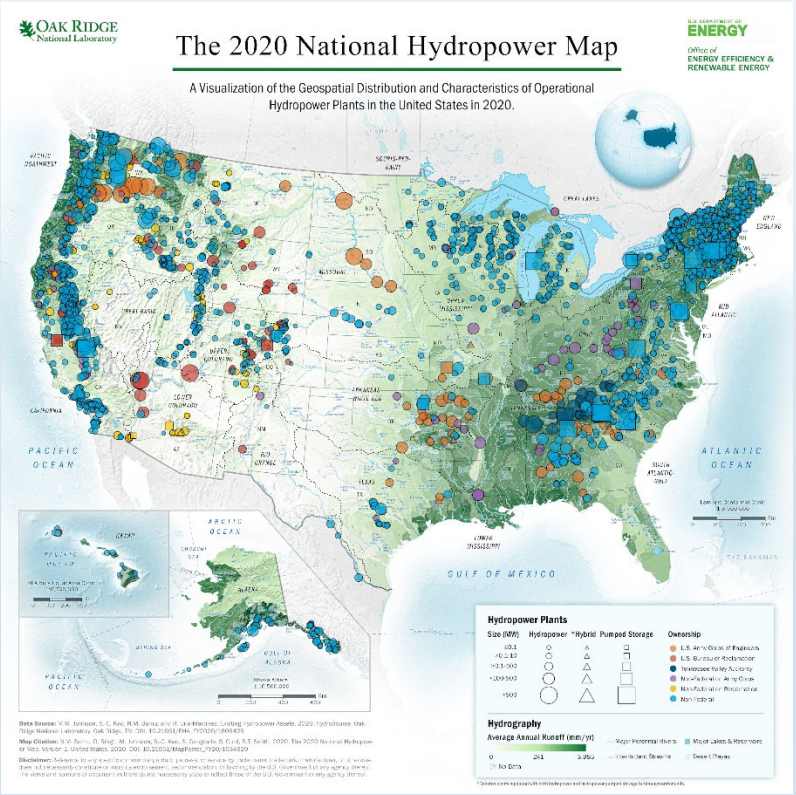
Dam Removal Webinar Series

Part 1B:
Dam Removal ~ Synthesis of the Science

(Part A Posted Separately)
October 27, 2020

- Jeff Duda
- Western Fisheries Research Center, Seattle
- jduda@usgs.gov



USGS science for a changing world

Dam removal in context

Order of Magnitude	Number of dams
11,000,000	Estimated world wide dams (total)[1]
2,000,000	Estimated U.S. dams (total)[2]
91,000	U.S. National Inventory of Dams[3]
1,700	Number of dam removals[4]
262	Number of dam removal studies[5]
196	Number of removed dams studied[5]

[1]Lehner et al. 2011
[2]Graf 1993
[3]U.S. Corps of Engineers 2018
[4]American Rivers 2020
[5]Duda et al. 2020

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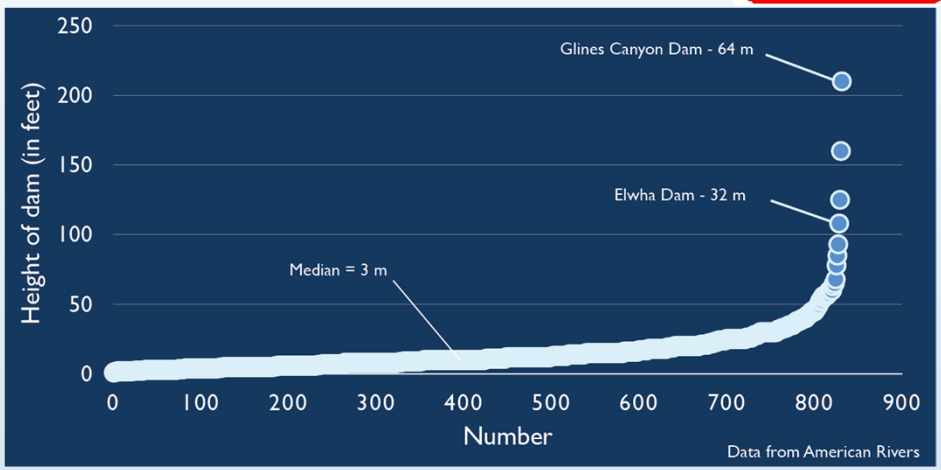

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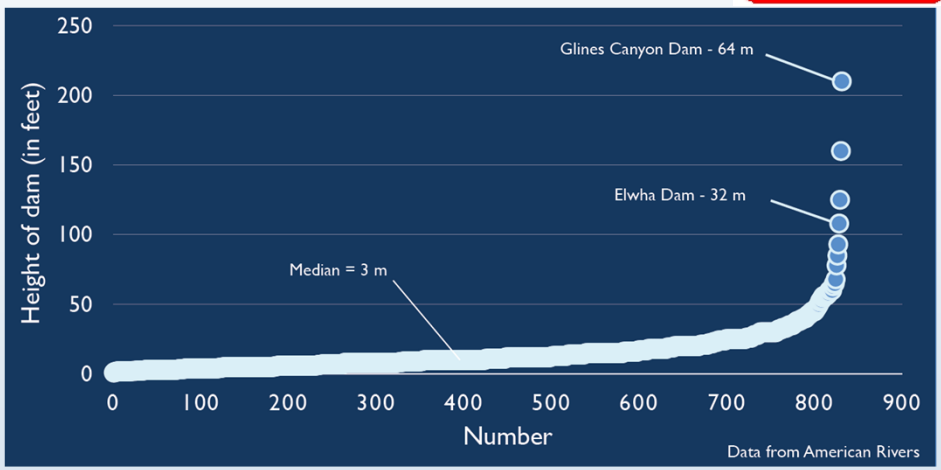

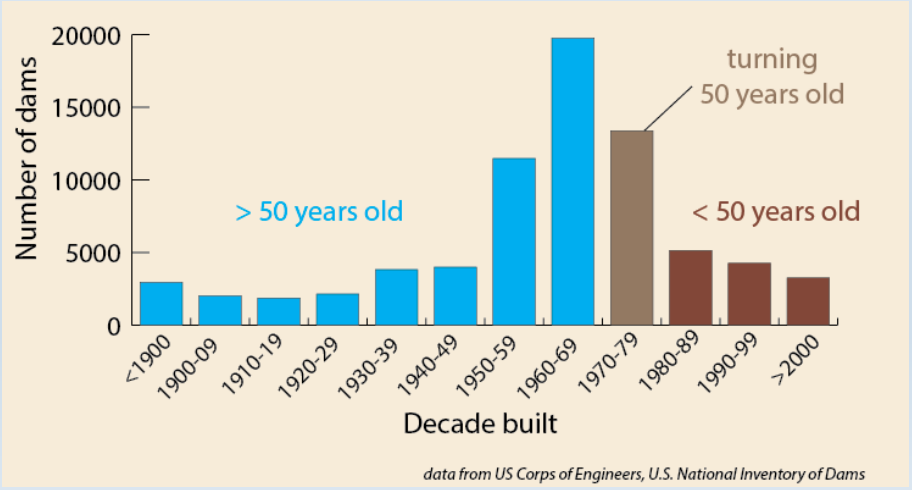

Dam removal responses: what do we know and why is it important?

Rising flood waters advance on Midland, Michigan, after the breach of the Edenville and Sanford dams.

Edited by **Jennifer Sills**

Preparing for proactive dam removal decisions

Science AAAS July 2020

Farshid Vahedifard[1]*, Kaveh Madani[2,3], Amir AghaKouchak[4], Sannith Kumar Thota[1]

"To move forward, we need a scientific and legal framework in place to evaluate if and when dam removal is required ... "

"To prepare for future decisions, scientists should document, share, and analyze the collected data and lessons from both past and ongoing dam removal missions."

Synthesis of Dam Removal Science

USGS John Wesley Powell Center for Analysis and Synthesis

Working Group

Dam removal: synthesis of ecological and physical responses

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Dam removal: synthesis of ecological and physical responses

Goals:

- Data compilation and organization
- Create conceptual models
- Identification of key information gaps
- Assess management and policy implications

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Dam removal: synthesis of ecological and physical responses

My talk

Jennifer's talk

Goals:

- Data compilation and organization
- Create conceptual models
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Conduct Literature Review

By Jun - https://www.flickr.com/photos/biker_jun/6141872902/, CC BY-SA 2.0

We searched

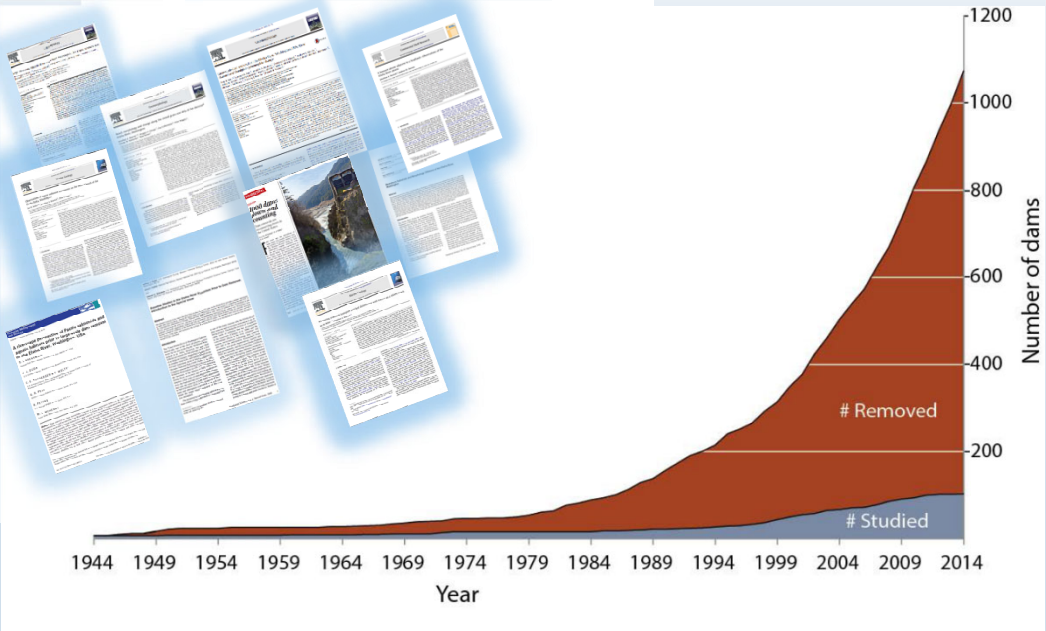
- Web of Science, Google Scholar, USGS Publication Warehouse,Clearinghouse for Dam Removal Information

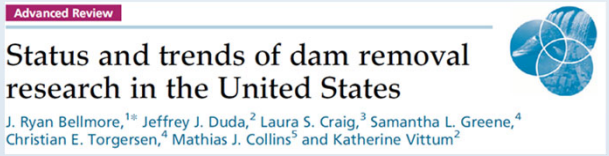
Identified over 6,000 potentially relevant studies~Those with empirical data

- But only around 600 studies were related to dam removal
- Only 179 studies that contained empirical data on dam removal responses
- 139 studies of US dam removals (from 115 different dams)

Literature Review

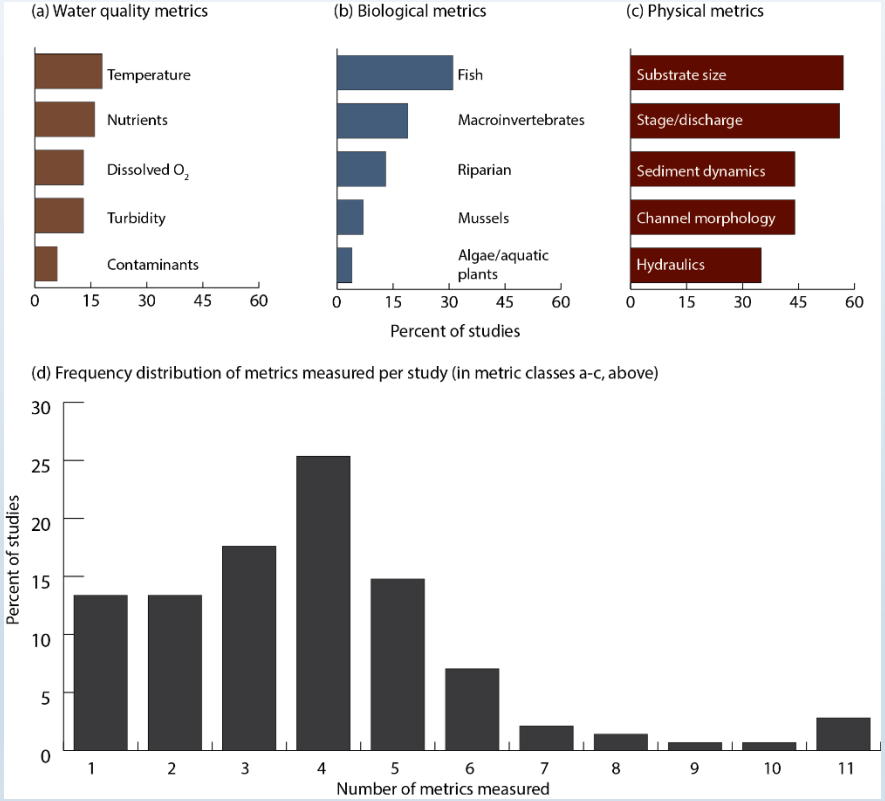
~ 9% of dam removals with studies

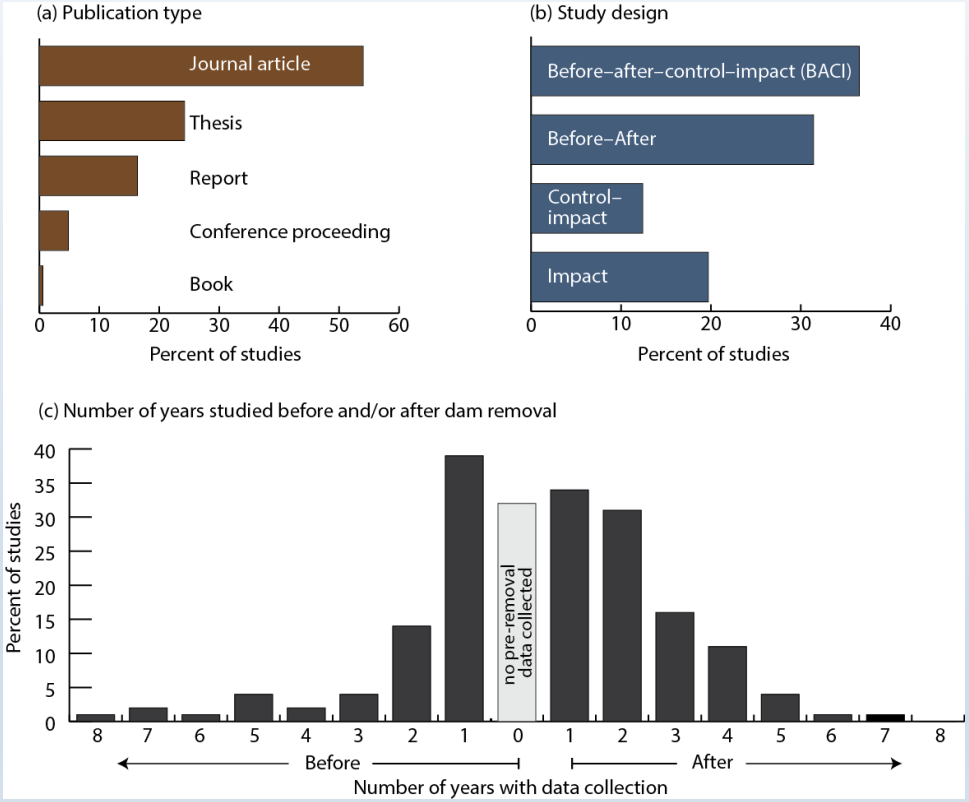




WIREs Water
DOI: 10.1002/wat2.1164.

Anatomy of the dam removal literature





USGS science for a changing world

Bellmore et al. 2017 WIREs Water

Living databases on removed dam science

USGS Dam Removal Science Database v3

https://doi.org/10.5066/P9IGEC9G.

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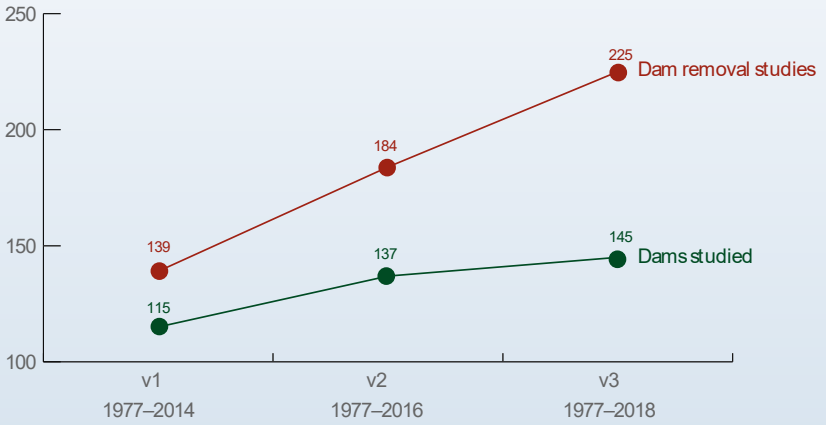

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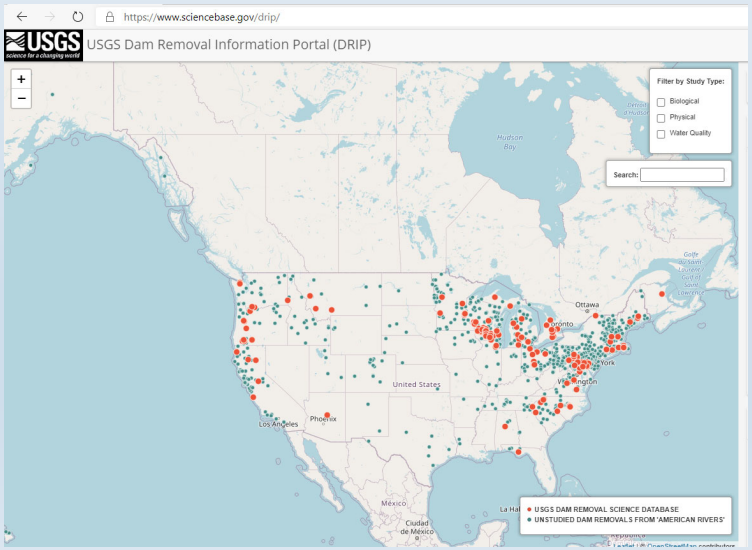


USGS Dam Removal Information Portal (DRIP)

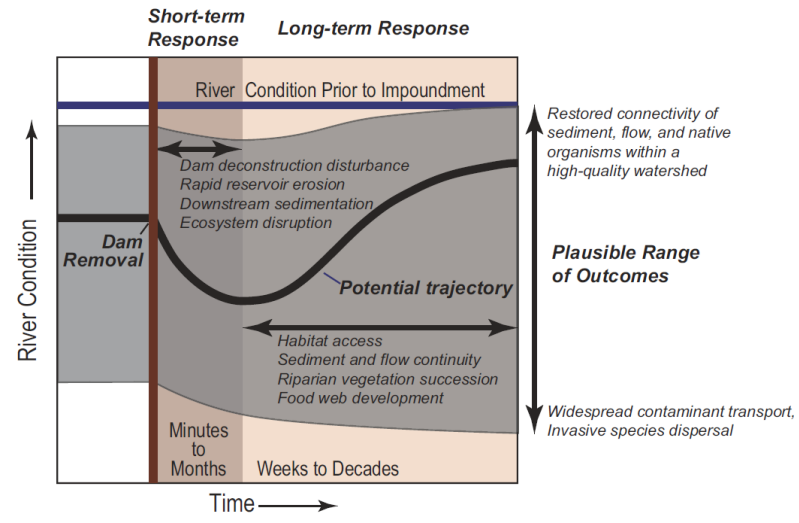
https://sciencebase.gov/DRIP

An online geospatial instance of the USGS Dam Removal Science Database

Synthesis

- **Sediment** – rivers can move it upon removal (often without peak flows) redistributing it within the reservoirs and transporting it downstream.
  - Knickpoint migration via base-level fall and lateral channel migration drive transport
  - Rate of removal, character of sediment
- **Species** – large turnover in reservoirs (lotic to lentic aquatic taxa); potential to homogenize up/downstream communities or introduce non-natives upstream
- **Size matters** – dam height, reservoir size, sediment volume
- **Surprises happen** – old dams can hide forgotten features
- **Rapid responses** – rivers are resilient, but there are a wide range of recovery trajectories

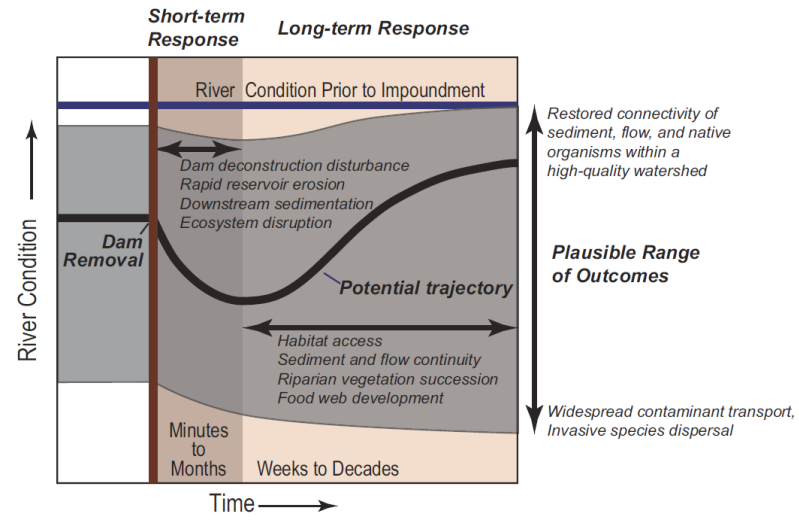
Local conditions matter



Foley et al. 2019 Water Resources Research

A challenge in understanding and predicting recovery trajectories is that ecological responses vary spatially and temporally

Local conditions matter



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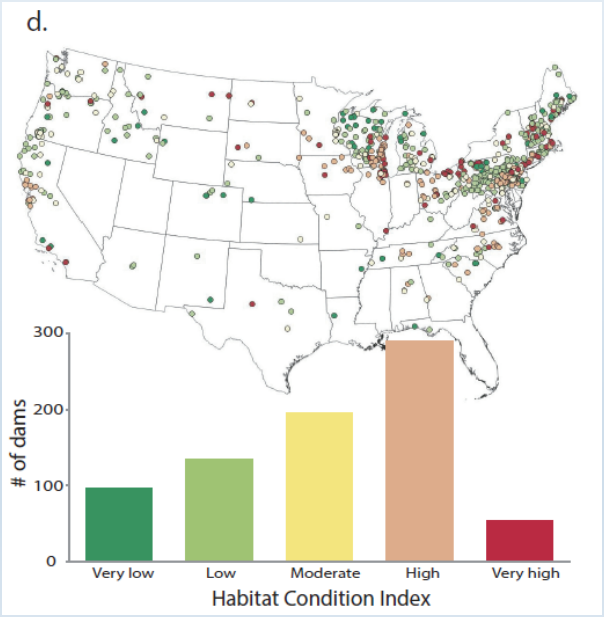
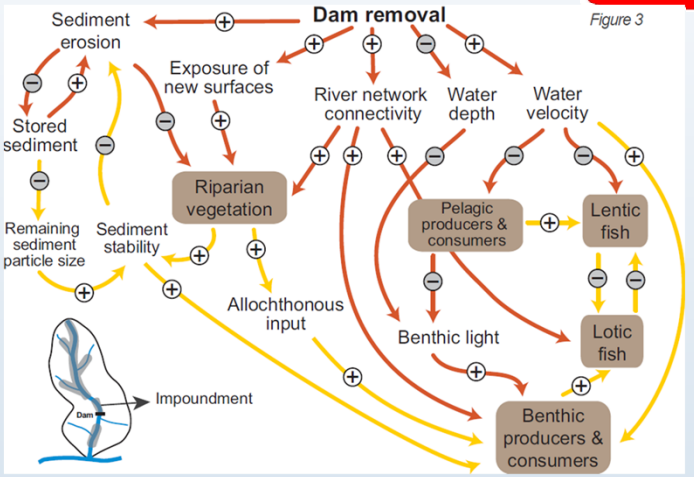


Foley et al. 2017 PLoS ONE

The local and regional context of each dam and watershed is distinct, and therefore, the responses to removal are unique.

Ecological Responses to dam removal

Ecological responses to dam removal are *generally* governed by a **common set of physical and biological linkages and feedback loops**.



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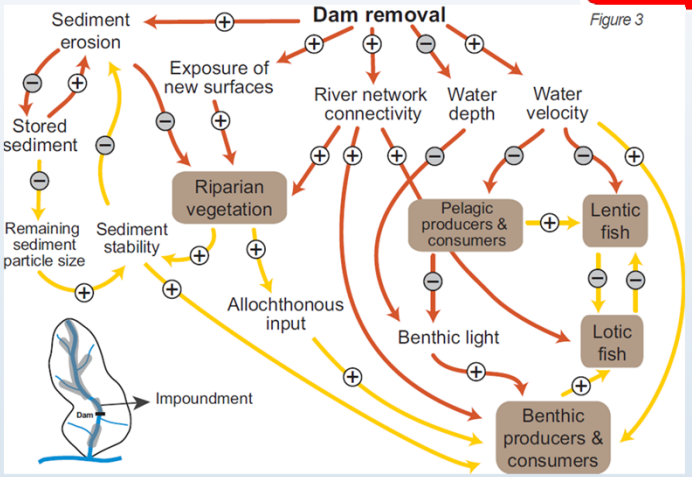
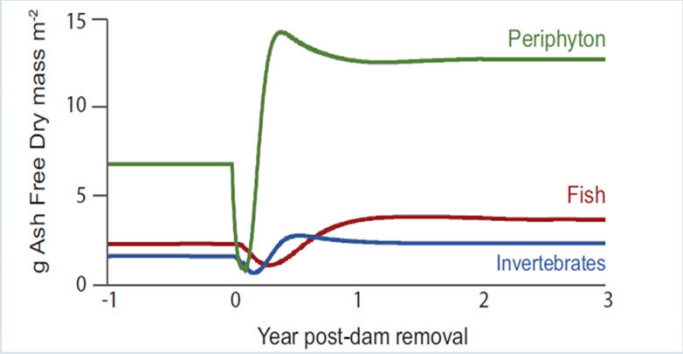
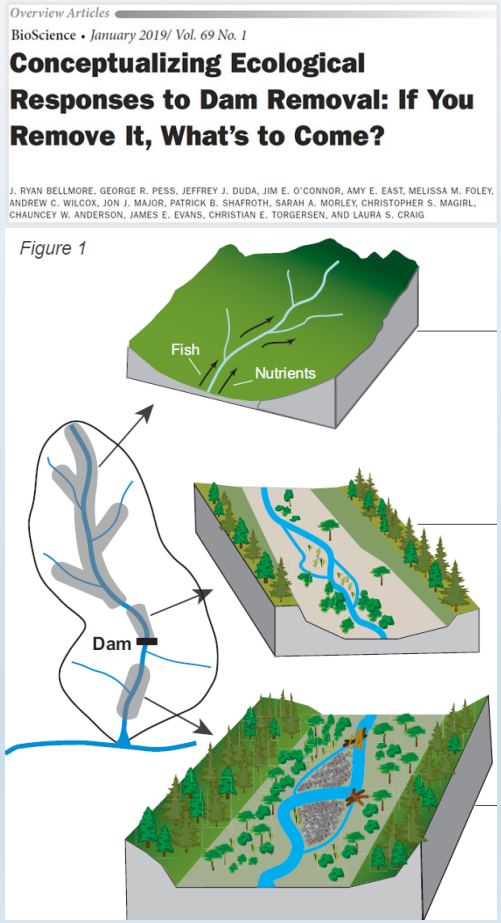




These shared linkages create dynamic, nonlinear ecological **response trajectories**, which are complex but *can* be predicted if the strength of the dominant linkages and feedback are known.

Bellmore et al. 2019 BioScience

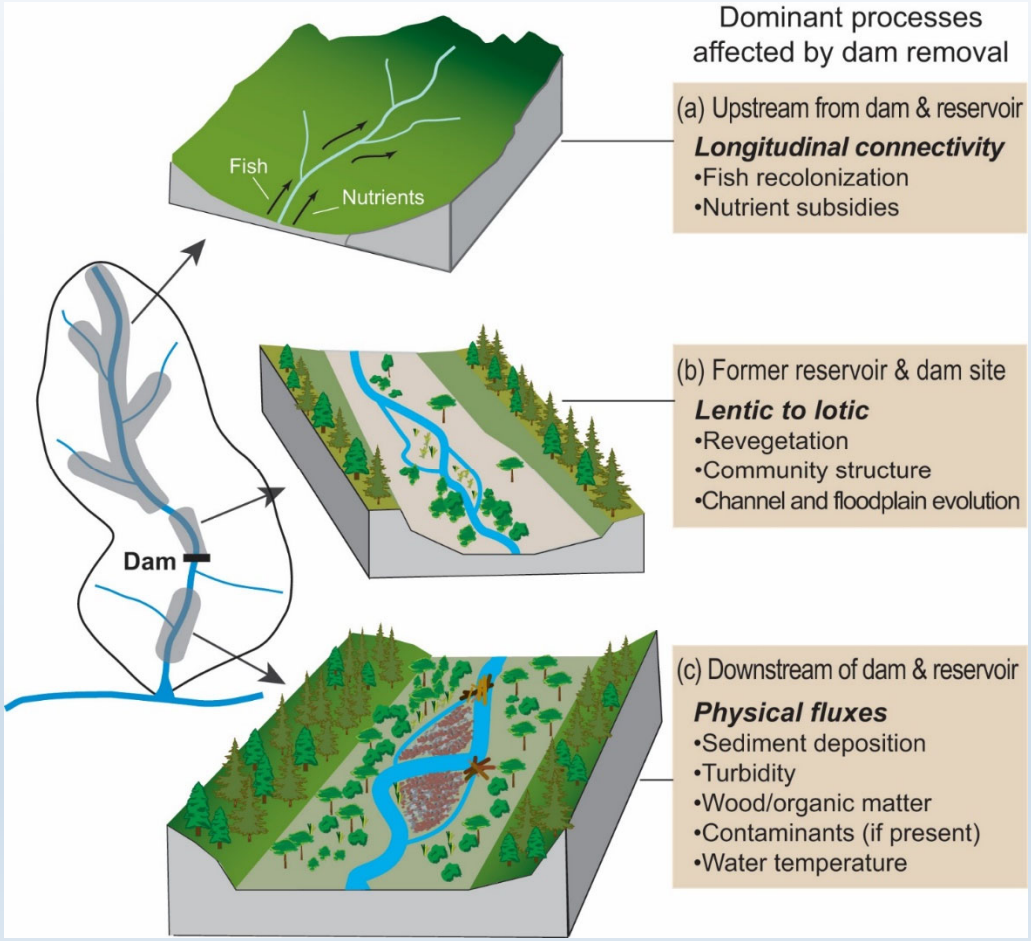
Spatial domains and ecological responses to dam removal



Our Conceptual Models:

- Define the processes affecting ecological responses to dam removal
- Clarify how ecological transitions in each spatial domain are affected by dam removal
- Illustrate that responses are complex but *predictable*

Spatial domains of dam removal



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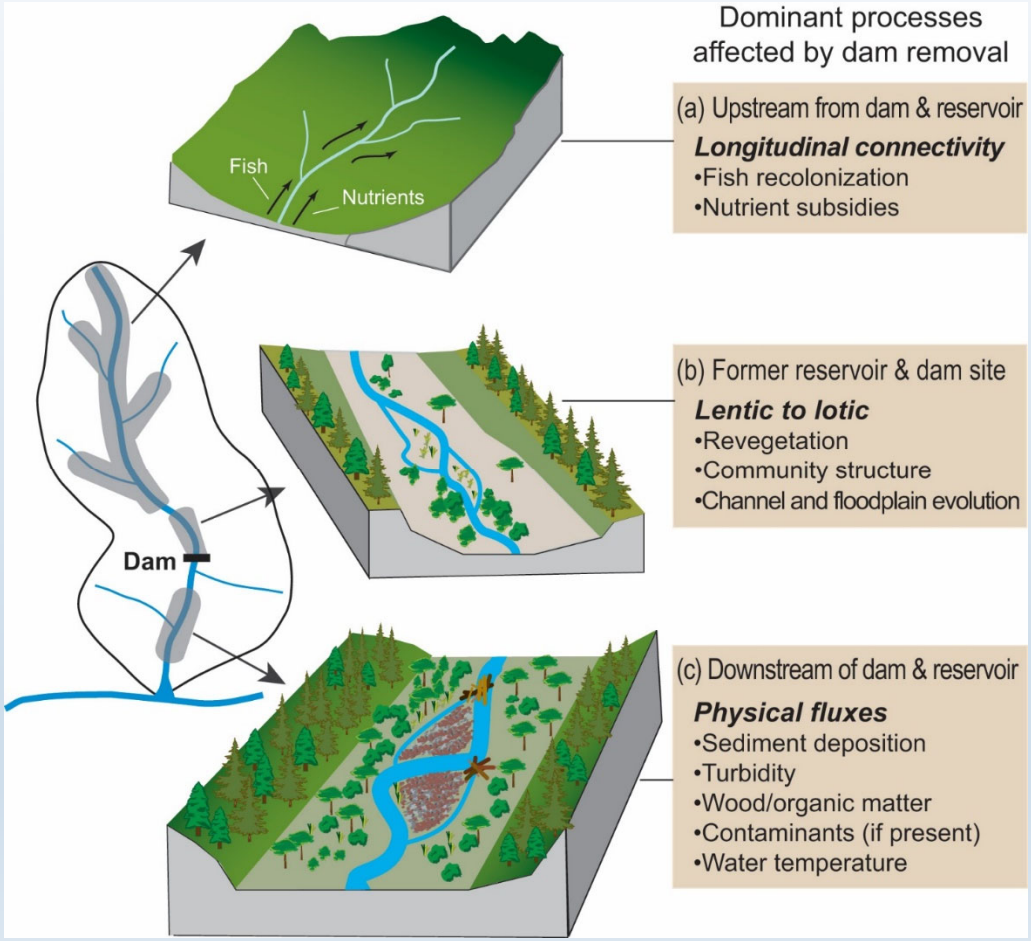

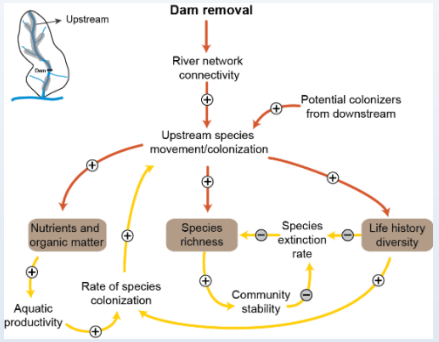

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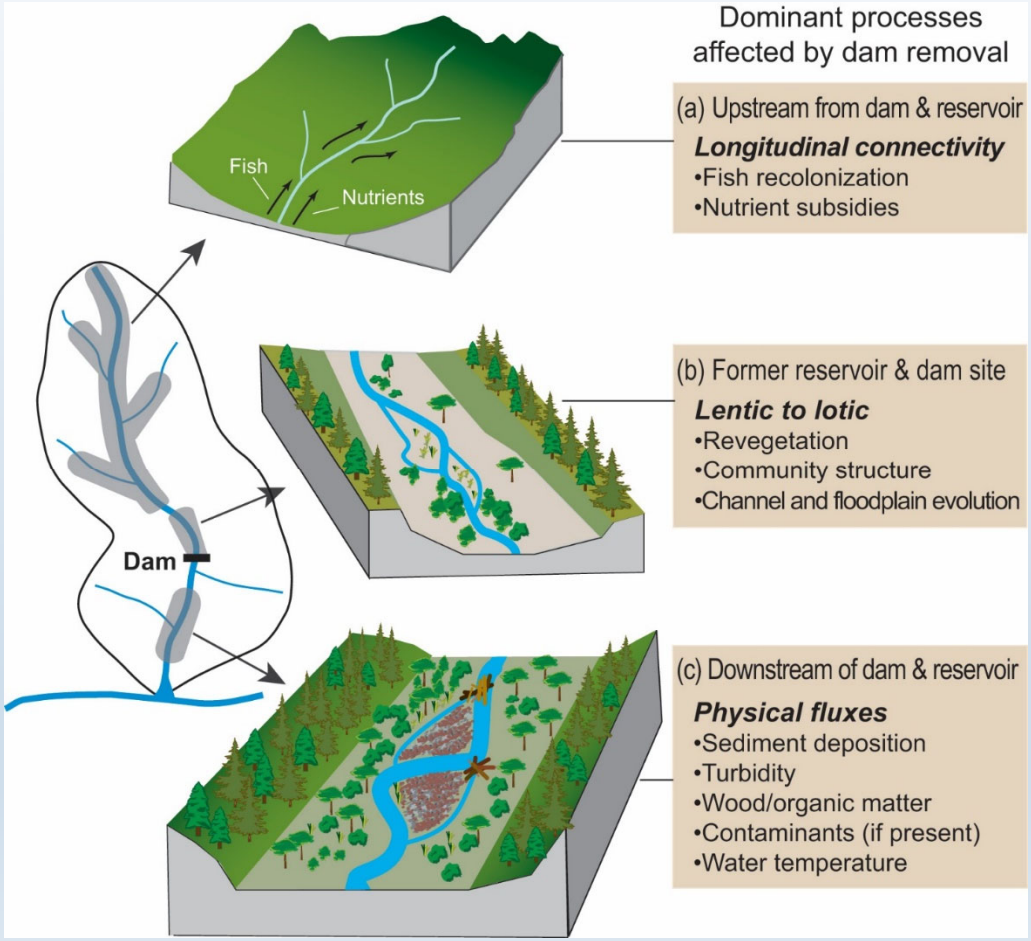
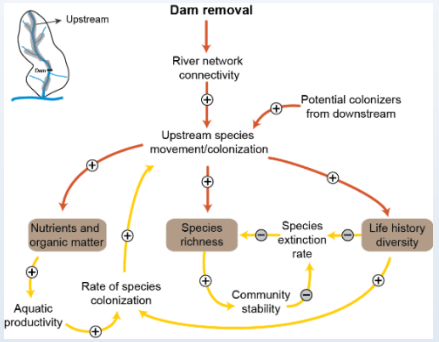
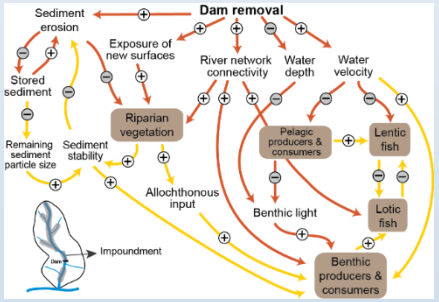
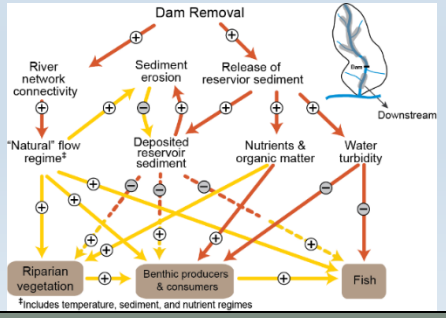




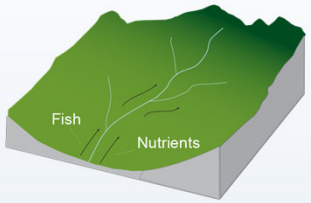




Examples from the Elwha River

- Short, steep mountainous river - 72 km in length
- Watershed is 822 km^2, 83% is protected National Park wilderness
- Dams were 8 and 21 km from river mouth
- No fish passage at either dam

Upstream of the dams



When the fish returned

Different fish returned at different times upstream of the Elwha and Glines Canyon dams.

Elwha Dam — Glines Canyon Dam

Oct. Coho
Sept. Pink
Aug. Chinook
June Winter steelhead
Oct. Summer steelhead
March Pacific lamprey
Nov. Chum
Sept. Chinook
Aug. Bull trout
July Sockeye
June Bull trout
May Winter steelhead
Oct. Coho
Aug. Summer steelhead
Sockeye
Aug. Pink
July Pacific lamprey

Jan. 2011 — Jan. 2012 — Jan. 2013 — Jan. 2014 — Jan. 2015 — Jan. 2016 — Jan. 2017

Sept. Elwha Dam removal begins
April Elwha Dam removed
Aug. Glines Canyon Dam removed
Oct. Glines Canyon rockfall
Oct. *Glines Canyon rock blasting*

Data from NPS, NOAA, LEKT, FWS and USGS
Visualization: Jeff Duda and San Brenkman

MARK NOWLIN / THE SEATTLE TIMES

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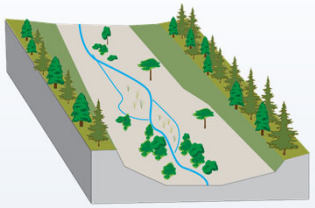
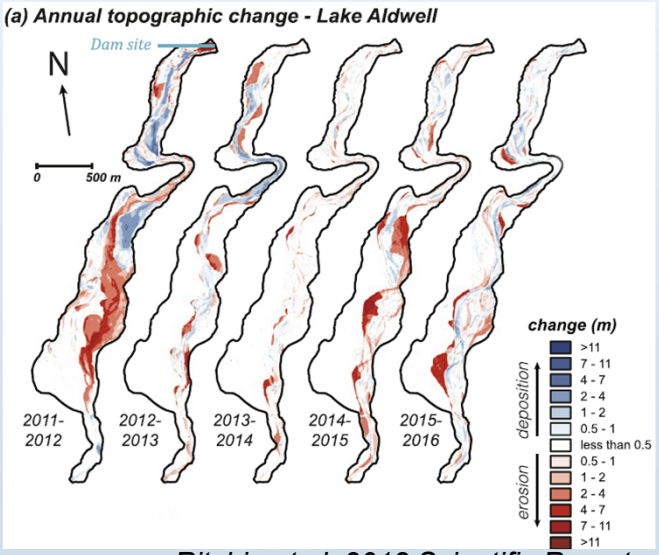
Former reservoirs



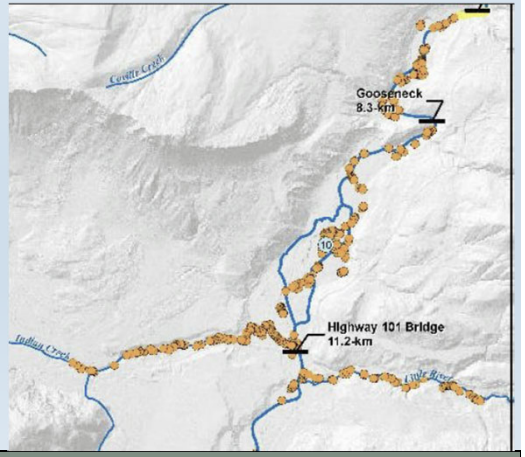
Sediment redistribution



Ritchie et al. 2018 Scientific Reports

Upland revegetation

Chinook spawning



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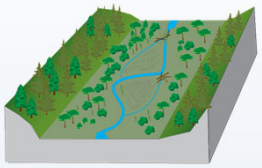
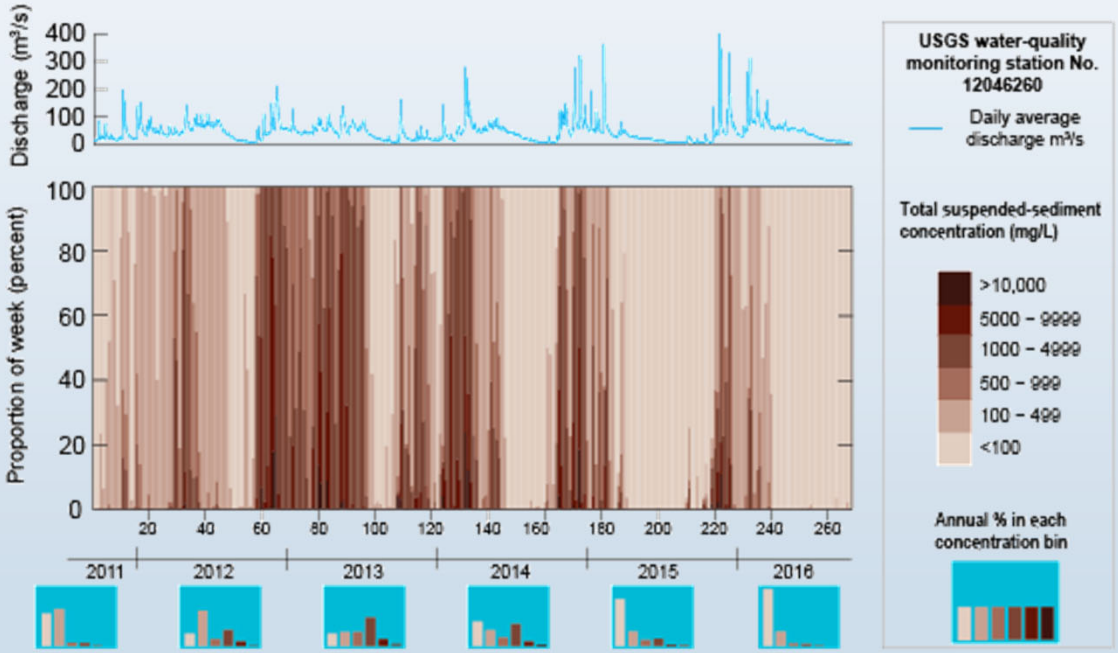
Downstream of the dams





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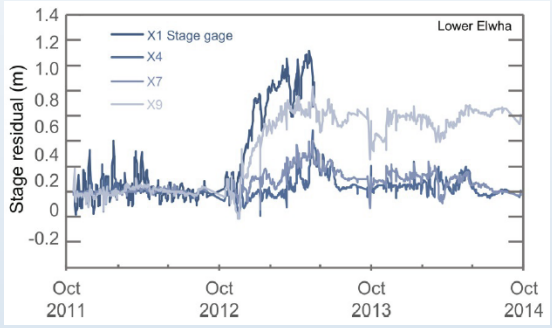
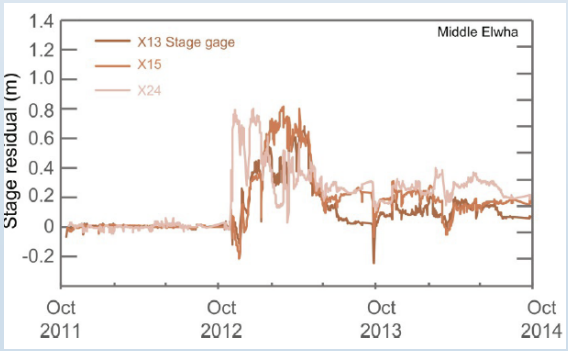




Morley et al. 2020 PLoS ONE

Fishy surprises from the Elwha

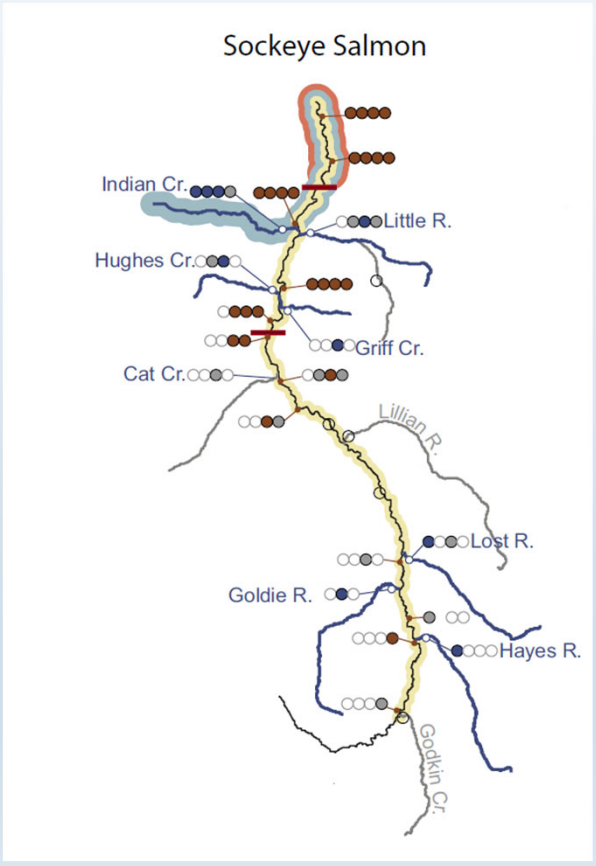
Summer steelhead in the Elwha rise from the ashes

TROUT UNLIMITED

by Sam Davidson

October 19, 2018

https://www.tu.org/blog/summer-steelhead-in-the-elwha-rise-from-the-ashes/



Duda et al. 2020 Environmental DNA

Dam Removal Webinar Series

Part 1B:
Dam Removal Case Studies

October 27, 2020

Jennifer Bountry, MS, PE

Manager, Sedimentation and River Hydraulics Group and Environmental Research Coordinator, Bureau of Reclamation

Common Management Concerns: What Do the Case Studies Tell Us?

Tullos, Desiree D., Mathias J. Collins, J. Ryan Bellmore, Jennifer A. Bountry, Patrick J. Connolly, Patrick B. Shafroth, and Andrew C. Wilcox, 2016. Synthesis of Common Management Concerns Associated with Dam Removal. Journal of the American Water Resources Association (JAWRA) 1-28. DOI: 10.1111/1752-1688.12450

Acknowledgements

Working group on *Dam removal: synthesis of ecological and physical responses* of the U.S. Geological Survey John Wesley Powell Center for Analysis and Synthesis

Study objectives: "Myth Busters"

1. Articulate common management concerns (CMCs) and their potential negative consequences

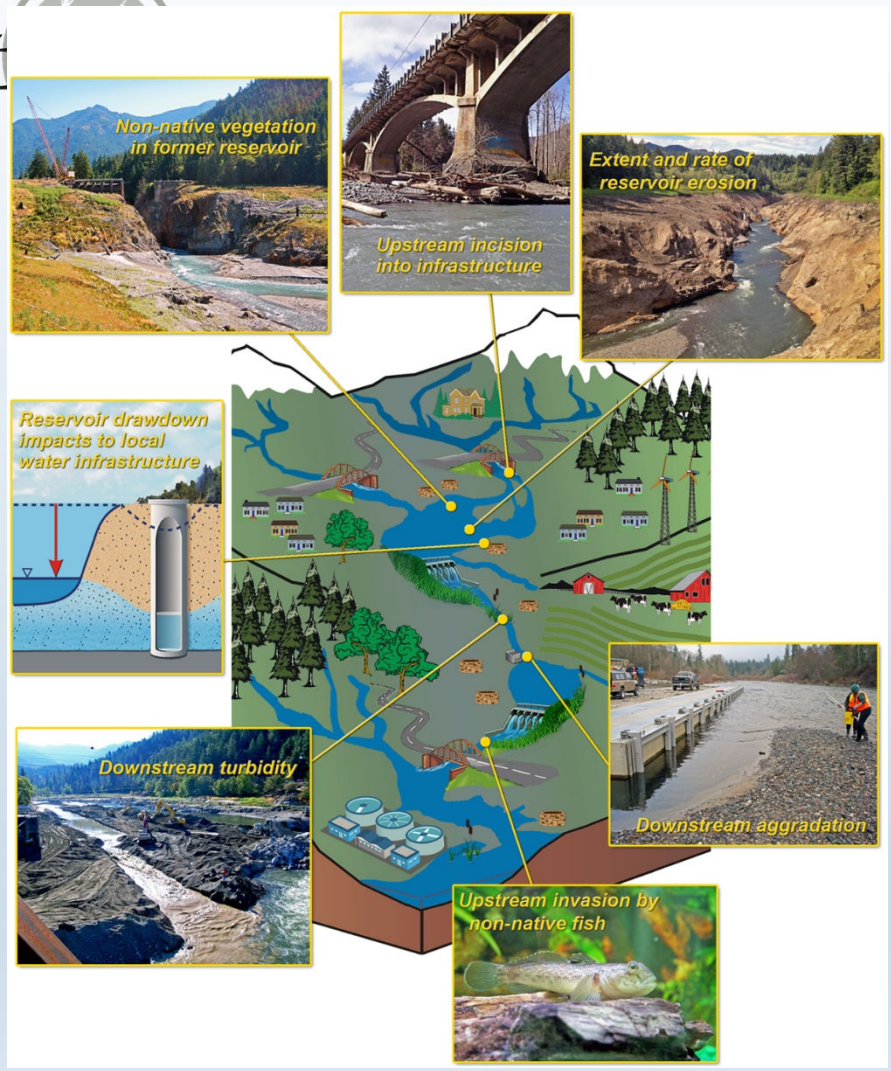
   What is a CMC?

   Dam removal outcomes that may require intervention but are broadly assumed, sometimes incorrectly, to occur at most sites

2. Identify where, and how commonly, CMCs occurred
3. Evaluate what conditions control their occurrence

Is this Bridge Located 2 miles Upstream of Elwha Dam Being Removed at Risk?

River Incision & Widening at Highway 101
3 Years After Elwha Dam Removal

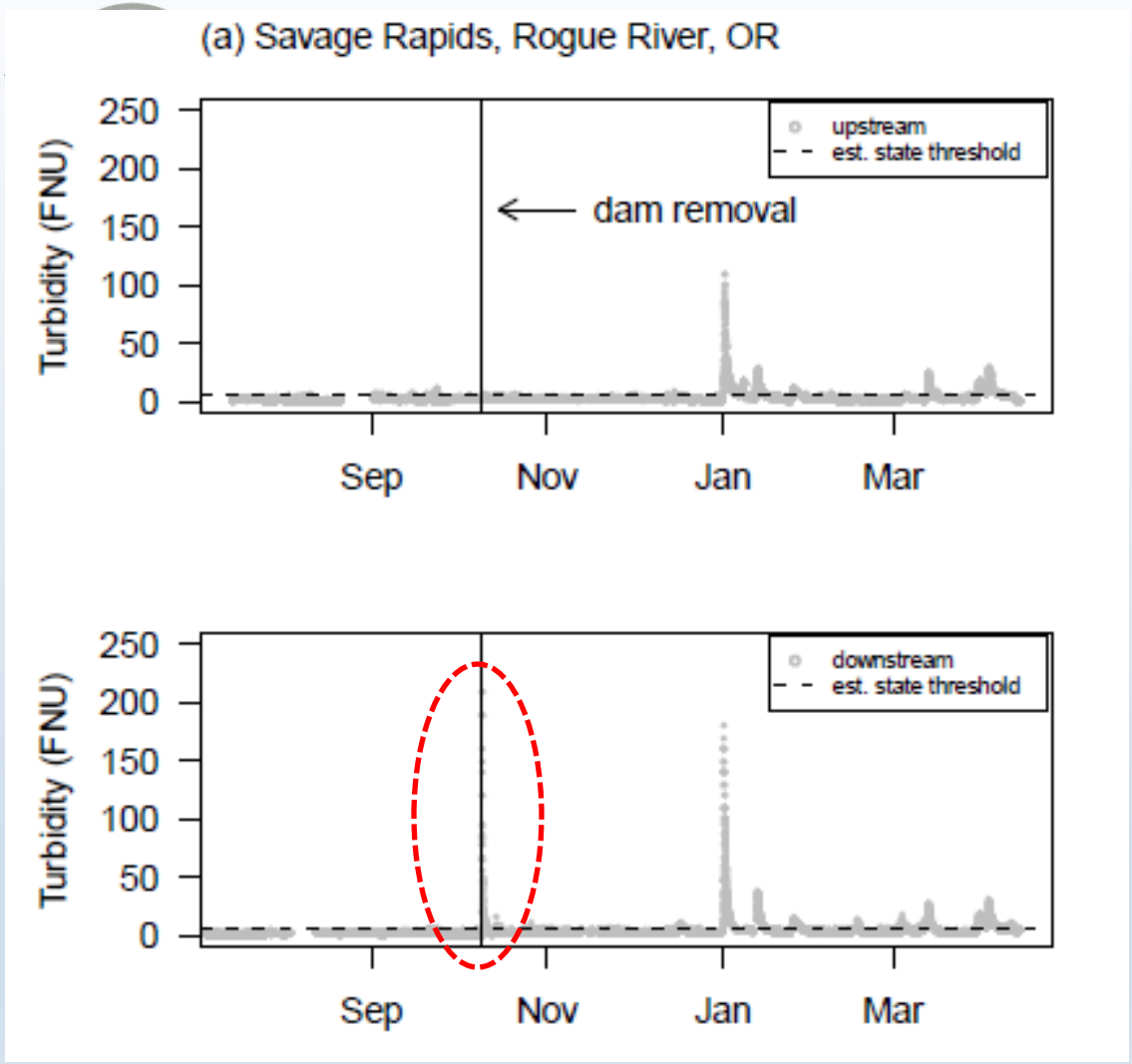


Tullos et al. 2016

1. Upstream incision into infrastructure
2. Non-native vegetation in former reservoir
3. Reservoir drawdown impacts to local water infrastructure
4. Downstream turbidity
5. Upstream invasion by non-native fish
6. Downstream aggradation
7. Extent and rate of reservoir erosion

How bad is this turbidity from Savage Rapids Dam removal in Oregon (scale 1 to 10)?

How long will it last (days, weeks, months)?


(a) Savage Rapids, Rogue River, OR
Turbidity (FNU)
250
200
150
100
50
0
upstream
est. state threshold
dam removal
Sep
Nov
Jan
Mar
Turbidity (FNU)
250
200
150
100
50
0
downstream
est. state threshold
Sep
Nov
Jan
Mar


B. October 2009

CMC	Case studies	Biophysical process controls	Site conditions suggesting management implications
Degree and rate of reservoir incision	N/A	• high % of stored fine sediments • average sediment deposit width/channel width > ~2.5 • phased removal	stakeholder values; fish passage needs or sensitive habitats
Excessive channel incision upstream of reservoir	38	• reach-scale incision d/s • high % of stored fine sediments • phased removal • coarse delta • ephemeral flow	infrastructure within reservoir deposit or along margins at risk for bank erosion; fish passage needs or sensitive habitats
Downstream aggradation	6	• high V* • proximal to dam	low-lying properties; transportation infrastructure; pump intakes; fish passage needs
Elevated turbidity	7	• high % of stored fine sediments • high V* (sediment stored/load) • rapid reservoir drawdown	sensitive aquatic organisms; human recreational uses; drinking water intakes
Drawdown impacts on local water infrastructure	5	• large drop in water surface elevation • high degree of connectivity between the reservoir, river, and groundwater • regionally deep water table	wells or intakes in the reservoir vicinity
Non-native plant colonization of reservoirs	23	• proximity to non-native seed sources • high % of stored fine sediments • no planting or weed control	legal requirements for noxious weed and/or invasive species control; stakeholder values
Non-native fish	7	• abundance and proximity of non-native fish • availability of suitable habitat and temperatures for non-natives	state fisheries regulations or management plans; stakeholder values

Summary

- Data for our seven CMCs not sufficient for broadly applicable conclusions about future occurrence
- But….do reveal biophysical controls on CMC occurrence
- Practitioners can effectively evaluate CMC risks by:
  - Assess likelihood of relevant biophysical phenomena
  - Investigate consequences to ecological or human use concerns important to stakeholders
  - Consider risks for multiple CMC occurrence via common biophysical controls

Guidelines for Estimating Costs of Dam Removal

Goal: Develop a process to estimate the cost of a dam removal at a concept level for comparing alternatives and initial funding requests

- Categories:
  - Low-head diversion dams with limited water and sediment storage relative to average annual flow (small hydrologic impact) and incoming sediment load (single storm event)
  - Large dams with high water and sediment storage relative to average annual flow (alters hydrology) and incoming sediment load (years to decades and often not full)

Guidelines for Estimating Costs of Dam Removal

- Cost drivers: cultural concerns, aesthetics, access, contaminants, water users, sensitive species, landowners, mitigation needed
- Geographic location: local regulatory requirements
  - Fish passage
  - Water quality
  - In-water work periods

Next Steps

- Form collaborator team with engineers, cost estimators, ecologists
  - Bureau of Reclamation
  - U.S. Geological Survey
  - U.S Army Corps of Engineers
  - Oregon State
  - U.S. Society of Dams Decommissioning Committee
- Establish metrics and steps to estimate costs
- Gather case study data and test metrics
- Adjust costs to common timeframe (e.g. 2021)
- Low-head guidance (asset management assessments)
- Large dam guidance (dam safety assessments)