



U.S. Department of the Interior
U.S. Geological Survey

RESTORING AQUATIC HABITATS THROUGH DAM REMOVAL: WATER QUALITY AND MACROINVERTEBRATES



Photo: Alex Hackman

Allison Roy, PhD

Unit Leader & Research Professor
U.S. Geological Survey
MA Cooperative Fish & Wildlife Research Unit
University of Massachusetts Amherst



Kate Abbott, PhD '23 Peter Zaidel, MS '18



Support:



This information is preliminary and is subject to revision. It is being provided to meet the need for timely best science. The information is provided on the condition that neither the U.S. Geological Survey nor the U.S. Government shall be held liable for any damages resulting from the authorized or unauthorized use of the information.

A NATION BUILT ON DAMS



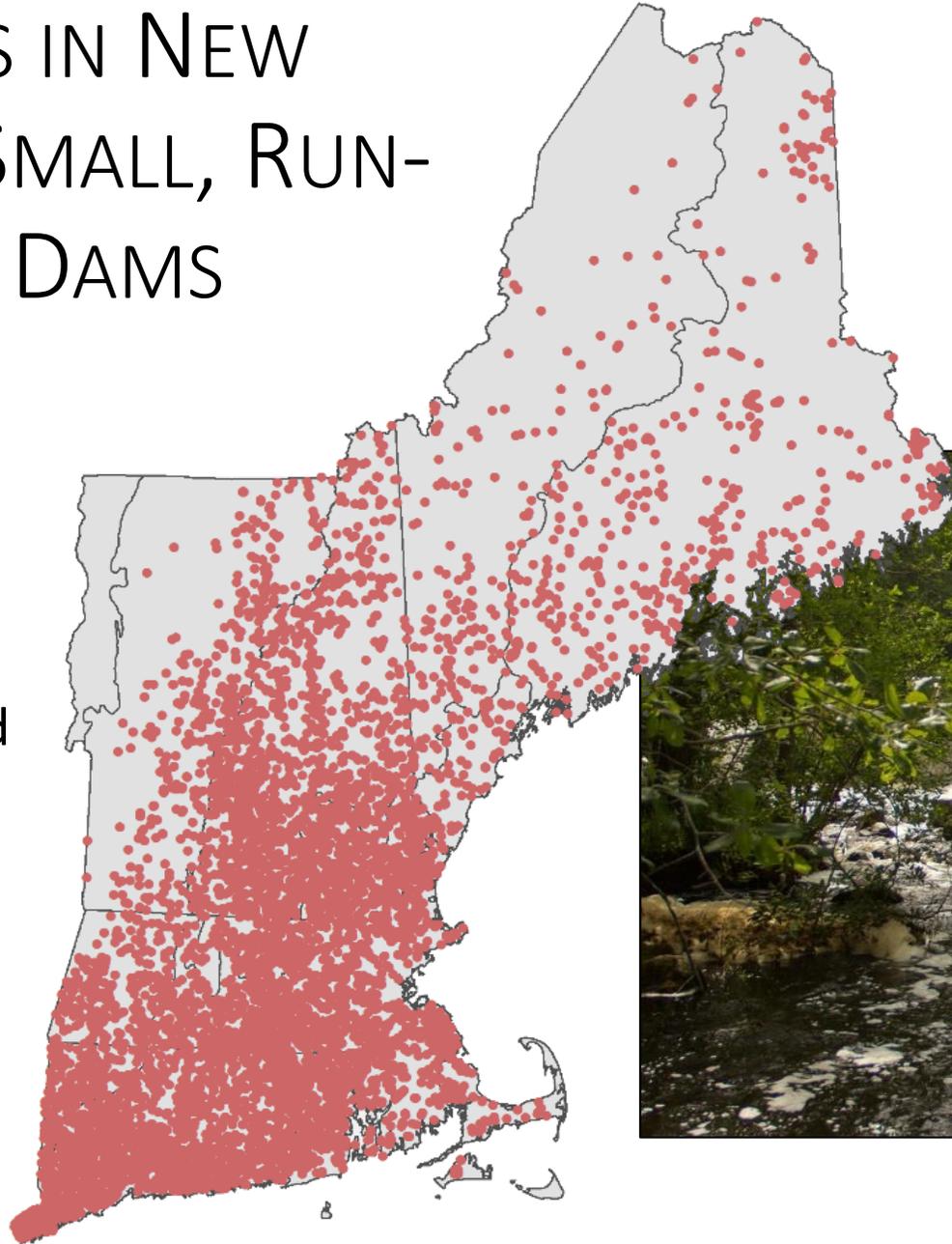
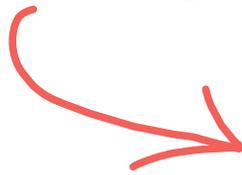
Lowell, MA 1910

online courtesy Locks and Canals Collection, Lowell National Historical Park

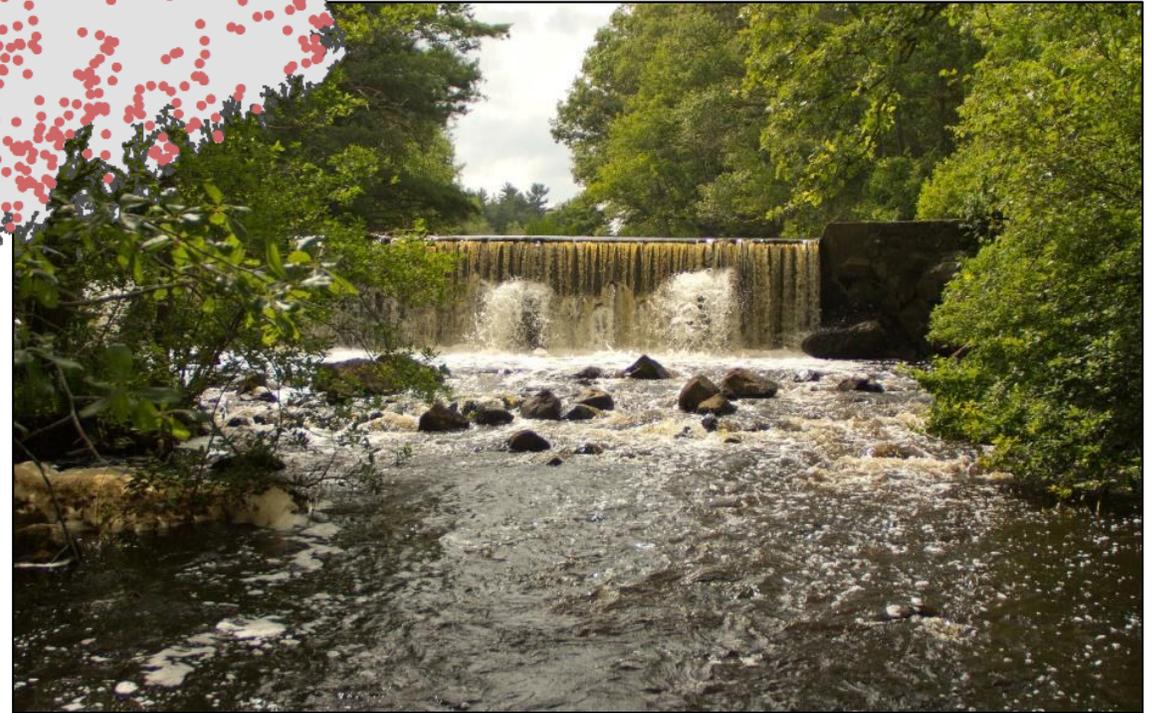
Created by James Syvitski of the University of Colorado

MOST DAMS IN NEW ENGLAND ARE SMALL, RUN-OF-RIVER DAMS

7,000+ documented dams (shown), but estimated >14,000 dams in New England



Data for the New England Dams Database was provided by the National Science Foundation's Research Infrastructure Improvement NSF #IIA-1539071



Bostik Dam, Ipswich River, Massachusetts

Small dams

Large impacts

Physical

Alter channel form, block sediment, alter velocities

Chemical

Increase temps, trap contaminants, alter nutrient dynamics

Biological

Block migration, alter fish & macroinvertebrate assemblages, affect mussel distributions, alter riparian vegetation



Small dams

Large impacts

Physical

Alter channel form, block sediment, alter velocities

What ecological responses are anticipated following dam removal?
What are the best ways to document ecological changes?

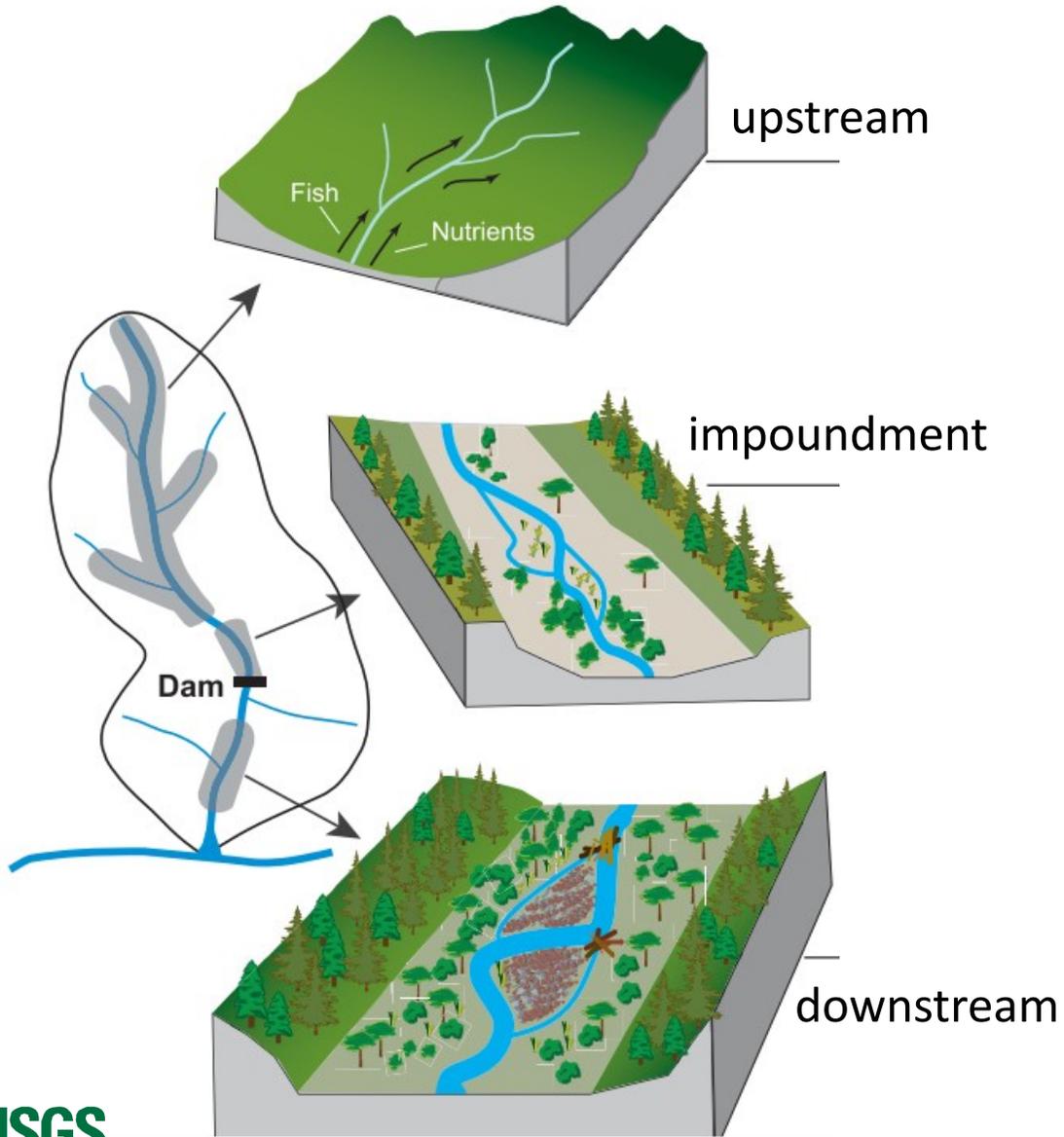
Increase temps, trap contaminants, alter nutrient dynamics

Biological

Block migration, alter fish & macroinvertebrate assemblages, affect mussel distributions, alter riparian vegetation



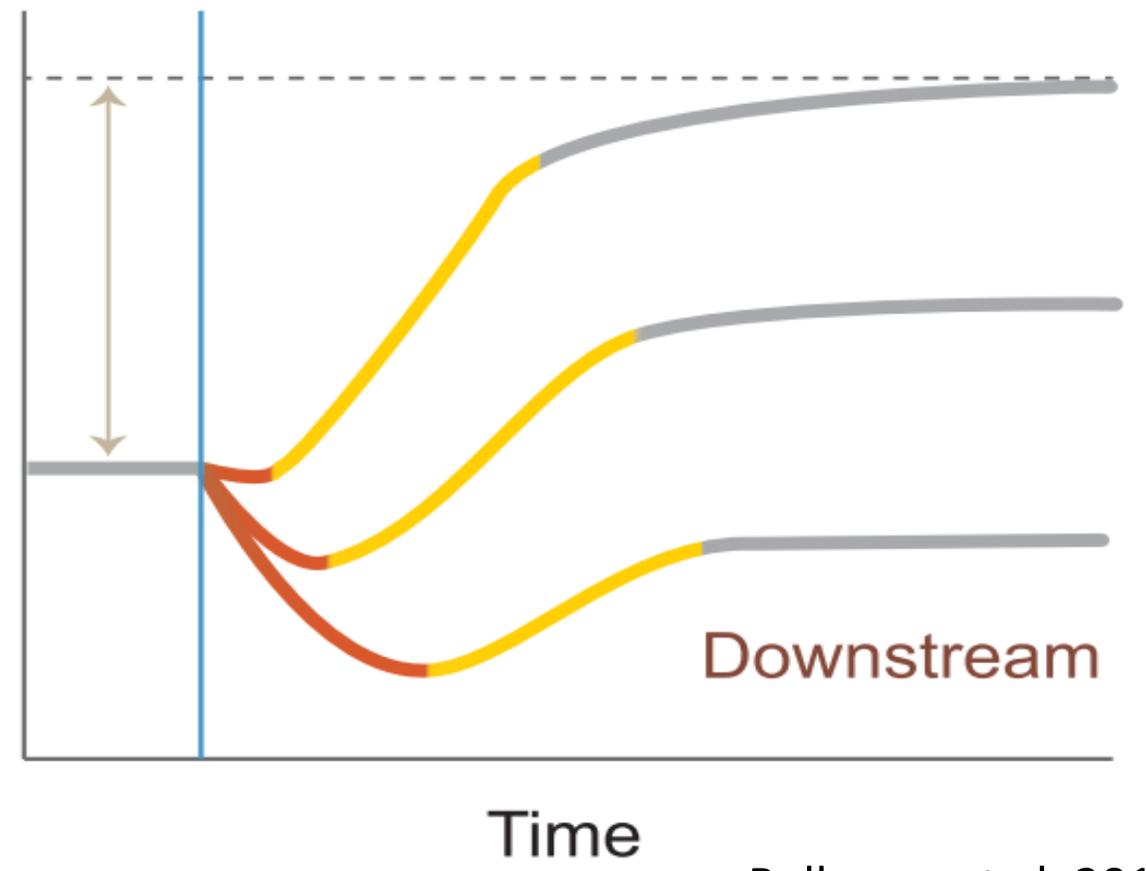
SPATIAL

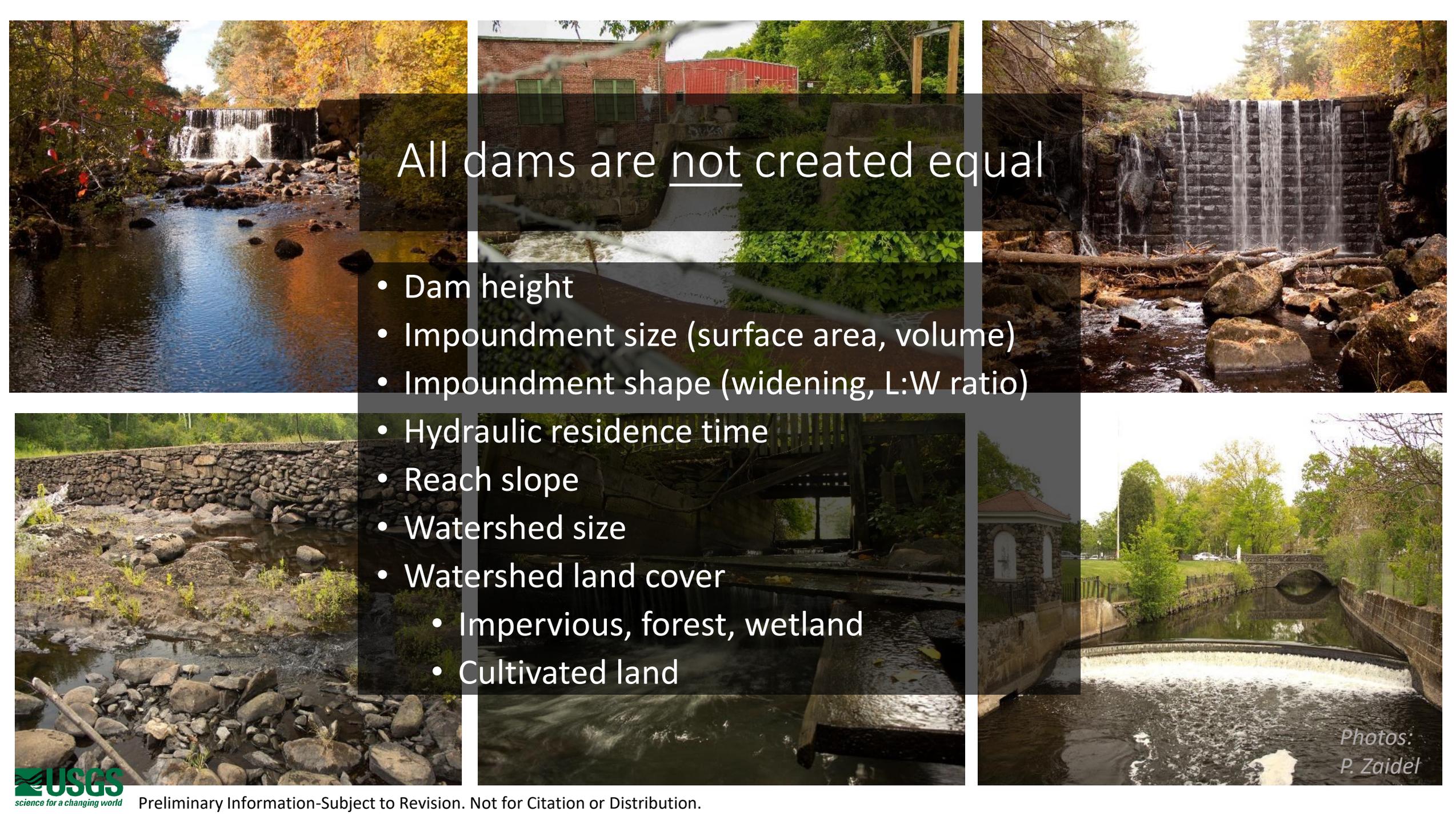


TEMPORAL

Dominant perturbation-response controls

- Short-term dam removal effects (hours to years)
- Long-term dam removal effects (years to decades)





All dams are not created equal

- Dam height
- Impoundment size (surface area, volume)
- Impoundment shape (widening, L:W ratio)
- Hydraulic residence time
- Reach slope
- Watershed size
- Watershed land cover
 - Impervious, forest, wetland
 - Cultivated land

Photos:
P. Zaidel

PRESENTATION OUTLINE



Effects of dams and dam removal on water quality



Effects of dams and dam removal on aquatic macroinvertebrates



Guidance for monitoring and prioritization

PRESENTATION OUTLINE



Effects of dams and dam removal on water quality

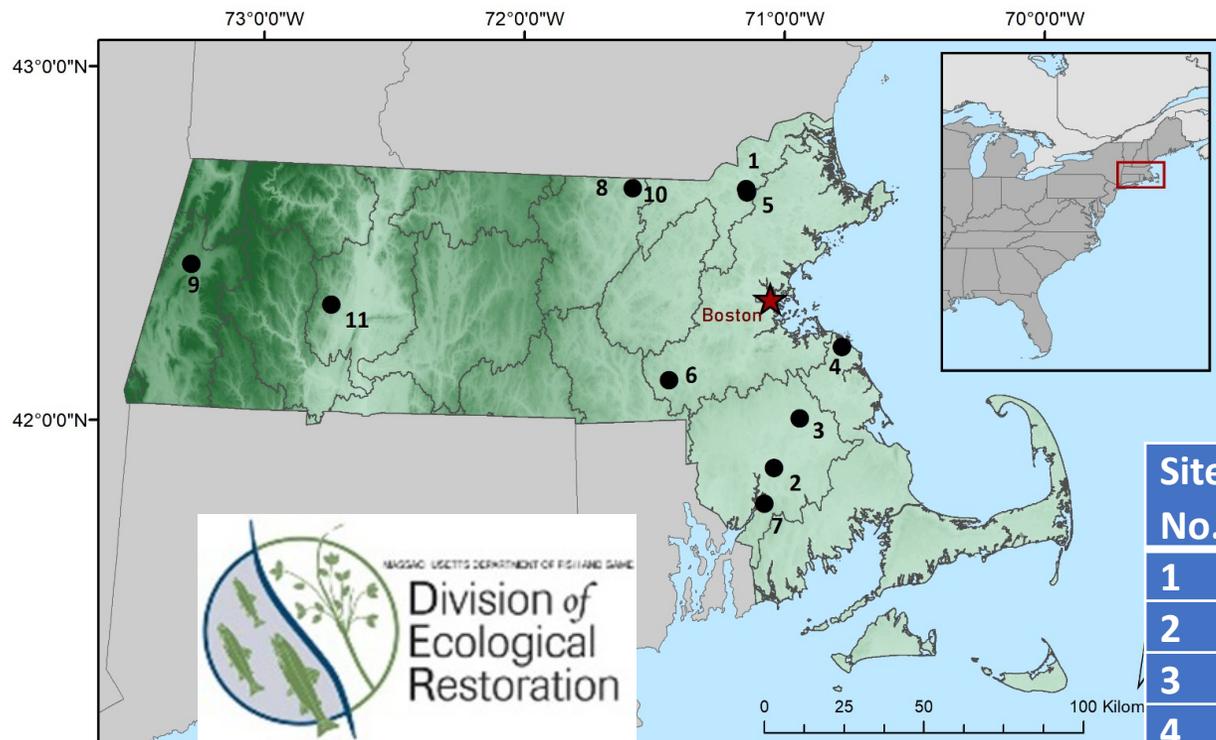


Effects of dams and dam removal on aquatic macroinvertebrates



Guidance for monitoring and prioritization

STUDY SITES



Site Characteristics

Dam height: 1.2 to 10.7 m

Drainage area: 6.8 to 188.8 km²

Forest cover: 25.3 to 89.7%

Site No.	Site Name	Stream Name	Removal Year
1	Balmoral	Shawsheen River	2017
2	Barstow's Pond	Cotley River	2018
3	Cotton Gin Mill	Satucket River	2017
4	Hunter's Pond	Bound Brook	2017
5	Marland Place	Shawsheen River	2017
6	Old Mill	Charles River	2017
7	Rattlesnake Brook	Rattlesnake Brook	2016
8	Sucker Brook	Sucker Brook	2021
9	Tel-Electric	West Branch Housatonic River	2020
10	Millie Turner	Nissitissit River	2015
11	Upper Roberts Meadow	Roberts Meadow Brook	2018

Other dams monitored pre-removal:

Ballardvale (Shawsheen)

Becker's Pond (Mt. Washington)

Bostik/South Middleton (Ipswich)

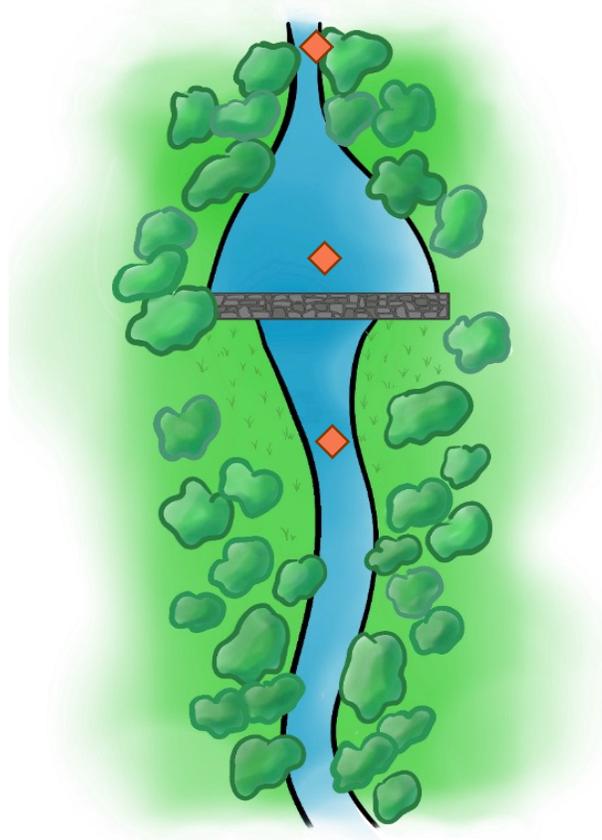
Ipswich Mills (Ipswich)

Wheelwright (Ware)



STUDY DESIGN

1-5 years BEFORE
removal



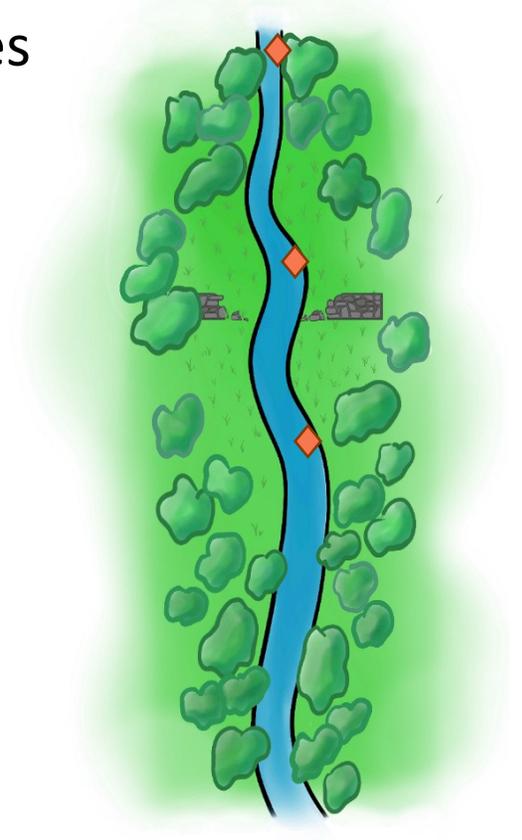
Water
quality



Aquatic
macroinvertebrates



1-5 years AFTER
removal

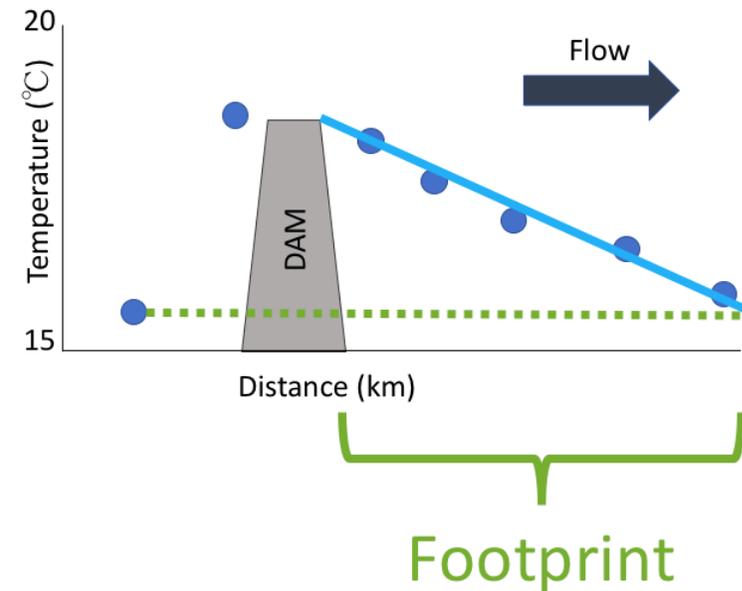
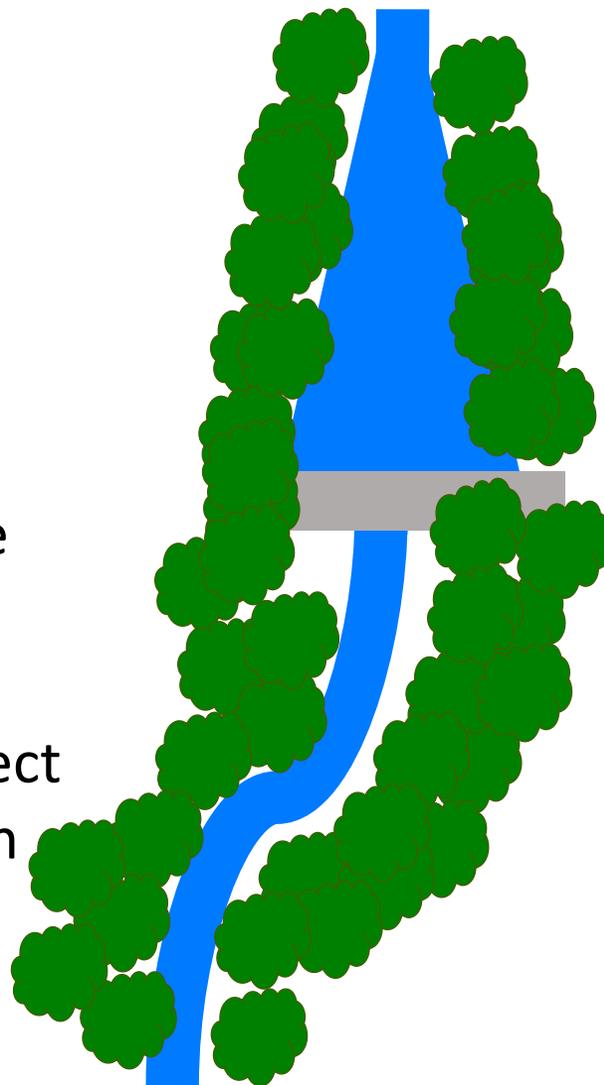




IMPOUNDMENT FORMATION



Surface Area ↑
Flow Rate ↓
Residence Time ↑
Exposure to Direct Solar Radiation ↑



Impoundment and Downstream Temperatures ↑
Dissolved Oxygen ↓



WATER QUALITY SAMPLING

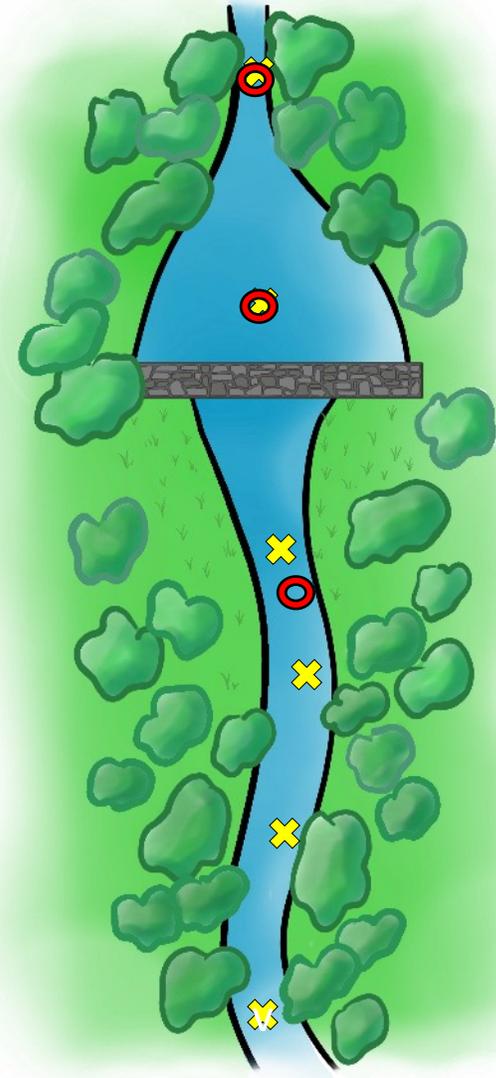
Temperature

- Year-round, 15-min
- Download May & Oct
- 5-7 loggers per site



Dissolved Oxygen

- 1 week/month (Jun – Aug)
- 15-minute interval
- 3 loggers per site



Impoundment Deployment

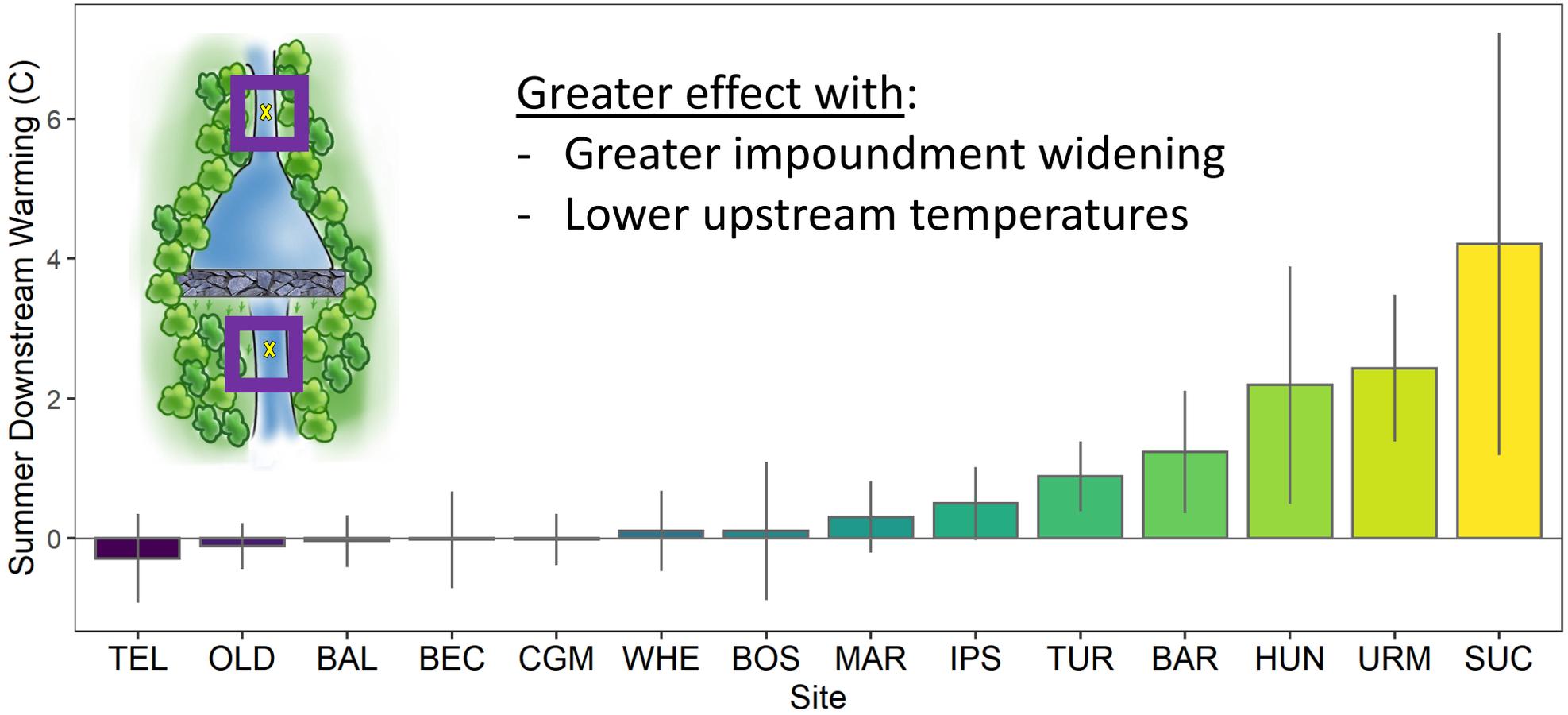


Stream Deployment



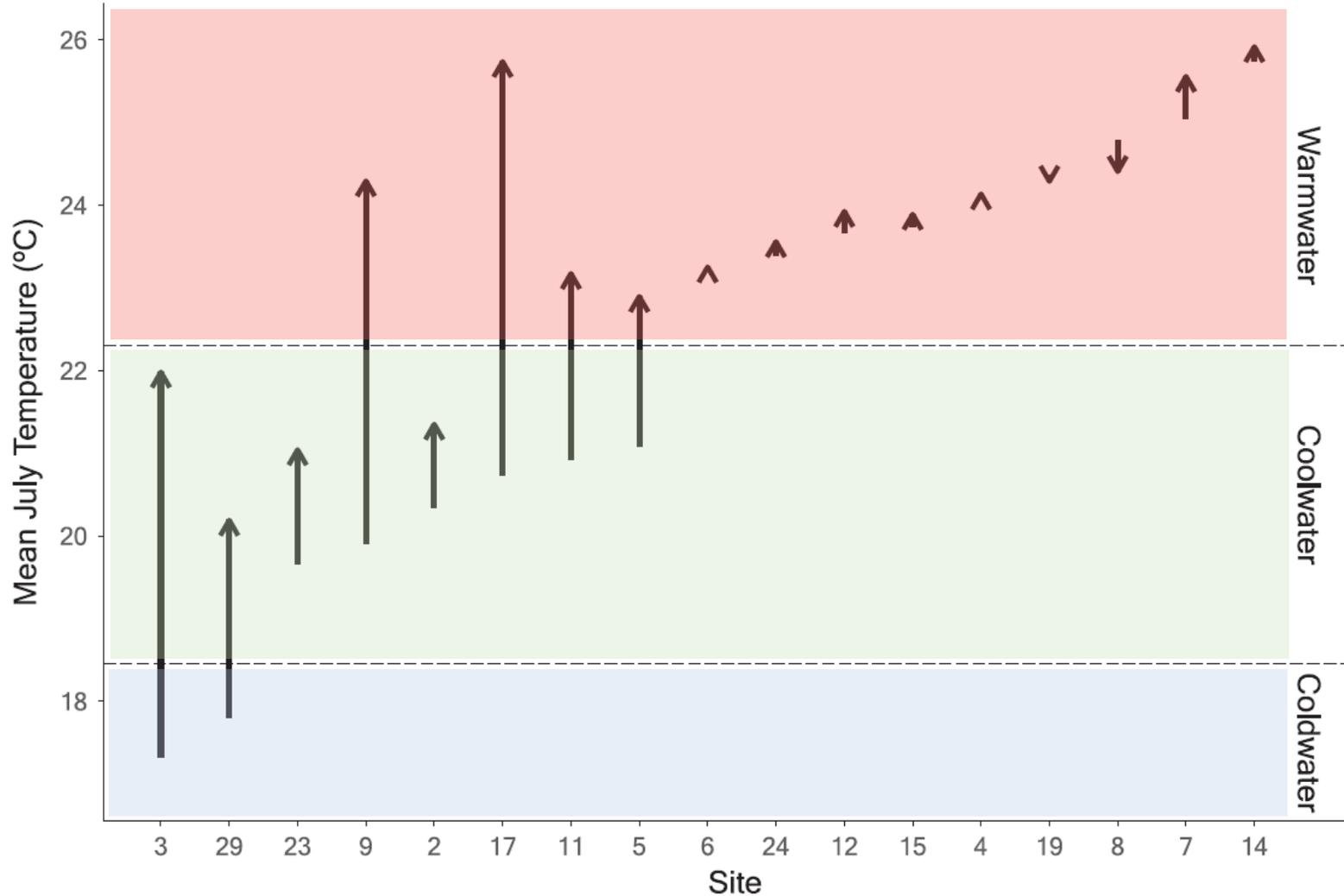


LARGE VARIATION IN DOWNSTREAM WARMING WITH DAMS





CONSEQUENCES FOR STREAM THERMAL REGIMES & FISHES



Legend:

- Warmwater >22.30 °C
- Coolwater 18.45 – 22.30 °C
- Coldwater <18.45 °C

Beauchene et al. 2014

Arrows indicate change in mean July temp from upstream to downstream of a dam



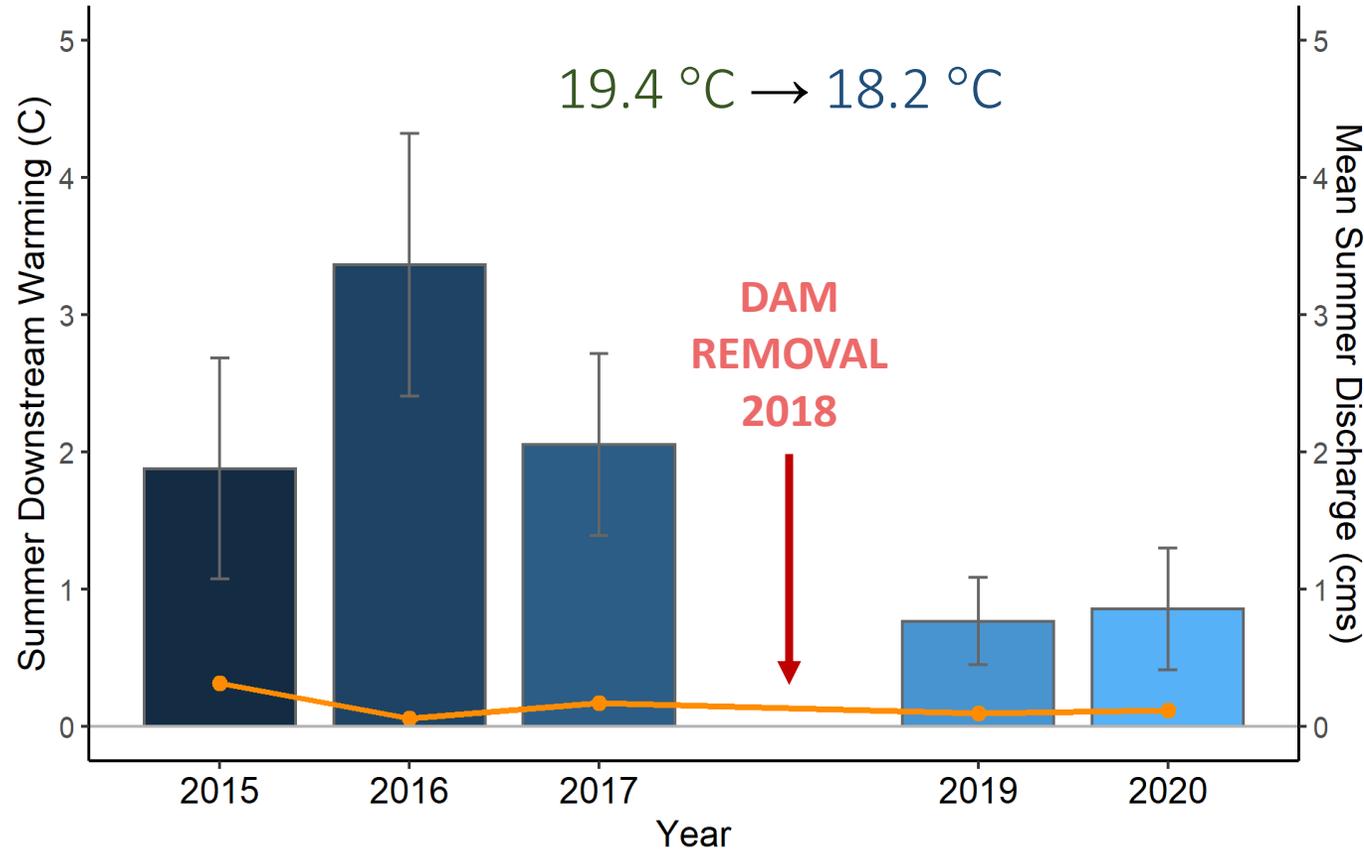
Zaidel et al. 2021



REDUCTION OF DOWNSTREAM WARMING FOLLOWING DAM REMOVAL

Coolwater → Coldwater

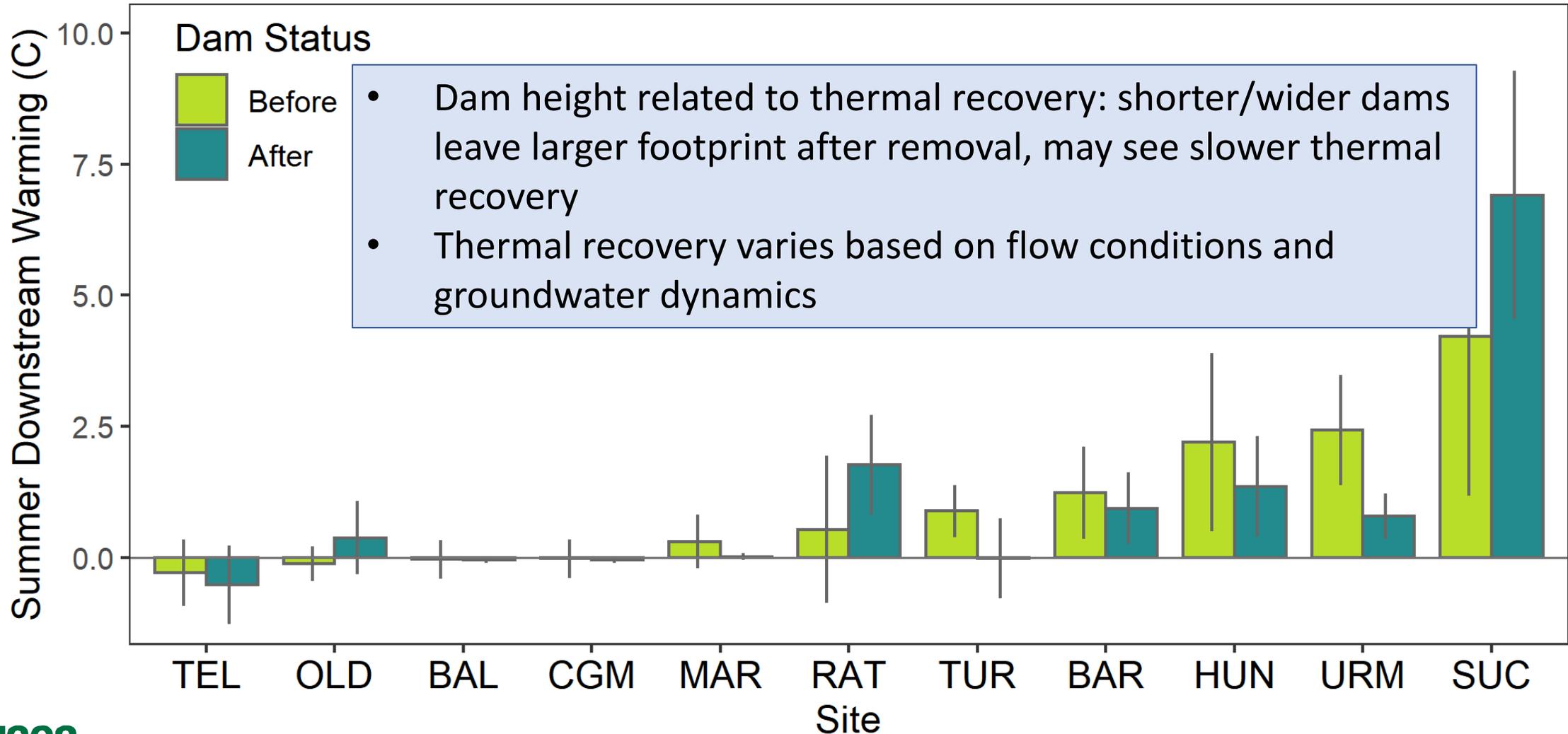
19.4 °C → 18.2 °C



Roberts Meadow Brook, Northampton, MA

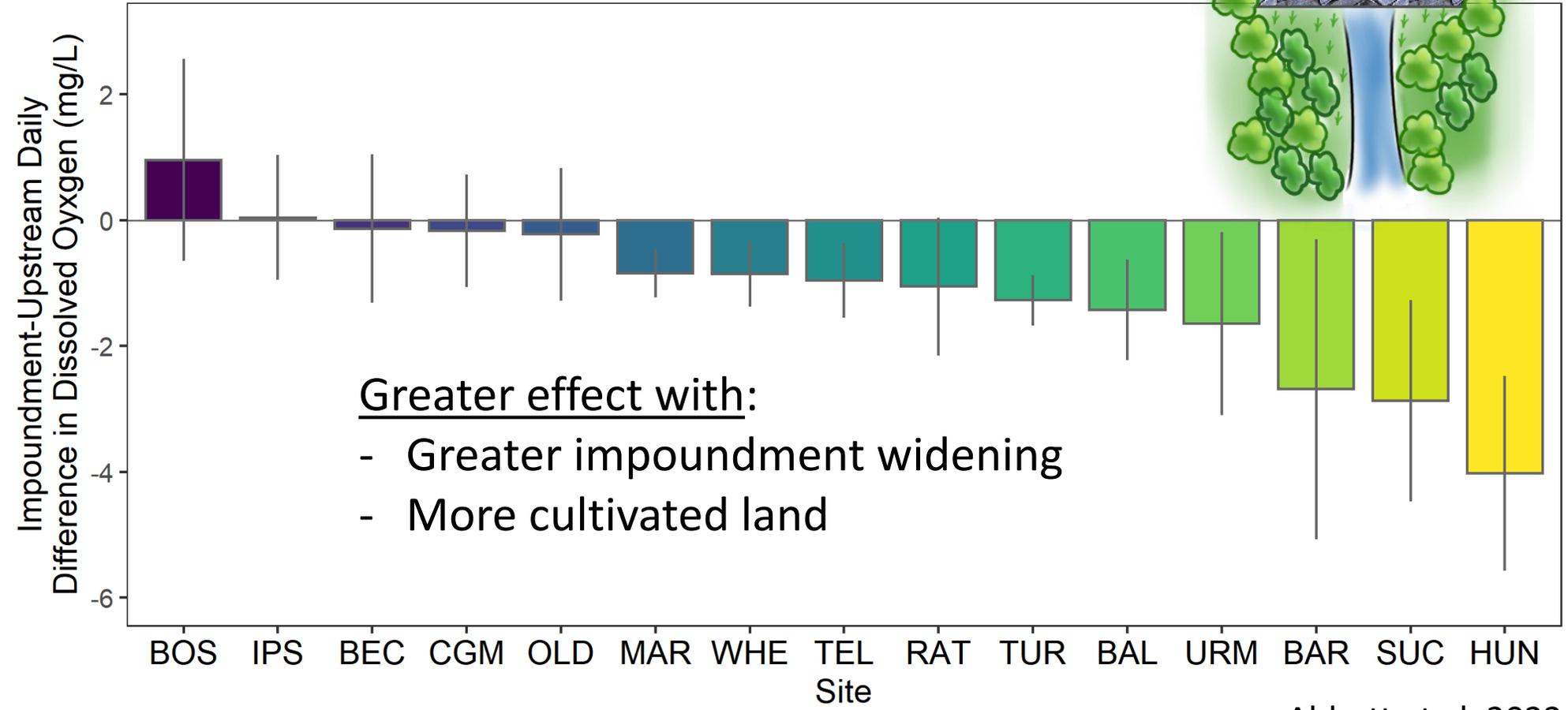
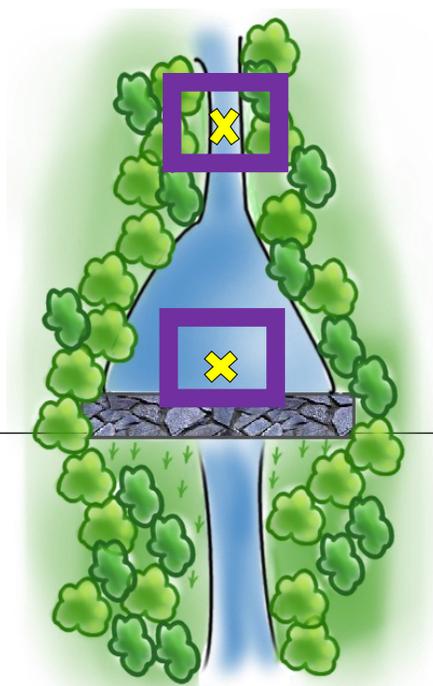


VARIABLE RECOVERY OF DOWNSTREAM WARMING AFTER DAM REMOVAL





MOST IMPOUNDMENTS EXPERIENCE LOW DISSOLVED OXYGEN COMPARED TO UPSTREAM REFERENCE



- Greater effect with:
- Greater impoundment widening
 - More cultivated land

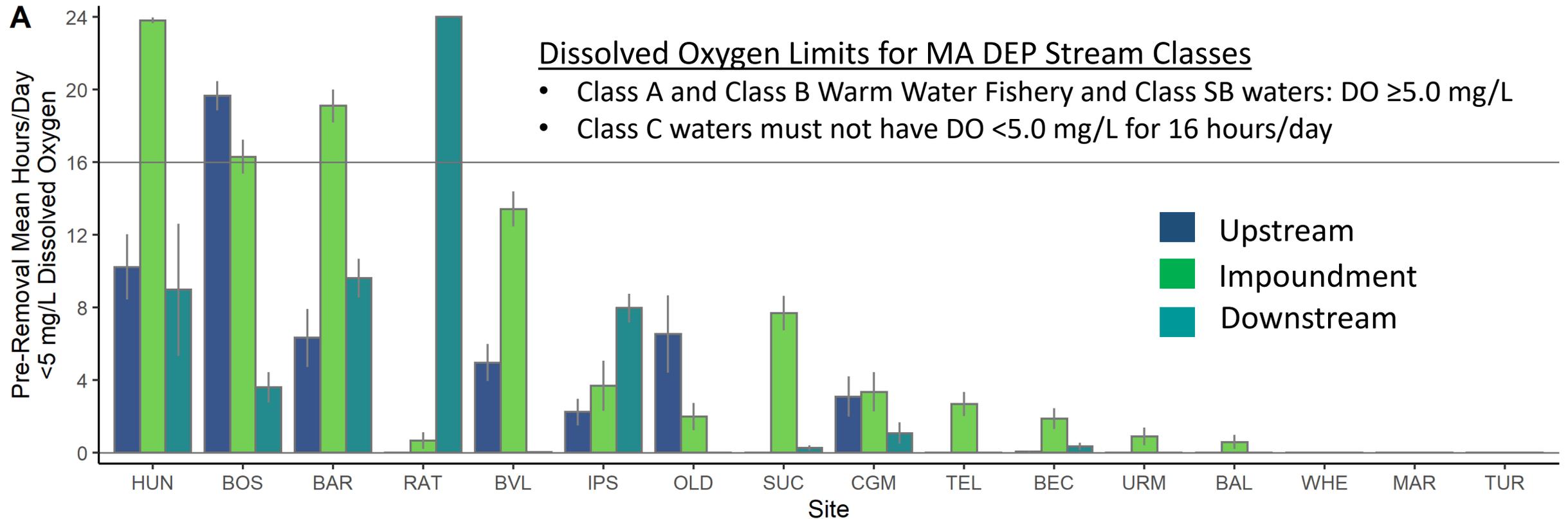




DAMS MAY ALTER INLAND WATER CLASSIFICATIONS

WITH CONSEQUENCES FOR WATER QUALITY AND BIOTA

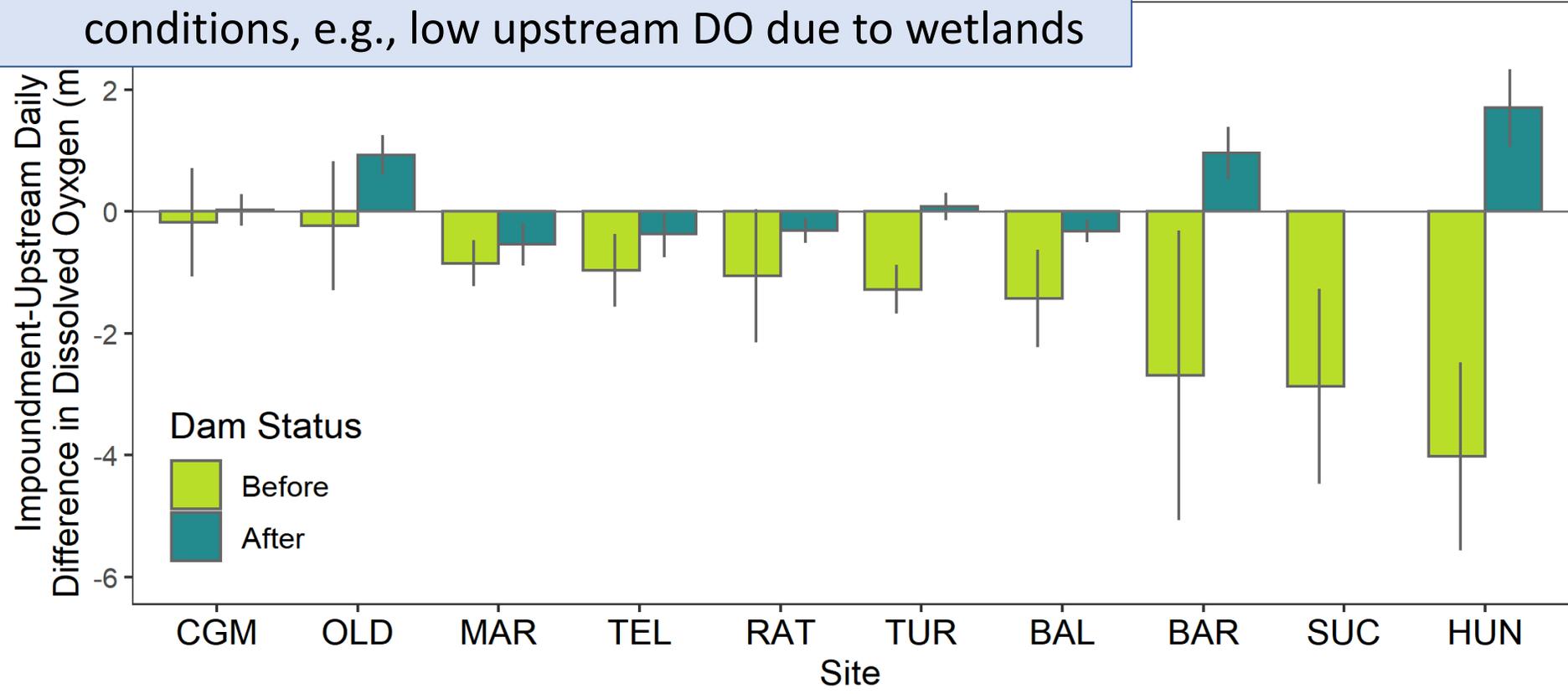
→ Most impoundments (13 of 16) experienced some period of time with dissolved oxygen less than 5 mg/L





DISSOLVED OXYGEN RECOVERED WITHIN ONE YEAR

- Most significant DO improvements occurred at sites most negatively impacted
- Restoration potential constrained by upstream conditions, e.g., low upstream DO due to wetlands





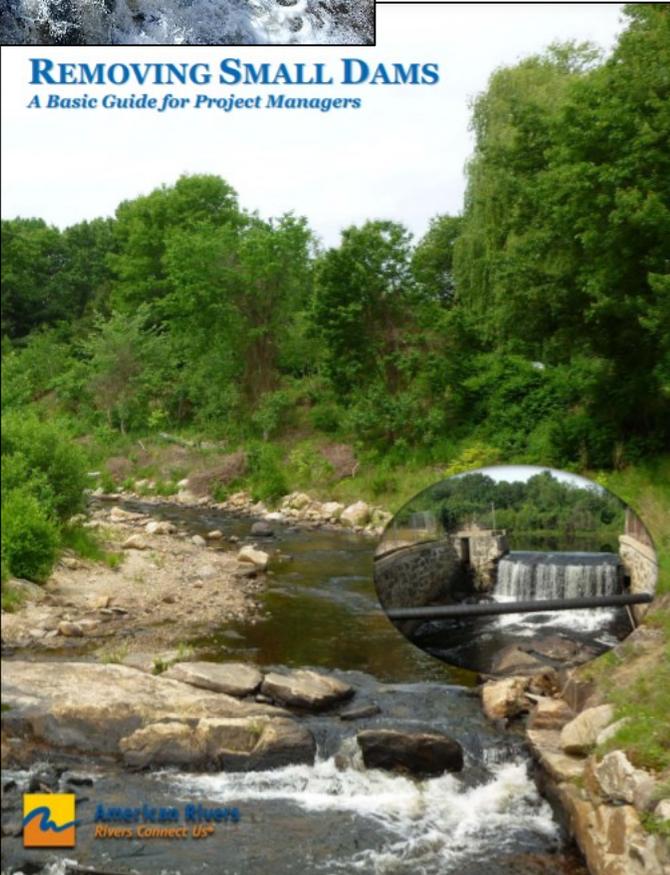
WATER QUALITY RESPONSES

Temperature

- Cooler temperatures downstream
 - BUT need to be aware of restoration process
 - Set a realistic recovery timeline based on site characteristics
- More than magnitude
 - Can also change frequency/duration of thermal exceedances

Dissolved Oxygen

- Improvement within one year following removal
- BUT magnitude of recovery related to magnitude of impact pre-removal



PRESENTATION OUTLINE



Effects of dams and dam removal on water quality



Effects of dams and dam removal on aquatic macroinvertebrates



Guidance for monitoring and prioritization



MACROINVERTEBRATES AS INDICATORS OF WATER QUALITY

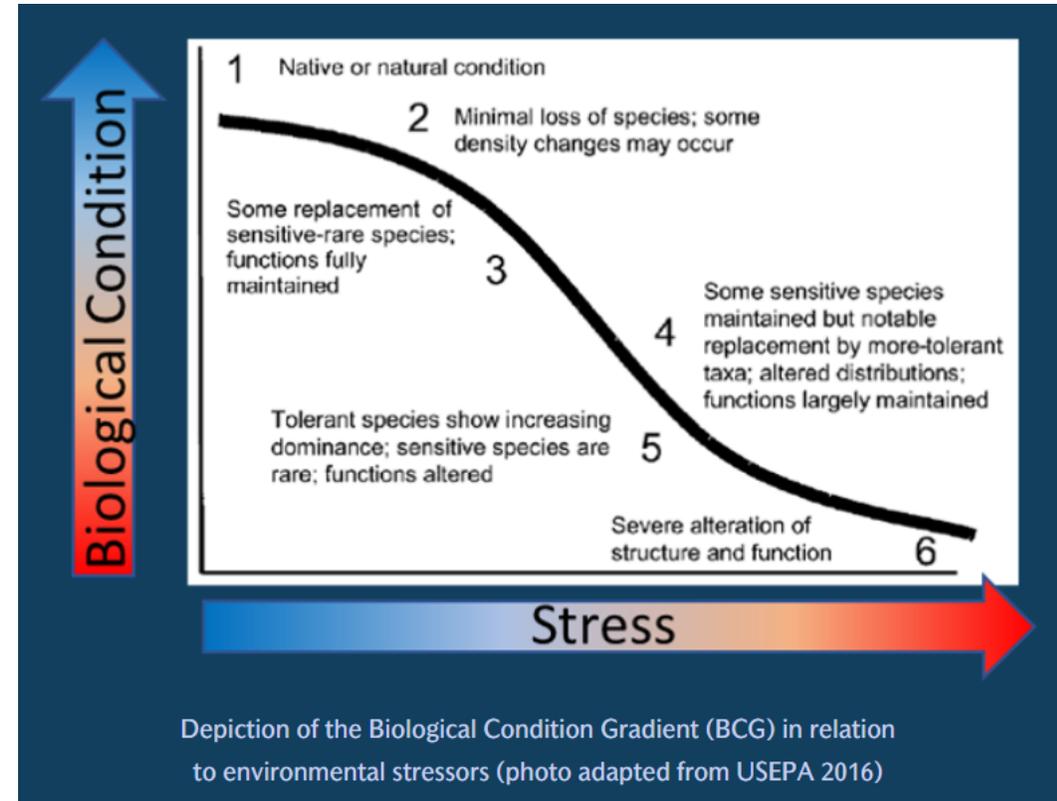


The **Clean Water Act** requires states to assess surface waters for physical, chemical, and biological integrity

“the capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having species composition, diversity, and functional organization comparable to that of the natural habitat of the region.”

The **Massachusetts Surface Water Quality Standards** has aquatic life use designations:

“waters shall be free from ... that would impair any use assigned ... or that would impair the benthic biota”

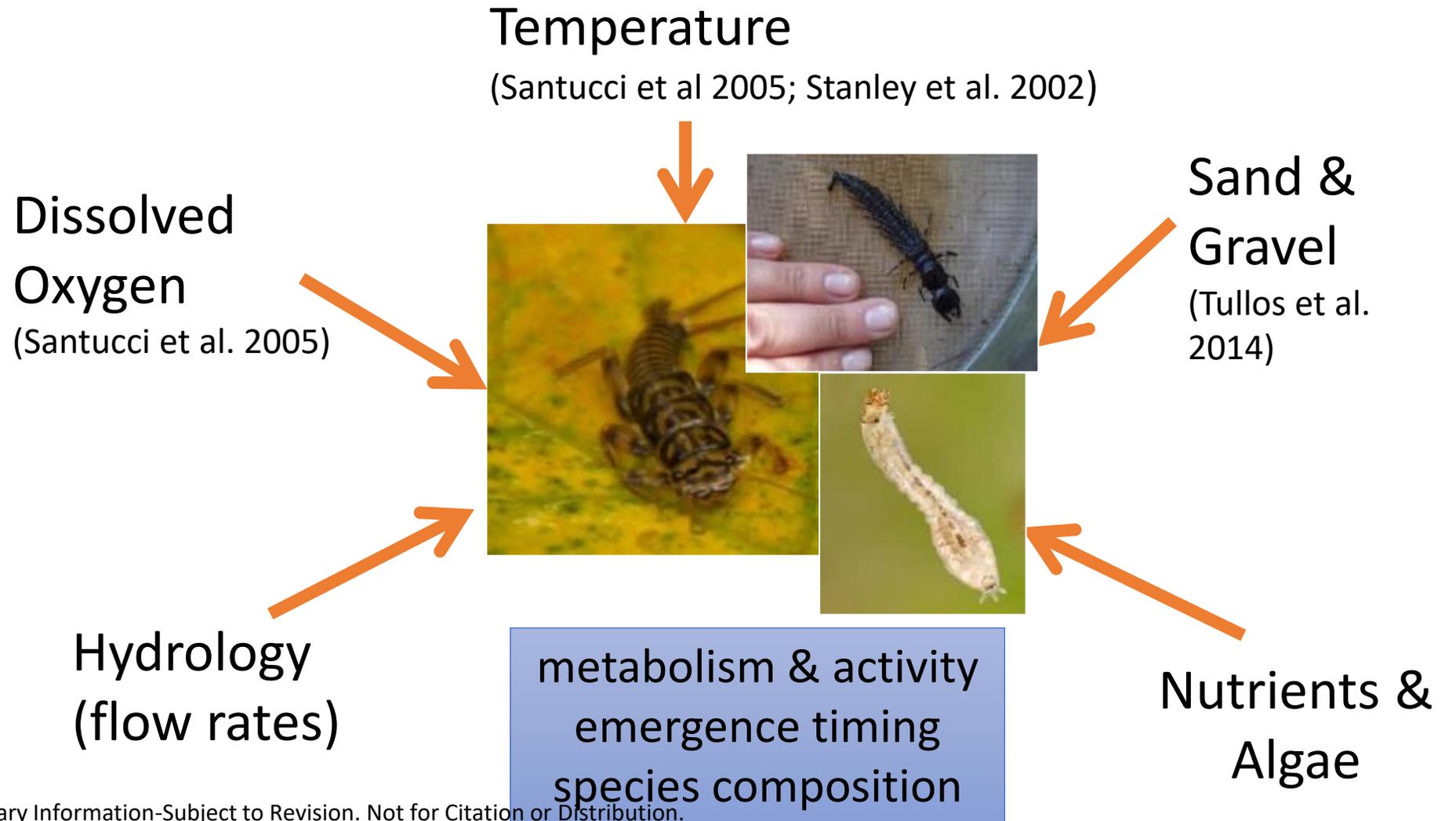


Source: MassDEP mIBI Development StoryMap: MassDEP mIBI Development





EXPECTED EFFECTS OF DAMS AND DAM REMOVAL ON AQUATIC MACROINVERTEBRATES





MACROINVERTEBRATE SAMPLING

STREAM REACHES:
Surber in riffle habitats
& multihabitat sweeps

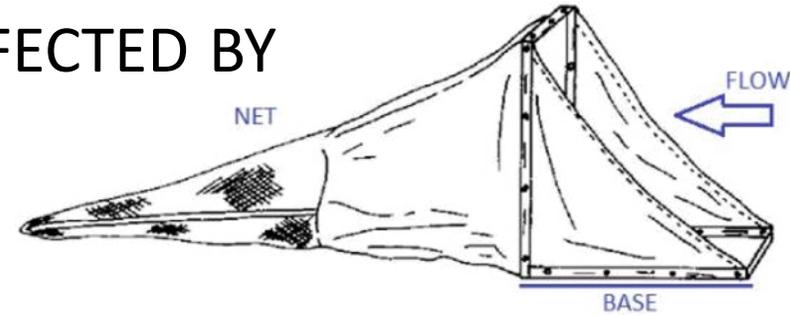


IMPOUNDMENTS:
Ponar grab in sediments
& vegetation sweeps

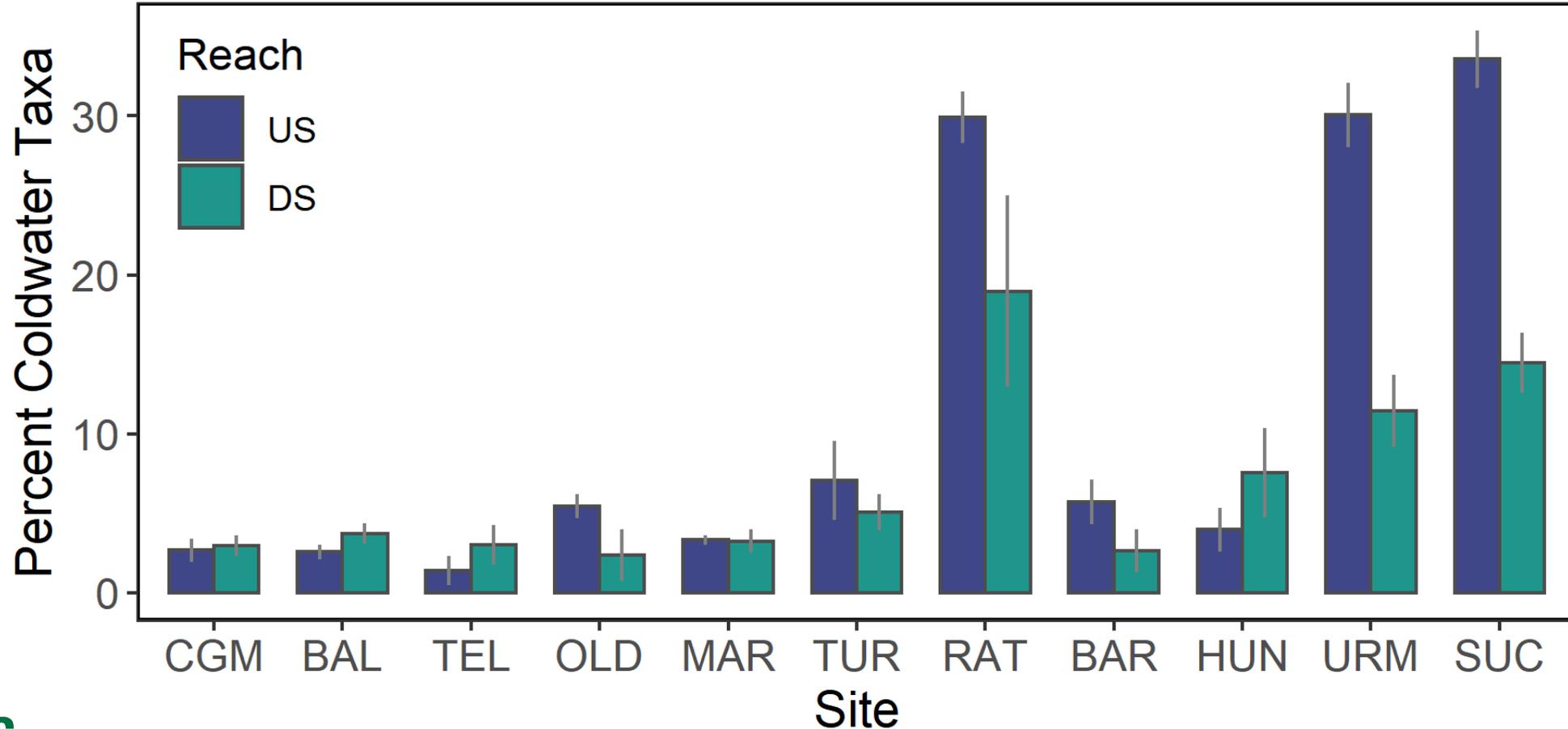




MACROINVERTEBRATE ASSEMBLAGES CAN BE AFFECTED BY DAM THERMAL IMPACTS

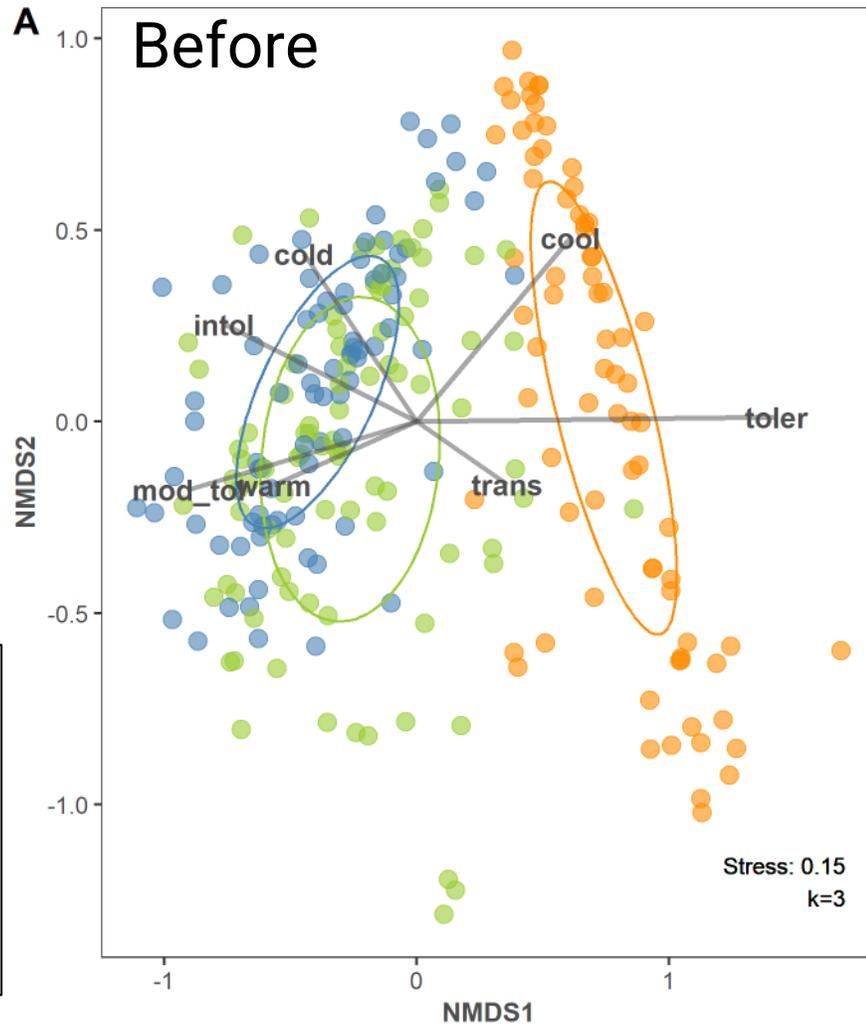


Before Removal





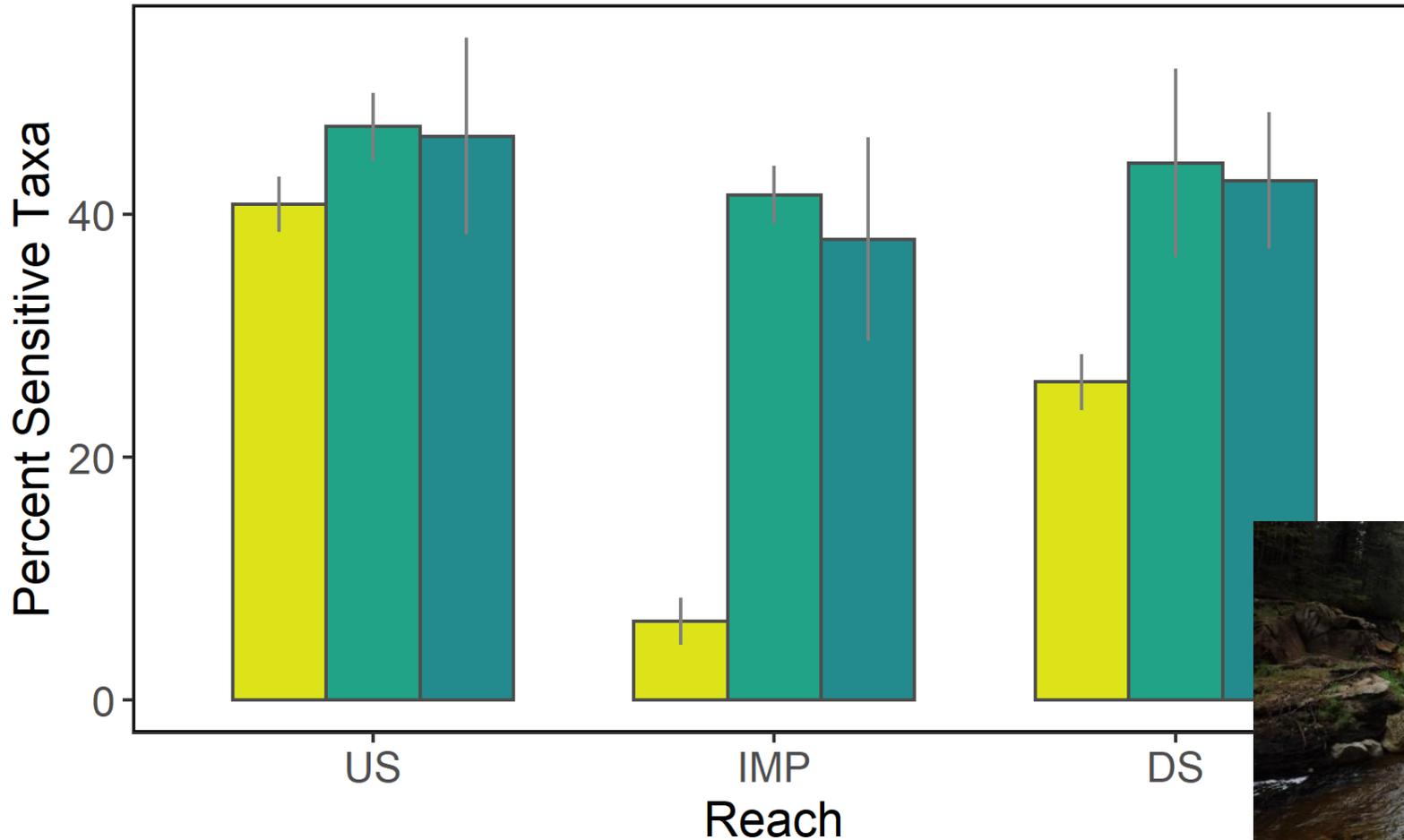
MACROINVERTEBRATE ASSEMBLAGES SHIFT AFTER DAM REMOVAL





SENSITIVE TAXA RECOVER AFTER DAM REMOVAL, EVEN AT A SITE WITH PASSIVE SEDIMENT RELEASE

Upper Roberts Meadow, Northampton, MA



Time Since Dam Removal

- Before
- 1-year
- 3-years



Roberts Meadow Brook

ECOLOGICAL RESPONSES TO DAM REMOVAL

Webinar
April 7th:
Mussels &
Fishes

Recurring theme: **Variability**

- Impacts and response to removals differ among **sites**
- **Taxa** respond differently to removal
- Impoundments & downstream **reaches** respond differently

General Recovery Timeline

- Temperature generally recovers quickly but some delayed recovery
- Dissolved oxygen improves within 1 year
- Macroinvertebrate biotic metrics indicate downstream resilience

Inform
Expectations



PRESENTATION OUTLINE



Effects of dams and dam removal on water quality



Effects of dams and dam removal on aquatic macroinvertebrates



Guidance for monitoring and prioritization



WATER QUALITY MONITORING CONSIDERATIONS

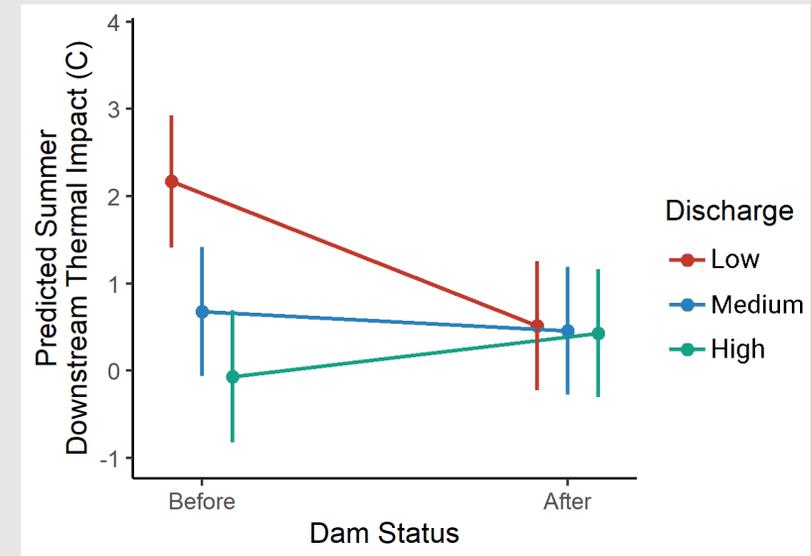
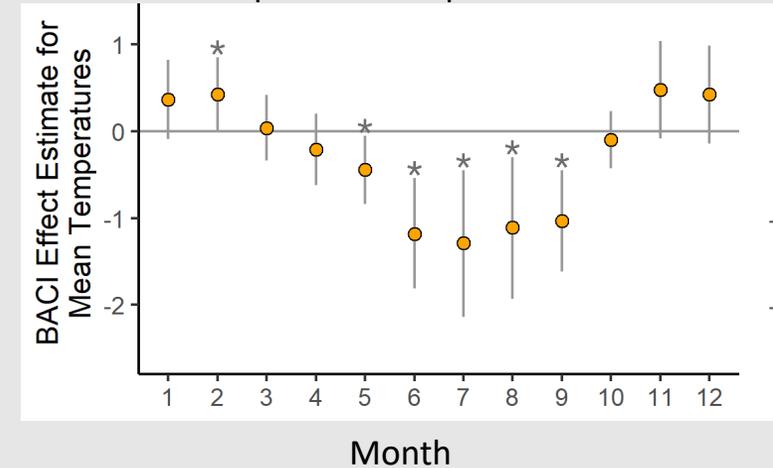
Timing:

- Years: Before and after removal, multiple years
- Time of year: when impacts are greatest
- Sample frequency: continuous

Location:

- Relative to dam: upstream, impoundment, downstream (several)
- In reach: spillage from impoundment, well-mixed areas

Upstream - Impoundment





MACROINVERTEBRATE MONITORING CONSIDERATIONS

Timing:

- Years: Before and after removal, multiple years
- Time of year: July to September
- Sample frequency: once per year

Location:

- Relative to dam: upstream, impoundment, downstream
- In reach: riffle and multi-habitats

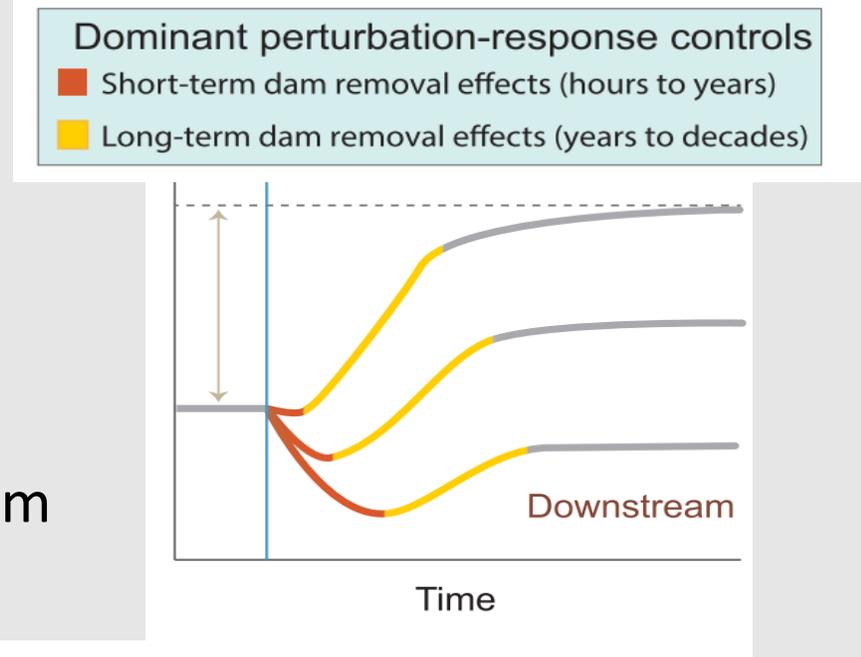


Table 1. Summary of the macroinvertebrate sample protocol elements for the MassDEP Rapid Bioassessment Protocol (RBP) kick net method.

Effort	Gear	Habitat	Sampling area	Index period	Target # organisms	Taxonomic resolution
10 kick-samples are taken in riffle habitats within the sampling reach and composited	Kick-net, 46-cm wide opening, 500-mm mesh	Riffle/run is the preferred habitat	Approximately 2 m ²	July 1–September 30	100	Lowest practical level

Bellmore et al. 2019

Tetra Tech & MassDEP



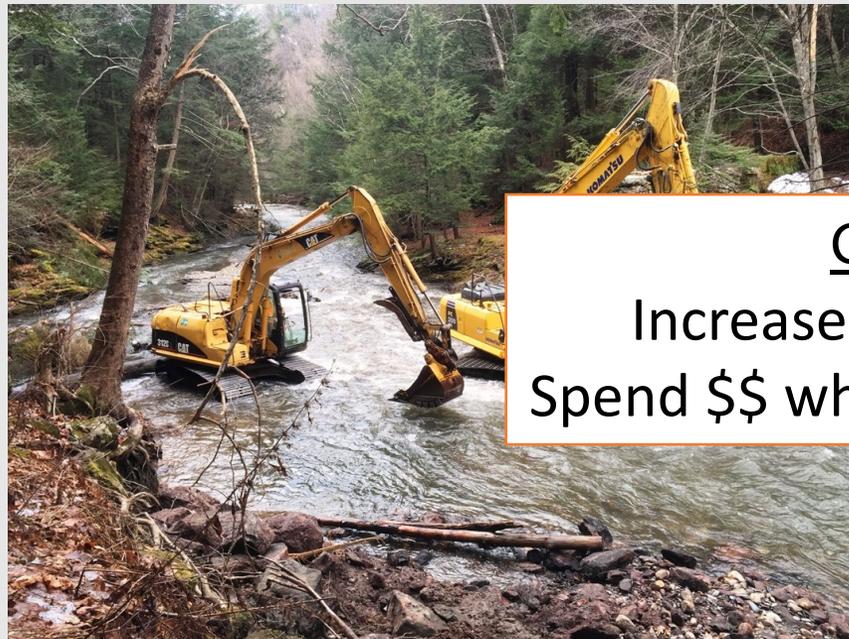
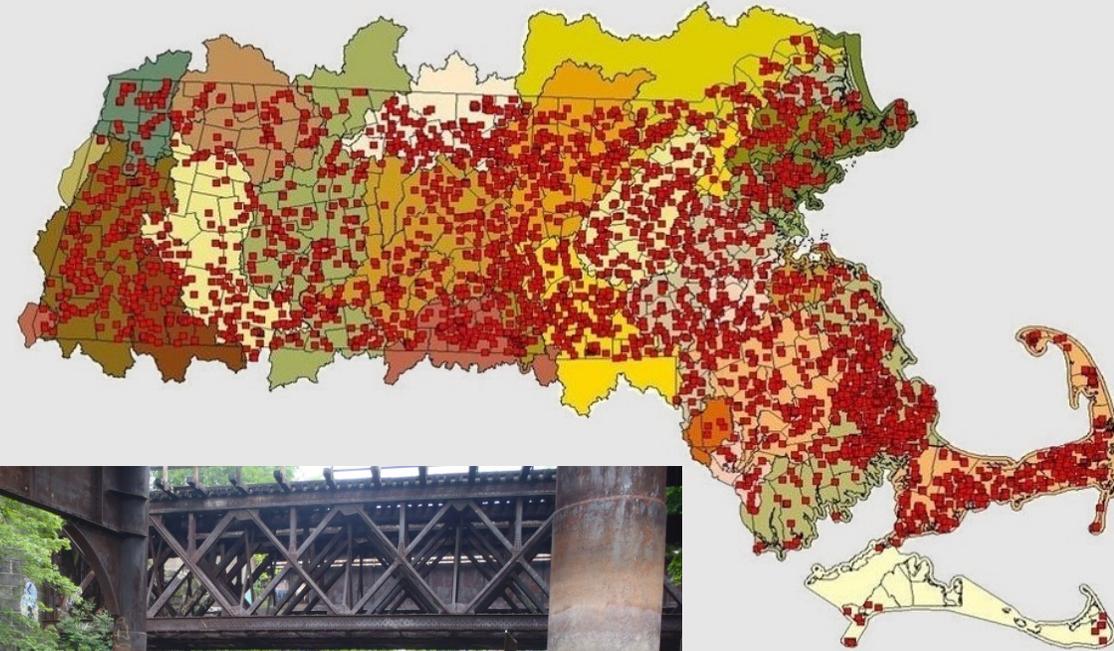
Prioritize
Restoration

DAM REMOVAL: WHERE TO BEGIN?

Current approach = opportunistic

- Passionate towns/non-profits
- Willing/motivated dam owners
- Low hanging fruit

→ Lots of variation in time & cost



Goals:
Increase removal rate
Spend \$\$ where most benefit



Prioritize
Restoration

DER'S RESTORATION POTENTIAL TOOL

Environmental Indicators:

1) Watershed position (20 pts)

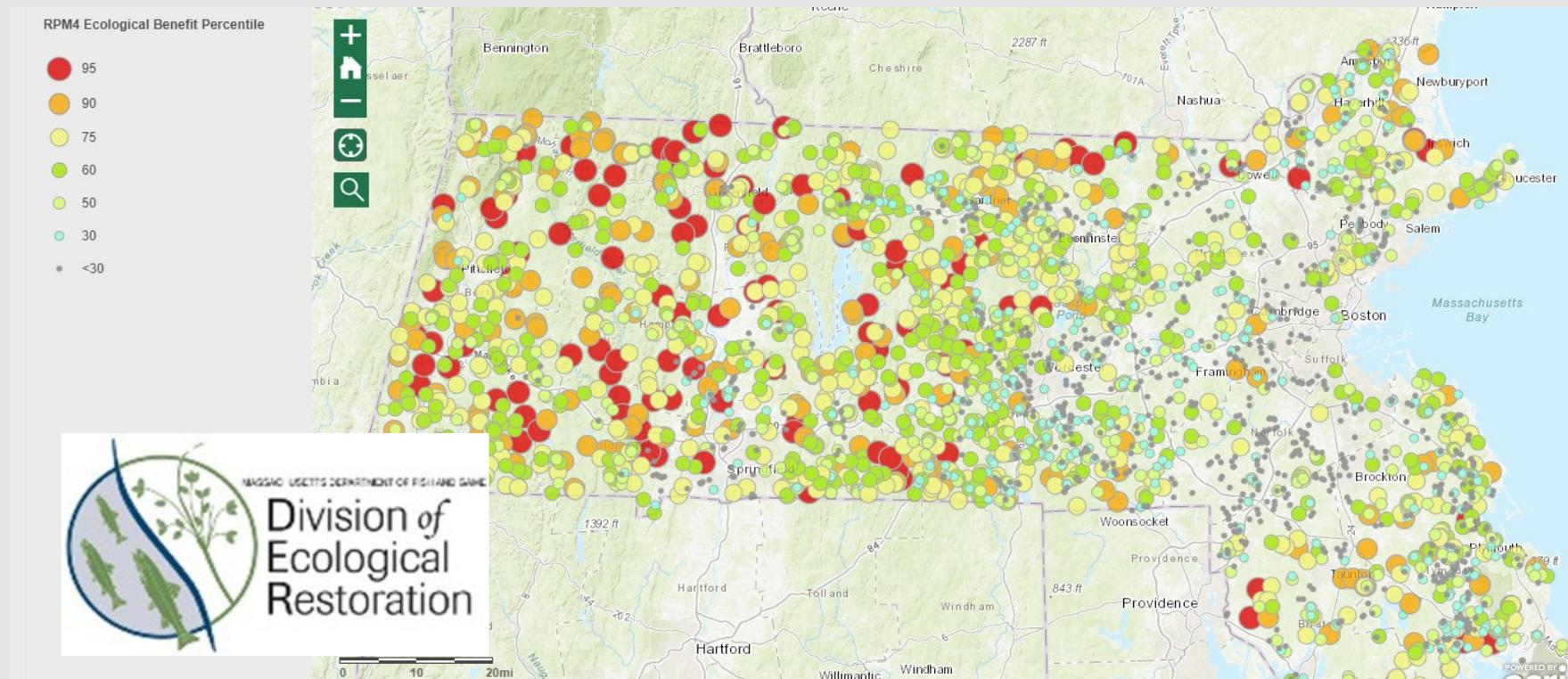
- head of tide (+)
- coastal streams (+)
- headwater streams (+)

2) Ecological integrity (55 pts)

- Rare species and habitats (+)
- Coldwater habitat (+)
- % impervious surfaces in watershed (-)
- % reduction in August flows (-)

3) Connectivity (25 pts)

- added connected
stream network





EXPANDING ON THE PRIORITIZATION TOOL

Prioritize
Restoration

Water quality data: rapid field assessment

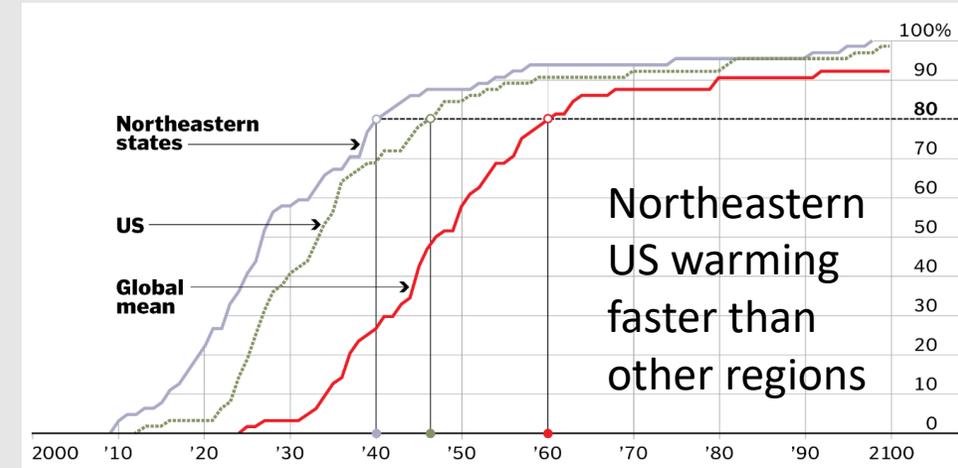
- Spot measurements upstream & downstream
- Short-term logger deployments in August low flow

Cumulative effects

- Distance to next downstream dam
- Potential for recovery from dam impacts

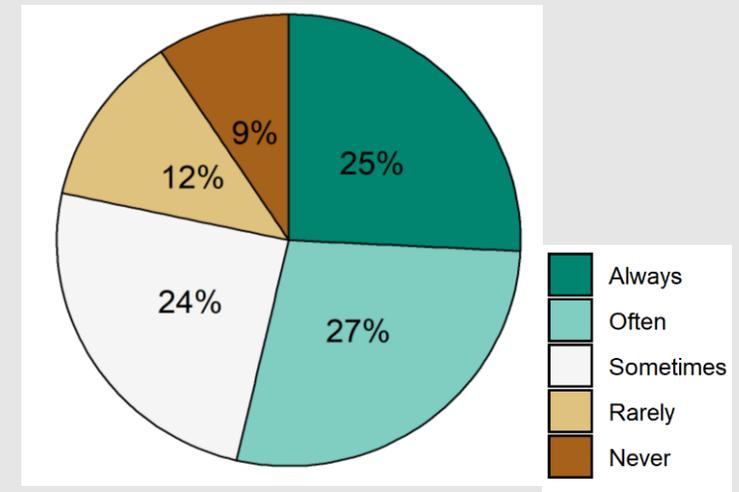
Climate resiliency

- Access to climate refugia
- Connected habitats
- Flood risk



Karmalkar and
Bradley 2017

How often is
climate change
incorporated in
dam removal
decisions?



Abbott et al. 2024.



P. Zaidel



Questions?

aroy@eco.umass.edu



UMASS
AMHERST



Preliminary Information-Subject to Revision. Not for Citation or Distribution.

Contact:
aroy@eco.umass.edu

RESOURCES



Abbott, K., A. Roy, and K. Nislow. 2022. Restoring Aquatic Habitats Through Dam Removal. U.S. Department of Interior, Fish and Wildlife Service, Cooperator Science Series FWS/CSS-148-2022, Washington, D. C. <https://doi.org/10.3996/css92498424>

Abbott K.M., P.A. Zaidel, A.H. Roy, K.M. Houle, and K.H. Nislow. 2022. Investigating impacts of small dams and dam removal on dissolved oxygen in streams. PLoS ONE 17(11): e0277647. <https://doi.org/10.1371/journal.pone.0277647>

Abbott, K.A. and Roy, A.H., 2022, Stream Temperature and Dissolved Oxygen Responses to Small Dams and Dam Removal in Massachusetts: U.S. Geological Survey data release. <https://doi.org/10.5066/P9L2ATHV>

Abbott, K.M. 2023. River restoration through dam removal: Examining ecological responses to small dam removals across Massachusetts. PhD dissertation, Department of Environmental Conservation, University of Massachusetts Amherst. <https://scholarworks.umass.edu/entities/publication/b21e1519-832e-48f0-872d-04bc0507b409>

Abbott, K. M., A. H. Roy, F. J. Magilligan, K. H. Nislow, and R. M. Quiñones. 2024. Incorporating climate change into restoration decisions: perspectives from dam removal practitioners. Ecology and Society 29(3):21. <https://doi.org/10.5751/ES-15182-290321>

Abbott, K.M, A.H. Roy, K.H. Nislow, R.M. Quiñones, and E. Rogers. In Revision. Shifting thermal regimes after small dam removals and implications for climate change. Elementa. (available upon request)

Zaidel, P. 2018. Impacts of small, surface-release dams on stream temperature and dissolved oxygen in Massachusetts. Master's Thesis. University of Massachusetts Amherst. https://scholarworks.umass.edu/masters_theses_2/680

Zaidel, P.A., A.H. Roy, K.M. Houle, B. Lambert, B.H. Letcher, K.H. Nislow, and C. Smith. 2020. Impacts of small dams on stream temperature. Ecological Indicators. <https://doi.org/10.1016/j.ecolind.2020.106878>