PARTNERING WITH BEAVER IN RESTORATION
BEAVER ECOSYSTEM
ENGINEERING & FEEDBACKS

Joe Wheaton
Nick Bouwes

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I. Eco-geo-hydro Feedbacks

II. Ecological Feedbacks

From: http://www.howstuffworks.com/beaver-dam.htm
WHAT IS AN ECOSYSTEM ENGINEER?
In blurring boundaries between rivers, wetlands and uplands, they expand riparian zones!

Where exactly is that line?
But it is precisely that messiness, that is so critical to ecosystem health.
WHAT’S GOOD ABOUT BEAVER DAMS?

- Natural filters for improved WQ
- Increased groundwater recharge & water tables
- Change timing, delivery and storage or water, sediment and nutrients

BEAVER INDUCED PHYSICAL CASCADE

- Dam Building
- Direct Alteration of Hydraulics
- Changes Hydrology
- Impacts Geomorphology
- Changes in Habitat
HYDRAULIC FEEDBACKS OF BEAVER...

• 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
HOW DOES FLOW CHANGE WITH DAMS?

Flow In

Flow Out
TYPICAL IMPACT ON FLOWS

- Lower peaks @ flood
- Elevated output rest of time

![Graph showing flow in and flow out over time](image-url)
IN THEIR ECOSYSTEM ENGINEERING, THEY CREATE STARK CONTRASTS IN DRY ENVIRONMENTS.
FLOW VECTORS...

- Train your eye to look for:
  - Shear zones
  - Convergent Flow
  - Divergent Flow
  - Topographic Steering of Flow
  - Flow ‘forcing’ elements
WHAT DO GEOMORPHOLOGISTS LOOK AT?

- Landforms & the Processes that shape them
- What processes?
  - Erosion, Transport & Deposition
- Piles of Sediment (i.e. bars)
What landforms does a beaver dam create?
- Geomorphic units?

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

Why?
PROCESS OF CHANNEL INCISION
LATERAL EROSION

Aggradation - Inset Floodplain
THE INCISION-AGGRADATION CYCLE

Figure from Pollock et al. (2014) Bioscience. DOI: 10.1093/biosci/biu036

Using Beaver Dams to Restore Incised Stream Ecosystems

Timescale (logarithmic)
THE INCISION-AGGRADATION CYCLE

Adapted from Clauer and Thorne 2013

Figure from Pollock et al. (2014)
THE INCISION-AGGRADATION CYCLE WITH BEAVER DAMS & BEAVER DAM ANALOGUES

Figure from Pollock et al. (Accepted) Bioscience
USING BEAVER TO RESTORE INCISED STREAMS

Figure from Pollock et al. (2014)
Bioscience
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.

ROLE OF ABANDONMENT & FAILURE

- What happens post dam failure?

- What if abandonment is permanent?

Typical Causes of Abandonment

<table>
<thead>
<tr>
<th><em>Seasonal Migration (temporary)</em></th>
<th><em>Dam Breach/ Failure (permanent or temporary)</em></th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Exhaustion of Food/Building Materials (permanent or temporary)</em></td>
<td><em>Permanent Migration (permanent)</em></td>
</tr>
<tr>
<td><em>Decreased Functionality (e.g. pond aggradation; permanent or temporary)</em></td>
<td><em>Trapping (human; permanent)</em></td>
</tr>
<tr>
<td><em>Predation (natural; permanent or temporary)</em></td>
<td><em>Mortality (natural; permanent)</em></td>
</tr>
</tbody>
</table>
AN OREGON STREAM

**Figure 10:** Progression of reach at upper Owens through a period without a dam (A; 2005), with an active, partially breached dam (B; Nov 2009), to an abandon, partially breached dam (C; April 2010).
CAPTURED THE POST FAILURE RESPONSE

Erosion: 28.2 m³ +/- 4
Deposition: 33.6 m³ +/- 6
MORE INTERESTING....

Bridge Creek - Upper Owens Reach

Geomorphologic Interpretation of Changes Between May and November 2009 (Post Dam Failure)
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 proceeding 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>Permeability</td>
<td>Impermeable</td>
<td>Locally permeable</td>
</tr>
<tr>
<td>Minimum capacity</td>
<td>100 to 150 years</td>
<td>20 to 100 years</td>
</tr>
<tr>
<td>Maximum capacity</td>
<td>200 to 250 years</td>
<td>50 to 100 years</td>
</tr>
<tr>
<td>Number of overflow channels</td>
<td>One</td>
<td>None</td>
</tr>
<tr>
<td>Silt content</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>Water holding capacity</td>
<td>50 to 100 years</td>
<td>20 to 100 years</td>
</tr>
<tr>
<td>Water temperature</td>
<td>Below freezing</td>
<td>Below freezing</td>
</tr>
<tr>
<td>Water quality</td>
<td>Excellent</td>
<td>Excellent</td>
</tr>
<tr>
<td>Sediment loading rate</td>
<td>Low</td>
<td>High</td>
</tr>
</tbody>
</table>

Figure 1. Examples of headwater segment types classified in this article: (a) free flowing, (b) beaver meadow, (c) valley beaver impoundment, and (d) in-channel beaver impoundment.

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

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

Billions of dollars are being spent in the United States to restore rivers to a desired, yet often unknown, reference condition. In the absence of a known reference, practitioners typically assume the paradigm of a connected watercourse. Ecological and ecological processes, however, create patchy and discontinuity (discontinuities). One of these processes is human alteration, creating discontinuities. We present a conceptual model to generate possible hypotheses addressing channel geomorphology, natural flow regime, water quality, and biology. This model is based on the importance of these factors in river restoration.

Figure 3. Discontinuity (discontinuities) in the landscape and how they can affect river restoration practices. The model is based on the importance of these factors in river restoration.

Figure 4. Schematic of the river discontinuum model. The model is based on the importance of these factors in river restoration.

Figure 5. Flowchart of the river discontinuum model. The model is based on the importance of these factors in river restoration.

Figure 6. Flowchart of the river discontinuum model. The model is based on the importance of these factors in river restoration.

Figure 7. Flowchart of the river discontinuum model. The model is based on the importance of these factors in river restoration.

Figure 8. Flowchart of the river discontinuum model. The model is based on the importance of these factors in river restoration.

Figure 9. Flowchart of the river discontinuum model. The model is based on the importance of these factors in river restoration.

Figure 10. Flowchart of the river discontinuum model. The model is based on the importance of these factors in river restoration.

Figure 11. Flowchart of the river discontinuum model. The model is based on the importance of these factors in river restoration.

Figure 12. Flowchart of the river discontinuum model. The model is based on the importance of these factors in river restoration.

Figure 13. Flowchart of the river discontinuum model. The model is based on the importance of these factors in river restoration.

Figure 14. Flowchart of the river discontinuum model. The model is based on the importance of these factors in river restoration.

Figure 15. Flowchart of the river discontinuum model. The model is based on the importance of these factors in river restoration.

Figure 16. Flowchart of the river discontinuum model. The model is based on the importance of these factors in river restoration.

Figure 17. Flowchart of the river discontinuum model. The model is based on the importance of these factors in river restoration.

Figure 18. Flowchart of the river discontinuum model. The model is based on the importance of these factors in river restoration.

Figure 19. Flowchart of the river discontinuum model. The model is based on the importance of these factors in river restoration.

Figure 20. Flowchart of the river discontinuum model. The model is based on the importance of these factors in river restoration.
THE DYNAMICS MATTER!

Hierarchical scale

River network
$10^3$ m
$10^5$ to $10^6$ years

Segment
$10^2$ m
$10^2$ to $10^4$ years

Reach
$10^1$ m
$10^1$ to $10^2$ years

Juxtaposition of functionally different segments modifies network-scale processes, working as bottom-up processes. Segments vary over space and time.

Free flowing
- Perennial surface water
- Floodplain (frequently saturated)

Beaver impoundment
- Scour zone (saturated)
- Terrace (infrequently saturated)

Beaver meadow
- Terrace
- Perennial surface water
- Meadow (saturated)

Alluvium - oxidizing

Colluvium / till / old alluvium

Alluvium - reducing

Floodplain vegetation

Channel
- Emergent vegetation
- Vegetated bed

Channel: coarsening bed

Channel: hard bed

Pool
- Bar
- Large wood
- Alluvium

Streambed

Mineral mat

Sediments
- Organic, oxidizing
- Organic, reducing

Grasses and herbs

Marsh

Marsh grass

Grit
DYNAMIC RIVERS = HEALTHY ECOSYSTEMS

- We *believe* this...
- Lots of cool studies showing feedbacks and links...

- We *know*: to get and maintain heterogeneous habitat, we need dynamic systems
TAKE AWAYS...

- The impacts of their dam building are what have the biggest feedbacks on:
  - Hydrology (timing & magnitude)
  - Hydraulics (flow depth & velocity)
  - Water Quality (temp & chemistry)
  - Geomorphology (landforms left behind)
  - Habitat for a plethora of aquatic, riparian & upland biota (flora & fauna)
PHYSICAL & BIOTIC FEEDBACKS

I. Eco-geo-hydro Feedbacks

II. Ecological Feedbacks

Bridge Creek © Wheaton

From: http://www.howstuffworks.com/beaver-dam.htm
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 1920-1995

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, birds, 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 groves 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.
DO BEAVER DAMS PREVENT FISH FROM GETTING UPSTREAM?

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</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</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</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!

Do Beaver Dams Impede the Movement of Trout?

Ryan J. Lokhoff and Brett R. Roper
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Abstract

Dams created by North American beavers Castor canadensis (hereafter, “beavers”) have numerous effects on aquatic habitats and by inference, many of these changes to the stream are seen as positive and many aquatic restoration projects seek to reintroduce beavers or to mimic the habitats that they create. The extent to which beaver dams act to movement barriers is still unknown and warrants further research. We investigated beaver dam passage by rainbow trout species in two northern Utah streams. We captured 1,375 trout above and below 21 beaver dams, and tagged them with PIT tags to establish whether fish passed the dams and to identify downstream and upstream trap passage. If individual trout were observed to make 481 passes of the 21 beaver dams. Native Bonneville Cutthroat Trout Oncorhynchus clarki and nonnative Rainbow Trout Salmo gairdneri showed frequent thermosensitive passage in the fall, and salmon passage by each species.

Physical characteristics of a dam, such as height and upstream location, affected passage of each species. Movement behaviors of each species were also estimated to help explain the observed patterns of dam passage. Our results suggest that beaver dams are not acting as movement barriers for Bonneville Cutthroat or Brook Trout but may be impeding the movement of native brown Trout.

*Corresponding Author: r.lokhoff@gmail.com
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MORE MULTI-STEMMED TREES CLOSE TO THE POND EDGE.... ALSO MORE LIGHT.
Waterfowl and Wetland Surveys

- 20 paired stream reaches (beaver and no beaver)
- 1 km reaches randomly selected
- All waterfowl counted
- Riparian width measured at 100 m intervals
# Riparian Width and Wetland Area

<table>
<thead>
<tr>
<th></th>
<th>With Beaver</th>
<th>Without Beaver</th>
</tr>
</thead>
<tbody>
<tr>
<td>Riparian Width</td>
<td>33.9 m (CI=56.1)</td>
<td>10.5 m (CI=19.7)</td>
</tr>
<tr>
<td>Wetland Area</td>
<td>3.3 ha/km (CI=0.74 ha)</td>
<td>1.0 ha/km (CI=0.25 ha)</td>
</tr>
<tr>
<td>Past Research</td>
<td>9.6 ha/km</td>
<td>0.8-1.6 ha/km</td>
</tr>
<tr>
<td>Munther 82, 83</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Slide Courtesy of Mark McKinstry
## Waterfowl Densities (Statewide 1st-3rd order)

<table>
<thead>
<tr>
<th>Known Areas Where Beaver Have Been Extirpated</th>
<th>With Beaver</th>
<th>Without Beaver</th>
</tr>
</thead>
<tbody>
<tr>
<td>39,000 ducks (5,261 km; 17,300 ha wetlands)</td>
<td></td>
<td>5,200 ha wetlands</td>
</tr>
</tbody>
</table>

| Total Areas in State (extrapolated 24% of total) | 200,000 ducks (28,000 km; 93,000 ha wetlands) | 28,000 ha wetlands |

WOOD FROG PRODUCTION

Karraker and Gibbs 2009
Table 1. Comparison of mean annual standing stocks and annual fluxes of carbon in a riffle and pond in Beaver Creek, Quebec. Data are from Naiman et al. 1986.

<table>
<thead>
<tr>
<th>Component</th>
<th>Carbon</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rifle</td>
<td>Pond</td>
</tr>
<tr>
<td>INPUT (g · m⁻² · yr⁻¹)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Precipitation and throughfall</td>
<td>16.9</td>
<td>6.9</td>
</tr>
<tr>
<td>Direct allochthonous</td>
<td>123.1</td>
<td>52.6</td>
</tr>
<tr>
<td>Lateral allochthono</td>
<td>55.8</td>
<td>4.3</td>
</tr>
<tr>
<td>Periphyton production</td>
<td>24.7</td>
<td>1.7</td>
</tr>
<tr>
<td>Total input</td>
<td>220.5</td>
<td>65.1</td>
</tr>
<tr>
<td>STANDING STOCK (g/m²)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water column</td>
<td>2.0</td>
<td>18.0</td>
</tr>
<tr>
<td>Coarse wood</td>
<td>3926.9</td>
<td>3129.2</td>
</tr>
<tr>
<td>CPOM</td>
<td>419.4</td>
<td>5152.0</td>
</tr>
<tr>
<td>FPOM</td>
<td>33.7</td>
<td>3738.8</td>
</tr>
<tr>
<td>Primary producers</td>
<td>0.5</td>
<td>0.1</td>
</tr>
<tr>
<td>Invertebrates</td>
<td>0.4</td>
<td>2.7</td>
</tr>
<tr>
<td>Total standing stock</td>
<td>4382.9</td>
<td>12040.8</td>
</tr>
<tr>
<td>OUTPUTS (g · m⁻² · yr⁻¹)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Detritus respiration</td>
<td>22.0</td>
<td>111.5</td>
</tr>
<tr>
<td>Autotrophic respiration</td>
<td>28.0</td>
<td>1.6</td>
</tr>
<tr>
<td>Methane evasion</td>
<td>0.5</td>
<td>7.4</td>
</tr>
<tr>
<td>Insect emergence</td>
<td>0.3</td>
<td>0.4</td>
</tr>
<tr>
<td>Total outputs</td>
<td>50.8</td>
<td>120.9</td>
</tr>
</tbody>
</table>

Naiman et al. 1988