Using Monitoring Data and Empirical Analyses to Predict the Long-Term Effects of Dam Removal on Nutrients, Water Quality, and Periphyton in the Klamath River

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OUTLINE

- Introduction
  - Background info
  - Study goals
- Methods
  - Data sources
  - Calculations
- Results/Discussion
- Conclusions

- Presentation based on two studies:

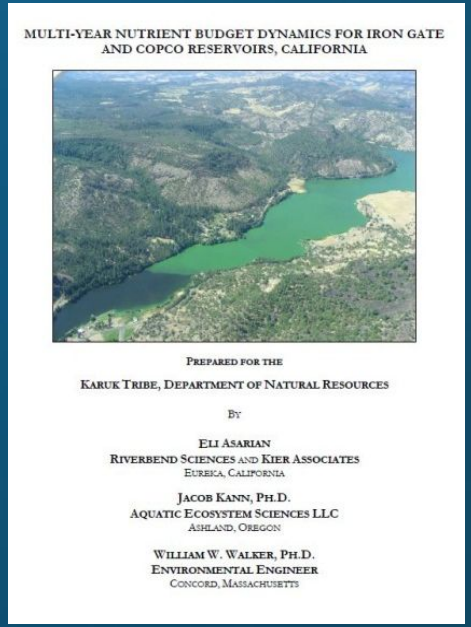
Funded by the Karuk Tribe and Klamath Basin Tribal Water Quality Work Group

Reservoir reaches:

Asarian, E. J. Kann, and W. Walker, 2009. Multi-year Nutrient Budget Dynamics for Iron Gate and Copco Reservoirs, California. Prepared by Riverbend Sciences, Kier Associates, Aquatic Ecosystem Sciences, and William Walker for the Karuk Tribe Department of Natural Resources, Orleans, CA. 55pp + appendices.

River reaches:

Asarian, E. J. Kann, and W. Walker. 2010. Klamath River Nutrient Loading and Retention Dynamics in Free-Flowing Reaches, 2005-2008. Final Technical Report to the Yurok Tribe Environmental Program, Klamath, CA. 59pp + appendices.


MULTI-YEAR NUTRIENT BUDGET DYNAMICS FOR IRON GATE AND COPCO RESERVOIRS, CALIFORNIA

PREPARED FOR THE
KARUK TRIBE, DEPARTMENT OF NATURAL RESOURCES

BY

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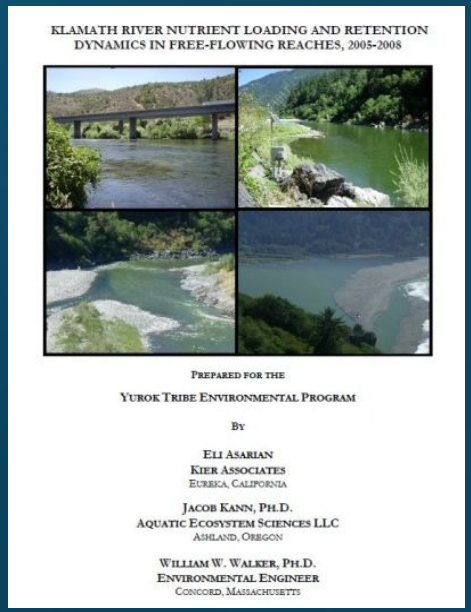
KLAMATH RIVER NUTRIENT LOADING AND RETENTION DYNAMICS IN FREE-FLOWING REACHES, 2005-2008

PREPARED FOR THE
YUROK TRIBE ENVIRONMENTAL PROGRAM

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INTRODUCTION

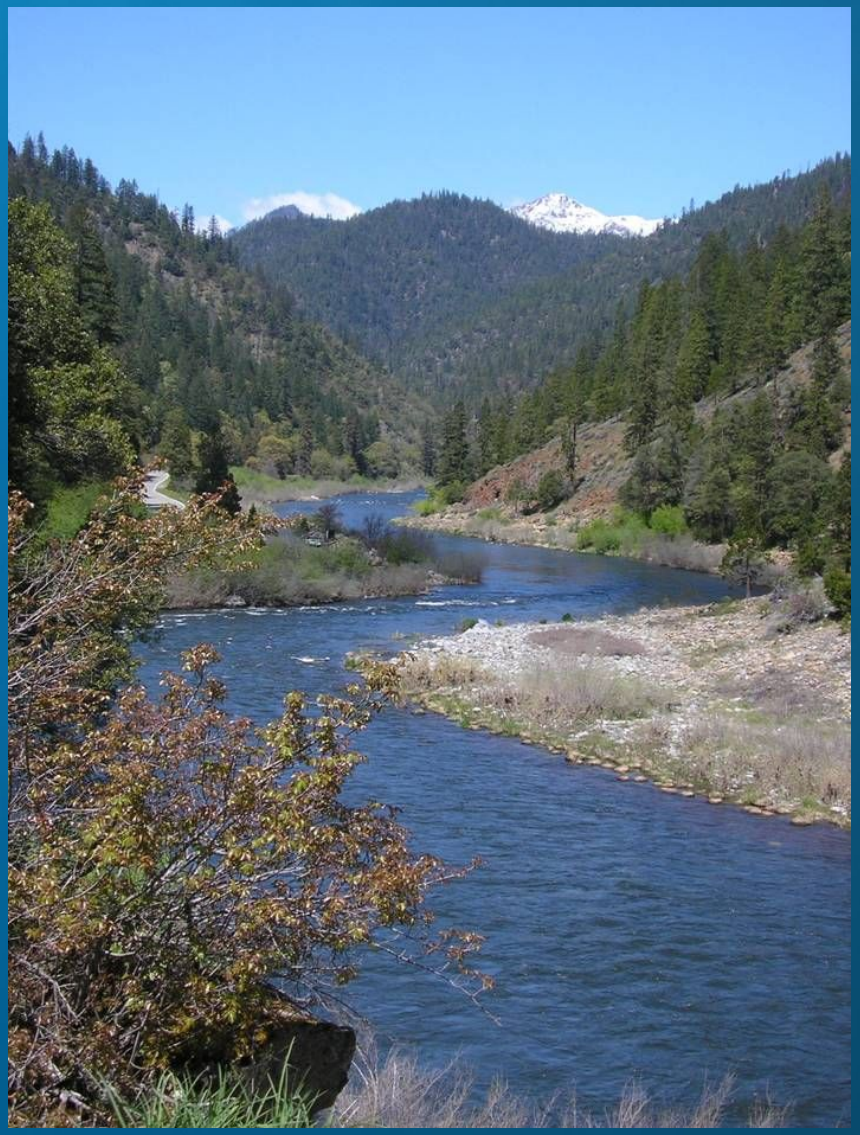


Photo: Eli Asarian

Photo: Eli Asarian

Photo: PacifiCorp

Background Info: Upper Klamath Basin

- Upper Klamath Basin has phosphorus-rich geology, exacerbated by current and past land use
  - Wetlands converted to agriculture
- Headwaters: Upper Klamath Lake
  - Shallow hypereutrophic lake with massive blooms of nitrogen-fixing cyanobacteria: *Aphanizomenon flos-aquae*
    - Algal material = organic load to river

Background Info: Iron Gate and Copco Reservo

- Seasonal stratification
- Harmful algal blooms (HAB):
  - Toxic cyanobacteria *Microcystis aeruginosa*
- Localized downstream effects:
  - High pH (peak blooms)
  - Low D.O. (bloom crash/turnover)
- Thermal lag

Klamath River

Background Info: Mid/Lower Klamath River

- High summer water temperature
- Toxic cyanobacteria (*Microcystis*) from reservoirs
- High nutrient concentrations
- Nuisance periphyton (benthic algae) and macrophytes
  - High pH and diel swings
  - Low D.O. and diel swings

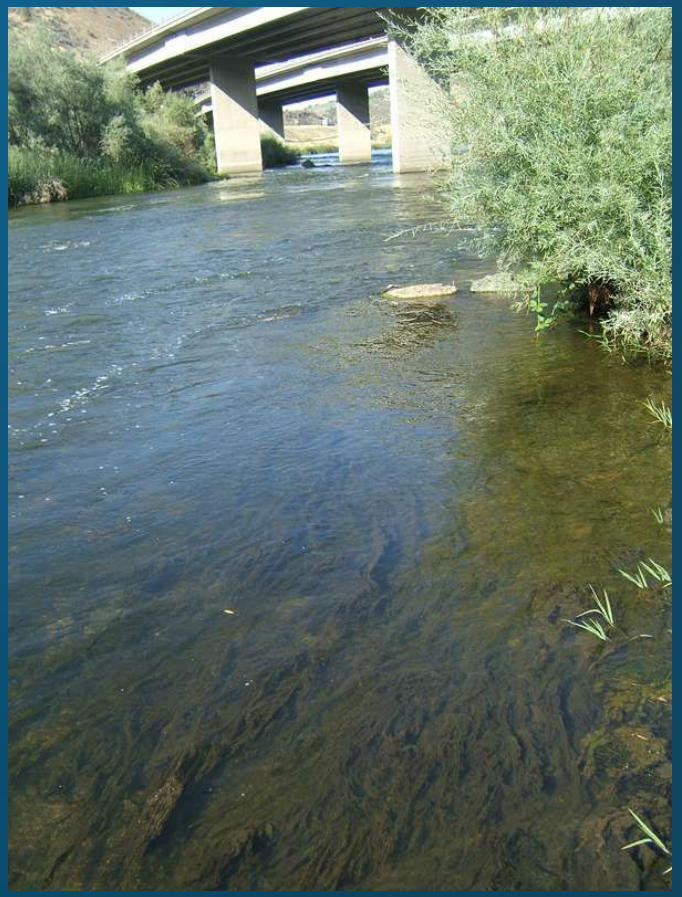


Photo: Eli Asarian

Background Info: Mid/Lower Klamath River

- Longitudinal patterns
  - Nutrient concentrations decrease
    - Clean tributaries = dilution
    - Periphyton = seasonal uptake
  - D.O. and pH improve

Photo: James Mitchell

Photo: Yurok Tribe

Study Goals

- Use mass-balance nutrient budgets to evaluate:
  - Nutrient retention
  - Longitudinal trends
- Compare free-flowing and impounded reaches
- Predict long-term response to dam removal:
  - Quantitative: Nutrient concentration
  - Qualitative: Other factors… complicated and many unknowns

METHODS

Photo: Eli Asarian

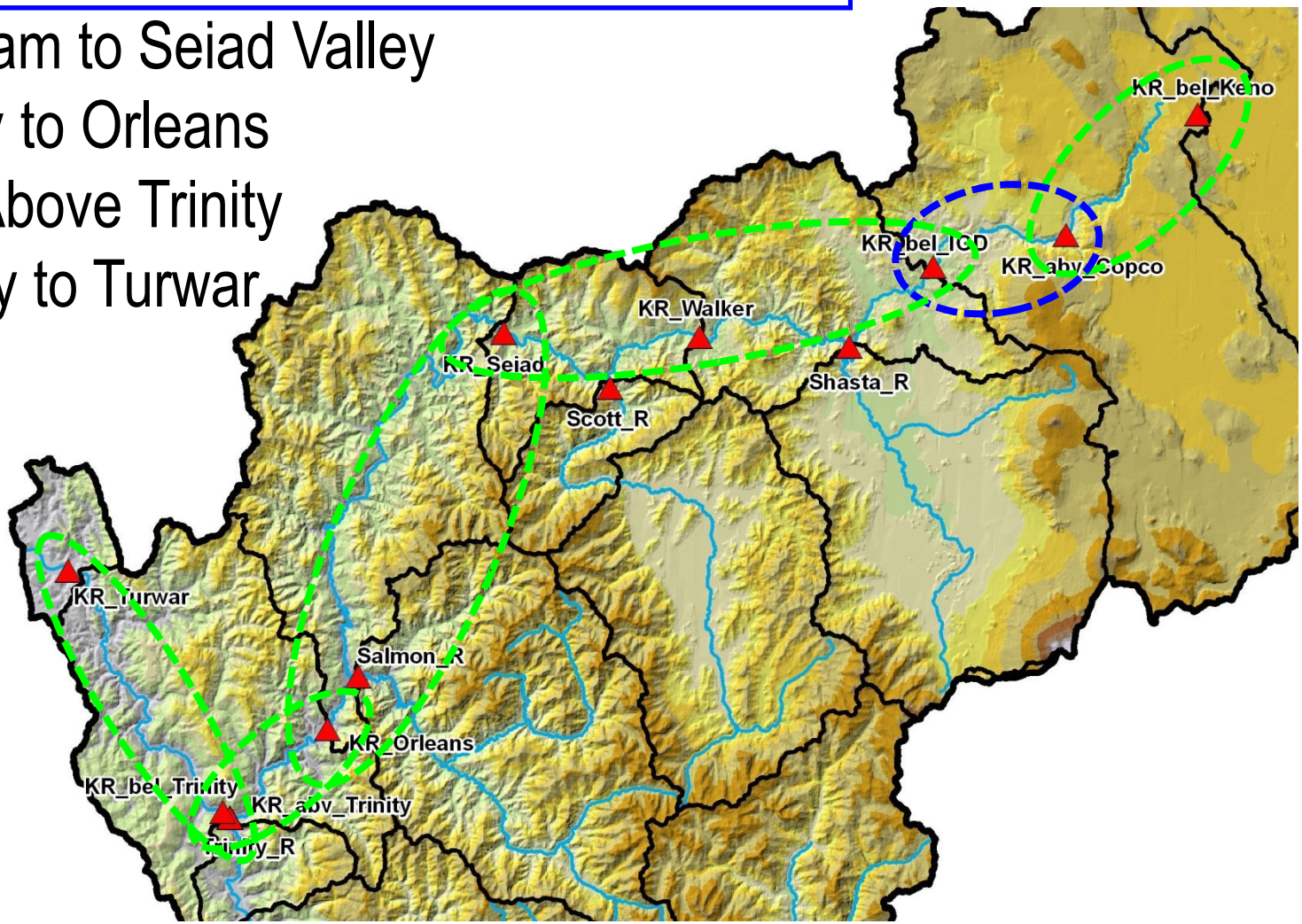
Nutrient Data Sources

- Weekly to monthly (mostly biweekly) samples at mainstem river, reservoir, and tributary sites from Keno to Turwar:
  - Months: June - October
  - Years: 2005-2008
- Nutrient Data sources:
  - Yurok Tribe
  - Karuk Tribe
  - PacifiCorp
  - U.S. Geological Survey
  - U.S. Bureau of Reclamation
  - Oregon Department of Environmental Quality

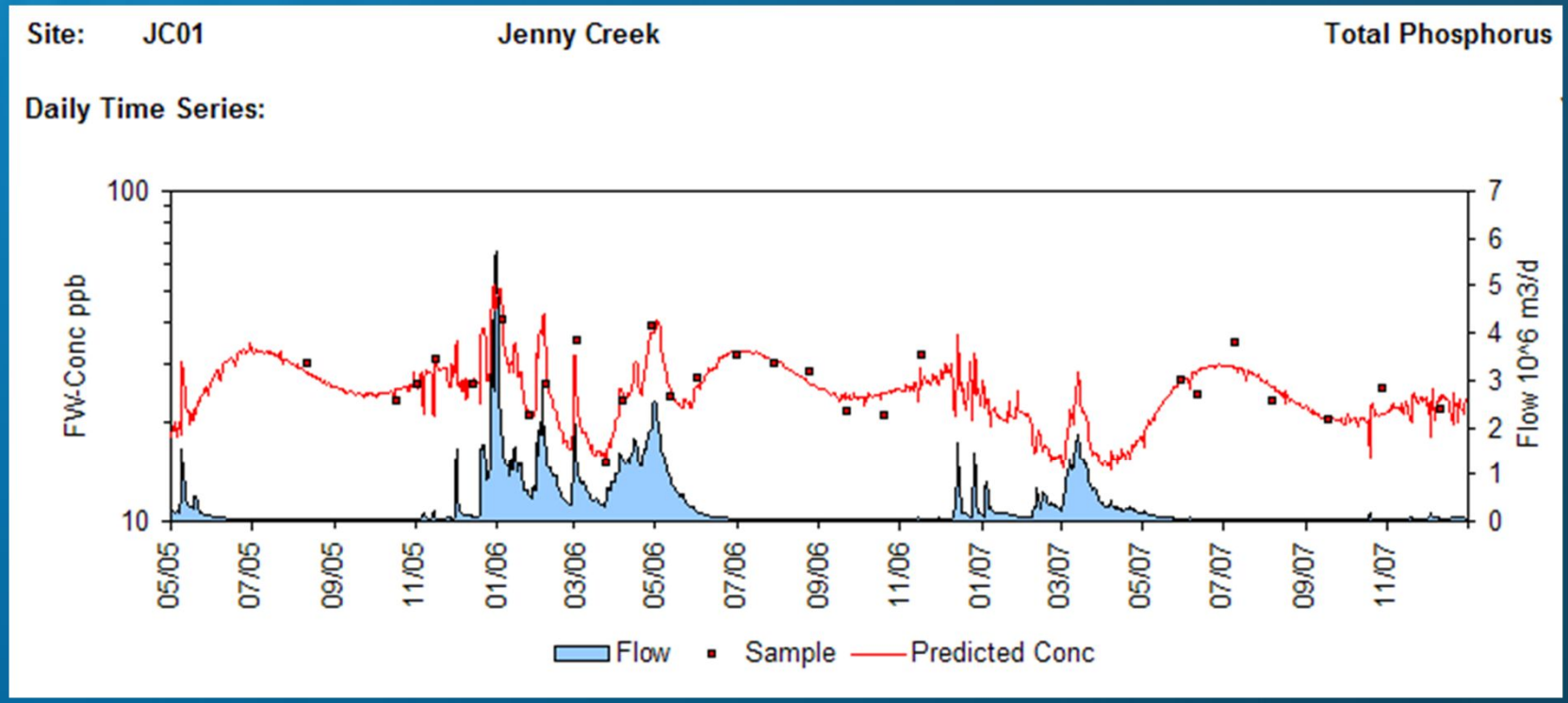
Photo: Stillwater Sciences

Seven primary study reaches:

1. Keno Dam to above Copco Res.
2. Copco Reservoir
3. Iron Gate Reservoir
4. Iron Gate Dam to Seiad Valley
5. Seiad Valley to Orleans
6. Orleans to Above Trinity
7. Above Trinity to Turwar



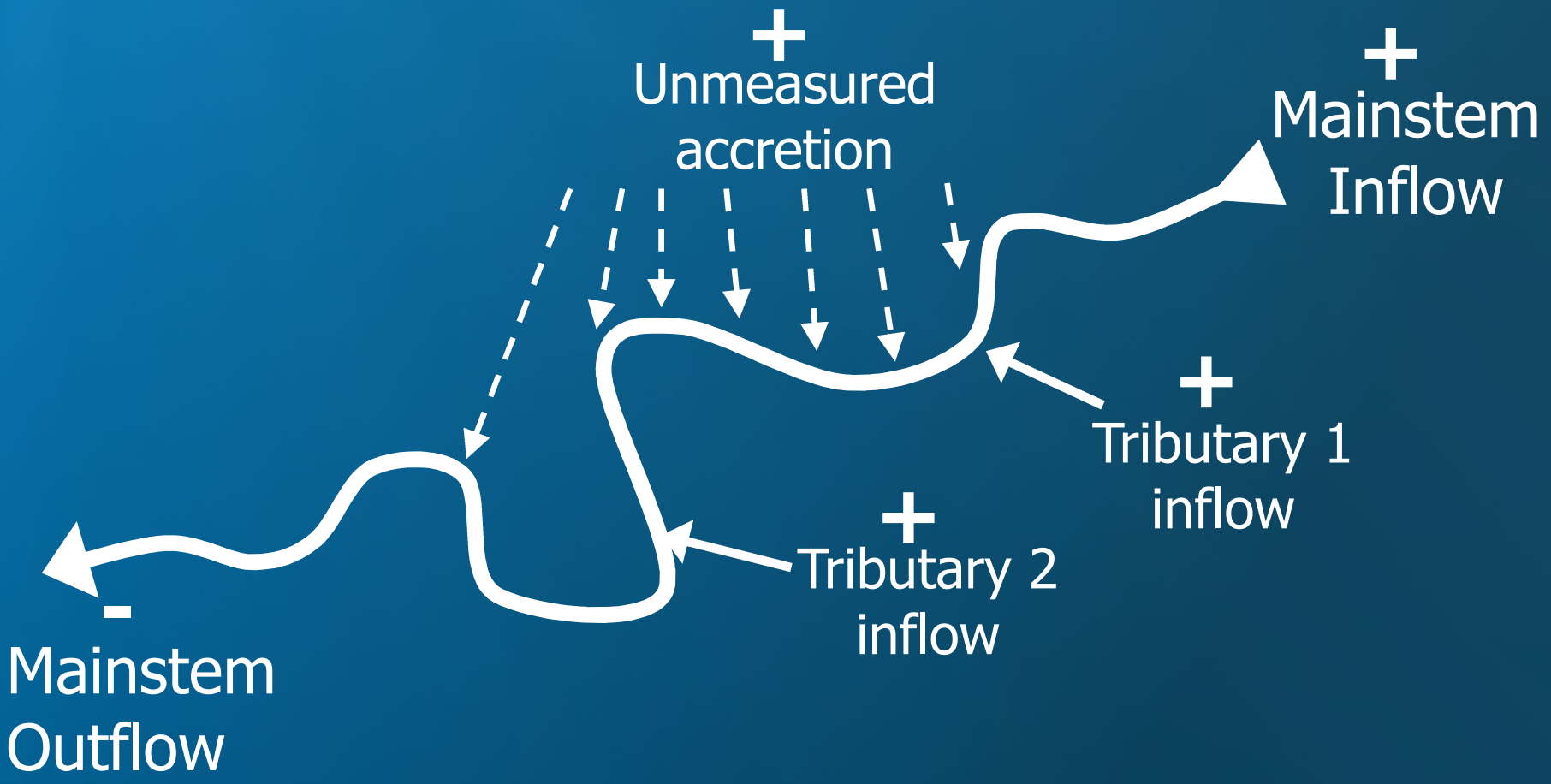
Nutrient Load Calculations



- Multiple regression model to predict concentration based on flow, season, and year
- Then locally fit predicted concentrations to fit measured concentrations

Nutrient Budget Calculations

Net Retention = Inflow - Outflow



Nutrient Budget Calculations

- Positive net retention indicates sink:
  - Periphyton uptake, settling, denitrification
- Negative net retention indicates source:
  - Release from periphyton, sediments
  - Nitrogen fixation

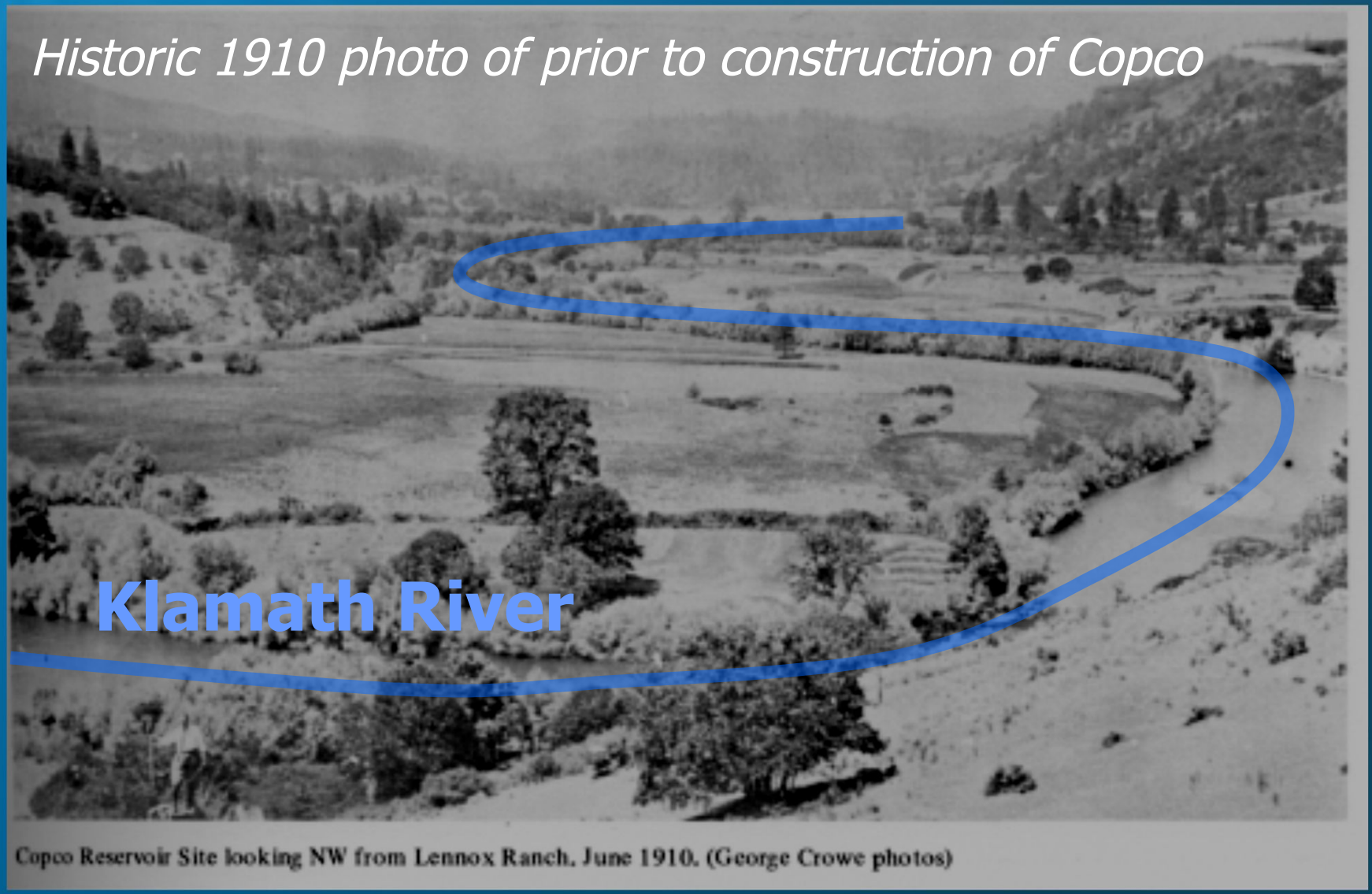
Photo: Eli Asarian

Nutrient Budget Calculations

- Results summarized by season
  - June-October (sampling season)
  - July-September (core periphyton growing season)
- Retention metrics
  - Absolute retention: kg/day/mile
  - Relative retention: (% of incoming)/mile

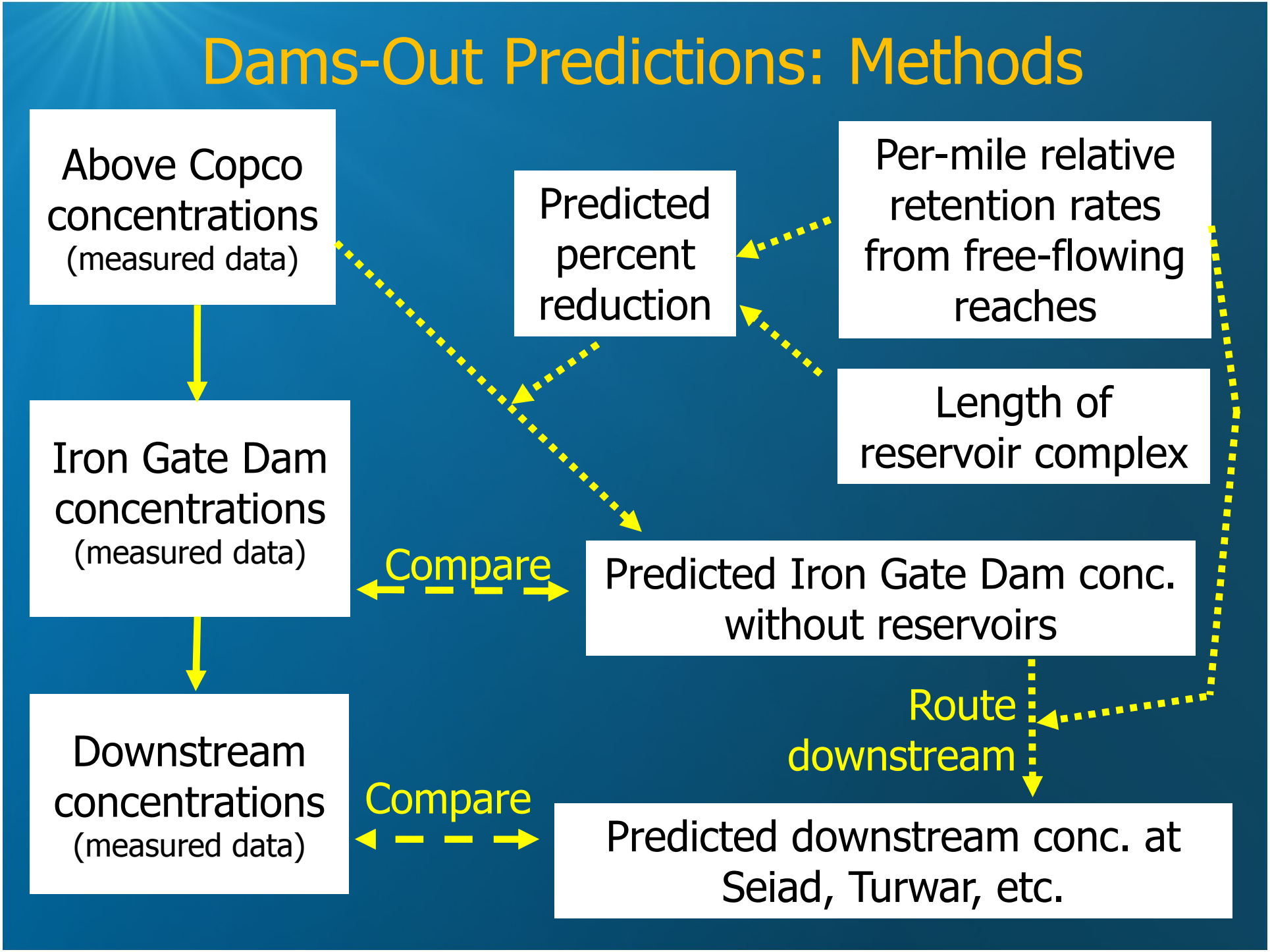
Dams-Out Predictions

Historic 1910 photo of prior to construction of Copco



Copco Reservoir Site looking NW from Lennox Ranch. June 1910. (George Crowe photos)

Dams-Out Predictions: Methods



RESULTS AND DISCUSSION

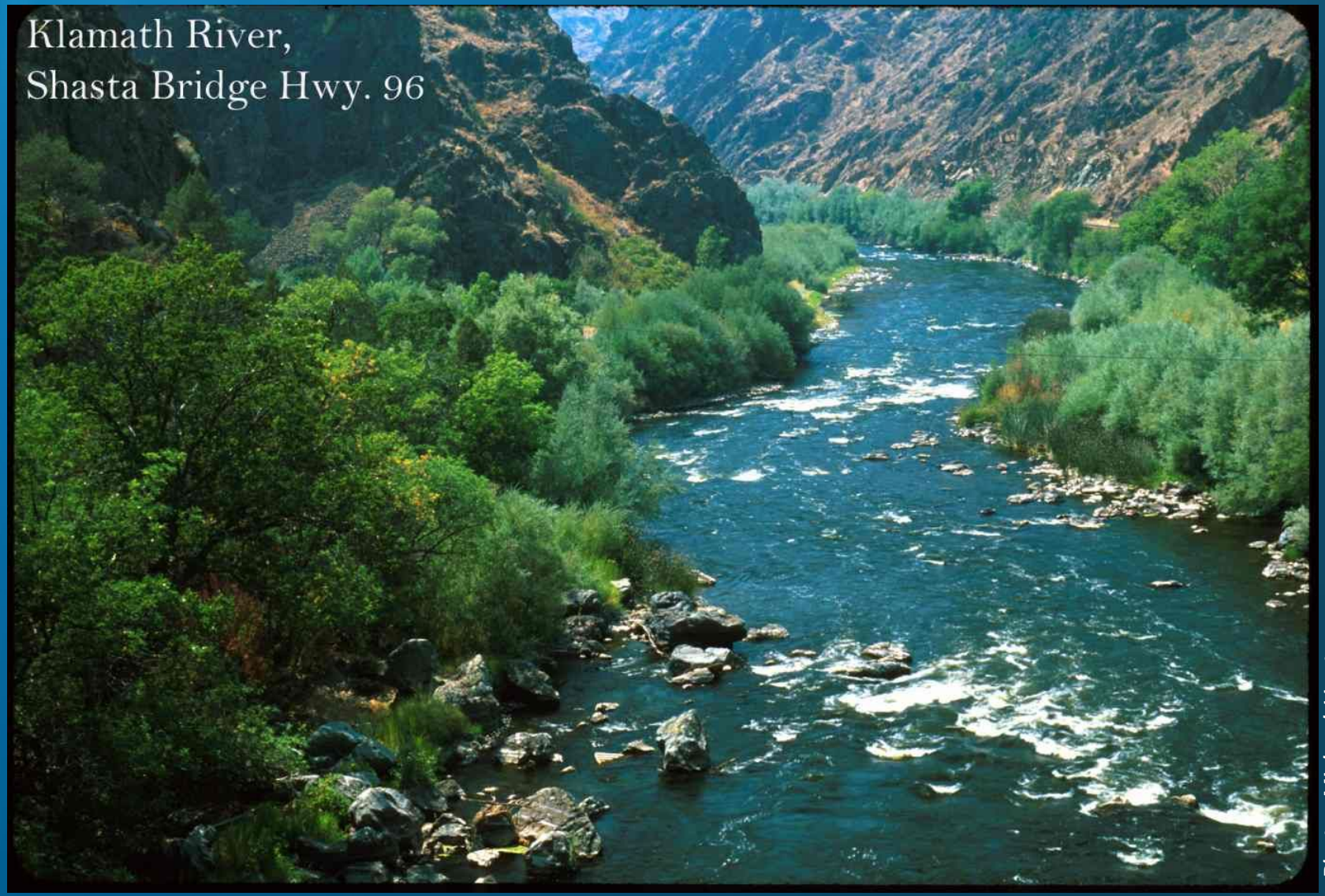
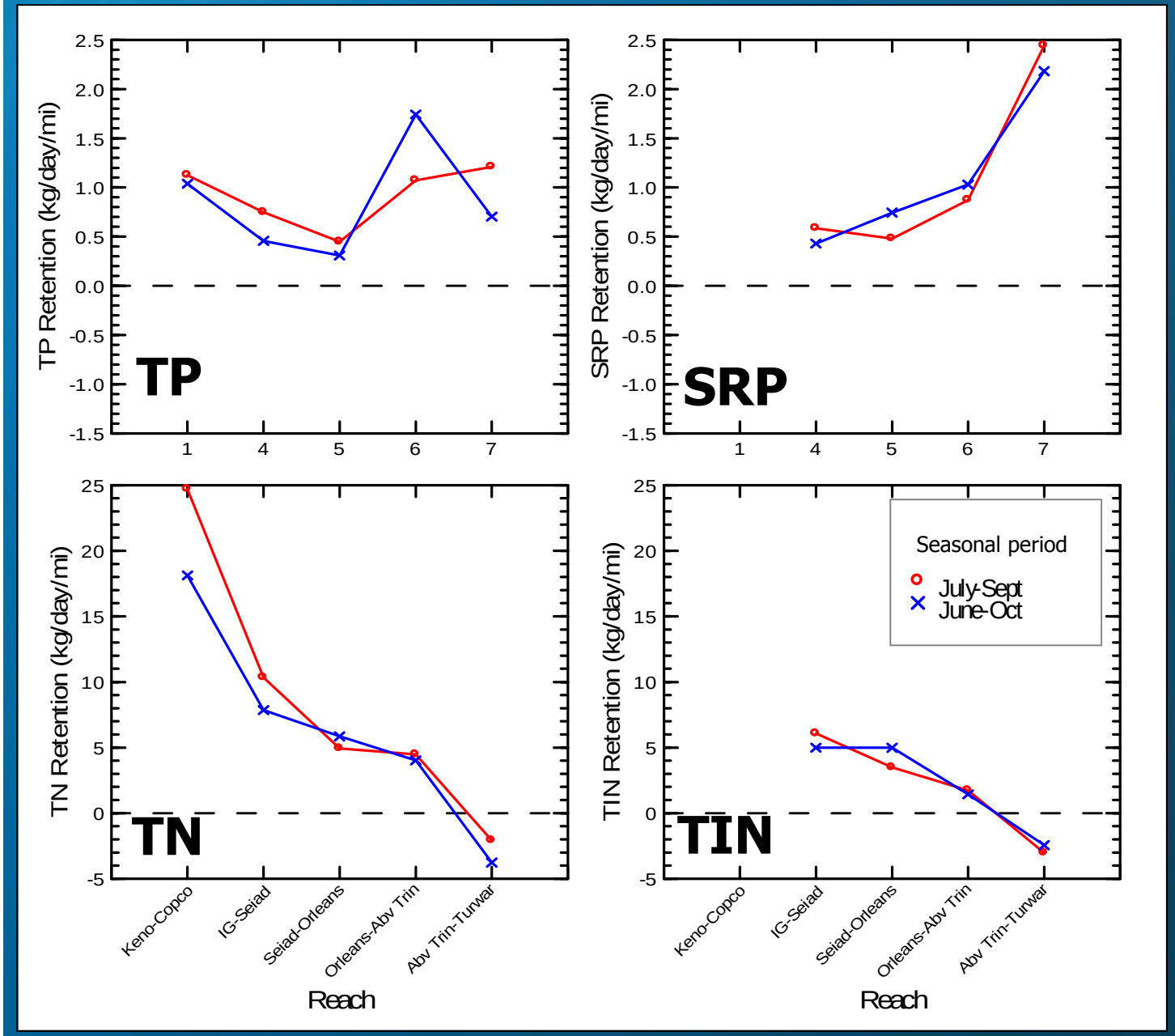


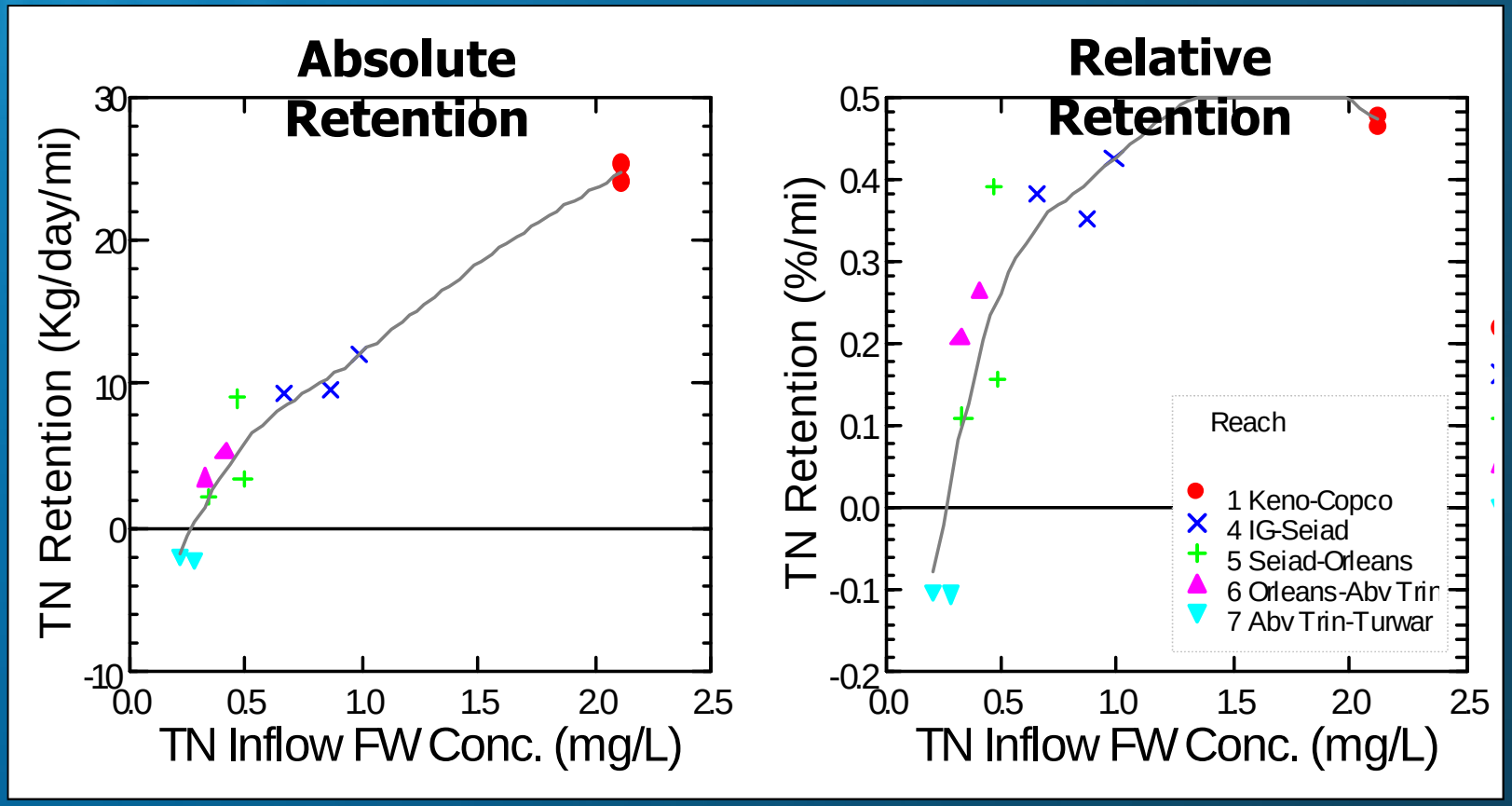
Photo: Michael Hentz

Absolute Retention: Summary by Parameter



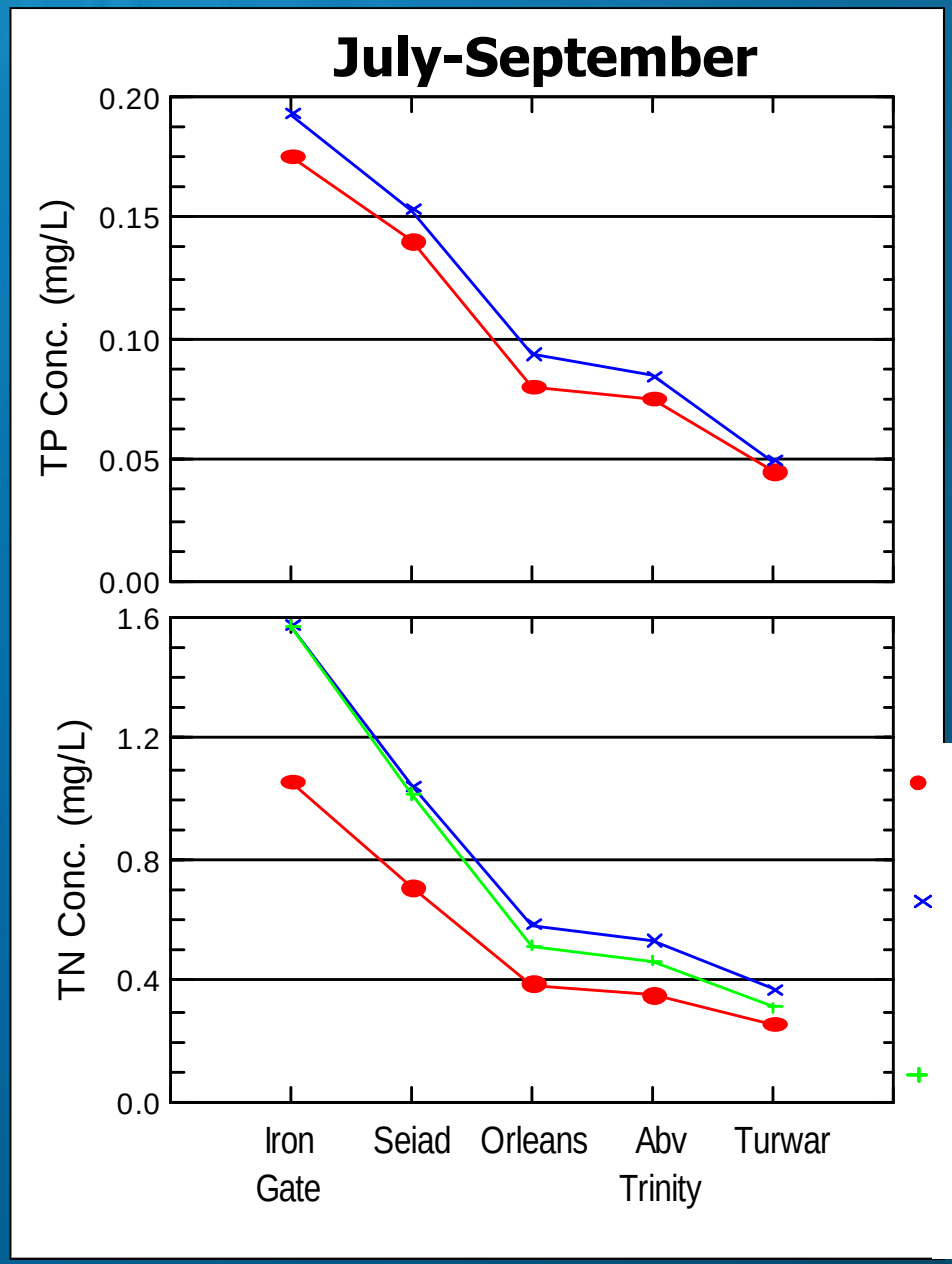
- Positive retention (sink) for nearly all reaches/ parameters

Influence of Inflow Concentration on Retention



- Reaches and years with higher incoming TN conc. (and loads) had higher retention on absolute (kg/day/mile) and relative (%/mile) basis
- TP did not show same pattern

Dam Removal Effects: Nutrient Conc.



- Increased conc. without reservoirs
  - Small for TP, more for TN
- Magnitude diminishes downstream, particularly by Orleans
  - Dilution
  - Downstream TN retention likely to rise, partially offsetting the increase

What is Effect of Dam Removal on Periphyton?

- Periphyton response driven by complex, interacting factors
  - Dam removal will push those factors in <u>opposing directions:</u>

Push towards more periphyton:	vs.	Push toward less periphyton:
- Increased nutrient conc.		- More dynamic flow regime - Restored sediment transport - Decreased water clarity

Wildcards: Biological interactions (e.g. grazing)

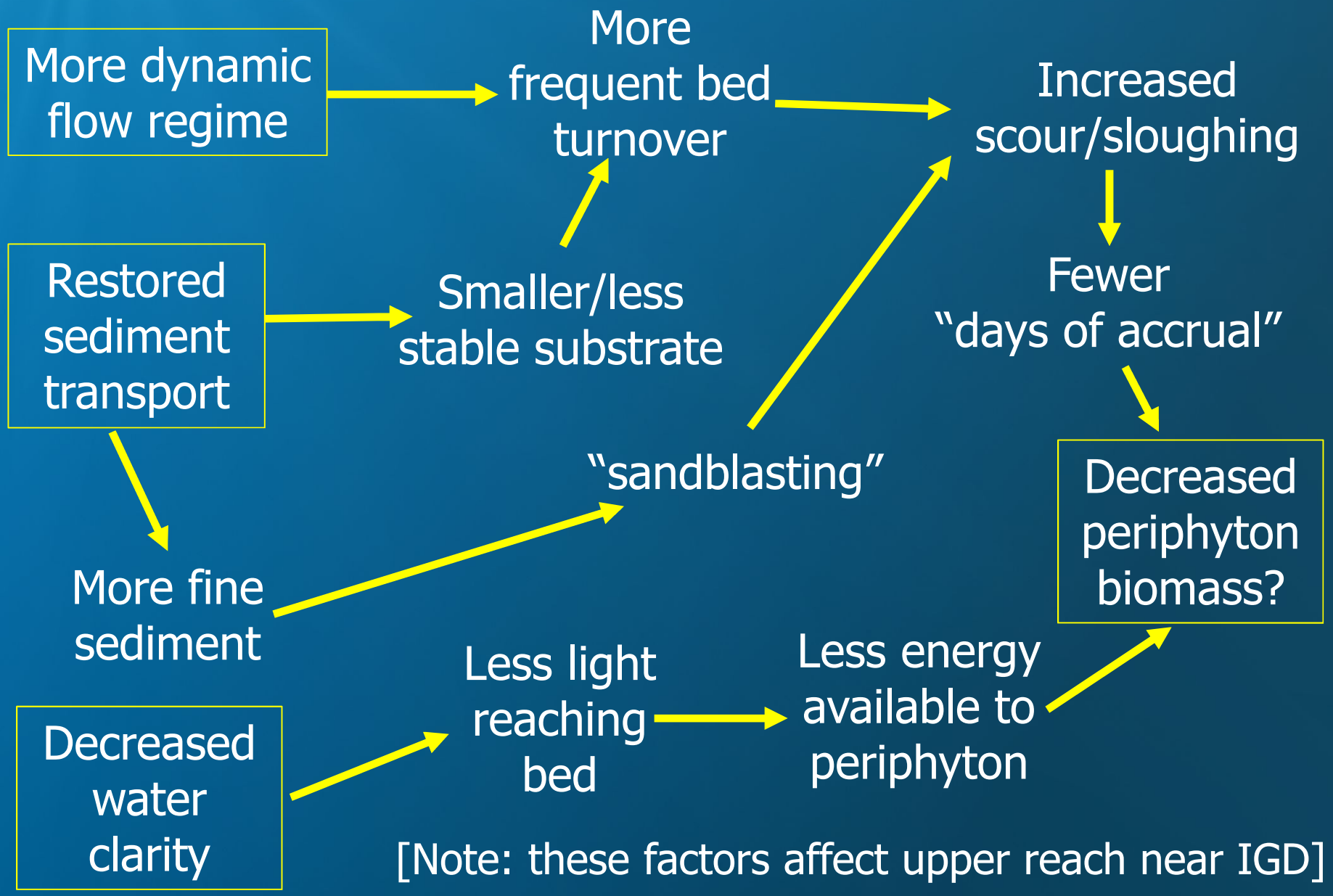
- Predicting the net effect is very difficult/uncertain
- Response likely to vary by reach

Effect of Increased Nutrients on Periphyton

- Change in nutrient concentrations with dam removal:
  - P: small increase, N: larger increase
- Nutrient concentrations already high
  - Nutrients likely not limiting in first 60 miles below Iron Gate Dam (Seiad Valley)
- Increased N concentrations likely to affect species composition
  - N-fixing periphyton
    - Currently dominate middle/lower reaches (current upstream limit of presence is ~Seiad Valley)
    - In middle reaches, could be replaced by non N-fixers
  - Effect of species composition shift on biomass is unknown

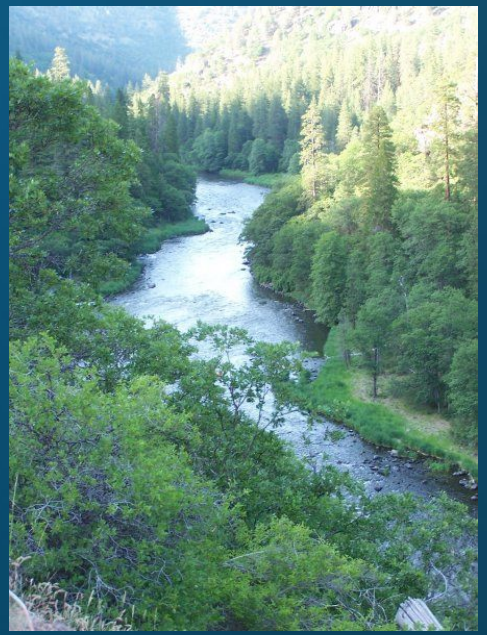
Factors That Could Decrease Periphyton Biomass

(higher nutrient conc. may not result in higher biomass)



[Note: these factors affect upper reach near IGD]

CONCLUSIONS



Photos: Eli Asarian

Conclusions: Nutrients

- Dam removal would eliminate localized release of low D.O., high pH water, and the thermal lag
- Nutrient concentrations likely to increase with removal of Iron Gate and Copco reservoirs
  - Small increase for TP, larger increase for TN
  - Effect diminishes with distance downstream, particularly by Orleans

Conclusions: Periphyton

- Periphyton response is complex and difficult to predict
  - Effects will vary by reach
  - Dam removal will push those factors in opposing directions
  - Periphyton-promoting effects:
    - Higher N concentrations (most effect on middle reach)
  - Periphyton-retarding effects:
    - Flow, sediment, light (most effect on upper reach)

Photos: Eli Asarian

Acknowledgements

- Data providers:
  - Yurok Tribe
  - Karuk Tribe
  - PacifiCorp
  - U.S. Geological Survey
  - U.S. Bureau of Reclamation
  - Oregon Department of Environmental Quality
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  - U.S. EPA

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