Climate Change Be Dammed!

AN INTRODUCTION TO THE ROLE OF BEAVERS IN A WARMING WORLD

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CALIFORNIA STATE UNIVERSITY CHANNEL ISLANDS
Climate is changing.

What can we do about it?
Climate Mitigation:
Long-term reduction in emissions, slow and/or stop trajectory of warming. **Doesn’t necessarily fix the consequences of climate change we are dealing with now.**

Climate Adaptation:
Long- and short-term actions to minimize damage from climate change that has already occurred. **Doesn’t necessarily slow or stop climate change, but protects lives and infrastructure being threatened today.**
We need engineers.

A Call to Action for Engineers on Climate Change

Future of Floods | Role of engineers in tackling flood risk
But what about nature’s engineer?
Climate is changing.

What can we beavers do about it?
Beavers dampen flood waves.
Beavers dampen flood waves.

Figure by Emily Fairfax, PhD
Beavers dampen flood waves.

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Beavers dampen flood waves.

**No Beavers**

**Beavers**

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No Beavers

- Erosion
- Soil Loss
- Scouring

Beavers

Figure by Emily Fairfax, PhD
Beavers dampen flood waves.

**No Beavers**
- Erosion
- Scouring
- Soil loss

**Beavers**
- Spread
- Stored
- SLOWED

Figure by Emily Fairfax, PhD
Do beaver dams and ponds stop all the water?

Do they starve the downstream area of water?
The American West is snowmelt dominated.
Beaver ponds slow, but don’t stop, water.

Streamflow (Volume/Time)
i.e. how much water is coming thru the stream

- **Snowpack Accumulates**
- **Peak Plant Water Demands**
- **Peak Fire Danger**

<table>
<thead>
<tr>
<th>Time</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
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Beaver ponds slow, but don’t stop, water.

Streamflow (Volume/Time)
i.e. how much water is coming thru the stream

Undammed Stream

Jan Feb Mar Apr May Jun Jul Aug Sept Oct Nov Dec
Beaver ponds slow, but don’t stop, water.

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</thead>
<tbody>
<tr>
<td>Streamflow (Volume/Time)</td>
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*Undammed Stream*  
*Beaver-Dammed Stream*
Beaver ponds slow, but don’t stop, water.

**Total Water Volume**
Mathematically the area under the curves.

Total water volume coming is only marginally less (GW recharge and ET “losses”) in a Beaver-Dammed Stream.

It “feels” like less water since there is such a dramatic reduction in peak flow during snowmelt, and a comparatively small (but very important) increase in baseflow during summer and fall.
What about the water “losses” to groundwater and plants?

Isn’t losing water a bad thing?
Beavers keep plants green during drought.
Beavers Buffer Droughts
the conceptual model
Conceptual Model: Beavers and Drought

Fairfax and Small (2018)
Conceptual Model: Beavers and Drought

stream without beavers

stream with beavers
Conceptual Model: Beavers and Drought

Fairfax and Small (2018)
Conceptual Model: Beavers and Drought

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Conceptual Model: Beavers and Drought

Fairfax and Small (2018)
Beavers Buffer Droughts
the science and data
How can we observe and quantify drought resistance?

Google Earth

Location and Length of Beaver Dams
How can we observe and quantify drought resistance?

- Google Earth
- Location and Length of Beaver Dams
- Landsat 8 and METRIC model (Allen 2007)
- Evapotranspiration (ET) of Riparian Vegetation

From Fairfax & Small (2018)
How can we observe and quantify drought resistance?

1. **Google Earth**
   - Location and Length of Beaver Dams

2. **Landsat 8 and METRIC model (Allen 2007)**
   - Evapotranspiration (ET) of Riparian Vegetation

3. **Landsat 8**
   - NDVI of Riparian Vegetation
How can we observe and quantify drought resistance?

Goal: Compare the vegetation health in dammed vs undammed areas throughout study area (near Elko, NV)
Data Example: Maggie Creek, NV
Data Example: Maggie Creek, NV
Data Example: Maggie Creek, NV

Evapotranspiration

July 2014

Satellite Image

Heavily Dammed Riparian Area (many beavers)

Undammed Riparian Area (no beavers)

NDVI

July 2014

From Fairfax & Small (2018)
This was in the middle of TWO droughts: seasonal and multi-year
Precipitation is extremely limited, but the beaver-dammed areas are staying green, plants are productive, and that portion of the landscape doesn’t “feel” the drought like the undammed riparian areas do.
Observed ET is driven by plant productivity, not open-water evaporation.
Beaver-dammed riparian zones don’t “feel” drought effects, year after year. Undammed riparian zones do.
Beavers irrigate the landscape. So do we. How do we compare?
Beavers are a close second at “managing” plant irrigation.
Beavers and Drought: the take home messages

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<th>Stream with Beavers</th>
<th>Stream without Beavers</th>
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<tr>
<td>• <strong>Higher</strong> overall ET</td>
<td>• <strong>Lower</strong> overall ET</td>
</tr>
<tr>
<td>• <strong>Not sensitive</strong> to long- or short-term drought</td>
<td>• <strong>Sensitive</strong> to long- and short-term drought</td>
</tr>
<tr>
<td>• Similar ET pattern to <strong>irrigated</strong> crops</td>
<td>• Similar ET pattern to <strong>hydrologically disconnected</strong> hillslopes</td>
</tr>
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From Fairfax & Small (2018)
Think back to the conceptual model.

- Recap my work on beavers and fire.

Fairfax and Whittle (2020)
What happens if there is an ignition event?

• Recap my work on beavers and fire.

Fairfax and Whittle (2020)

One careless match... Yours?

Our most shameful waste!

Remember—Only you can prevent forest fires!
Beavers Fight Fire
the conceptual model
What happens if there is an ignition event?

**stream without beavers**
- Stream impact on groundwater
- Drought conditions: less precipitation, veg relies on groundwater

**stream with beavers**
- Beaver pond and channel impact on groundwater
- Deep water table

**ONE CARELESS MATCH!**
(or power line)
Beavers create refugia during fire.

**stream without beavers**
- drought conditions: less precipitation, veg relies on groundwater
- fire conditions: dry vegetation ignites/burns
- stream impact on groundwater
- infiltrating precipitation
- deep water table

**stream with beavers**
- drought conditions: less precipitation, veg relies on groundwater
- fire conditions: dry vegetation ignites/burns
- beaver pond and channel impact on groundwater
- deep water table

Fairfax and Whittle (2020)
Beavers create refugia during fire, at least sometimes.
Beavers Fight Fire
the science and data
Beavers create refugia during fire.

Smokey the Beaver: beaver-dammed riparian corridors stay green during wildfire throughout the western United States

First published: 02 September 2020 | [https://doi.org/10.1002/eap.2225](https://doi.org/10.1002/eap.2225)
Similar Methods; New Question

Google Earth

Location of Beaver Dams and Wildfires
Similar Methods; New Question

Google Earth

Location of Beaver Dams and Wildfires

Landsat 7 & 8

NDVI of Riparian Vegetation Before, During, and After Wildfires

From Fairfax & Whittle (2020)
Similar Methods; New Question

- **Google Earth**
  - Location of Beaver Dams and Wildfires

- **Landsat 7 & 8**
  - NDVI of Riparian Vegetation Before, During, and After Wildfires

- **GIS & Statistics**
  - Classify Stretches of Creeks as Beaver Impacted or Not; Compare Groups at Multiple Spatial Scales

From Fairfax & Whittle (2020)
Goal: Compare the vegetation health in dammed vs undammed areas throughout study area as fire occurred (5 wildfires – CA, CO, ID, OR, WY)
Study Areas: fires, beavers, and high-quality imagery!

From Fairfax & Whittle (2020)
California Manter Fire

Domeland Wilderness
part of Sequoia National Forest

Manter Fire
Burn Date: Summer 2000
Burn Area: 79,000 acres
“It is a humbling expression of nature.

Walls of **flame 70 feet high**, twice as high as the nearest tree.

Leaping through **canyons and valleys**, at times in five directions at once.

Left behind, quite literally, is **scorched earth**.”

-LA Times, August 2\textsuperscript{nd}, 2000 on the Manter Fire in California
Imagine walking along each creek, from a designated start point to a stop point. And doing this for every creek.
Making sure you walk as close to the river as possible, seeing how green plants are as you go.

That is essentially what we did, except instead of walking them we looked at satellite images and extracted “pixel” values along the river corridors.
Look back into the past with satellites

Satellite Image (dams marked)

July 1999 (before fire)

July 2000 (during fire)

July 2001 (after fire)

○ = beaver dams

From Fairfax & Whittle (2020)
Look back into the past with satellites

Satellite Image (dams marked)

July 1999 (before fire)

July 2000 (during fire)

July 2001 (after fire)

○ = beaver dams

From Fairfax & Whittle (2020)
Beaver dams appear to reduce impact of fire on plants.
Beaver dams appear to reduce impact of fire on plants.

From Fairfax & Whittle (2020)
Beaver-driven fire resistance is not an isolated event.
Beaver-driven fire resistance is not an isolated event.

...but there is a better way to visualize that.
Quantifying fire resistance in all studied fires.
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Quantifying fire resistance in all studied fires.

\[
\text{NDVI Difference at each pixel along creek profile} \quad \frac{\text{Max NDVI Difference on that Creek}}{=} \quad \text{Scaled NDVI Difference}
\]

In plain English, please...

\[
\text{How much did veg actually burn within a pixel?} \quad \frac{\text{How much could riparian veg have burned given the fire characteristics?}}{=} \quad \text{Percent of max burning that actually occurs in a given pixel}
\]
Quantifying fire resistance in all studied fires.

\[
\text{NDVI Difference at each pixel along creek profile} \quad \frac{\text{Max NDVI Difference on that Creek}}{= \quad \text{Scaled NDVI Difference}}
\]

Why scale the NDVI?

- easier to conceptualize: think of it as % of max vegetation burning that happened in each pixel based on the max burning a given fire was capable of

- it lets us generalize between varying fire intensities, land covers, etc. and talk about beaver-related fire resistance as a general process instead of only in the context of a specific case study
Beavers repeatedly create refugia during fire.
Fairfax and Whittle (2020)

Beavers repeatedly create refugia during fire.

Scaled NDVI Differences on Sections of Creek with and without Beaver

- **No Beaver Activity**
  - Mean = 0.56
  - veg in these areas average 56% of max NDVI reduction experienced on the creek
  - veg if fire causes a max of 0.7 NDVI reduction on a creek, these areas experience an average 0.41 NDVI reduction

- **Beaver Activity**
  - Mean = 0.19
  - veg in these areas average 19% of max NDVI reduction experienced on the creek
  - veg if fire causes a max of 0.7 NDVI reduction on a creek, these areas experience an average only 0.13 NDVI reduction
Beavers repeatedly create refugia during fire.
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Looks like Smokey Bear got a helping hand from Smokey the Beaver.
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<td>• 19% NDVI reduction on average</td>
<td>• 58% NDVI reduction on average</td>
</tr>
<tr>
<td>• Satellite and aerial images show</td>
<td>• Satellite and aerial images show burned vegetation during fires</td>
</tr>
<tr>
<td>green patches during fires</td>
<td>• Increasingly large burn areas and spread rates make escaping fire</td>
</tr>
<tr>
<td>• Effect occurred in varying climate,</td>
<td>challenging</td>
</tr>
<tr>
<td>landcover, and antecedent conditions</td>
<td>• Invasive plants often recolonize burned sites</td>
</tr>
<tr>
<td>• Potential for green patches to</td>
<td>• Highly burned areas often followed by uncontrolled debris flows and</td>
</tr>
<tr>
<td>protect sensitive flora and fauna</td>
<td>flooding</td>
</tr>
<tr>
<td>during fires, harbor native plants</td>
<td></td>
</tr>
<tr>
<td>• Potential for preserved patches to</td>
<td></td>
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<tr>
<td>attenuate post-fire runoff and</td>
<td></td>
</tr>
<tr>
<td>debris flows</td>
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From Fairfax & Whittle (2020)
The Role of Beavers in a changing climate

a final summary
Beavers create and maintain resilient landscapes.
They’re doing climate adaptation and mitigation.
They’re doing climate adaptation and mitigation.

1 ha = 0.01 sq km

Ecosystem services provided by beavers Castor spp.

Stella Thompson, Mia Vehkaaja, Jani Pellikka, Petri Nummi

First published: 01 October 2020 | https://doi.org/10.1111/mam.12220
QUESTIONS?

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