B. BEAVER ECOLOGY, HISTORY, HABITAT REQUIREMENTS & FEEDBACKS

Nate Hough-Snee
Joe Wheaton

ICRRR Design Workshop
PURPOSE OF TALK

Share some work we’ve been doing on beaver...

- Too easy to get people excited about beaver as a restoration tool... so we need expectation management:
  1. Where could beaver work?
  2. Where are they a problem?
  3. What do we do where beaver alone are not enough?
A HABITAT GENERALIST, AND HIGHLY ADAPTABLE

- Lakes
- Rivers and streams
- Abandoned channels on floodplains
- Wetlands
FROM BOREAL FORESTS....
...TO DESERTS

http://www.rv-boondocking-the-good-life.com/
EVEN SOME UNLIKELY PLACES...

- Estuaries
- Glacier outwash streams

Mendenhall Glacier, AK (Photo Bob Armstrong)

Beaver Dam Creek, Long Island, NY
COMMON HABITAT INGREDIENTS: WATER + TREES

- Northern tundra and treeline range boundary: wood limitation
- Southern desert range boundary: perennial streamflow and/or wood limitation
AQUATIC HABITAT IS CRITICAL TO THEIR SUCCESS

- Beaver more agile in water than on land; maximize time in the water
- Ponds provide cover from predators and foraging pathways
- Lodge includes underwater entrance, nest area above water
LODGES

- Bank lodge vs. Central Above Ground

Bank den (Colorado Natural Heritage Program)

Mid-stream lodge in Hinsdale County, CO (Colorado Natural Heritage Program)

Mid-lake lodge
AN EXPOSED LODGE

- They dig lots of tunnels
THE COLONY

- Colony unit = 6–8 related individuals
- Avg. litters = 2–5 kits
- Young stay with parents at least 2 years
- Adults (>2 yrs) disperse to establish new lodge
- Territories marked with scent mounds
- Home ranges tend to follow shorelines
WHAT DO BEAVER EAT?

• Spring/Summer: herbaceous plants, incl. aquatic and riparian forbs, grasses, grains and row crops
• Fall/Winter: tubers, bark and cambium of cached woody plants
• Woody plants comprise 86% of winter diet; 16% of summer diet
WOODY FOOD CONSIDERATIONS

• Maximizes energy intake with low costs
• Easy digestibility; short gut retention time
• Avoid bad-tasting secondary compounds
• Willows, aspen most commonly preferred; conifers avoided

Photo by Michael S. Quinton, National Geographic Society

Photo by Anna M. Harrison
A BEAVER FOOD CACHE...
THE LODGE AND FOOD CACHE

- Active lodges indicated by fresh food cache in fall
- Active lodges spaced at least 0.5–1 km apart
- Colony saturation densities vary with landscape and region
- Max. density ranges 0.5–5 colonies/km² (Hill 1976, Novak 1987, Baker and Hill 2003)
WHAT IS AN ECOSYSTEM ENGINEER?
SO WHY DO THEY BUILD DAMS?
DAMS & BUILDING MATERIALS

- Created to impound water around lodge
- Dam location cued by running water
- Dams constructed of wood and available debris (e.g., plastic, metal)
CAN THEY MOVE A WHOLE TREE?
DAM/POND COMPLEXES

- Multiple dams create safe transportation corridors to connect large ponds
- Dams complexes grow over time, allowing beaver more access to food sources
- Canals constructed to float materials in...
Historically, 60–400 million pre-European settlement
Extirpated to near extinction by late 1800s
Currently, 6-12 million
Spatial distribution approaches its historical range

Why so few?

Slide from John Stella
BEAVER WERE THE MAIN REASON EUROPEANS CAME HERE!

- From 1600s to 1800s beaver essentially extirpated...
- Their pelts were ‘worth more than gold’
- Beaver Wars
- Today, a pelt goes for $30-$40... even in 1700s they went for $30!

Fascinating read
Dolin (2011)
THE HABITAT THEY MAKE IS GOOD FOR OTHERS TOO!

Before & After Wolves

Restoring wolves to Yellowstone after a 70-year absence as a top predator—especially of elk—set off a cascade of changes that is restoring the park’s habitat as well.

YELLOWSTONE WITHOUT WOLVES 1926-1995

ELK overbrowsed the streamside willows, cottonwoods, and shrubs that prevent erosion. Birds lost nesting space. Habitat for fish and other aquatic species declined as waters became broader and shallower and, without shade from streamside vegetation, warmer.

ASPEN trees in Yellowstone’s northern valleys, where elk winter, were seldom able to reach full height. Elk ate nearly all the new sprouts.

COYOTE numbers climbed. Though they often kill elk calves, they prey mainly on small mammals like ground squirrels and voles, reducing the food available for foxes, badgers, and raptors.

YELLOWSTONE WITH WOLVES 1995-PRESENT

ELK population has been halved. Severe winters early in the reintroduction and drought contributed to the decline. A healthy fear of wolves also keeps elk from lingering at streamside, where it can be harder to escape attack.

ASPENS The number of new sprouts eaten by elk has dropped dramatically. New growth in some areas now reach 10 to 15 feet tall.

COYOTES Wolf predation has reduced their numbers. Fewer coyote attacks may be a factor in the resurgence of the park’s pronghorn.

WILLOWS, cottonwoods, and other riparian vegetation have begun to stabilize stream banks, helping restore natural water flow. Overhanging branches again shade the water and welcome birds.

BEAVER colonies in north Yellowstone have risen from one to 12, now that some stream banks are lush with vegetation, especially willows (a key beaver food). Beaver dams create ponds and marshes, supporting fish, amphibians, birds, small mammals, and a rich insect population to feed them.

CARRION Wolves don’t cover their kill, so they’ve boosted the food supply for scavengers, notably bald and golden eagles, coyotes, ravens, magpies, and bears.
HOW BEAVERS DRIVE RIPARIAN VEGETATION

Herbivory
(Dam building)
Raised water tables
Moderated flows
Changes in Riparian Habitat
# BEAVER IMPACTS ON FISH?

Table 3 Citation of negative impacts of beaver activity on fish populations and the percentage of citations based on quantitative analysis or speculation. Different impacts are expressed as the number of times they are cited in 108 literature sources and as a percentage of the total number of citations.

<table>
<thead>
<tr>
<th>Negative impacts</th>
<th>Number</th>
<th>% of total citations</th>
<th>Data driven (%)</th>
<th>Speculative (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barriers to fish movement</td>
<td>51</td>
<td>42.9</td>
<td>21.6</td>
<td>78.4</td>
</tr>
<tr>
<td>Reduced spawning habitat</td>
<td>20</td>
<td>16.8</td>
<td>40.0</td>
<td>60.0</td>
</tr>
<tr>
<td>Altered temperature regime</td>
<td>11</td>
<td>9.2</td>
<td>9.1</td>
<td>90.9</td>
</tr>
<tr>
<td>Reduced oxygen levels</td>
<td>12</td>
<td>10.1</td>
<td>50.0</td>
<td>50.0</td>
</tr>
<tr>
<td>Reduced habitat quality</td>
<td>2</td>
<td>1.7</td>
<td>0.0</td>
<td>100</td>
</tr>
<tr>
<td>Altered flow regimes</td>
<td>4</td>
<td>3.4</td>
<td>75.0</td>
<td>25.0</td>
</tr>
<tr>
<td>Loss of cover</td>
<td>5</td>
<td>4.2</td>
<td>0.0</td>
<td>100</td>
</tr>
<tr>
<td>Reduced productivity</td>
<td>9</td>
<td>7.6</td>
<td>33.3</td>
<td>66.7</td>
</tr>
<tr>
<td>Retarded growth</td>
<td>2</td>
<td>1.7</td>
<td>50.0</td>
<td>50.0</td>
</tr>
<tr>
<td>Abandonment of beaver settlements</td>
<td>1</td>
<td>0.8</td>
<td>100</td>
<td>0.0</td>
</tr>
<tr>
<td>Reduced water quality</td>
<td>2</td>
<td>1.7</td>
<td>50.0</td>
<td>50.0</td>
</tr>
<tr>
<td>Total</td>
<td>119</td>
<td>100</td>
<td>28.6</td>
<td>71.4</td>
</tr>
</tbody>
</table>
DO BEAVER DAMS PREVENT FISH FROM GETTING UPSTREAM?

- Native cutthroats can pass easier than invasive Browns!

MITIGATE IMPACTS OF CLIMATE CHANGE?

Climate Change
• Less snowfall, earlier snowmelt
• Earlier Spring runoff, late; reduced or absent late-season flows or
• Higher temperatures and increased evaporation
• Longer, more intense droughts
• Reduced wetlands

Dam-building Beaver
• Slow snowmelt and other runoff
• Extend the seasonal flow
• Store and cool water underground
• Slow release water during drought
• Create wetlands
Figure 7. Beaver activity results in multisuccesional pathways, some of which can affect the landscape for centuries. Shown is our concept of how beaver may be affecting the boreal forest landscape of northern Minnesota.

BEAVER: DRIVER OF THE RIVER DISCONTINUUM

Table 1. Comparison of beaver and run-of-the-river human dams as an example of human-built replacement of one type of preexisting discontinuity along the river corridor.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Run-of-the-river human dam</th>
<th>Select beaver dam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance</td>
<td>Imperative</td>
<td>Limited or nonwet, permanent</td>
</tr>
<tr>
<td>Dam size (length)</td>
<td>100 to 3000 years</td>
<td>10 to 100 years</td>
</tr>
<tr>
<td>Number of outlets/paddle chambers</td>
<td>One</td>
<td>One or more</td>
</tr>
<tr>
<td>Creep geometry</td>
<td>Steep, usually linear</td>
<td>Gentle, irregular</td>
</tr>
<tr>
<td>Hydraulic cross section at the weir</td>
<td>Stream-flood level</td>
<td>Variable, influenced by flood level, water level, and floodplain dynamics</td>
</tr>
<tr>
<td>Low level water storage</td>
<td>Little to no release</td>
<td>Water continues to flow through dam</td>
</tr>
<tr>
<td>Upstream water stage variability</td>
<td>Little to none</td>
<td>Variable over the water year</td>
</tr>
<tr>
<td>Riverbed width</td>
<td>Narrow</td>
<td>Wide</td>
</tr>
</tbody>
</table>

Note: list of the river dams are the most common existing and removed dam type in the United States (Poff and Hart 2002).

Source: Miller-Schulte and Fosberg 2015, Rushford et al. 2015.

Articles

The River Discontinuum: Applying Beaver Modifications to Baseline Conditions for Restoration of Forested Headwaters

DENISE BURCHSTED, MELINDA DANIELS, ROBERT THORSON, AND JASON VOKOUN

Billions of dollars are being spent in the United States to restore rivers in a desired, yet often unknown, reference condition. In lieu of a known reference, preexisting conditions typically assume the paradigm of a connected watercourse. Ecological and ecological processes, however, create patchy and discontinuous stream systems. One of these processes, dam building by North American beavers (Castor canadensis), generates discontinuities throughout preexisting river systems of northern North America. Under modern conditions, beaver dams create dynamic sequences of ponds and wetlands among free-flowing segments. Over 400 years along the river, find the valley foundation, and functionally alter hydrogeomorphic and ecological structures. In this article, we use hierarchical patch dynamics to investigate beaver-mediated discontinuities across spatial and temporal scales. We then use this conceptual model to generate testable hypotheses addressing channel geomorphology, natural flow regimes, water quality, and flow, the importance of these features in river restoration.

Keywords: fluvial geomorphology, hierarchical patch dynamics, stream ecology, river continuums, river restoration

Private and public agencies across the United States spend billions of dollars on river restoration (Schnetzer et al. 2003) in attempts to return targeted systems to a state similar to that below disturbance. Our understanding of the predisturbance system, however, is limited by recent human alterations (e.g., Wunder and Merritts 2008). To successfully implement a project that achieves even partial restoration, it is essential to understand the predisturbance system. The baseline typically used in river restoration is a continuous, free-flowing system (Schnetzer 1998). However, in catchments with limited modern human impact, the predisturbance condition of the headwaters is fragmented by beaver, colliery, large wood, past glacial scouring and deposition, and North American beaver (Castor canadensis) dams (Naiman et al. 1988, Gallanty 2002, Benda et al. 2005), among other discontinuities. These discontinuities occur on a longitudinal scale, such as the bottom-up process. Segments vary over space and time.

Riverine and floodplain habitats are often the most important habitats in the United States (Poff and Hart 2002). However, rather than viewing...
Hydrologic Impacts

• Discharge
  • Decreased velocity, increased depth, increased wetted surface
  • Attenuation of flood waters (storage)
  • Overbank/overland flooding
  • Increased base flow → slow release throughout the season

• Groundwater – Surface Water Interaction
  • Groundwater recharge and retention
  • Raised water table
  • Downwelling/Upwelling locations within and below dams
Water Quality Impacts

- **Sediment**
  - Sedimentation – filling beaver ponds
  - Decreased downstream turbidity

- **Temperature**
  - Increased temperature in the ponds (in some locations)
  - Decreased temperature downstream of beaver dam – upwelling

- **Fish species**
- **Time of the year**
- **Reach**
- **Geographic location**

- **Oxygen**
  - cooler water = more oxygen, more plants = more and less oxygen, more oxygen demanding material = less oxygen

- **Nutrients**
  - increase in captured nutrients, increase in residence time, response = f(temp, oxygen, pH)

- **Others**
  - heavy metals (sorption), harmful bacteria
State of the Science – Hydrologic Impacts

- **Discharge**
  - Attenuation of flood waters

- **Groundwater – Surface Water Interaction**
  - Beaver dams and overbank floods
  - Influence of beaver dams on hyporheic zone

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Nyssen, et al., 2011

Westbrook et al., 2006

Lautz et al., 2006

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Not as many studies
More qualitative than quantitative
State of the Science – Water Quality Impacts

- Sediment
  - Sediment accumulation and restoring incised river
  - Sedimentation and possible danger of beaver dam failures

- Temperature
  - Hyporheic exchange dynamics—high-resolution distributed temperature sensing

Briggs et al., 2012
State of the Science – Water Quality Impacts

• Oxygen
  • Saturated below dams (e.g., Smith et al. 1991)
  • Saturated to depleted within dams (Curtis Creek)

• Nutrients
  • Nutrients = stored in the sediments
  • Potentially transformed due to increased residence time
  • Potentially transformed due to contact with anoxic sediments

• Other
  • Benthic invertebrates (e.g., Fuller et al. 2011)
  • Heavy metals (e.g., mercury, Roy et al. 2009)
  • Gases (e.g., methane production, Weyhenmeyer 1999)

AGAIN, NOT AS MANY STUDIES.....GENERALLY SITE SPECIFIC EXPLANATIONS
Curtis Creek, UT

• Thermal Imagery

(a) Low density STS

(b) High density STS

Stream Temperature:
- 18.0°C
- 14.5°C
- 11.0°C

Beaver Dam

(1) (2) (3) (4)

(5) (6)

Frequency

Temperature (C)

Meters

(1) 14 cm
(2) 30 cm
(3) 52 cm
(4) 12 cm
(5) 34 cm
(6) 60 cm
WHAT DO GEOMORPHOLOGISTS LOOK AT?

- Landforms & the Processes that shape them
- What processes?
  - Erosion, Transport & Deposition
- Piles of Sediment (i.e. bars)
What are the primary hydraulic variables?
- Velocity, Depth
What do they do to hydraulic variables & geometry (+ or -)?
How do they change when a beaver dam is present?
- Upstream vs. Downstream
FLOW VECTORS...

• Train your eye to look for:
  – Shear zones
  – Convergent Flow
  – Divergent Flow
  – Topographic Steering of Flow
  – Flow ‘forcing’ elements
SOME FLUVIAL TRIVIA...

• Sediment laid down by water (fluvially) is:
  – Alluvium
  – Well sorted
  – Well rounded

• Sediment supply...

• Sediment is food for depositional landforms

• Geomorphic units = habitat
BEAVER & GEOMORPHOLOGY

• What landforms does a beaver dam create?
  – Geomorphic units?

• What are the ‘piles of sediment’ in the pond made of?

• Why?