How Can Research on the Effects of Beaver Activity Inform Better Stream and Wetland Restoration Design?

Anne Arundel County Department of Public Works

BeaverCon, March 4, 2020

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Anne Arundel County WATERSHED Protection & Restoration PROGRAM

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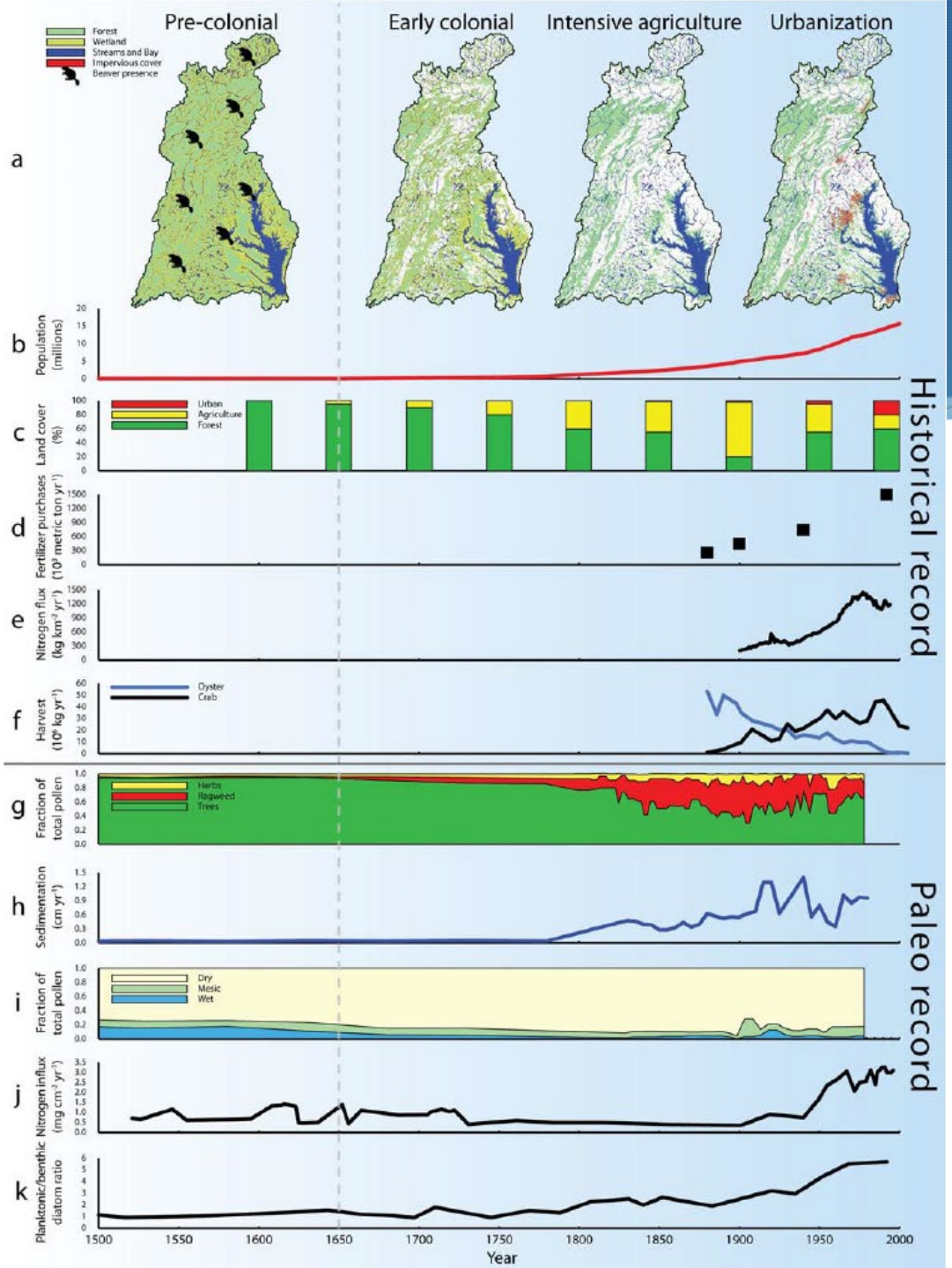


Brush, G. (2008). Historical land use, nitrogen, and coastal eutrophication: A paleoecological perspective. *Estuaries and Coasts*.


The beaver population in North America in precolonial time is
estimated to have been between 60 and 400 million individuals.

"Every River where the current was moderate and sufficiently deep, the banks at the water edge were occupied by their houses. To every small Lake and all the Ponds they builded Dams, and enlarged and deepened them to the height of their dams. Even to grounds occasionally overflowed by heavy rains, they also made dams, and made the permanent Ponds, and as they heightened the dams [they] increased the extent and added to the depth of the water; Thus all of the low lands were in possession of the Beaver, and all of the hollows of the high grounds." David Thompson (1770-1857)

StreamMechanics

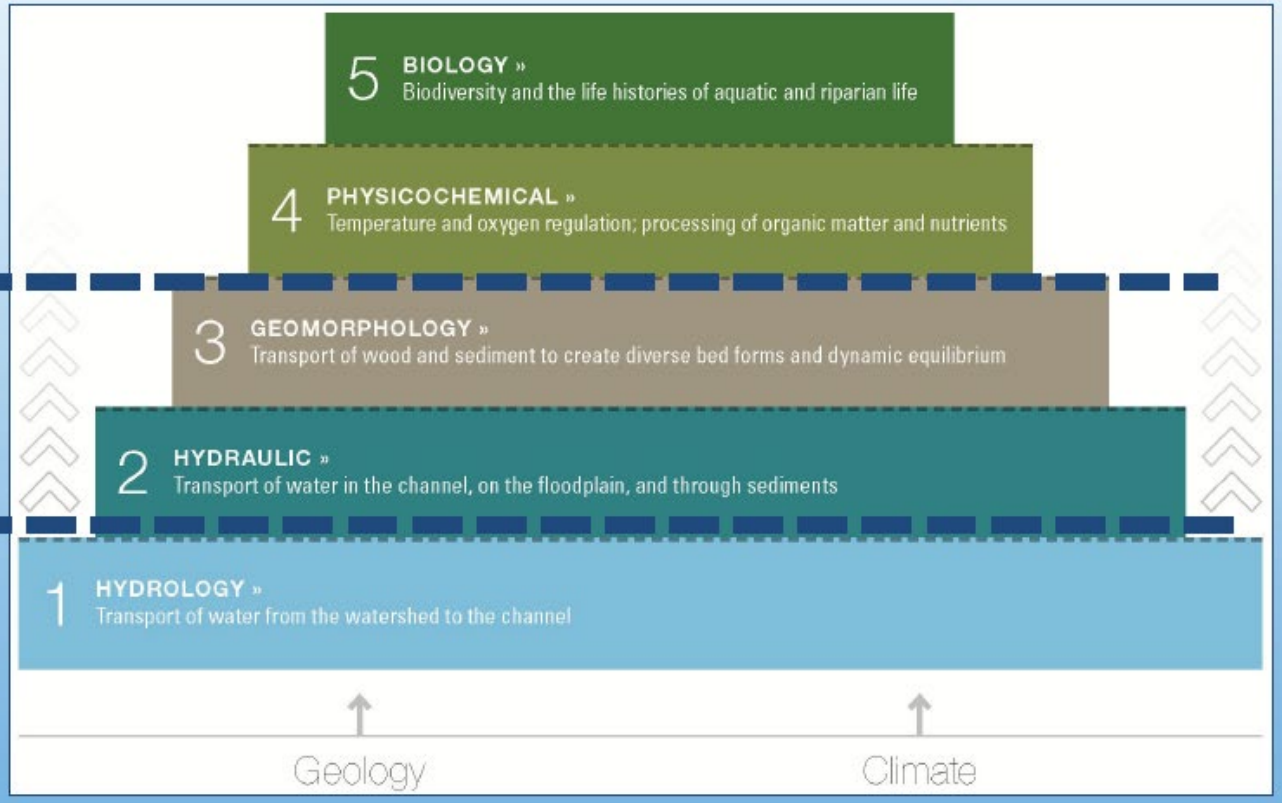
From Harman, 2013

Site Selection

Reach Scale Improvements

Generally Independent Variables.

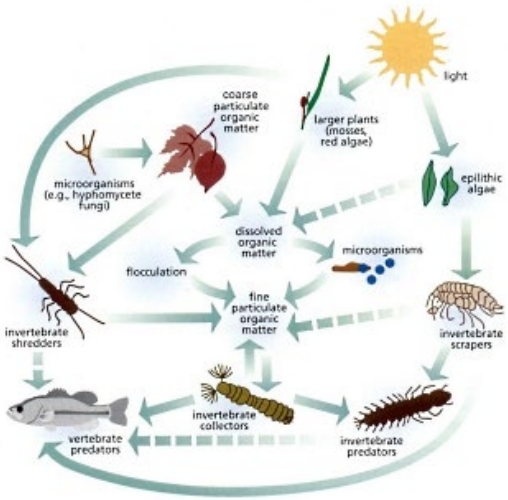
May be altered in headwater streams.



Transport Reach - A stable channel that transports water and sediment without aggrading or degrading

What Does the Science Tell Us About the Functional Effects of Transport Reaches?

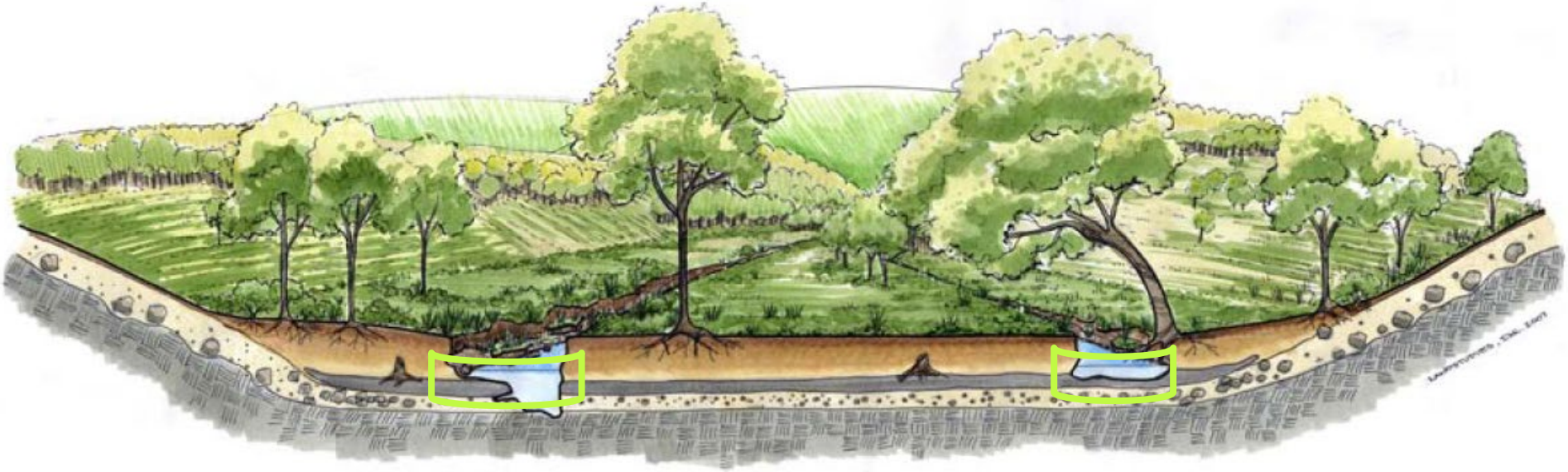
- **Hydrologically**
  - Channel restoration involving channel re-alignment can reduce transient water storage within the system (possibly due to loss of hyporheic exchange). (Mason et al, 2012; Price et al, 2015).
- **Hydraulically**
  - The single most important predictor of coarse particulate organic material loss is current velocity at bank-full flow (Lepori et al, 2005).



Federal Interagency Stream Restoration Working Group (FISRWG)

What Does the Science Tell Us About the Functional Effects of Transport Reaches?

- **Geomorphologically**
  - In many stream restoration projects, wood structures are placed parallel to flow, reducing their beneficial effect on stream hydraulics (Kail et al, 2007).
- **Physicochemically**
  - Streams with restored, high "non-connected" banks had substantially lower rates of denitrification than riparian areas with low, hydrologically "connected" streambanks designed to promote flooding (Kaushal et al, 2008).
  - Mass removal of nitrate-N appears to be strongly influenced by hydrologic residence time.
- **Biologically**
  - Though Natural Channel Design restoration projects increased bank stability, they had no significant effects on most macroinvertebrate community metrics (Ernst et al, 2011; Meisenbach et al, 2012).
  - There is no evidence that habitat heterogeneity was the primary factor controlling stream invertebrate diversity (Palmer, 2009).



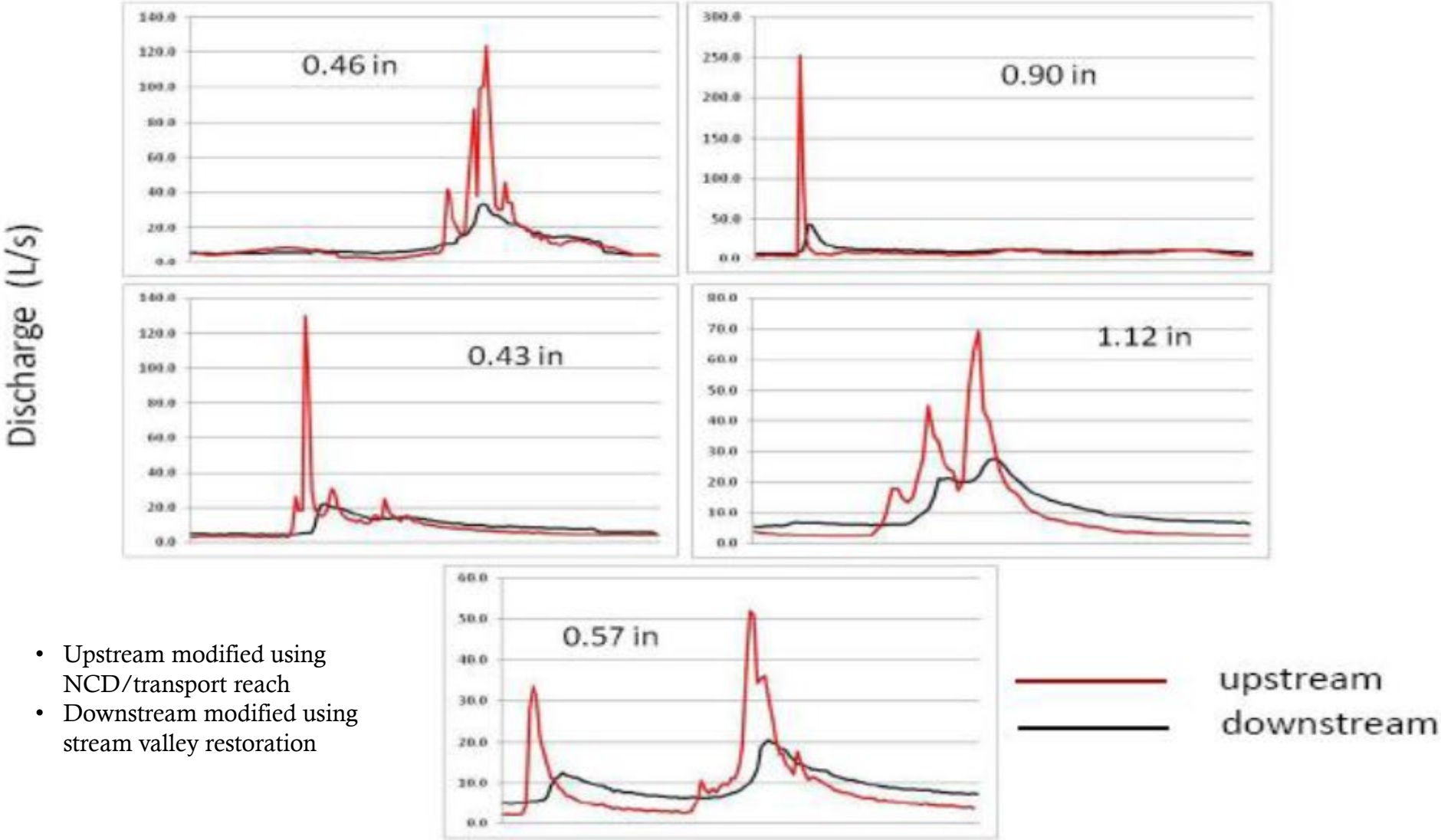
Land Studies

*The **hyporheic zone** is the area under and alongside the stream where groundwater interacts with surface water.*

Transport v. Retention

What Does the Science Tell Us About the Functional Effects of Retention Reaches?

- **Hydrologically**
  - Channel spanning in-stream geomorphic structures drive significant hyporheic exchange in streams under baseflow conditions through both local steepening of the streambed and creating backwater behind obstructions. (Hester & Doyle, 2008).
  - Beaver dams can increase downstream low flows (i.e., baseflow) (Nyssen et al, 2011).
- **Hydraulically**
  - Placement of boulders interrupting flow in stream restoration can reverse the impacts of channelization and reduce loss of organic material (Lepori et al, 2005).
  - Beaver dams can significantly lower discharge peaks in downstream river reaches (Nyssen et al, 2011).
- **Geomorphologically**
  - Most of the geomorphic effects of wood in rivers arise from large, stable logs that catalyze changes in the routing and storage of both smaller wood and sediment (Montgomery et al, 2003).



- Upstream modified using NCD/transport reach
- Downstream modified using stream valley restoration

Hydrographs During Individual Storms of Two "Restored" Reaches

Filoso, 2011

What Does the Science Tell Us About the Functional Effects of Retention Reaches?

- **Physicochemically**
  - The beaver pond reduced annual discharge of water, total-N, total-P, dissolved silicate, TOC, and TSS by 8, 18, 21, 32, 28, and 27%, respectively. (Correll et al, 1999).
  - Only those restoration projects that converted lowland streams to stream-wetland complexes seemed to be effective at reducing nitrogen fluxes. Restoration design should include features that enhance the processing and retention of different forms of nitrogen (Filoso & Palmer, 2011).
  - Relict beaver meadows represent ~8% of total carbon storage within the landscape, but the value was closer to 23% when beaver actively maintained wet meadows. (Wohl, 2013).
  - De-nitrification from beaver ponds may remove 5 to 45% of watershed nitrogen loading (Lazar et al, 2015).

- **Biologically**
  - Installation of in-stream structures which increased pool area and depth, included large woody debris, and decreased riffle area were associated with increases in salmonid density and biomass (Whiteway et al, 2005).
  - Beaver ponds were positively associated with fish species richness in low-order, blackwater streams (Snodgrass & Meffe, 1998).
  - At the landscape scale, invertebrate richness increased by an estimated 28% in the presence of beaver (Law et al, 0216).
  - Increased dam and pond creation contributes to moderation of diel temperature cycles during periods of low surface flow by increasing water storage, and encouraging surface water—groundwater exchange in a manner that matches the thermal optima of steelhead (Weber et al, 2017).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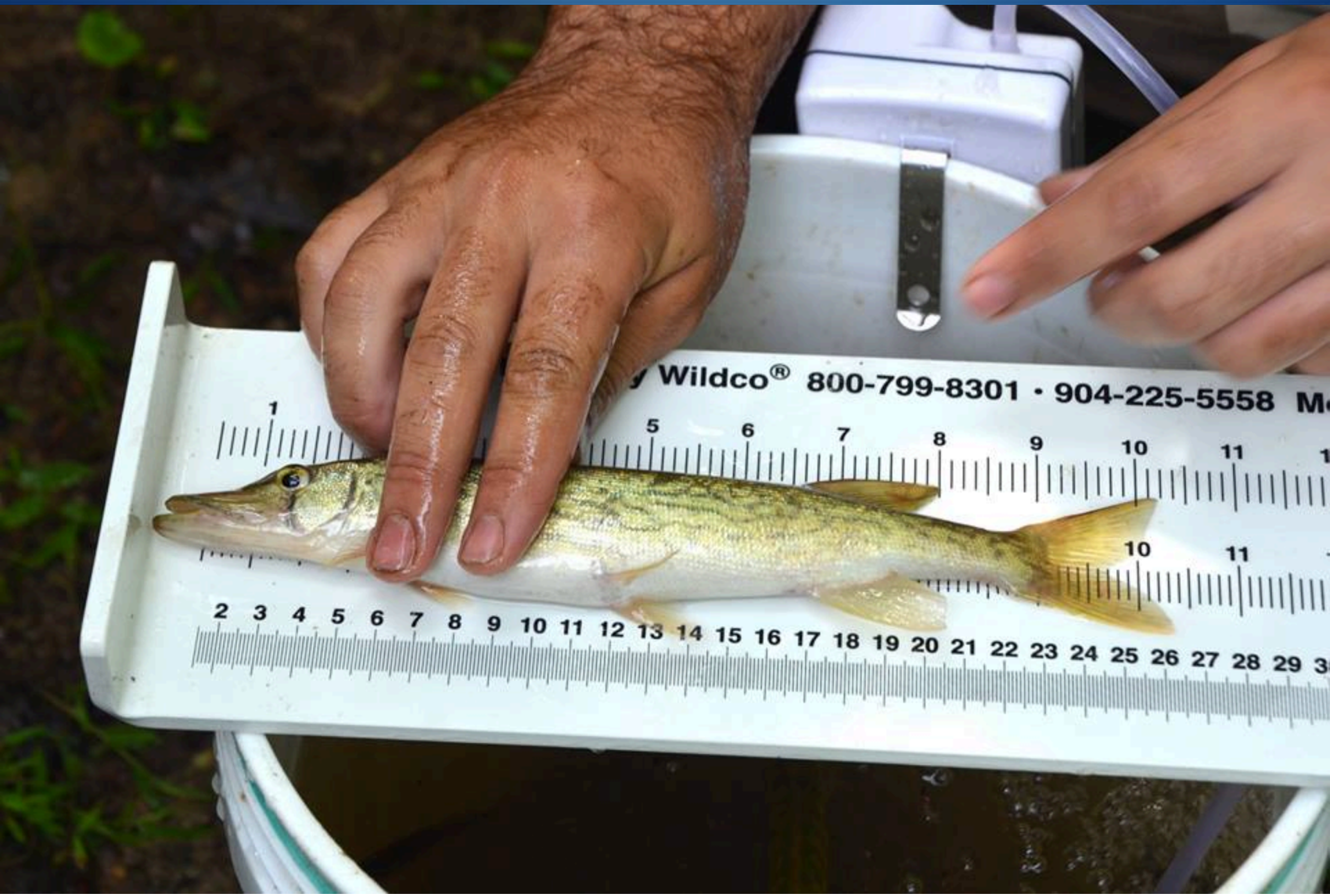
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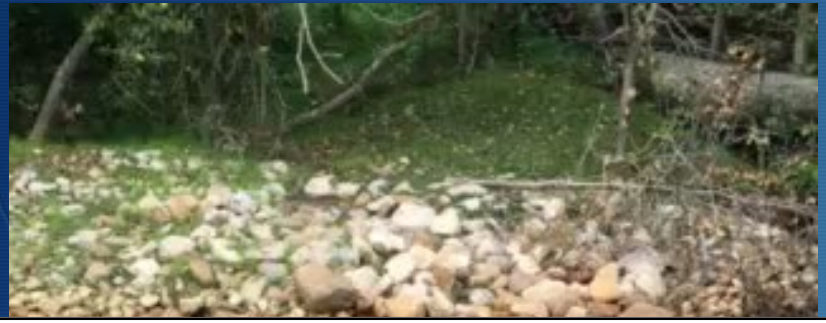
STORIES OF PROGRESS IN ACHIEVING HEALTHY WATERS
EPA Region 3 Water Protection Division

Dam Removal Provides Fish Passage, Water Quality Benefits

Bishopville, Maryland · June 25, 2015

The Bishopville Pond Dam in Maryland has been replaced with a series of pools, runs and step-like structures, improving water quality downstream and providing access for key fish species to spawn upstream.



Newcomer, et al (2016). Nutrient Retention in Restored Streams and Rivers: A Global Review and Synthesis

- Through stream restoration, managers can increase nutrient removal rates by optimizing the surface area and depth of reactive sediments and lengthening transient storage times.
- When restoring streams, projects can be designed to improve nutrient uptake by raising water levels, lowering velocity, increasing transient storage, and increasing organic matter accumulation.
- Coarse woody debris (CWD) treatments increased ammonium uptake velocity (Vf) by 23%–154% and uptake rate (U) by 61%–235% when compared to the control reaches.

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The multiscale effects of stream restoration on water quality

J. Thompson*, C.E. Pelc, W.R. Brogan III, T.E. Jordan

Smithsonian Environmental Research Center, Edgewater, MD, USA

At the Smithsonian Project in Edgewater, MD, found:

- 44.8% of phosphate removal
- 45.8% of total phosphorus removal
- 48.3% of ammonium removal
- 25.7% of nitrate removal
- 49.7% of total nitrogen removal
- 73.8% of suspended sediment removal

"It is likely that in a watershed with other nutrient removal systems, such as the beaver ponds in our study, much larger nutrient and sediment reductions in restored reaches are necessary to observe watershed-scale reductions in nutrient and sediment export."

System Hydrology Drives Functionality at Every Level of the System, and "Restoration" that Does Not Improve Groundwater and Carbon Retention is Unlikely to Provide Significant Benefit in the Other Levels of the Pyramid


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Questions?

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