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GIS Practicum

Investigating Relationships Between Native Arizona Fish Populations and Riparian Vegetation Composition Using GIS

Introduction:

Aravaipa Creek is an important conservation location for biologists who look to preserve native fishes in Arizona. This narrow, winding canyon is lined with lush riparian habitat and meanders through both private and federal lands. Its 19-mile long perennial reach supports a multitude of native wildlife. Flows in the upper reaches of the creek are intermittent. Within the preserved lands the flow becomes perennial, fed by springs, seeps, and tributary streams. Aravaipa Creek has been known to flood and many projects have described the watershed system in the area. Aravaipa Creek is the strongest assemblage of native endangered fish species with 7 remaining species and this habitat is critical to their survival. While many studies have been conducted about the health of this ecosystem and the species that reside in the creek there is still a lack of information about the area. This study helps to provide more insight into the relationship of vegetation cover and endangered fish habitat, specifically for the spikedace (*Meda fulgida).*

Keeping Aravaipa Creek healthy is not only critical for the native fishes but also for the well being of the San Pedro River Valley as it is a major tributary to the San Pedro River. It is an important source of water for both humans and wildlife. An area near Aravaipa Creek called Cobra Ranch was incorporated into the preserve a few years ago and the land was in rough shape. Without healthy native grasses to hold the soil into place the land failed to absorb water properly, causing runoff and significant soil erosion. Less water in the soil meant less water to nourish plants and less water in the aquifer, which recharges Aravaipa Creek. Mark Haberstich, who works for The Nature Conservancy, has helped to plant native grasses on Cobra Ranch to help the overall health of Aravaipa Canyon. This is just one example of why vegetation is so important to the health of this ecosystem. It brings into question the importance of different plant species along the river. Arguably different plant assemblages can impact fish diversity and abundance.

Riparian vegetation is a good measure of ecosystem health and provides excellent habitat for terrestrial species. It also provides excellent support for fish assemblages. It can provide bank stabilization and water quality protection. Roots of riparian trees and shrubs help hold the stream bank into place to prevent erosion. It can also trap sediments and pollutants, helping keep the water clean and habitable. It supports the local food chain by providing shelter for aquatic insects, which spend most of their time in the water and are a food source. Standing riparian vegetation also houses other insects, which sometimes fall into the water, providing another source of input in the riparian food web. The vegetation also provides thermal cover, shielding the creek from summer and winter temperature extremes that may be very harmful, or even fatal, to fish and other aquatic life. Cover brings shade, which helps keep the creek temperature cool in the summer and moderate in the winter. Cooler, shaded streams have fewer algae and are able to hold more

dissolved oxygen. Finally, dying, uprooted trees fall into the steam. Their trunks, roots, and branches slow the flow of water and create large snags. These snags are good fish habitat because they form pools and riffles in the stream. Riffles are shallow, gravelly sections of the stream where water runs faster. Many insects can leave in these riffles and are a great place for fish to feed.

This study investigates if there is a relationship between riparian vegetation along Aravaipa Creek and native endangered fish habitat. Many studies have been done to look at the correlation between stream depth, water clarity, and available nutrients for native endangered fishes but none have questioned the relationship between native vegetation and endangered habitat. Considering the importance of the native vegetation into the creek system is appears there could be a strong correlation between the two, especially for sensitive endangered species.

Methods:

Seven native fish species still appear in parts of Aravaipa Creek, though the extent of their habitats along the creek is debatable. While all species have been historically caught along the full length of Aravaipa Creek some have not been spotted in certain recesses for quite some time. The Nature Conservancy's Center for Science and Public Policy has constructed an Arizona Statewide Freshwater Assessment GIS package. It includes 4 GIS datasets mapped 1:100,000 scale stream-based hydrography in Arizona. This includes the habitat for 33 native fish species, former and current perennial flow, and the distribution for threatened and endangered species that require aquatic or riparian habitats. The seven species in Aravaipa Creek share, according to The Nature Conservancy, a stronghold of habitat within a portion of the creek. This area consistently hosts the highest diversity of native endangered species and was used in this analysis.

The spikedace (*Meda fulgida)* was looked at more in depth than the other 6 remaining endangered species. For each aquatic habitat it resides in (Aravaipa Creek, Verde River, Cienega Creek, and Gila River) a comparison was done between its known/historical habitat vegetation, and the vegetation of the entire stream. This same process was done for the stronghold habitat in Aravaipa Creek. The vegetation data comes from the Southwest Regional GAP Analysis Project (GAP). A seamless landcover product was produced in 2004. In Arizona there are approximately 77 different vegetation classifications. This is arguably the most complex, large-scale landcover analysis of the state. It works well for this particular hypothesis because of the number of distinct classes. Riparian vegetation occurs only along the sides of an aquatic environment. They are considered corridors because they are narrow and hug water. Since there is a large number of detailed classes it makes it easier to delineate between different environments along this very narrow stretch of land. If there were only 2 or 3 riparian vegetation classes this analysis would not be accurate or even possible.

The majority of this analysis was done using ArcGIS 10.0. The products were then inputted into excel and additional calculations were made. The GAP land cover vegetation layer was added along with the hydrologic routes layer. The spikedace, speckled dace, Sonora sucker, roundtail chub, longfin dace, loach minnow, and

desert sucker Arizona habitat layers were also added, making up the 7 endangered fish species studied. Aravaipa Creek was then clipped out of the Arizona hydrologic routes layer. Each of the 7 fish habitats in Aravaipa Creek were then clipped out of their respective general habitat layer. Since the true habitat of each of the 7 endangered species in Aravaipa Creek is constantly fluxing, The Nature Conservancy has made it so that each of the 7 species has the same polyline for Aravaipa Creek which means analysis needs to be done only on that one polyline for all 7 species.

The common polyline was then buffered by 30 meters on both sides to assess the riparian vegetation classes around the creek. This unit of measurement was chosen because the GAP vegetation layer was created from an original Landsat ETM+ image with a 30-meter resolution. This is the smallest unit possible to buffer the edge of the creek. The GAP layer was then extracted by mask for the 30-meter buffer zone to get land cover in that buffer zone. Open water was eliminated from the vegetation classes, as it is not a plant assemblage. The extracted vegetation cells were then saved into an excel spreadsheet for further analysis. The entire Aravaipa Creek was then buffered at 30-meters and the vegetation information was extracted by mask to an excel worksheet. These two vegetation assemblages were then compared to one another to assess probability that the vegetation the endangered species were found in was randomly chosen from the overall vegetation of Aravaipa Creek.

This same methodology was used for the spikedace habitat. Verde River, Gila River, and Cienega Creek were clipped out of the Arizona hydrologic routes layer. It is important to note that The Nature Conservancy has the spikedace also inhabiting Eagle Creek, but the shapefile shows that it inhabits the full length of Eagle Creek and therefore is not useful in this experiment. Each hydrologic unit was then buffered by 30-meters and the vegetation information was extracted by mask and then uploaded into excel. The spikedace habitat for each hydrologic unit was then clipped from the overall habitat, the vegetation was extracted by mask for each unit, and that information was then also uploaded into excel.

To test whether the endangered fish were more likely to use a specific vegetative area a chi-square test was performed. For each habitat the percent of each vegetative class was calculated for the whole aquatic habitat, and then for the habitat used by the endangered fish. These percentages were used in the chi-square analysis.

Results:

Table 1: Aravaipa Creek, All Species

Endangered Species Habitat (7)			All Habitat			
Veg Type	Count	Percentage	Veg Type	Count	Percentage	Chi-Square
15	0	0.0	15	10	0.2	0.2
19	0	0.0	19	22	0.5	0.5
45	0	0.0	45	12	0.3	0.3
51	0	0.0	51	30	0.6	0.6
52	536	22.6	52	1543	33.0	3.3
55	0	0.0	55	1	0.0	0.0
56	0	0.0	56	308	6.6	6.6
57	227	9.6	57	176	3.8	8.9
59	0	0.0	59	39	0.8	0.8
60	0	0.0	60	12	0.3	0.3
65	0	0.0	65	729	15.6	15.6
80	197	8.3	80	203	4.3	3.6
83	1105	46.5	83	730	15.6	61.3
84	233	9.8	84	169	3.6	10.6
92	47	2.0	92	30	0.6	2.8
96	10	0.4	96	381	8.1	7.3
105	19	0.8	105	268	5.7	4.2
114	0	0.0	114	15	0.3	0.3
118	1	0.0	118	1	0.0	0.0
TOTAL	2375		TOTAL	4679		127.3
						DF=18
						P(0.001)=42.312

<u>Endangered Species Dominant Landcover</u>: North American Warm Desert Riparian Woodland and Shrubland (46.5%)
<u>Description</u>: This ecological system consists of low-elevation (<1,200 m) riparian corridors along medium to large perennial streams. The vegetation is a mix of riparian woodlands and shrublands. Dominant trees include *Acer negundo*, *Fraxinus velutina*, *Populus fremontii*, *Salix gooddingii*, *Salix lasiolepis*, *Celtis laevigata* var. *reticulata*, and *Juglans major*. Shrub dominants include *Salix geyeriana*, *Shepherdia argentea*, and *Salix exigua*. Vegetation is dependent upon annual or periodic flooding and associated sediment scour and/or annual rise in the water table for growth and reproduction.

<u>Aravaipa Dominant Landcover</u>: Apacherian-Chihuahuan Mesquite Upland Scrub (33%)
<u>Description</u>: Substrates are typically derived from alluvium, often gravelly without a well-developed argillic or calcic soil horizon that would limit infiltration and storage of winter precipitation in deeper soil layers. *Prosopis* spp. and other deep-rooted shrubs exploit this deep soil moisture that is unavailable to grasses and cacti.

Prosopis glandulosa or *Prosopis velutina* and succulents typically dominate vegetation. Other desert scrub that may codominate includes *Acacia neovernicosa*, *Acacia constricta*, *Juniperus monosperma*, or *Juniperus coahuilensis*. Grass cover is typically low. During the last century, the area occupied by this system has increased through conversion of desert grasslands as a result of drought, overgrazing by livestock, and/or decreases in fire frequency.

Table 2: Spikedace (*Meda fulgida)* Verde River

Verde River-Spikedace			Verde River-All			
Veg Type	Count	Percentage	Veg Type	Count	Percentage	Chi-Square
19	27	0.4	19	33	0.2	0.4
33	30	0.4	33	31	0.2	0.6
36	309	4.6	36	322	1.6	5.9
51	670	10.0	51	803	3.9	9.5
52	1814	27.1	52	3238	15.8	8.1
56	9	0.1	56	7	0.0	0.3
57	14	0.2	57	6761	33.0	32.6
60	19	0.3	60	258	1.3	0.8
61	0	0.0	61	8	0.0	0.0
64	1	0.0	64	1	0.0	0.0
65	2	0.0	65	48	0.2	0.2
80	2592	38.8	80	3564	17.4	26.3
83	3	0.0	83	1525	7.4	7.3
84	0	0.0	84	276	1.3	1.3
92	715	10.7	92	865	4.2	9.9
95	15	0.2	95	135	0.7	0.3
105	93	1.4	105	157	0.8	0.5
110	98	1.5	110	2019	9.8	7.1
112	275	4.1	112	310	1.5	4.5
114	0	0	114	117	0.6	0.6
118	0	0	118	29	0.1	0.1
TOTAL	6686		TOTAL	20507		116.5
						DF=20
						P(0.001)=45.32

<u>Spikedace Dominant Land Cover</u>: North American Warm Desert Lower Montane Riparian Woodland and Shrubland (38.8%)
<u>Description</u>: The vegetation is a mix of riparian woodlands and shrublands. Dominant trees include *Populus angustifolia*, *Populus deltoides* ssp*. wislizeni*, *Populus fremontii*, *Platanus wrightii*, *Juglans major*, *Fraxinus velutina*, and *Sapindus saponaria*. Shrub dominants include *Salix exigua*, *Prunus* spp., *Alnus oblongifolia*, and *Baccharis salicifolia*. Vegetation is dependent upon annual or periodic flooding and

associated sediment scour and/or annual rise in the water table for growth and reproduction.

Dominant Verde River Land Cover: Sonoran Paloverde-Mixed Cacti Desert Scrub (33.0%)
Description: The vegetation is characterized by a diagnostic sparse, emergent tree layer of *Carnegia gigantea* and/or a sparse to moderately dense canopy codominated by xeromorphic deciduous and evergreen tall shrubs *Parkinsonia microphylla* and *Larrea tridentata* with *Prosopis* sp., *Olneya tesota*, and *Fouquieria splendens* are less prominent. Other common shrubs and dwarf-shrubs include *Acacia greggii*, *Ambrosia deltoidea*, *Ambrosia dumosa*, *Calliandra eriophylla*, *Jatropha cardiophylla*, *Krameria erecta*, *Lycium* spp., *Menodora scabra*, *Simmondsia chinensis*, and many cacti including *Ferocactus* spp., *Echinocereus* spp., and *Opuntia* spp. The sparse herbaceous layer is composed of perennial grasses and forbs with annuals seasonally present and occasionally abundant.

Table 3: Spikedace (*Medafulgida*) Gila River

Gila River-Spikedace			Gila River-All			
Veg Type	Count	Percentage	Veg Type	Count	Percentage	Chi-Square
19	0	0.0	19	115	0.2	0.2
33	0	0.0	33	3	0.0	0.0
51	0	0.0	51	88	0.2	0.2
52	154	3.9	52	5230	9.9	3.6
56	6	0.2	56	594	1.1	0.8
57	942	23.8	57	11788	22.2	0.1
60	99	2.5	60	11391	21.5	16.8
61	0	0.0	61	1533	2.9	2.9
65	0	0.0	65	225	0.4	0.4
80	0	0.0	80	1001	1.9	1.9
83	1015	25.7	83	6673	12.6	13.6
84	475	12.0	84	4195	7.9	2.1
92	0	0.0	92	26	0.0	0.0
95	0	0.0	95	1	0.0	0.0
96	35	0.9	96	1113	2.1	0.7
105	0	0.0	105	926	1.7	1.7
111	1	0.0	111	1	0.0	0.3
112	1	0.0	112	27	0.1	0.0
113	0	0.0	113	49	0.1	0.1
114	845	21.4	114	3511	6.6	32.9
118	379	9.6	118	4507	8.5	0.1
TOTAL	3952		TOTAL	52997		79
						DF=20
						P(0.001)=45.32

Spikedace Dominant Landcover: Rocky Subalpine Mesic Meadow (25.7%)
Description: Vegetation is typically forb-rich, with forbs contributing more to overall herbaceous cover than graminoids. Important taxa include *Erigeron* spp., *Asteraceae* spp., *Mertensia* spp., *Penstemon* spp., *Campanula* spp., *Lupinus* spp., *Solidago* spp., *Ligusticum* spp., *Thalictrum occidentale*, *Valeriana sitchensis*, *Balsamorhiza sagittata*, *Wyethia* spp., *Deschampsia caespitosa*, *Koeleria macrantha*, and *Dasiphora fruticosa*.
Spikedace Dominant Landcover: Sonoran Paloverde-Mixed Cacti Desert Scrub (23.8%)
Description: The vegetation is characterized by a diagnostic sparse, emergent tree layer of *Carnegia gigantea* and/or a sparse to moderately dense canopy codominated by xeromorphic deciduous and evergreen tall shrubs *Parkinsonia microphylla* and *Larrea tridentata* with *Prosopis* sp., *Olneya tesota*, and *Fouquieria splendens* are less prominent. Other common shrubs and dwarf-shrubs include *Acacia greggii*, *Ambrosia deltoidea*, *Ambrosia dumosa*, *Calliandra eriophylla*, *Jatropha cardiophylla*, *Krameria erecta*, *Lycium* spp., *Menodora scabra*, *Simmondsia chinensis*, and many cacti including *Ferocactus* spp., *Echinocereus* spp., and *Opuntia* spp. The sparse herbaceous layer is composed of perennial grasses and forbs with annuals seasonally present and occasionally abundant.
Spikedace Dominant Landcover: Agriculture (21.4%)
Description: An aggregated landcover type that includes both pasture and hay. Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle, where pasture/hay vegetation accounts for greater than 20 percent of total vegetation. Areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards, where crop vegetation accounts for greater than 20 percent of total vegetation. Also includes land being actively tilled.

Gila River Dominant Landcover: Inter-Mountain Basins Greasewood Flat (22.2%)
Description: This system usually occurs as a mosaic of multiple communities, with open to moderately dense shrublands dominated or codominated by *Sarcobatus vermiculatus*, *Atriplex canescens*, *Atriplex confertifolia*, or *Krascheninnikovia lanata* may be present to codominant. Occurrences are often surrounded by mixed salt desert scrub. The herbaceous layer, if present, is usually dominated by graminoids. There may be inclusions of *Sporobolus airoides*, *Distichlis spicata*, or *Eleocharis palustris* herbaceous types.
Gila River Dominant Landcover: Sonora-Mojave Creosotebush-White Bursage Desert Scrub (21.5%)
Description: This desert scrub is characterized by a sparse to moderately dense layer of xeromorphic microphyllous and broad-leaved shrubs. *Larrea tridentata* and *Ambrosia dumosa* are typically dominants, but many different shrubs, dwarf-shrubs, and cacti may codominate or form typically sparse understories. Associated species may include *Atriplex canescens*, *Atriplex hymenelytra*, *Encelia farinosa*, *Ephedra nevadensis*, *Fouquieria splendens*, *Lycium andersonii*, and *Opuntia basilaris*. The herbaceous layer is typically sparse, but may be seasonally abundant with

ephemerals. Herbaceous species such as *Chamaesyce* spp., *Eriogonum inflatum*, *Dasyochloa pulchella*, *Aristida* spp., *Cryptantha* spp., *Nama* spp., and *Phacelia* spp. are common.

Table 4: Spikedace (*Meda fulgida*) Cienega Creek

Cienega Creek-Spikedace			Cienega Creek-All			
Veg Type	Count	Percentage	Veg Type	Count	Percentage	Chi-Square
33	16	5.1	33	339	15.0	6.6
34	0	0.0	34	231	10.2	10.2
45	0	0.0	45	21	0.9	0.9
51	193	61.3	51	350	15.5	134.7
52	17	5.4	52	43	1.9	6.4
65	0	0.0	65	35	1.6	1.6
80	56	17.8	80	273	12.1	2.7
92	31	9.8	92	959	42.5	25.1
95	2	0.6	95	3	0.1	1.9
TOTAL	315		TOTAL	2254		190.1
						DF=8
						P(0.001)=26.13

<u>Spikedace Dominant Landcover</u>: Mogollon Chaparral (61.3%)
<u>Description</u>: The moderate to dense shrub canopy includes species such as *Quercus turbinella*, *Quercus toumeyi*, *Cercocarpus montanus*, *Canotia holacantha*, *Ceanothus greggii*, *Forestiera pubescens*, *Garrya wrightii*, *Juniperus deppeana*, *Purshia stansburiana*, *Rhus ovata*, and *Rhus trilobata*. Most chaparral species are fire-adapted, resprouting vigorously after burning or producing fire-resistant seeds. Stands occurring within montane woodlands are seral and a result of recent fires.

<u>Cienega Creek Dominant Landcover</u>: Madrean Pinyon-Juniper Woodland
<u>Description</u>: Substrates are variable, but soils are generally dry and rocky. The presence of *Pinus cembroides*, *Pinus discolor*, or other Madrean trees and shrubs are diagnostic of this woodland system. *Juniperus coahuilensis*, *Juniperus deppeana*, *Juniperus pinchotii*, *Juniperus monosperma*, and/or *Pinus edulis* may be present to dominant. Madrean oaks such as *Quercus arizonica, Quercus emoryi*, *Quercus grisea*, or *Quercus mohriana* may be codominant. *Pinus ponderosa* is absent or sparse. If present, understory layers are variable and may be dominated by shrubs or graminoids.

Table 5: Spikedace (*Meda fulgida)* Eagle Creek

Eagle Creek		
Vegetation Type	Count	Percentage
33	23	0.4
51	552	8.8
52	2083	33.3
56	37	0.6
57	36	0.6
65	97	1.6
80	1875	30.0
83	14	0.2
84	4	0.1
92	1218	19.5
95	15	0.2
105	298	4.8
TOTAL	6252	

Dominant Eagle Creek Landcover: Southern Rocky Mountain Montane-Subalpine Grassland (33.3%)
Description: Usually consists of a mosaic of two or three plant associations with one of the following dominant bunch grasses: *Danthonia intermedia*, *Danthonia parryi*, *Festuca idahoensis*, *Festuca arizonica*, *Festuca thurberi*, *Muhlenbergia filiculmis*, or *Pseudoroegneria spicata*. The subdominants include *Muhlenbergia montana*, *Bouteloua gracilis*, and *Poa secunda*. These large-patch grasslands are intermixed with matrix stands of spruce-fir, lodgepole, ponderosa pine, and aspen forests.
Dominant Eagle Creek Landcover: North American Warm Desert Lower Montane Riparian Woodland and Shrubland (30.0%)
Description: The vegetation is a mix of riparian woodlands and shrublands. Dominant trees include *Populus angustifolia*, *Populus deltoides* ssp. *wislizeni*, *Populus fremontii*, *Platanus wrightii*, *Juglans major*, *Fraxinus velutina*, and *Sapindus saponaria*. Shrub dominants include *Salix exigua*, *Prunus* spp., *Alnus oblongifolia*, and *Baccharis salicifolia*. Vegetation is dependent upon annual or periodic flooding and associated sediment scour and/or annual rise in the water table for growth and reproduction.

*The landcover descriptions were referenced from the GAP analysis project. These descriptions were printed in their final report and correspond to the GAP vegetation layer used in ArcGIS. The landcover legend description database can be found at http://earth.gis.usu.edu/swgap/legenddataquery.php.

Discussion:

Aravaipa Creek has a dominant vegetation of Apacherian-Chihuahuan Mesquite Upland Scrub. The other vegetation types that make up the rest of the habitat along the creek are only small percentages of other vegetation classes. However, the area that the 7 endangered species make up consists mainly of North

American Warm Desert Riparian Woodland and Shrubland. This class only compromised 15.6% of Aravaipa Creek vegetation and yet it made up 45.6% of the endangered species habitat. The Apacherian-Chihuahuan landcover consisted mainly of *Prosopis* spp. with some *Acacia* spp. with little grass cover. The Warm Desert Riparian landcover includes *Fraxinus velutina, Populus fremontii,* and *Salix gooddingii.* It also has a prominent shrubland including some *Salix* spp. The Apacherian-Chihuahuan vegetation has increased due to the conversion of desert grasslands into mesquite lands due to drought, overgrazing by livestock, and decreases in fire frequency. This disturbed environment, while the majority of Aravaipa Creek, is likely not good cover for the endangered fish species which is likely why they have flocked to the lusher Warm Desert Riparian area that has a higher density of native grasses and larger trees, such as the *Fraxinus velutina* and *Populus fremontii*.

The results for the spikedace were not as predictable as the Aravaipa Creek endangered species. In the Verde River the spikedace was found in the North American Warm Desert Lower Montane Riparian Woodland and Shrubland, which was the same for the endangered species in Aravaipa Creek. This specific habitat only consisted of 17.4% of all Verde River vegetation. The most dominant landcover class in Verde River was Sonoran Paloverde-Mixed Cacti Desert Scrub at 33%, but it only compromised 0.2% of spikedace habitat. This vegetation class is characterized by *Larrea tridentata* and *Prosopis* spp. The area is also home to many cacti. The herbaceous layer is sparse but does consist of native vegetation. Between Aravaipa Creek and Verde River it appears that *Prosopis* spp. and cacti are not favorable environmental factors for spikedace but having a native herbaceous layer can be favorable.

The results for the Gila River for the spikedace was not as expected and it deviated significantly from Aravaipa Creek and Verde River. The landcover for spikedace habitat was split relatively evenly between Rocky Subapline Mesic Meadow (25.7%), Sonoran Paloverde-Mixed Cacti Desert Scrub (23.8%), and Agriculture (21.4%). The Rocky Subapline is typically forb-rich and shares the general characteristics of a meadow with a lack of large trees for cover. This is a significant change from Aravaipa Creek and Verde River where the presence of *Populus fremontii, Platanus wrightii, Juglans major,* and *Fraxinus velutina* appeared to be the key contributor in spikedace habitat. The Sonoran Paloverde-Mixed Cacti also had vegetation that was unexpected and was not utilized at the Verde River at only 0.2%. The herbaceous layer of perennial grasses and forbs may be the reason that it was considered suitable habitat for spikedace at the Verde River. Finally, the agriculture land compromised a large portion of the Gila River spikedace habitat. It only compromises 6.6% of all of Gila River vegetation but compromises 21.4% of spikedace habitat. This is odd considering traditionally in Aravaipa Creek the damaging effects of agricultural use constricted endangered species habitat. The Gila River dominant landcover was also split between Inter-Mountain Basins Greasewood Flat (22.2%) and Sonora-Mojave Creosotebush-White Bursage Desert Scrub (21.5%). The Greasewood Flats is dominated by salt desert scrub, which is generally an indicator of a drier environment, which probably indicated stream/water quality that is unfavorable to the spikedace. The Sonora-Mojave is

dominated by *Larrea tridentata* and cacti. This is similar to the Aravaipa Creek and Verde River assessments.

In Cienega Creek Mogollon Chaparral dominates spikedace habitat with a strong 61.5%. The moderate shrub canopy includes several *Quercus* spp., *Ceanothus greggii*, and *Garrya wrightii*. Most chaparral species are fire-adapted and resprout after burning or producing fire-resistant seeds. This, along with the strong presence in agriculture land in Gila River, suggests that the spikedace can do well in habitats that are prone to disturbance. The *Quercus* spp. is also a genus that has been environmentally advantageous because of its acorns. The Mogolloan Chaparral only consists of 15.5% of Cienega Creek vegetation but is the majority of spikedace landcover. Madrean Pinyon-Juniper is the most common landcover type in Cienega Creek but is only 9.8% of spikedace habitat. It is dominated by pine species and the substrate is generally dry and rocky. Considering they are evergreen their input into the river system will not be as substantial as other species of plants, but they could still provide shade and insulation to the water.

Finally, the spikedace is found in all reaches of Eagle Creek. Its landcover is split fairly evenly to Southern Rocky Mountain Montane-Subalpine Grassland (33.3%) and North American Warm Desert Lower Mountain Riparian Woodland and Shrubland (30.0%). The Riparian Woodland is the same vegetation aggregation as Aravaipa Creek and Verde River and is beneficial for the same reasons. The Southern Rocky Mountain habitat is dominated by bunch grasses with subdominants of *Muhlenbergia montana, Boutelous gracilis,* and *Poa secunda*. The combination of native grasses can be very beneficial for spikedace and the sporadic cover of pine, fir, or aspen could provide adequate cover.

For each aquatic habitat it was statistically shown at P(0.001) that the vegetation the endangered species or spikedace was found differed from the overall landcover classes for the entire habitat. There could be several reasons for this, many of them likely due to aquatic habitat, but there are some apparent conclusions about vegetation and habitat quality for endangered native fishes. Good tree cover provided by large *Populus* spp., *Quercus* spp., pine, etc. is an indicator of appropriate habitat for the endangered species. However, *Prosopis* spp. and *Larrea tridentata* seemed to be negatively associated with suitable habitat. The same was also true of most cacti species. A common chord throughout each potential habitat was that herbaceous native grasses were present. This seems to be a great indicator for endangered species being present, even when larger shade trees are not present they are strongholds for native fish. This expounds on Mark Haberstich's work with The Nature Conservancy. While his goal was not to improve native fish abundance directly it appears that by planting native grasses it improves endangered fish habitat. However, there is some unexplained data.

It was confounding that native fishes seemed to selectively choose agricultural land in Gila River. There could be other factors that determined the choice of that particular habitat, such as water quality at other sites, but the Gila River is of good size and there are 21 different landcover classes along its banks. But it also must be taken into consideration that the agriculture lands, as described by the GAP vegetation index, include lands that are dominated by harvested herbaceous species, which is an indicator of native fishes. Native fishes are used to

disturbance in their habitats due to the unpredictable rains and long summers of Arizona. This could perhaps indicate that they can withstand some human disturbance so long as key habitat qualities remain, such as native herbaceous vegetation. There also seems to be a hierarchy within the habitat selection. Some habitats were dominant in some systems and then underutilized in others, especially when North American Warm Desert Riparian Woodland and Shrubland was present. This suggests that specific species could input the greatest benefits into the system but others can do an appropriate job in their absence, which can impact how we improve and revegetate existing riparian areas.

Conclusion and Considerations:

As an exploratory experiment is it evident that are many more questions to be investigated when it comes to landcover composition and native fish abundance. There seems to be some general ties, such as adequate tree cover and native grass abundance, but there are still several vegetation compositions left unexplained. There are also limitations to this experiment. While the GAP vegetation is comprehensive and adequately detailed it only encompasses three years of Landsat ETM+ data, from 1999-2001. The Nature Conservancy's map of endangered species is, while up to date, debatable. The location of many native Arizona fishes is a point of contention between biologists as they can be hard to find. However, considering the crisis the native fishes of Arizona are facing, this experiment is a foot in the right direction. By understanding any relationships between landcover vegetation, aquatic health, and endangered species there is potential to revegetate riparian habitats for the benefit of native fishes.