# NM WRRI Student Water Research Grant Progress Report Form

**Progress Report due Thursday, February 1, 2024**
**Draft Final Report due Monday, July 15, 2024**
**Final Report due Friday, August 30, 2024**

1. Student Researcher: Ashlyn Reynolds
   Faculty Advisor: Dr. Zachary A. Mitchell

2. Project title: *Does Beaver Presence Increase Wildfire Resistance of Streams in New Mexico?*

3. Description of research problem and research objectives.

Seasonal drought is an expected occurrence of climate. However, due to climatic change, persistence and intensity are expected to increase in following decades, particularly in the southwestern arid region of the United States, including New Mexico (Garssen et al., 2014). Precipitation rates in the spring are expected to decrease while summer evaporation rates increase, posing considerable potential threat to vulnerable aquatic ecosystems (Garssen et al., 2014). Drought conditions lead to lower river and stream flows and wetland water regimes, adversely impacting quality and availability of habitat for freshwater organisms, contributing to the decline in freshwater fauna diversity and richness. Additionally, drought depletes surface and groundwater supply relied on by riparian ecosystems. Seasonal drought occurs when water expectations of vegetation exceed precipitation and water supply amount, usually resulting in the reduction of health and spatial distribution of a riparian corridor.

Beaver populations as a management tool for freshwater restoration and conservation has become an increasingly studied idea. The beaver is a well-known ecosystem engineer – an organism capable of altering available abiotic and biotic resources, significantly modifying or creating and maintaining a habitat (Jones et al., 1944). Through a series of dam construction (e.g., complex), flow is reduced, and water is impounded, altering hydrological, chemical, and physical characteristics of a stream. Complexes are novel habitats composed of varying successional stages – a disturbance (e.g., beaver activity) changing an ecosystem over time. The successional pattern of beaver wetlands has been well described as stream impoundment, maturation, and abandonment (Naiman et al., 1988). Immature wetlands are narrow in width and dominated by trees, while mature wetlands are relatively larger and marshy areas exist due to flooding stress killing terrestrial vegetation. In the events of tree depletion, sediment accrual, storm flooding, or frequent breaching of the dam, the dam may become abandoned and the pond drains. Ranging from decades to centuries after abandonment, wetlands eventually return to forested streams (Bush et al., 2019). The goal of this study is to observe the impacts of beaver-influenced successional landscape on both aquatic communities and drought resiliency within the riparian corridor.

The response of freshwater fish and macroinvertebrate communities to beaver disturbance is complex and shaped by factors such as pond size, age, and season of sampling (Schlosser & Kallemeyn, 2000). Generally, beaver activity has positive effects on freshwater diversity by increased habitat heterogeneity (Pollock et al., 1955). Diversity and community composition in a single tributary can vary significantly depending on the spatial scale measured. Beaver wetlands have a wide range of effects on freshwater fish communities, but the specifics of these effects are dependent on numerous factors, such as pond size. Beaver wetland successional stages effects on fish and invertebrate community assemblages are variable (Schlosser & Kallemeyn, 2000).

While many studies have assessed the diversity of fish and macroinvertebrate communities in individual wetlands (alpha diversity), this represents only a subset of the potential diversity across the ecosystem (Beta-diversity). The relationship between beaver activity and B-diversity of fish and macroinvertebrates have been explored by few (Bush et al., 2019, Fritz & Gangloff, 2022) and is otherwise lacking. Beta-diversity assesses the uniqueness of diversity in local communities when compared among two or more similar communities (Whittaker, 1960, 1972). The first objective of this study is to assess the impact of beaver activity on aquatic communities (e.g., fish and macroinvertebrates) across different successional stages of beaver wetlands. Considering how alpha-diversity varies among a beaver-influenced successional landscape and its contribution to the ecosystems Beta-diversity is important to help ecologists fully understand the influence of beaver on changes in aquatic communities.

Additionally, beaver activity positively influences the riparian corridor, a unique interface responsible for the process and transport of energy and matter between aquatic and terrestrial habitat. By slowing and retaining water through dam construction, water availability to vegetation is increased during peak drought season (Pilliod et al., 2016). Because drier vegetation is more likely to burn in the event of a wildfire (Liu et al. 2010), recent studies have suggested that vegetation within beaver inhabited riparian corridors experience increased wildfire resilience, therefore acting as a protective barrier to the riparian and freshwater ecosystem (Fairfax & Whittle, 2020). Furthermore, riparian systems provide refuge, food, and other resources to terrestrial species. The second objective of the study is to quantify the drought resilience of riparian vegetation across different successional stages of beaver wetlands using measures of vegetation health (e.g., Normalized Difference Vegetation Index and Evapotransportation). In previous studies, Normalized Difference Vegetation Index (NDVI) and Evapotranspiration (ET) scores have been used as reliable methods for quantifying vegetation health, and therefore will be used for this objective (Fairfax & Whittle, 2020).

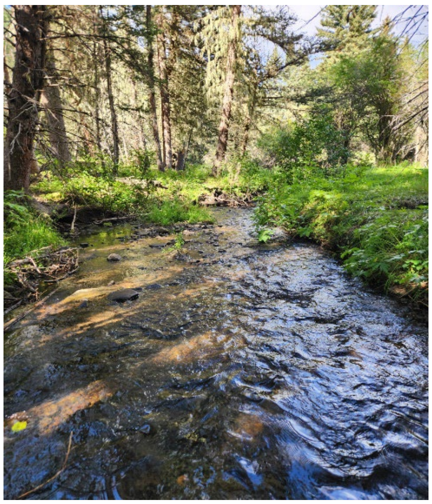
4. Description of methodology employed.

i. Study Design: Two tributaries (Rito de la Olla and Rio Chiquito) were chosen for similarity in elevation, annual precipitation, stream size, presence of beaver activity and location within the same hydrological unit code (HUC) 8 (Upper Rio Grande). Approximately 300 dams were surveyed in July 2024 and categorized into a wetland successional stage based on evident observable features. Stream-wetland complexes were interspersed with five stages of defined habitat succession: (1) natural free-flowing stream segments; (2) new wetlands wetlands; (3) immature wetlands; (4) mature wetlands; and (5) abandoned wetlands. Unaltered habitats were free-flowing segments that had no beaver activity present, active or inactive. New wetlands contained ponds ≤9 meters; impounded water did not exceed the stream bank and therefore, the riparian area lacks marsh and is dominated by trees. Immature wetlands had impounded water >9 and ≤22 meters; the riparian area contained wetland features including marsh-like regions containing both tree and marsh vegetation. Mature wetland ponds are >22 meters; the riparian has a significantly larger wetland marsh with little to no tree vegetation due to excessive flooding stress. Abandoned wetlands had remnant dam structures similar in length to immature or mature wetland dams and a braided network from drained ponds; apparent features indicating a mature or immature wetland once existed. Although significant water quantities are no longer impounded, abandoned wetlands usually become wetland-meadows that seasonally flood, creating a mosaic habitat. An additional category, breached dams, was defined as dams lacking features of historical immature or mature wetlands and were therefore not categorized as abandoned wetlands. These dams contributed to the total surveyed dams but were excluded from the study.

i. Biotic Sampling: Due to limited accessibility from overgrown riparian vegetation on the Rito de la Olla, biotic sampling occurred only within Rio Chiquito. Using probabilistic random sampling, a subset of sample sites was chosen for each successional stage: (1) unaltered stream channels (n=3); (2) new wetlands (n=3); immature wetlands (n=3); immature wetlands (n=3); mature wetlands (n=3); and abandoned wetlands (n=3). Sample sites were >100 meters from each other as well as >100 meters downstream from any successional stage other than their own. Additionally, successional stage 1 sample sites were >200-m downstream from any observed beaver site, including breached and abandoned, to ensure they were unaltered by beaver activity. To ensure the comparison of Beta-diversity across successional stages was statistically defendable, sampling effort across all stages was standardized. To account for habitat variability, samples were taken from all mesohabitats visually assessed in each site (e.g., shorelines, woody debris, submerged vegetation, muddy benthos, beneath undercut banks, runs, riffles, pools). Free-flowing sites (e.g., abandoned wetlands & unaltered) were 100-m segments partitioned to include pools, riffles, and runs. Fish were sampled first using pulsed-DC electrofishing backpacks (Smith-Root LR-20B) and dip nets. To prevent escape, sample sites were constrained by seine net blocks. Electrofishing was standardized to approximately 1800 seconds per site at 250 Hz on a 3 pulsed duty cycle. Additionally, seine drag surveys were conducted for approximately 1200 seconds per site. Fish were identified to the species level, measured in length (mm) and released upstream from the seine block to prevent the same fish from being sampled twice. Invertebrates were then sampled using D-frame net sweeps. Eight sweeps per site were divided to include all mesohabitats present in ponds (submerged vegetation, muddy benthos, woody debris, and shoreline) and free-flowing reaches (pools, riffles, runs, and shoreline). Mesohabitats were visually determined at each site and the designated number of sweeps was appointed. The net was moved continuously for the whole sweep; if the motion was interrupted, the sample was retaken. Specimens were stored in ethanol and returned to the Eastern New Mexico University laboratory for identification to the lowest possible taxonomic level (family).

ii. Environmental Data: A set of water quality parameters were collected at each site using a YSI Pro 2030, including dissolved oxygen (mg/L and %), conductivity (µS/cm), temperature (˚C), and pH. At free-flowing reaches (successional stages 1 & 5), flow velocity and discharge ($ft^3/s$) were measured with a Hach FH950 portable velocity system, as well as average stream depth and stream width (m). At impounded sites (successional stages 2-4), pond width (m), length (m), and depth (m) were collected to calculate an approximate area ($m^3$). As well as dam structure measurements including length (m), height on the pond size (m), and height on the non-pond side (m).

iii. Remote Satellite Imagery – Drought resiliency will be compared amongst successional stages. A subset of dam sites on both tributaries will be used to quantify the level of beaver-induced drought buffering within the riparian corridor. Remote satellite imagery databases (e.g., Landsat 8) and modelled ET will be used to evaluate the density and fitness of vegetation across the terrain. These reference points will be indicative of the overall productivity of the riparian ecosystem. Geospatial information will be recorded for each beaver dam site, including dam coordinates, area of the pond displayed as a polygon, and length of the dam. Studies suggest that Normalized Difference Vegetation Index (NDVI) and Evapotranspiration (ET) scores are adequate techniques for remotely quantifying vegetation health. ET and NDVI scores will be compared amongst the four successional stages as well. An NDVI score will be calculated for each site, with values near 1 indicating healthier vegetation and values near 0 or negative implying poor or declining health. Within riparian corridors, NDVI values below 0.3 represent low vegetation health. This threshold will be applied to determine whether riparian vegetation is healthier in areas surrounding beaver dams. ET will be estimated using the mapping evapotranspiration at high resolution with internalized calibration (METRIC) model. This model merges satellite imagery and meteorological data to generate a landscapes ET score. To ensure consistency and evaluate the correlation between beaver damming and drought buffering, scores will be calculated on the same day and month in both pre-seasonal and peak seasonal drought. Riparian zones will be within 30 meters parallel to the stream as this range is most significantly influenced by beaver activity and least likely to be affected by external influences. Due to METRIC errors (~30%) and expected lack of vegetation resulting from decreased contact with ground and surface water, pixels including observable hillslope will be excluded.


Unaltered stream


New wetland


Immature wetland


Mature wetland


Abandoned wetland

5. Description of results; include findings, conclusions, and recommendations for further research.

## Results

| | Unaltered stream (n=3) Mean (min-max) | SE | New wetland (n=3) Mean (min-max) | SE | Immature wetland (n=3) Mean (min-max) | SE | Mature wetland (n=3) Mean (min-max) | SE | Abandoned wetland (n=3) Mean (min-max) | SE |
|---|---|---|---|---|---|---|---|---|---|---|
| Dissolved oxygen mg/L | 7.75 (6.91-8.25) | .42 | 7.08 (6.79-7.34) | .16 | 6.11 (5.31-6.54) | .40 | 7.05 (6.62-7.6) | .29 | 7.16 (6.2-7.73) | .48 |
| Dissolved oxygen % | 75.83 (71.6-79.7) | 2.35 | 73.17 (69.9-75.1) | 1.64 | 61.27 (56.4-66.1) | 2.8 | 71.93 (68.5-77.2) | 2.67 | 71.13 (61.7-76.4) | 4.73 |
| Conductivity uS/cm | 238.27 (224.1-248.8) | 7.36 | 243.07 (219.1-264) | 13.05 | 246.17 (230.4-254.3) | 7.88 | 246.53 (240.9-254.7) | 4.18 | 247.1 (239.2-258.1) | 5.67 |
| Specific conductance uS/cm | 297.77 (260.9-317) | 18.44 | 285.67 (275.3-298.5) | 6.81 | 291.77 (289.6-294.5) | 1.44 | 296.07 (295.4-296.8) | .41 | 292 (288.8-294.9) | 1.77 |
| pH | 8.27 (7.93-8.49) | .17 | 8.16 (7.97-8.34) | .11 | 8.28 (8.24-8.32) | .02 | 8.26 (8.1-8.36) | .08 | 8.25 (8.19-8.37) | .06 |
| Temperature | 14.53 (12.6-17.1) | 1.34 | 17.17 (14.3-19) | 1.45 | 16.8 (13.6-18.5) | 1.6 | 16.23 (15.3-17.6) | .7 | 16.97 (15.1-18.9) | 1.1 |

**Table 1** Water quality parameters of successional stages
Including mean values, min and max values in parentheses, and standard error (SE)

| | Unaltered Stream | New wetland | Immature wetland | Mature wetland | Abandoned wetland |
|---|---|---|---|---|---|
| Total sampled | 100 | 52 | 57 | 51 | 107 |
| Mean length (mm) | 151.3 | 173.31 | 201.12 | 204.1 | 126.27 |
| Min-Max length (mm) | 53-284 | 58-290 | 53-294 | 72-351 | 51-305 |
| Standard Error | 5.73 | 7.74 | 7.19 | 8.56 | 6.88 |

**Table 2** Brown Trout samples per successional stage
Including total sampled, mean length (mm), min and max values, and standard error

### 1. Fish Abundance

Although sampling of numerous fish species was expected, the only species sampled was Brown trout (*Salmo trutta*). A total of 368 Brown trout were sampled across the five successional stages (100, 52, 57, 51, 107; unaltered streams, new wetlands, immature wetlands, mature wetlands, abandoned wetlands respectively).

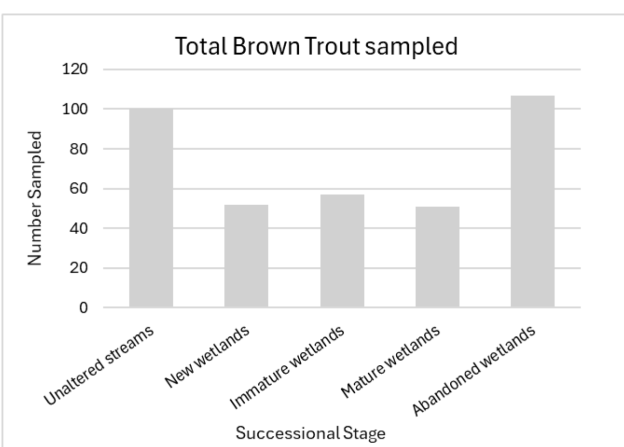



**Figure 1** Total Brown Trout sampled for each successional stage

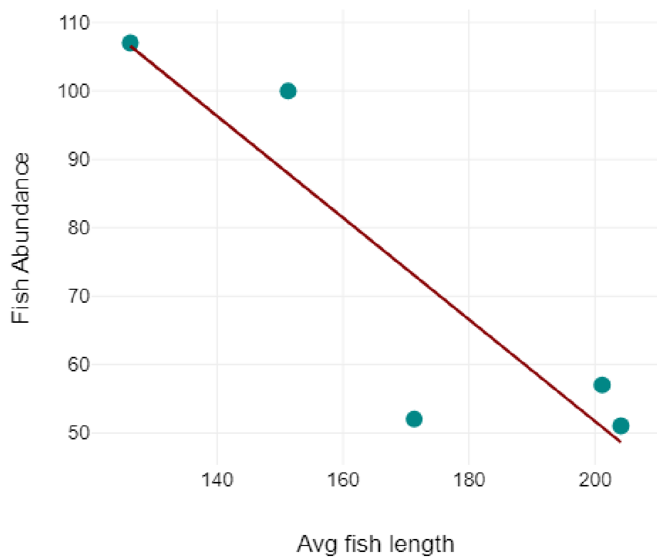
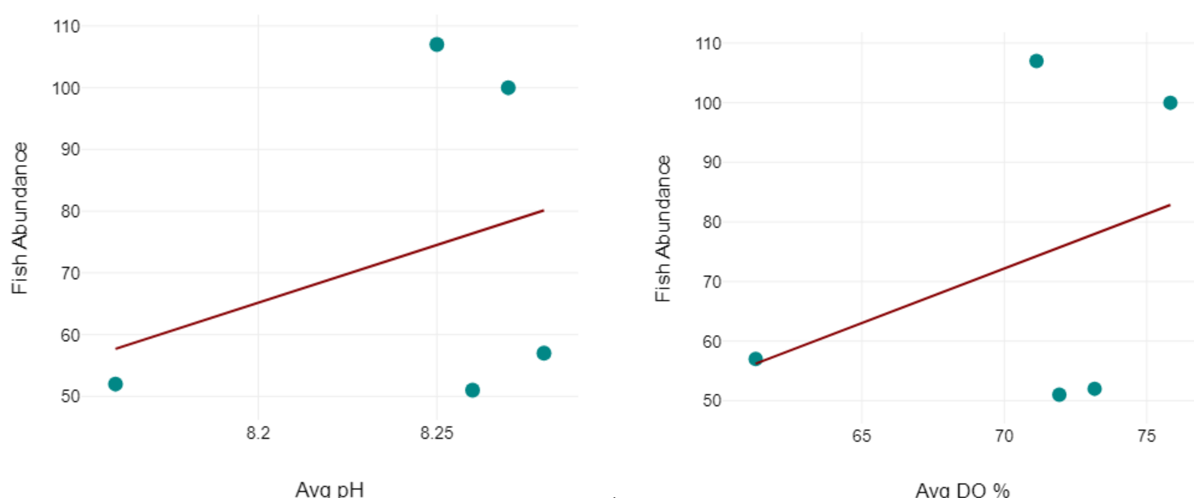



**Figure 2** Scatter plot comparing the correlation between average fish length and fish abundance Including regression lines

### 1.3 Fish Abundance and Water Quality

Spearman correlation analyses were conducted to determine correlations between fish abundance per successional stage and average water quality parameters (e.g., pH, DO %, conductivity, temperature). There is a low, positive correlation between fish abundance and average pH ($r = 0.1$); the correlation is not statistically significant ($p = .873$). There is a low, negative correlation between fish abundance and average dissolved oxygen % ($r = -0.1$); the correlation is not statistically significant ($p = .873$). There is a low, positive correlation between fish abundance and average conductivity ($r = 0.1$); the correlation is not statistically significant ($p = .873$). There is no correlation between fish abundance and average temperature ($r = 0$) and no statistical significance ($p = 1$).

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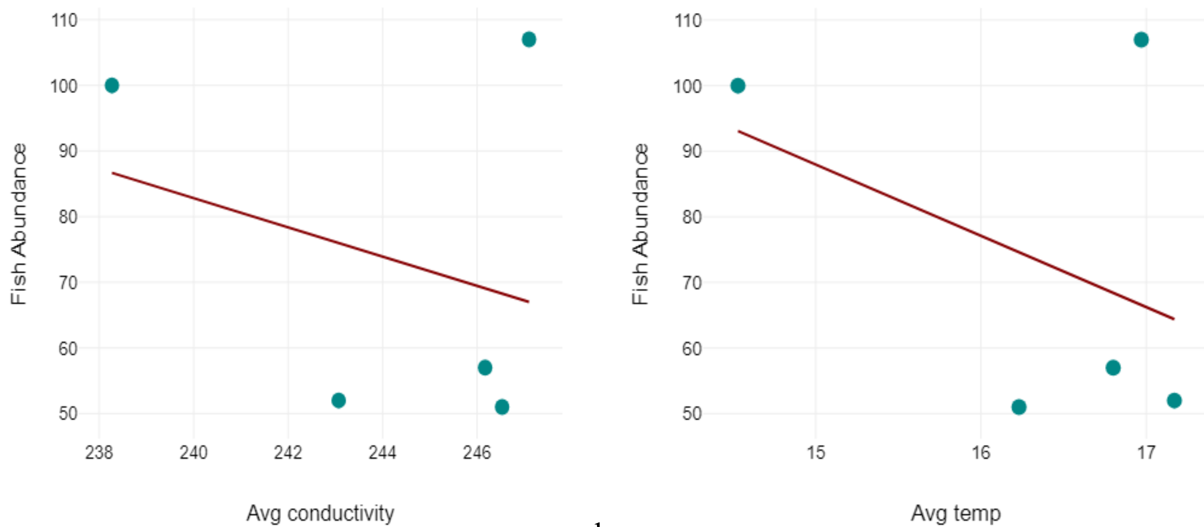

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**Figure 3** Scatter plots comparing the correlation between fish abundance and (a) average pH; (b) average dissolved oxygen %; (c) average conductivity; and (d) average temperature.
Including regression lines

### 1.1 Fish Length

The range and average length (mm) for each successional stage differed. Tests (e.g., Shapiro-Wilk and Anderson-Darling) determined that data from each successional stage did not follow a normal distribution, therefore Kruskal-Wallis, as opposed to ANOVA, was used to determine if significant difference (.05) in fish lengths across successional stages occurs. A p-value of <.001 was calculated, indicating significant difference between at least two of the stages, as a result the alternative hypothesis was accepted. To explore the exact nature of these differences (i.e., which stages differed from which others) a post-hoc Dunn-Bonferroni test was performed. Based on the adjusted p-values, significant differences were identified between unaltered streams-immature wetlands (<.001), unaltered streams-mature wetlands (<.001), new wetlands-abandoned wetlands (.008), immature wetlands-abandoned wetlands (<.001), and mature wetlands-abandoned wetlands (<.001). Additionally, according to adjusted p-values, two pairs exhibited the least statistical difference in fish length: unaltered streams-abandoned wetlands (.99), and immature wetlands-mature wetlands (1).

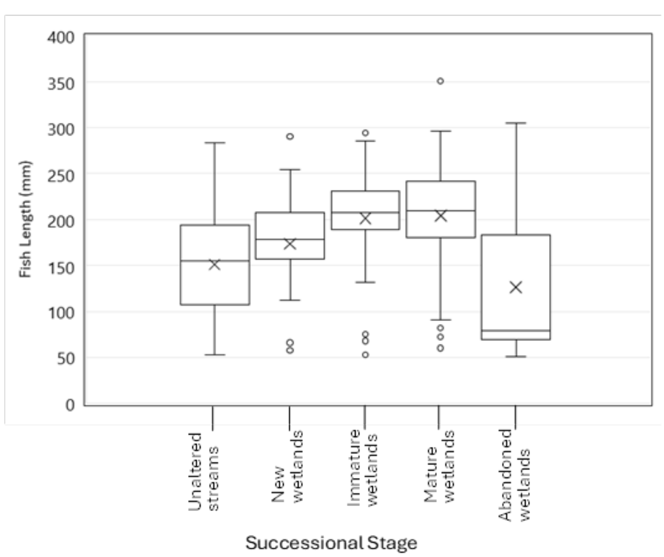
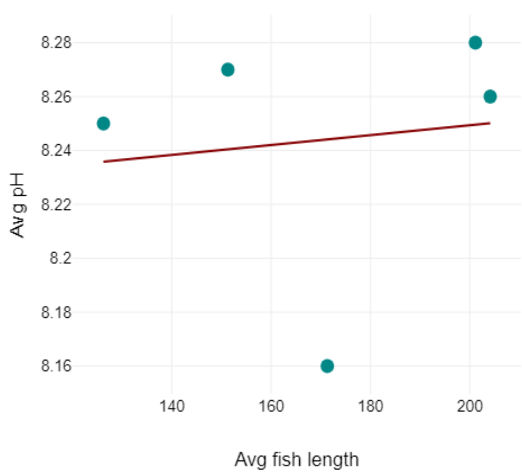


**Figure 4** Box plot comparing successional stages in terms of fish length
Boxes show median and enclose interquartile range, whiskers show 10th and 90th percentiles, and dots show outliers

## 1.2 Fish Length and Water Quality

To analyze the correlation between fish length and water quality variables (e.g., pH, temperature, DO %, conductivity), Spearman correlation analyses were conducted. Strength of correlation is determined by the amount of r, where 0.0<1 indicates no correlation; 0.1<0.3 indicates low correlation; 0.3<0.5 indicates medium correlation; 0.5<0.7 indicates high correlation; and 0.7<1 indicates very high correlation. Statistical significance is determined by the p-value, where a p-value less than 0.05 is considered statistically significant. There is moderate, positive correlation between average fish length (r = 0.3) and average pH; the correlation is not statistically significant (p = .624). There is a low, negative correlation between average fish length and average dissolved oxygen % (r = -0.2); the correlation is not statistically significant (p = .747). There is no correlation between average fish length and average conductivity (r = 0) and no statistical significance (p = 1). There is a low, negative correlation between average fish length and average temperature (r = -0.2); the correlation is not statistically significant (p = .747). Correlations that exhibit lack of statistical significance indicate a correlation likely due to chance. The result of a Spearman correlation analysis showed a very high, negative correlation between average fish length and fish abundance (r = -0.9); the correlation was statistically significant (p = .037).

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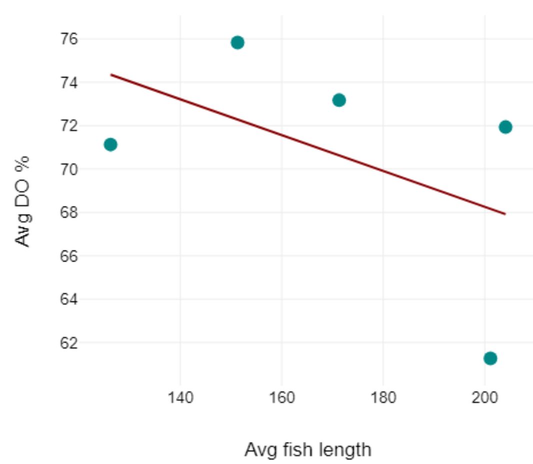


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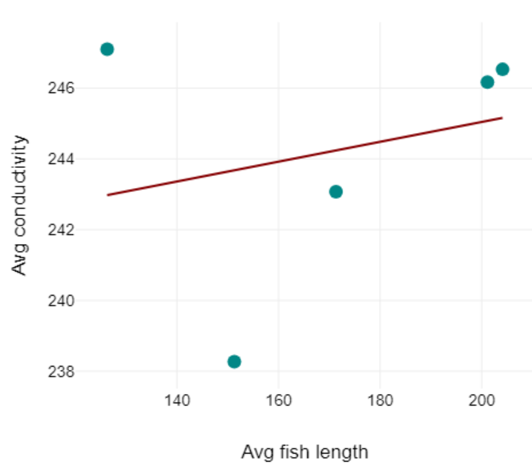


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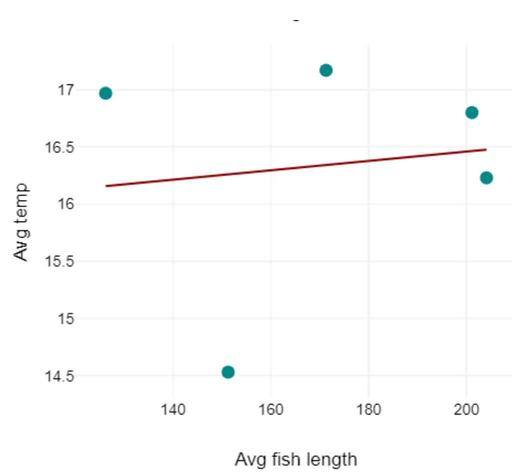


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**Figure 5** Scatter plots comparing the correlation between average fish length and (a) average pH; (b) average dissolved oxygen %; (c) average conductivity; and (d) average temperature Including regression lines

**2. Macroinvertebrates**

Macroinvertebrate abundance and identification to the lowest possible taxonomic level (e.g., family) is currently being evaluated in the Eastern New Mexico University Aquatic Ecology laboratory.

**3. NDVI/ET**

Objective 2 (e.g., NDVI and ET) will be assessed during the 2024-2025 academic year.

6. Provide a paragraph on who will benefit from your research results. Include any water agency that could use your results.
    i. Studying the impact of beaver populations as management tools for freshwater restoration and conservation could potentially benefit drought sensitive regions. Especially New Mexico, a state expecting an increase in drought severity. There are numerous imperiled aquatic species within New Mexico, such as the Pecos bluntnose shiner (*Notropis simus pecosensis*), Texas hornshell mussel (*Popenaias popeii*) and Pecos pupfish (*Cyprinodon pecosensis*) that could potentially benefit from beaver as management tools. Additionally, freshwater provides resources for humans, including clean drinking water, irrigation, and food. Using ecosystem engineers, such as beaver, may require less human intervention, providing a nature-based, low-cost management tool.

7. Describe how you have spent your grant funds. Also provide your budget balance and how you will use any remaining funds. If you anticipate any funds remaining after August 30, 2024, please contact Carolina Mijares immediately. (575-646-7991; mijares@nmsu.edu)

    i. Funds have been spent on supplies (e.g., seining nets, YSI supplies, waders, and ethanol and sample storage bottles for macroinvertebrates). As well as travel expenses for the WRRI conference, surveying, and data collection.

8. List presentations you have made related to the project.

    i. Reynolds, A.D. & Mitchell, Z.A. New Mexico Water Resources and Research Institute Conference, Poster session.

9. List publications or reports, if any, that you are preparing. For all publications/reports and posters resulting from this award, please attribute the funding to NM WRRI and the New Mexico State Legislature by including the account number: NMWRRI-SG-FALL2023.

10. List any other students or faculty members who have assisted you with your project.

11. Provide special recognition awards or notable achievements because of the research including any publicity such as newspaper articles, or similar.

12. Provide information on degree completion and future career plans. Funding for student grants comes from the New Mexico Legislature and legislators are interested in whether recipients of these grants go on to complete academic degrees and work in a water-related field in New Mexico or elsewhere.

i. The expected completion of my M.S. in Biology is May 2025. I intend on continuing my career in New Mexico, specifically in aquatics. I am passionate about freshwater restoration and conservation from an ecological approach. I am thankful for the opportunity from WRRI to have pursued my interest in studying a nature-based management tool for freshwater ecosystems. My goal is to continue as a research biologist in aquatics. Specifically, focusing on ecosystem changes and beneficial water quality impacts driven by beaver disturbance. I believe it would be beneficial to continue a long-term dataset of beaver dams in New Mexico and hope to accomplish this in following years.

You are encouraged to include graphics and/or photos in your draft and final report.

Final reports will be posted on the NM WRRI website and should be verified by the student's advisor.