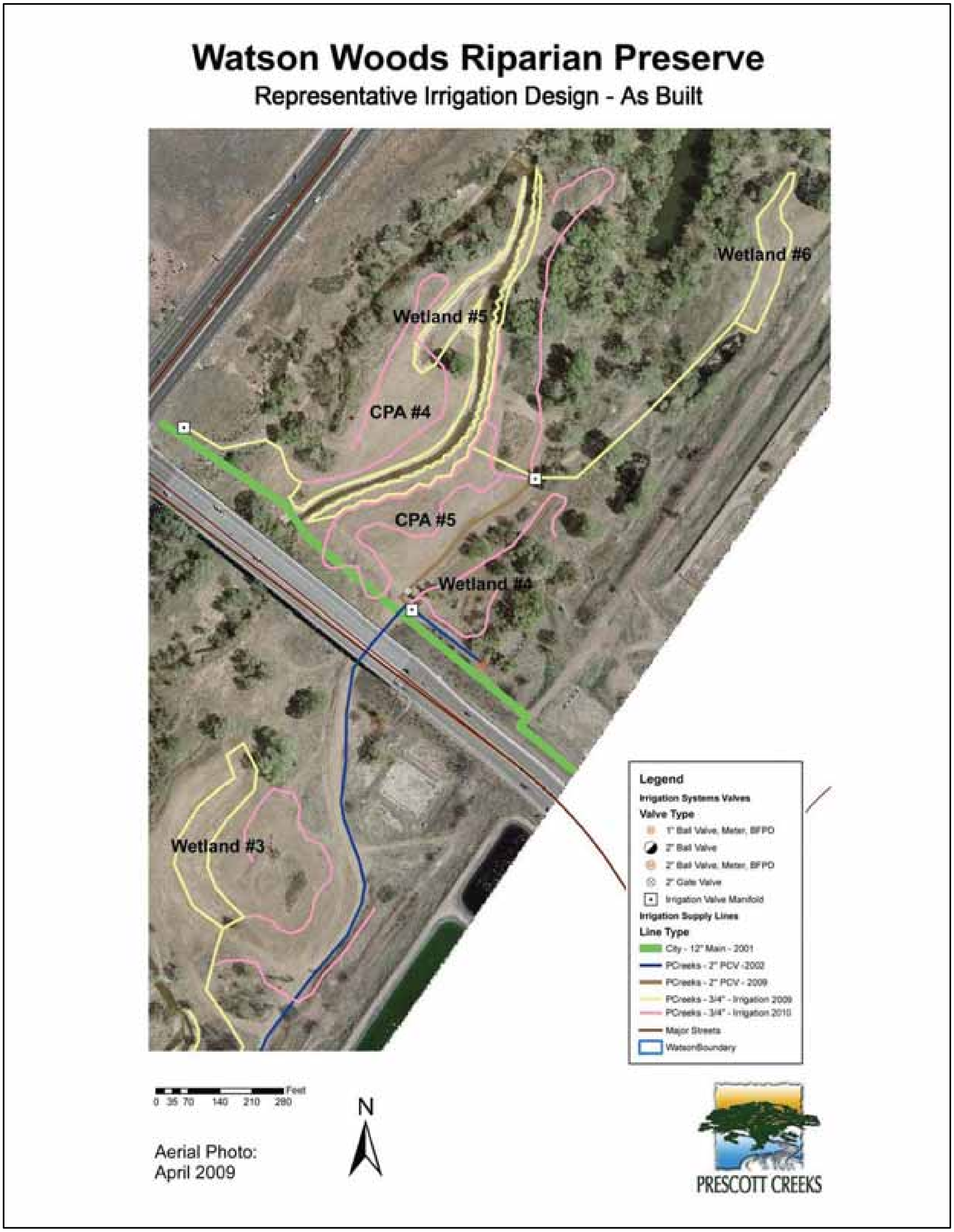


Figure 4-Irrigation As-Built Drawing (North)

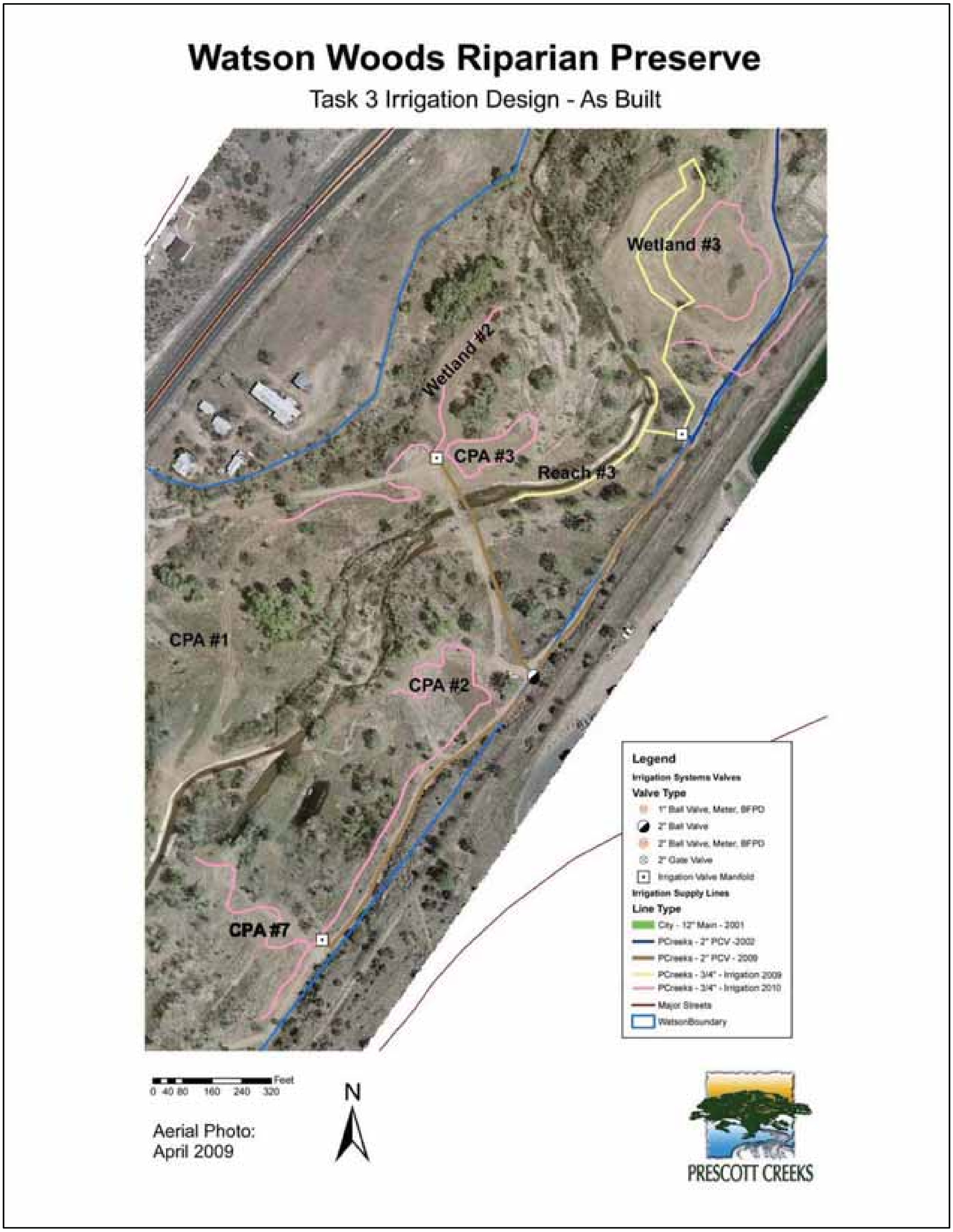


Figure 5-Irrigation As-Built Drawing (South)

As Built Drawings

Figure 6 illustrates the final location/extent of critical planting areas and wetlands. In addition, Appendix E contains fully engineered "as built" drawings.

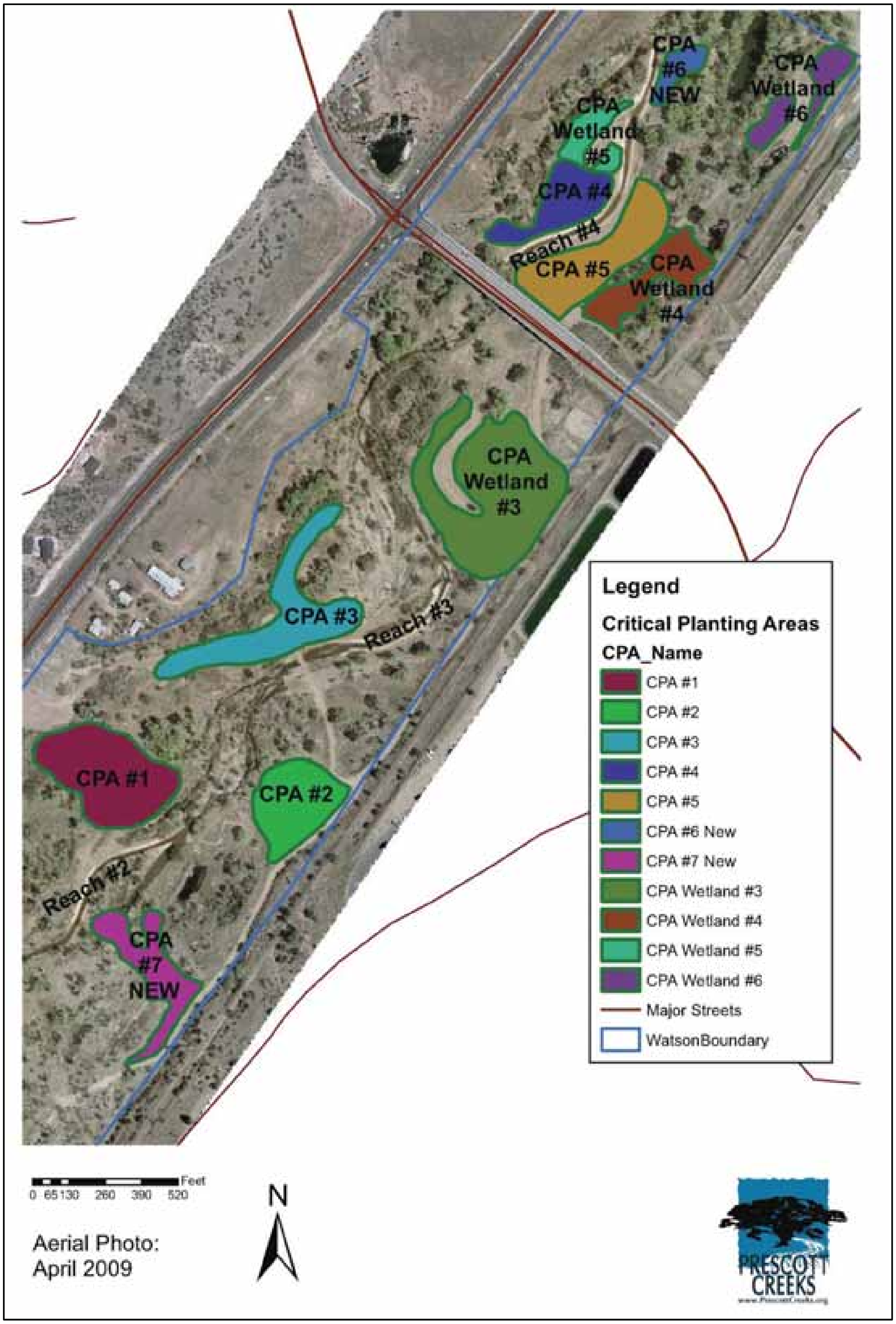


Figure 6-Final Planting Design

Current Reach Conditions

Prescott Creeks engaged Vertical Mapping Resources, Inc (Scottsdale) to conduct 2 aerial flyovers (2009 and 2012) in order to take digital photographs of the Preserve for use in GIS. Figures 7-10 illustrate the existing conditions in August 2012 of each restored project reach.

Figure 7-Reach 1 Channel Location (2012)
The historic channel location is now a wetland

Figure 8-Reach 2 Channel Locations (2012)
The historic channel location is now a wetland

Figure 9-Reach 3 Channel Locations

Figure 10-Reach 4 Channel Locations

Post Restoration Monitoring

Geomorphology

Methods

Post-construction monitoring occurred in April 2009, September 2009, October 2010, September 2011, and September 2012. Monitoring evaluated the success of installed structures and bioengineering treatments completed in the project area. Six cross-sections in the project area were re-surveyed to measure channel stability and six banks were re-surveyed using the Bank Erodibility Hazard Index (BEHI) to monitor bank stability (Figure 11). Photos were taken annually at eleven photo points as well as at each cross-section and BEHI location.

Any evaluation of change in condition in a riparian area is dependent on the climatic conditions since the last monitoring effort. Drought periods can reduce the growth and vigor of vegetation, while wet periods are a benefit. Morphologic changes must be balanced against the magnitude and duration of stream flows. For each monitoring effort, annual stream flow and precipitation data was gathered and analyzed to determine the duration and force of water that the banks would have experienced that year. This information can be found in the Annual Monitoring Reports associated with this project. The following section summarizes the final (2012) monitoring data.

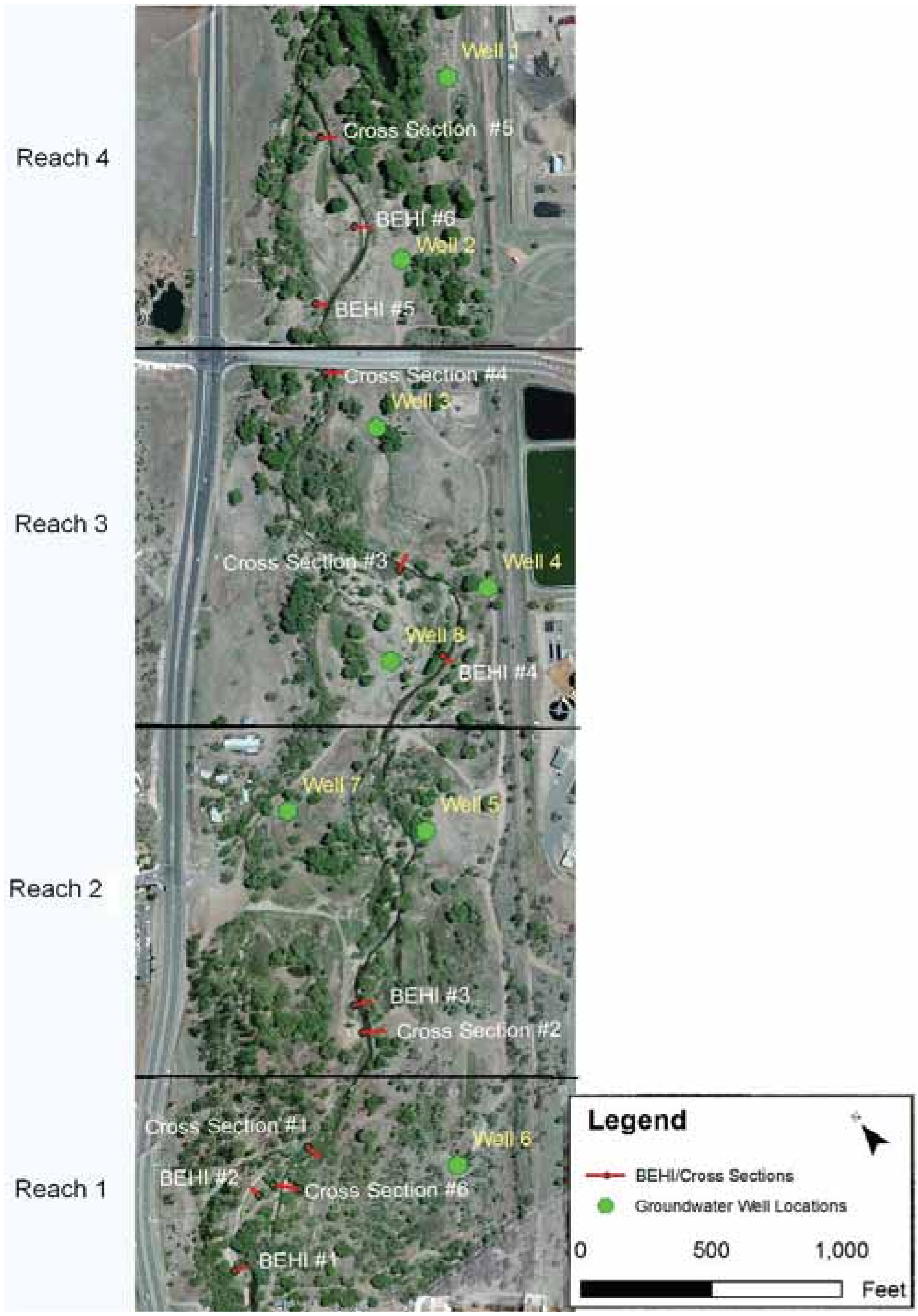


Figure 11-location of monitoring cross sections, BEHI, and groundwater wells

Hydrology
Stream gages near the site are used to gather real time data to determine quantity and duration of high water events that pass through the Preserve. There is a USGS Gage located approximately 0.5 mile upstream from the project (09503000 - Granite Creek near Prescott) that is used to determine magnitude and duration of flow events that pass through the project area.

Groundwater
Groundwater wells were installed in 1998 by Prescott Creeks to track changes in groundwater elevation. Depth to groundwater is recorded weekly.

Stream Channel Stability
Six permanent cross-sections, as shown in Figure 11 are located within the project area to monitor stream channel stability (Harrelson et al. 1994). Cross-sections 1 and 4 are located in areas unaltered by construction and act as reference cross-sections for monitoring purposes. Cross-section locations were marked at each end by permanent pins set well away from the stream channel (see Appendix D for locations). Bankfull stage was identified at each cross-section to provide a common reference point using standard protocols (Dunn & Leopold 1978).

Utilizing the Rosgen classification system, the river through the project area is classified as a "C" type channel. This type of channel meanders through the valley with a riffle/pool sequence and typically has well developed floodplains.

The channels characteristically have a width/depth ratio (w/d) greater than 12. The w/d ratio is the bankfull channel width divided by the mean bankfull channel depth and defines the channel shape. In a stable stream channel, the w/d ratio should not change significantly from year to year. If the w/d ratio increases significantly at a cross section it is an indication of either bank erosion causing the channel to widen or of excessive aggradation. A decrease in the w/d ratio can be either a positive or negative change. A decrease due to vegetative growth (and thus an increase in bank stability) would be a positive change. If the decrease in the w/d ratio has an associated increase in the bank/height ratio, the stream may be trending towards becoming entrenched and unstable.

Stable stream systems should also have a bank height ratio that remains constant. This is the ratio of the river's bank height divided by the bankfull height. A change in the bank height ratio can indicate stream channel aggradation or degradation. However, rivers are dynamic and some change over time is within the boundaries of natural variation. The w/d ratio and the bank height ratio are the variables that will be used to determine the stability of the channel for this monitoring effort.

Bank Stability
Bank stability is evaluated using the Bank Erodibility Hazard Index (BEHI), an empirical model developed by Dave Rosgen used for assessing bank erosion potential (Rosgen 2002). The BEHI consists of a set of physical characteristics of the stream bank that indicate erodibility. These include bank height, bank slope, root depth, root density, surface protection, bank material, and soil stratification. The locations of the BEHI sites are shown in Figure 11. Permanent pins were set post-construction for baseline monitoring and are resurveyed annually (see Appendix D for locations). All monitoring sites are located at new banks that received project treatments. It is expected that individual BEHI scores will decrease over time toward an optimum value as the bank heals and stabilizes.

Structures
The types of structures installed during this project include:

- Toe rock (rock rip-rap set along the toe of a bank),
- Rock sills and plugs (rock rip-rap set in a trench across the floodplain or abandoned channel to prevent overland scour)
- Log sills (logs used in place of rock rip-rap sills or plugs, typically less costly than rock)

During the annual monitoring effort, all structural components were assessed qualitatively to determine whether they were meeting their intended purpose and for any signs of failure through scour or bank erosion. Installed structures are referred to by the numbered bank within a project Reach (see As-Built Construction Sheets for more detailed location). It was expected that all structures will accomplish their intended purpose without failure, short of an extremely large flood event (> 20 year event).

Bioengineering Treatments
Bioengineering includes the use of native vegetation to provide bank stabilization properties instead of a more typical engineering practice such as riprap. This type of practice helps to restore native vegetation and increases riparian habitat. The types of practices installed for this project include willow clusters and trenches, and cottonwood post plantings and are discussed later in the report.

Bioengineering practices have been identified as to type and quantity of treatments installed per reach. The total number or length of each bioengineering practice installed is recorded for each bank. All bioengineering practices will be visually assessed to qualitatively determine the success of live plantings and ensure practices are providing the expected protection to banks. Successful establishment is identified by active sprouting or other signs of growth and are quantified by a count during the first year for willows and all monitoring years for cottonwood posts. Once established, percent cover is calculated for willows colonizing a given area. It is expected that at least 80% of all installed bioengineering practices will survive and colonize the treated banks.

Photo Monitoring
A series of photo points were established to capture changes over time in stream channel morphology, treated bank areas, and revegetation areas. Post-construction qualitative measurement of channel changes, bank erodibility, revegetation efforts, and structure stability were made using photo monitoring. At the cross-section survey sites, photos were taken from slightly upstream of the cross-section location with a view downstream through the middle of the cross section. At the BEHI survey sites, photos were taken from the point bar opposite the bank to be treated, viewing the bank at a downstream 45-degree angle. Photos were also taken at photo points within the project area to document general site characteristics. All photo points are marked with permanent pins with caps and their locations are recorded for future monitoring (Figure 12, Appendix D). Photographs were taken annually to document changes in stream channel morphology, bank stability, vigor of revegetation, and general site characteristics.

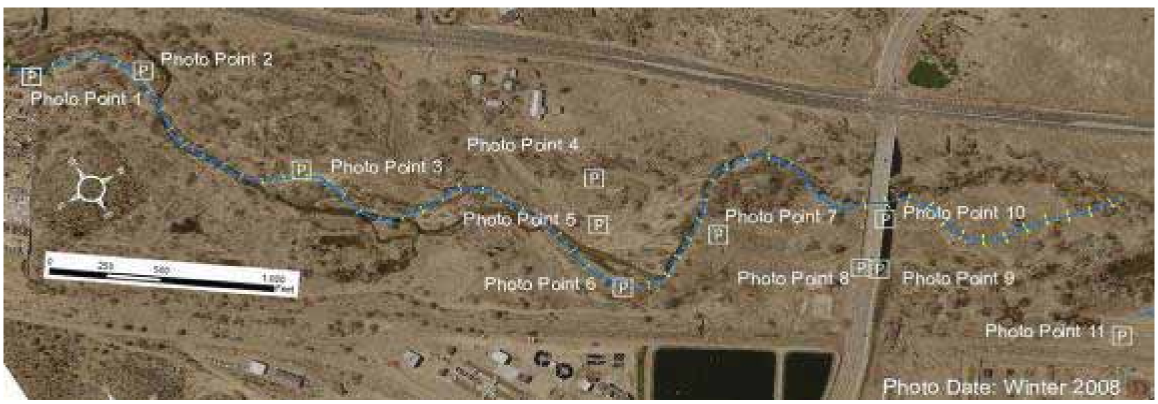


Figure 12-General photo point locations

Results and Discussion
Monitoring at Watson Woods Preserve was conducted in September 2012. Natural Channel Design, Inc. with assistance from Prescott Creek personnel completed the stream and bank stability, photo monitoring, bioengineering, and structural stability monitoring tasks. Groundwater well monitoring data was collected by volunteers and compiled by Prescott Creeks.

Hydrology and Precipitation
Drought conditions prevailed in the Prescott vicinity during 2011 and 2012. Approximately 10.8 inches of precipitation was recorded at the local weather station (APRSWXNET -MAS857). On average, Prescott sees around 19 – 20 inches of precipitation annually. All months with the exception of December 2011, July 2012, and August 2012 saw below normal precipitation. December, July and August saw average precipitation amounts (Figure 13).

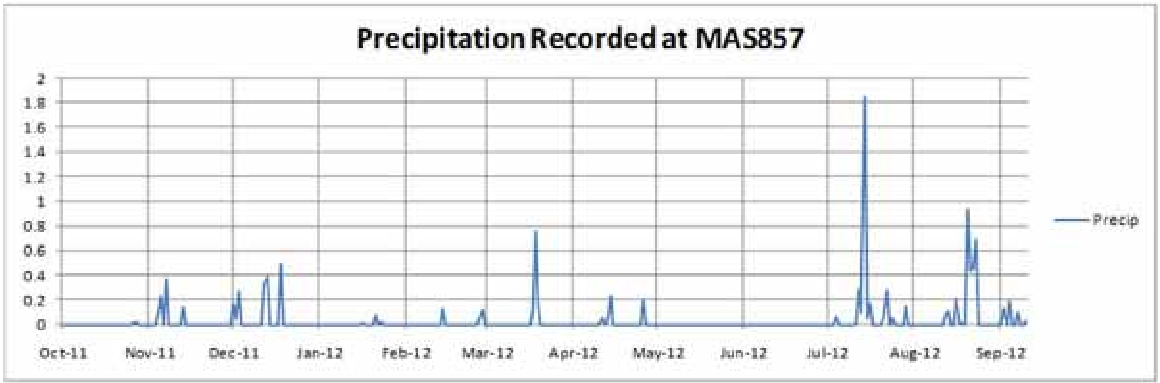


Figure 13-Daily Precipitation totals for 2012 at weather station MAS857
The weather station MAS857 is located approximately 1.6 miles from Watson Woods

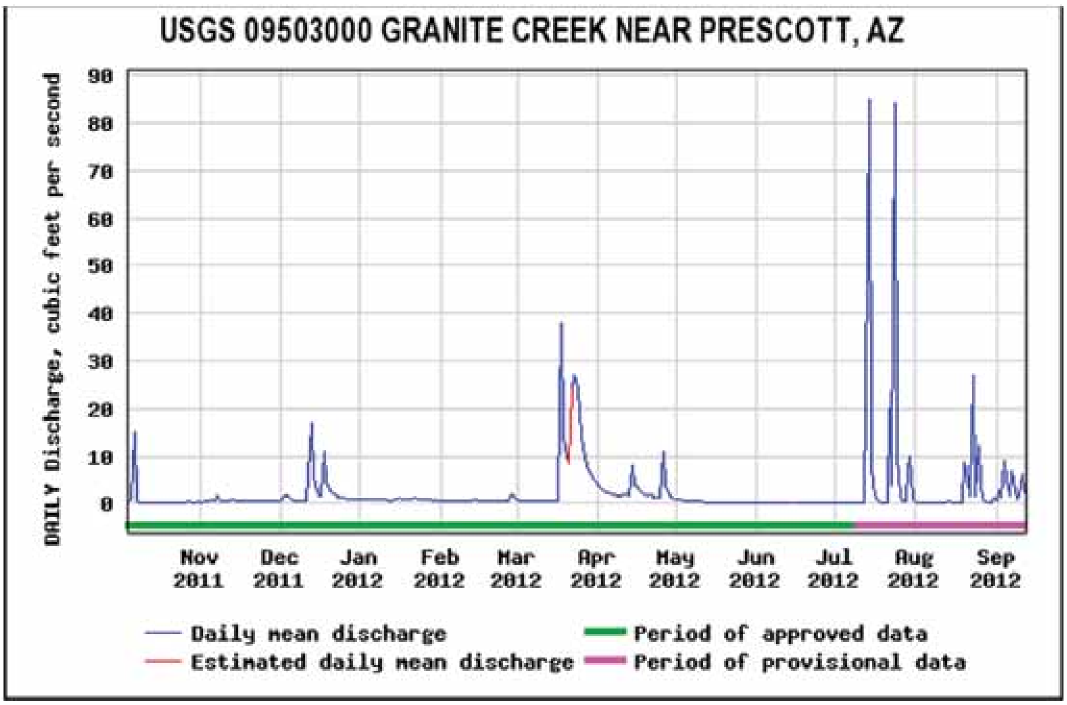


Figure 14-Mean Daily Discharge at USGS gage 0903000 for November 2010 to mid-October 2011
The mean discharge is the average flow for the day. The double spikes in July 2012 show an almost identical mean discharge on those two days, but magnitude of flows was much different.

During the previous year, there were three periods where stream flows in the Preserve significantly exceeded baseflow. In March, stream flows approached 200 cfs. Then in July, several storms produced flows that were near bankfull over a three day period. The final large flow of the year was on July 24th with a flow near 1,200 cfs (close to a 2 year event, Table 2 and Figure 15). These flows allowed for the distribution of sediment, but did not cause any damaging erosion. The vegetation along the banks withstood the flows without any damage.

Table 2-Calculated peak discharge for 2012 for the following recurrence

Return Interval (years)	1.5	2.0	5	10	20	40	50	100
Discharge (cfs)	480	1,300	2,600	3,700	4,800	6,200	6,600	8,000

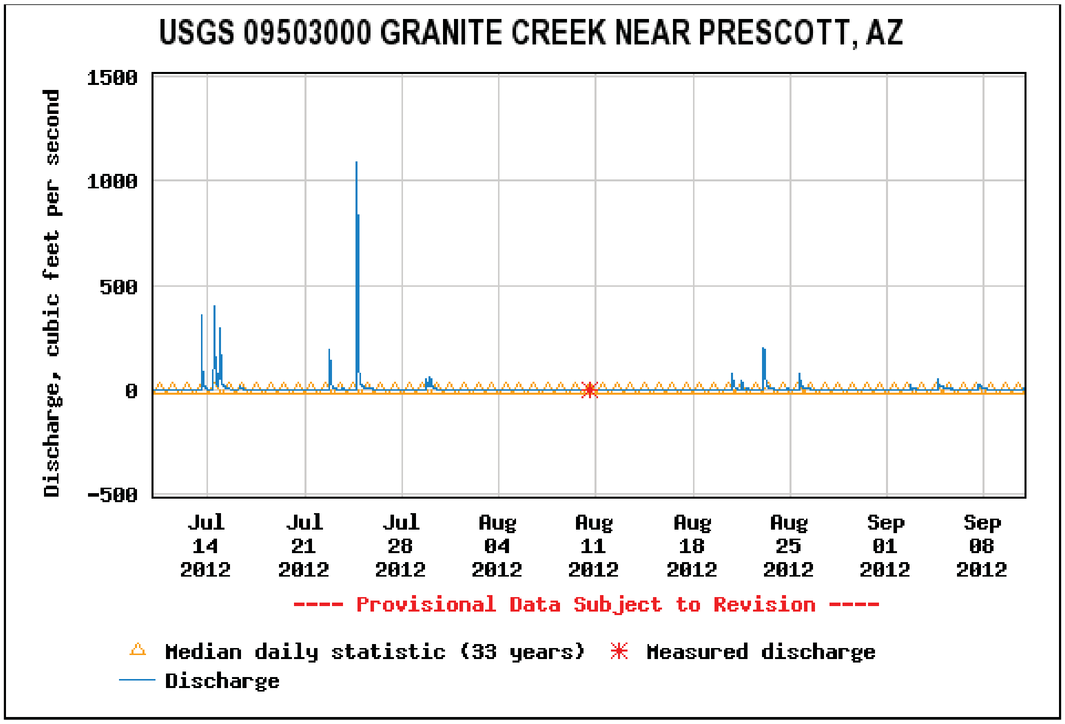


Figure 15-Maximum discharges at Granite Creek Gage 09503000 from July 11 to September 10, 2012
The USGS Gage 09503000 is located approximately 0.5 miles upstream from the entrance to Watson Woods

Groundwater Monitoring

Groundwater elevation is monitored weekly to track changes in groundwater elevation throughout the project area. During dry years, it can help to understand how far groundwater elevation drops, which may help explain plant stress. Figure 16 shows groundwater elevation from January 2009 to August 2012 from all eight wells. The fluctuation closely follows the hydrograph from the USGS Gage upstream, indicating that stream channel flows are linked to groundwater elevations.

The summer of 2011 saw a prolonged period of low groundwater elevations during the summer growing season. This low water resulted in stress and some die off of the planted vegetation, especially for willows planted in trenches away from the active channel. Ground water elevation rose back to normal by November and stayed up until June, 2012 when it again dropped.

The period from June to mid-July 2012 saw some of the lowest groundwater elevations since fall 2009 but the levels came up quickly once the monsoonal rains started. The plants that were stressed the previous year were growing robustly at the time of the monitoring efforts, possibly indicating that additional root growth since the previous year allowed the plants to withstand this dry period.

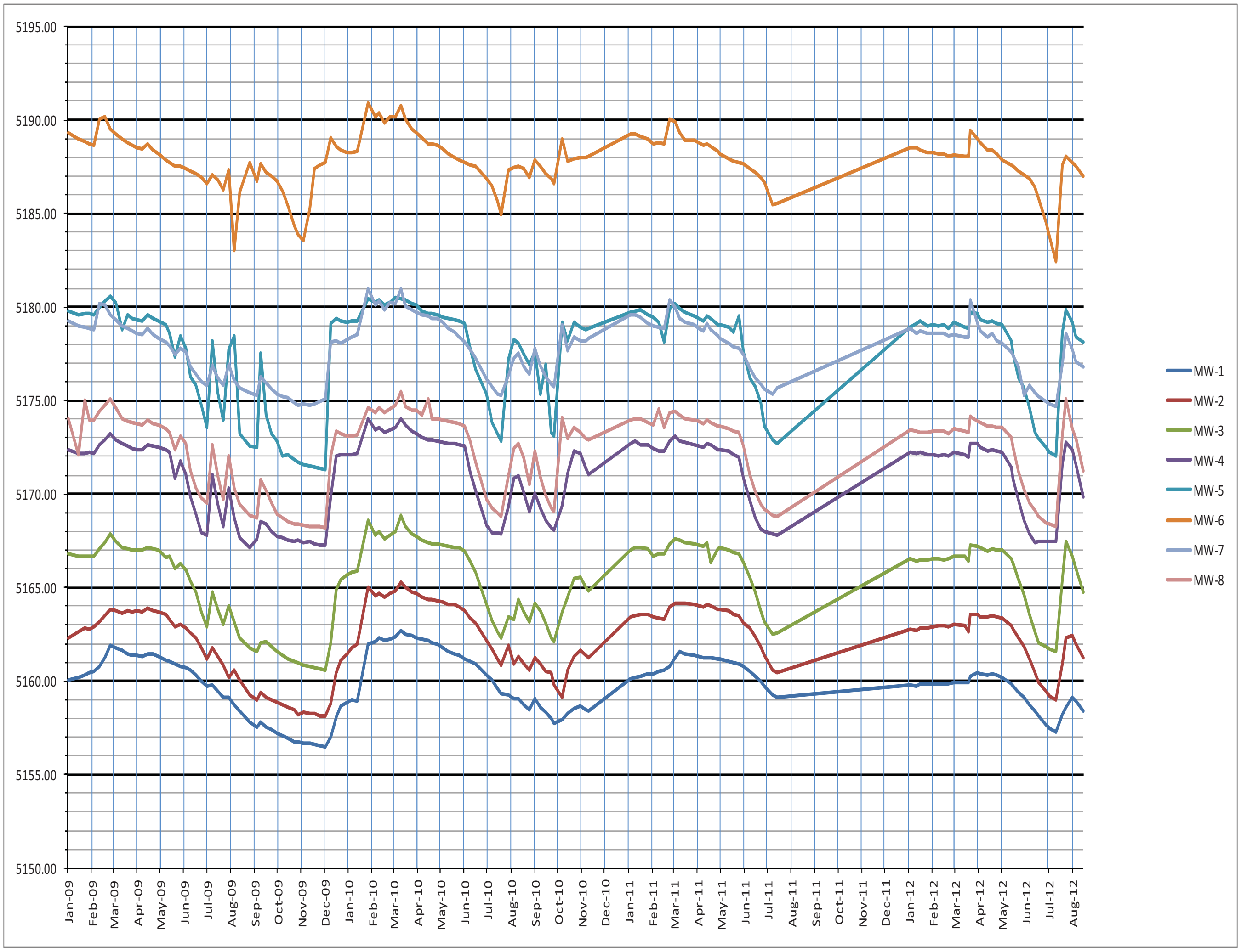


Figure 16-Monthly water elevation (ft) at each well from January 2009 to August 2012
2012 saw higher groundwater elevations while 2012 had generally lower elevations

Stream Channel Monitoring

As stated, flows that occurred in the channel during 2012 were within the normal range. No exceptionally high water events occurred that would cause significant scouring of banks or removal of vegetation. The graphs of the cross-section and associated photos are located in Appendix A.

Lateral Stability

There was no significant change between 2011 and 2012 in channel width at any of the cross-sections, which is to be expected since there were no extremely large flow events that would have caused erosion (Table 3). Any flows higher than base flow typically lasted only a few days before returning to base flows. The vegetation growing on the stream banks is providing stability through an increase in root mass and protecting the soil surface with the above ground biomass. Most of the treated banks are expected to withstand a significant flow without additional erosion.

Table 3-Channel width comparison and percent change

	Base line	Fall 2009	Fall 2010			Fall 2011			Fall 2012		
XS#	Width (ft)	Width (ft)	Width (ft)	Percent Change		Width (ft)	Percent Change		Width (ft)	Percent Change	
1	48	46	46	0%	no change	46	0%	no change	46	0%	no change
2	36	60	62	3%	w ider	62	0%	no change	62	0%	no change
3	56	58	64	9%	w ider	64	0%	no change	64	0%	no change
4	54	52	54	4%	w ider	54	0%	no change	54	0%	no change
5	38	36	38	5%	no change	38	0%	no change	38	0%	no change
6	Installed in 2011					34	na		34	0%	no change

Vertical Stability

Again, due to the average flows experienced in the channel in 2012, there was very little change in the maximum depth of the channel cross-sections. Most cross-sections experienced a change of around 0.1 ft, which is within the normal range of variability, and is due to sediment transport from the filling or scouring of sediment (Table 4). The exception was at cross-section #1, which is on the abandoned channel at the beginning of the project area (Figure 11). This accumulation of bed sediment was typically finer grained sediments that were deposited in the channel as seen in Figures A-5 & A-6. The 2-yr high flow event happened a few weeks prior to the monitoring while the vegetation was in full leaf. The vegetation caused a reduction of flow velocity at this cross section causing sediment to be deposited.

Table 4-Maximum Channel Depth comparison and percent change

	Base line	Fall 2009	Fall 2010			Fall 2011			Fall 2012		
XS#	Max. Depth (ft)	Max. Depth (ft)	Max. Depth (ft)	Percent Change		Max. Depth (ft)	Percent Change		Max. Depth (ft)	Percent Change	
1	2.8	2.3	2.1	9%	shallow er	2	5%	no significant change	1.5	25%	shallow er
2	3.1	3	4.6	53%	deeper	4.7	2%	no significant change	4.8	2%	no significant change
3	2.6	2.6	2.4	8%	shallow er	2.5	4%	no significant change	2.4	4%	no significant change
4	3.4	3.4	3.4	0%	no change	3.4	0%	no change	3.4	0%	no change
5	2.4	3.6	4	11%	deeper	4.1	2%	no significant change	4	2%	no significant change
6	Installed in 2011					3.4	na		3.4	0%	no change

Analyzing the width/depth (w/d) ratios can provide more information on the change in channel cross-sections (Table 5). Since there was no change in overall channel width and only slight changes in maximum depth, the width/depth ratios did not change significantly. The cross-section width/depth ratios remain within the range of a stable "C" channel type.

Table 5-Width/Depth and Bank Height/Bankfull Height Ratios

XS#	Baseline	Fall 2009	Fall 2010	Fall 2011	Fall 2012
1	32.4	36.3	38	39.8	53.1
2	48	48	28.6	27.8	27.6
3	37.5	38.9	49.8	48.2	49.2
4	35.7	35	37.6	36.6	37.2
5	29.8	21.5	18.3	17.5	17.7
6	na	na	na	17.7	12.5

Bank Stability

The BEHI scores continue to slowly decline as vegetation on the banks matures (Table 6). Root depth and density continue to increase, especially with the planted willows. Above ground, the biomass provides increasing amounts of surface protection that slows water velocities along the bank and encourages deposition of fine sediments. A yearly comparison of all bank profile and photos taken during each monitoring effort for the BEHI sites are in Appendix B.

Table 6-Baseline through 2012 BEHI at survey sites

#	Value	Index	Value	Index	Improvement over previous year	Value	Index	Improvement over previous year	Value	Index	Improvement over previous year
1	28.7	moderate	13.9	low	52%	12.3	low	12%	10.8	low	12%
2	31.8	high	16.2	low	49%	13.3	low	18%	12.3	low	8%
3b			13.2	low	na	12.1	low	8%	7.7	v. low	36%
4	36.7	high	16.2	low	56%	15.7	low	3%	12.3	low	22%
5	36.5	high	18.5	low	49%	17.5	low	5%	13.5	low	23%

Structural Stability

All structures are intact and functioning. No alterations or damage was noted during 2012 monitoring which is to be expected for flows less than a 20 year event. Table 7 lists the structures with their current condition. Following the table is a set of comparative photos of these structures.

Table 7-Function of Installed Structures

Structure ID	Type	Fall 09	Fall 10	Fall 11	Fall 12
R1-RP	Rock Plugs	Functioning	Partially Functioning	Repaired, Functioning	Functioning
R2-RP	Rock Plugs	Functioning	Partially Functioning	Repaired, Functioning	Functioning
R2-RP 2	Toe Rock, Bank sloping	Functioning	Partially Functioning	Repaired, Functioning	Functioning
R3-RP	Rock Plugs	Functioning	Functioning	Functioning	Functioning
R4-RP	Rock Plugs	Functioning	Functioning	Functioning	Functioning
R2-TR	Rock Sill	Functioning	Functioning	Functioning	Functioning
R1-Log	Log sill		Installed	Functioning	Functioning
R2-Log	Log sill		Installed	Functioning	Functioning

2010, taken after flood event

2012

Figure 17-Rock Plug in Reach 1

This structure was repaired in 2010. Soil was spread over the surface to encourage vegetation growth

2009 prior to installation of new channel and rock plug on right

2012

Figure 18-Rock Plug in Reach 2
This Structure was repaired in 2010

2010 after repairs to the bank post flood

2012 after two growing seasons. Recent flood debris can be seen at the top of the bank

Figure 19-Reach 2 toe rock and sloped bank

The scour at this bank downstream of the remaining rock was filled and sloped with multiple plantings of willow clusters

2009 prior to channel re-alignment

Figure 20-Reach 3 rock plug
Arrow points to the same cottonwood

2009 during construction and prior to placement of rock plug

2012

Figure 21-Reach 4 rock plug
Growing Vegetation is starting to camouflage the rock

In addition to the existing rock structures, three log sills were installed in 2010. The purpose of the sills is to prevent overbank flows from cutting softer bank materials and creating new channels that could capture the main channel flows. These three structures were not overtopped by the high water event in 2012 (Figures 22 and 23). Since these structures are buried, there is little evidence of them above ground. The planted willows are growing vigorously.

2011

Figure 22-Log sill location in Reach 1
The two logs are buried here and are intact

2011

2012

Figure 23-Log sill location at Reach 2
There was one log sill buried at this location

Mound Removal Area in Reach 2.
During the construction period in 2010, a large mound of soil was removed at the upstream end of Reach 2. This mound of soil was restricting the floodplain width contributing to increased stress along the banks of the channel. This area was critical since the channel here was re-routed to avoid an existing landfill that the old channel path cut through. The area continues to fill in with vegetation (Figure 24).

Mound prior to its removal in 2010

Mound after its removal in 2010

Mound in 2012

Figure 24-Mound in Reach 2

Bioengineering Treatments

Willow Clusters

Willows planted during the initial construction period in 2009 are well established along the channel. Most of these willows are healthy and growing, with additional sprouting beginning to be seen between clusters. Willow clusters planted in December 2010 did experience some stress during the summer of 2011 due to low ground water elevations and very low channel flows throughout the summer. Channel flows during summer 2012 were more numerous and groundwater levels did not remain as low. The willows are growing well, providing cover and protecting the banks.

Willow Trenches

Willow trenches were installed across plugged channels or behind some of the rock structures with the purpose of establishing a porous wall of vegetation. Additional trenches were installed in 2010 across areas that were scoured in the previous flood. This vegetation slows down the velocity of water running across the floodplain, helping to prevent erosion across an abandoned channel and to help prevent the recapturing of the stream channel.
As with the willow clusters, the willows planted in trenches showed signs of stress due to the lack of precipitation and a prolonged lowering of the ground water elevation in 2011. The stems that did not perish during the last season were growing well in 2012. New stems have emerged around the bases of willows thought to have been dead the previous summer (2011) (Figures 25 and 26).

Figure 25-Brush trench in Reach 4

Many of the stems in this brush trench that were thought to have died back in 2011 have re-sprouted in 2012

Figure 26-Brush trench in Reach 3 showing improved growth in 2012

Posts Plantings

The cottonwood post monitoring table shows the number of cottonwood pits installed during the project (Table 8). Within each pit, at least three cottonwood posts were installed. Willow poles were also installed in many of the pits. This helps to increase the odds that if the cottonwoods don't survive, at least there will be a willow growing in that space (Figure 27). Not all cottonwood posts within a pit have to survive for the planting to be successful. The goal of these plantings is to establish riparian species on the flood plains. As long as one cottonwood post or willow is growing, the planting effort is considered successful.

Table 8-Summary of cottonwood post survival (2012)

	Total Plantings	Live Cottonwood only	Live Cottonwood and Willow	Live Willow only	Total Live	% Plantings Survival
CPA 1	18	12	6	0	18	100%
CPA 3	20	4	4	12	20	100%
CPA 4/Wetland 5	28	16	6	4	26	93%
CPA 5/Wetland 4	84	65	2	12	79	94%
Wetland 3	47	36	6	4	46	98%
Reach 1	43	22	1	4	27	63%
Reach 2	35	3	0	11	14	40%
Project Total	275	158	25	47	230	84%

Wetland 2 in 2009

Wetland 2 in 2012

Figure 27-Cottonwood Posts in Wetland 2

Table 8 summarizes the total number of cottonwood plantings that were installed during the project. Included is a break down on pits with surviving cottonwood trees, pits with trees and willows, and pits where the cottonwoods died but willows survived. Overall, 84% of the holes had live vegetation with 66% containing live cottonwood posts in 2012. Many of the surviving species are 10-15ft in height and are growing robustly, now able to support avian habitat.

Photo Monitoring
Photo monitoring from fixed points documents the plant establishment and progression of the restoration efforts in the project area. The photos from this monitoring effort can be seen in Appendix C.

Botany

Performance of restoration efforts at Watson Woods Riparian Preserve, Prescott, Arizona, was assessed four consecutive years in terms of changes in cover for both woody and herbaceous vascular flora and survivorship of shoots planted. Baseline data were taken spring of 2009 in reaches and wetlands where old vegetation was removed during the early stages of restoration and replanted. Data were recollected fall of 2009, fall 2010, and fall 2011, and fall 2012. In fall 2009, overall average percent cover for woody plants was 4.5%, ranging among plots between 0.72% and 10.74%. In fall 2010, overall average percent cover was 15.6%, ranging between 5.0% and 29.7%. In fall 2011, overall average percent cover was 19.0%, ranging between 8.0% and 45.9%. In fall 2012, estimated overall average percent cover for transects along reaches and wetlands were 31.9%, ranging between 10.1% and 48.4%. Between spring 2009 and fall 2009, there was no significant increase in woody species cover among any of the eight plots.

Between fall 2009 and fall 2010, a single plot showed a significant increase (p = or less than .001) in cover of woody species. Between spring 2009 and fall 2012, average height classes among plots increased from 1.0 (< .5m) to 3.5, increased to 3.7 in fall 2011, and to 4.2 in fall 2012. Survivorship was 97.9% by fall 2009 and fell to only 94.6% by 2011, indicating a high overall success rate. By this time, however, estimates were difficult because of flooding events, dead shoot decay, and the sprouting of new shoots from rhizomes and root crowns. In light of these factors, estimates of survivorship were not attempted in 2012. Average herbaceous cover over all plots increased from 34% in fall 2009 to 43% in fall 2010, decreased to 28.1% in fall 2011, and increased to 59% in fall 2012. From fall 2009 to fall 2010 exotic perennials and annuals increased from 44% to 46% of total average herbaceous cover. In fall 2011 exotic perennials and annuals decreased to 37% and to 30% in fall 2012.

In addition to monitoring critical planting areas and restored wetland/riparian areas, the entire Preserve was analyzed using foliar height density (FHD, also referred to as foliar height distribution and foliar height diversity) cover of perennial and annual herbs, and density of trees and shrubs. Vegetation associations were also digitally mapped and a checklist of vascular plant taxa was made. FHD surveys were conducted in 1997, 2005, and 2012 in order to characterized the vegetation within the Preserve and to document progress. .

Methods

A line-intercept method (Bonham 1989) modified to include height estimate was used to sample percent cover of surviving planted perennial vegetation along the re-vegetated reaches and wetlands. Sampling was designed to include simplicity, ease, repeatability, and a sample size adequate for testing statistical differences for parameters among repeat samplings. Baseline data were collected by Marc Baker, Michael Byrd, and Jay Crocker 19 May and 20 September, 2009. Fall 2010 data were collected by Marc Baker 14 September, 2010, fall 2011 data were collected by Marc Baker and Gregg Fell 9 and 10 September 2011, and fall 2012 data were collected by Marc Baker and Kanin Routson 20-30 September 2012.

Two hundred seventeen transects were sampled, 20 along Reach 1, 20 along Reach 2, 20 along Reach 3, 36 along Reach 4, 21 within Wetland 2, 32 within Wetland 3, 31 within Wetland 5, and 37 within Wetland 6. Transects began at the edge of the channel, continued perpendicular to it for 10-14 meters, and alternated in direction, the first proceeding onto the right bank. Transect lengths varied according to area re-vegetated but were consistent across samplings. Transects were positioned approximately every 10 meters (straight line distance) in a stratified random manner. No attempt was made to permanently mark transects. Measurements for woody plant cover were made along a flexible scale (tape) accurate to the nearest centimeter and included the in-point at which an individual of a perennial vascular plant species crossed (under or over) the tape and the out-point. Gaps less than 10 centimeters were ignored and, thus, estimated covers for each species are potentially slightly higher than actual cover. Estimated total cover using this method is also potentially higher than actual total cover because of layers of the different species within the canopy. For each length measurement of woody vegetation, the maximum height (directly over the tape) was measured according to the following size classes: 1 = < 0.5 m, 2 = 0.51-1.0 m, 3 = 1.1-2.0 m, 4 = 2.1-5.0 m, 5 = 5.1-10.0 m, 6 = > 10.0 m.

Data were recorded on a field form (Appendix 1) printed on Rite-in-the-Rain® paper. To compare samples, an analysis of variance (ANOVA) was performed using SPSS 16® on the percent covers for each transect. ANOVA or univariate general linear model tests the statistical significance between or among trials by the Levene's Test of Equality of Error Variances. The null hypothesis was that the error variance of the dependent variable is equal across groups. A significance of 0.001 would indicate that means between the two groups were statistically different. For comparisons of two trials, a two-sample T-test was used.

In years 2009, 2010, and 2011, survivorship was estimated within a 2 m wide belt, 1 m on either side of the line-intercept transects. The counting of individuals, by species, was somewhat subjective because several stems can arise from the same original planted shoot. An individual was therefore defined as a separate stem or clump of stems of a single taxon. By fall 2012, among flooding events, dead shoot decay, and the sprouting of new shoots from rhizomes and root crowns, the estimation of dead vs. living planted material became impractical.

Herbaceous cover was estimated using a daubenmire frame at the beginning of each transect. For the non-riparian and non-wetland disturbed areas, the daubenmire frame was measured at 30 randomly placed points.

Results and Discussion

Percent cover data

In fall 2012, estimated overall average percent cover for transects along reaches and wetlands were 31.9%, ranging between 10.1% and 48.4% (Table 9). Woody cover data collected in fall 2012 are summarized in Table 10. Data for spring and fall 2009, fall 2010, and fall 2011 samplings are summarized in Tables 11-15 and Figures 28 and 29. Spring 2009, overall average percent cover for woody species (planted) was 0.2%, ranging among plots between 0.0% and 0.4%. In fall 2009, overall average percent cover was 4.4%, ranging among plots between 0.7% and 10.4%. In the fall 2010, overall average percent cover was 15.6%, ranging between 5.0% and 29.7%. In fall 2011 overall average percent cover was 24.8%, ranging between 5.6% and 45.9

In fall 2012, *Salix lasiolepis* had the highest overall average percent cover among plots, with a more than 3-fold increase from the previous year (Table 11). None of the eight plots, however, showed a significant increase (p = .001 or less) in woody species cover since 2011 (Table 10). In 2009 overall average percent cover among plots was also highest for *S. lasiolepis* in spring but highest for *S. exigua* in the fall, the average cover for the latter increased by over 40-fold (Table 14). In 2010 overall average percent cover among plots was highest for *S. lasiolepis* which showed a cover increase of 4.5-fold from the previous year (Table 13). In 2011 overall average percent cover among plots was highest for *Populus fremontii* which showed a cover increase of 4-fold from the previous year (Table 12). Five of the eight plots showed a significant increase in the cover of woody species between spring 2009 and fall 2009, and fall 2009 and fall 2010 (Table 9). Two plots, Reach 1 and Wetland 2 did not change significantly for either period. Wetland 6 changed significantly between spring 2009 and fall 2009 but not between fall 2009 and fall 2010 (p = .015).

Table 9-Average percent cover for woody plants

Plot	*Spring 2009*	*Fall 2009*	*Fall 2010*	*Fall 2011*	*Fall 2012*
Reach 1	0.4	5.8	12.0	45.9	44.7
Reach 2	0.1	2.3	22.4	35.7	48.4
Reach 3	0.0	2.6	15.7	29.8	43.5
Reach 4	0.2	6.7	21.4	26.8	41.4
Wetland 2	0.1	0.7	8.4	20.1	14.8
Wetland 3	0.2	1.5	10.0	5.6	18.7
Wetland 5	0.3	10.4	29.7	25.4	33.6
Wetland 6	0.0	5.3	5.0	9.1	10.1
Overall Average	0.2	4.4	15.6	24.8	31.9

Table 10-ANOVA results for woody species cover

Reach 1		*Spring 2009*	*Fall 2009*	*Fall 2010*	*Fall 2011*
	Fall 2009	1.000			
	Fall 2010	1.000	1.000		
	Fall 2011	**0.000**	**0.000**	**0.000**	
	Fall 2012	**0.000**	**0.000**	**0.000**	1.000
Reach 2		*Spring 2009*	*Fall 2009*	*Fall 2010*	*Fall 2011*
	Fall 2009	1.000			
	Fall 2010	0.309	0.619		
	Fall 2011	**0.000**	**0.000**	0.079	
	Fall 2012	**0.000**	**0.000**	**0.000**	0.829
Reach 3		*Spring 2009*	*Fall 2009*	*Fall 2010*	*Fall 2011*
	Fall 2009	1.000			
	Fall 2010	0.608	1.000		
	Fall 2011	**0.000**	**0.000**	0.021	
	Fall 2012	**0.000**	**0.000**	**0.000**	0.224
Reach 4		*Spring 2009*	*Fall 2009*	*Fall 2010*	*Fall 2011*
	Fall 2009	1.000			
	Fall 2010	0.004	0.115		
	Fall 2011	**0.000**	0.004	1.000	
	Fall 2012	**0.000**	**0.000**	0.002	0.057
Wetland 2		*Spring 2009*	*Fall 2009*	*Fall 2010*	*Fall 2011*
	Fall 2009	1.000			
	Fall 2010	1.000	1.000		
	Fall 2011	0.068	0.086	1.000	
	Fall 2012	0.066	0.084	1.000	1.000
Wetland 3		*Spring 2009*	*Fall 2009*	*Fall 2010*	*Fall 2011*
	Fall 2009	1.000			
	Fall 2010	0.010	0.045		
	Fall 2011	0.787	1.000	1.000	
	Fall 2012	**0.000**	**0.000**	0.312	0.003
Wetland 5		*Spring 2009*	*Fall 2009*	*Fall 2010*	*Fall 2011*
	Fall 2009	0.405			
	Fall 2010	**0.000**	**0.000**		
	Fall 2011	**0.000**	**0.001**	1.000	
	Fall 2012	**0.000**	**0.000**	1.000	0.283
Wetland 6		*Spring 2009*	*Fall 2009*	*Fall 2010*	*Fall 2011*
	Fall 2009	0.481			
	Fall 2010	0.685	1.000		
	Fall 2011	0.002	0.774	0.547	
	Fall 2012	**0.000**	0.272	0.181	1.000

Table 11-Average percent cover by taxon (Fall 2012)

Taxa whose average percent cover values are less than 0.1% over all transects are not included.

	Taxon									
Plot	*Brickellia floribunda*	*Juglans major*	*Populus fremontii*	*Populus ×hinckleyana*	*Robinia pseudoacacia*	*Salix exigua*	*Salix laevigata*	*Salix lasiolepis*	*Ulmus pumila*	
Reach 1	0.0	0.8	5.3	0.0	0.0	4.0	14.0	11.8	8.7	
Reach 2	3.1	0.0	8.2	3.0	0.0	4.0	4.5	14.0	4.6	
Reach 3	0.0	0.0	15.9	2.1	4.4	2.6	10.6	8.0	0.0	
Reach 4	0.1	0.0	6.3	1.9	0.0	10.6	10.4	12.2	0.0	
Wetland 2	1.6	0.0	10.7	0.0	0.0	0.8	0.0	1.6	0.0	
Wetland 3	0.0	0.0	5.4	1.4	0.0	2.7	0.0	9.2	0.0	
Wetland 5	0.0	0.0	0.0	.5	0.0	20.0	0.8	12.3	0.0	
Wetland 6	0.0	0.0	2.3	0.0	0.0	4.3	0.0	3.5	0.0	
Ave.	0.60	0.10	6.76	1.11	0.55	6.13	5.04	9.08	1.66	

Table 12-Average percent cover by taxon (Fall 2011)

Taxa whose average percent cover values are less than 0.1% over all transects are not included.

	Taxon									
Plot	*Acer negundo*	*Brickellia floribunda*	*Populus fremontii*	*Populus ×hinckleyana*	*Robinia pseudoacacia*	*Salix exigua*	*Salix laevigata*	*Salix lasiolepis*	*Ulmus pumila*	
Reach 1	0.9	1	24.8	0	0	4	5.3	1.8	7.5	
Reach 2	0.6	0.4	1.8	2.4	0	1.2	10.8	8.3	10.0	
Reach 3	0	0	11.9	0.1	4.0	0.5	8.7	2.2	2.3	
Reach 4	0	0	3.6	0.6	0	8.7	3.2	10.6	0.0	
Wetland 2	0	0	15.8	0.44	0	0.1	0	4.3	0.0	
Wetland 3	0	0	1.2	0.2	0	0	1.6	2.7	0.0	
Wetland 5	0	0	0	1	0	17.3	0	7.1	0.0	
Wetland 6	0	0	2.6	0	0	3.4	0	3.1	0.0	
Ave.	0.19	0.18	7.71	0.59	0.5	4.4	3.7	5.01	2.5	

Table 13-Average percent cover by taxon (Fall 2010)

	Taxon								
Plot	*Populus angustifolia*	*Populus fremontii*	*Populus ×hinckleyana*	*Robinia neomexicana*	*Salix exigua*	*Salix laevigata*	*Salix lasiolepis*	*Ulmus pumila*	
Reach 1	0.0	0.4	0.0	0.0	5.1	0.0	6.5	0.0	
Reach 2	0.0	0.0	0.0	0.0	3.4	5.9	10.6	2.5	
Reach 3	0.0	7.3	0.0	1.3	3.2	0.0	3.9	0.0	
Reach 4	0.0	2.6	0.2	0.0	6.7	0.1	11.3	0.0	
Wetland 2	0.0	0.4	0.0	0.0	2.2	0.0	5.7	0.0	
Wetland 3	0.2	4.1	0.2	0.0	2.6	1.8	1.2	0.0	
Wetland 5	0.0	0.0	0.0	0.0	20.2	0.0	8.2	0.0	
Wetland 6	0.0	0.6	0.0	0.0	1.7	0.3	2.5	0.0	
Ave.	0.0	1.9	0.1	0.2	5.6	1.0	6.2	0.3	

Table 14- Average percent cover by taxon (Spring 2009)

	Taxon						
Plot	*Populus angustifolia*	*Populus fremontii*	*Populus ×hinckleyana*	*Salix exigua*	*Salix laevigata*	*Salix lasiolepis*	
Reach 1	0.00	0.00	0.00	0.12	0.00	0.29	
Reach 2	0.00	0.00	0.00	0.01	0.00	0.08	
Reach 3	0.00	0.00	0.00	0.01	0.00	0.01	
Reach 4	0.00	0.01	0.00	0.07	0.07	0.08	
Wetland 2	0.00	0.00	0.00	0.01	0.00	0.13	
Wetland 3	0.00	0.05	0.10	0.00	0.00	0.00	
Wetland 5	0.00	0.00	0.00	0.15	0.03	0.09	
Wetland 6	0.00	0.00	0.00	0.03	0.00	0.05	
Ave.	0.00	0.01	0.01	0.05	0.01	0.09	

Table 15-Average percent cover by taxon (Fall 2009)

	Taxon						
Plot	*Populus angustifolia*	*Populus fremontii*	*Populus ×hinckleyana*	*Salix exigua*	*Salix laevigata*	*Salix lasiolepis*	
Reach 1	0	0.13	0.05	2.44	1.64	1.55	
Reach 2	0	0.13	0	1	0.58	0.57	
Reach 3	0	0.45	0.15	2.37	0	0.36	
Reach 4	0.24	1.26	0.02	1.54	0.2	3.4	
Wetland 2	0	0	0.31	0	0	0.41	
Wetland 3	0	0.58	0.08	0.23	0.2	0.42	
Wetland 5	0	0	0	6.93	0.38	3.09	
Wetland 6	0	0.76	0	2.55	0.31	1.41	
Ave.	0.03	0.41	0.08	2.13	0.41	1.4	

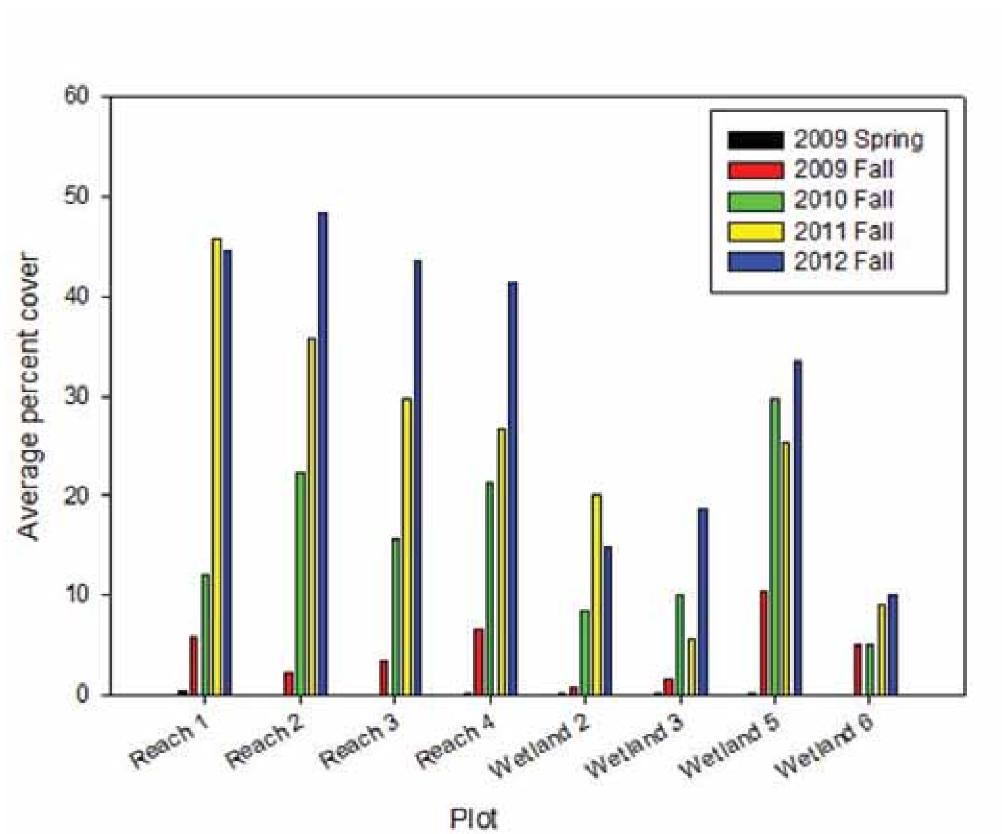


Figure 28-Average percent woody species cover (plot)

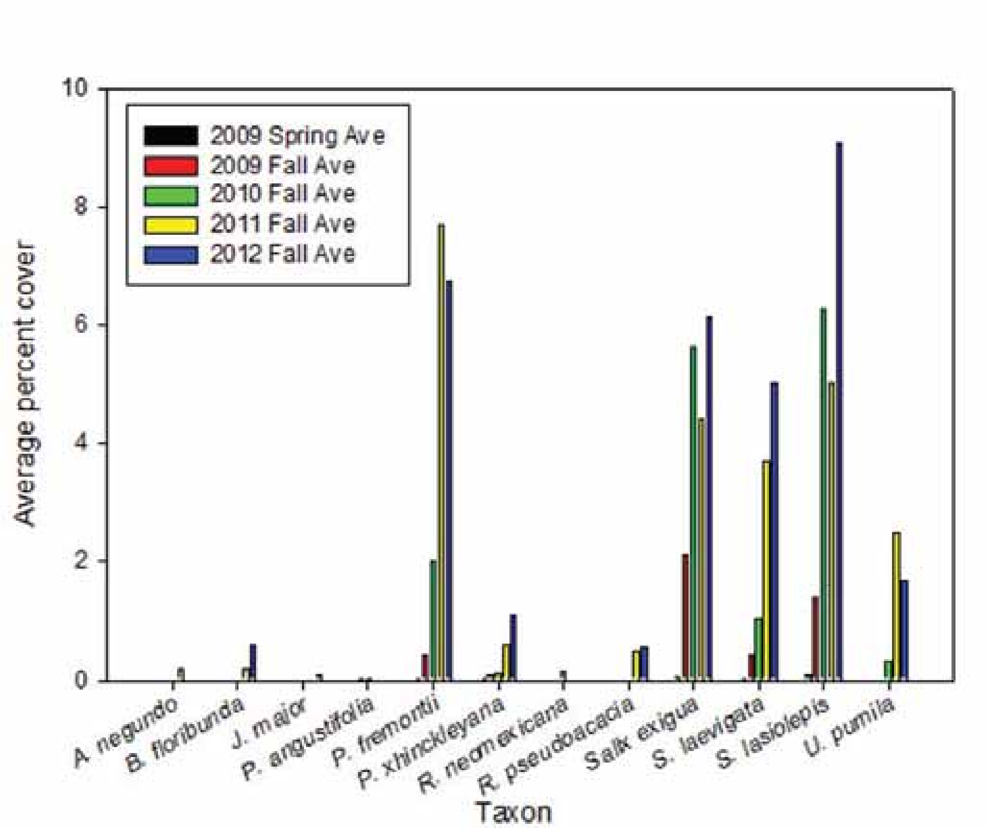


Figure 29-Average percent woody species cover (taxon)

In fall 2012, *Salix lasiolepis* had the highest overall average percent cover among plots, with a more than 3-fold increase from the previous year (Table 11). None of the eight plots, however, showed a significant increase (p = .001 or less) in woody species cover since 2011 (Table 10). In 2009 overall average percent cover among plots was also highest for *S. lasiolepis* in spring but highest for *S. exigua* in the fall, the average cover for the latter increased by over 40-fold (Table 14). In 2010 overall average percent cover among plots was highest for *S. lasiolepis* which showed a cover increase of 4.5-fold from the previous year (Table 13). In 2011 overall average percent cover among plots was highest for *Populus fremontii* which showed a cover increase of 4-fold from the previous year (Table 12).

Survivorship

In fall 2012, survivorship was not estimated because of flooding events, dead shoot decay, and the sprouting of new shoots from rhizomes and root crowns. In spring 2009 estimated survivorship was 100% and decreased only slightly in fall 2009, with the lowest at 80.8% and an average of 97.9%. Survivorship for fall 2010 was slightly higher than fall 2009, with the lowest at 92.3% and an average of 98.2%. Average survivorship decreased in fall 2011 to 94.6%, with the lowest at 87.5% (Table 16). The high value for survivorship in 2010 and 2011 suggests that sampling error has become large enough such that survivorship measurements are no longer meaningful. Error associated with survivorship measurements was caused primarily by flooding and the large volume of new growth, both of which obscure the identification of original plantings.

Table 16-Percent Survivorship

Plot	Spring 2009	Fall 2009	Fall 2010	Fall 2011
Reach 1	100.0	100.0	100.0	88.0
Reach 2	100.0	100.0	92.3	92.3
Reach 3	100.0	99.0	97.7	97.7
Reach 4	100.0	99.7	100.0	100.0
Wetland 2	100.0	80.8	100.0	87.5
Wetland 3	100.0	100.0	95.3	100.0
Wetland 5	100.0	100.0	100.0	100.0
Wetland 6	100.0	97.2	100.0	91.1
Average	100.0	97.9	98.2	94.6

Average Height

Average height classes among plots increased from 1.0 (< .5m) in spring 2009 to 4.2 in fall 2012 (Table 17, Figure 30). In fall 2009, there were five plots with an average height class greater than 2 (.5-1m), including a single plot with an average height class of 3 (1.1-2.0 m). Fall 2010 showed an increase of average heights for all plots over the previous year with an average height class of over 3 in all plots, including two greater than 4 (2.1-5.0 m). Fall 2011 showed four plots increased in average heights over the previous year, with a maximum of 1.9. However three plots showed decrease with a maximum of –1.1m, and one plot did not change. Fall 2012 data revealed an increase in average heights for all plots except one, with a range of –1.5m to 1.8.

Table 17-Average Height Class (Spring 2009, Fall 2012)

Plot	Spring 2009	Fall 2009	Fall 2010	Fall 2011	Fall 2012
Reach 1	1.0	2.8	3.0	3.1	4.0
Reach 2	1.0	1.4	4.1	3.0	4.8
Reach 3	1.0	1.9	3.7	4.0	4.4
Reach 4	1.0	2.5	3.0	3.7	4.9
Wetland 2	1.0	1.5	3.4	5.3	3.8
Wetland 3	1.0	2.1	4.1	3.4	4.1
Wetland 5	1.0	3.0	3.6	3.6	3.9
Wetland 6	1.0	2.8	3.4	3.1	3.4
Ave	1.0	2.2	3.5	3.7	4.2

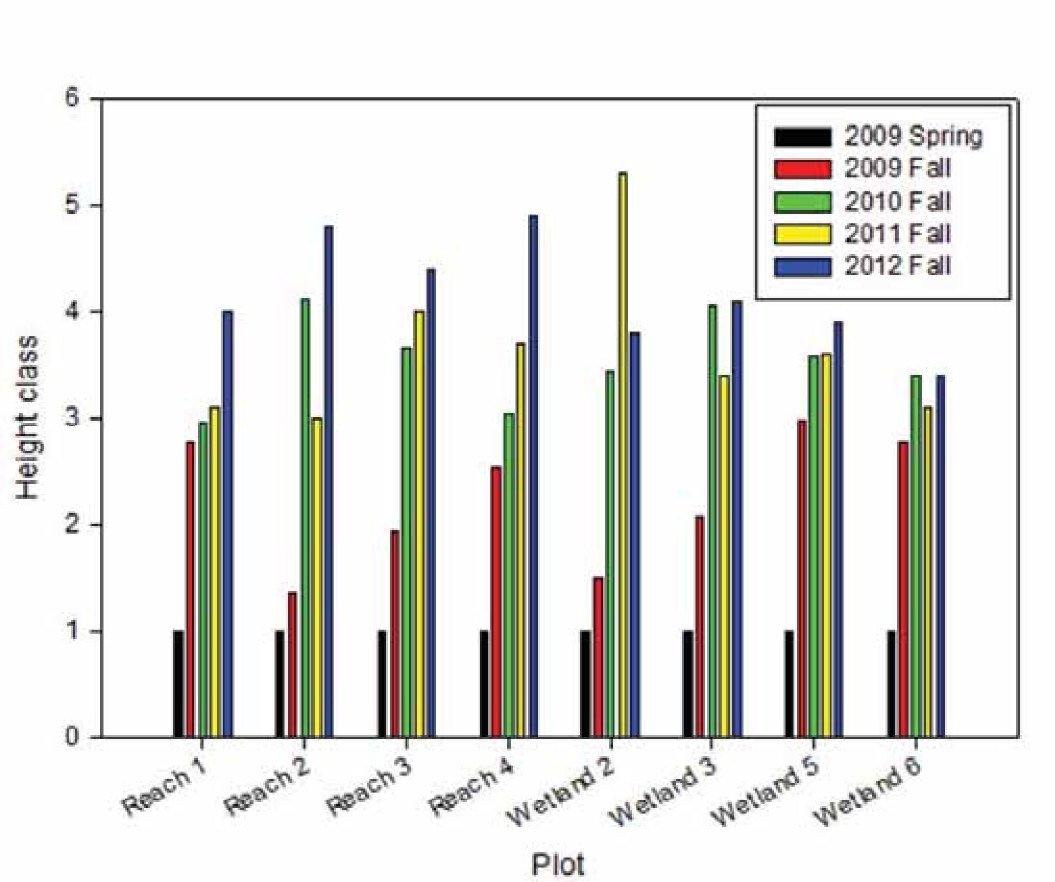


Figure 30-Average height Class

Average herbaceous cover

Average herbaceous cover over all plots increased from 34% in fall 2009 to 59% in 2012 with a dip to 28% in 2011 (Figures 31-33 and Tables 18-21). Fall 2012 data exhibited a further decrease of exotic perennials and annuals at 30% of total average herbaceous cover as compared to 37% in 2011 and 46% in 2010. Three of the eight plots showed a significant increase ($p = .001$ or less) in herbaceous species cover since 2011 (Table 22). Percent herbaceous cover was significantly ($p < .01$) less between fall 2009 and fall 2010 for Reach 1 and Reach 4 but was significantly greater for all disturbed sites (Table 22). Average percent cover for Watson Woods was estimated to be 18.2% in 1997 and 24.9% in 2005 (Baker 2006).

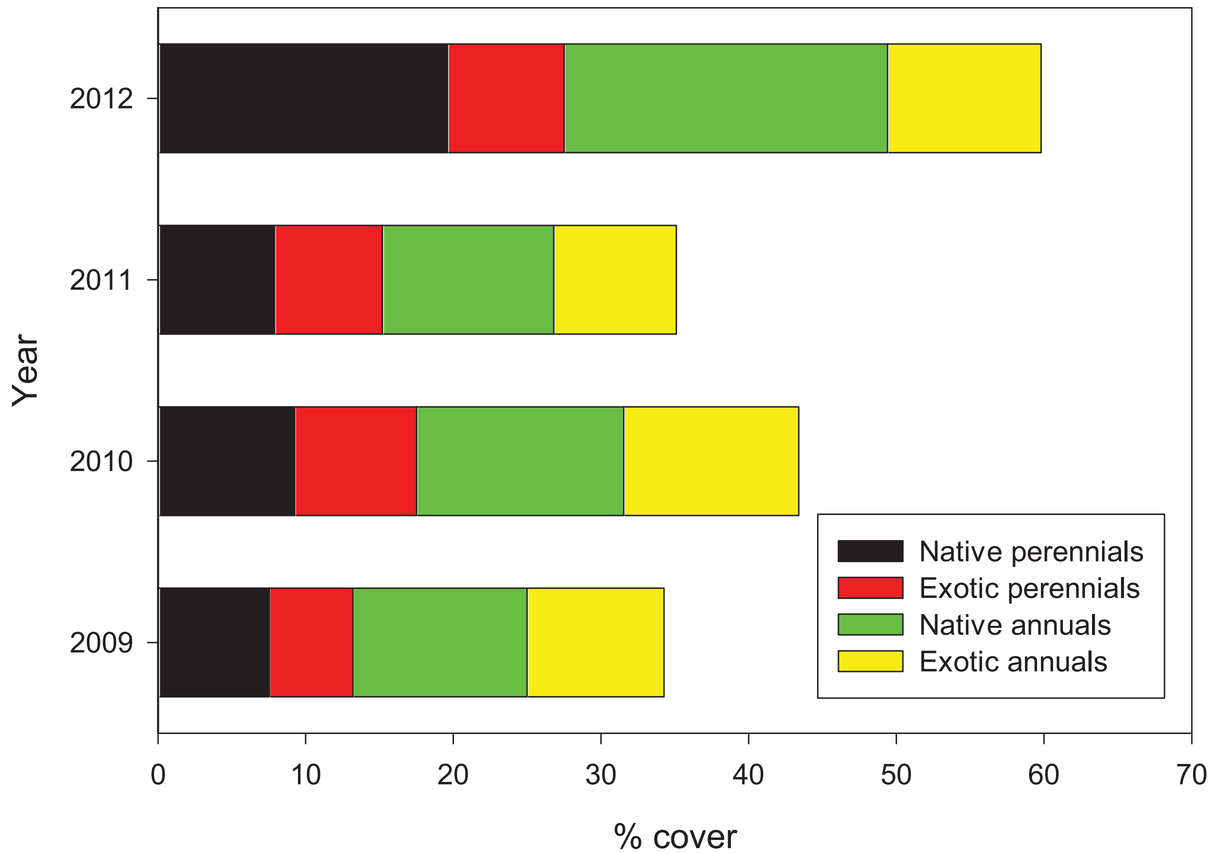


Figure 31-Average Percent Cover of Herbaceous Flora (All Plots)

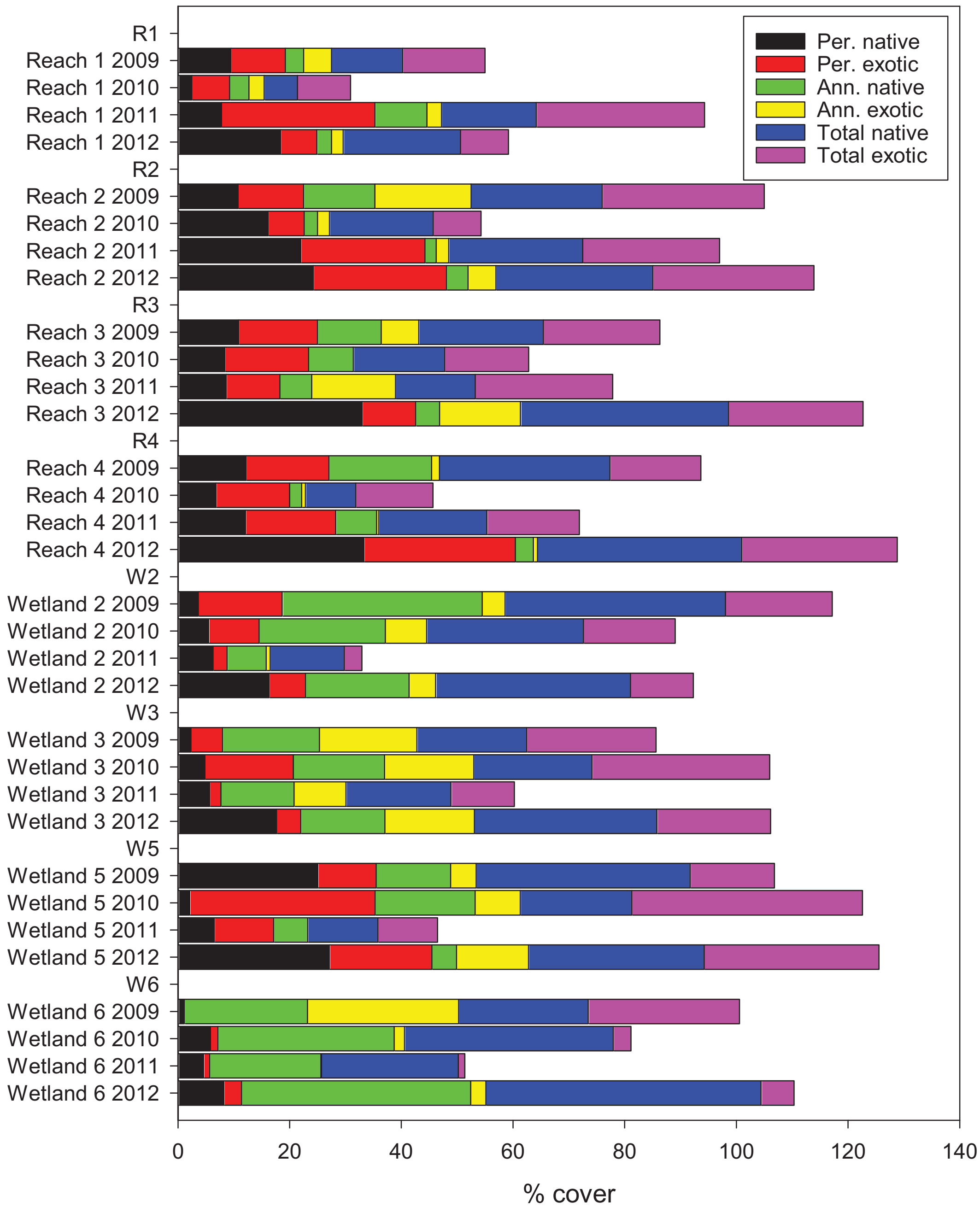


Figure 32-Comparison of Average Percent Cover (Reach and Wetland Plots)

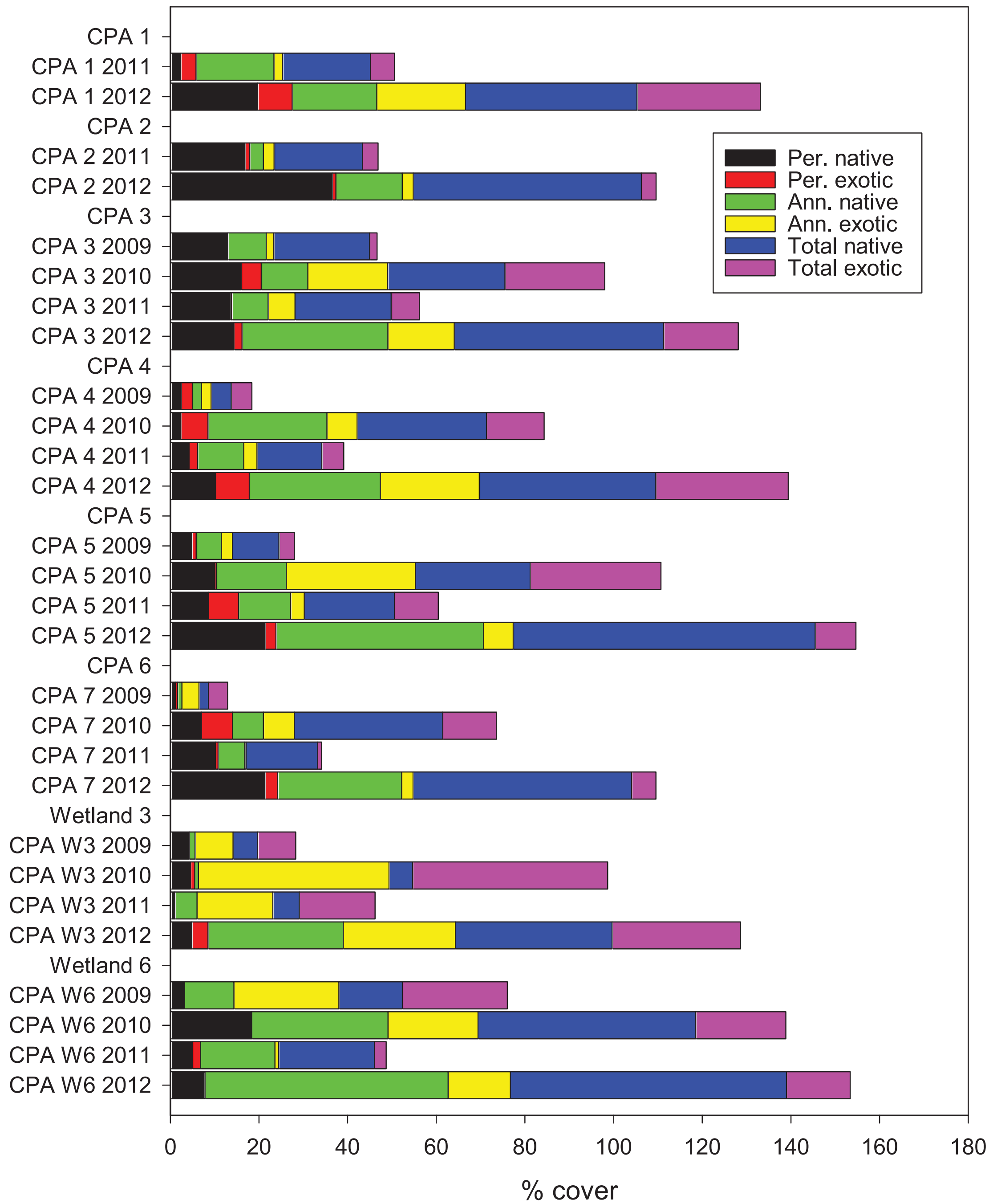


Figure 33-Comparison of Average Percent Cover (CPA Monitoring Plots)

Table 18-Average percent herbaceous cover by plot (Fall 2012)

Plot	*Perennial native*	*Perennial exotic*	*Annual native*	*Annual exotic*	*Total native*	*Total exotic*	*Total perennial*	*Total annual*	*Plot Total*
Reach 1	18.40	6.50	2.60	2.10	21.00	8.60	24.90	4.70	29.60
Reach 2	24.25	23.85	3.85	5.00	28.10	28.85	48.20	8.85	57.05
Reach 3	33.00	9.60	4.25	14.50	37.25	24.10	42.60	18.75	61.35
Reach 4	33.33	27.08	3.25	0.75	36.58	27.83	60.42	4.00	64.42
Wetland 2	16.35	6.5	18.55	4.75	34.9	11.25	21.7	19.05	40.75
Wetland 3	17.67	4.33	15.07	16.00	32.73	20.33	25.00	31.07	56.07
Wetland 5	27.10	18.39	4.39	12.90	31.48	31.29	45.48	16.65	62.13
Wetland 6	8.23	3.17	41.03	2.73	49.27	5.90	11.40	43.77	55.17
CPA 1	19.67	7.83	19.07	20.00	38.73	27.83	27.50	39.07	66.57
CPA 2	36.50	0.83	14.97	2.50	51.47	3.33	37.33	17.47	54.80
CPA 3	14.33	1.83	32.90	15.00	47.23	16.83	16.17	47.90	64.07
CPA 4	10.23	7.57	29.57	22.33	39.80	29.90	14.30	51.90	66.20
CPA 5	21.33	2.50	46.83	6.67	68.17	9.17	23.83	53.50	77.33
CPA 7	21.30	2.90	28.00	2.57	49.30	5.47	24.20	30.57	54.77
CPA Wetland 3	4.83	3.67	30.50	25.33	35.33	29.00	8.50	55.83	64.33
CPA Wetland 6	7.50	0.33	54.83	14.03	62.33	14.37	7.83	68.87	76.70
Over All plots	19.6	7.9	21.9	10.4	41.5	18.4	27.5	32.0	59.5
Relative	*33%*	*13%*	*37%*	*17%*	*70%*	*30%*	*46%*	*54%*	*100*

Table 19-Percent herbaceous cover by plot (Fall 2011)

Plot	*Perennial native*	*Perennial exotic*	*Annual native*	*Annual exotic*	*Total native*	*Total exotic*	*Total perennial*	*Total annual*	*Plot Total*
Reach 1	7.8	27.5	9.3	2.6	17.00	30.10	35.3	11.9	47.10
Reach 2	22.0	22.25	2.0	2.25	24.00	24.5	44.25	4.25	48.50
Reach 3	8.4	9.85	6.7	6.75	15.05	16.60	18.25	13.4	31.65
Reach 4	12.1	16.17	7.3	0.4	19.36	16.57	28.2	7.7	35.93
Wetland 2	6.3	2.5	7.0	0.7	13.3	3.15	8.8	7.7	16.45
Wetland 3	5.7	2.00	13.1	9.3	18.8	11.33	7.7	22.5	30.13
Wetland 5	6.5	10.65	6.1	0.00	12.58	10.65	17.1	6.1	23.23
Wetland 6	4.6	1.1	19.9	0.1	24.5	1.17	5.7	20.0	25.67
CPA 1	2.3	3.47	17.6	1.9	19.86	5.42	5.8	19.5	25.28
CPA 2	16.8	1.1	3.1	2.4	19.94	3.5	17.9	5.5	23.44
CPA 3	13.5	0.33	8.2	6.1	21.67	6.39	13.8	14.3	28.06
CPA 4	4.2	1.94	10.4	3.0	14.61	4.94	6.1	13.4	19.56
CPA 5	8.6	6.81	11.7	3.1	20.33	9.91	15.4	14.8	30.24
CPA 7	10.2	0.56	6.0	0.3	16.17	0.86	10.8	6.3	17.03
CPA Wetland 3	1.0	0.00	5.0	17.1	5.97	17.1	1.0	22.1	23.10
CPA Wetland 6	4.9	1.90	16.8	0.8	21.64	2.65	6.8	17.5	24.29
Over All plots	8.43	6.76	9.39	3.55	17.80	10.30	15.18	12.93	28.10
Relative	*30%*	*24%*	*33%*	*13%*	*63%*	*37%*	*54%*	*46%*	*100%*

Table 20-Average percent herbaceous cover by plot (Fall 2010)

Plot	*Perennial native*	*Perennial exotic*	*Annual native*	*Annual exotic*	*Total native*	*Total exotic*	*Total perennial*	*Total annual*	*Plot Total*
Reach 1	2.50	6.75	3.45	2.75	5.95	9.50	9.25	6.20	15.45
Reach 2	16.19	6.43	2.38	2.14	18.57	8.57	22.62	4.52	27.14
Reach 3	8.40	15.00	8.00	0.00	16.40	15.00	23.40	8.00	31.40
Reach 4	6.83	13.17	2.17	0.67	9.00	13.83	20.00	2.83	22.83
Wetland 2	5.48	9.05	22.62	7.38	28.10	16.43	14.52	30.00	44.52
Wetland 3	4.83	15.83	16.33	16.00	21.17	31.83	20.67	32.33	53.00
Wetland 5	2.10	33.23	17.90	8.06	20.00	41.29	35.32	25.97	61.29
Wetland 6	5.83	1.33	31.57	1.83	37.40	3.17	7.17	33.40	40.57
CPA 1	Not sampled								
CPA 2	Not sampled								
CPA 3	16.00	4.50	10.50	18.00	26.50	22.50	20.50	28.50	49.00
CPA 4	2.33	6.17	26.83	6.83	29.17	13.00	8.50	33.67	42.17
CPA 5	10.00	0.33	15.83	29.17	25.83	29.50	10.33	45.00	55.33
CPA 7	26.38	2.83	7.07	9.31	33.45	12.14	29.21	16.38	45.59
CPA Wetland 3	4.50	1.00	0.83	43.00	5.33	44.00	5.50	43.83	49.33
CPA Wetland 6	18.33	0.00	30.77	20.33	49.10	20.33	18.33	51.10	69.43
Over All plots	9.26	8.26	14.02	11.82	23.28	20.08	17.52	25.84	43.36
Relative	*21%*	*19%*	*32%*	*27%*	*54%*	*46%*	*40%*	*60%*	*100%*

Table 21-Percent herbaceous cover by plot (2009)

Plot	*Perennial native*	*Perennial exotic*	*Annual native*	*Annual exotic*	*Total native*	*Total exotic*	*Total perennial*	*Total annual*	*Plot Total*
Reach 1	9.50	9.75	3.25	5.00	12.75	14.75	19.25	8.25	27.50
Reach 2	10.75	11.75	12.75	17.25	23.50	29.00	22.50	30.00	52.50
Reach 3	12.25	7.75	12.25	10.50	24.50	18.25	20.00	22.75	42.75
Reach 4	12.21	14.85	18.35	1.41	30.56	16.26	27.06	19.76	46.82
Wetland 2	3.67	15.00	35.81	4.10	39.48	19.10	18.67	39.91	58.58
Wetland 3	2.33	5.67	17.33	17.47	19.67	23.13	8.00	34.80	42.80
Wetland 5	25.03	10.48	13.32	4.58	38.35	15.06	35.51	17.90	53.41
Wetland 6	1.17	0.00	22.03	27.08	23.20	27.08	1.17	49.11	50.28
CPA 1	Not sampled								
CPA 2	Not sampled								
CPA 3	12.97	0.00	8.67	1.67	21.64	1.67	12.97	10.34	23.31
CPA 4	2.44	2.49	2.07	2.20	4.51	4.69	4.93	4.27	9.20
CPA 5	4.83	1.00	5.67	2.50	10.50	3.50	5.83	8.17	14.00
CPA 7	1.12	0.50	1.00	3.83	2.12	4.33	1.62	4.83	6.45
CPA Wetland 3	4.23	0.00	1.33	8.57	5.56	8.57	4.23	9.90	14.13
CPA Wetland 6	3.17	0.00	11.17	23.67	14.34	23.67	3.17	34.84	38.01
Over All plots	7.55	5.66	11.79	9.27	19.33	14.93	13.21	21.06	34.27
Relative	*22%*	*17%*	*34%*	*27%*	*56%*	*44%*	*39%*	*61%*	*100%*

Table 22-ANOVA results for herbaceous cover

Reach 1		*Fall 2009*	*Fall 2010*	*Fall 2011*
	Fall 2010	0.961		
	Fall 2011	0.117	0.002	
	Fall 2012	1.000	0.558	0.232
Reach 2		*Fall 2009*	*Fall 2010*	*Fall 2011*
	Fall 2010	0.122		
	Fall 2011	1.000	0.311	
	Fall 2012	1.000	0.037	1.000
Reach 3		*Fall 2009*	*Fall 2010*	*Fall 2011*
	Fall 2010	0.822		
	Fall 2011	1.000	0.743	
	Fall 2012	0.096	0.001	0.110
Reach 4		*Fall 2009*	*Fall 2010*	*Fall 2011*
	Fall 2010	**0.000**		
	Fall 2011	0.439	0.106	
	Fall 2012	0.025	**0.000**	**0.000**
Wetland 2		*Fall 2009*	*Fall 2010*	*Fall 2011*
	Fall 2010	0.825		
	Fall 2011	**0.000**	0.002	
	Fall 2012	0.715	1.000	0.002
Wetland 3		*Fall 2009*	*Fall 2010*	*Fall 2011*
	Fall 2010	1.000		
	Fall 2011	0.643	0.024	
	Fall 2012	0.546	1.000	0.007
Wetland 5		*Fall 2009*	*Fall 2010*	*Fall 2011*
	Fall 2010	1.000		
	Fall 2011	**0.000**	**0.000**	
	Fall 2012	0.999	1.000	**0.000**
Wetland 6		*Fall 2009*	*Fall 2010*	*Fall 2011*
	Fall 2010	0.180		
	Fall 2011	**0.000**	0.002	
	Fall 2012	1.000	1.000	**0.000**

FHD Analysis

Between 1997 and 2012, FHD increased markedly for six species: 1) *Festuca arundinacea*, is an exotic perennial grass; 2) *Salix exigua,* and 3) *S. lasiolepis*, are desirable native shrubs; 4) *Populus angustifolia,* 5) *P.×hinckleyana,* are desirable native trees; and 6) *Ulmus pumila,* an undesirable exotic and highly invasive tree. Estimates for average canopy cover increased between fall 2005 and fall 2012, with riparian species increasing from 25.4% in 2005 to 31.9% in 2012. Similarly, average canopy cover for non-riparian species jumped from 8.4% in 2005 to 20.4% in 2012. Specimens were made of approximately 15 previously undocumented taxa. For a complete FHD Report, including survey points/transect photographs taken at identical locations during 1997, 2005, and 2012, please see Appendix C.

Macroinvertebrate Zoology

Macroinvertebrate bioassessments were conducted in order to assess aquatic conditions within Watson Woods and selected tributaries of Granite Creek. The objectives for this study were to: 1) describe baseline biological conditions for nine sites on Granite Creek and tributaries; 2) utilize ADEQ data and the data from this survey to develop and test metrics and an index for identifying impairment; 3) track macroinvertebrate trends for 2 years following restoration activities within Watson Woods and 4) provide a simplified bioassessment method for use by volunteers that is tailored for intermittent streams.

The bioassessment of aquatic macroinvertebrate communities is an important and widely accepted environmental indicator of water quality (Barbour et al., 1999). Aquatic organisms living in the water are directly impacted by pollutants in their environment. The abundance and diversity within the community reflect the cumulative impacts of pollutant exposure over time. Where chemical analyses of pollution in streams provide only a snapshot in time, macro-invertebrate samples provide a cumulative look at pollutant effects in the stream year-round. The larval forms of these macroinvertebrates are easily collected and identified from running waters in both intermittent and perennial streams of Arizona.

The bioassessment study consisted of a collection of macroinvertebrate, habitat and water chemistry sampling at nine intermittent stream sites and the Watson Woods wetland ponds over a 2-year study period (spring 2011 and 2012). Data previously collected by ADEQ from five of these nine stations plus four additional sites (2008-2010) were also utilized to create a larger dataset for the metric testing and Index development analyses. All index development methods followed USEPA methods for developing and testing a multi-metric bioassessment index.

Within Watson Woods, the samples from 2008 and 2012 were in marginally "good" condition. While the taxa richness was not similar to the reference sites, the percent midges were lower and the percent blackflies (filter feeders) were greater in the 2008 and 2012 samples, resulting in high IBI scores. In addition, the fact that this site is not dominated by midges and worms means that the habitat is not limiting the macroinvertebrate taxa, which is a hopeful step toward recovery of a fully functional aquatic community.

Habitat conditions did improve in the Watson Woods reach. Canopy cover, Habitat index score, Pfankuch channel stability score, riparian PFC score and percent riffle habitat all increased following the channel restoration work, whereas percent embeddedness and the riffle-D50 value decreased; all positive improvements in substrate and channel habitat for aquatic life. It appears that the stream recovery following the channel restoration work was successful not only for restoring the physical integrity and functional riparian community but in creating a stable channel and substrate sufficient for a functional intermittent stream community to develop.

Methods

The bioassessment study objectives of this project were met through collection of macroinvertebrates, habitat and water chemistry sampling at nine intermittent stream sites and the Watson Woods wetland ponds over a 2-year study period (spring 2011 and 2012). Data previously collected by ADEQ from five of these nine stations plus four additional sites (2008-2010) were also utilized to create a larger dataset for the metric testing and Index development analyses. The locational data for 13 intermittent monitoring stations are provided in Appendix A.

Figure 34 outlines the study area and streams monitored for this project.

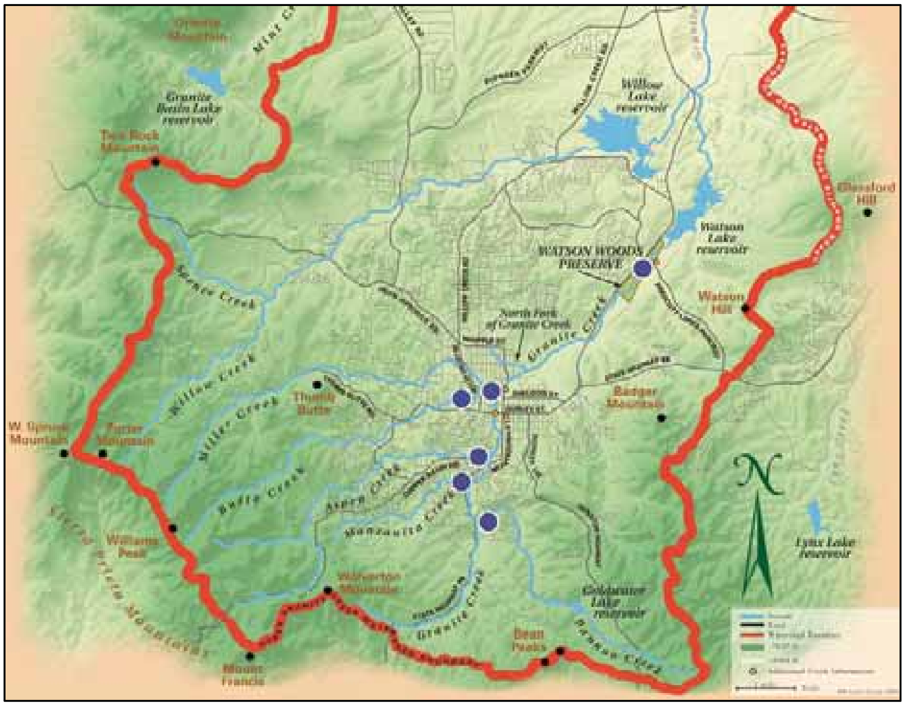


Figure 34-Study area of streams sampled for macroinvertebrates
Survey locations are represented by blue dots

Macroinvertebrate collection method

There are several different macroinvertebrate collection methods available which utilize different net types, habitats sampled and net mesh size. For this study, we employed a D-frame dip net and collected 10 jabs of 30 seconds each, representatively sampled from all habitat types in the stream reach and composited into a 5-minute bug sample (Appendix B). This method was a modification of the U.S. Environmental Protection Agency (USEPA) 20-jab multi-habitat approach (Barbour et al., 1999). The 10-jab multi-habitat approach was used instead of a riffle-based approach because some intermittent streams may not have riffle habitat. The EPA cobble or mud bottom stream approach suggested in Marsh and Spindler (2007) was not used because it does not composite among all habitats present, therefore the sampling method is different depending on substrate type, which could produce samples with sufficient taxonomic differences that would preclude use of a single index. The multi-habitat approach accommodates all habitat types from riffle to run to pool to woody debris, and substrate types from cobble to silt. The multi-habitat approach also composites proportionately across all habitat types within the study reach. This 10-jab method was used at all sites in the ADEQ dataset and the "Prescott Creeks" collections for the 2011-12 surveys.

Altogether there were 29 samples collected at 13 sites over 5 years, during the spring index period. These samples composed the dataset that was used in the index development analyses. Replicates were collected over the 5-year period of 2008-2012, rather than within the same season. In some cases we have three or more replicates over the 5-year period 2008-2012. "Special collections" were made from the wetland ponds at Watson Woods. These wetland pond collections were intended to produce a more comprehensive aquatic species inventory for the Watson Woods Preserve. Different methods were used for the wetland ponds than for the intermittent streams. These wetland pond special collections consisted of three 10-second sweeps in each of three wetland ponds composited into one pond water sample to identify lentic and surface dwelling species of the wetland ponds.

Habitat data collection method

Habitat data was collected following the ADEQ Stream Ecosystem Monitoring habitat assessment protocols and documented on ADEQ SEM field forms (Jones, 2012). A complete set of habitat data was collected during the April 2011 sample event, and a similar set of habitat data was collected during the April 2012 sample event with the exception that the pebble count was not done if stream bottom conditions appeared similar or unchanged from

2011. Habitat parameters that were collected and calculated for all samples are listed in Table 23. Habitat values are presented in table format in Appendix C and habitat reports provided in Appendix D.

Table 23-Habitat Parameters collected from 12 Prescott Area Stream Sites

Physical channel measurements	Riparian measurements	Biological measurements	Visual-based indexes of habitat
Rosgen stream type	Riparian association	%algae and %macrophyte cover	Pfankuch channel stability index
Organic debris quantity	Canopy density over the channel		PFC Riparian condition index
Depositional features	Riparian regeneration		Habitat assessment index
Percent fines and percent embeddedness from pebble count	Identification of tree species		
Riffle geometry and %riffle, %run, %pool habitats	Riparian vegetation cover on the floodplain		

Water chemistry field data collection method
Water quality data were collected following ADEQ protocols (Jones, 2012) and was documented on ADEQ SEM field forms (Jones, 2012). Field parameters (water temperature, pH, dissolved oxygen, TDS, Conductivity, and turbidity) were collected on-site and concurrently with the macroinvertebrate data. Flow data was also collected concurrently to calculate discharge at all monitoring stations.

Taxonomic identifications
Taxonomic identifications of 2011 and 2012 samples from the nine study sites plus the wetland pond sample were analyzed by Patti Spindler, with insects identified to family level. Previous ADEQ samples from 2008-10 were analyzed by Ecoanalysts Inc. and were identified to standard levels of taxonomy listed in ADEQ's Biocriteria Program Quality Assurance Program Plan (QAPP; ADEQ, 2006) with insects identified to genus level. These samples were aggregated to family level for combination with 2011-12 samples for analyses herein.

Analytical methods
All three index development methods followed USEPA methods for developing and testing a multi-metric bioassessment index. The Intermittent Index of biological integrity was based on protocols in the *Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers* guidance document (Barbour et al., 1999). The multi-metric approach to developing an index involved: collecting and utilizing a set of reference sites and samples, identifying and testing metrics which best discriminate between a-priori reference and stressed samples, selecting and calibrating metrics, compiling metrics into an index, and establishing meaningful assessment thresholds to determine impairment.

The two volunteer indexes proposed here were based on protocols found in *Volunteer Stream Monitoring: a Methods Manual* (USEPA, 1997) and modified protocols in the *draft Arizona Biosurvey Protocols* (Marsh and Spindler, 2007). The "Simple Four-Metric Index" was based on EPA's "Intensive Stream Biosurvey" approach which utilizes a reference site approach, preserved specimens, detailed taxonomy to family level in the lab, and recommends use of four basic metrics for the index, with the thresholds based on a percentage of reference scores. The "Tolerance Index" was based on EPA's "Streamside Biosurvey" first developed by Ohio Department of Natural Resources and the Izaak Walton League of America's Save Our Streams program and adapted by many volunteer monitoring programs throughout the United States. It utilizes in-the-field collection and identification of specimens by volunteers to the order level, with a return of live specimens to the stream, requires less taxonomy training and uses a preset index which places counts of specimens into tolerance categories which are multiplied by a tolerance value and summed for a final score, which results in a stream quality rating of good, fair or poor.

Several statistical analyses were performed. Systat software was used for box and whisker plots to analyze metrics. Pearson correlations were employed to determine the degree of correlation among the index scores of the three methods. Multiple regression analysis was used to determine which stressors most influence the indexes. Excel spreadsheets were used for metric calculations, bar charts and linear regressions. Hydrographs and flow regime data were collected with HOBO flow sensors with data-loggers.

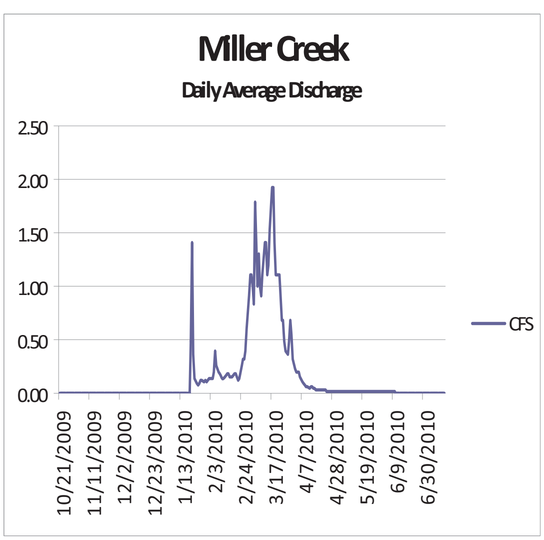
Results and Discussion

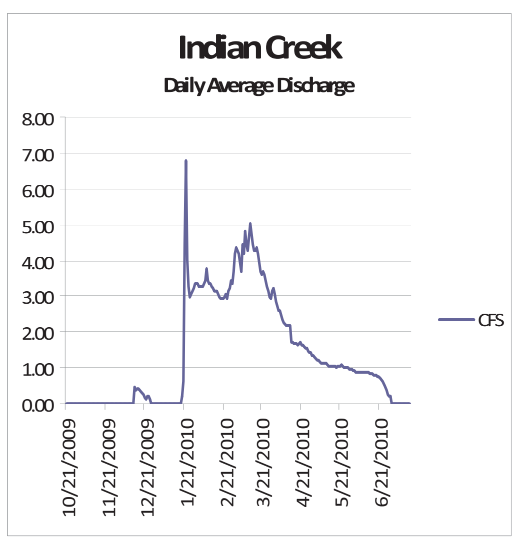
Objective #1: Baseline biological conditions on Granite Creek and tributaries
The biological condition of aquatic life in intermittent streams of the Prescott area is predicted to be different from macroinvertebrate communities of perennial streams across the state. The shortened flow patterns of intermittent streams and the associated riparian vegetation, in-stream food resources, water temperature and substrate conditions all contribute to a habitat that favors macroinvertebrates with special adaptations. These adaptations include: body armoring, multi-voltinism (short lived taxa), respiration adaptations including aerial breathers, functional feeding group (FFG) shifts, desiccation resistance, large body size, high crawling rate, strong adult flyers/dispersers, and burrowers (Richards, 2012, Bogan et al., 2012). Several of these adaptations were observed in macroinvertebrate taxa found in Granite Creek and its tributaries.

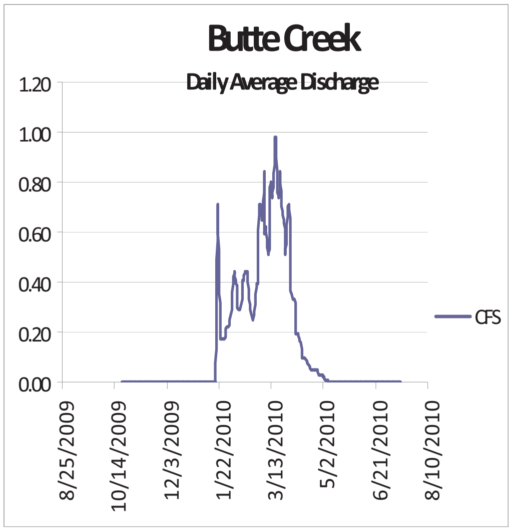
The results in this section discuss the hydrology, habitat conditions and taxonomic composition of intermittent streams of the Prescott area, how they are different from perennial streams, and displays what the typical intermittent macroinvertebrate community looks like. Bioassessment reports, including the taxonomy and IBI score for each site and year are provided in Appendix E.

Hydrology

The flow regime of the majority of streams in the Granite Creek watershed is intermittent with snowmelt in the winter and summer monsoon rains which provide the water that sustains flow in the creeks. ADEQ installed flow sensors at four headwater stream stations to quantify the duration of flow in these intermittent streams (Figure 35). These streams flowed for 148-191 days (5-6.5 months) in 2009 and 107 - 163 days (4-5 months) during calendar year 2010 (Table 24). Since these streams do not flow year-round, most semi-voltine to univoltine (long-lived) macroinvertebrates do not occur in these streams. Instead, the intermittent macroinvertebrate community consists of many multi-voltine insects which, like other desert streams, can complete their life cycles in <8 weeks (Gray, 1981) and taxa that have adaptations to drying such as burrowing, crawling or flying (Richards, 2012).







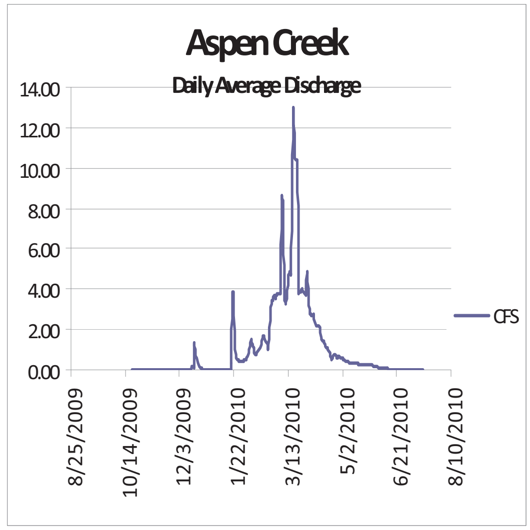


Figure 35-Hydrographs showing duration of flow

The USGS gage on Granite Creek near Prescott (USGS gage #09503000) provides estimates of flow for the Watson Woods site; however the flows in Granite Creek at Watson Woods are less than what is recorded at the gage station. For instance, the gage recorded only 29 days with no flow in 2009 and no days with zero flow in 2010. Granite Creek in this reach is intermittent being wetter November to May, then dry mid-May to mid-July, and then temporarily wet from July to October. The gage records are provided in Table 24 for reference but should be considered an overestimate.

Table 24-Flow Statistics and Duration of Surface Water Flow

Station	2009			2010		
	Peak Discharge	**Avg Discharge**	**Days of Flow**	**Peak Discharge**	**Avg Discharge**	**Days of Flow**
MGIDN002.66	5.7	0.79	179	170.0	2.26	163
VRASP005.07	12.9	0.94	172	34.0	1.92	145
VRBTT005.70	1.1	0.14	148	14.0	0.36	107
VRMIL006.07	8.1	0.33	191	16.0	0.31	143
Granite Cr @ USGS gage nr Prescott	806	6.94	336	6200	17.6	365

Habitat Conditions

There is a large range of habitat values between reference and stressed sites in the Granite Creek watershed (Figure 36). Mean percent canopy cover over the streambed was similar among reference, non-reference and stressed sites, but slightly lower at reference sites. The median particle size in riffles (D50), an important measure of substrate habitability, was significantly different between reference and stressed sites, with cobble-sized particles common at reference sites and sand as the mean particle size at stressed sites. Embeddedness is a measure of the degree that larger particles are surrounded with finer particles. Percent embeddedness was least for reference sites and greatest for stressed sites. Percent fines is a measure of the amount of fine sediment that is <2mm in size, that makes up the surface layer of sediment in the stream bottom in a count of 100 particles. The least percent fines (cleanest substrates) were found at reference sites and the greatest percent fines (most clogged substrates) were found at the stressed sites. Habitat percent of ideal score, a measure of substrate diversity and excess sediment, had greater values at the reference sites than stressed sites. The Pfankuch channel stability score did not differ significantly among the classes of sites. Riparian condition (PFC) percent of ideal score was not different between reference and stressed sites. Percent riffle habitat was significantly greater at reference sites and percent run habitat was much greater at stressed sites. Habitat scores for all samples are listed in Appendix C and habitat reports for all the nine sites sampled 2011-2012 are provided in Appendix D.

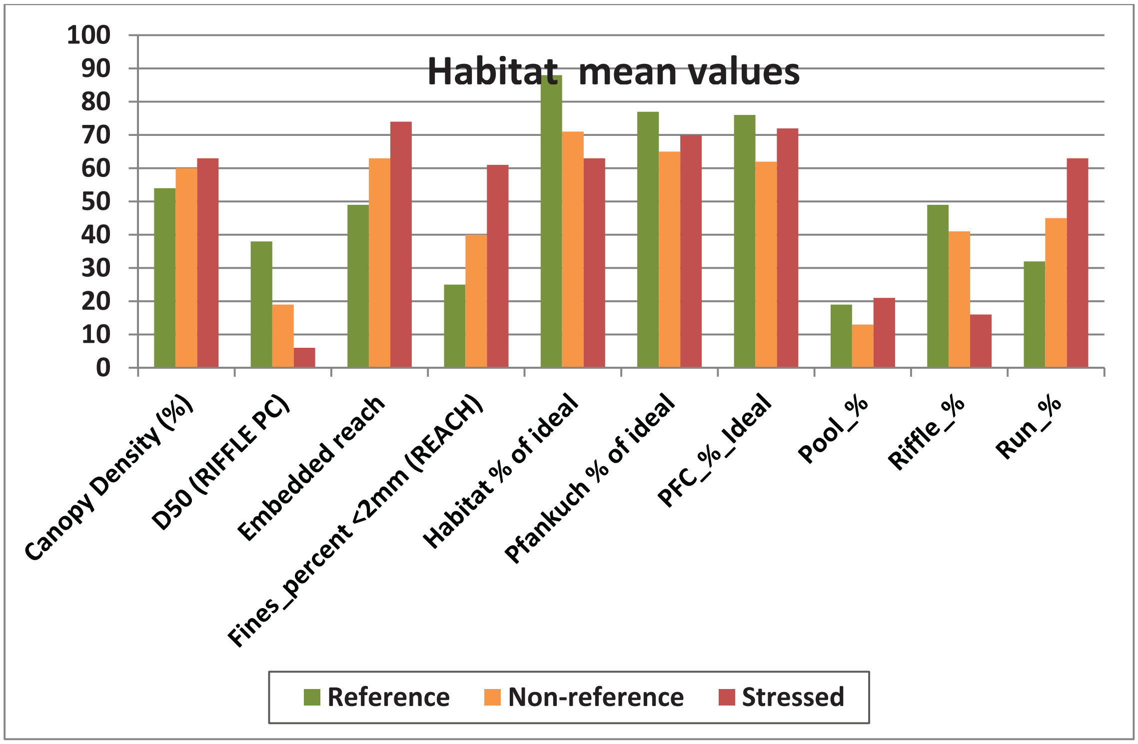


Figure 36-Stream Habitat Mean Values

Taxonomic composition of intermittent stream macroinvertebrate communities

Intermittent streams of the Granite Creek Watershed have a surprising diversity of macroinvertebrates living there, with some sensitive and many tolerant groups. Some general characteristics of all these intermittent stream communities are: 1) low taxa richness compared with perennial streams, 2) a lack of mayflies, stoneflies and caddisflies (the EPT taxa) which are generally the most sensitive indicator species (except for the winter stonefly), 3) a high percent composition by diptera, especially midges, 4) a high percentage of collector-gatherer and filterer feeding groups, 5) a high percentage of the most dominant taxon, and 6) ubiquitous distribution of beetles and black flies among all stream sites (Table 25).

Table 25-Basic Statistics for Macroinvertebrate Characteristics

Macroinvertebrate metrics	Reference, Range (mean)	Stressed, Range (mean)
Total taxa richness	6-17 (12)	5-10 (8)
Diptera taxa richness	3-7 (5)	1-4 (3)
Intolerant taxa richness	0-2 (1.4)	0
HBI	4.5-6.6 (6.0)	6.1-6.9 (6.3)
Stoneflies, percent	0.8-51 (14)	0
Scrapers, percent	0-8.3 (1.5)	0-1.4 (0.3)
Scraper taxa richness	0-1 (0.8)	0-2 (0.7)
Caddisfly taxa richness	0	0
Mayfly taxa richness	0-1 (0.2)	0
Midge taxa richness	7-19 (12)	5-12 (10)
Mayflies, percent	0-1 (0.1)	0
Dominant taxon, percent	31-75 (53)	55-93 (78)
Midges, percent	5-68 (32)	55-93 (78)
Diptera, percent	22-99 (75)	57-93 (81)
Beetles, percent	0-4.2 (1.2)	0-1.7 (0.8)
Non-insect, percent	0.2-46.7 (10)	6.3-41 (18.1)
Worms, percent	0-22 (4.4)	6.2-30.1 (15)
Molluscs, percent	0	0-1.4 (0.4)
Collectors, percent	12-70 (37)	86-99 (95)
Filterers, percent	8-75 (40)	0.2-13.2 (3.8)
Predators, percent	0.2-37 (9)	0.7-5.1 (2.1)
Individuals, total number	507-44772 (7842)	2192-6293 (4773)
Shannon-Wiener Index	1.1-3.2 (2.5)	0.6-2.5 (1.5)
ADEQ perennial Index score	16-45 (33)	14-18 (16)

There are various macroinvertebrate adapations to intermittent streamflow present in Granite Creek and tributaries. For example, stoneflies of the family Taeniopterygidae cope with drying by having a period of dormancy as eggs or young larvae and can complete larval development in as little as three months (McCafferty and Provonsha, 1983). These stonefly adults emerge during the cold months of early spring, earning them the nickname “winter stoneflies”. Beetles, such as *Agabus*, a dytiscid beetle (predaceous diving beetle), is an excellent flier and disperser and can fly shortly after emergence giving them an avoidance strategy to deal with stream drying. Other taxa such as blackflies and midges are early colonizers and have multiple life cycles per year, completing their life cycle before drying of the streambed, and appear in many seasonally intermittent streams (Richards, 2012). Dobsonflies, commonly known as hellgrammites, are an example of taxa with the adaptations of large body size, good crawlers and burrowers. These characteristics provide resistance to drying, migration to wetter habitat or burrowing into damp substrates to avoid desiccation.

In comparing reference and stressed sample macroinvertebrate characteristics, some other differences become apparent (Figure 37). Reference sites have greater taxa richness, presence of stoneflies, less dominance by a single taxa group, far less percent composition by midges and non-insects, less of the collector-gatherer feeding group, more filterers, and greater Shannon-Wiener diversity index values, when compared to the stressed samples. In contrast, the stressed samples have no stoneflies, abundant midges and diptera, greater percentages of worms, non-insects and molluscs, dominance by the collector-gatherer feeding group, and an ADEQ index score that is half that of the reference sample scores. Macroinvertebrate metric scores for individual samples are listed in Appendix F.

Figure 37-Reference and Stressed Macroinvertebrate Samples Compared

Differences between macroinvertebrate communities of intermittent versus perennial streams

Intermittent stream macroinvertebrate communities differ significantly from those of perennial streams (Figure 38). The 25th percentile of reference metric values were calculated for statewide intermittent macroinvertebrate communities and compared with the reference perennial values used in the ADEQ cold-water IBI for comparison purposes. The overall taxa richness of the intermittent community is less than a third of the taxa richness of perennial stream communities. There are six times as many sensitive/intolerant taxa in perennial vs. intermittent stream communities. The scraper functional feeding group, comprised of insects with a longer life cycle which include taxa such as mayflies, is almost non-existent in intermittent streams compared to 11 taxa and 45 percent composition in perennial streams. The presence and abundance of stoneflies in intermittent streams is a quarter the abundance in perennial streams and the overall community tolerance value (HBI) is far greater in intermittent streams than perennial ones. Clearly the expectation for intermittent stream reference condition is very different than that for perennial streams.

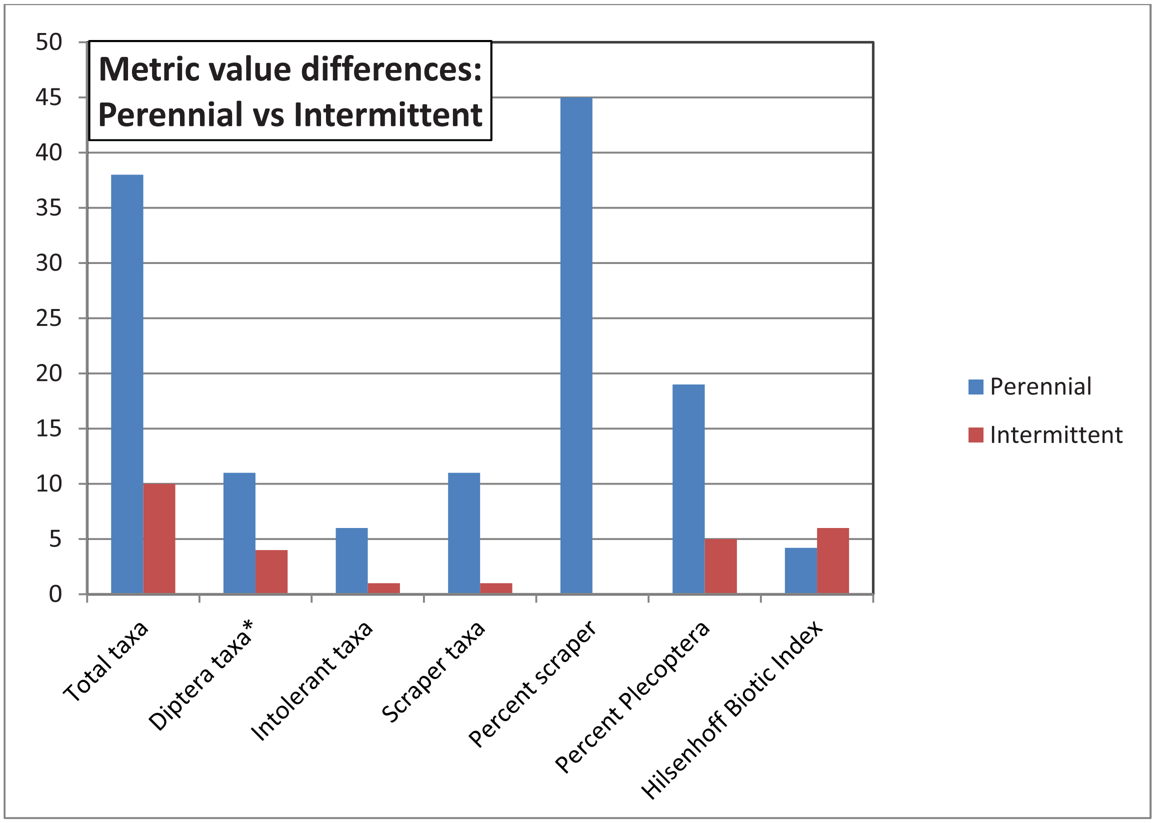


Figure 38-Macroinvertebrate metric values in perennial/intermittent stream types

Objective #2: Develop an intermittent stream Index of Biological Integrity
A relatively large dataset of intermittent stream macroinvertebrate samples from reference to stressed sites is needed to develop and Index of biological integrity. To conduct this analysis, samples collected during this survey were combined with reference and stressed samples collected by ADEQ from 2008-2010. This combined dataset of macroinvertebrate taxonomic and abundance data and the metrics calculated thereby were used to develop an Index of biological integrity to assess aquatic life condition in intermittent streams.

Macroinvertebrate metric analysis and Index development
A multi-metric approach was undertaken to develop a bioassessment tool which makes sense of macroinvertebrate biological data from the Prescott area intermittent streams. This approach followed the USEPA's methodology documented in the "*Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers*" (Barbour et al., 1999). The general steps for developing a bioassessment index involve:

1) Classifying the resource by ecoregion type and identify what constitutes "reference" condition,

2) Identifying metrics that are relevant to the stream type under study,

3) Metric selection and calibration,

4) Compiling multiple metrics into a single index, and

5) Establishing meaningful assessment thresholds for determining impairment.

The following analyses demonstrate how these steps were applied to the streams and study area of the Granite Creek Watershed.

1) Classifying the resource: The study area for this project, streams of the Granite Creek Watershed lie entirely within one ecoregion, the Arizona-New Mexico Mountains ecoregion thereby negating the need to classify streams into different ecological regions. Reference condition had to be defined and utilized to identify "reference streams" and "reference macroinvertebrate communities" by which to compare all other streams and samples. The following ADEQ general criteria for defining a-priori "reference" and "stressed" sites were used (ADEQ, 2006). The reference sites meeting the criteria included upper Miller Creek, upper Butte Creek, and Indian Creek. The stressed sites meeting the criteria included lower Miller Creek at Campbell Street and Granite Creek at Granite Creek Park.

   The Reference criteria are as follows:

   - No known discharges upstream
   - No major impoundments upstream
   - No human caused channel alterations at the site; e.g. diversions, dredge and fill projects
   - At least 0.5 miles downstream of road crossings
   - The site should be free of local land use impacts
   - The Habitat Assessment Index score should be greater than 14.

   The stressed site criteria are as follows:

   - Known discharges occur upstream of study site
   - Channel alterations may be present upstream
   - Bank erosion may be present
   - Local land use impacts
   - Water quality standards may be exceeded
   - Habitat Assessment score less than 14

Metric identification: Macroinvertebrate metrics that are relevant to intermittent streams of the Prescott area were identified by conducting significance tests on reference versus stressed samples (Table 26). The samples used for this test were 10 ADEQ reference samples (2008-2010) and 2 reference site samples from this survey (2011) plus 6 stressed samples from both surveys. A Mann-Whitney U significance test was used to test differences in mean metric values between the a-priori identified reference and stressed sample sets. Four of the metrics used in the ADEQ cold-water IBI also were identified as important indicators for this analysis: total taxa richness, diptera taxa richness, intolerant taxa richness, and percent composition by stoneflies. Other important metrics were: percent composition by the dominant taxon, percent composition by midges (chironomidae), percent worms, percent molluscs, percent collectors, percent filterers, percent predators and the Shannon-Wiener diversity index.

Table 26-Macroinvertebrate Metrics

Macroinvertebrate metrics significantly different between reference and stressed groups (Mann-Whitney U signifgance test, with bolded values indicating significant difference at $p<0.05$)

Macroinvertebrate Metric	Mean Metric value for Reference samples (n=12)	Mean Metric value for Stressed samples (n=6)	p-value
Total taxa richness	12	8	**0.013**
Diptera taxa richness	5	2.7	**0.003**
Intolerant taxa richness	1.4	0.0	**0.001**
Hilsenhoff biotic index (HBI)	6.0	6.3	0.349
Plecoptera (Stonefly), percent composition	14	0.0	**0.001**
Trichoptera (caddisfly) taxa richness	0.0	0.0	1.000
Ephemeroptera (mayfly) taxa richness	0.2	0.0	0.303
Chironomidae (midge) taxa richness	9.2	9.5	0.342
Mayfly, %composition	0.1	0.0	0.303
Dominant taxon, %composition	53	76	**0.009**
Chironomidae (midges), percent composition	32.4	69.4	**0.002**
Diptera (true flies) %composition	74.5	81.2	0.925
Coleoptera (beetles) %composition	1.2	0.8	0.510
Non-insect % composition	10	17.8	0.092
Worms, % composition	4.4	14.7	**0.015**
Molluscs, % composition	0.0	0.4	**0.002**
Scrapers, % composition	1.5	0.3	0.115
Collectors, % composition	37.1	95.3	**0.001**
Filterers, % composition	39.7	3.8	**0.001**
Predators, % composition	8.5	2.1	**0.039**
Individuals, total number in sample	7842	4865	0.640
Shannon-Wiener Diversity Index	2.5	1.5	**0.021**

Metric Selection: An index of biological integrity should be composed of a set of core metrics that discriminate well between good and poor quality ecological conditions. The discriminatory ability of metrics can be evaluated by comparing the distribution of scores between reference and stressed distributions. If there is minimal overlap between the distributions, the metric can be considered a strong discriminator between reference and impaired conditions. This test was conducted using box and whisker plots (Appendix G) and most important indicators are shown in Figure 39. In addition, metrics should be selected from four categories to ensure that different elements of community structure and function are addressed. The four categories are: Richness measures, Composition measures, Tolerance measures, and Trophic or Habit measures. From these 12 metrics, six were selected which had the best discriminatory ability (in bold) and which occurred throughout the dataset (were not rare indicators): total taxa richness, percent composition by stoneflies and by midges, percent composition by the dominant taxon, and the functional feeding group measures, percent collectors and percent filterers (Table 27).

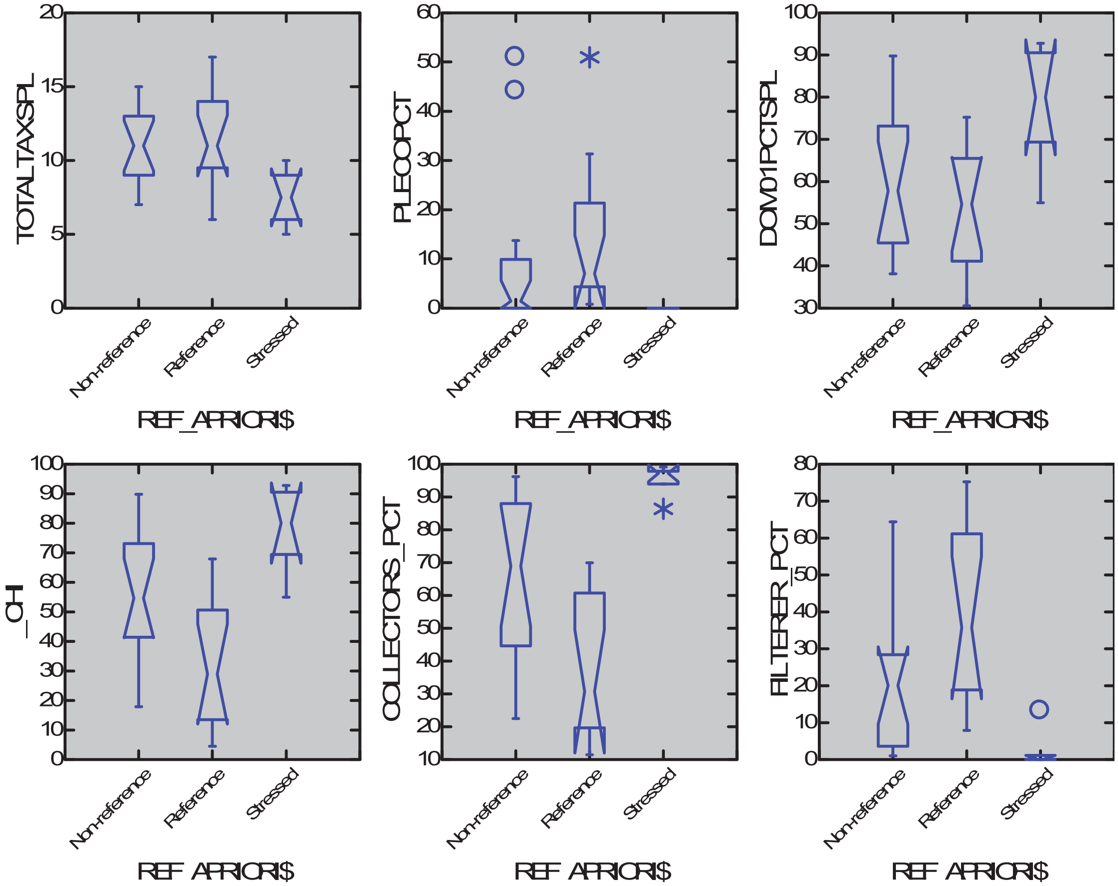


Figure 39-Box and Whisker plots of 6 best performing metrics

Table 27-Best Metrics for discriminating reference from stress sites

Richness measures	Composition measures	Tolerance measures	Trophic measures
Total taxa	**Stoneflies, %**	Intolerant taxa richness	**Collectors, %**
Diptera taxa	**Midges, %**	**Dominant taxon %**	**Filterers, %**
	Worms, %	Shannon-Wiener diversity	Predators, %
	Molluscs, %		

Compilation of metrics & thresholds into an index: An index provides a way of integrating information from a composite of various measures of the biological community. To combine metric values of differing ranges/scales, the metric values are transformed to unitless metric "scores" which are a percentage of the reference condition maximum value. To avoid using outlier values and to set an achievable maximum score for reference condition, the 95th or 5th percentiles of the reference distribution are used. The range of reference values for each metric and the maximum values based on the 95th or 5th percentiles are shown in Table 28. Metric scores can then be calculated as a percentage of these reference values, and the index calculated as an average of all six metric "scores". The calculation method for the metrics and index are described in detail in the ADEQ Biocriteria QAPP (ADEQ, 2006).

Table 28-Selected metrics and threshold values

Metric	Reference Range of values	Reference Mean value	5^{th} or 95^{th} percentile value	Response to disturbance
Total taxa richness	6 - 17	12	15.9 (95^{th})	Decrease
Stoneflies, %	0.8-51	13.9	40.2 (95^{th})	Decrease
Midges, %	4.5-68	32.4	6.7 (5^{th})	Increase
Dominant taxon, %	31 - 75	53.0	32.6 (5^{th})	Increase
Collectors, %	11.5-70	37.1	12.4 (5^{th})	Increase
Filterers, %	8-75	40.0	72.6 (95^{th})	Decrease

Establishing meaningful assessment IBI thresholds for determining impairment: To determine relevant IBI thresholds, reference and stressed sample IBI scores were compared in a box and whisker graph (Figure 40). The full range of intermittent IBI scores (0-100) was divided into three assessment categories based on the 25^{th} and 50^{th} percentile of the reference scores, commonly used statistics for setting biocriteria standards. This resulted in scoring categories of good (57-100), fair (51-56), and poor (0-50). Impaired biology is considered an IBI score $\leq$ 50 (poor condition). The a-priori defined reference sample IBI scores ranged from 39-97 with 3 samples in poor condition and 8 in good to fair condition, and the stressed site samples ranged in IBI score from 10 – 36 with all 6 samples in poor/impaired condition. In Figure 40, the notched areas of the reference and stressed box and whisker plots (95^{th} percentile confidence interval), did not overlap, which indicated good discriminatory ability of the index. Thus these scoring categories were accepted for use in assessments of macroinvertebrate samples from intermittent streams of the Prescott area for future sampling efforts. Metric values and IBI scores for the 29 samples used in this study are provided in bioassessment reports in Appendix E.

When applied to the 29 samples in the dataset, 17 samples from 9 sites were poor or failing this intermittent biocriteria. These sites included:

- Aspen Creek @ FS boundary
- Aspen Creek @ confluence
- Banning Creek
- Butte Creek-upper
- Butte Creek @ Sheldon St
- Granite Creek @ Granite park
- Granite Creek @ Watson Woods
- Manzanita Rd at park
- Miller Creek at park
- Miller-upper
-

There were 8 samples from 5 sites meeting reference conditions or in the good to fair categories. These sites were:

- Granite Creek @ White Spar camp
- Indian Creek
- Miller Creek-upper
- Aspen Creek @ FS boundary
- Butte Creek-upper

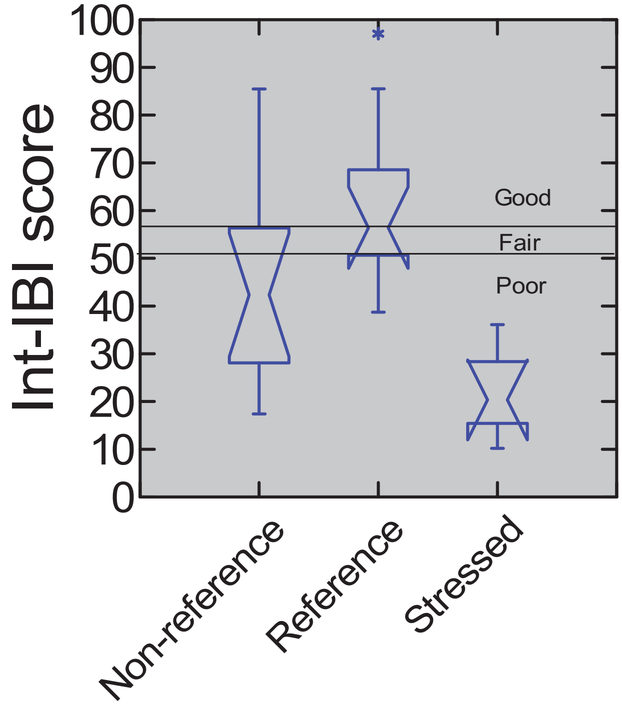


Figure 40-Distribution of Intermittent IBI Scores (29 Samples)

Objective #3: Trends in macroinvertebrate condition at Granite Creek-Watson Woods restoration reach, 2008-2012

Three macroinvertebrate samples from April 2008, 2011 and 2012 were collected and used to analyze trends in biological condition in the restored reach of Granite Creek at the Watson Woods Preserve. The restoration work featured relocation of the stream channel into a more stable pattern, large quantities of tree plantings, removal of exotic species and other activities. Relocating the channel involved bulldozing a new sinuous path through the floodplain, thereby creating a fresh streambed surface not yet colonized by any aquatic biota. Ample colonization sources are available in the watershed; from the wetlands and lake downstream to the intermittent and ephemeral reaches of Granite Creek and tributaries upstream to wastewater treatment ponds just upstream. Macroinvertebrates could recolonize by aerial dispersers, drift from upstream waterbodies, and crawling from neighboring wet spots. The following analyses track changes in the macroinvertebrate metrics and the Intermittent IBI score at the restoration reach over the four year period, looking for improvements following the channel and revegetation restoration improvements made during March and April 2009. Taxa lists and bioassessment scores using the newly developed Intermittent stream IBI are provided in Appendix F.

The bioassessment scores varied widely from year to year at the Granite Creek-Watson Woods site (Figure 41). The Intermittent IBI score was greatest in 2008 (pre-restoration), then fell to half the score following the channel restoration work in 2009, then recovered to near 2008 levels by spring 2012. The Intermittent IBI scores for this site met criteria for "good" condition in 2008 and 2012, but failed to meet the lowest criteria in 2011 (poor condition). The 2011 sample was different in part because the sample was dominated by midges (55%) and low taxa richness with respect to other taxa groups.

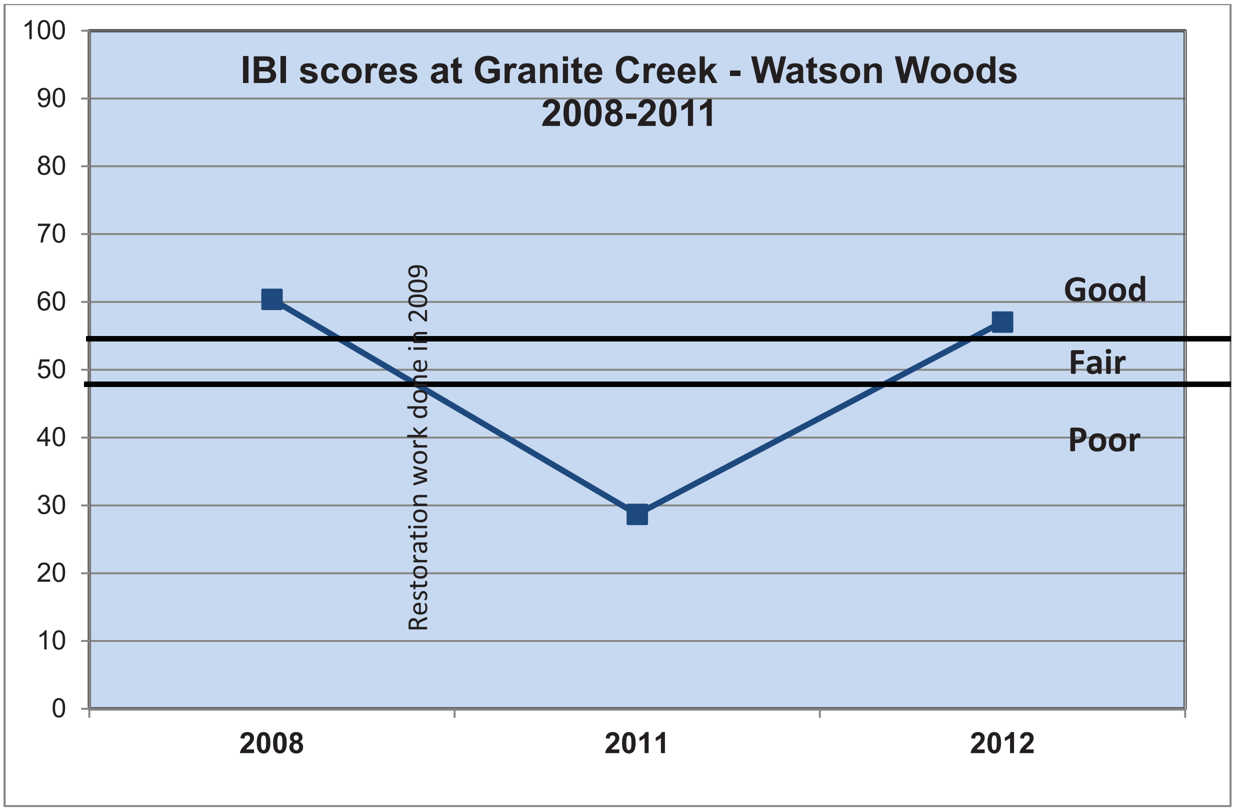


Figure 41-Trends in the Intermittent IBI Score at Watson Woods

Macroinvertebrate metric scores exhibited a similar pattern, with most metric scores being greatest in 2008 and least in 2011 (Figure 42). The high percent composition by midges in 2011 had a large effect on the bioassessment: 1) it resulted in a low percent midges "score" (percent of reference threshold) and 2) contributed to the low percent collectors "score" because at the family level Chironomidae are considered "collectors". While a dip in bioassessment score was expected following the major channel modifications of the restoration project and then a gradual recovery, a drop in IBI score of 50% in 2011 and subsequent recovery of 50% the following year was much larger than expected.

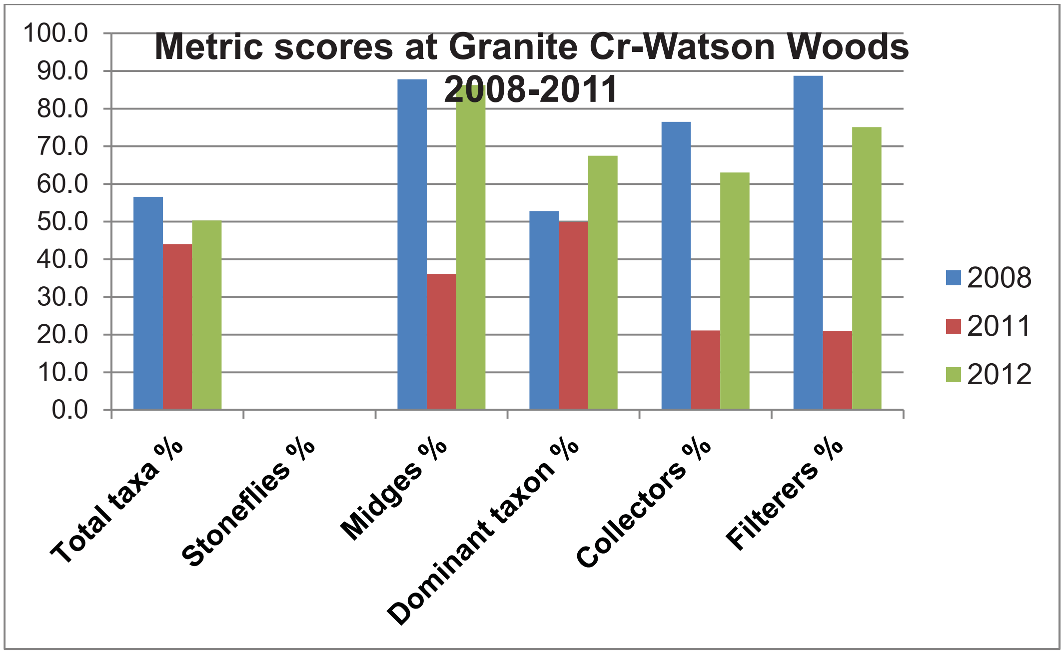


Figure 42-Trends in Macroinvertebrate metric scores at Watson Woods

There were also changes in habitat parameters during the 5-year study period. Habitat conditions did improve in the Watson Woods reach with canopy cover, Habitat index score, Pfankuch channel stability score, riparian PFC score and percent riffle habitat all increasing following the channel restoration work. Percent embeddedness and the riffle-D50 value decreased. These are all positive improvements in substrate and channel habitat for aquatic life (Figure 43). While the habitat values at the end of this survey in April 2012 do not yet achieve mean reference site habitat values, the substrate and channel conditions have improved substantially which will eventually be reflected in the aquatic life.

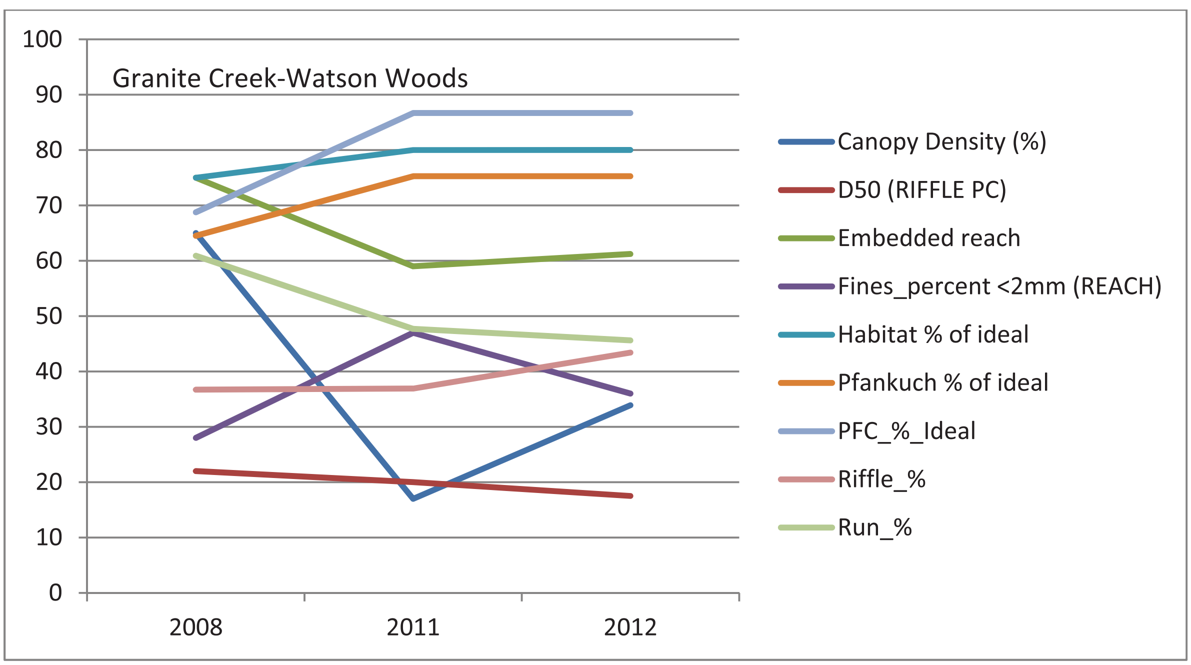


Figure 43-Trends in Habitat Conditions at Watson Woods

Objective #4: Bioassessment Method for Volunteers

The objective of this project component was to develop a simple bioassessment method for use by volunteers, tailored for Prescott area intermittent streams. This bioassessment index for volunteers was to be translated from and calibrated with the Intermittent IBI for the region. Two methods from the EPA Volunteer Stream Monitoring Manual were pursued; 1) a Tolerance Index used in EPA's Streamside Biosurvey and 2) a Simple Four-Metric Index used in EPA's Intensive Stream Biosurvey. The Tolerance Index was selected because it is the simplest method requiring the least volunteer training and is the method suggested in the draft Arizona Biosurvey Protocols: Level 2 (Marsh and Spindler, 2007). The Simple Four-Metric Index was selected because it is a direct translation of metrics used in the detailed Intermittent IBI, thereby producing more accurate results. The results of a comparison of these two analysis tools with the Intermittent IBI provides an assessment of the accuracy of these tools, which can aid in selecting a tool for use by Prescott Creeks in the Granite Creek Watershed. Before doing the comparison analysis, each index was tested to determine how well it performed in classifying reference and stressed site samples and to develop appropriate scoring thresholds. The following are the results of the index testing and comparisons to the Intermittent IBI.

Testing of the Tolerance Index:

The Tolerance Index was tested and calibrated with the Intermittent IBI to ensure that accurate bioassessments of reference and stressed site samples are made. The Tolerance Index score was based on "order level" taxonomic identifications of 500 specimens per sample. The taxa were classified by sensitivity group (Sensitive, moderate or tolerant) and a weighted factor applied to the number of taxa in each sensitivity group, then the three scores were summed for a total score. Tolerance Index scores ranged from 5-11 for stressed samples and 10-23 for reference samples. A threshold of impairment was selected at a score of less than 12, which falls below the 25th percentile of reference and above the 75th percentile of stressed scores (Figure 44). All of the stressed samples (6/6) fall at or below this score, and all but two of the reference scores are above it. The data in Table 29 display the correct placement of scores in assessment categories. So, this analysis indicated that the Tolerance Index can be used to make accurate assessments, when an appropriate threshold, based on a statistical distribution of a-priori reference and stressed sites was identified.

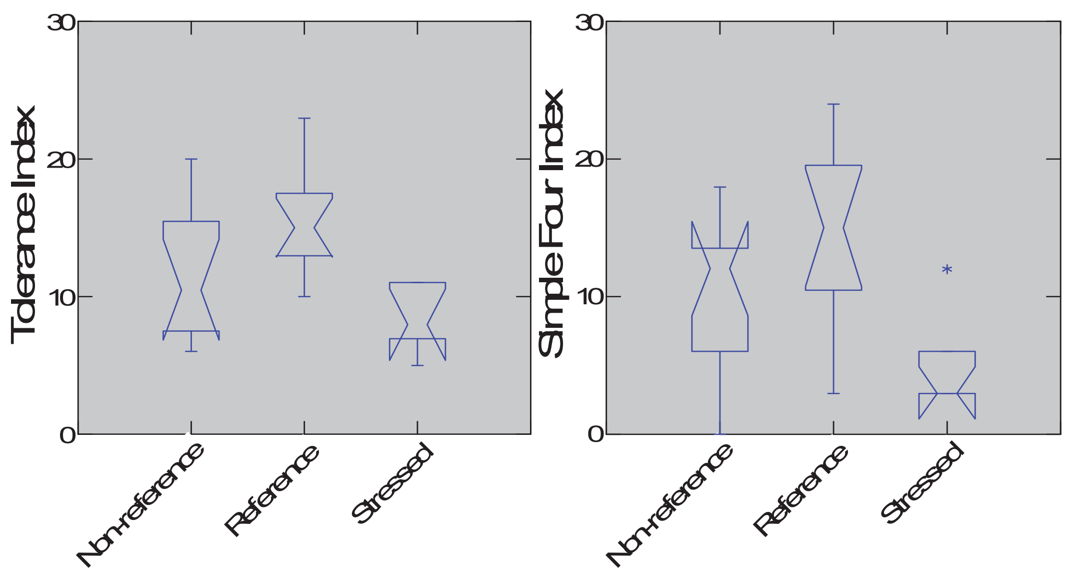


Figure 44-Distribution of volunteer index scores

Table 29-Evaluation of accuracy intermittent indexes

Asessment category	Intermittent IBI			Tolerance Index			Simple Four-Metric Index		
	Ref	NR	S	Ref	NR	S	Ref	NR	S
Good	5	3	0	9	5	0	7	3	0
Fair	3	1	0	na	na	na	1	4	1
Poor/Impaired	3	8	6	2	7	6	3	5	5

Testing of the Simple Four-Metric Index:
The Simple Four-Metric Index was tested to ensure that it worked effectively for making accurate bioassessments of reference and stressed site samples, then an appropriate threshold of impairment was identified. This Index was also based on "order level" taxonomic identifications of 500 specimens per sample. The four metrics used in this index were: taxa richness (order level), percent composition by stoneflies, percent composition by the dominant taxon, and percent composition of Chironomidae (midges) in the whole sample. A three category scoring system modeled after the EPA approach was used to place metric scores into good, fair or poor categories worth 6, 3, or 0 points respectively. These scoring points were added up for the four metrics for each sample. The summed score constitutes the Index score for a sample. The Simple-Four Index scores for stressed samples ranged from 3-12 and reference samples ranged from 3-24. A threshold of impairment was selected at a score of ≤11, the 25th percentile of the reference scores (Figure 44). Five of six stressed samples fall at or below this score, and all but 3 of eleven reference scores are above it. The data in Table 29 display the correct placement of scores in assessment categories. This analysis indicated that the Simple Four-Metric Index can also be used to make accurate assessments, when an appropriate threshold based on a statistical distribution of a-priori reference and stressed sites was identified and used. Thresholds for assessment categories for each index are shown in Table 30.

Table 30-Bioassessment Thresholds

Asessment category	Intermittent IBI	Tolerance Index	Simple Four-Metric Index
Good	57-100	≥12	≥15
Fair	51-56		12-14
Poor/Impaired	0-50	0-11	0-11

Comparison of the three bioassessment tools:
A comparison of these two simple volunteer bioassessment tools with the Intermittent IBI provides an assessment of the accuracy of these tools. Figure 45 shows that the Simple Four Metric Index scores for the 29 samples were strongly correlated with the Intermittent IBI score (R^2=0.84, p<0.001). Reference sample scores placed at high scores on the graph and stressed sites grouped at the low end of the graph. The correct classification of reference and stressed samples is another way to evaluate the accuracy of the Simple Four Index. The Simple Four Index classified 10 samples as meeting reference condition versus 8 samples of the Intermittent IBI meeting reference thresholds, and 13 samples as impaired vs 17 samples impaired with the Intermittent IBI.

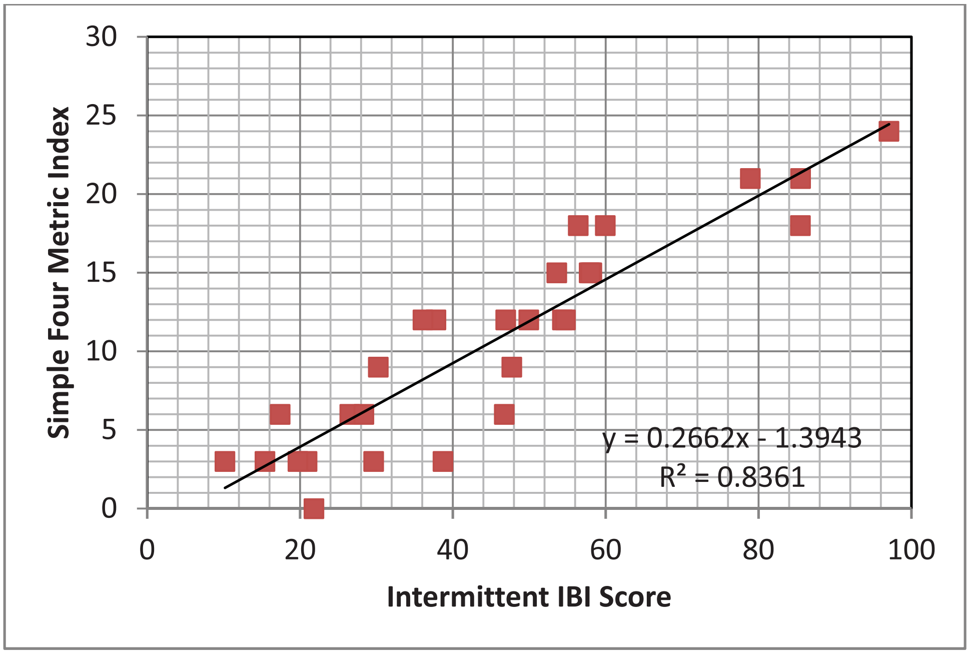


Figure 45-Regression Analysis (Simple Four Metric Index vs. IBI Score)

Figure 46 shows that the volunteer Tolerance Index scores for the 29 samples were correlated with the Intermittent IBI score (R^2=0.67, p<0.001). Reference sample scores placed at high scores on the graph and stressed sites grouped at the low end of the graph. The correct classification of reference and stressed samples is another way to evaluate the accuracy of the Tolerance Index. The Tolerance Index classified 14 samples as meeting reference condition versus 8 samples of the Intermittent IBI meeting reference thresholds, and 15 samples as impaired vs 17 samples impaired with the Intermittent IBI. The tolerance index appeared to identify more samples in “good” condition than the Intermittent IBI method, suggesting that it may be overestimating aquatic life condition. These two indexes appear to provide two viable methods for volunteer use in assessments of Granite Creek at Watson Woods and in intermittent streams of the Granite Creek watershed.

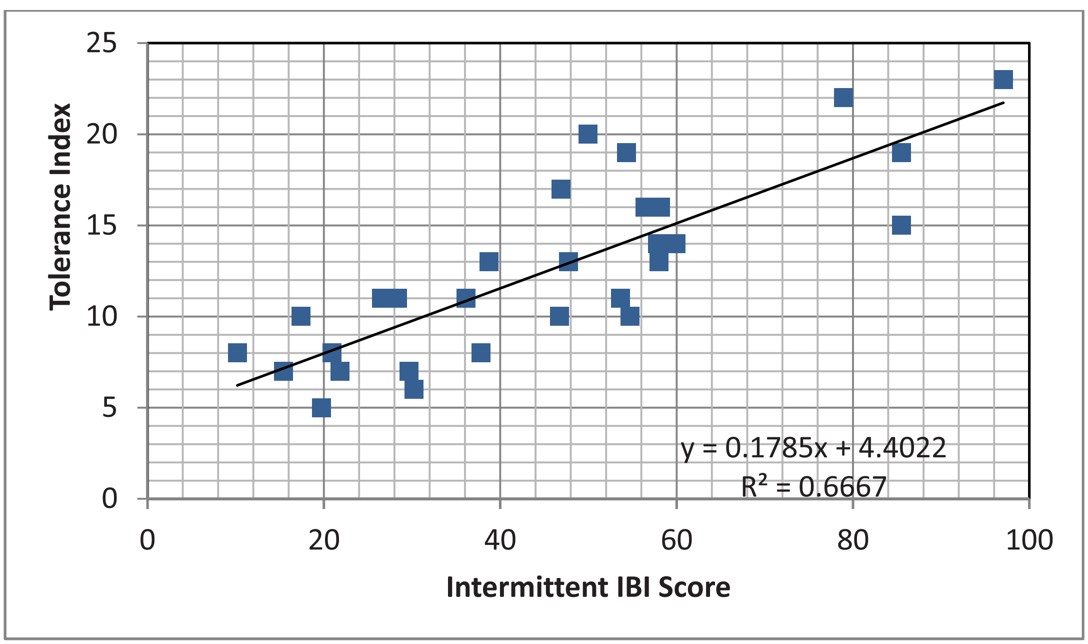


Figure 46-Regression Analysis (Volunteer Tolerance Index vs. Int. IBI Score)

Additional objectives/data analyses:

Identify rare, threatened or endangered aquatic invertebrates found on the Watson Woods Preserve
We did not identify any rare, threatened or endangered aquatic invertebrates during these surveys. Only family level of identification was required and utilized for the major objectives and analyses of this project. Unfortunately, "species level" identification of macroinvertebrates is necessary to enable checking for special status species. So, this additional analysis could not be conducted at this time. However, specimens have been preserved and stored and will be transmitted to "Prescott Creeks" and species level identifications of these specimens and checking their threatened and endangered status could be conducted at a later date.

Multivariate analysis of stressors associated with macroinvertebrate impairment
While it is important to have bioassessment tools to identify where aquatic life is impaired, it is also important to understand most probable stressors affecting macroinvertebrates. A multivariate analysis of a variety of habitat stressors was conducted to determine which ones are most affecting the macroinvertebrate community. Ten habitat parameters were evaluated:

- percent canopy density over the streambed
- the median particle size of the streambed (D50)
- percent embeddedness of large particles by fine sediment
- percent fine sediment that is <2mm in size
- habitat index score
- Pfankuch channel stability score
- Riparian condition score, Proper Functioning Condition (PFC)
- percent riffle habitat
- percent pool habitat
- percent run habitat

To avoid autocorrelations, this set of parameters was reduced down to five variables using Pearson correlation scores with Bonferroni probability scores. The parameters which showed strongest differences between the reference and stressed groups of sites were:

- Percent embeddedness
- Percent fines
- Riparian condition
- Habitat index score
- Percent run habitat

The dataset of 15 reference and stressed sites, the associated Intermittent IBI score and the five habitat parameters were input into a discriminant function analysis. This multivariate analysis identifies stressor variables that are most strongly associated with two or more predefined groups of sites (ie., reference and stressed groups). The model was able to classify all sites correctly using all five variables and had a significant Wilks-Lambda value ($p<0.001$). Percent run habitat was the most important variable, followed by percent embeddedness, habitat index score, riparian condition score, and percent fines.

The discriminant function analysis showed that several habitat features were important to the structure and function of the intermittent macroinvertebrate community and the resulting Intermittent IBI score. Percent run habitat was the most important variable discriminating reference from stressed samples followed by percent embeddedness, habitat index score, riparian condition score, and percent fines. Stressed sites were characterized by a high percentage of run habitat, greater percent embeddedness and percent fines and lower habitat scores and PFC scores (Figure 44). Conversely, reference sites were characterized by lower percent embeddedness, percent fines and percent run habitat and greater habitat score and PFC scores. These habitat factors indicate the importance of substrate conditions and riparian cover to the macroinvertebrate community. Increased percentages of fine sediment in the stream bottom leads to more embeddedness of cobble-gravel particles and reduced interstitial space for macroinvertebrates to colonize. Percent run habitat is an expression of excess sediment in a study reach because as sediment deposits form in channels, riffles and pools are filled in thereby reducing fish habitat and clean substrates and diverse habitats for macroinvertebrates. Riparian cover is often linked with macroinvertebrate condition because streamside vegetation provides shade and reduced stream temperature, increased food resources in terms of leaf litter, and bank stability to maintain instream habitats and reduce bank erosion and excess sedimentation. While thresholds for these habitat parameters were not set as part of this project, the box and whisker plots in Figure 47 provide general ideas for thresholds based on the reference distribution. In summary, this multivariate analysis identified five habitat variables (percent embeddedness, percent run habitat, percent fine sediment, habitat score and riparian PFC score) as the most important stressors affecting the macroinvertebrate community in intermittent streams of the Granite Creek watershed.

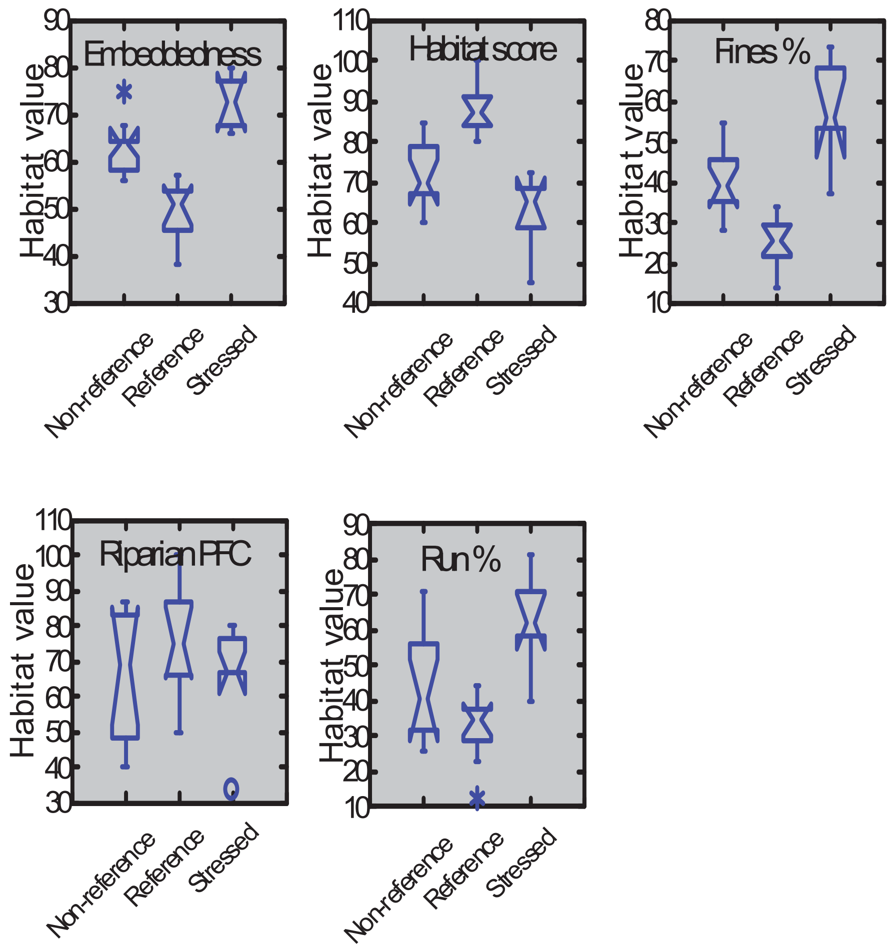


Figure 47-Comparisons of habitat parameter values

Evaluation of sampling method and index period

The 10-jab 5-minute composite sampling method provided more than enough samples to identify 500 bugs. The EPA 20-jab method would produce too much material to sort. The ADEQ 3-minute riffle sample method would not work well at some of the Prescott area streams as there was little to no riffle habitat. The multi-habitat sampling method was selected over the riffle approach as the preferred method in a recent study of intermittent streams (Richards, 2012). Riffle samples tended to have more taxa, greater percent Ephemeroptera and greater percent Plecoptera but less percent dominant taxon than multi-habitat samples, so standards based on riffle samples will be hard to meet for multi-habitat samples. The multi-habitat method will better represent the macroinvertebrate assemblage of intermittent streams than riffle sampling methods, particularly if only run and pool habitats are present. In these habitats, more beetles, true bug, and rare taxa will be found.

The spring index period has been used by ADEQ for perennial stream sampling for over 20 years and for intermittent streams for the past 5 years. The spring index period is the time period (March-May) when winter flooding has subsided, the longest wetted period of the year occurs, and the presence of water is most predictable. The hydrographs in Figure 48 shows the wetted periods of the year at several monitoring stations in the Granite Creek watershed. Note the sustained flows occurring January to April/May. While there are some peak flows during the summer monsoon period, they are generally not sufficient to provide predictable long term flow conditions that are necessary for macroinvertebrates to complete their life cycle. The spring index period is the most reliable index period for sampling due to predictable water and the longest period of flow and also because similar taxa reoccur during this time period in the 5 year dataset provided by ADEQ.

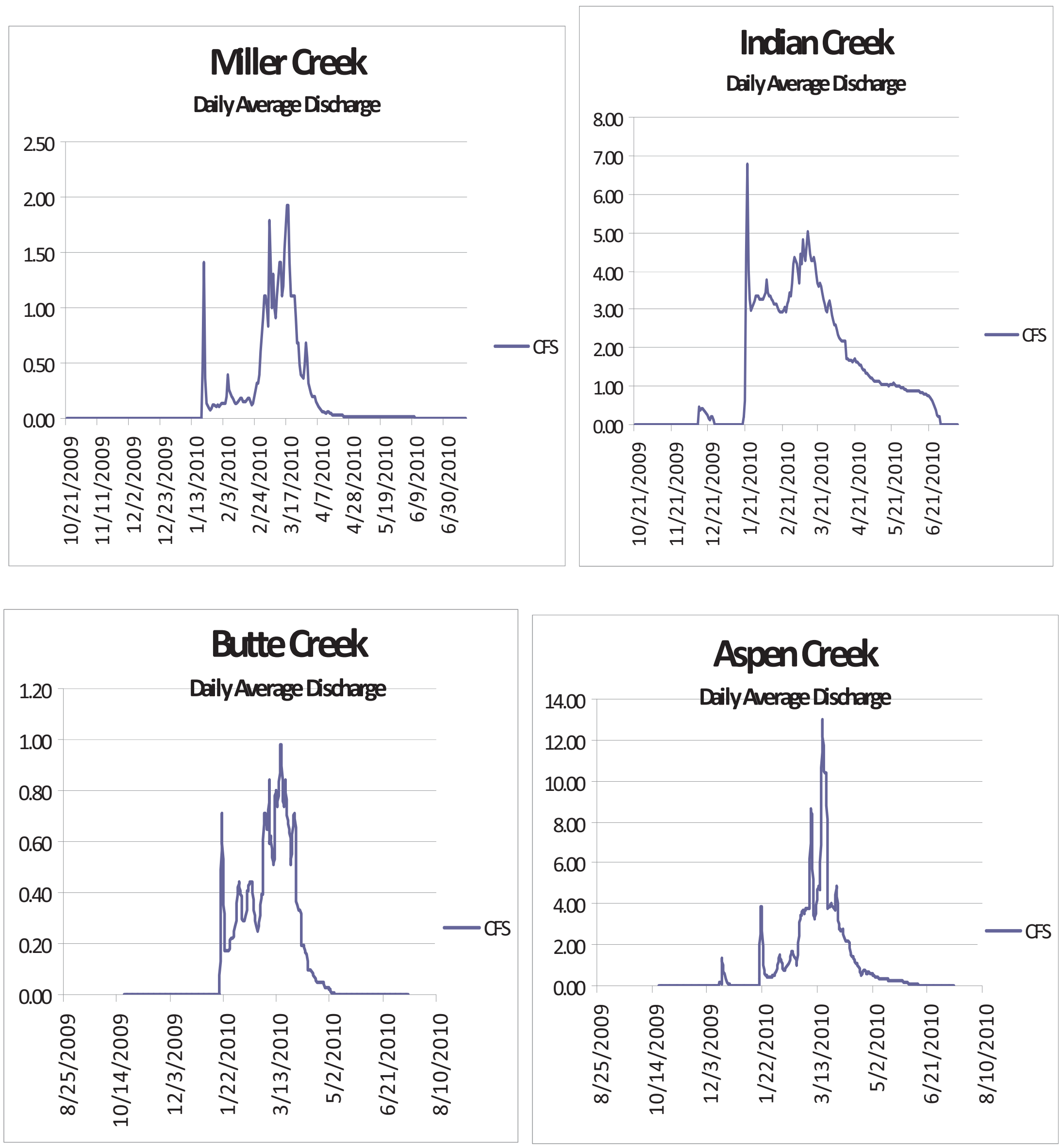


Figure 48-Hydrographs showing during of flow (Spring)

Discussion

The bioassessment of aquatic macroinvertebrate communities is an important and widely accepted environmental indicator of water quality (Barbour et al., 1999). The majority of bioassessment studies in the literature have focused on perennial stream types. However an emerging body of literature on intermittent and headwater streams is bringing to light the importance of these temporary waters to aquatic life and wildlife and assessments of their condition (Bogan et al., 2012; Fritz et al., 2006; Levick et al., 2008; Richards, 2012). This study sought to add to the literature by developing an intermittent IBI and associated volunteer assessment methods for cold water intermittent and headwater streams of the Granite Creek watershed of Prescott, Arizona. Additional objectives were to define baseline aquatic biological conditions of Granite Creek and its tributaries and to examine trends in bioassessments following channel restoration work on Granite Creek at Watson Woods.

The intermittent streams of the Granite Creek watershed are seasonally intermittent, flowing from 4-8 months of the year depending on quantities of winter snowpack and monsoon rain. The resulting amount of streamflow is not sufficient to sustain many of the long-lived macroinvertebrates of perennial streams, such as most mayflies, caddisflies and stoneflies (EPT), taxa we typically look for as indicators of good ecological health. However, intermittent streamflows for half to three-quarters of the year are sufficient to support a fairly diverse community of invertebrates adapted to these habitats (Gray, 1981). A well developed riparian corridor was evident at most of the study sites with the exception of headwater sites and Manzanita Creek. There were variations in stream bottom habitat with percent riffle habitat and median particle size greatest and percent fines and percent embeddedness least at reference sites. Substrate conditions were generally poor at the stressed sites with high percent fines and percent embeddedness, poor habitat index score and high percent run habitat. Since sensitive macroinvertebrate species prefer clean cobble-gravel substrates with open interstitial spaces to colonize (ie. low fines & percent embeddedness, with abundant riffle habitat), high percentages of fine sediment, high percent embeddedness and high percent run habitat are indicators of a degraded stream channel and poor habitat for macroinvertebrates.

Macroinvertebrate characteristics for all these sites (reference to stressed) include low taxa richness, a lack of EPT taxa, high percent composition by diptera (especially midges) and a high percentage of the collector-gatherer and filterer functional feeding groups. Other findings included the presence of the winter stoneflies Taeniopterygidae and Capniidae and dobsonflies/hellgrammites occurring at higher/wetter elevations (upper Miller and Butte Creeks). We also found more worms, gastropods, and ostracods in lower elevations and sandier substrates. Beetles and black flies were ubiquitous at all stream sites. We found only one caddisfly (Limnephilidae) and one mayfly (Siphlonuridae) in Banning Creek, the only perennial stream in this study area. The crayfish Cambaridae was found at only one site during this survey period in Granite Creek at Granite Park. Some of the macroinvertebrate life history strategies and adaptions for intermittency include short life cycles (midges), having a dormant life stage (winter stoneflies), being a strong flier to avoid drying (beetles), and having a large body size, ability to crawl and burrow (dobsonfly). Similarly, Bogan et al. (2012) found depauperate communities of intermittent streams consisting of primarily blackflies, stoneflies, and midges, which he states were not just a subset of perennial species that had colonized via drift, but rather were a suite of taxa with special adaptations to intermittency.

Macroinvertebrate metrics were selected for the Intermittent IBI that discriminated well between reference and stressed samples. Reference sites have greater taxa richness, presence of stoneflies, less dominance by a single taxa group, far less percent composition by midges and non-insects, less of the collector-gatherer feeding group and more filterers. In contrast, the stressed samples have no stoneflies, abundant midges and diptera, greater percentages of worms, non-insects and molluscs, and dominance by the collector-gatherer feeding group. The metrics selected for the Intermittent Index of Biological Integrity included: total taxa richness, percent composition by stoneflies, percent composition by midges, percent composition by the most dominant taxon, percent collectors and percent filterers. Thresholds for impairment to assess samples into good, fair and poor classes were based on the 25th percentile of reference values and the 50th percentile of reference values, respectively. This resulted in 8 of 9 sites from 2011 and 7 of 9 sites from 2012 identified as impaired. Interestingly, the Granite Creek @ Watson Woods sample from 2012 was the only site in "good" condition. In 2011, the reference sites upper Miller Creek and upper Butte Creek were in fair condition, whereas the remainder of sites were in poor condition.

The Granite Creek @ Watson Woods site had variable Intermittent IBI scores over the 5-year study period. The samples from 2008 and 2012 were in marginally "good" condition, whereas the 2011 sample was in poor condition, being half the IBI score of the other samples. While the taxa richness was not similar to the reference sites, the percent midges were lower and the percent blackflies (filter feeders) were greater in the 2008 and 2012 samples, resulting in high IBI scores. The marginally "good" IBI scores do not mean that a full recovery has taken place at the Watson Woods site. However the fact that this site is not dominated by midges and worms, like the stressed sites, means that the habitat is not limiting the macroinvertebrate taxa. This is a hopeful step toward recovery of a fully functional aquatic community.

Habitat conditions did improve in the Watson Woods reach. Canopy cover, Habitat index score, Pfankuch channel stability score, riparian PFC score and percent riffle habitat all increased following the channel restoration work, whereas percent embeddedness and the riffle-D50 value decreased; all positive improvements in substrate and channel habitat for aquatic life. It appears that the stream recovery following the channel restoration work was successful not only for restoring the physical integrity and functional riparian community but in creating a stable channel and substrate sufficient for a functional intermittent stream community to develop. The hydrology of the site is vitally important; drought and flooding can have as much impact on the aquatic community as the habitat conditions of the channel. Low flow conditions in 2011 could be responsible in part for the "poor" condition of the community in 2011. Winter peak flows were smallest in 2011 (70 cfs) than any other year during 2008-2012, perhaps leading to lower flows and less duration of flow in spring 2011 which would favor short-lived taxa such as the midges. No stoneflies were observed at this site during any of the biosurveys conducted. This could be due in part to water temperatures. Most stoneflies have a peak thermal tolerance value of approx 13-17°C (Yuan, 2006). Gray (1981) suggested a maximum temperature of 20°C for egg hatching of another winter stonefly genera in a desert stream, *Mesocapnia*. The temperature at time of sampling in 2011 and 2012 was 13°C and 18°C respectively, right about at the limit for most stoneflies. The broadback stoneflies (Taeniopterygidae) are "winter stoneflies" that emerge during the cold seasons. So the reason for not finding them could be that they emerged as winged adults much earlier than the April sample collection event or the Watson Woods site is too warm to support this coldwater species. Improvements in aquatic life to watch for in the future are more beetle and diptera taxa and abundances, more midges, greater overall taxa richness, and perhaps presence of winter stoneflies.

A multivariate analysis identified five habitat variables as the most important stressors affecting the macroinvertebrate community in the study area: percent run habitat, percent embeddedness, habitat index score, riparian PFC score and percent fine sediment, in order of importance. Stressed sites were characterized by a high percentage of run habitat, greater percent embeddedness and percent fines and lower habitat scores and PFC scores. Conversely, reference sites were characterized by lower percent embeddedness, percent fines and percent run habitat and greater habitat score and PFC scores. These habitat factors indicate the importance of substrate conditions and riparian cover to the macroinvertebrate community. Increased percentages of fine sediment in the stream bottom leads to more embeddedness of cobble-gravel particles and reduced interstitial space for macroinvertebrates to colonize. Percent run habitat is an expression of excess sediment in a study reach because as sediment deposits form in channels, riffles and pools are filled in thereby reducing fish habitat and clean substrates and diverse habitats for macroinvertebrates. Riparian cover is often linked with macroinvertebrate condition because streamside vegetation provides shade and reduced stream temperature, food resources in terms of leaf litter, and bank stability to maintain instream habitats and reduce bank erosion and excess sedimentation. Habitat conditions were likely an important stressor resulting in poor macroinvertebrate community health at several sites in the Granite Creek Watershed.

Two bioassessment indexes were developed for use by volunteer groups on macroinvertebrate samples from intermittent streams of the Prescott area. The first, a Tolerance Index uses order level identification of macroinvertebrates in the field, a simple classification of bugs into three tolerance categories, application of multipliers for each category, and a summed score. The resulting score is compared to the 25th percentile threshold reference value to identify impairment or attainment. This index threshold classified sites/samples similarly as the Intermittent IBI, validating it as a usable tool. The second index is the "Simple Four Metric Index" which also uses order level identification in the lab and calculation of four metrics in common with the Intermittent IBI (taxa richness at order level, percent composition by stoneflies, percent composition by the dominant taxon, and percent composition by midges. A three category scoring system, based on reference thresholds is used to score the sample with the resulting scores ranging from 0-24. Again the 25th percentile of reference score is used as the threshold of impairment. This index threshold also classified Prescott area samples similarly as the Intermittent IBI, validating it as a useful tool for volunteers. Regression R^2 values and corresponding correlation significance scores between each of the volunteer indexes and the Intermittent IBI were highly significant, indicating that either tool could be used to make accurate bioassessments. The choice of which index to use will depend on the skill level of the volunteers, with the Tolerance Index being easiest to use.

According to the USEPA, Izaak Walton League and Engel and Voshell (2002), data from volunteer biological monitoring can be very useful for making biological assessments on streams and watersheds of interest. The data can be used as a screening level tool to look for problem areas or can be used to track stream improvements over time. The accuracy of the assessments will depend on the volunteer training on sampling methods, field documentation, and taxonomy training and oversight. With these pieces of a volunteer monitoring program in place, valuable monitoring data can be collected to help track aquatic life condition and stream and watershed health.

Recommendations:

- For a more complete inventory of aquatic species at Watson Woods Preserve, obtain genus/species level identifications of sorted larval samples and collect adult insects.
- Conduct larval collections monthly from November to April to determine if winter stoneflies are present in Granite Creek at Watson Woods.
- Conduct crawfish surveys within the historic and current channel, trap and remove wherever possible to keep this destructive invasive species from damaging the aquatic life.
- The diptera (true flies) family of insects, Chironomidae (midges), is very abundant and diverse on the preserve and throughout the watershed. This group of insects is diverse not only in species names, but in various tolerances to temperature, pollution, nutrients. With better identification, indicator species could be used to more specifically track improvements of aquatic life in the watershed.
- Watershed improvements/trends can also be tracked using the various habitat parameters collected during this study using ADEQ habitat assessment protocols.

Herpetology

Herpetological monitoring was conducted between 2009 and 2012 as part of the Restoration Project. The objectives of the herpetological component of the restoration project were to use existing baseline data and standardized survey methods to assess a monitoring program for the herpetofauna of Watson Woods; and to foster public appreciation of the ecological importance of riparian herpetofauna. Survey methods included trapping at pitfall grid and array sites, dip-netting, deployment of box funnel and minnow traps, and two types of visual encounter surveys.

Reptiles and amphibians (herpetofauna) were identified as priority fauna for inventory due to their importance in riparian foodwebs, and due to some species' sensitivity to environmental perturbation. Herpetofauna may achieve high densities in riparian and other aquatic systems (e.g. Petranka and Murray 2001, Brischoux et al. 2007), and thus may be important predators on insects, fishes, small mammals, birds, and other herpetofauna (e.g. Reichenbach and Dalrymple 1986, Stewart and Woolbright 1996, Gibbons et al. 2006). Herpetofauna are in turn favored prey items for riparian birds such as common black-hawks and zone-tailed hawks (Ehrlich et al. 1988), and also for other bird species, fish, and mammals (Brennan and Holycross 2006). Herpetofauna in general are sensitive to habitat alteration due to their limited mobility, and amphibians in particular due to their permeable skins (Lannoo 2005). Many species are dependent on permanent water and thus may be considered indicator species of the ecological health of any given riparian area (Jones 1988, Rosen and Schwalbe 1995, Pough et al. 1998).

In total, 19 reptile and amphibian species were observed in Watson Woods, including two non-native turtle, one lizard, and three snake species not detected during the previous inventory. Several mammal, bird, and fish species were also detected; of these, one mammal and all fish species were non-native. Survey methods were not equally likely to detect each species; however, common diurnal lizards were detected during all methods. Plateau Fence Lizard and amphibian larvae constituted the vast majority of detections. Several snake and one lizard species were only detected once or twice; three of these detections were made by volunteers or Prescott Creeks staff, illustrating the important role of citizen scientists. Important amphibian breeding areas include the semi-permanent ponds (for Tiger Salamanders), and Granite Creek, especially Reaches 2 and 4 and historic channels (Woodhouse's and Southwestern Toads).

Both biodiversity and abundance appears to be increasing in riparian woodlands, likely a function of both previous and current restoration efforts. Although lizards quickly colonized restoration sites, more detailed analyses are needed to ascertain correlation in species population trends with current restoration efforts. Recurring stochastic events occasionally affected trap function and coverboard persistence, illustrating the need to carefully identify and secure traps during long-term monitoring programs, especially in public spaces. Possible conservation concerns include the unknown effects of noise pollution on amphibian breeding success, loss of suitable amphibian breeding habitat due to dense woody vegetation plantings, loss of cover through removal of downed logs, and a projected decrease in abundance and diversity of large-bodied snakes from the area.

Methods

Study Area. Watson Woods Riparian Preserve is located just north of Prescott, Arizona at approximately 5100 ft (1554 m), and encompasses 125 acres. It is dominated by approximately 100 acres of mixed riparian woodland associated with the perennial/intermittent surface flows and perennial sub-surface flows of Granite Creek (Byrd et al. 1996). Included in this woodland are approximately four acres of palustrine habitat associated with standing perennial water (recharged from main channel overflow). Dominant woody species include willows (*Salix spp*.), cottonwoods (*Populus spp*.), box-elder (*Acer negundo*), velvet ash (*Fraxinus velutina*), Arizona walnut (*Juglans major*), and Siberian elm (*Ulmus pumila*) (Baker 1996). The remaining 25 acres represents transitional habitat between the riparian zone and upland habitats outside the boundaries. Dominant woody species include Siberian elm, Apache-plume (*Fallugia paradoxa*), cliffrose (*Purshia subintegra*), scrub oak (*Quercus turbinella*), California buckthorn (*Rhamnus californicus*), wax currant (*Ribes cereum*), and Arizona grape (*Vitis arizonica*). Common graminoid species include sedges (*Carex spp*.), bulrushes (*Scirpus spp.*), spikerush (*Eleocharis spp*.), rushes (*Juncus spp*.), grama grasses (*Bouteloua spp*.), cheatgrasses (*Bromus spp*.), meadow fescue (*Festuca* *arundinacea*), barnyard grass (*Echinochloa crus-galli*), and deergrass (*Muhlenbergia rigens*) (Baker 1996). The presence of flood debris here provides woody debris and wrack cover, which are important for small animals, including reptiles and amphibians, and small mammals (Nowak and Spille 2001).

Sampling Locations. To stratify habitats for sampling purposes, following Nowak and Spille (2001), we divided the preserve into four functional habitat types: riparian woodland, disturbed grassland, predominantly native grassland, and aquatic habitats (i.e. Granite Creek, permanent ponds, and ephemeral pools); for the current monitoring project we also added upland shrub habitat (dominated by cliffrose). One pitfall grid, and one pitfall array, each with associated coverboard and tin transects were located in woodland and grassland habitats when possible using the same sites originally sampled by Nowak and Spille (2001; Figure 49). Three sites (# 3, 5, and 6) were reused with almost no reconfiguration to the original trap layout; two sites (#1 and #2) were recreated using existing traps (trap placement was modified slightly from the original layout), and one site (#4) had to be entirely recreated near the original site when none of its traps could be relocated (Figure 50). Four coverboard transects were also reinstalled in their original locations (Nowak and Spille, 2001; Figure 50). Non-permanent sampling sites (visual encounter surveys, amphibian call surveys, minnow-trapping, and dipnetting, see below) were located throughout the Preserve to maximize coverage.

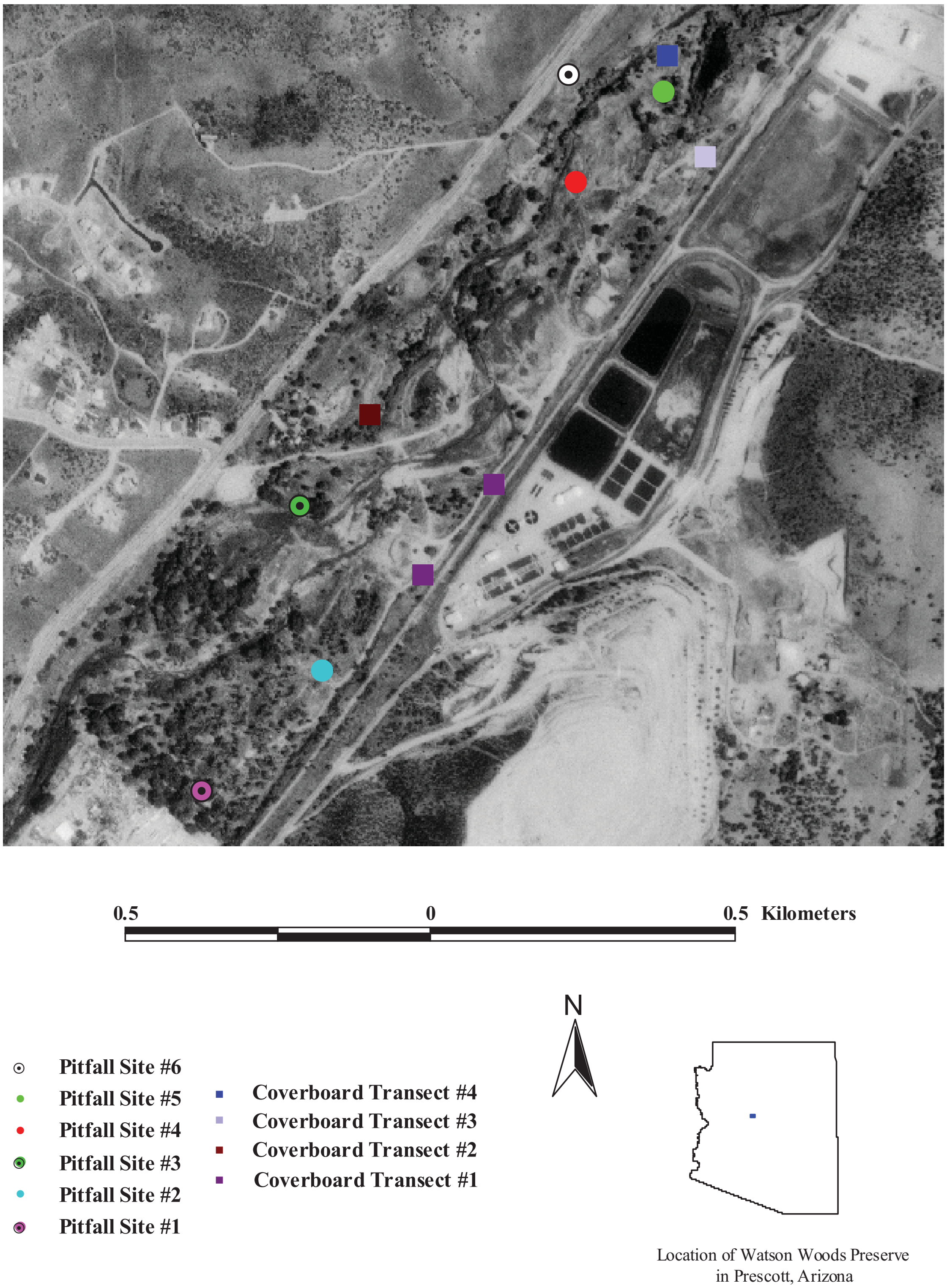


Figure 49-Original Sampling Site Locations

Figure 50-Trap Locations for Herpetological Monitoring (2009-2012)

Sampling Techniques. Sampling was typically conducted over a five day/four night period (a "sampling session"), with some shorter or longer trips. We replicated and added to the methods of Nowak and Spille (2001), to enable direct comparisons of faunal composition change, and also adaptively employ improved sampling methods. We used a combination of trap grids and arrays in conjunction with box funnel traps, coverboard transects, visual encounter surveys, amphibian call surveys, minnow-traps, and dipnetting in aquatic environments, to determine species occurrence and relative abundance (after Drost and Nowak 1997, Drost et al. 2001, Nowak and Persons 2010, Emmons and Nowak 2012). Trap locations, coverboard locations, and survey area perimeters were georecorded using a hand-held GPS unit in the NAD 83 Datum.

Permanent Pitfall Array and Grid Trapping Sites.– Pitfall arrays were the same basic design and layout as detailed in Nowak and Spille (2001), after Corn (1994). Each consisted of a "Y"-shaped fence of three 25 ft (7.6 m) long arms of 36 in (0.91 m) high ¼-in (0.63 cm) metal hardware cloth fencing (permeable hardware cloth was a modification from Nowak and Spille 2001 intended to improve durability), with a 5-gallon pitfall bucket sunk level with the ground surface at the ends and center of the arms, for a total of four buckets per site (Figure 51a). To allow for more captures of snakes, on either side of the end of each arm, we placed two ¼ in hardware cloth 59 x 39 x 23 cm box funnel traps (each with one 5–6 cm inner funnel opening), for a total of six traps per site (K.

Baker and C. Schwalbe, pers. comm.; detailed in Nowak and Persons 2010). The traps were shaded with large pieces of cardboard.

Each pitfall grid consisted of nine five-gallon plastic buckets sunk flush with the ground, each spaced seven meters apart (Figure 51b, Nowak and Spille 2001). Each bucket was covered with a 2 x 2 ft x ½ in (60 x 60 x 1 cm) plywood coverboard raised slightly off the ground. Each bucket had multiple holes punched in its bottom and sides to allow drainage.

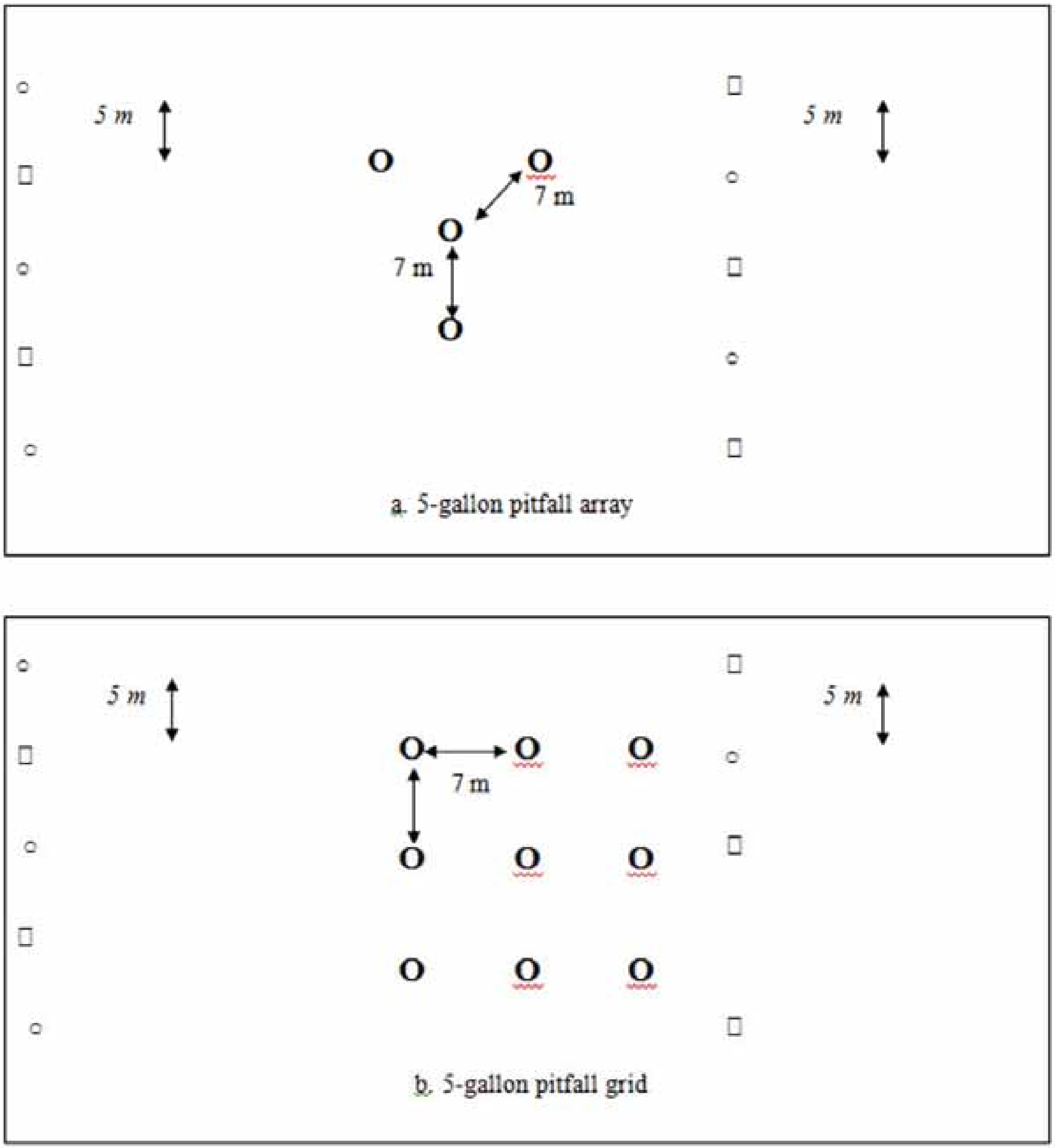


Figure 51-Diagram of Sampling Sites

Diagram of sampling sites for herpetofauna inventory and monitoring at Watson Woods Preserve during summer 2000, employing two pitfall and coverboard transects and two arrays. ***a****. Pitfall array.* ***b****. Pitfall grid. □ = 2 x 4 ft plywood coverboard; ○ = scrap tin cover:* ***O*** *= 5-gallon pitfall.*

In both pitfall and box traps, water and sponges or rocks were provided in shallow plastic bowls to prevent amphibian and rodent mortality, along with socks, small cardboard boxes, and/or cotton balls in box funnel traps to discourage rodent mortality and predation on trapped animals. During some seasons, we added sunflower seeds and peanuts to try to increase trapped rodent survival. In sites where Desert Shrews (*Notiosorex crawfordi*) were detected, we also provided small amounts of dried fish (whole or in chunks) to try to increase shrew survival.

Traps were typically open for four nights during each sampling session, and were checked daily in the morning, and occasionally again during the early evening. Pitfall traps were securely closed with snap-down lids, and box funnel traps were removed when not in use. At the end of the project, we filled all of the pitfall traps with rocks and sand to prevent future accidental mortality.

Coverboard Transects.– Fellers and Drost (1994) and Fitch (1987) describe the successful use of artificial cover for sampling reptiles and amphibians. Two coverboard and tin transects were recreated 15 m from the edge of each pitfall grid and arrary site (Figure 51a, Nowak and Spille 2001). Each transect contained five 2 x 4 ft x 3 in (60 x 122 x 2 cm) plywood boards and five corrugated roofing tin pieces (minimum dimensions of 2 x 2 ft or 60 x 60 cm), placed flush on the ground about 5 m apart, for a total of ten cover pieces per site. We checked the coverboards at least one time per sampling trip, in the morning or rarely, early evening, by flipping them up and attempting to catch animals sheltering underneath.

In addition to coverboard transects at the trap sites, we re-installed four separate 2 x 4 ft x 3/8 in plywood coverboard transects (Nowak and Spille 2001). Each of these transects consisted of five to six boards placed on the ground, with a gap underneath at least one edge of the board to encourage use by larger snakes. Boards were positioned in favorable microhabitats, with no set distance between them. The coverboard transects were also checked at least once per sampling trip, in the morning or early evening, as detailed previously. We plan to install rebar and tether each coverboard to these stakes to minimize movement and loss due to minor flooding.

Visual Encounter Surveys and Call Surveys.– We conducted two to four diurnal time constrained searches (a version of the visual encounter survey defined by Crump and Scott 1994) during sampling sessions. The four previously defined major habitat types were surveyed using an adaptive sampling regime to ensure coverage of all areas of the Preserve. Each survey consisted of one person walking systematically through a given habitat for one hour (½ hour with two or more surveyors), searching all reasonable areas within that habitat, and recording reptiles and amphibians encountered. These surveys were conducted between morning and late afternoon hours, seasonally adjusted to ensure coverage during periods of peak reptile activity.

Nocturnal amphibian call surveys or audio strip transects (Zimmerman 1994) were conducted during sampling sessions from late March to early June. These surveys consisted of one person walking systematically along Granite Creek (adjusted as above for the number of surveyors), starting near or after dusk and/or the permanent and temporary ponds, and recording the total number and species of amphibians heard calling or observed.

Dip Netting.– Dip netting was conducted in permanent and temporary ponds and in Granite Creek to sample for amphibian larvae and eggs at least every other week from April until August. Nets were 12 in (30 cm) x 16 in (40 cm), with a mesh size of 1000 microns, and a handle length of 48 in (122 cm) (Forestry Suppliers, Jackson, MS). Each dip netting session lasted one hour; unlike in Nowak and Spille (2001), we focused on netting in temporary pools.

Minnow traps.– During some sampling trips, ten to 20 standard Gee™ ¼ or ½-inch mesh minnow traps were placed in Granite Creek, or in permanent or temporary pools, with an emphasis on edges where snakes would normally travel, e.g. creek banks, next to fallen logs, and in emergent vegetation (Holycross et al. 2006, Emmons and Nowak 2012). Traps were tied to streamside structures, stakes, or vegetation to ensure a 3–4 in airspace above the water. Traps were checked and their contents emptied daily.

Animal Processing.– We identified all vertebrates trapped or detected to species, and when feasible, uniquely marked non-larval individuals captured in traps or by hand. Common and scientific names used in this report follow the nomenclature of Crother (2008). All methods of animal marking were approved by the Herpetological Animal Care and Use Committee of the American Society of Ichthyologists and Herpetologists (2004). We used toe-clipping (autonomy of the distal part of no more than one digit on each foot) to create permanent individual number combinations to identify lizards (Ferner 1979). Bullfrogs were also toe-clipped. For individual identification of snakes, we microbranded individuals on the subcaudal (tail) scales in unique patterns using a heat cautery pen (Winne et al. 2006). Microbrands can be read on snakes for at least four years and it cauterizes the mark, leaving no open wound (Ehmann 2000). We also attempted to use this method on juvenile and adult amphibians; while successful in producing a readable brand, we ultimately abandoned this method for amphibians due to apparent delays in healing, resulting in skin sloughing. For permanent identification of some larger (> 40 g) snakes, we also injected an 8-11 mm passive integrated transponder (PIT) tag into the ventral coelomic cavity in the posterior third of the body using field-sterile techniques (Gibbons and Andrews 2004); we sealed each injection site with veterinary skin glue. We uniquely marked small mammals with sufficiently large ears by tagging the base of one ear with a numbered metal tag using field-sterile techniques (after Rudran 1996). Smaller mammals and metamorphic toads were temporarily batch-marked or individually marked with a Sharpie™ or non-toxic paint pen (Nowak and Persons 2010). Fish and larval amphibians were not marked, and we did not capture and release any turtles.

Fecal (diet) and shed skin (genetic) samples were collected opportunistically from herpetofauna and have been stored in 95% ethanol for future analyses. Animals that died accidentally during trapping were collected if in good condition, and are being stored at Northern Arizona University.

The number of species or individuals captured was corrected for sampling effort and/or area per unit effort by dividing the number of individuals captured or number sighted by the total effort for that method. For pitfall and funnel traps, effort was measured as the number of trap-nights (i.e. number of traps X number of nights that the traps were open per sampling session); for coverboards, effort was quantified as board-nights (number of boards X number of times checked). For time-area constrained searches, dip netting, and amphibian call surveys, effort was calculated as the number of person-hours (number of surveyors X number of hours) for each method. We compared abundance (catch per unit effort and estimated population size) and species richness detected by different methods, to determine the best sampling methods for continued long-term monitoring of the herpetofauna at Watson Woods. Where possible, species presence, abundance, and richness at sampling sites were compared to expected values generated from Nowak and Spille (2001) to determine long-term trends.

Results and Discussion

Sampling Effort. We initiated herpetological monitoring after trap installation was completed in May 2009 and finished sampling in August 2012. Primary sampling trips were five days/four nights in duration during every year except 2010, when trips were four days/three nights; each year we also sampled during several additional one or two-day trips (e.g. to fix traps or conduct supplemental surveys). We conducted six primary sampling trips in 2009, nine in 2010, eight in 2011, and six in 2012.

We spent approximately 158 person-hours installing traps in 2009, and at least ten person-hours each year fixing traps and recovering or replacing coverboards. Once traps were set up, sampling effort varied between years (Table 31), largely based on availability of volunteers, with the most effort spent in 2011. Across survey methods, the most effort was spent checking permanent pitfall trap sites, and the least amount of time spent in dip-netting surveys (Table 31). Each coverboard at the permanent sampling sites was checked at least once per sampling session. We also employed methods adaptively: In 2011, we installed a drift fence in front of the reconstructed snake hibernation site near Rosser Street, and trapped at that site using box funnel traps. We also supervised removal of two likely shelter sites for amphibians and reptiles: a large wood slash pile in 2009, and a spoil pile (possible hibernation sites) in 2010. These monitoring projects were considered to be a type of diurnal visual encounter survey in data analyses.

Table 31-Annual Sampling Effort (2009-2012)

Effort is measured in trap-nights (# traps x # nights open) during sampling using pitfall, box funnel, and Gee minnow traps; and in person-hours (# of observer x # of hours) during amphibian call surveys, diurnal visual encounter surveys, and other types of visual monitoring. Each coverboard at the permanent sampling sites was checked at least once per sampling session. The number of estimated person-hours spent checking traps is also given for perspective. Box funnel traps are divided into sites with fences (pitfall arrays and at an artificial hibernaculum) and those set along natural cover ("supplemental" sites). The number of each type of visual monitoring survey is also given.

Survey Method	Year				
	2009	**2010**	**2011**	**2012**	**Total**
Trap-nights					
Pitfall Traps	906	972	1278	779	3935
Minnow Traps	160	277	600	220	1257
Box Funnel Traps – pitfall arrays	197	234	294	172	897
– hibernaculum	0	0	70	84	154
– supplemental	63	8	0	12	83
Person-hours					
Trap-checking	170.75	151.98	308.90	286.85	918.48
Amphibian Call Surveys	5 (5 surveys)	6 (5 surveys)	10 (10 surveys)	3.5 (2 surveys)	24.5
Diurnal Visual Encounter Surveys	26 (16 surveys)	11.80 (10 surveys)	26 (21 surveys)	20.95 (18 surveys)	84.75
Monitoring	4.5 (woodpile removal)	17.42 (3 spoil pile removal pre-surveys)	0	0	21.92
Dip-Netting	120 (2 surveys)	0	0	0	2

We employed the same methods used by Nowak and Spille (2001); however, funnel trap design was improved, and more captures of all taxa were made as a result. We discontinued dip-netting surveys after spring 2009 in favor of using Gee minnow traps, a method that is arguably more standardized and less subject to observer bias.

Species Detections. We detected 19 reptile and amphibian species in the Watson Woods during the monitoring period (Table 32). We found two turtle species (Spiny Softshell and Red-eared [Pond] Slider), one lizard species (Greater Short-horned Lizard), and three snake species (Western Groundsnake, Black-necked Gartersnake, and Black-tailed Rattlesnake) that were not previously detected in Watson Woods by Nowak and Spille (2001). American Bullfrogs were the most commonly-encountered amphibians, followed by Eastern Tiger Salamanders, and Southwestern Toads were the least commonly detected amphibians. We found at least five subadults and one adult toad that appeared to be hybrids between Woodhouse's and Southwestern Toads. Plateau Fence Lizards were the most common lizard species detected, and Greater Short-horned Lizards were the least commonly detected. Wandering (Western Terrestrial) Gartersnakes were the most common snake species encountered, and Black-tailed Rattlesnake was only documented once.

Table 32-Reptile and Amphibian Species (2009-2012)

Numbers of overall detections are given; these may include multiple detections of the same individuals. Species not detected by Nowak and Spille (2001) are in bold; non-native species are in red font. Nomenclature generally follows Crother (2008). Animals not identified to species are not included, including many juvenile/larval toads and lizards.

TAXA		Number of Detections
Salamanders		
Eastern Tiger Salamander	*Ambystoma tigrinum*	2077 (many larvae)
Frogs and Toads		
American Bullfrog	*Lithobates catesbeiana*	2401 (many larvae)
Woodhouse's Toad	*Anaxyrus woodhousii*	447
Southwestern Toad	*Anaxyrus microscaphus*	18
Turtles		
Spiny Softshell	***Apalone spinifera***	**1**[a]
Red-eared [Pond] Slider	***Trachemys scripta elegans***	**3**
Lizards		
Plateau Fence Lizard	*Sceloporus tristichus*	1936
Ornate Tree Lizard	*Urosaurus ornatus*	94
Greater Short-horned Lizard	***Phrynosoma hernandesi***	4
Madrean Alligator Lizard	*Elgaria kingii*	21
Gila Spotted Whiptail	*Aspidoscelis flagellicauda*	24
Plateau Striped Whiptail	*Aspidoscelis velox/innotatus*	277
Desert Grassland Whiptail	*Aspidoscelis uniparens*	260
Snakes		
Wandering [Western Terrestrial] Gartersnake	*Thamnophis elegans vagrans*	55
Black-necked Gartersnake	***Thamnophis cyrtopsis***	2
Western Groundsnake	***Sonora semiannulata***	2
Common Kingsnake	*Lampropeltis getula*	44
Gopher Snake	*Pituophis catenifer*	5
Black-tailed Rattlesnake	***Crotalus molossus***	1[b]

[a]Photographed by Jason Beyer, Watson Woods Field Projects Coordinator.
[b]Found by Robert Bowker, volunteer from Glendale Community College.

Patterns of detection for species during this project and those found in 2000 (Nowak and Spille 2001) remained the same for amphibians (American Bullfrogs were the most commonly detected species, and Southwestern Toads were least commonly detected), and also for snakes (Western Terrestrial Gartersnakes were the most commonly detected species and Gopher Snakes were least commonly detected). Within lizards, Plateau Fence Lizards remained the most common species by far, but in the current study Madrean Alligator Lizards were the least commonly-detected species, while in 2000 Gila Spotted Whiptail was the least commonly detected species. During the current project, we did not detect Striped Whipsnake (*Coluber taeniatus*), a species found at Watson Woods in 2000 (Nowak and Spille 2001).

Detection Rates Among Years. Although each survey method (e.g. pitfall, box, and minnow traps and visual encounter surveys) was used each year, species detections were not constant among the years (Table 33), likely due to species-specific method effectiveness as well as differing environmental conditions among years. While monsoon precipitation was relatively constant across the monitoring period, total winter/spring precipitation (November to April) varied from a high of 12.85 in (32.64 cm) in 2009-2010 to a low of 6.95 in (17.65 cm) in 2011-2012; 2008-2009 had 8.26 in (20.98 cm) and 2010-2011 had 7.91 in (20.09 cm); Western Regional Climate Center 2012). Despite conducting the most nocturnal amphibian call surveys in 2011 of any year during the project, comparatively fewer toads, and almost no toad tadpoles, were detected during that year. This observation may be due to Granite Creek being more ephemeral that year as a result of comparatively less precipitation during the preceding winter and drier spring conditions compared to the two previous years. This weather pattern may have resulted in the decreased availability of persistent shallow pools favored by toads for breeding. Conversely, that year had among the highest rates of detection for Tiger Salamanders and American Bullfrogs. These species breed in deeper water and during times of the year (early spring for salamanders and later summer for bullfrogs) that may increase the hydroperiod and enable their breeding habitats to be less susceptible to rapid drying. The lowest total winter/spring precipitation was observed preceding the 2012 breeding season, and we again noticed a general lack of persistence of suitable breeding pools in Granite Creek. Although toad detections were higher in 2012 compared to 2011, in 2012 most of the tadpoles were concentrated in a few pools in the north end of Reach 1 and the south end of Reach 2, and only three toad metamorphs were found.

Lizard and snake detections were generally lower in 2012 compared to previous years (Table 31). It is possible that two successive winters of comparatively low precipitation resulted in lower hatching success and survival of neonate lizards for common species. There were fewer detections of Madrean Alligator Lizards in 2011 and 2012 compared to 2009 and 2010; it is possible that drier conditions caused these animals to be less active closer to the surface and therefore decreased their detectability to surveyors. Overall trends in this species are hard to determine given the low number of detections.

Table 33-Reptile and Amphibian Species Detected Annually (2009-2012)

Numbers of overall detections are given; these may include multiple detections of the same individuals. Excluding toad tadpoles, which are either Woodhouse's or Southwestern toads, animals not identified to species are not included.

	2009	2010	2011	2012
Amphibians				
Eastern Tiger Salamander	91	762	637	587
American Bullfrog	1032	127	1133	109
Woodhouse's Toad	277	80	22	68
Southwestern Toad	5	8	5	0
Unidentified Toad Tadpoles and Metamorphs	2853	3436	21	1075
Turtles				
Spiny Softshell	1	0	0	0
Red-eared Slider	3	0	0	0
Lizards				
Plateau Fence Lizard	586	464	504	382
Ornate Tree Lizard	45	19	17	13
Greater Short-horned Lizard	0	0	2	2
Madrean Alligator Lizard	6	9	4	1
Gila Spotted Whiptail	8	9	4	3
Plateau Striped Whiptail	88	71	75	43
Desert Grassland Whiptail	78	90	40	52
Snakes				
Wandering Gartersnake	13	7	20	15
Black-necked Gartersnake	0	1	0	1
Western Groundsnake	2	0	0	0
Common Kingsnake	32*	6	5	1
Gopher Snake	2	1	2	0
Black-tailed Rattlesnake	0	0	0	1

Comparison of Methods. The different methods we used were not equally likely to detect all taxa (Tables 34 and 35). Common diurnal lizards (e.g. Plateau Fence Lizard, Desert Grassland Whiptail, and Plateau Striped Whiptail) were detected by almost all terrestrial methods, whereas rare turtle and snake species (Red-eared Slider, Spiny Softshell, Black-tailed Rattlesnake), were commonly detected outside of dedicated surveys (e.g. by "Random Encounters"). Spiny Softshell and Black-tailed Rattlesnake were detected by volunteers. Opportunistic detection of rare species illustrates the importance of simply putting in time at the Preserve (see also Nowak and Persons, 2010), and of working with keen-eyed observers who carefully record their observations.

Traps.– Pitfall traps were most effective in capturing diurnal small-bodied lizards, particularly Plateau Fence Lizards (1.10 lizards/trap night; Table 34). They also captured amphibians, especially Woodhouse's Toad (0.34 toads/trap-night), and the occasional small snake. In general, pitfall traps were least effective in trapping snakes. Six snakes were found in pitfall traps, including four in pitfalls at grid sites (Groundsnake and Common Kingsnake), and two in pitfalls at array sites (Common Kingsnake and Gopher Snake). The Gopher Snake was apparently waiting for a White-throated Woodrat (*Neotoma albigula*) that had taken up shelter under the 2' x 2' board covering the trap; when the cover was lifted, the rodent jumped into the trap, literally into the waiting jaws of the snake (C. Loughran, pers. obs.).

Table 34-Reptile and Amphibian Species found (2009-2012)

Reptile and amphibian species found by different survey types during herpetological monitoring at Watson Woods Preserve, Prescott, Arizona between 2009 and 2012. Detections during amphibian call surveys and diurnal visual encounter surveys (VES) are corrected by person-hours of survey effort, while the number found in traps is corrected by trap-nights (see Methods Section). For ease of comparison among methods, we have used detection rates; some individuals were likely counted more than once.

	Pitfall Traps	Minnow Traps	Box Funnel Traps at pitfall arrays	Box Funnel Traps at hibernaculum	Box Funnel Traps – supplemental	Amphibian Call Surveys	Diurnal VES
Amphibians							
Eastern Tiger Salamander	0.008	3.80	0	0.014	0.016	0	0
American Bullfrog	0.12	4.65	0.012	0	0	1.45	37.70
Woodhouse's Toad	0.338	0	0.149	0.011	0.016	5.29	3.109
Southwestern Toad	0.007	0	0.004	0	0	1.13	0.034
Toad tadpoles and metamorphs	0.037	0.023	0.004	0	0	33.53	254.37
Turtles							
Spiny Softshell	0	0	0	0	0	0	0.065
Red-eared Slider	0	0	0	0	0	0	
Lizards							
Plateau Fence Lizard	1.10	0	0.642	0.4809	0.8273	0	7.0929
Ornate Tree Lizard	0.012	0	0.013	0	0.10	0	2.538
Greater Short-horned Lizard	0	0	0	0	0	0	0
Madrean Alligator Lizard	0.001	0	0.004	0	0	0	0.082
Gila Spotted Whiptail	0.018	0	0.011	0	0	0	0.101
Plateau Striped Whiptail	0.1407	0	0.1667	0.026	0.0634	0	3.1566
Desert Grassland Whiptail	0.139	0	0.1447	0.0119	0.111	0	2.817

Table 34 Continued

	Pitfall Traps	Minnow Traps	Box Funnel Traps – pitfall arrays	Box Funnel Traps – hibernaculum	Box Funnel Traps – supplemental	Amphibian Call Surveys	Diurnal Visual Encounter Surveys
Snakes							
Wandering Gartersnake	0	0.0679	0.009	0	0.0158	0	0.365
Black-necked Gartersnake	0	0	0.0011	0	0	0	0
Western Groundsnake	0.001	0	0	0	0	0	0
Common Kingsnake	0.004	0	0.018	0	0	0	0
Gopher Snake	0	0	0.005	0	0	0	0.032
Black-tailed Rattlesnake	0	0	0	0	0	0	0

Several animals were captured as they traveled along drift fences at array sites and at the artificial snake den (Table 35), including rarely-seen species (e.g. Southwestern Toad and Greater Short-horned Lizard). This method of detection again illustrates the importance of detections made simply as a function of time spent in the field, as well as the importance of careful observing.

Box traps placed in conjunction with drift fences captured the highest diversity of herpetofauna of all the trapping methods (Table 34). They were the most effective trapping method for detecting actively-foraging reptiles, including whiptail lizards and snakes. Box traps were the best overall method for detecting snakes, capturing four of the six species seen, including the only two Black-necked Gartersnakes found at Watson Woods. It is likely that snakes went into box traps partly because they were following the scent trails of smaller prey animals (lizards, mammals, and amphibians) captured within them. Unfortunately, no snakes were captured in box traps at the artificial snake hibernaculum; however, this site did produce four species of lizards and two amphibian species (Tables 34 and 35); suggesting the site may be used by other herpetofauna. Box traps placed away from trap sites using natural cover (e.g. downed logs) did not detect a high diversity of species, but did produce relatively high numbers of species per unit effort, including the highest number of Ornate Tree Lizards (0.10 per trap-night) of any trapping method.

Coverboards were also effective in detecting all taxa, especially lizards (Table 35). The square coverboards covering pitfall traps (2’ x 2’) were most effective in detecting lizards, especially Plateau Fence Lizards (165 captures); based on the high recapture rates for this species tied to individual pitfall traps (see below), it is likely that the lizards set up territories around these coverboards. Similarly, several alligator lizards were recaptured under certain tin or 2’ x 4’ coverboards; these covers were the most effective method of detecting this species in Watson Woods, and it is likely the lizards selected these boards and tin as part of the important cover in their home ranges. As seen in previous Arizona herpetological inventories (e.g. Drost et al. 1999, Nowak and Spille 2001, Nowak and Persons 2010), larger covers (2’ x 4’) detected a higher diversity of herpetofauna compared to the smaller 2’ x 2’ coverboards (Table 35), especially snakes. Wandering Gartersnakes were the snake species most commonly detected under these boards (nine detections). As reported by Nowak and Spille (2001), despite predictions of success (largely based on anecdotal observations from the eastern US), tin covers were not particularly effective in detecting herpetofauna compared to the wood coverboards (Table 35). This result is likely due to the tin covers becoming hot and supporting drier under-board microclimates compared to the boards. It is surprising that tin covers occasionally harbored amphibians; these were likely opportunistically sheltering overnight before moving to other locations.

Table 35-Reptile and Amphibian Species Found (2009-2012)

Reptile and amphibian species found by different non time-recorded survey types during herpetological monitoring at Watson Woods Preserve, Prescott, Arizona between 2009 and 2012. For ease of comparison among methods, we have used detection rates; some individuals were likely counted more than once.

	2 x 2 Cover-board	2 x 4 Cover-board	Tin Cover-board	Hand Capture at Drift Fence	Hand Capture at Pitfall Sites & Minnow Traps	Random Encounter
Amphibians						
Eastern Tiger Salamander	0	0	0	0	0	0
American Bullfrog	0	0	0	0	0	5
Woodhouse's Toad	10	8	15	0	5	14
Southwestern Toad	0	0	0	1	0	0
Toad tadpoles & metamorphs	2	0	0	0	2	3
Turtles						
Spiny Softshell	0	0	0	0	0	1
Red-eared Slider	0	0	0	0	0	1
Lizards						
Plateau Fence Lizard	165	193	106	3	2	3
Ornate Tree Lizard	0	4	0	1	1	1
Greater Short-horned Lizard	0	0	0	1	3	0
Madrean Alligator Lizard	0	6	7	0	1	2
Gila Spotted Whiptail	1	0	0	0	0	1
Plateau Striped Whiptail	3	4	2	1	0	2
Desert Grassland Whiptail	3	4	2	1	0	0
Snakes						
Wandering Gartersnake	0	9	0	0	4	13
Black-necked Gartersnake	0	0	0	0	0	0
Western Groundsnake	0	0	0	0	0	1
Common Kingsnake	1	1	1	0	0	31*
Gopher Snake	0	0	0	0	1	2
Black-tailed Rattlesnake	0	0	0	0	0	1

*An estimated 25 individuals were detected by other observers during an excavation near Rosser St in March 2009 (M. Byrd, pers.comm)

When pitfall grid and pitfall array sites were compared with coverboard transects, likely due to the addition of box funnel traps and hardware cloth drift fences, pitfall arrays detected a greater diversity of taxa and species compared to pitfall grids (Figure 52). Overall numbers of individuals were generally higher in arrays compared to grids as well. Coverboard transects were most effective in detecting lizards, especially Plateau Fence Lizards, and Wandering Gartersnakes (Figure 52). Turtles and Black-necked Gartersnake were not detected by these methods.

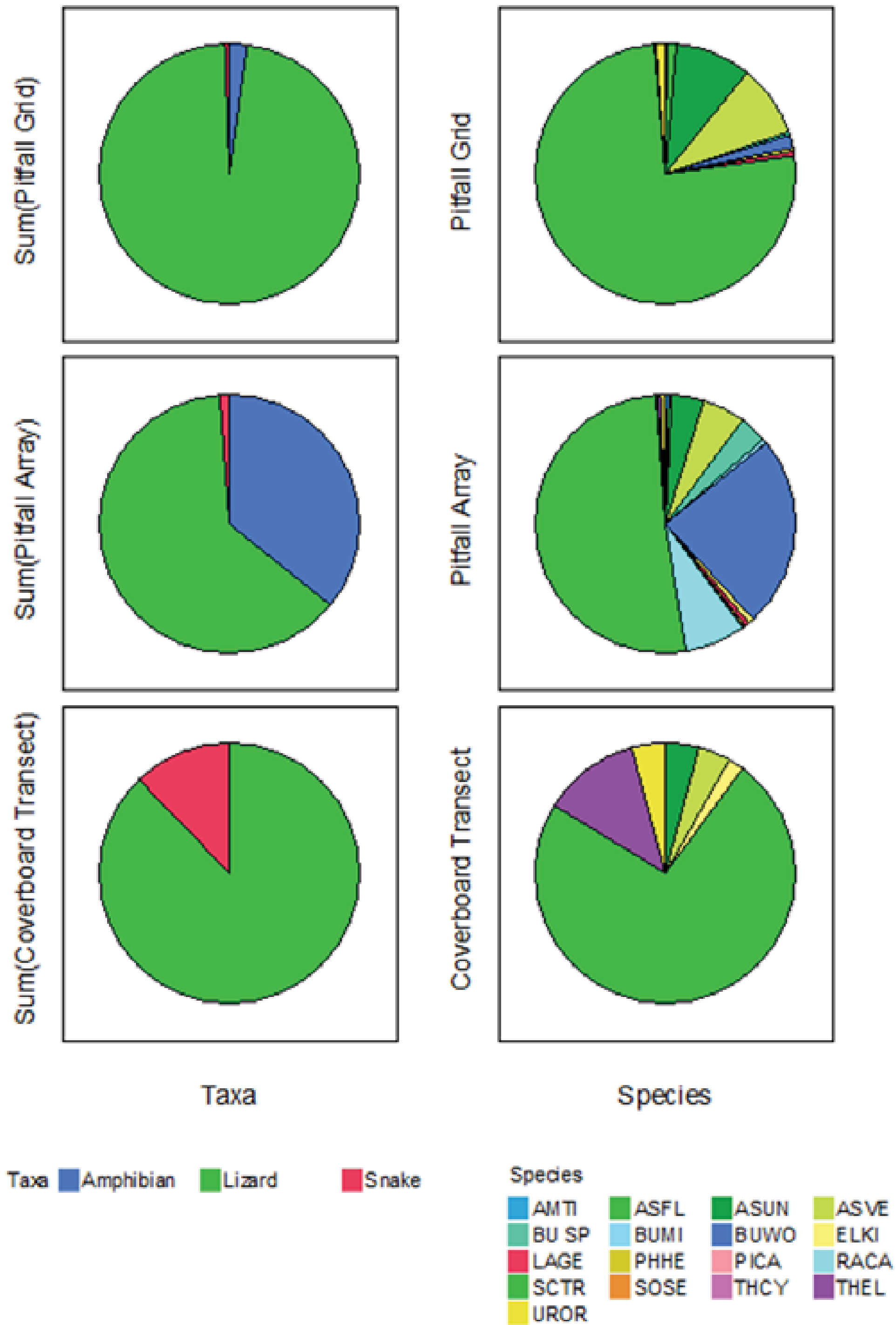


Figure 52-Summary of Number of Detections of Each Taxa

Summary of the number of detections of each taxa (amphibians, lizards, and snakes; left) and relative detections of each species trapped by pitfall grids (top), pitfall arrays (middle), and stand-alone coverboard transects (bottom) during herpetological monitoring at Watson Woods Preserve, Prescott, Arizona between 2009 and 2012

Active Surveying and Visual Encounter Methods.– Dip-netting was very effective in producing Tiger Salamanders (43.5 detections per person-hour of surveys), and also resulted in detection of one American Bullfrog per person-hour. However, sweeping through temporary pools with a net may disrupt the benthic habitat, and was also time-intensive. We discontinued this method in favor of using minnow traps, which were the most effective method in detecting Tiger Salamanders outside of dip-netting (3.8 animals detected per trap-night), and also produced

Wandering Gartersnakes (0.07 snakes/trap-night), American bullfrogs (4.65 tadpoles/trap-night) and toad tadpoles (0.02 tadpoles/trap-night).

Amphibian call surveys detected all frog and toad species present at the Preserve (although not every species was detected every year, see Table 33), and were critical for determining breeding locations of toads, both through auditory detections and visual observations of tadpoles. Not unexpectedly, no lizards were found during these nocturnal surveys; also no snakes were detected, likely because a majority of the surveys were conducted during the spring when nights were too cold to encourage snake activity.

Although diurnal visual encounter surveys were arguably the most susceptible to observer bias among the methods we used, they were also useful in detecting a diversity of species. During diurnal visual encounter surveys, we detected all four amphibian species, one of the two turtle species, six of seven lizard species, and two of six snake species. This was the most successful method in producing toad tadpoles. Visual encounter surveys also produced high numbers of whiptail lizards, but differentiation between Desert Grassland and Plateau Striped Whiptails, particularly juveniles, was often difficult: 69 whiptails found during these surveys could not be identified to species. Although observers were wide-ranging during these surveys, we did not encounter many snakes.

Comparison of Animals Detected Among Habitats. As we previously defined the habitats at Watson Woods, there is now considerable overlap between the disturbed and native grassland habitats, especially in floodplain areas affected both by restoration treatments and flooding events. As well, there are some examples of small-scale habitat type conversions; i.e. some areas have changed from open grassland or weedy habitats to primarily riparian woodland, and other previously-defined native grassland sites have been invaded by non-native species (e.g. the southwest corner of Watson Woods). Stochastic events are also important: one pitfall grid site (Site #1) was situated in a cottonwood gallery forest patch during 2000 surveys; in the intervening years this site has burned twice and now is characterized by dead and downed cottonwoods and some live elms.

In terrestrial habitats, the highest number of detections of herpetofauna occurred in riparian woodland (Table 35). The most species were found in woodland and disturbed grassland habitats (14 species each). The lowest number of detections and the fewest species were in upland habitats; this is not surprising given the relative paucity of this habitat type in Watson Woods. We found rare species in each terrestrial habitat (e.g. Black-tailed Rattlesnake in riparian woodland; Groundsnake in upland shrub and native grassland habitats, and Red-eared Slider in disturbed grassland). Importantly, Greater Short-horned Lizard was found only in native grassland habitats (and only at one site). This species is a sit-and-wait predator that forages in open habitats with ant colonies (Brennan and Holycross 2006), thus open native grassland and shrub upland are likely the most suitable habitats available to this species at Watson Woods.

In aquatic habitats, most animal detections and the most species occurred in Granite Creek, a number in part driven up by the detections of high numbers of toad tadpoles (Table 36); however, Granite Creek comprises the majority of permanent aquatic habitat in Watson Woods. Woodhouse Toads bred primarily in Granite Creek (all reaches, including historic channels, which in some years held water in pools longer than the restored channel), but also in the permanent pond and in semi-permanent ponds (Figure 53). Southwestern Toads bred only in Granite Creek, mostly in Reaches 2 and 4 (Figure 53). The fewest detections and species occurred in the temporary and semi-permanent pools; these areas were typically wet in the early spring but dry by mid-summer. These areas, particularly two semi-permanent ponds (one in Reach 2 and one in Reach 4), were critical breeding habitat for Tiger Salamanders (Figure 53). The permanent pond had intermediate numbers of detections and species compared to the other habitats; however, this habitat type has outsized importance in fostering herpetological species diversity in Watson Woods given the very small area it occupies. Even though non-native herpetofauna species breed in the pond, including American Bullfrog and possibly Red-eared Slider, the pond is also used by native Tiger Salamander and Woodhouse Toad (Figure 53).

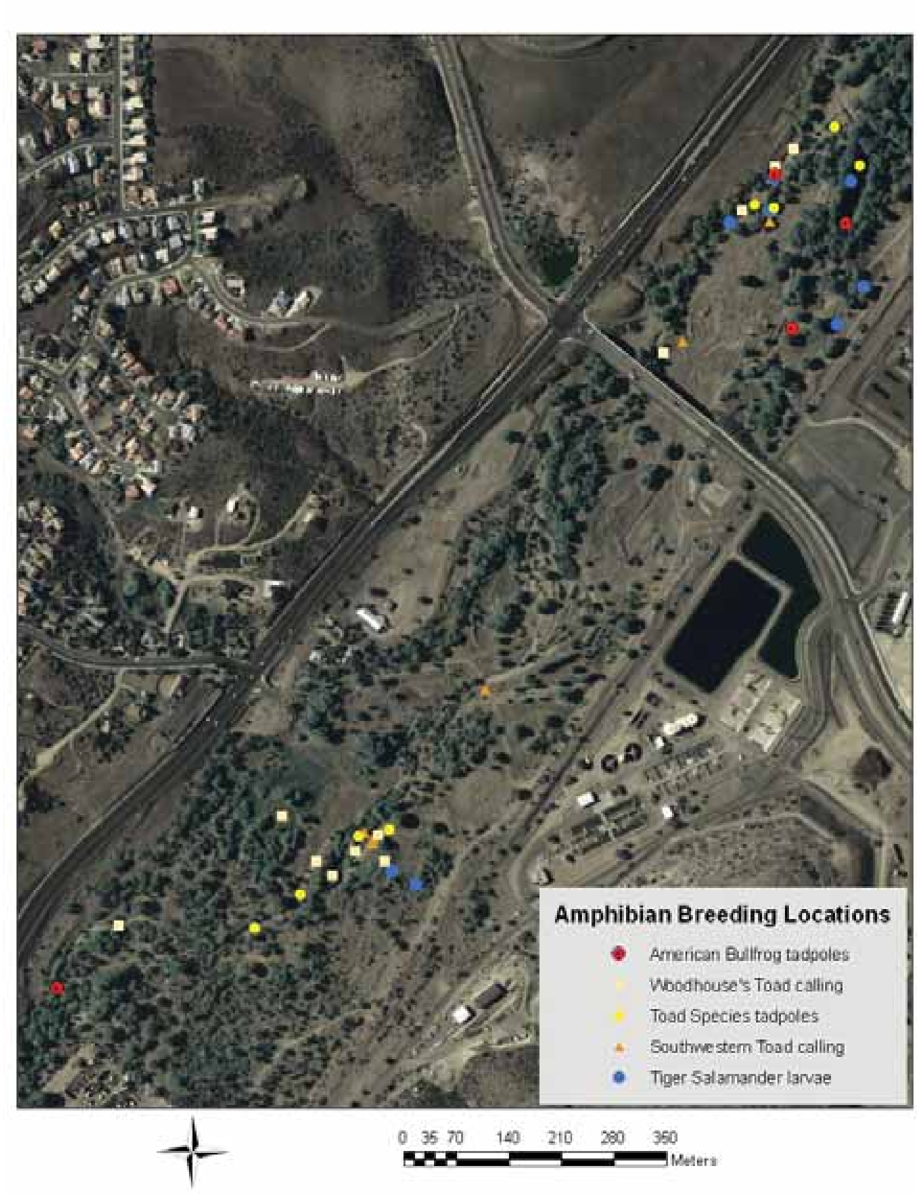


Figure 53-Location of primary amphibian breeding areas

Location of primary amphibian breeding areas during herpetological monitoring at Watson Woods Preserve, Prescott, Arizona, during 2009-2012. Species include: Tiger Salamander (larvae detections; blue circles); Southwestern Toad (calling males; orange triangles), Woodhouse's Toads (calling males; peach boxes); and American Bullfrog (tadpoles; red bulls-eye circles). Also shown are locations of toad tadpoles (Southwestern or Woodhouse's Toad; yellow circles); these were not identified to species. For ease of interpretation purposes, multiple detections of a given species in a single creek area or pond are represented by one point.

Species-Habitat Trends.– The results from monitoring during 2009-2012 are generally similar to the initial inventory conducted during 2000 (Nowak and Spille 2001), particularly in aquatic habitats (Table 36). During 2000 in terrestrial habitats, the highest number of animal detections occurred in disturbed grasslands, but the most species were detected in riparian woodlands; the lowest number of animal detections occurred in native grasslands, with the fewest species tied between the grassland types. In aquatic habitats during both survey periods, the highest number of detections and the most species occurred in Granite Creek. The lowest number of detections occurred in temporary ponds during both periods, but in 2000 the fewest species were found in the permanent pond.

Table 36-Comparison of total number of detections and species captured.
Comparison of total number of detections and species captured in different pre-defined habitat types during a herpetological inventory at Watson Woods Preserve, Prescott, Arizona, in 2000 (Nowak and Spille 2001) and during monitoring between 2009-2012. All methods are included, as are unidentified whiptail species and toad toadpoles; thus the number of species is a minimum estimate. In 2000, "Native Grassland" likely included captures made in "Upland Shrub" habitats. Aquatic habitats include animals seen on shore but in close proximity to water during aquatic habitat surveys.

HABITAT	Total Individuals		Total Species	
	2000	2009-2012	2000	2009-2012
Riparian Woodland	139	2236	10	14
Upland Shrub	–	766	–	11
Native Grassland	151	1083	8	13
Disturbed Grassland	153	916	8	14
Temporary and Semi-permanent Pond	40	2344	5	7
Permanent Pond	141	4728	4	9
Granite Creek	1722	5632	8	10

It is likely that the overall patterns of species abundance and diversity through time reflect both historic and contemporary vegetation restoration at Watson Woods, as well as ongoing natural habitat conversion and succession. Overall increases in species diversity are likely due in large part to more intensive survey efforts in 2009-2012 compared to 2012. At the same time, Preserve management (e.g. Byrd et al. 1996) and natural succession are fostering maturation and additional development of extensive areas of riparian woodlands. This habitat has the most structural complexity relative to other available habitat types, so it is not surprising that herpetofauna diversity remains high and has increased in this habitat. Increases in species diversity overall in aquatic systems are partly due to non-native turtles; it is unclear whether these species have permanently colonized Watson Woods, or were only passing through. The detection of both common and rare species in native and disturbed grasslands illustrates the importance of retaining a variety of habitat types within Watson Woods in encouraging high levels of biodiversity.

Recapture Rates. Individuals in 11 out of the 19 species found at Watson Woods were captured more than once, almost exclusively at trap sites; these include: American Bullfrog (n = 3 individuals); Woodhouse's Toad (n = 17); Southwestern Toad (n = 1); Plateau Fence Lizard (n = 415); Ornate Tree Lizard (n = 2); Greater Short-horned Lizard (n = 1); Madrean Alligator Lizard (n = 3); Gila Spotted Lizard (n = 3); Plateau Striped Whiptail (n = 27); Desert Grassland Whiptail (n = 40); and Wandering Gartersnake (n = 3). As some Plateau Fence lizards lost one or more digits after initial marking and we had difficulty finding a non-injurious method of marking toads, recapture rates for those species are estimates.

The most commonly-trapped lizard species were also the most likely to have recaptured individuals; especially Plateau Fence lizards, which likely set up territories around trap coverboards. Snakes were almost never recaptured; this seems surprising given the number of Common Kingsnakes we detected and the detection of an apparent hibernaculum for this species at Watson Woods. Data for most species was insufficient for population-level analysis; however, we will examine population parameters and body condition for Plateau Fence Lizards, Desert Grassland Whiptails, and Plateau Striped Whiptails separately.

Amphibian Breeding Phenology. Adult Tiger Salamanders were found in trap sites in mid-March and in early April in 2011. We detected larval Tiger Salamanders in temporary and semi-permanent ponds by mid-April or early May during every year of monitoring. Larva were seen in breeding pools as late as mid-July (2010) and in Granite Creek until the end of August (2011); juvenile terrestrial forms were found in traps away from breeding sites by mid-August (2009).

American Bullfrogs were heard calling in Granite Creek as early as mid-May (2009), and calling lasted through the summer during all years. Tadpoles were first detected in the permanent pond in mid-June (2009, 2010); some of these were likely first-year animals (i.e. < 2 cm – Snout-VentLength- SVL), and others (generally > 3 cm SVL) were beginning to transform; the latter likely overwintered (e.g. Brennan and Holycross 2006). First-year tadpoles were commonly detected in the permanent pond by late August during all years, and recently-transformed dispersing metamorphs were found in traps in late August (2012) through early September (2011).

Woodhouse's Toads were heard calling by late April to early May during every year; the latest we recorded calling was May 3 (2010). Southwestern Toads had a similar but possibly shorter calling period, with the first detections made on April 20, and the last being May 4 (2010). Toad tadpoles were detected beginning in mid-May and lasting through mid-June during all years, with the latest detections made in late August (2011).The first terrestrial forms were detected in early June (2012), but the typical metamorph dispersal period was from mid-July to mid-August during all years, with a few individuals still transforming and dispersing in early September (2012).

Questionable Species and Species Not Detected. During one survey in March 2009 along Granite Creek (Reach 2), we observed about 150 tadpoles foraging in riffles in the center of the creek and apparently feeding on algae-covered rocks. This behavior was different from the majority of toad tadpoles seen at Watson Woods, which tend to congregate in the silty-bottom shallows along the edge of the creek. These tadpoles also had a slightly different appearance compared to Woodhouse's Toad tadpoles (e.g. more speckled pattern, eyes on the top of the head), and it is possible they were either Southwestern Toads (as males of this species were observed calling in riffles in Granite Creek), or possibly Canyon Treefrogs (*Hyla arenicolor*). Positive identification of tadpoles at this stage cannot be made without preserving the animals and examining their mouthparts under a microscope; given the sensitive nature of Southwestern Toads, we did not pursue this option. No Canyon Treefrogs have been observed in Watson Woods, but the species was observed in the neighborhood just west of SR-89 in 2011 (Jay Crocker, pers. comm.).

Russell Fosha (Prescott Creeks Board Member and volunteer) possibly saw an Arizona Black rattlesnake (*Crotalus cerberus*) in the Preserve in late May 2009 near monitoring well #3. While identification may be confused with Black-tailed Rattlesnake in some cases, this species has also been likely detected near Watson Woods on the Peavine Trail near Watson Lake (R. Fosha and other visitors, pers. comm.). It seems possible that the species could yet be confirmed in Watson Woods.

We confirmed several reptile and amphibian species predicted by Nowak and Spille (2001) to occur in Watson Woods, including one species (Greater Short-horned Lizard) which they predicted was locally extirpated. We also found two species of non-native turtles not expected to be present. Additional species documented from the area and/or which historically occurred remain to be confirmed at Watson Woods. These include New Mexico Spadefoot (*Spea multiplicata*), Great Plains Toad (*Anyraxus cognatus*), Gilbert Skink (*Plestiodon gilberti*), Great Plains Skink (*P. obsoletus*), Lesser Earless Lizard (*Holbrookia maculata*), Eastern Collared Lizard (*Crotaphytus collaris*), Coachwhip (*Coluber flagellum*), long-nosed snake (*Rhinocheilus lecontei*), and Sonoran Mountain Kingsnake (*Lampropeltis pyromelana*). Sonora mud turtle (*Kinosternon sonoriense*) likely occurs in areas of Granite Creek with permanent pools, so it is likely that the species will enter Watson Woods during a period of continuous flow.

Non-target Species Detections. *Vertebrates.–* We trapped and detected additional small and large vertebrates during our surveys, including at least nine small mammal species and four larger mammals (Table 36). Nine small mammal species were trapped (Table 37), primarily in pitfall traps and box traps. Many rodents also created nests, stored food, and raised young under coverboards. The most common small mammal species captured was White-footed Deer Mouse (we did not differentiate between *Peromyscus maniculatus* and *P. leucopus*). We hosted an overnight small mammal trapping session led by Northern Arizona University Mammalogist Tad Theimer in 2011, during which Dr. Theimer confirmed that despite previous misidentifications, the most likely only *Peromyscus* spp. present at the Preserve are *P. maniculatus* and *P. leucopus*. The rarest species trapped was Apache Pocket Mouse (*Perognathus apache*).

Table 37-Non-Target Vertebrate Species Detected (2009-2012)

Non-target vertebrate species detected during herpetological monitoring at Watson Woods Preserve, Prescott, Arizona, during 2009-2012. Number detected is the minimum number of animals identified and recorded during surveys; some fish species were not identified, and Bluegill may include a few specimens of Green Sunfish (Lepomis cyanellus). Some species were only recorded through tracks, scat (e.g. Elk), or nests (White-throated Woodrat). The primary method of detection for each survey (excluding random encounters) is also given. Non-native species are shown in red font.

SPECIES	Latin Name	Number Detected	Primary Methods of Detection
Mammals			
White-footed Mouse	*Peromyscus maniculatus/leucopus*	413	All traps and coverboards
White-throated Woodrat	*Neotoma albigula*	28, nests	All methods
Western Harvest Mouse	*Reithrodontomys megalotis*	68	All traps and coverboards
Botta's Pocket Gopher	*Thomomys bottae*	8	Pitfall traps, coverboards
Silky Pocket Mouse	*Perognathus flavus*	42	Pitfall traps, box traps
Apache Pocket Mouse	*Perognathus apache*	1	Pitfall trap
House Mouse	*Mus musculus*	5	All traps and coverboards
Mexican Vole	*Microtus mexicanus*	71	All traps and coverboards
Desert Shrew	*Notiosorex crawfordi*	27	All traps and coverboards
Cottontail Rabbit	*Sylvilagus* spp.	10, scat	All visual encounter methods
Mule Deer	*Odocoileus hemoinus*	2, tracks, scat	All visual encounter methods
Elk	*Cervus canadensis*	tracks, scat	Diurnal visual encounter survey
Fox species	*Vulpes vulpes* or *Urocyon cinereoargenteus*	1	Amphibian call survey
Northern Raccoon	*Procyon lotor*	tracks	All visual encounter
Fish			
Mosquitofish	*Gambusia affinis*	485	Minnow trap
Golden shiner	*Notemigonus crysoleucas*	5	Minnow trap
Bluegill	*Lepomis macrochirus*	79	Minnow trap
Largemouth Bass	*Micropterus salmoides*	1	Minnow trap
Smallmouth Bass	*Micropterus dolomieui*	1	Minnow trap

Nowak and Spille (2001) trapped only six small mammal species during the herpetological inventory. Species not detected in 2000 (Nowak and Spille 2001) included the non-native House Mouse (*Mus musculus*), and two pocket mice species, Silky Pocket Mouse (*Perognathus flavus*) and one likely Apache Pocket Mouse. The appearance of House Mouse likely represents a local invasion; whereas the appearance of pocket mice is harder to explain, and it is possible that this species was not correctly identified in 2000.

After not capturing Mexican Vole (*Microtus mexicanus*) in traps in 2009 or 2010, in 2011 we documented a surge in captures of the species throughout Watson Woods; this appears to be an irruption (sudden increase in population), as captures declined in 2012. We plan to further analyze small mammal captures during the current monitoring project during future integrative studies at Watson Woods.

Small mammals were only occasionally recaptured after marking; however, small-eared species (Silky Pocket Mouse) and juveniles were not permanently marked, so recapture rates are conservative. We recaptured White-footed Deer Mouse (n = 21), Western Harvest Mouse (n = 3), Silky Pocket Mouse (n = 2), White-throated Woodrat (n = 1), and Mexican Vole (n = 1).

We detected at least five non-native fish species in minnow traps (Table 36). An additional species, Green Sunfish (*Lepomis cyanellus*) was recorded; we suspect this identification may have been confused with that of Bluegill (L. *macrochirus*). Of these, Mosquitofish was the most common species detected, and was primarily trapped in the permanent pond. Bluegill was also only detected in the permanent pond. Smallmouth Bass (*Micropterus dolomieui*) was detected only once in Granite Creek. Fish were found in temporary or semi-permanent ponds only during 2010; because these ponds dried up by mid-summer during most years, it is likely that these individuals accidentally washed in during the large flooding event that happened in January 2010.

We found the remains of four birds (one each of Lesser Goldfinch, House Finch, unidentified hummingbird, and an unidentified passerine with dark blue feathers) near the array fence and/or under 2 x 2 coverboards at pitfall array site #4 north of the SR 69 bypass bridge. We suspect these birds died or were killed nearby and then were dragged under the boards for consumption by unknown small mammals, but have no good explanation for this phenomenon.

Invertebrates– We also found invertebrates during all survey methods and in all trap types; these were typically not identified to species or genus nor quantified. A partial list of aquatic invertebrates trapped includes: mayflies, dragonflies, damselflies, helgramites, snails, diving beetles, and non-native crayfish (*Orconectes virilis*). Crayfish were detected in all water sources. These predatory invertebrates have been implicated in the decline of several native amphibian and snake species (Rosen and Schwalbe 1995; US Fish and Wildlife Service 2002, 2008; Kats and Ferrer 2003). We often found injuries on the bodies or tails of larval amphibians when they co-occurred in the same minnow trap as crayfish; we suspect predation by crayfish and non-native fish may be significant in some areas at Watson Woods during amphibian larval stages. We will analyze data from the semi-permanent ponds to determine if Tiger Salamanders in ponds with crayfish transformed at smaller sizes and/or in poor condition. The co-occurrence of invertebrate and fish predators has been shown to facilitate faster hatching and metamorphosis rates in other amphibian species (e.g. Lawler et al. 1999, Johnson et al. 2003).

Education. We encouraged local and regional student and volunteer participation in all aspects of the monitoring project, from assisting with trap installation to conducting surveys and entering data. Each year, classes from either Prescott College (Restoration Ecology, Mammalogy, and Herpetology) and/or Northern Arizona University (Herpetology, Vertebrate Zoology, Mammalogy, Ornithology) assisted with trap installation, maintenance, and field surveying. Dr. Nowak, Prescott Creeks staff, and professors from both universities gave on-site lectures to these classes on the restoration process, survey and monitoring techniques for herpetofauna and small mammals, and the ecological importance of small vertebrates in riparian systems. Many individuals also assisted with trap installation and recording survey data, including several primary school students. As in 2000, we provided Prescott College students with opportunities to assist with research and collect field data independently and under supervision during this project; one student became a paid field assistant. We also strived to educate interested Watson Woods visitors about the research and its results when we met them in the field; in general this was very successful. In a few cases, the visitors subsequently assisted with our research and/or provided observations.

Discussion

We hypothesized that because of the short generation times of many herpetofauna species found at Watson Woods, we would detect quick responses in these taxa attributable to the restoration project. Indeed, we re-installed the pitfall array site #4 and its coverboards in recently-bladed and barren habitat on April 18, and the first Plateau Fence Lizards had colonized the site a week later, by April 25. Although this species was clearly capable of quick responses, no obvious patterns of increasing abundance were seen in any species, either at traps or in visual encounter surveys along different reaches of the river. Additional analyses of reproduction in different habitats during the course of the monitoring project are needed. There was an apparent increase in species diversity found in riparian woodlands compared to 2000 surveys; it is not clear if this is a statistical artifact (e.g. simply due to more time spent surveying) and/or if it represents a response to restoration.

While we added six new reptile species and three new mammal species compared to those found during the 2000 inventory (Nowak and Spille 2001), it is likely that we have not detected all of the small vertebrate species that will yet colonize Watson Woods, especially as the restoration plantings mature, and as non-native species continue to spread. It is also possible that larger species will be lost from Watson Woods, even among the herpetofauna.

Amphibians–Amphibians are particularly sensitive to environmental perturbations (Lanoo 2005), and may be affected by two issues at Watson Woods. Primary breeding areas for toads along Granite Creek (particularly Reaches 2 and 4, and historic channels), are characterized by wide, deeper, silt-bottomed pools with shallow edges and abundant algae growth; many toad species appear to use similar habitats (Sullivan 2005, Hancock unpubl. 2009). Part of the necessary environmental conditions encouraging algae growth (tadpole forage) in these habitats appears to be abundant sunlight. We are concerned that many of the previous restoration efforts using willows planted densely along the edge of Granite Creek could ultimately result in narrow shaded channels that will be unsuitable as breeding habitat for toads. We suggest that no additional willows, trees, or other woody vegetation be planted along Granite Creek, and in some areas willows previously planted close to the creek banks may need to be thinned to create more sunny patches on the creek.

We had difficulty detecting calling amphibians, particularly Arizona Toads, especially near the junction of roads, due to constant traffic noise. This result is in rather sharp contrast to surveys in 2000 (Nowak and Spille 2001) when human populations, adjacent development, and traffic levels were presumably lower and the Prescott Lakes Parkway bridge had not been built. It is likely that we were not able to detect all of the individuals and all of the breeding locations of Arizona Toad during the most recent monitoring surveys. The negative effects of noise pollution on amphibians are only just beginning to be understood, but it is already clear that anurans, which rely on auditory signaling for successful mate finding, may be negatively impacted by anthropogenic noise, including traffic (Sun and Narins 2005, Bee and Swanson 2007, Lengagne 2008). Unless toads can adapt or have already somehow adapted to increased levels of noise pollution in the area as traffic increases, populations may decrease at Watson Woods irrespective of habitat changes resulting from restoration.

Snakes–We detected very few large-bodied terrestrial snakes in Watson Woods (e.g. Gopher Snake, Black-tailed Rattlesnake), and did not find Striped Whipsnakes during the current project. These species are particularly susceptible to habitat fragmentation and road mortality (Swann 1999, Gibbons et al. 2006), and may not persist in Watson Woods due to its small size and being bordered by heavily-used roads on three sides. Given high levels of persecution of rattlesnakes by humans outside of the Preserve (e.g. Greene and Campbell 1992, Nowak and van Riper 1999), rattlesnakes may continue be rare in Watson Woods.

Stochastic Events– Throughout the course of monitoring, trap sites were occasionally moved and/or damaged by Preserve visitors. Natural stochasticity was also a factor during the monitoring such as animal damage and floods in January 2010. Examples include washed out fences, buried pitfall traps, redistributed coverboards, large ungulates, and falling tree branches. We spent approximately 5-10 hours each year fixing traps, fences, and replacing coverboards. To decrease future coverboard losses, and to make the sites look more official to visitors, we are working with Prescott Creeks staff and volunteers to install rebar with numbered tags and tether each coverboard to these stakes. To prevent accidental animal mortality between active monitoring projects, Prescott Creeks staff have coordinated filling each pitfall bucket with sand.

Mortality and injuries of trapped animals during our research was observed, primarily small mammals that died of exposure or injured each other, lizards that were killed by small mammal trap-mates (including the White-throated Woodrat eaten by a Gopher Snake), and toad metamorphs that desiccated. These issues were addressed as they arose. While at first we added sunflower seeds and peanuts to traps to increase rodent survival, it appeared that this supplemental food might act as bait and attract even more rodents into traps. We ultimately settled on providing socks, and cardboard boxes in funnel traps, to prevent death from exposure and also provide a diversion for trapped mammals. In the future, we suggest the addition of a small piece of ½-¾" PVC pipe, which biologists in Phoenix and at Petrified Forest National Park have used successfully to prevent mammal predation on lizards (H. Bateman and A. Bridges, unpubl. data). At sites where Desert Shrews (*Notiosorex crawfordi*) were detected, we also provided small amounts of dried fish (whole or in chunks), which helped increase survival if traps were checked in the early morning. To prevent amphibian mortality, each trap was provisioned with a shallow lid containing water and a sponge.

Ornithology
Avian monitoring was conducted in order to document bird population and to analyze these results in comparison to the Restoration Project. Surveys were conducted during the months of January, March, April, May, June, July, August, September and November using two survey protocols as designed by the Arizona Important Bird Area (IBA) Program—transect surveys, point count surveys, and census surveys. Point count surveys occurred in March, June, and July, while transect surveys were conducted during the other months as above. Both transect surveys and point count surveys are field sampling surveys which take a sample of avian populations. Transect surveys involve counting the number of individual birds by species along a transect (Granite Creek) within 50 meters of the transect line. Point counts are taken from the same point during each point count survey and individual birds are counted by species within 100 meters of each point. Census surveys are used for water bodies and water body edges, and are designed to count 95% of all the individual birds present on the water body and along the edge.

Results suggest an increased trend in numbers of two neotropic migrant species, common black-hawk and Bullock's oriole. It is unlikely that four years of monitoring is enough time to ascertain clear changes in avian species numbers and diversity that may result from the restoration effort. However, it is anticipated that the continued growth of the recently planted vegetation (especially cottonwood and willow trees) will continue to improve avian populations.

Methods

Line Transect Survey
Line Transect Surveys were conducted along Granite Creek in its entirety from the south to the north boundary of Watson Woods. In addition, the line transect survey was conducted from the north boundary of Watson Woods along Granite Creek north to the "power line cut." All birds found north of the north boundary are identified as "Granite Creek North Control". Granite Creek was divided into three transect sections: 1) south boundary of Watson Woods to Rosser St., the *South Granite Creek* transect; 2) Rosser Rd. to the north reach of the Granite Creek channel restoration, the *Middle Granite Creek* transect; and 3) the north end of Granite Creek channel restoration to the north boundary and the control section identified above, the *North Granite Creek* transect. It was anticipated that section #3 (as described above) will be the least impacted by the restoration project. Thus, section #3 (including the control section) served as a quasi-control section. Line Transect surveys included both the old and the new creek channels where they occur. While Granite Creek is divided into three separate transects, the survey was continuous along the creek from the southern boundary of Watson Woods to the "power line cut" north of the northern boundary of Watson Woods. The entire Granite Creek transect was divided into three sections as these shorter sections were more easily managed by each team in regard to both distance and time. Line Transect surveys recorded birds within a 50 meter radius of the creek that were both seen or heard. Line transect surveys were conducted during each calendar year, 2009-2012, in January, late April/early May, late May, late August, mid-September, and mid-November (2008-2011). A baseline survey of Watson Woods was conducted on November 23, 2008, using two survey methods, the Line Transect survey and the Point Count survey.

Point Count Survey
The Point Count Survey was used to survey areas/habitats of Watson Woods not directly adjacent to Granite Creek. Within the Preserve, established monitoring wells were used as permanent markers for each point except one point which is a knoll in the southwest section of Watson Woods that was not impacted by creek channel reconstruction. Points were at least 250 meters apart with a 100 meter radius for counting birds for each point. The specific wells used as "points" were Monitoring Well (MW) #1=Point #1, MW#2=Point #2, MW#3=Point #3, MW#8=Point #4, MW#5=Point #5, and MW#6=Point #6. The knoll, dubbed Red-tail Knoll, was Point #7. After a brief period following arrival at the specific point, point counts occurred for a ten minute period, with the birds either seen or heard in the first five minutes differentiated from the birds either seen or heard in the five to ten minute period. Point counts were conducted during each calendar year, 2009-2012 in late March, early June, and mid-July. One Point Count survey was **not** conducted in March 2009.

Point counts were not done on the same day as the line transect surveys except for the November 23, 2008 Baseline Survey. Both Transect and Point Count surveys were done on the same day for the Baseline Survey in order to establish to the greatest extent feasible the birds present on that day in Watson Woods.

Census Survey

Census surveys of the Watson Woods pond were conducted starting in January 2009 at the recommendation of the Arizona IBA program biologist (Scott Wilbor). According to the *Arizona Important Bird Areas Program, Protocols for IBA Avian Surveys: A guide for citizen IBA Bird Survey Teams in Arizona* (AZ IBA Avian Science program, Version 4.4, November 2008), a census survey is used "when it is reasonable to assume we can count almost all individuals (>95%) of the species…of interest …at an area (lake, pond, or wetland" (p. 5). At the Watson Woods pond, the census survey included the water body itself and the pond edge/shoreline including the trees within approximately six feet of the edge. The surveys were conducted by first checking the pond itself, and then slowly circling the circumference of the pond checking the shoreline and adjacent trees. Census surveys of Watson Woods' pond were generally conducted on the same dates as Transect Surveys.

As might be expected, species numbers and diversity, especially on the pond itself, decreased over the course of the year. This is because most water fowl spend the winter only in the Prescott area, and as any given year progresses the pond becomes drier and the amount of water in the pond diminishes significantly. Often the pond dries up completely by June. If the summer monsoons produce a lot of rain in the Preserve, the pond may temporarily have water in it again, but it usually takes the more sustained winter precipitation to fill it up enough again for it to be suitable for water birds.

A census survey of Watson Woods' pond was not conducted in August 2010, or in September 2010 or 2011, or in January 2012. In August and September 2010 and in January 2012, it was incorporated in with the Line Transect survey of Granite Creek North, and in September 2011, the pond was dry.

All surveys, regardless of type, were conducted in the mornings, usually starting one-half hour to one hour (especially in winter) after sunrise, and continuing until the survey was done. Length of time for each survey varied depending on the number of individual birds observed (and therefore recorded) and the agility of the team members in walking on uneven terrain. Temperature, cloud cover, wind speed, and precipitation occurrence were also recorded. Teams usually consisted of two or three observers, one of whom recording the observations. Occasionally, there were four members, and on one transect survey on one transect section there was only one individual. The location and extent of each survey method is illustrated in Figure 54.

Supplemental Species Observed

Supplemental species observed are those individual birds observed (visual/auditory) by team members beyond the transect line or the point count limits, or beyond the census boundary. Birds that fly over the habitat rather than through it (except for point counts) are also counted as supplemental. Thus, supplemental species may be observed by team members on their walk to or from a given transect or point, outside the limits established by the survey protocol, or in the case of "fly overs", during transect line and census surveys. There are however, no clear rules for reporting supplemental species. Sometimes they are ignored, especially in the case of abundant species such as common ravens, house finches, and lesser goldfinches, and sometimes they are not. The specificity of reporting supplemental species counts varied with the individual observers and recorders on any given survey. As a result, about all supplemental species observations indicate is the presence of whatever numbers of individual birds and species observers decide to record on any given team and survey which is almost certainly not the total numbers of species or individual birds of a given species observed. The one exception is raptors (hawks, eagles, falcons, owls). These are the "top of the food chain" birds so their presence or absence is considered to be an indirect indicator of the health of the habitat. Thus, while never abundant, the more raptors present, the more likely the relevant prey animals and birds are available. The observers were cognizant of this relationship, and were conscientious about counting and recording observed raptors including those observed as supplemental species.

Figure 54-Location of Transect, Point Count, and Census Surveys Zones within Watson Woods

Results and Discussion

Prescott Creeks has summarized the results of the surveys below. Appendices A-C contains a complete list of volunteers who conducted the surveys, number and species of birds recorded, and an overall list of avian species observed within Watson Woods, respectively. As shown in Table 38, there were 133 individual species observed within the Preserve. Each species was recorded by a unique acronym.

Table 38- Species Recorded at Watson Woods Riparian Preserve 2008 - 2012

Canada goose	CANG	Nashville warbler	NAWA	Barn owl	BNOW
Wood duck	WODU	Virginia's warbler	VIWA	Great-horned owl	GHOW
Gadwall	GADW	Lucy's warbler	LUWA	Black-chinned hummingbird	BCHU
American wigeon	AMWI	Yellow warbler	YWAR	Anna's hummingbird	ANHU
Mallard	MALL	Yellow-rumped warbler	YRWA	Broad-tailed hummingbird	BTLH
Cinnamon teal	CITE	Black-throated gray warbler	BTYW	Rufous hummingbird	RUHU
Northern shoveler	NSHO	Townsend's warbler	TOWA	Unidentified hummingbird	?HUM
Northern Pintail	NOPI	Northern waterthrush	NOWA	Belted kingfisher	BEKI
Green-winged teal	GWTE	Black-headed grosbeak	BHGR	Acorn woodpecker	ACWO
Canvasback	CANV	Blue grosbeak	BLGR	Williamson's sapsucker	WISA
Ring-necked duck	RNDU	Lazuli bunting	LAZB	Red-naped sapsucker	RNSA
Bufflehead	BUFF	Indigo bunting	INBU	Ladder-backed woodpecker	LBWO
Common goldeneye	COGO	Unidentified bunting	?BUN	Hairy woodpecker	HAWO
Unidentified duck	?DUC	Red-winged blackbird	RWBL	Unidentified Picoides	?PIC
Gambel's quail	GAQU	Western meadowlark	WEME	Northern flicker	NOFL
Pied-billed grebe	PBGR	Yellow-headed blackbird	YHBL	Unidentified woodpecker	?WOO
Double-crested cormorant	DCCO	Great-tailed grackle	GTGR	Western wood-pewee	WEWP
Unidentified cormorant	?COR	Bronzed cowbird	BROC	Hammond's flycatcher	HAFL
Great blue heron	GBHE	Brown-headed cowbird	BHCO	Dusky flycatcher	DUFL
Great egret	GREG	Unidentified cowbird	?COW	Hammond's/dusky flycatcher	HFDF
Green heron	GRHE	Bullock's oriole	BUOR	Gray flycatcher	GRFL
Warbling vireo	WAVI	Unidentified oriole	?ORI	Cordilleran flycatcher	COFL
Western scrub-jay	WESJ	House finch	HOFI	Unidentified Empidonax	?EMP
Common raven	CORA	Pine siskin	PISI	Black phoebe	BLPH
Horned lark	HOLA	American goldfinch	AMGO	Say's phoebe	SAPH
Tree swallow	TRES	House sparrow	HOSP	Ash-throated flycatcher	ATFL
Violet-green swallow	VGSW	Black-crowned night-heron	BCNH	Cassin's kingbird	CAKI
Northern rough-winged swallow	NRWS	Turkey vulture	TUVU	Western kingbird	WEKI
Cliff swallow	CLSW	Bald eagle	BAEA	Unidentified Tyrannus	?TYR
Barn swallow	BARS	Northern harrier	NOHA	Plumbeous vireo	PLVI
Unidentified swallow	?SWA	Sharp-shinned hawk	SSHA	Cassin's vireo	CAVI
Bridled titmouse	BRTI	Cooper's hawk	COHA	Plumbeous or Cassin's vireo	PCBV
Juniper titmouse	JUTI	Unidentified accipiter	?ACC	MacGillivray's warbler	MGWA
Bushtit	BUSH	Common black-hawk	CBHA	Common yellow-throat	COYE
White-breasted nuthatch	WBNU	Zone-tailed hawk	ZTHA	Wilson's warbler	WIWA
Brown creeper	BRCR	Red-tailed hawk	RTHA	Unidentified warbler	?WAR
Rock wren	ROWR	American kestrel	A.KESTREL	Green-tailed towhee	GTTO
Bewick's wren	BEWR	Merlin	MERL	Spotted towhee	SPTO
House wren	HOWR	Peregrine falcon	PEFA	Canyon towhee	CANT
Winter wren	WIWR	Sora	SORA	Chipping sparrow	CHSP
Unidentified wren	?WRE	American coot	AMCO	Brewer's sparrow	BRSP
Ruby-crowned kinglet	RCKI	Killdeer	KILL	Lark sparrow	LASP
Blue-gray gnatcatcher	BGGN	Spotted sandpiper	SPSA	Savannah sparrow	SASP
Western bluebird	WEBL	Unidentified sandpiper	?SAN	Song sparrow	SOSP

(Table 38 continued)

American robin	AMRO	Wilson's snipe	WISN	Lincoln's sparrow	LISP
Northern mockingbird	NOMO	Ring-billed gull	RBGU	Swamp sparrow	SWSP
Crissal thrasher	CRTH	Unidentified gull	?GUL	White-crowned sparrow	WCSP
European starling	EUST	Rock pigeon	ROPI	Dark-eyed junco	DEJU
American pipit	AMPI	Eurasian collared-dove	ECDO	Summer tanager	SUTA
Phainopepla	PHAI	White-winged dove	WWDO	Western tanager	WETA
Orange-crowned warbler	OCWA	Mourning dove	MODO	Unidentified tanager	?TAN

November 2008-2011 Surveys

The first survey conducted was in November 2008 when a baseline survey was carried out with the knowledge that only resident and some wintering species would be present. Neotropic migrants that come to the Prescott area to breed typically leave by the end of September. This is also the only time when both a Transect Line Survey and a Point Count Survey were conducted on the same day. In 2009 through 2011, only the Transect Line Survey was conducted. The 2008 exception was made because this was a baseline survey and the goal was to establish to the greatest extent feasible the species diversity and numbers present in the Preserve. Of the 40 species observed on this baseline survey, two species stand out in regard to large numbers relative to numbers in following months, not only in November, but in the winter/early spring months. These species are ruby-crowned kinglet and yellow-rumped warbler. Both are common species throughout their ranges in the United States (Kaufman, 1996), both are wintering species in the Prescott area, and both winter from the southern tier of the USA well into central America (National Geographic Society [NGS], 2006). Figure 55 demonstrates that there were a total of 36 ruby-crowned kinglets (RCKI) in November 2008 and 39 in November 2010 along the entire Granite Creek transect. The Point Count survey in 2008 added an additional 12 individual birds.

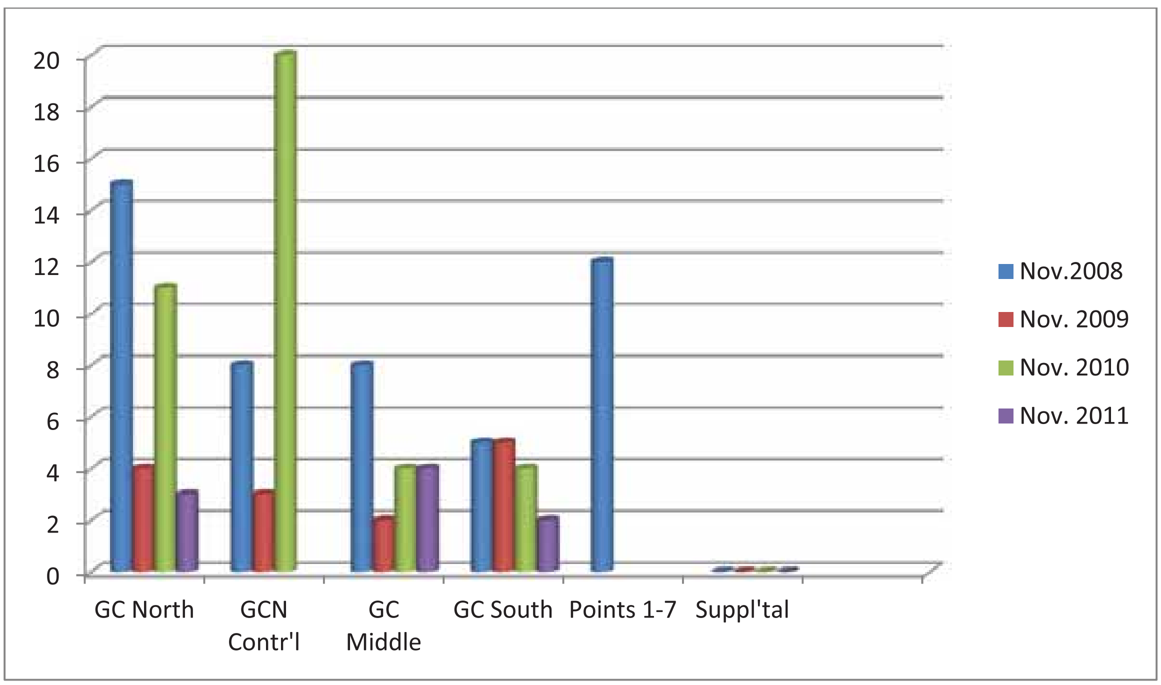


Figure 55-Ruby-Crowned Kinglet - November

Yellow-rumped warbler numbers in November across the years were also higher than in other winter/early spring months. Figure 56 indicates that there were 43 yellow-rumped warblers (YRWA) along the entire Granite Creek transect, while in the next highest year, November 2010, there were 16. The total of the Point Count Survey in 2008 added another 26 individual birds.

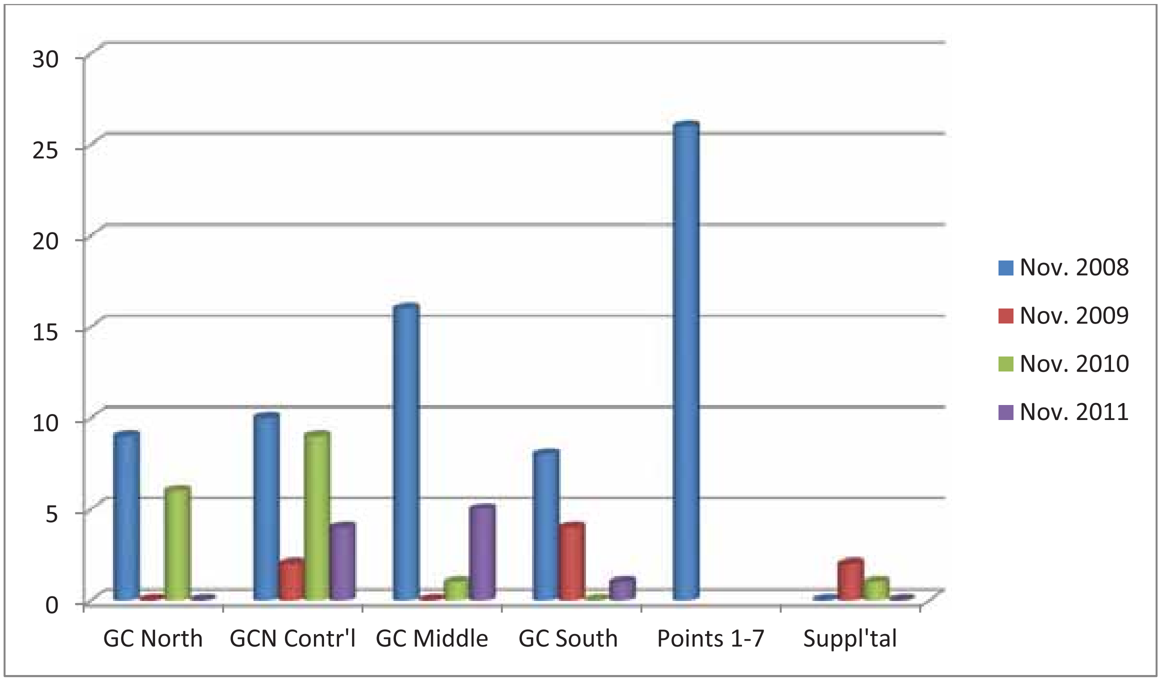


Figure 56-Yellow-rumped warbler – November

While the reasons for these larger numbers of both of these species in November 2008 (with the exception of 2010 ruby-crowned kinglets) along the entire Granite Creek transect may not ever be known, it seems unlikely that weather was a significant factor. Temperatures ranged from the 30's to 40's in 2010 and ranged from the 40's to 50's in the other years. There were no significant differences in either cloud cover or wind speed, and there was no precipitation in any of the years on the dates of the surveys.

January 2009-2012 Transect Surveys

January surveys indicated the presence of several species of ducks on Watson Wood's pond, although not always the same species each year. Both dabbling ducks and diving ducks were present. Watson and Willow Lakes are within easy flying distance from Watson Woods, so the numbers of individuals of any given species tend to be variable at any given time. Both lakes are considerably larger than the pond and most likely provide a more dependable food supply for all ducks. Red-tailed hawks were the most prevalent raptor species found in Watson Woods in January. Again, this is an expected finding as they are understood to be the most common species of raptor across the entire nation. Those present most likely represent both resident and wintering individuals.

Resident species included mourning doves which were abundant especially in the Granite Creek Middle and South sections across the monitoring period. Hairy woodpecker and northern flicker numbers, while small, were relatively consistent. Resident songbirds such as black phoebe, white-breasted nuthatch, Bewick's wren, European starling, and spotted towhee were present in small numbers, while house finches and lesser goldfinches were abundant across the monitoring period. No obvious trends in numbers of any of these residents were noted. Except for the black phoebe which is a riparian obligate species, all the other resident species listed can and do reside in a variety of habitats in the Prescott area so can be found virtually anywhere.

Commonly found wintering songbirds in January included ruby-crowned kinglets whose numbers were relatively low compared to November. Yellow-rumped warbler numbers in January across the monitoring period were consistently way down compared to November (Figure 57).

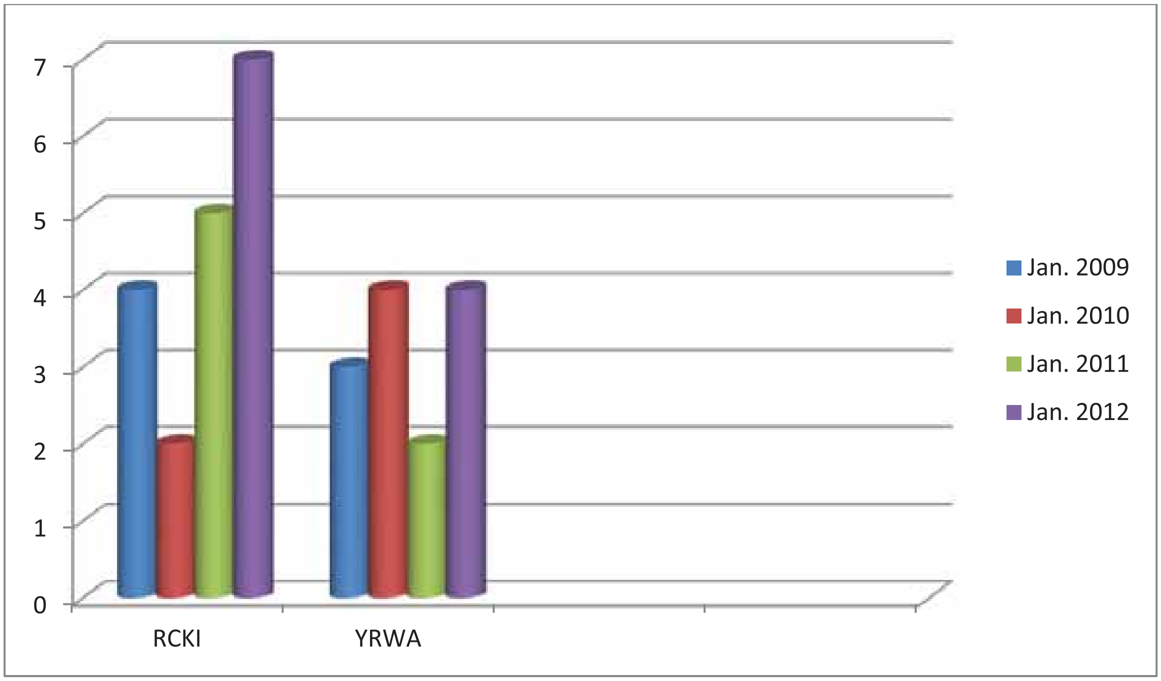


Figure 57-RCKI and YRWA (January)

White-crowned sparrow numbers were way up on the Granite Creek North (including the "control" section) and Granite Creek Middle sections of the transect in 2011, while dark-eyed juncos were particularly abundant on the Granite Creek South section in 2012. Other wintering sparrows in small numbers included chipping sparrows, song sparrows and Lincoln sparrows especially in 2009 and 2010. One savannah sparrow was observed on the Granite Creek North section in 2009. This species is more commonly found in grasslands habitat during the winter in the Prescott area.

March 2010-2012 Point Count Surveys

Late March is a transitional time of year in that early migrants have started to arrive on their breeding grounds (or are migrating through the area) while wintering species are still present. Two species which are known to migrate through the Prescott area (but not usually stay), northern rough-winged swallow and tree swallow were observed in very small numbers in March across the monitoring period. Early migrants which breed in the Prescott area include Anna's hummingbird (ANHU), violet-green swallow (VGSW), cliff swallow (CLSW), and Lucy's warbler (LUWA).

Of particular interest is LUWA because it is listed as a species of conservation concern by Arizona Partners in Flight and is on National Audubon Society's Arizona Watchlist. It is a cavity nester and is found in both low and high elevation riparian areas where there are willows and cottonwoods (good for cavities) and mesquite woods. Both of these types of habitats are threatened in Arizona. Additionally, the breeding range of this species is comparatively small in the United States, with its breeding range largely in Arizona and to a much smaller degree in southwestern New Mexico, southeastern Utah and the extreme southern border of Nevada and California (NGS, 2006). Personal observations of many of the survey volunteers over a number of years indicated that LUWA usually arrive in Watson Woods during the third week of March. Point count surveys in all three years support those observations.

ANHU build tiny cup nests across several habitat types in the Prescott area including Watson Woods, while VGSW are, like LUWA, cavity nesters. Suitable cavities for both these species are typically found in cottonwood trees where branches that break off from trunks often leave holes suitable for nests. CLSW builds mud nests attached to cliff walls. While cliffs are not present within the Peserve across its USA breeding range the CLSW has found that bridges serve as suitable substitutes for cliff walls for nest building. Large numbers of CLSW nests have been observed annually for years under the Prescott Parkway bridge.

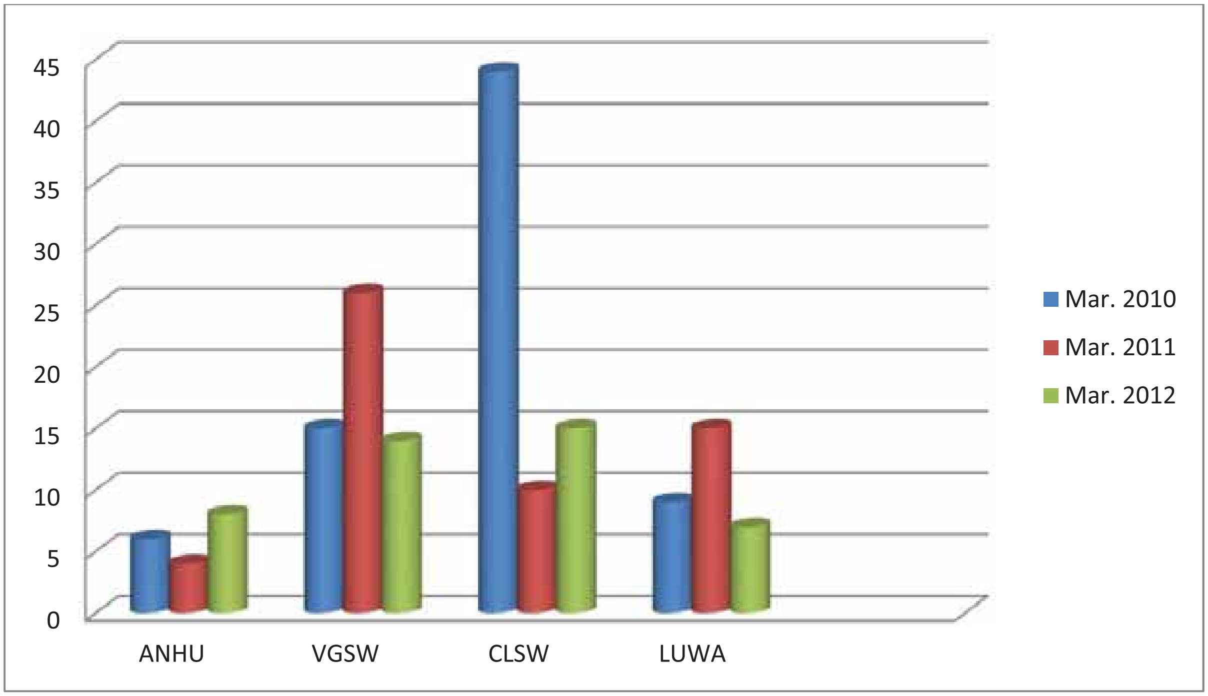


Figure 58-Early migrant breeding species (March)

Variation in numbers at all points combined for each year of each of these early migrant breeding species is most likely due to the early dates in the migration season. Total individuals observed (including supplemental observations) ranged from four to eight for ANHU, from 14 to 26 for VGSW, from 10 to 44 for CLSW, and from 7 to 17 for LUWA (Figure 58).

Two wintering species that remained in varying numbers in late March across the monitoring period were RCKI and YRWA. Numbers of YRWA particularly were up in March as compared to January (Figure 59).

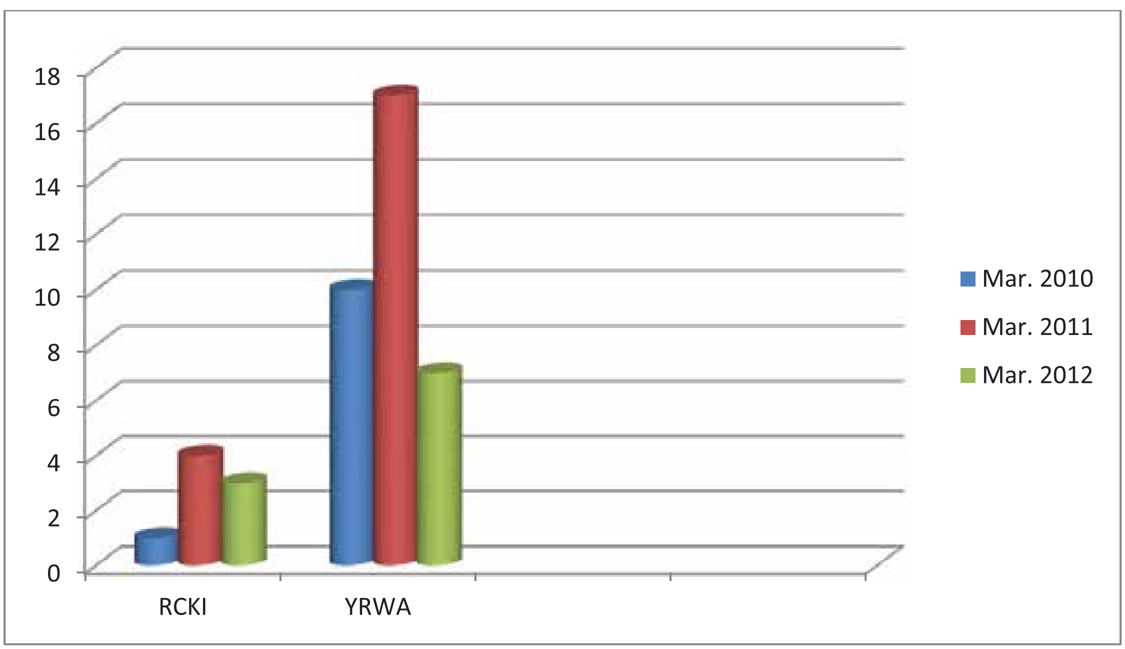


Figure 59-RCKI and YRWA in March

Late April/early May 2009 – 2012 Transect Surveys

Late April through May is typically the height of spring migration in Arizona. Not only does this mean the arrival of most neotropical migrants that breed in the Prescott area. It also means that several neotropical migrants pass through the Prescott area on their way to their breeding grounds either elsewhere in Arizona or elsewhere in North America. Interestingly, Yellow-rumped warblers are still present in good numbers while ruby-crowned kinglets had already left Watson Woods for their breeding grounds (Figure 60). The most likely reason for their presence in this time period is that the numbers are bolstered by YRWA migrating north from further south. At the same time, the resident species are also gearing up for the breeding season. Throughout Watson Woods birds are singing—classic behavior indicative of the claiming of territory for breeding to attracting mates. Neotropical migrants that breed in the Preserve that have arrived by this time of year include black-chinned hummingbirds (BCHU), yellow warblers (YWAR), common yellow-throats (COYE), summer tanagers (SUTA), brown-headed cowbirds (BHCO), and Bullock's orioles (BUOR).

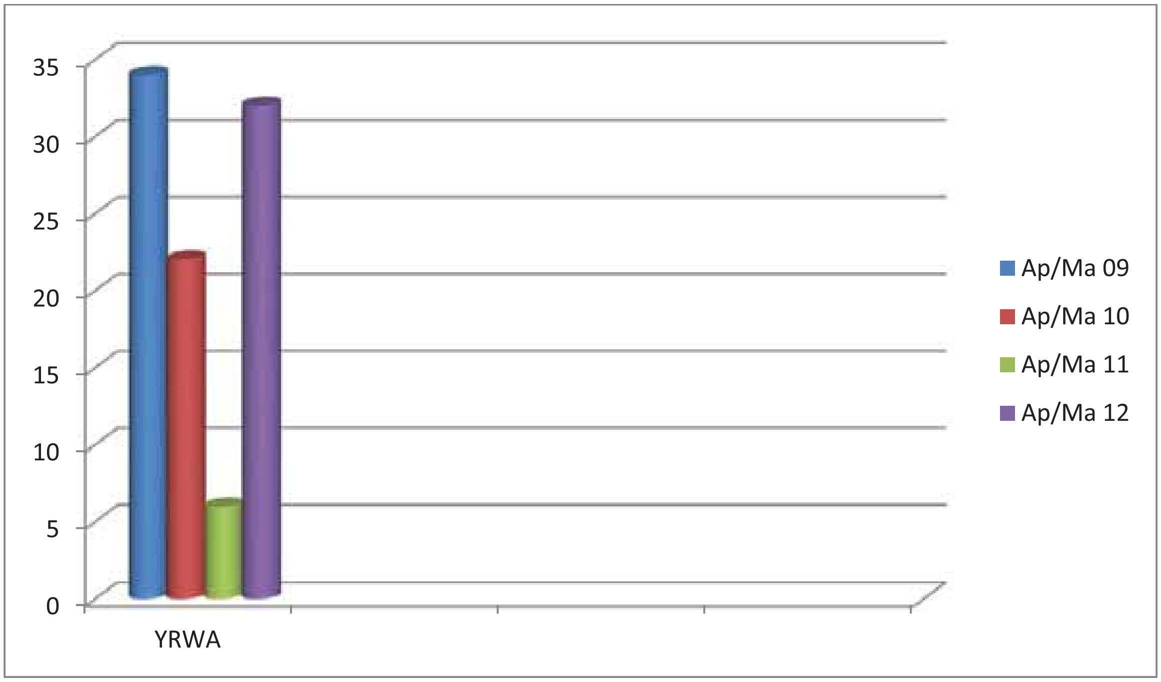


Figure 60-YRWA in late April/early May

Total numbers of neotropic migrants in late April/early May that breed in Watson Woods are shown by year in Figure 61 and Figure 62 (split into two graphs for ease of reading).

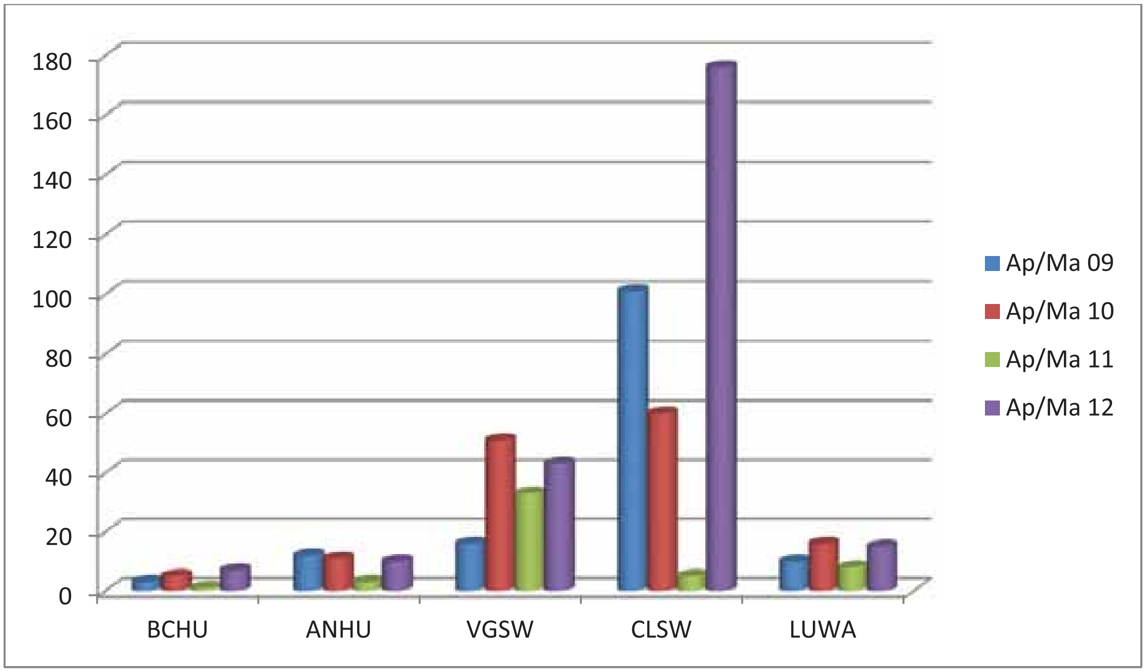


Figure 61-Breeding Neotropic Migrants (late April/Early May)

Relative to late March numbers, all numbers of ANHU, VGSW, CLSW, (except in 2011) and LUWA are higher. This is not unexpected, as late March is the beginning of spring migration while late April/early May is closer to the peak of spring migration.

The neotropic migrant species which breed in Watson Woods are those that arrived sometime between late March and late April/early May. Except for the hummingbirds and the cowbirds, the rest are either riparian obligates or associated with riparian areas in Arizona (ABBA, 2005).

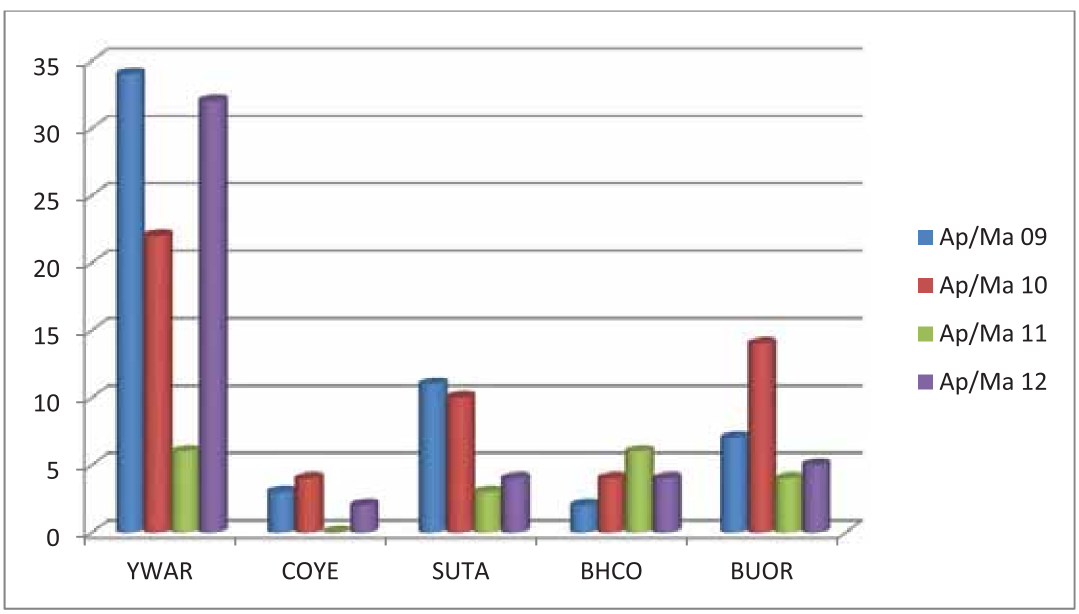


Figure 62-Breeding Neotropic Migrants (late April/Early May)

Clearly yellow warblers are the most common neotropic migrant of the five indicated in Figure 62 and common yellow-throats are the least common. There is also less suitable habitat generally for COYE (wetlands and riparian areas with thick, low vegetation [ABBA, 2005]). Brown-headed cowbirds which are brood parasites to birds that make cup nests, particularly yellow warblers, were observed in low numbers. Except for BHCO, numbers observed all species in both Figure 60 and Figure 61 are lower in 2011 than in any of the other monitoring years. While potential explanations are many, the most obvious reason is wind. Birds tend to "hunker down" and to sing less when it is windy, and even if present, are more difficult to find. Of the four monitoring years in this time frame, 2011 was the only year in which wind speeds during the survey went as high as 8-12 mph. While there were temperatures differences, temperature did not seem to be a factor.

Migrants on their way through the area include dusky and Hammond's flycatcher, plumbeous and warbling vireo, orange-crowned, Nashville, Townsend's, and Wilson's warblers, and lark sparrow. Resident species include mourning doves, ladder-backed and hairy woodpeckers, northern flicker, black and Say's phoebe, common raven,white-breasted nuthatch, Bewick's wren, house finch, and lesser goldfinch.

May 2009-2012 Transect Surveys

Surveys in May continue to observe neotropic migrants arriving on their breeding grounds as well as migrants passing through the Preserve on their way to breeding grounds elsewhere. Yellow-rumped warblers have mostly left for their breeding grounds in spruce forests. Only two were observed in 2010 and again in 2012. By May another neotropic migrant has arrived to breed, the blue grosbeak (BLGR). Figures 63 and 64 show the numbers of all the neotropic migrants plus BLGR and unidentified hummingbirds (?HUM). These are also included as these birds almost certainly are either Anna's or black-chinned hummingbirds. The other two relatively common hummingbirds are rufous and broad-tailed. Both of these have most likely migrated through the Prescott area to, respectively, southeast Alaska or to higher elevation, coniferous forests where they breed. Both black-chinned and Anna's hummingbirds are known to breed in Watson Woods (personal observations; ABBA, 2005; Tomoff, 2010).

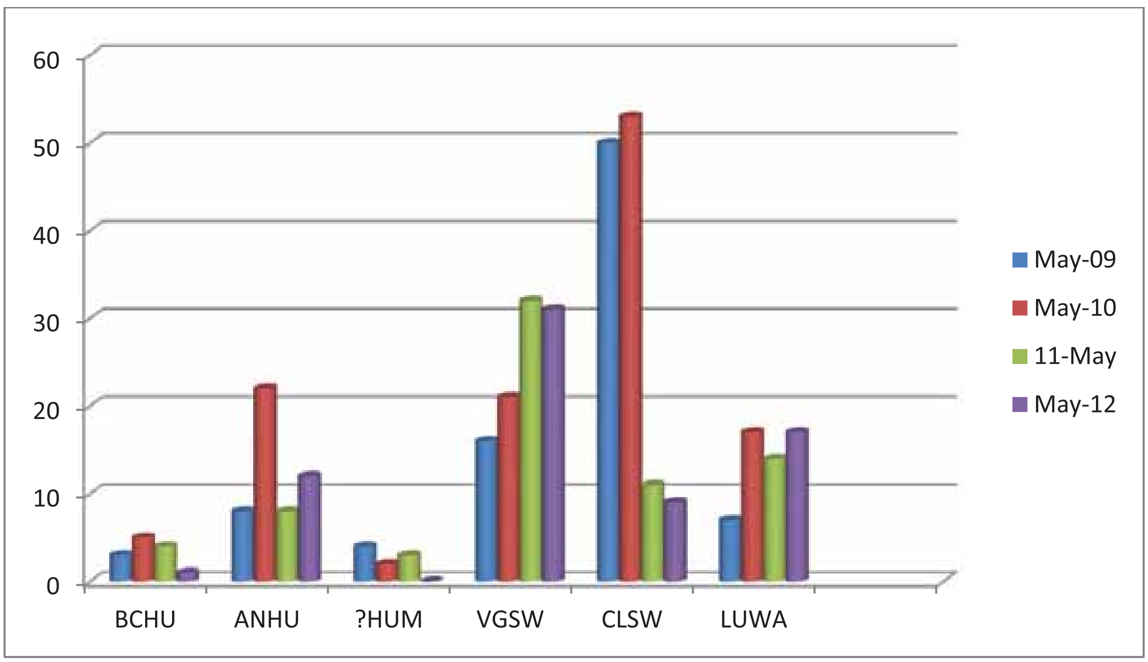


Figure 63-Breeding Neotropic Migrants (late May)

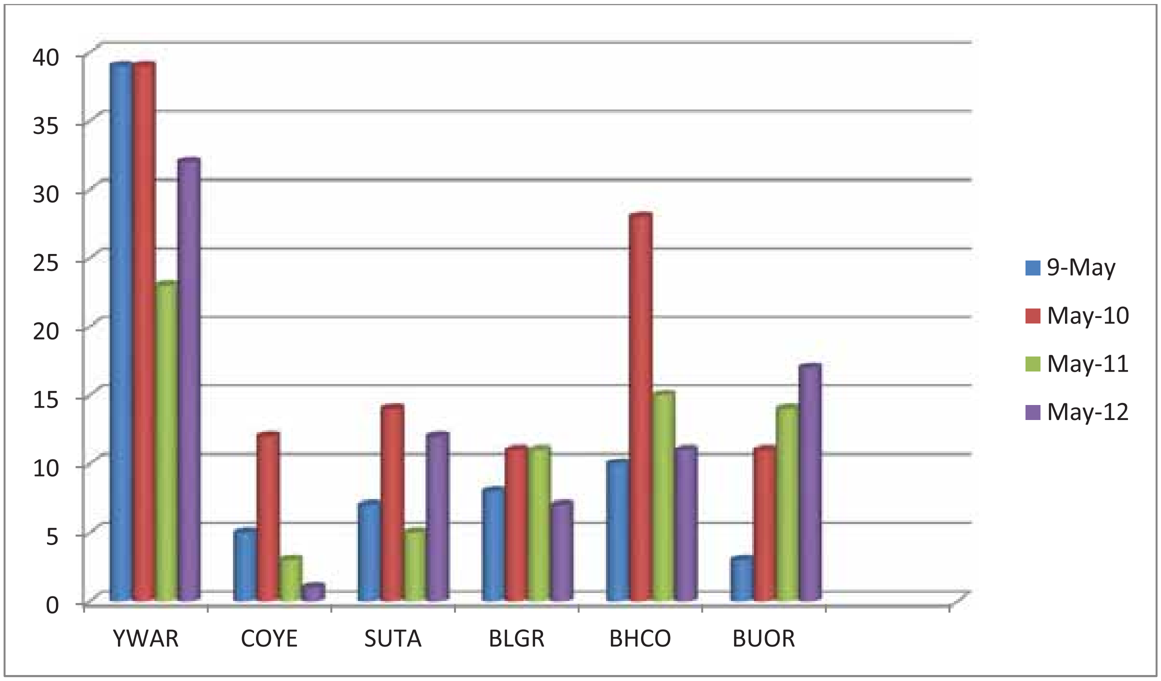


Figure 64-Breeding Neotropic Migrants (late May)

There were no differences in numbers of black-chinned hummingbird numbers between late April/early May and later May in 2009 and 2010. In 2011, there was just one BCHU in April compared to four in May. Recall that wind speeds increased as time passed during the survey in April 2011, while it was minimal through the survey time in May. In 2012 only one BCHU was observed in May while there were seven in April. Weather does not appear to be a factor. Anna's hummingbird numbers in May across the monitoring years were higher than in late April/early May. There were almost no unidentified hummingbirds observed in late April/early May in any years, while there were four in May 2009, two in 2010, three in 2011, and none in 2012.

Violet-green swallow numbers were the same in early May 2009 and late May 2009. More VGSW were observed in late April than in late May in 2010 through 2012. Since VGSW are early migrants, it is likely that they begin nesting earlier than those breeding migrants that arrive in late April/early May or later in May. It is at least possible that many of the females are on nests in cavities and thus not observed by later in May. Cliff swallow numbers were higher in late April/early May in all years except 2011 when they were higher in May than in late April. Again this result could have been influenced by higher winds in late April. CLSW females are also more likely to be in nests later in May than in late April/early May.

Wind seemed to be a factor in late April 2011 for Lucy's warbler observations relative to late May 2011. In the other years, there was little change in numbers observed between late April/early May and later in May. Common yellow-throat numbers were higher in later May than in the previous month, but except for May 2010, when 12 were observed compared to four in late April 2010, the number differences are minimal.

Except for 2009 when early May numbers were higher (11) than in late May (7), summer tanagers were higher in late May each year than in early May. In 2011, however, numbers were the lowest of any of the monitoring years in both late April and late May. While wind could be a possible factor in late April, this does not account for the low number in late May. Another neotropic migrant that breeds in Watson Woods and was not present in late April/early May but were present in late May is the Blue Grosbeak (BLGR). Numbers observed across the four years were eight in 2009, 11 in both 2010 and 2011, and seven in 2012.

Bullock's oriole numbers were higher in early May/late April in both 2009 (7) and 2010 (14) than in late May 2009 (3) and 2010 (11), but higher in late May in 2011 (14) and 2012 (17) than in late April 2011 (4) and 2012 (5). Interestingly, BUOR numbers were higher in the Granite Creek South section than in any of the other transect sections across all four years. This species is closely allied with riparian communities, especially those with large, deciduous shade trees (ABBA, 2005). While there are large cottonwood trees in all sections of the Granite Creek transect, there are areas, especially in the southern half of the South section, where several of these cottonwood trees are bunched together forming an almost continuous canopy. Based on the *Arizona Breeding Bird Atlas*, this kind of habitat occurrence seems ideal for BUOR. In addition to BUOR, not observed in either 2009 or in 2010, but found in 2011 and 2012 (two each year) were bronzed cowbird (BROC). This species is a brood parasite and is particularly fond of laying its eggs in the nests of orioles, particularly those of hooded orioles (ABBA, 2005). While no hooded orioles were found in any year, it is suspected that these birds were interested in the nests of Bullock's orioles. Both years they were found in the Granite Creek South section, and both years the individual birds were males. Whether or not females were ever present is unknown.

June and July 2009-2012 Point Count Surveys

Point counts were conducted in early June and mid-July in all four years. By early June, the early migrants will have fledged young from their first brood. Those that migrated to Watson Woods in late April to late May may be sitting on nests or feeding nestlings. By mid-July, a few of the early migrant species may have already started their migration south or are experiencing what is referred to as post-breeding dispersal, meaning that the young are no longer dependent on parents for food, the pair-bonds of the parents are separated, and each individual is "on its own". Later migrants are likely feeding either nestlings or fledglings. In Table 39 below, the "2+1" in the 2012 ?HUM row means that one of the unidentified hummingbirds was neither a black-chinned hummingbird nor an Anna's hummingbird. This is known because the observers reported a "very large, dark" hummingbird. It was perched in the shade which is one explanation for it being "dark". There are only two "very large" hummingbirds known in Arizona, the blue-throated and the magnificent. Both are most typically found in the mountain habitats of southeastern Arizona. However, the blue-throated is listed by Tomoff (2010) as "accidental" (five or fewer records in approximately 30 years) while the magnificent is listed as "casual" (more than five records, not occurring annually). Thus, statistically, the probability lies with the magnificent hummingbird. Additionally, the magnificent hummingbird appears "dark" relative to the blue-throated hummingbird unless the sun hits it just right, but almost any bird perched in shade can look dark. This hummingbird was not conclusively identified. The 8+7 in the 2012 CLSW row indicates that adults were observed feeding young in seven nests.

Table 39-Breeding Neotropic Migrants (early June)

Species	6/3/2009	5/23/2010	6/5/2011	6/3/2012
BCHU	1	1	0	2
ANHU	4	1	3	1
?HUM	2	0	1	2+1
VGSW	14	4	11	12
CLSW	28	32	58	8+7
LUWA	6	5	9	6
YWAR	10	10	11	10
COYE	2	5	5	3
SUTA	3	4	6	5
BLGR	4	3	7	8
BHCO	10	10	4	7
BUOR	4	3	4	7

Additionally, one bronzed cowbird was observed in 2009 and two were observed in 2011.

Table 40-Breeding Neotropic Migrants (Mid July)

Species	7/16/2009	7/16/2010	7/17/2011	7/15/2012
ANHU	8	5	6	1
?HUM				4
VGSW	3	3	3	5
CLSW	62	30	125	44
LUWA	1	0	3	1
YWAR	10	10	7	10
COYE	2	1	2	2
SUTA	3	3	5	4
BLGR	7	5	5	4
BHCO	6	7	15+3	4
BUOR	5	3	1	1

In July (Table 40), no black-chinned hummingbirds or bronzed cowbirds were observed. The very large number of cliff swallows observed in 2011 is puzzling. The number may reflect fledged young, but if so, why did such a change not occur in the other three years?   Lucy's warbler numbers are noticeably lower in July. It is one of the early migrants, and this data suggests that they only raise one breed a year. In keeping with their breeding behavior (ABBA, 2005), peak nesting period is from late April to mid-May, and declines significantly after early June. Thus, even the majority of juveniles would be capable of migrating south by mid-July. Common yellowthroat numbers, while never high, are lower in July than in June, but this may be a reflection of the species' behavior. This species tends to be a "skulker", meaning it is often difficult to see. In June, however, they were most likely singing, while in July, they would tend to be quieter while feeding young, possibly still in nests. In brown-headed cowbirds, the "+3" refers to the entry of "unidentified cowbirds". It is almost certain that these were brown-headed cowbirds, as no more than two bronzed cowbirds were observed on any survey during the monitoring years. Additionally, the large number of BHCO in July 2011 is puzzling. In June Bullock's orioles were observed across Watson Woods, while those observed in July were observed at only Points #6 and #7—both located in the southern part of Watson Woods

Late August Transect Surveys 2009-2012

By late August, migrants are moving through Watson Woods. These included broad-tailed and rufous hummingbirds, Cassin's and warbling vireos, northern rough-winged and barn swallows, orange-crowned, Nashville, MacGillivray's, and Wilson's warblers, the rare (in the west) northern waterthrush in 2009, western tanagers, black-headed grosbeaks, and Lazuli and indigo buntings. Of the neotropic migrants that breed in Watson Woods, there were seven violet-green swallows in 2010 and one in 2012, no cliff swallows, one Lucy's warbler in 2011, one common yellowthroat in 2009 and one in 2010, no brown-headed cowbirds, and two Bullock's orioles in the Granite Creek South section in 2012. Numbers of the remaining species are reported below in Table 41.

Table 41-Breeding Neotropic Migrants (Late August)

Species	8/30/2009	8/29/ 2010	8/28/2011	8/26/2012
BCHU	10	2	0	3
ANHU	19	6	6	14
?HUM	5	3	4	2
YWAR	25	7	10	13
SUTA	9	4	1	9
BLGR	9	16	14	8

September Transect Surveys 2009-2012

Two weeks later in September, migrants continue to pass through the Preserve. In addition to those observed in late August, were a few flycatchers—western wood-pewee and Empidonax species flycatchers, plumbeous vireo, house wren, and a green-tailed towhee in 2011. Of the neotropic migrants that breed in Watson Woods, one Lucy's warbler was found in 2010, and one common yellowthroat was observed in 2010 and two in 2011. No Bullock's orioles were found. Violet-green swallows were present in 2009 (18) and 2011 (28) but not in 2010 or 2012. Most likely those observed in 2009 and 2011 were migrants passing through from further north. Numbers of the remaining species are reported in Table 42 below.

Table 42- Breeding Neotropic Migrants (September)

Species	9/13/2009	9/17/2010	9/11/2011	9/9/2012
BCHU	4	1	1	0
ANHU	12	8	8	9
YWAR	1	2	20	1
SUTA	6	4	7	8
BLGR	10	5	5	6

The large number of yellow warblers in 2011 is most likely the result of migrants passing through from other riparian areas.

There are two other groups of species that are commonly found in the Preserve. These are raptors and residents. Residents are those species can be found all year round. Twelve species of raptors were found during the four years of monitoring. Of these, two species are owls, barn owl and great-horned owl, and while residents, are notoriously difficult to find. This is, in part, because being nocturnal (active at night), they roost most usually in large cottonwood trees during the day. The great-horned owl is also very cryptic in its coloration, and as large an owl as it is (one of the largest in North America), it can be easily overlooked. Barn owls are listed by Tomoff (2010) as rare. The occasional one found was roosting under the Prescott Parkway Bridge where it was more noticeable than if hidden in a cottonwood. Great-horned owls are listed as common (Tomoff, 2010).

Of the other ten raptors, all are hawks or falcons except the bald eagle, which is primarily a wintering species in the Prescott area, although a pair has nested annually for several years in the vicinity of Lynx Lake in Prescott National Forest south of the city. One was observed in November 2011, one in January 2009 and three in January 2012, two in March 2012, and one in late April 2011. Among hawks, two are residents, Cooper's hawk (COHA) and red-tailed hawk (RTHA). One falcon is a resident, the American kestrel (A.KES). Two are wintering species, northern harrier and sharp-shinned hawk. One northern harrier was seen in January 2009, 2010, and 2011. Four sharp-shinned hawks were observed in November 2010, and one in January 2012. Two hawk species are neotropic migrants—common black-hawk (CBHA) and zone-tailed hawk. One zone-tailed hawk was observed during the entire monitoring period on August 29, 2010. While they are known to nest in Arizona from high-elevation forests to lowland riparian areas (ABBA, p. 144), they are considered rare and found only locally, although a presumed breeder (Tomoff, 2010). Common black-hawks are "riparian obligate species" (ABBA, 2005, p. 138). A nest was discovered in a large cottonwood tree in the Granite Creek Middle transect in 2012. Two other falcons were observed once each in the four years.

One peregrine falcon was observed on April 25, 2010, in flight. This large falcon is seen quite commonly in winter, hunting ducks and American coots around Watson and Willow Lakes. They nest in the Prescott area on rocky cliffs on Granite Mountain and Thumb Butte, and these areas are closed off to hikers and rock-climbers during the breeding/nesting season. Once listed as endangered, the peregrine falcon is still considered a "special conservation status avian species in Arizona" by the US Fish and Wildlife Service. The other falcon observed once is the merlin, a small falcon which is a rare "transient" (spring and fall migration) and wintering species (Tomoff, 2010, p. 4). One was observed on September 9, 2012.

Table 43 vindicates numbers for each of the three most common resident raptors observed in Watson Woods. While it is unclear what (if anything) is significant about these numbers, some discussion is relevant. In May of 2009, one red-tailed hawk is an adult and two are nestlings. In May 2012, two red-tailed hawks are adults and two are nestlings. Additionally, the many-year nest of a pair of RTHA in a large cottonwood tree next to Point #7 was in use in 2009, but clearly abandoned by 2012 when a new nest in a large cottonwood tree along the Granite Creek South transect section with nestlings was observed. No nestlings were found in 2010 or 2011. A nest of Cooper's hawks was also observed in spring 2009 along the trail between Points #1 and #2, and 2011 and 2012, a nest was observed near Watson Woods Pond. Observers were unable to see whether or not these nests actually ever contained nestlings. American kestrels nest in cavities, so finding their nests is next to impossible. None were observed entering cavities with nesting materials or food.

Table 43-Raptor Residents

Year	Nov.	Jan.	March	April	May	June	July	Aug.	Sept.
2008	COHA 0 RTHA 8 A.KES 2								
2009	COHA 0 RTHA 5 A.KES 2	COHA 0 RTHA 5 A.KES 3		COHA 1 RTHA 2 A.KES 2	COHA 2 RTHA 3 A.KES 1	COHA 1 RTHA 1 A.KES 1	COHA 1 RTHA 1 A.KES 0	COHA 3 RTHA 0 A.KES 4	COHA 0 RTHA 0 A.KES 1
2010	COHA 2 RTHA 5 A.KES 1	COHA 0 RTHA 5 A.KES 0	COHA 1 RTHA 2 A.KES 0	COHA 1 RTHA 2 A.KES 0	COHA 4 RTHA 2 A.KES 1	COHA 0 RTHA 1 A.KES 0	COHA 1 RTHA 1 A.KES 0	COHA 1 CBHA 1 RTHA 0 A.KES 4	COHA 1 RTHA 2 A.KES 0
2011	COHA 3 RTHA 4 A.KES 3	COHA 0 RTHA 3 A.KES 0	COHA 1 RTHA 2 A.KES 2	COHA 1 RTHA 0 A.KES 4	COHA 2 RTHA 2 A.KES 2	COHA 1 RTHA 3 A.KES 3	COHA 2 CBHA 1 RTHA 1 A.KES 0	COHA 2 RTHA 3 A.KES 3	COHA 0 CBHA 1 RTHA 4 A.KES 1
2012		COHA 0 RTHA 5 A.KES 1	COHA 1 RTHA 3 A.KES 4	COHA 6 CBHA 1 RTHA 0 A.KES 1	COHA 1 CBHA 3 RTHA 4 A.KES 3	COHA 1 CBHA 2 RTHA 1 A.KES 3	COHA 4 RTHA 7 A.KES 0	COHA 3 CBHA 3 RTHA 1 A.KES 3	COHA 4 CBHA 3 RTHA 4 A.KES 4

It is possible that the increased numbers of Cooper's hawks in August and September reflect juveniles possibly either hatched in Watson Woods, or these numbers may be reflective of post-breeding dispersal of juveniles or even adults.

The common black-hawk numbers in both August and September of 2012 reflect one juvenile. Given that a nest with a common black-hawk was found in Watson Woods along the Granite Creek Middle transect section with an adult sitting on it in April and around it in May is indicative that the juvenile observed was hatched in Watson Woods in 2012. This is the first record of common black-hawks nesting in the Preserve, although they have been found nesting downstream along Granite Creek north of Granite Dells for the past several years. This is a particularly exciting observation as the common black-hawk is a species of special conservation concern in high-elevation riparian areas by Arizona Partners in Flight program. Additionally, Prescott and the Verde Valley represent the northern-most extent of this raptor's range in Arizona (NGS, 2006).

There were no reports of a nesting pair in that area in 2012. Their nests have mostly been observed along streams with permanent water flow, and their diet, while varied, is mostly small creatures found in water such as fish, frogs, and crayfish (Kaufman, 1996). Since Granite Creek is not a permanent stream, and even standing water is less likely to be found in the Middle transect section than in either the North or the South sections, why did they choose to nest in Watson Woods especially in the area where the nest was found? Kaufman offers a possible answer. "In the United States [they also eat lizards], some small birds, snakes, rodents, and insects." (p. 125). These are all known to reside in the Preserve.

The final suite of birds to review are the resident birds. There are a number that live year round in Watson Woods. In addition to the raptor species discussed above, these include great blue herons, ladder-backed and hairy woodpeckers, northern flickers (also a woodpecker), black and Say's phoebes, white-breasted nuthatches, Bewick's wrens, European starlings, and red-winged blackbirds. With the occasional exception of red-winged blackbirds, they occur regularly but in low numbers. The four most abundant species, however, are mourning doves (MD), common ravens (CR), house finches (HF), and lesser gold-finches (LG). And while they live and breed in the Preserve, and are always present, their abundance seems to wax and wane. While reasons for this are not clear, but probably involve food availability, each of these species is quite adaptable, and they can and do live in other habitats such as suburban areas (they are frequently seen at yard feeders), pinyon-juniper habitat, and pine-oak habitat. Common ravens are even found in high-elevation mountains and tundra habitat and lower elevation desert habitat. Mourning doves and house finches can also be found in low-elevation desert habitat. Table 44 indicates the above four abundant resident species.

Table 44-Abundant Resident Species

Year	Nov.	Jan.	March	April	May	June	July	Aug.	Sept.
2008	MD 115 CR 32 HF 76 LG 47								
2009	MD 90 CR 17 HF 86 LG 34	MD 72 CR 65 HF 21 LG 25		MD 19 CR 17 HF 33 LG 54	MD 12 CR 5 HF 15 LG 31	MD 11 CR 2 HF 22 LG 22	MD 7 CR 3 HF 25 LG 33	MD 32 CR 13 HF 121 LG 133	MD 67 CR 15 HF 99 LG 304
2010	MD 60 CR 13 HF 24 LG 10	MD 42 CR 29 HF 90 LG 17	MD 19 CR 43 HF 31 LG 23	MD 33 CR 12 HF 33 LG 63	MD 35 CR 18 HF 55 LG 83	MD 7 CR 9 HF 18 LG 10	MD 12 CR 3 HF 26 LG 40	MD 16 CR 22 HF 99 LG 145	MD 35 CR 5 HF 174 LG 327
2011	MD 11 CR 27 HF 10 LG 10	MD 30 CR 10 HF 47 LG 9	MD 17 CR 14 HF 15 LG 19	MD 31 CR 24 HF 37 LG 112	MD 35 CR 7 HF 49 LG 47	MD 14 CR 9 HF 32 LG 37	MD 14 CR 5 HF 42 LG 26	MD 49 CR 27 HF 38 LG 86	MD 31 CR 16 HF 54 LG 121
2012		MD 52 CR 40 HF 50 LG 33	MD 19 CR 15 HF 19 LG 27	MD 28 CR 25 HF 52 LG 113	MD 53 CR 8 HF 70 LG 114	MD 21 CR 5 HF 18 LG 38	MD 24 CR 12 HF 20 LG 21	MD 32 CR 6 HF 30 LF 69	MD 23 CR 11 HF 114 LF 62

Of all the species listed and discussed in this report, the only two that show any trend in regard to increasing numbers across the four years is the common black-hawk and Bullock's oriole which showed an increased trend in numbers in late May and early June. Additionally, the data indicates minimal difference in species diversity across the four years. Of the neotropic migrants, only the bronzed cowbird was seen only in 2011 and 2012. It seems clear that four years of new habitat growth is not enough time to demonstrate recognizable changes in avian species numbers or diversity.

Overall Project Conclusions

In summary, Prescott Creeks believes the Restoration Project was a success. The restored reaches of the Granite Creek Channel are stable and functioning properly, and survivorship of planted trees exceeds 80%. In regard to vegetative analyses, overall average percent cover for woody plants increased from 4.5% (2009) to 31.9% (2012), and average height classes among plots increased from 1.0 (2009) to 4.2 (2012). In regard to macroinvertebrate studies, results showed habitat improvements within the Preserve, including increased canopy cover, riparian PFC score, and improved riffle habitat, as well as the establishment of a substrate sufficient for a functional intermittent stream community to develop.

While additional studies may be necessary to evaluate the effects of the Restoration Project on Herpetological and Avian Habitat, valuable baseline data was gathered and existing inventories were further expanded. In total, 19 reptile and amphibian species were observed within Watson Woods, and biodiversity and abundance of herpetological species appears to be increasing the Preserve. In regard to the bird surveys, results suggest an increase trend in numbers of two neotropic migrant species; common black-hawk and Bullock's oriole.

The goals of this project were to enhance and restore creek function and riparian habitat and create additional riparian habitat. Also, Prescott Creeks seeks to educate and involve the community in the restoration process of Granite Creek, summarized in Prescott Creeks' *Community Involvement Report* for the Watson Woods Riparian Preserve Restoration Project.

The objectives of the project were to:

- Restore the stability of the Granite Creek stream channel while maintaining natural dynamic stream processes, proper hydrologic conditions and functions, stream morphology and channel characteristics, and floodplain function;
- Enhance, restore, and create riparian vegetation and habitat within the Watson Woods Riparian Preserve;
- Educate and involve community members in the restoration process; and
- Monitor the biotic and abiotic environment to evaluate and communicate project performance.

Considering the overall results and analyses of the Restoration Project Professional Team and visible improvements within Watson Woods, Prescott Creeks believes that these goals and objectives were met.

Future Project Considerations

Watson Woods lends itself to additional restoration, enhancement, and preservation opportunities, along with additional monitoring activities and associated management plans. Following the conclusion of the Watson Woods Restoration Project, Prescott Creeks remains committed to managing the Preserve for the benefit of wildlife habitat, the City of Prescott, and the Granite Creek Watershed.

Management Considerations
Prescott Creeks will continue to practice sound management for Watson Woods in order to maintain the success of the Restoration Project and add new ecological features, again designed for the benefit of wildlife habitat and overall public awareness of the importance of riparian/wetland ecosystems. These considerations include the following:

- *Long-Term Protection*-The current management lease expires in 2020. Prescott Creeks intends to renew this management lease with the City of Prescott and explore the practicability for long-term protection.
- *Expansion Opportunities*-Prescott Creeks will continue to seek site expansions to Watson Woods, such as the adjacent upstream property that borders Granite Creek (Sundog Reach), the adjacent private land between Rosser St and Prescott Lakes Parkway on the western border of the Preserve, and the ~40 acres of cottonwood/willow forest associated with the upper reaches of Watson Lake.
- *Site Improvements*-Prescott Creeks believes that additional site improvements will be beneficial to the Preserve. Examples include new fencing, gates, parking area improvements, as well as artistically painting the existing Prescott Lakes Parkway Bridge.
- *Preserve Use-Policy*-Prescott Creeks is committed to managing Watson Woods primarily as a nature preserve for the purpose of improving wildlife habitat. As such, any program such as nature walks and school presentations will be organized and conducted with this goal as the primary focus.
- *Watershed Programs*-Watson Woods is a key area within the Granite Creek Watershed, as a vast majority of surface water in Prescott ultimately flows through the Preserve prior to entering Watson Lake. Prescott Creeks intends to further develop its existing Watershed Program, and seek ecological restoration projects in order to enhance the features of the Preserve as well as the watershed as a whole.

Habitat Improvements
Prescott Creeks will begin to develop the "next phase" of habitat restoration/enhancement/preservation projects within Watson Woods in 2013. This includes targeted invasive species control of several herbaceous species such as Scotch Thistle, Common Teasel, Dalmation Toadflax, and Spotted Knapweed, along with woody species such as Tamarisk and Siberian Elm. As shown in the vegetation analyses, these species are not only prevalent within the Preserve but are widespread throughout the Granite Creek Watershed. Prescott Creeks considers invasive species control and eradication crucial to overall ecosystem health.

Prescott Creeks intends to conduct additional vegetative plantings to promote a more diverse forest structure, which would incorporate species such as Arizona walnut (*Juglans major*), velvet ash (*fraxinus velutina*), boxelder (*Acer negundo*), and chokecherry (*Prunus virginiana*), along with additional plantings of native grasses and forbs. Further analyses of existing surface elevation within the Preserve could also reveal additional locations to establish wetlands and expand the riparian corridor.

Stream Restoration
There have been new developments and refinement of some stream stabilization practices since the initial design was conceived and implemented. Below is a summary of practices that could be implemented during future work at the Preserve or other areas that might help to further stabilize/improve Granite Creek and benefit the watershed. The first is the design and placement of pools to help with energy dissipation of the channel. Within Watson Woods, a meandering stream alignment was designed with the thought that the stream would create pools at the proper areas based on the energy dissipation needs of the stream. While this does take place naturally, it can be a slow process and unanticipated adjustments to a re-designed channel can occur, as was the case in the Preserve when the large flow took place prior to pool development. Dr. Dave Rosgen of Wildland Hydrology has been

developing design criteria for the sizing and placement of pools within a stream. With proper sizing and placement, a pool can help to alleviate stresses and erosion along a meander, ultimately stabilizing the stream and enhancing riparian/aquatic habitat.

Another practice that has been developed is the use of toe wood and the formation of bankfull benches. This is a practice that is used along the outside banks along meanders in lieu of rock. This practice utilizes tree trunks and associated root balls placed along the toe of the bank as a scaffold to hold soil. A narrow bench is then constructed on top of the wood which allows flood waters to spread out of the channel thereby reducing the stress against a bank. In addition, submerged aquatic habitat can be developed with this type of structure. Within the Preserve, this practice could replace several sections of toe rock, thereby eliminating the need for importing large rock into a system that does not have naturally occurring large rock.

Monitoring along Granite Creek in Watson Woods should continue. At the very least, the channel should be walked seasonally and again after any larger (> 5 year) flood event. This observation will help to identify any potentially detrimental or undesirable channel changes so that appropriate action can be taken.

Re-measuring the channel cross sections can provide valuable insight to the continuing evolution of the channel morphology. Measuring channel cross-sections every three to four years (as well as after major flooding events) can provide insight to the formation and maintenance of stable channel cross-sections. This monitoring can also capture subtle changes that occur over time. If the cross sections are measured only after flooding events, some changes to the cross-sections could mistakenly be attributed to the flood event, even though they have actually been slowly evolving over time.

In addition to monitoring the cross-sections, measuring of the channel bed profile can also provide insight to channel evolution. The formation of riffle-pool sequences can provide valuable reference for future projects both within the Preserve and elsewhere. Photo monitoring at the photo points could be continued yearly with little effort and would show the continuing progression of the riparian habitat and stream channel. These photos can also help in future restoration activities by giving an indication on how long it will take vegetation to reach a desired growth height and cover.

Macroinvertebrate Zoology

The study of macroinvertebrates is critical to understanding the overall health of the waters within Watson Woods, as well as the larger Granite Creek Watershed. Prescott Creeks' aquatic biologist, Patti Spindler, has developed and utilized methods as part of this project, such as the *Intermittent Index of Biological Integrity* and the *Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers*¸ along with methods that can be used by volunteers. With these methods in place and initial baseline data complete, Prescott Creeks will continue to seek available programs for these studies.

Herpetological Studies

Prescott Creeks believes that dedicated inventories and continued monitoring of herpetofauna would be beneficial to understanding conditions within the Preserve and planning for future projects. There are many interesting ecological questions that could be asked by building on the current inventory; e.g. how will the abundance of Plateau Fence Lizards, which seem to occupy every terrestrial habitat at Watson Woods, and Ornate Tree Lizards, which appear primarily restricted to habitats containing trees or dead logs, change as restoration plantings mature? Will new species of litter-adapted herpetofauna, (e.g. skinks, *Plestiodon* spp.) expand into Watson Woods as its riparian woodland habitat matures? How, or will, climate change affect amphibian and other species' breeding phenologies and persistence? Will native or non-native species currently living elsewhere expand their ranges into this area if regional climate patterns cause vegetation community changes? It is important to address these questions as additional restoration work is pursued within the Preserve.

Watson Woods could also be used as sort of a natural laboratory or comparison site to assess the importance of environmental perturbation on aquatic organisms. One such study could assess the degree to which the Granite Creek Watershed contaminants, particularly estrogenic compounds, are affecting local amphibian and fish populations; ongoing research near Flagstaff might provide suggestions for comparison sites (C. Propper, pers.

comm.). Previously-mentioned studies include the assessment of the effects of invertebrate predators (and perhaps contaminants) on the transformation rates of larval amphibians, and also an assessment of observable effects of noise pollution on amphibian breeding success.

Even without the presence of dedicated monitoring or experimental research, important observations can continue to be made and new species documented, as they were during our research, by careful volunteer observers. Proper documentation of unusual species should include the date, location within Watson Woods, GPS coordinates, and a picture or careful description of the animal in question.

Large Mammal Studies

Although a variety of large mammals have been observed/documented within the Preserve, Prescott Creeks believes that formal studies/surveys could provide further insight on management concerns, the effects of the restoration activities and future project considerations. Basic surveys using motion-detection cameras, live traps, and analyzing footprints could be conducted in order to establish a baseline, but surveys spanning across multiple seasons/years would be ideal as this would allow analyses of species composition and abundance compared to vegetative growth and climatic conditions, establishing patterns of species that occupy the Preserve.

Ornithology

As noted above, it seems clear that four years of new habitat growth is not sufficient to demonstrate recognizable changes in avian species numbers or diversity resulting from the restoration efforts at the Preserve. Prescott Creeks, the Prescott Audubon Society, and the Arizona Important Bird Area program have all expressed an interest in continued collaboration to assess change in the Preserve. All have expressed support for additional survey efforts continuing for the foreseeable future. A core of the 34 volunteers has offered to continue monitoring efforts although at a reduced level of effort (four times a year). These results will be entered in *eBird*, an international internet data base that is a program of Cornell Laboratory of Ornithology and from which the results can be easily downloaded to the Arizona Bird Area program. Results will also be shared with Prescott Creeks.

Collaborative Planning

Prescott Creeks is committed to gather additional resources, gain partners, and maintain a collaborative professional team. The Watson Woods Riparian Preserve Restoration Project could have only been possible with all parties working towards common goals. While the project was largely a success, many unforeseen circumstances required various members of the team to employ adaptive management practices and adjust previous plans and typical methodologies. As new projects are developed, planned, and implemented, Prescott Creeks will consider team collaboration a top priority.

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