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Ecogeomorphology
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Beaver dam influence on wet meadow habitat

Introduction

The North American beaver (*Castor Canadensis*) was once present in nearly all temperate, riparian ecosystems in North America, where its dam building activity created areas with increased groundwater and surface water elevation and storage, lowered stream velocity, aggregated fine sediment, and increased stream length and complexity (Pollock et al. 2015). This wet meadow habitat is often referred to as a beaver meadow complex, and is characterized by saturated, fine sediment substrate and herbaceous vegetation (Polvi and Wohl 2012). Beaver meadow complexes have substantial ecological importance; they are hotbeds for biodiversity, supporting highly productive ecosystems comprised of unique species of plants, insects, fishes, birds, and amphibians adapted to specific wet meadow conditions.

Due to heavy hunting for their pelts however, beaver populations have been extirpated or dramatically reduced (Pollock et al. 2015). This absence, combined with use of meadows for livestock grazing, has resulted in a decline in both number of beaver meadow complexes and quality of wet meadow conditions within historic beaver ranges. Without beavers to maintain wet conditions and trap fine sediment, many meadows now have a substantially lowered water table, are deeply incised by streams, and support invasive vegetation (Pollock et al. 2015). As a result, dry conditions dominate and have endangered species that are dependent on wet meadow habitat.

The high risk of losing this biodiversity necessitates investigation of restoration strategies for wet meadows. Due to their ability to engineer meadow complexes, reintroduction of beavers is becoming an increasingly recognized strategy to facilitate recovery of meadow-dependent species. There is great potential for this restoration strategy in degraded meadows in the Sierra Nevada, where many endemic species have ben made vulnerable by habitat loss. Beaver activity has the potential to create valuable wet meadow habitat in places like Tuolumne Meadows in the Sierra Nevada by altering the hydrologic and geomorphic regimes. To make informed decisions about the employment of beavers, it is important to understand these mechanisms.

Hydrologic Effects

Beaver dams significantly affect both the spatial and temporal qualities of water movement. Dams increase both surface water and groundwater storage, dissipate stream power, divert water onto the floodplain, lessen the magnitude of floods, and create a persistent and elevated water table (Green and Westbrook 2009, Curran and Cannatelli 2014). These effects facilitate creation of wet meadow habitat by maintaining saturated conditions and preventing erosion of fine sediment substrate, which supports native herbaceous vegetation and species.

Surface Water

Beaver dams increase surface water storage by effectively dissipating stream energy and increasing the depth, duration, and extent of inundation associated with floods (Levine and Meyer 2014). After a dam is completed, its structure dissipates stream energy to form backwater ponds with reduced flow velocity, decreased water surface slope, and increased surface water storage (Levine and Meyer 2014). These conditions provide habitat for species in and around the pond, store water through times of drought, and saturate surrounding areas. Additionally, dissipation of stream power prevents erosion of fine sediment or stream incision, which allows the persistence of wetland vegetation and supporting species that require wet meadow habitat.

Raised surface water elevation and dissipated stream energy also change the flooding regime of the stream (Westbrook et al. 2011). Westbrook et al. (2011) found that beaver dams increased flooding duration, which lengthened snowmelt runoff further into the growing season due to storage in and gradual release from ponds. This supplies wetland vegetation with sufficient water for a long period of time into the dry summer season. At average flows, the stream was observed to inundate a terrace usually only flooded in a 200-year event due to presence of a beaver dam.

Levine and Meyer (2014) found that flow was diverted around a beaver dam and onto the surface of the floodplain. When this avulsion rejoined the main channel downstream, there was notably less discharge, indicating that water was remained on the floodplain as both infiltration and depression storage. This created shallow, ephemeral pools that served as important habitat.

Increased duration and diversion of water attenuated flooding both upstream and downstream of the beaver dam (Westbrook et al. 2011, Levine and Meyer 2014). This reduction of flood intensity results in a specific disturbance regime to which meadow dependent species are adapted. When beaver dams are not present and floods become more scouring, the fine substrate that vegetation depends upon is removed (Green and Westbrook 2009), and a higher intensity disturbance regime to which meadow species are not adapted results. Therefore, beaver dams serve to stabilize meadow habitat and facilitate persistence of both physical and biotic meadow attributes.

Groundwater

Changes in surface water hydrology from beaver ponds are linked to changes in groundwater dynamics. Storage of surface water in ponds increases the duration of soil-water interaction, which results in higher groundwater recharge due to percolation through pond banks. As a result of this increased recharge, hydraulic head was observed to rise to surface elevation along a reach of the Colorado River in the Rocky Mountain National Park (Westbrook et al. 2006). Soil cores taken from beaver dams show that soils were formed in anoxic conditions, indicating that the water table was steadily maintained at the soil surface (Westbrook et al. 2006, Polvi and Wohl 2012).

The effectiveness of beaver dams in maintaining hyporheic flow from the pond into surrounding riparian areas is proven by the rapid decline in the water table upon beaver dam failure (Westbrook et al. 2006, Green and Westbrook 2009). Westbrook et al. (2006) found groundwater levels dropped by approximately 50% in the 12 hours after a dam failed. When removal of beavers was studied in British Columbia, vegetation changed from riparian to xeric species, indicating a drop in the water table and decrease in soil moisture (Green and Westbrook 2009).

A high hydraulic head results in a losing stream, where water from the stream constantly feeds the meadow and maintains saturated conditions that support wetland vegetation. Because of the constant supply of water from beaver ponds, groundwater drawdown during the dry season was greatly attenuated in the Rocky Mountains (Westbrook et al. 2006). This further creates and stabilizes wet meadow habitat by maintaining conditions that support meadow species.

Geomorphology

Hydrologic changes due to beaver activity result in changes in the sedimentation and geomorphology of a stream. Reduced stream power decreases shear stress and stream competence, which induces deposition and aggregation of fine sediment and an increase in stream base level (Burchsted and Daniels 2014, Levine and Meyer 2014). This aggregated fine sediment has a high water holding capacity, which maintains saturated conditions. Increased stream elevation also maintains a raised water table, and indicates beaver potential to repair incised streams. Diversion of water around dams increases channel complexity, and promotes braiding and meandering (Polvi and Wohl 2012). This complexity further increases biodiversity, and also serves to expand meadow habitat as beavers colonize avulsed channels.

Sediment Distribution

Beaver dams have been observed to effectively trap sediment (Levine and Meyer 2014). This can be explained by dissipation of stream energy by beaver dams, which both induces deposition and aggregation of suspended sediment in beaver ponds. Stream competence is also reduced by the decrease in stream energy, which prevents the stream from evacuating sediment from ponds and stream banks (Curran and Cannatelli 2014, Levine and Meyer 2014). Additionally, woody debris from before dams were present and high macrophyte growth in beaver ponds further stabilize sediment (Burchsted et al. 2010). Polvi and Wohl (2012) proved the effectiveness in sediment trapping through their analysis of sediment cores by interpreting depositional environment from sediment texture. They found that a majority of post-glacial alluvium in beaver meadow complexes was fine sediment deposited from beaver ponds, compared to sediment deposited from a stream channel or hillslope.

Although beaver systems act as long term storage of suspended and bed load sediment (Green and Westbrook 2009), short term sedimentation rates vary widely. Green and Westbrook (2009) observed that sedimentation rates in beaver ponds in British Colombia ranged from 2.5 cm/year to 27.9 cm/year. Variability in sedimentation rates could be due to breaching of dams in high flow, which has been observed to evacuate large volumes of sediment from beaver ponds due to sudden increase in discharge and velocity (Woo and Waddington 1990, Levine and Meyer 2014). However, despite the scour that occurred in the pond, channel filling was observed downstream of the dam so that net change in bed elevation over the reach was within range of error for survey equipment (Levine and Meyer 2014). Time for accumulation, quality of the dam, stream energy, and sediment supply from headwaters affect spatial and temporal sedimentation patterns (Polvi and Wohl 2012).

Increased overbank flooding also results in higher deposition of sediment across the floodplain than observed in free flowing streams (Polvi and Wohl 2012). Sediment deposition varies over the floodplain due to changes in roughness and water surface by topography and vegetation (Westbrook et al. 2011). More frequent inundation of the floodplain results in deposition of sediment, which creates nutrient- and mineral-rich substrate for riparian vegetation (Westbrook et al. 2011). Fine sediment deposited also has a high water holding capacity, which promotes saturated conditions. The resulting increase in riparian vegetation increases roughness, which traps even more sediment (Levine and Meyer 2014). This forms a positive feedback loop, where the presence of vegetation supports its own persistence, which creates and maintains wet meadow conditions.

Channel Morphology

Beaver dams greatly increase channel complexity and length. Flow diverted around beaver dams at high flows may aggregate enough sediment to become perennial channels (Westbrook et al. 2011). Due to decreased stream energy, these avulsions create an anastomosing network, which increases channel length (Polvi and Wohl 2012). Dam breaching has also been observed to create a forced meander, which is then sometimes secured by vegetation growing from the dam remnants (Levine and Meyer 2014). Analysis of current stream conditions shows that removal of beavers results in a drop in channel length and complexity below historic range (Green and Westbrook 2009, Polvi and Wohl 2012). Additionally, beavers are able to crate more dams with an increase in stream length, which expands the area of wet meadow habitat and riparian vegetation. These complex habitats facilitate biodiversity.

Implications

Removal of beavers and their dams has resulted in degraded habitat across North America (Green and Westbrook 2009). However, reintroduction of beavers has great potential to reverse some of this damage and recreate wet meadow habitat by decreasing stream power, raising the water table, aggregating sediment, and increasing channel complexity (Pollock et al. 2015). These results could have important significance in the Sierra Nevada and beloved places such as Tuolumne Meadows in Yosemite National Park, where livestock grazing has resulted in degraded meadow habitat and greatly reduced populations of species that rely upon it. Currently, many meadow-dwelling species, such as the Yosemite Toad, Cascades Frog, Sierra Nevada Yellow-Legged Frog, Long–toed salamander, and Willow Flycatcher, are listed as threatened or endangered. A factor in the decline of these species is degradation of their habitat. We must take action, so that these unique and vulnerable communities are not lost. Reintroduction of beavers is proving to be a promising solution for these at risk habitats and species.

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