

Aquatic invertebrate communities in old, new, and re-formed beaver ponds in the Trail Creek watershed

ABSTRACT

1. Beavers are ecosystem engineers. They alter the structure of their habitats when they cut woody vegetative material to create dams that result in ponds. Ponding slows water flow, resulting in fine sediment deposition. A wetland is created as the sediment continues to deposit.
2. The formation of these new water bodies creates new habitat for aquatic invertebrates. These ponds will have unique aquatic invertebrate communities that utilize the slow, deep, depositional habitat. Though the shifts in aquatic invertebrates between lotic and beaver-created lentic habitats are well studied, the effects of beaver pond age on these aquatic invertebrates is still very unclear.
3. Successional patterns of beaver ponds occur over time as wetlands continue to accumulate sediment, but how long this process takes is not known. Also, if beaver ponds are abandoned, they can turn back into stream habitats surrounded by meadows with high nutrient soil. How ponds that are old, new, and re-formed after abandonment differ in habitat structure is unknown, as is how potential differences affect the inhabiting invertebrate community.
4. The project objective was to determine if aquatic invertebrate communities differed in old, new, and re-formed ponds. We collected three aquatic invertebrate samples from different sections of each pond: one adjacent to the dam and two in random locations on the shoreline. Samples were taken using a D-net, sweeping along 1m for ten seconds.
5. Our findings will elucidate if there is a difference between communities in beaver ponds of different ages. We predict that due to the proximity of these ponds and similar habitat components, the invertebrate communities of the ponds will have no significant difference.

INTRODUCTION

Beavers populations were at their peak prior to European settlement in North America (Naiman et al., 1988). They were later commercially hunted for their fur starting in the 17th century, causing a rapid decline in their population (Naiman et al., 1988). More recently, through regulating trapping and reintroduction efforts, beaver populations have recovered. Since recovery, they have been able to continue their roles as ecosystem engineers, with the ability to impact their ecosystem physically, chemically, and biologically (Fuller & Peckarsky, 2011).

Beavers can alter aquatic environments by changing the water flow patterns (Fuller & Peckarsky, 2011). These ecosystem engineers flood wet areas to reduce the chance of predation by land predators. They alter these wetlands by making dams, ponds, and canals, increasing water depths and the extent of inundation (Bush & Wissinger 2016). This disturbance can change riparian plant growth and water temperatures due to higher water table levels (Fuller & Peckarsky, 2011). In areas where beaver dams are removed, water tables drop, causing a loss of diversity and productivity of riparian vegetation (Butler & Malanson, 2005). Beaver activity can also alter the hydrology of stream channels (Bigler et al., 2001). Dams slow water flow velocity, resulting in sediment deposition (Bigler et al., 2001). This allows for infilled ponds to be a home for sedges and grasses that create beaver meadow (Butler and Malanson,

1994). Changes in benthic substrate towards fine sediment can result in limited surfaces for the growth of biofilms (Mackay, 1992). Changes in water velocity can also disturb patterns of organic matter deposition in these habitats (Mackay, 1992).

Changes to habitat structure, biofilm growth, and organic matter availability can affect which aquatic invertebrates live in the waterbody (Washko et al., 2022). These physical and biological changes will influence traits needed for aquatic invertebrates to maneuver through and feed in that particular environment (Washko et al., 2020). The substrate in ponds, with slow moving water and increased depth, may benefit swimming taxa more, such as mayflies, dragonflies, and beetles (Washko et al., 2020, Mackay, 1992). Whereas ponds with finer sediment may have burrowing or sprawling macroinvertebrates, such as fly larvae (Mackay, 1992, (Washko et al., 2020). Anaerobic conditions within these fine sediments limit the organisms to those which can tolerate low-oxygen conditions. The patches of large woody debris in dams can be dominated by grazers and filter feeder invertebrates, such as fingernail clams (Bush & Wissinger, 2016). The presence and abundance of Amphipoda and large case-building caddisflies in beaver ponds is associated with the large contents of organic material that is added by beavers (Bush & Wissinger, 2016). Aquatic invertebrate communities change with beaver engineering, but the effects of these changes appear to be context-dependent (Washko et al., 2022).

Beaver-created habitats undergo successional patterns, but it is unclear how these stages influence aquatic invertebrate community composition. Beaver pond successional patterns are described as a cycle of wetland creation, maturation, and abandonment (Bush et al., 2019). The successional patterns induced by beaver engineering across the world have not been well-studied (Washko et al. 2022). Therefore, how the aquatic invertebrate community changes through creation, maturation, abandonment, and re-formation processes is unknown.

In the Elk Mountains of Colorado, beavers became more prevalent in the 80s and 90s, so pond age is a newer factor to consider when comparing communities within beaver-created habitats. This study will investigate the effects of beaver pond age on the community composition of aquatic invertebrates in old ponds (>20 years), re-formed (absent for some time) and new ponds (<10 years) on hillslopes along Trail Creek. This study is important to improve scientific understanding as to how these ecosystem engineers affect the aquatic ecosystem over time. We expect that despite the differences in successional stages, there will be no significant difference between invertebrate communities in the new, old, and re-formed ponds. We anticipate that the close proximity of the ponds and similar enough habitat conditions will allow colonization from neighboring ponds of different ages.

Research Question: Do aquatic invertebrate communities of young, old, and re-formed beaver ponds differ?

METHODS

Study Site

This study took place in several ponds located along hillslope drainages surrounding Trail Creek in the Elk Mountains of Colorado. Trail Creek is located in Gunnison National Forest (10,764 feet elevation; 38.899884, -106.626194). Trail Creek is a headwater tributary of the Taylor River and is known for recreation activities like hiking, horseback riding, and mountain

biking (US Forest Service, 2024). The hillslope drainages are spring-fed first-order tributaries that have been dammed by beavers for decades. Using Google Earth's imagery and timeline features, we estimated the age of each pond and classified them as old (first formed 20+ years ago), as re-formed (if a pond was formed, abandoned and disappeared, then re-formed due to continued beaver maintenance), or as new (created within the last ten years; Figure 1). We chose the areas to sample by using images of the ponds from Google Earth.



Figure 1: Succession patterns of beaver ponds can vary over time. From 1999 to 2019 at Trail Creek (Colorado; 38.899884, -106.626194), beaver ponds changed in both size and presence. Notably, some ponds disappeared, turning back into stream conditions, only to be re-formed years later. Some beaver ponds are present for all years, and others formed for the first time in recent years.

Upon arriving at the sites, not all ponds were the same as the imagery because the most recent imagery was five years old. For example, all ponds in drainage C (Figure 2) were breached and therefore not sampled. In total, we sampled ten new ponds, four old ponds, and seven re-formed ponds on hillslopes in the Trail Creek watershed (Figure 3).

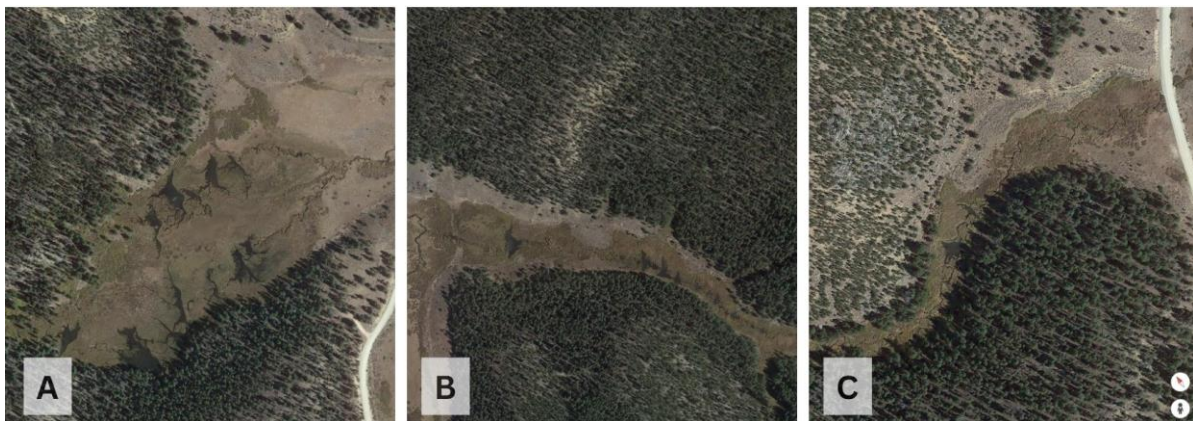


Figure 2: The three sample drainages where we collected aquatic invertebrates at Trail Creek in the Gunnison National Forest. Each drainage is approximately 0.5-0.75 kilometers from the others.

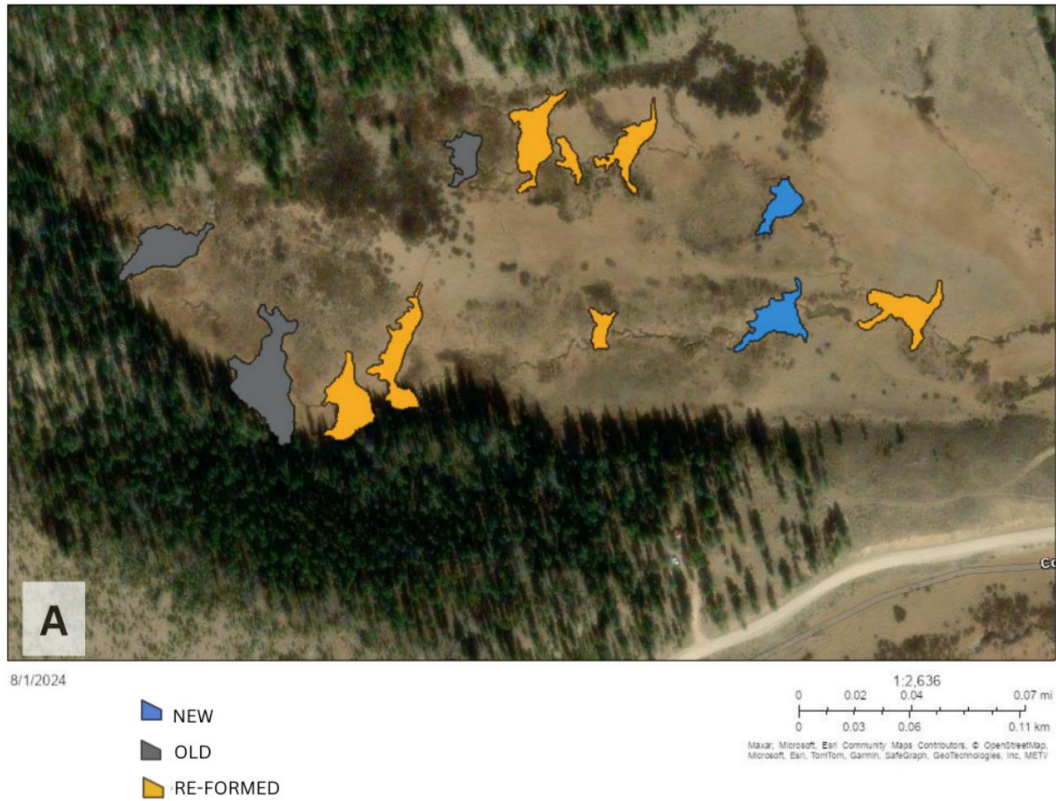


Figure 3: 2024 Aerial image of mapped polygons of pond sites where data was collected from hillslope A and B.

Aquatic Invertebrate Sampling & Habitat Variables

We sampled aquatic invertebrate communities using 10-second 1m benthic D-net sweeps. We then took three separate sweeps along the perimeter of each pond: one randomly-chosen location along the dam and two randomly-chosen locations along the other edges. Randomness of the sample locations took into consideration which areas were safe and accessible. Netted invertebrates were placed into an examining tray, identified to family level or lower, enumerated, and recorded before releasing the invertebrates back into the pond.

In addition to invertebrate samples, we measured various habitat parameters to better understand potential differences in the habitat structure of different successional stages that might explain community differences. Water depth was measured at each sampling location, taking three measurements across the 1m sweep and averaging them. Visual observations were also made on the edge vegetation (sedge, willow, mixed sedge and willow, dead willow, moss, bare sediment), sediment size (fine, gravel and sand mix), detritus (present or not; woody, unidentifiable herbaceous, or both), and aquatic vegetation (algae, aquatic plants, inundated sedge).

Statistical Analysis

RStudio software was used for all statistical tests. We ran an ANOVA test for differences in species richness between old, re-formed, and new beaver ponds. We also used the 'vegan' package (Oksanen et al., 2024) to run a non-metric multidimensional scaling (NMDS) visualization and accompanying PERMANOVA test to analyze differences in community composition of aquatic invertebrates. Lastly, an indicator species analysis was performed ('indicspecies' package; Cáceres & Legendre, 2009). Graphs were made in 'ggplot2' (Wickham, 2016).

RESULTS

The aquatic invertebrate communities were not significantly different by pond type (PERMANOVA, $F_{2,18} = 1.390$, $R^2 = 0.134$, $p = 0.145$; Figure 4). In the NMDS plots, the aquatic invertebrates from all three pond types (new, old, and re-formed) are clustered with close proximity to each other (i.e., each group does not occupy a unique position in space; Figure 4). Also, the 95% confidence ellipses seem to have high overlap. These observations are consistent with the PERMANOVA results.

Beaver Pond Aquatic Invertebrate Communities

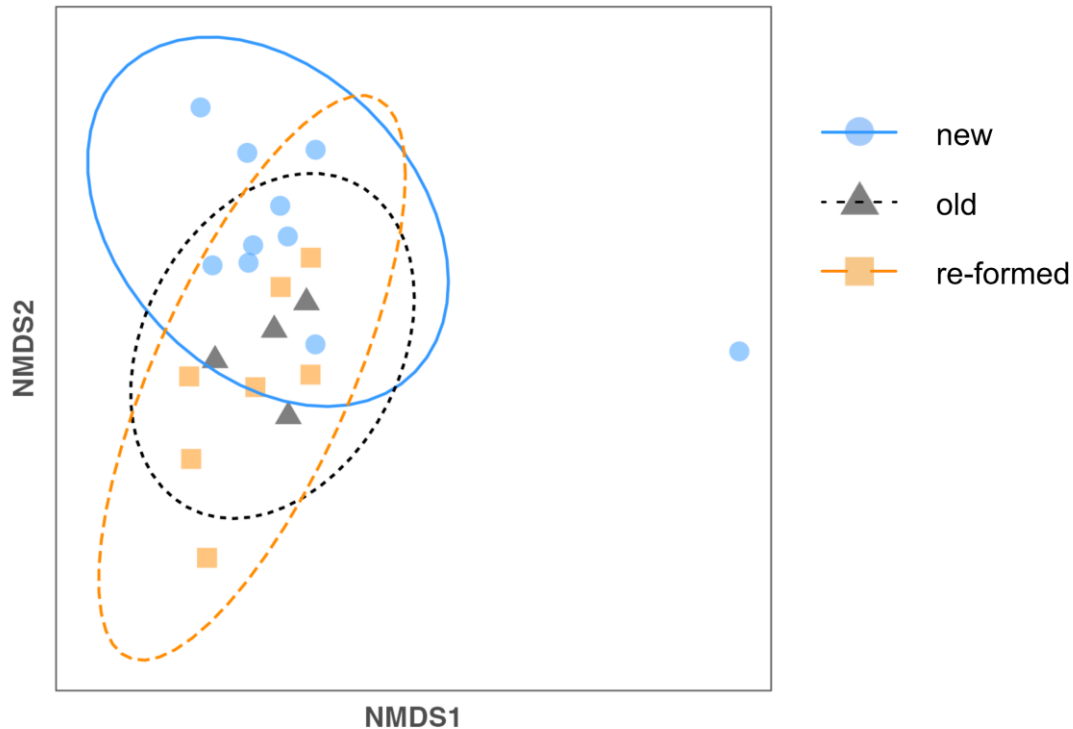


Figure 4: Non-metric multidimensional scaling (NMDS) visualization on pond age categories: new, old, and re-formed. Points with more similar community compositions (taxa present and their abundances) are clustered more closely together. The points are interspersed regardless of pond age and the 95% confidence ellipses overlap heavily, indicating lack of difference between groups.

One taxon was identified as an indicator through the indicator species analysis. According to this analysis, Ostracoda are indicators for re-formed ponds (indicator value = 0.010 $p = 0.029$). Ostracods were unique to re-formed ponds, however, they were only found in half the re-formed ponds sampled and never in densities higher than three individuals.

When analyzing taxa richness as a function of pond age, results were significant (ANOVA, $F = 4.333$, $p = 0.0291$; Figure 5). A post-hoc test revealed a difference in richness between new and re-formed ponds (TukeyHSD, $p = 0.024$), with new ponds having lower taxa richness. There was no difference in richness between old and new ponds and between old and re-formed ponds.

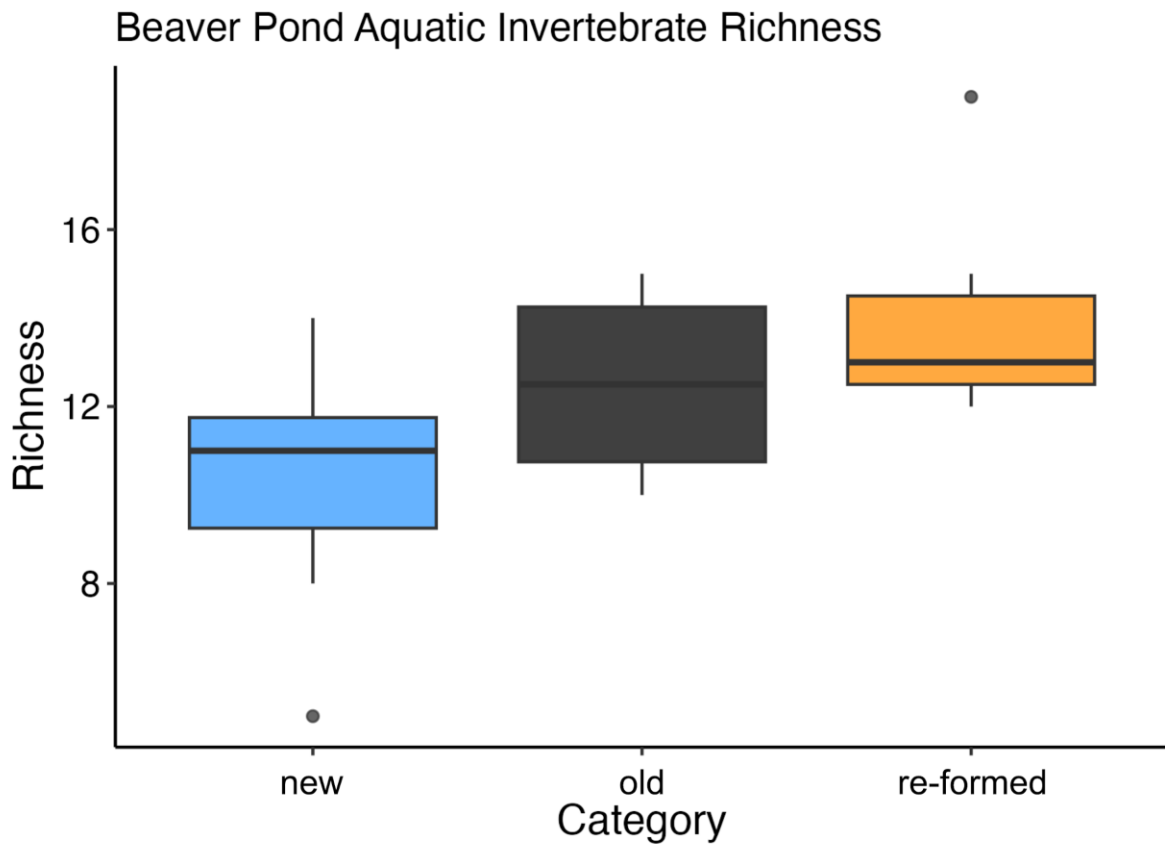


Figure 5: Boxplots comparing taxa richness in new, old, and re-formed beaver ponds. The only significant difference is between new and re-formed ponds.

DISCUSSION

Our results demonstrate no significant differences in aquatic invertebrate community structure by pond age: new (< 10 yrs), re-formed (formed >20 years ago, abandoned and disappeared, re-formed in the last 10 yrs), and old (> 20 yrs). The aquatic invertebrates found in each of the pond ages were very similar in both the types of taxa present and their abundances (Figure 4). Although there was one taxon unique to re-formed ponds, our analyses didn't conclude this to be a defining factor of much difference. Our results did find a difference in richness between re-formed and new ponds, but no other differences. Our results suggest that pond age, through its many successional stages, does not strongly impact the aquatic invertebrate community composition in the beaver ponds on tributaries to Trail Creek.

Other studies on how successional stages influence aquatic invertebrate communities in beaver ponds found contrasting results, where aquatic invertebrates did vary with pond age. One study done in Georgia (U.S.A.) looked at the communities found in natural stream channels, forested wetlands created by newly formed beaver dams, mature open wetland marshes, and abandoned wetland meadows in autumn and in spring (Bush et al., 2019). In autumn, the invertebrate communities were different between successional stages. Mature wetlands were also different from abandoned wetlands in autumn (Bush et al., 2019). In spring, only the mature beaver wetland communities were unique, differing from both newly formed

and abandoned wetland (Bush et al., 2019). Some of the factors discussed to be of influence to these results are drought tolerant invertebrates more common in abandoned wetlands and invertebrates reliant on aerial recolonisation from neighboring wetlands (Bush et al., 2019). The connecting channel habitats containing similar taxa found in streams, are thought to be the reason there were similarities in communities between streams and abandoned ponds (Bush et al., 2019).

To better understand how successional stages affect a specific taxa, another study investigated how water beetles responded to the different stages of wetlands in a beaver-altered landscape in southern Finland . The results in this study found that new beaver wetlands could support higher species richness and abundance of water beetles compared to old beaver wetlands (Nummi et al., 2021). Beavers' contributions to the habitat provide many changes favored by water beetles, such as beaver dams flooding surrounding areas, resulting in lentic, shallow water zones with emergent vegetation and an increase in organic matter (Nummi et al., 2021). Resource enhancements that benefit water beetles include muddy bottoms rich in detritus harboring a variety of prey (Nummi et al., 2021). The authors also found that the presence of invertivorous fish affected the water beetle population through predation As beaver ponds become mature, fish abundance increased, therefore new beaver wetlands had higher richness because of reduced predation pressure (Nummi et al., 2021).

The factors behind the differences in the other successional studies are potential reasons behind the lack of differences in aquatic invertebrate communities at Trail Creek. Unlike previous studies, the habitat observations made in our ponds involved similar components regardless of age category, such as soft sediment, detritus, wood detritus, and sedge. We plan to do a more formal habitat analysis to support this idea. Further, trout inhabited all of the beaver ponds at Trail Creek. The presence of trout in all ponds could have an effect in homogenizing the aquatic invertebrate community through predation. In previous work in the East River Valley of Colorado (about one hour north of Trail Creek), an old pond with trout had a lower taxa richness compared to the other old ponds with no fish and was missing the indicator taxa for old ponds (Rivera 2023 unpublished data). The trout in this pond may have eaten the larger taxa, such as dragonfly larvae and large case-building caddisflies, leaving only smaller taxa. Some aquatic invertebrates may also avoid ovipositing in habitats with fish (Why, 2012), limiting the potential community breadth.

Whether aquatic invertebrate communities differ in beaver ponds of different successional stages may be a factor of the specific geographic context (Washko et al., 2022). Further studies should be done in different regions focusing more on how habitat types affect aquatic invertebrates of beaver ponds. An understanding of how succession affects aquatic invertebrate communities can also be used for evaluating beaver-aided restoration projects in the Gunnison National Forest. This research will also add to our understanding of how beavers contribute to aquatic biodiversity conservation in the face of the freshwater biodiversity crisis (Washko et al. 2022).

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