WATS 6900 – Ecohydraulics
WEEK 13: Stream Temperature and Gross Primary Production

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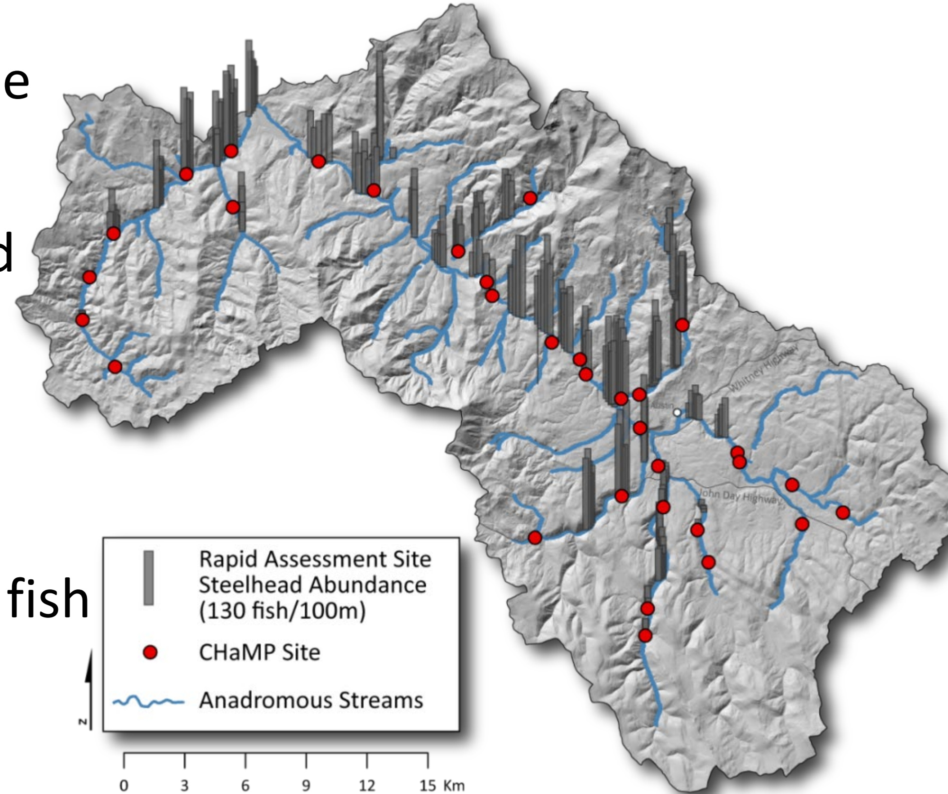
DEPARTMENT OF WATERSHED SCIENCES

NICK BOUWES

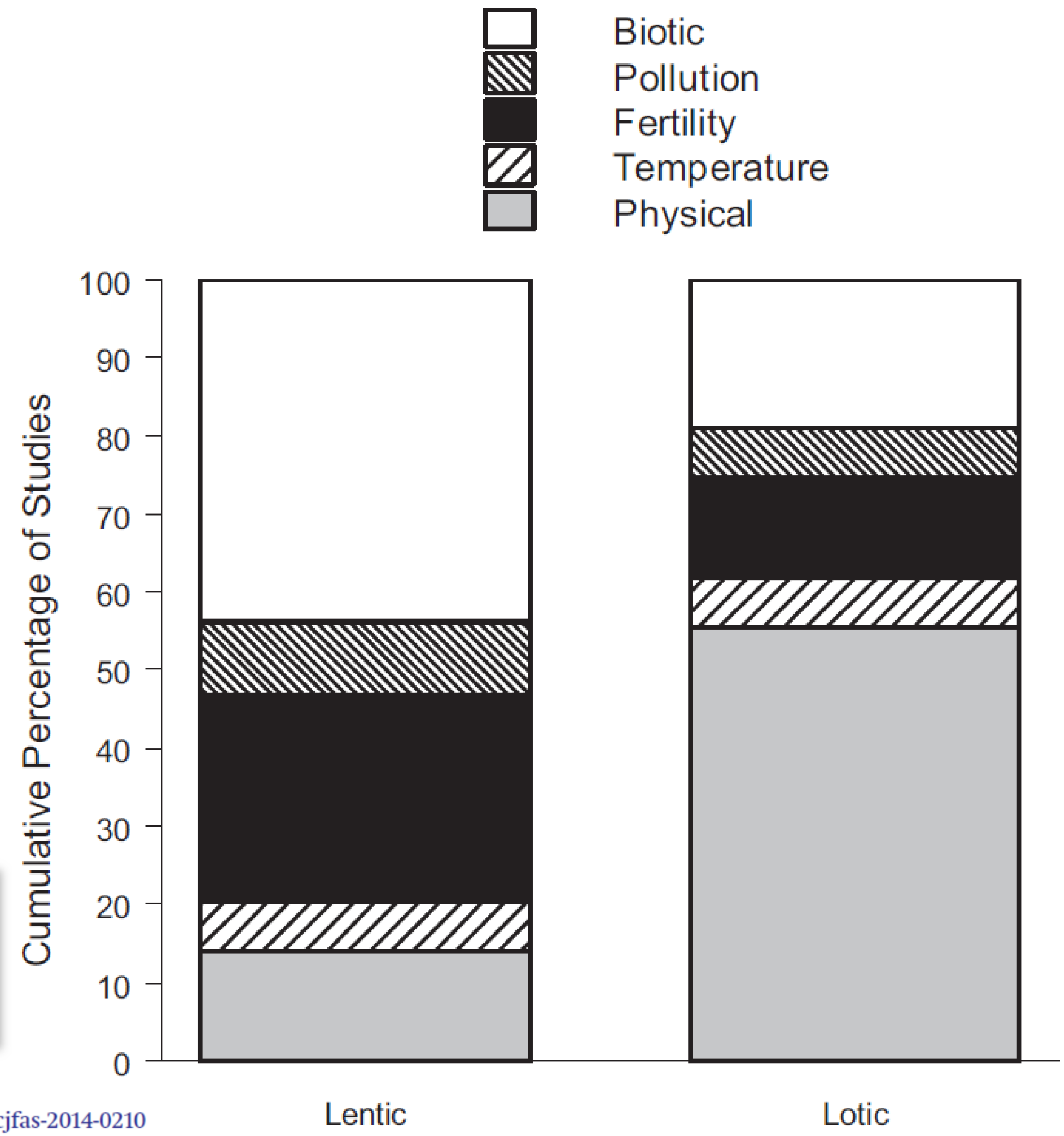
- Fish populations are highly variable throughout river networks
- Temperature, physical habitat, and prey resources are likely driver of spatial variation

- Understanding spatial variation in fish populations is important because
  - Prioritize restoration
  - Optimize monitoring
  - Understand impacts of changes to the physical template of watersheds
- Variation in the production of prey resources is one driving factor that has received little attention, in terms of understand spatial variation



Research focus of streams vs lakes

Fig. 6. Proportion of predictor variable categories reported in papers that examined only one predictor variable category (e.g., physical, biotic) in lentic and lotic ecosystems.




NRC Research Press
PERSPECTIVE

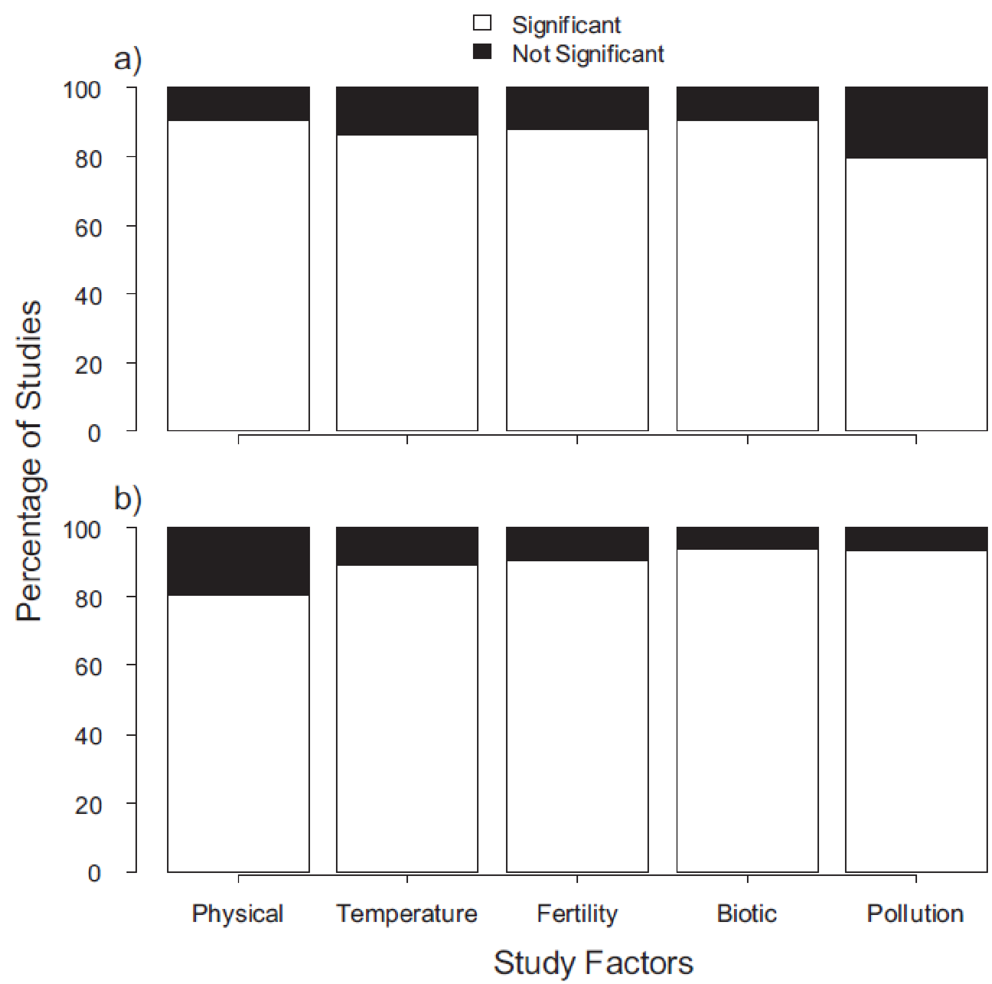
Approaches for studying fish production: Do river and lake researchers have different perspectives?

Wayne A. Wurtsbaugh, Nicholas A. Heredia, Brian G. Laub, Christy S. Meredith, Harrison E. Mohn, Sarah E. Null, David A. Pluth, Brett B. Roper, W. Carl Saunders, David K. Stevens, Richard H. Walker, and Kit Wheeler

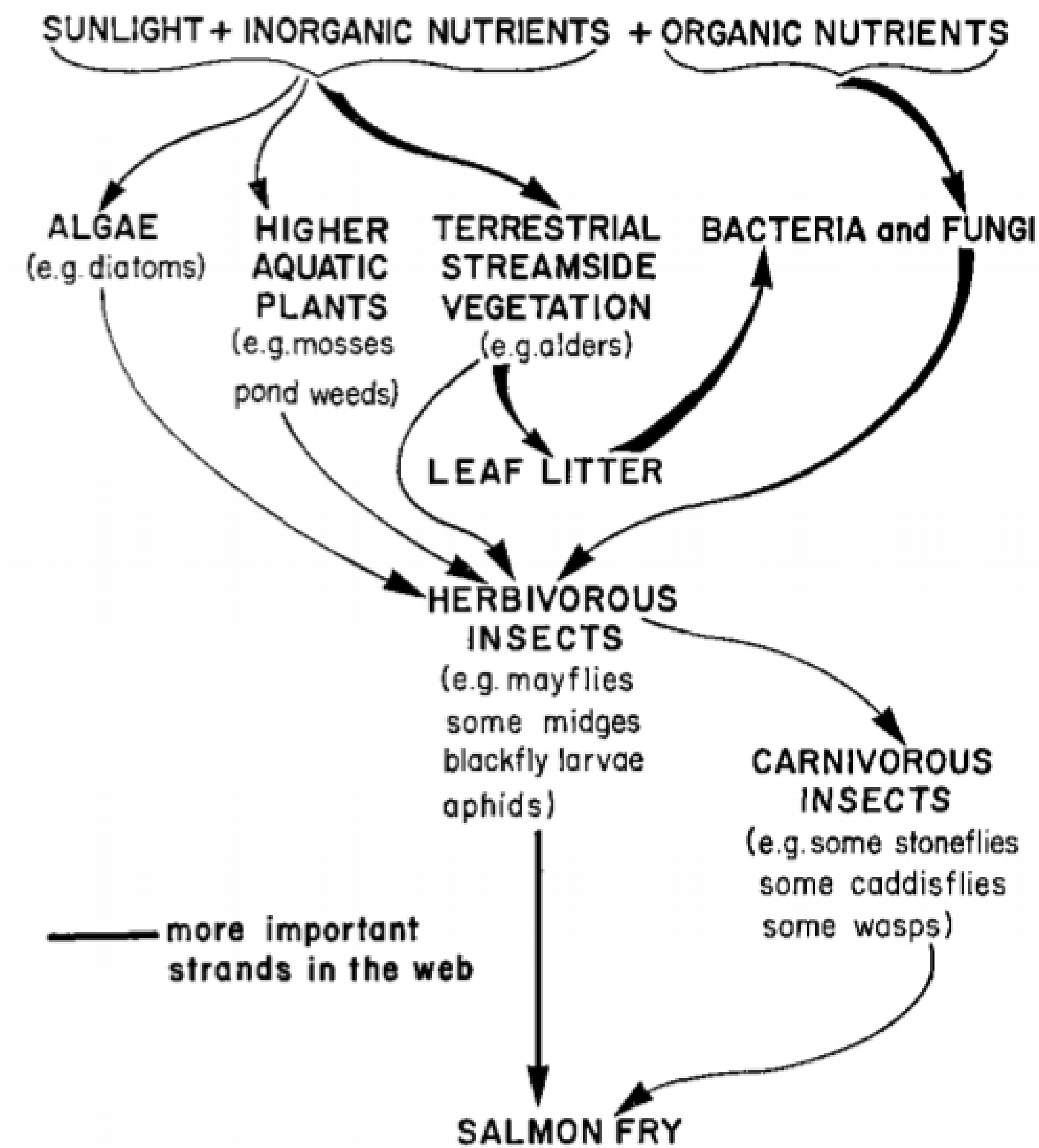
Can. J. Fish. Aquat. Sci. **72**: 149–160 (2015) dx.doi.org/10.1139/cjfas-2014-0210

Factors that are statistically significant

Fig. 8. Proportion of studies that reported statistically significant predictors of salmonid production by category type for lotic (*a*) and lentic (*b*) systems. Note the difference between the frequency of individual control variable categories that significantly affect salmonid production (this figure) and the frequency of individual control variable categories that were actually studied (Fig. 4).

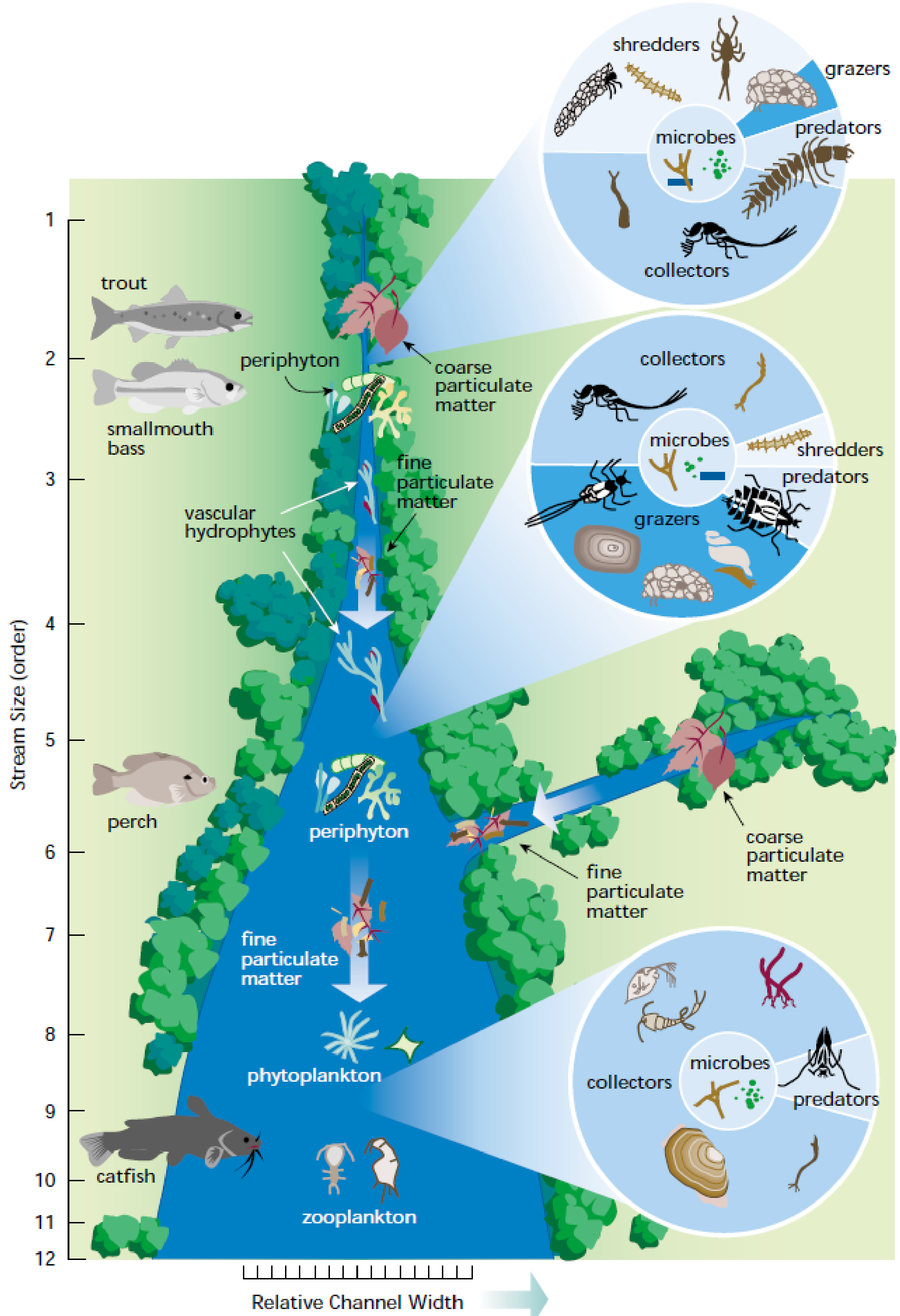


Stream Food Webs (highly simplified)



Mundie 1974

River Continuum
(Vannote et al. 1980)

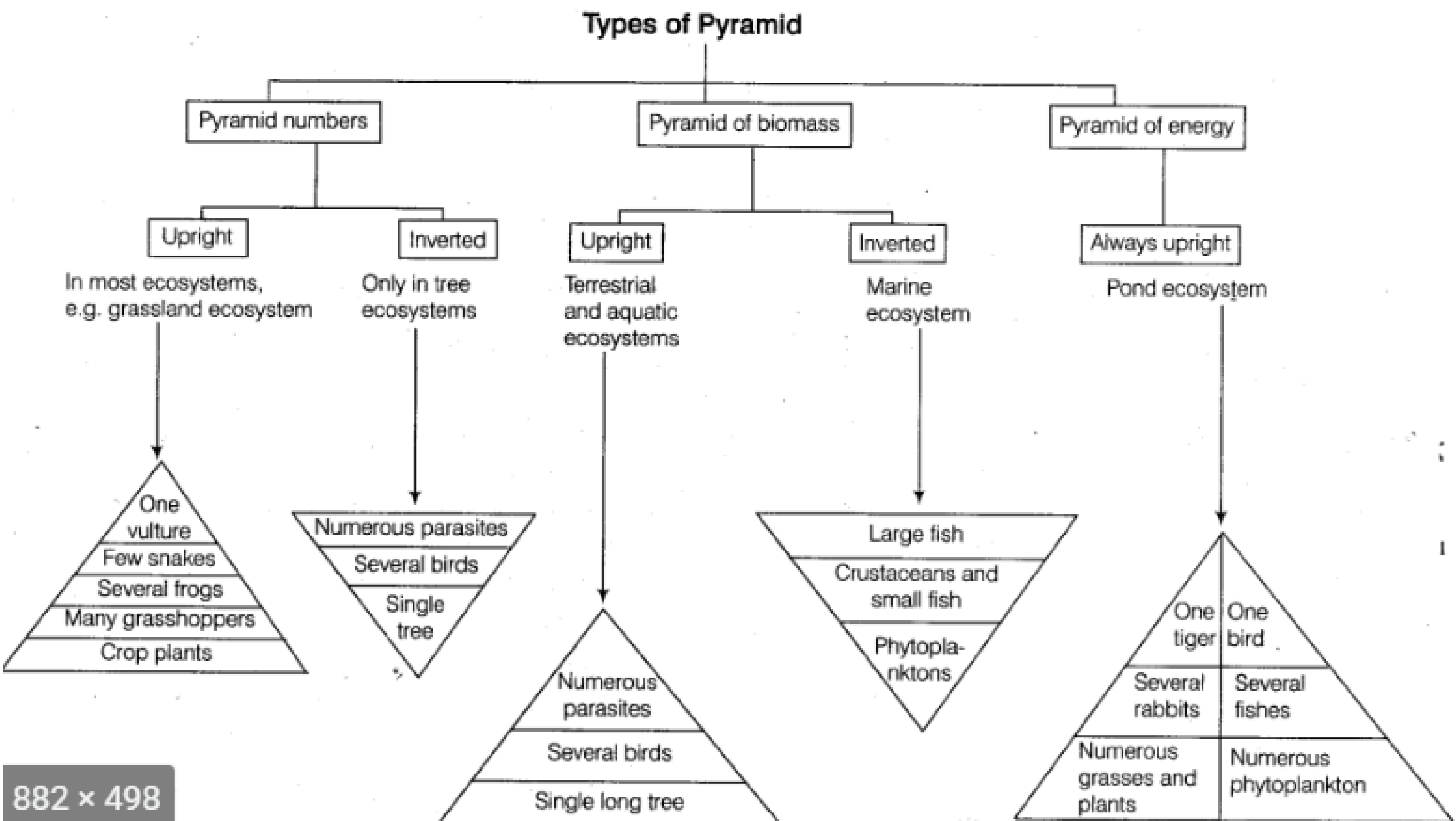


RCC-Headwater stream

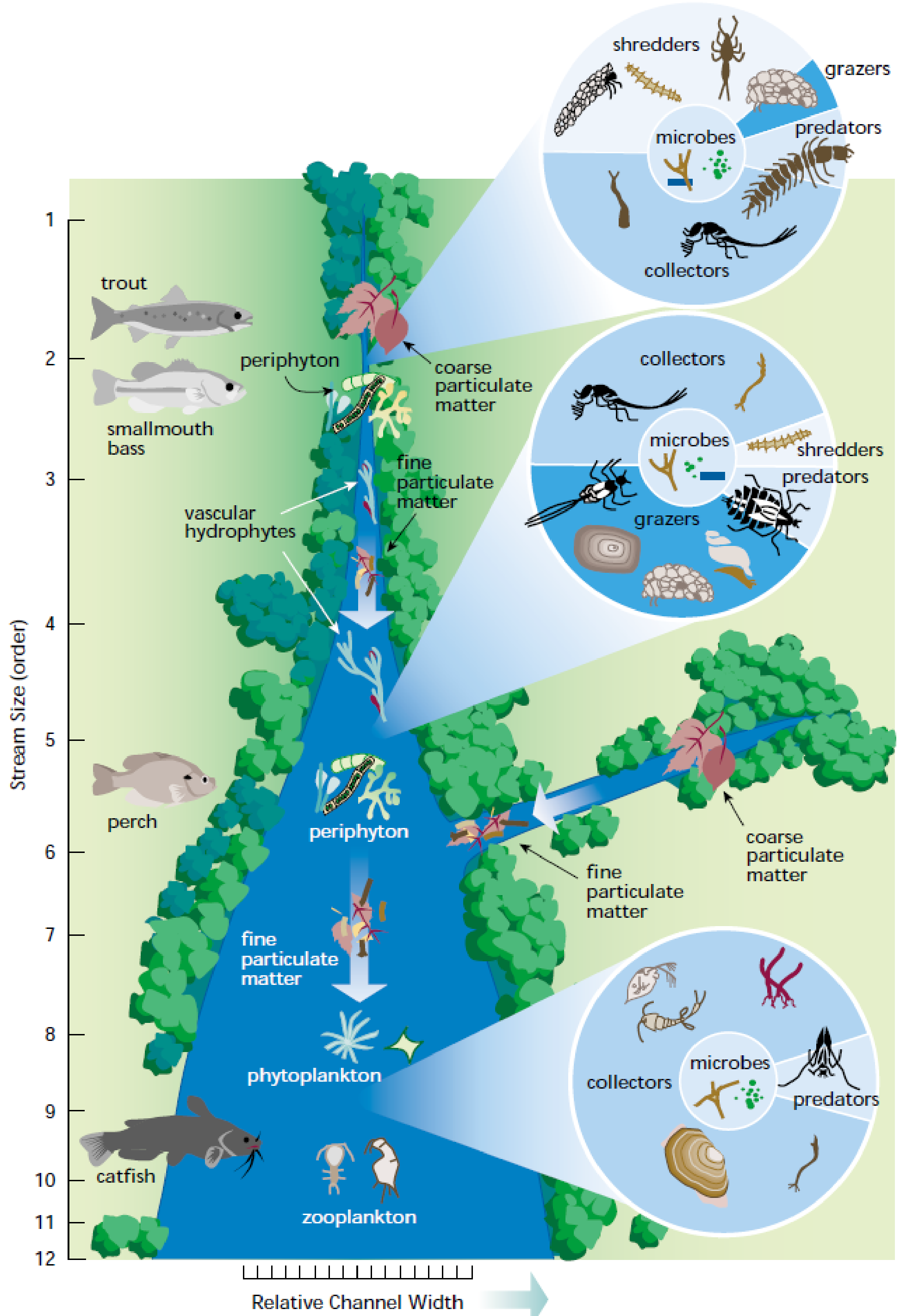
- Steep, high gradient
- Shaded
- Clear
- Cool
- Organic input is allochthonous
- Invert community mainly shredders and collectors
- Heterotrophic – P/R<1

Why describe production (mass C/area/time)?

Ecological Pyramids



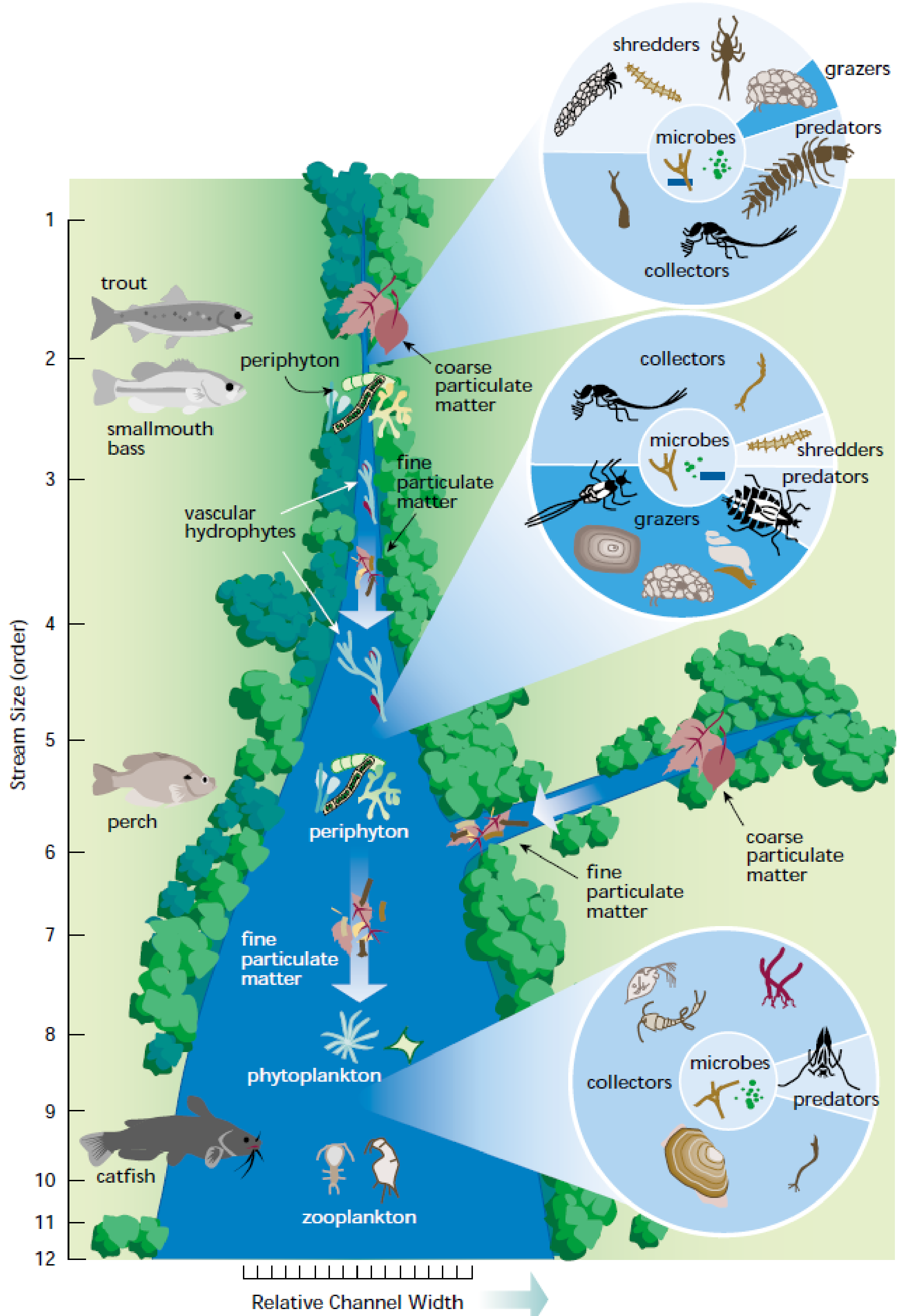
River Continuum
(Vannote et al. 1980)



RCC-Mid-reach of a stream

- Solar inputs important
- Clear
- Warmer
- FPOM
- Autochthonous-primary production generated instream, mainly from periphyton
- Shredders replaced by grazers
- Autotrophic- P/R>1

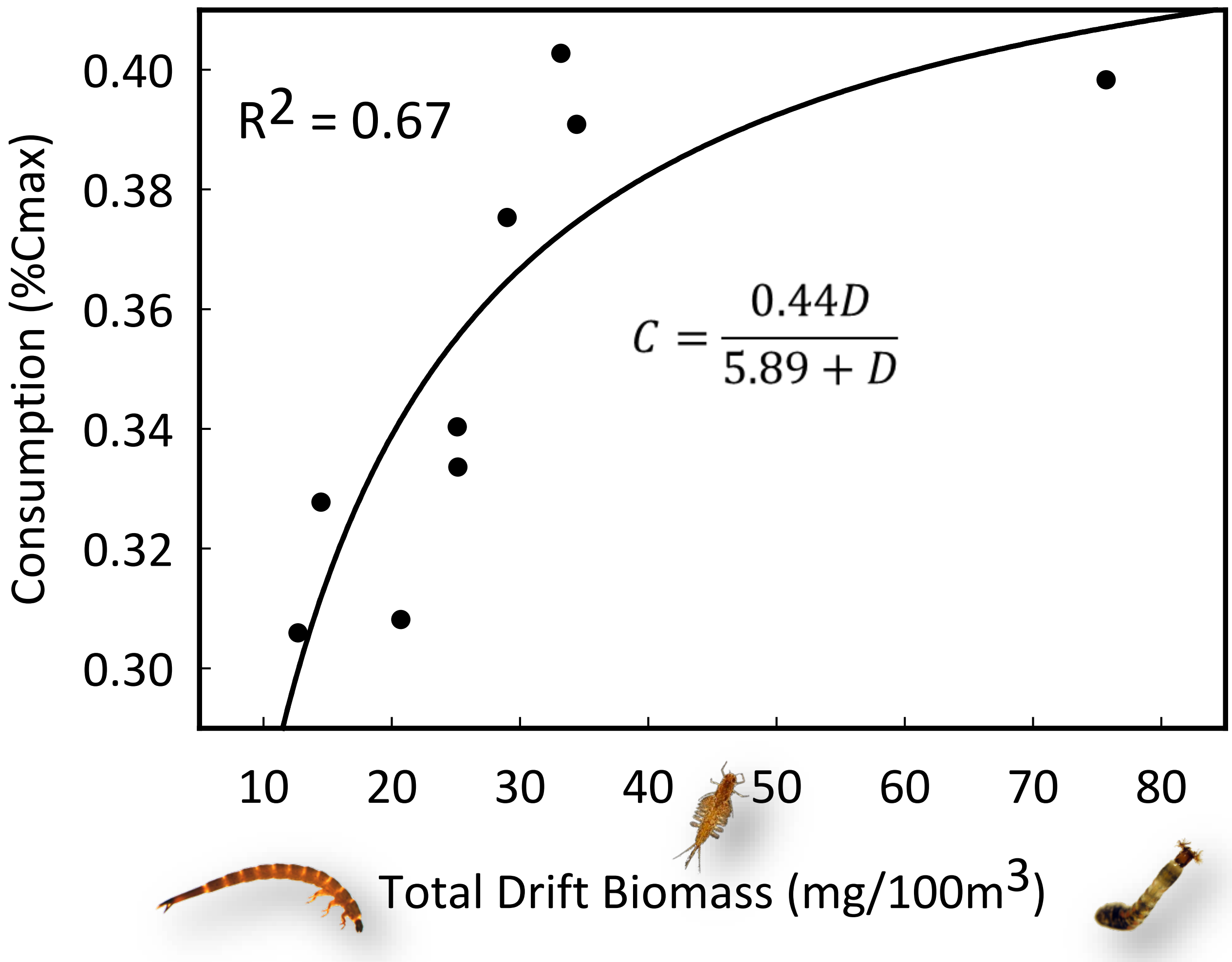
River Continuum
(Vannote et al. 1980)



RCC- lower reach of a stream

- Slower, deeper water
- Turbid
- FPOM
- Autochthonous-primary production generated instream, mainly from phytoplankton
- Collectors and zooplankton
- Heterotrophic- P/R<1

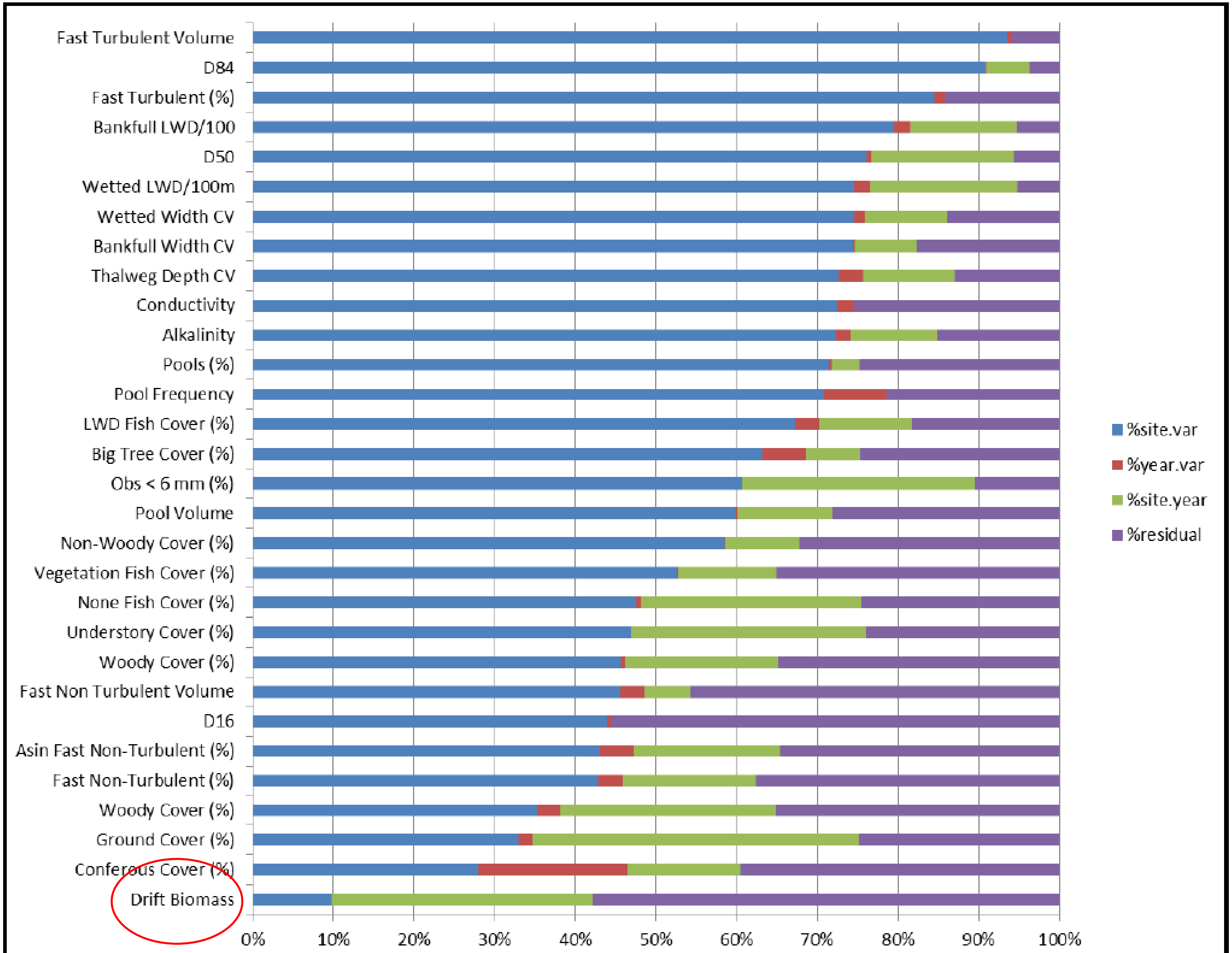
Invertebrate density effect on trout consumption rate



Weber et al. 2014

Repeatability – Field Sampling Precision

CHaMP 2011 - 2012



S:N

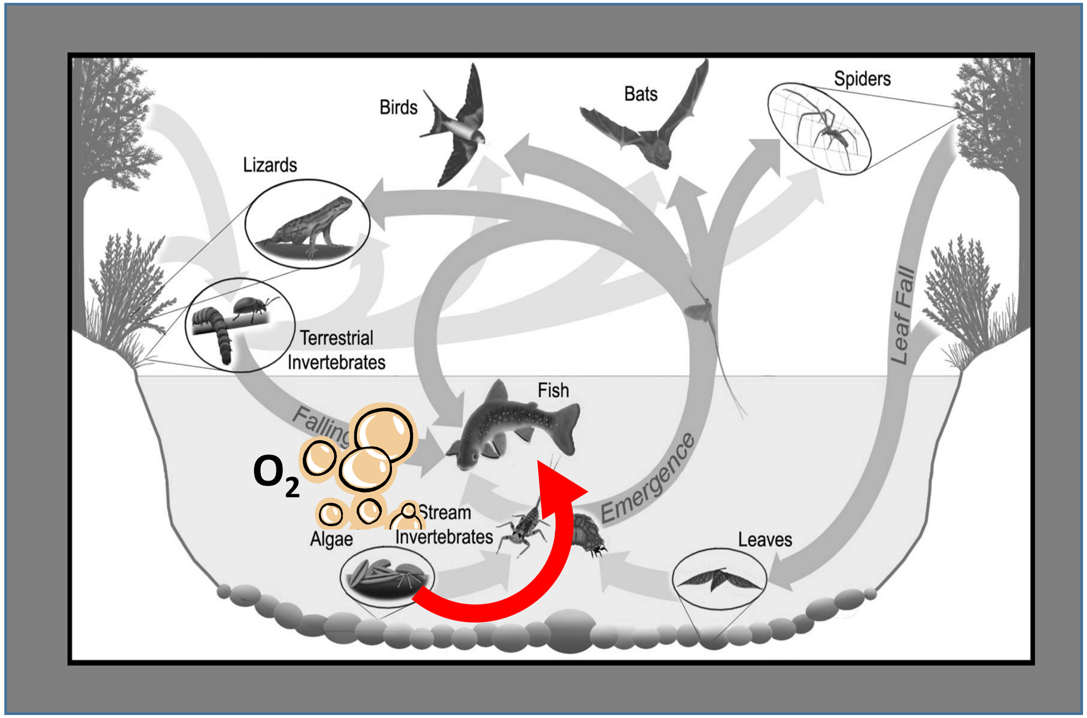
0-2 poor

2-8 good

> 8 excellent

Prey Resources

- Stream food webs are complex
- Traditional measurements of prey resources focus on insects
  - Benthic and drift
  - CHaMP, PIBO, etc.



- Alternatively, use primary production as index of resource availability throughout a river network

Measuring primary production

- Sources of DO in rivers:
  a) Primary production (P) - Plants give of O_2 during the day
  b) Reaeration from surface turbulence (K)

- Ecosystem Respiration (ER) - Both plants and animals uptake O2 for respiration during the day and night

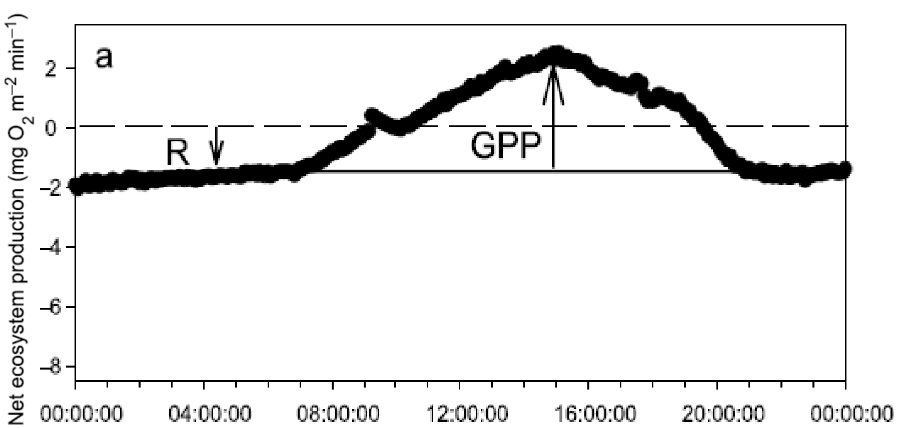
- Estimate rates of production and respiration from diel O_2 curves

$$O_2\ deficiency = P - ER + K$$

- Grace and Imberger (2006): MLE estimates of P, ER, K

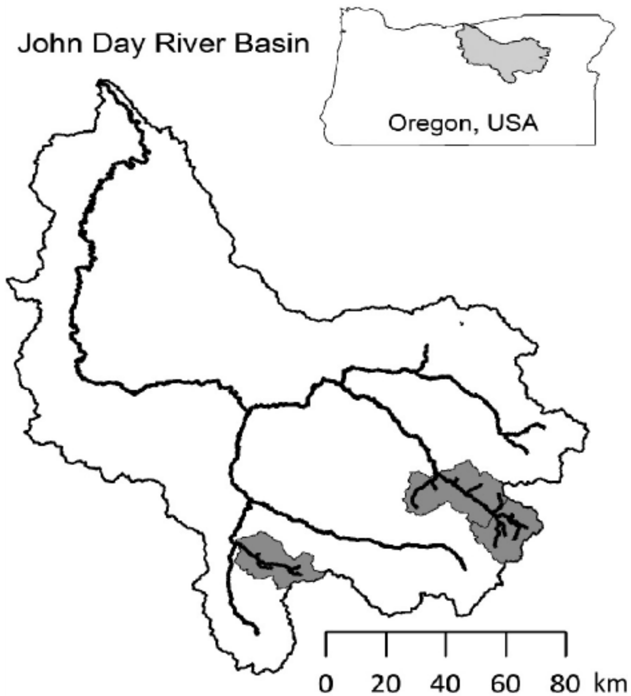
GPP measurements

- Open channel method
- Estimated from diel dissolved oxygen curves
- Single-station open channel measurement
- PME miniDOT loggers
- 2-3 day deployment

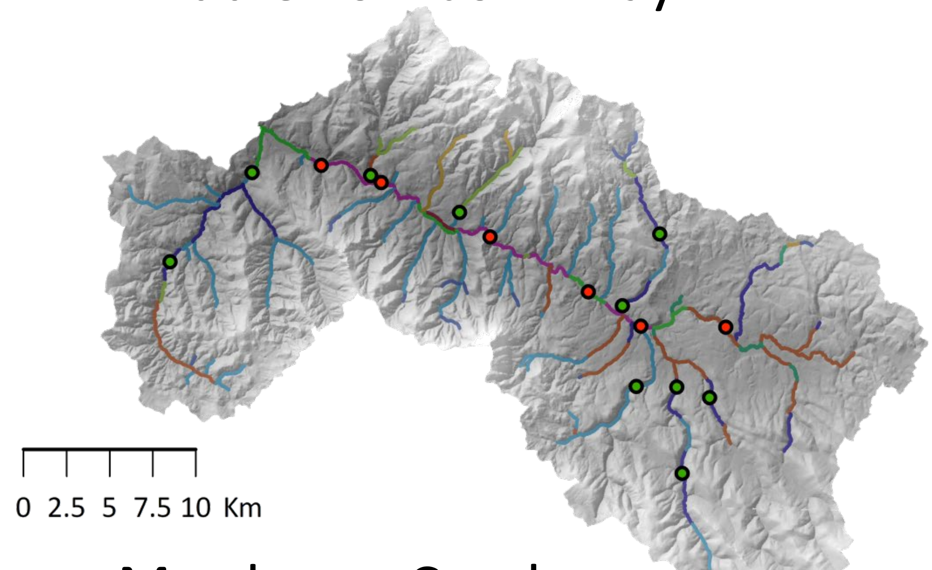


Sampling design

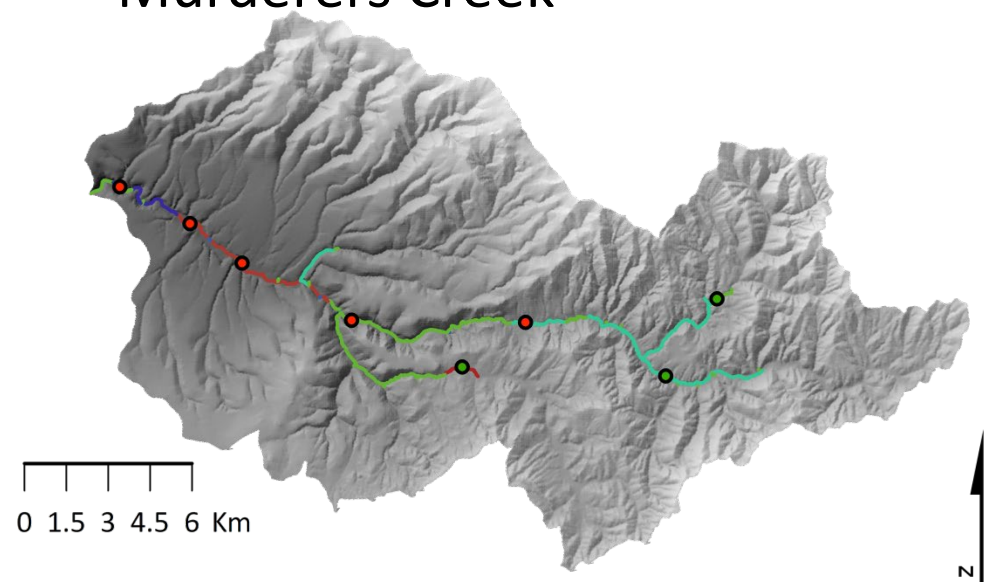
- 23 sites
  - Middle Fork and South Fork John Day River
  - Stratified by geomorphic classification unit

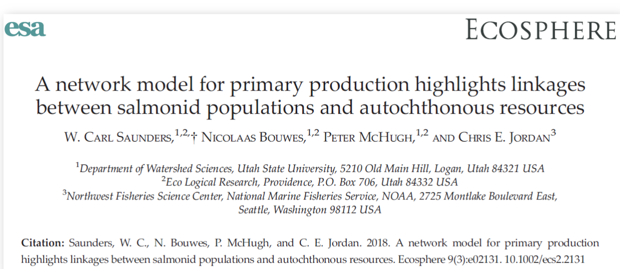


Middle Fork John Day



Murderers Creek




esa ECOSPHERE

A network model for primary production highlights linkages between salmonid populations and autochthonous resources

W. Carl Saunders,[1,2,]† Nicolaas Bouwes,[1,2] Peter McHugh,[1,2] and Chris E. Jordan[3]

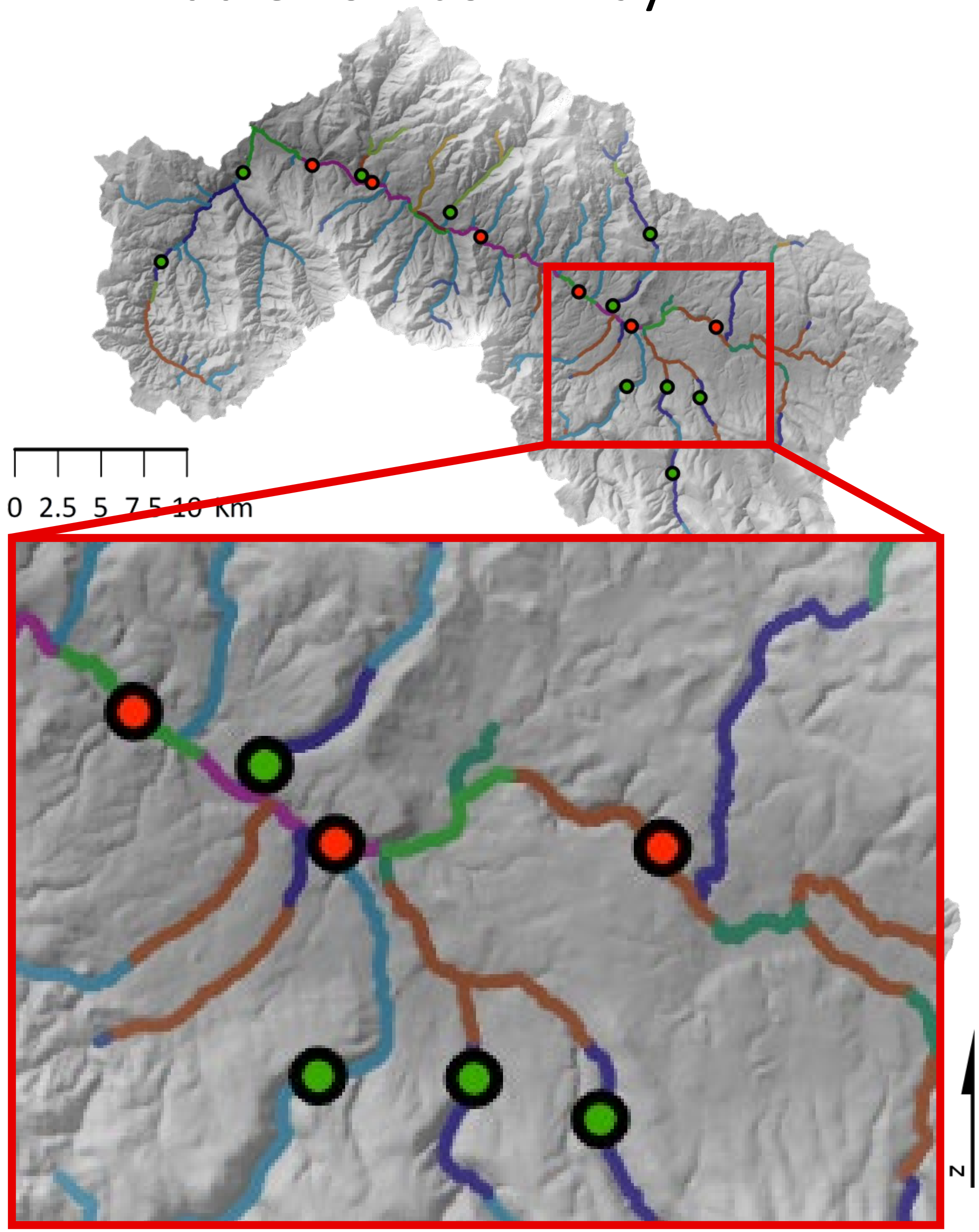
[1]Department of Watershed Sciences, Utah State University, 5210 Old Main Hill, Logan, Utah 84321 USA
[2]Eco Logical Research, Providence, P.O. Box 706, Utah 84332 USA
[3]Northwest Fisheries Science Center, National Marine Fisheries Service, NOAA, 2725 Montlake Boulevard East, Seattle, Washington 98112 USA

Citation: Saunders, W. C., N. Bouwes, P. McHugh, and C. E. Jordan. 2018. A network model for primary production highlights linkages between salmonid populations and autochthonous resources. Ecosphere 9(3):e02131. 10.1002/ecs2.2131

Sampling design

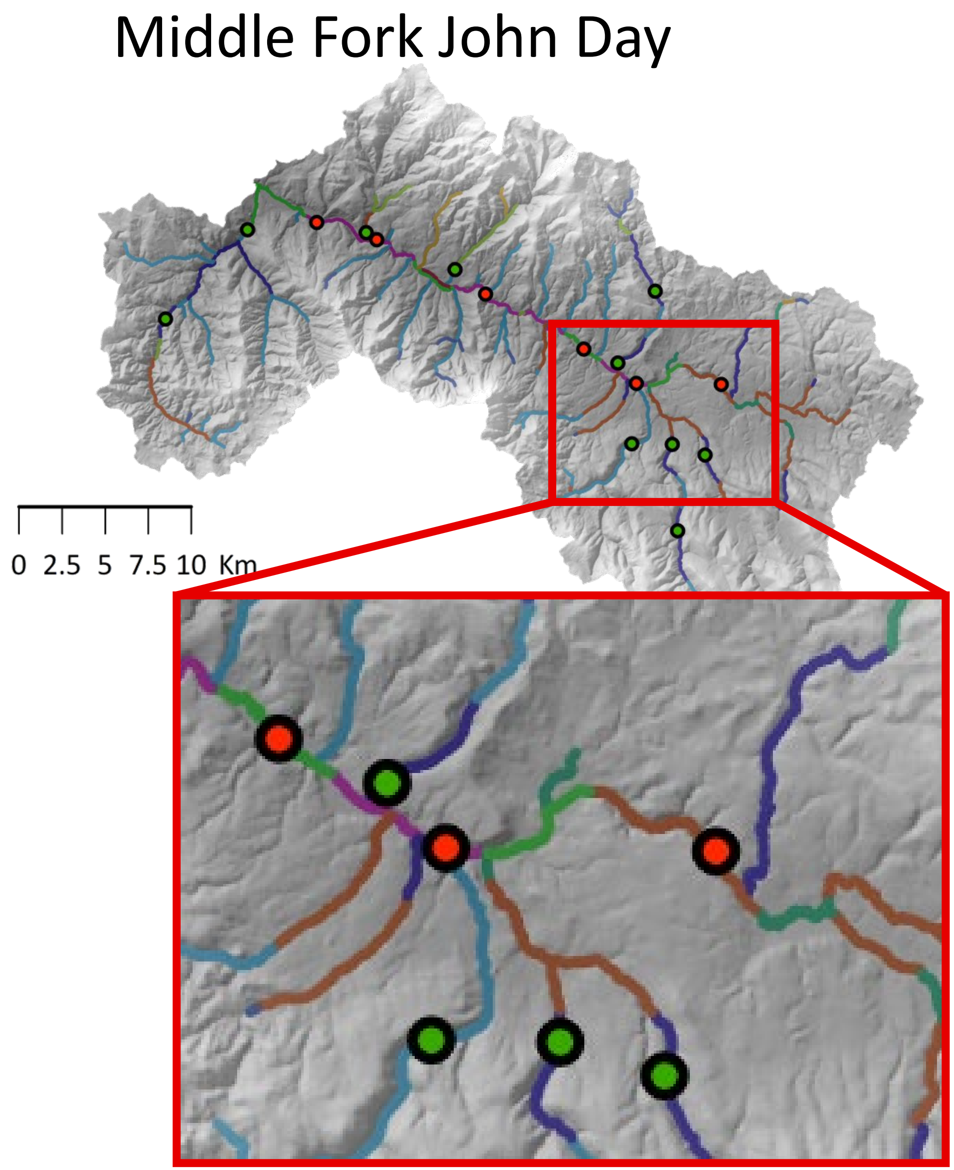
- 23 sites
  - Middle Fork and South Fork John Day River
  - Sites simultaneously monitored for fish and habitat metrics by CHaMP
  - Stratified by geomorphic classification unit

Middle Fork John Day



Sampling design

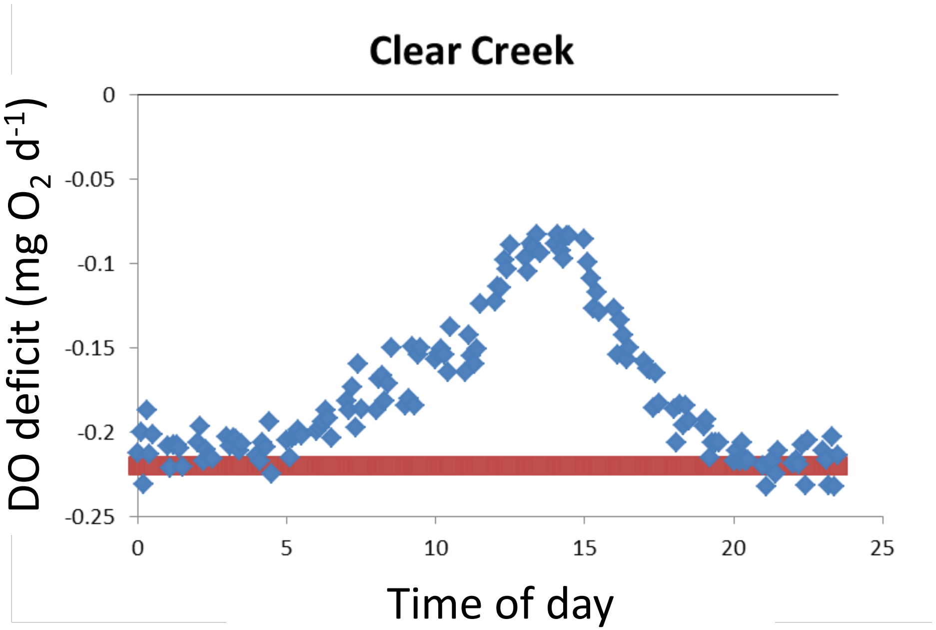
- 23 sites
  - Middle Fork and South Fork John Day River
  - Sites simultaneously monitored for fish and habitat metrics by CHaMP
  - Stratified by geomorphic classification unit
- Short and long-term deployment
  - 2-3 day
  - 21 day



Results

Tributaries

- Net production negative
- Gross production 0.15 – 6.1 mg O_2 L d^{-1}



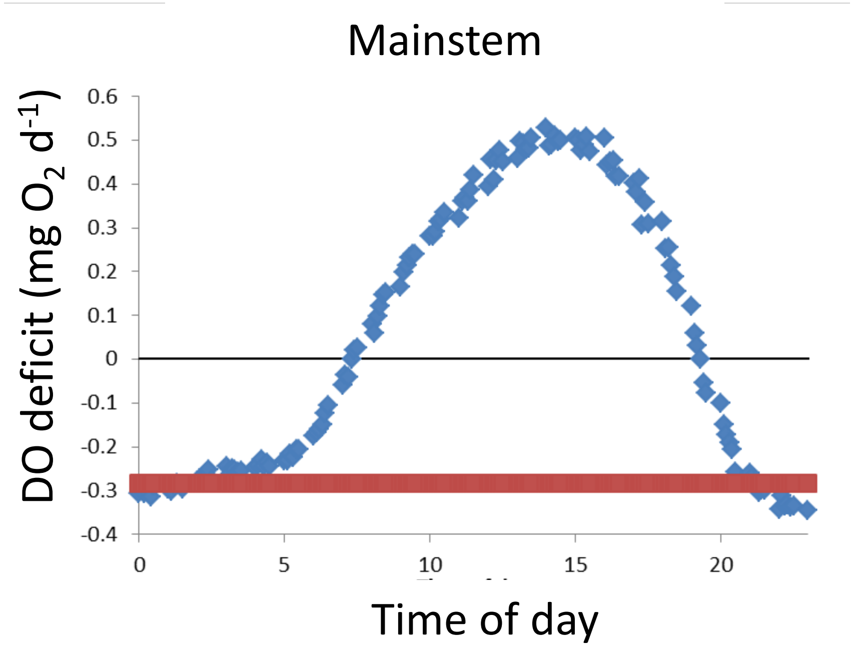
Results

Tributaries

- Net production negative
- Gross production 0.15 – 6.1 mg O_2 L d^{-1}

Mainstem

- Net production positive
- Gross production 4.3– 17.2 mg O_2 L d^{-1}



Results

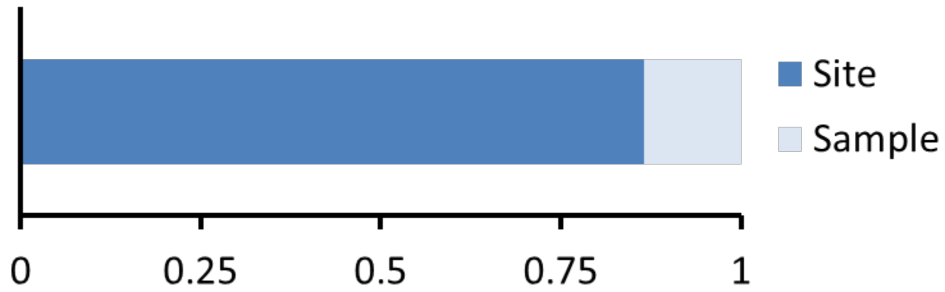
Tributaries

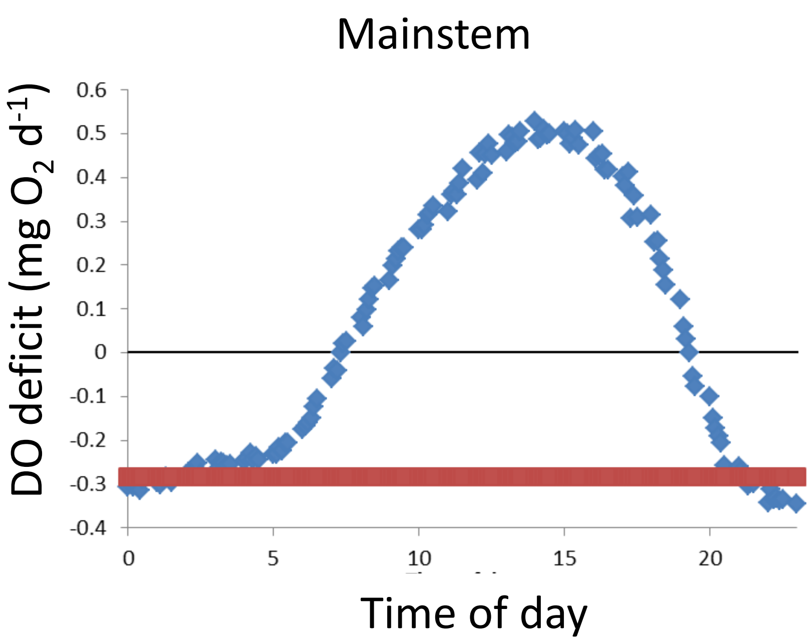
- Net production negative
- Gross production 0.15 – 6.1 mg O_2 L d^{-1}

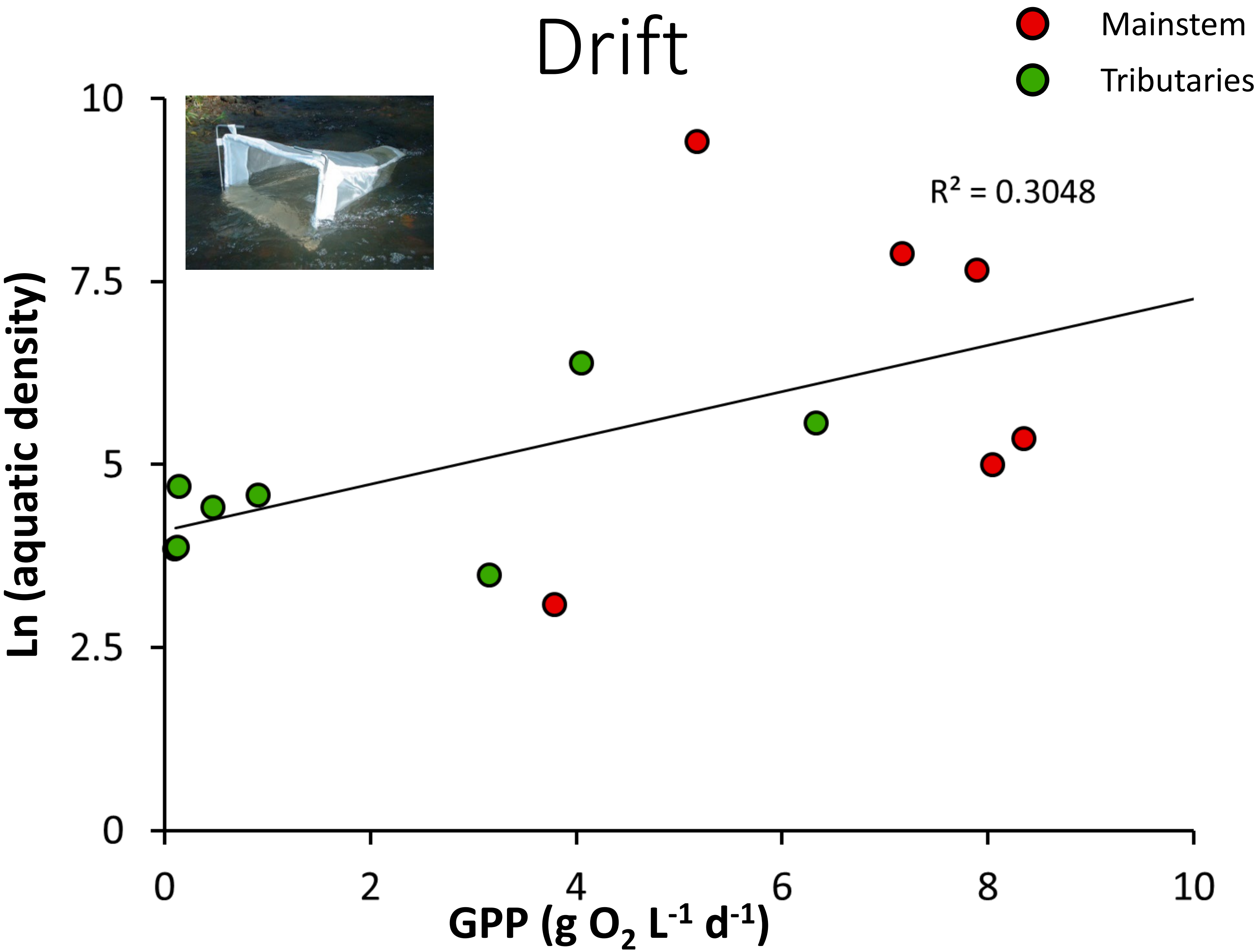
Mainstem

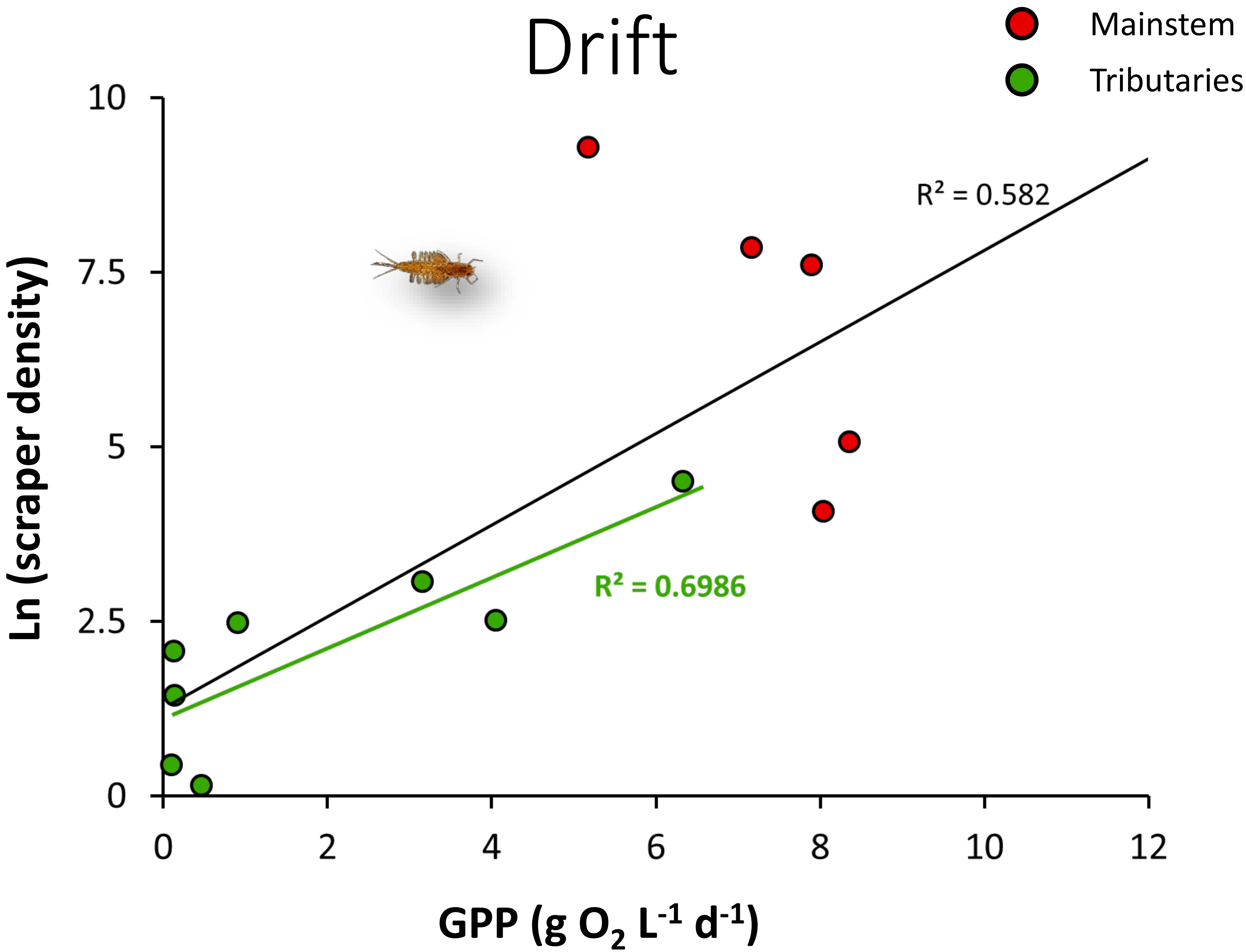
- Net production positive
- Gross production 4.3– 17.2 mg O_2 L d^{-1}

Signal to noise: 6.5



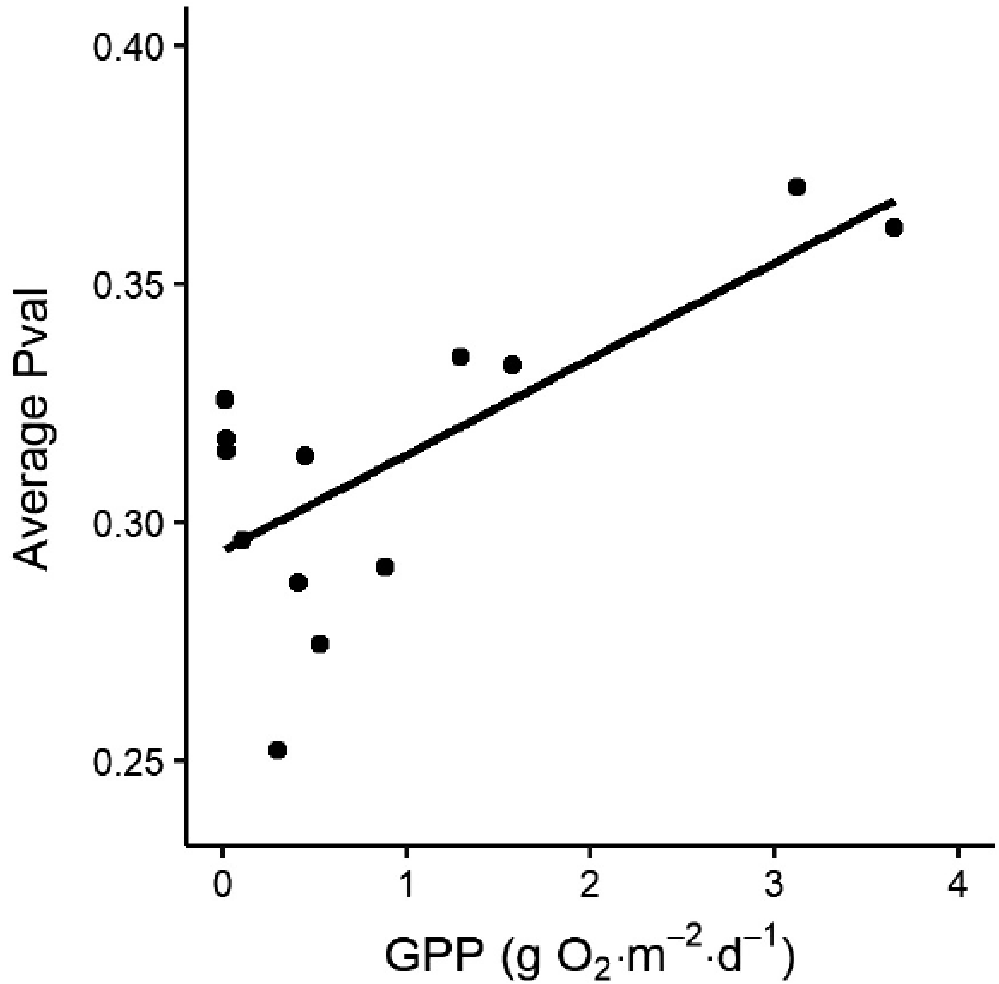



Drift
Mainstem
Tributaries
R² = 0.3048
Ln (aquatic density)
10
7.5
5
2.5
0
0
2
4
6
8
10
GPP (g O2 L-1 d-1)

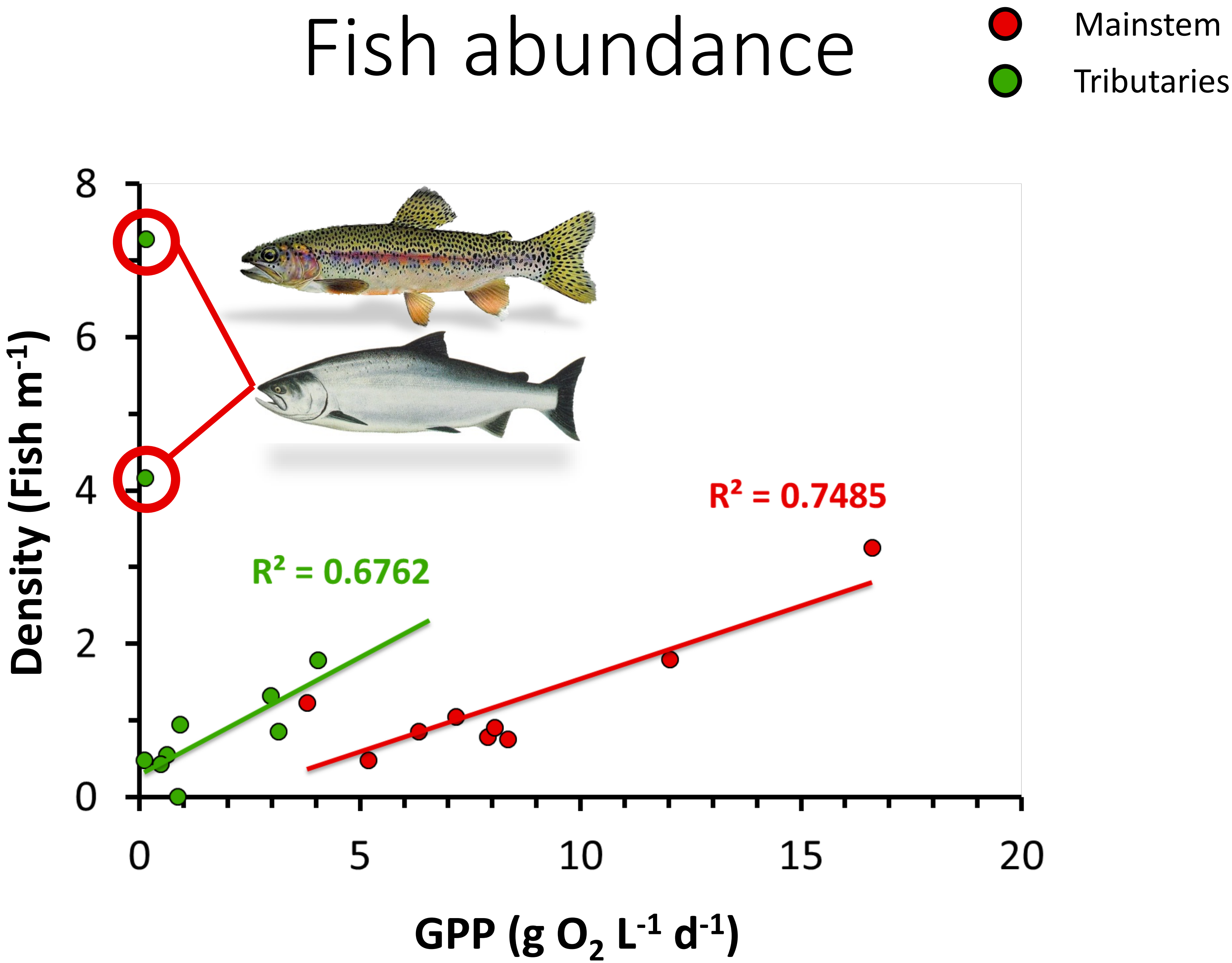


Drift
Mainstem
Tributaries
10
7.5
5
2.5
0
0
2
4
6
8
10
12
R² = 0.582
R² = 0.6986
Ln (scraper density)
GPP (g O2 L-1 d-1)

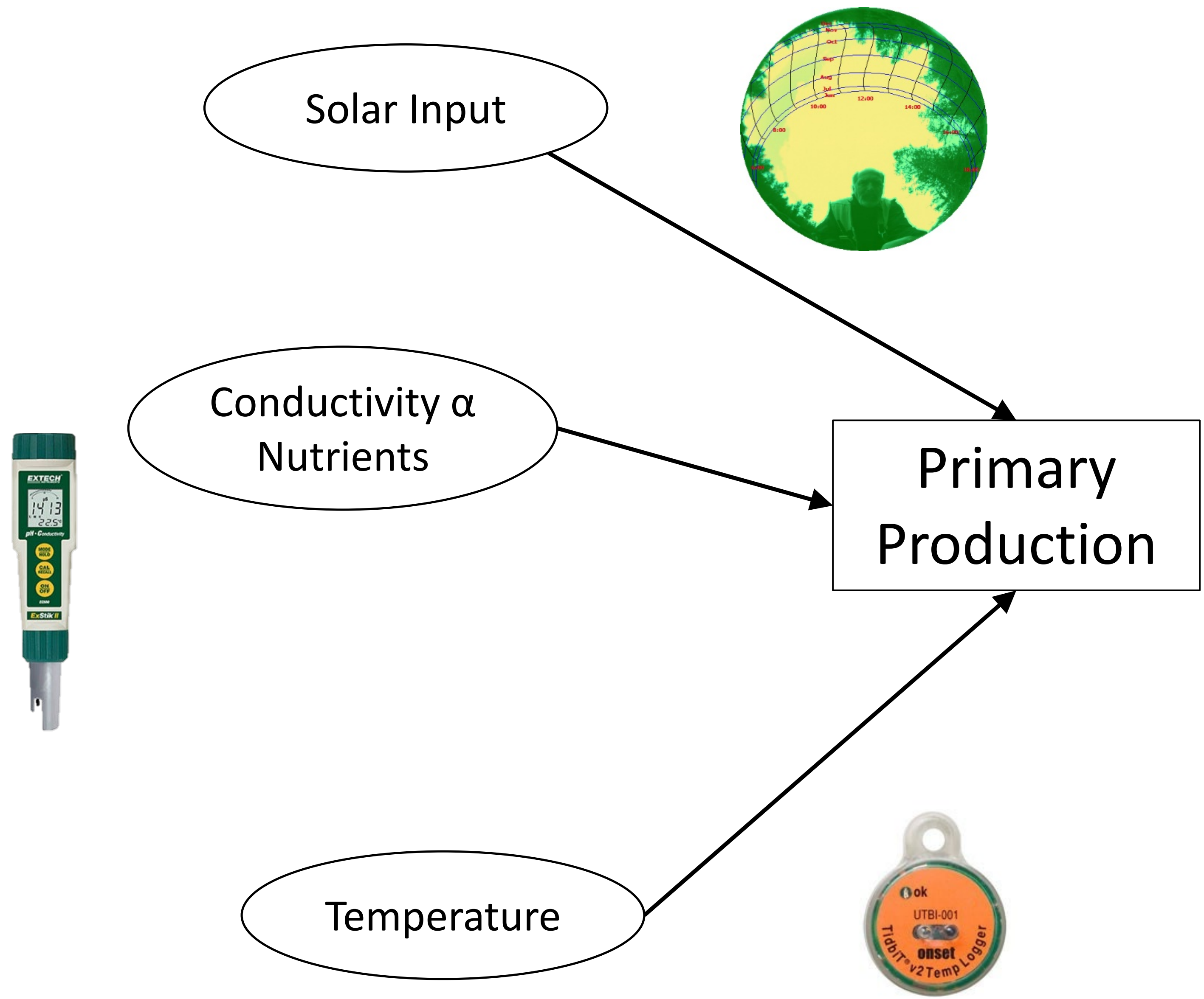
Fish consumption/growth

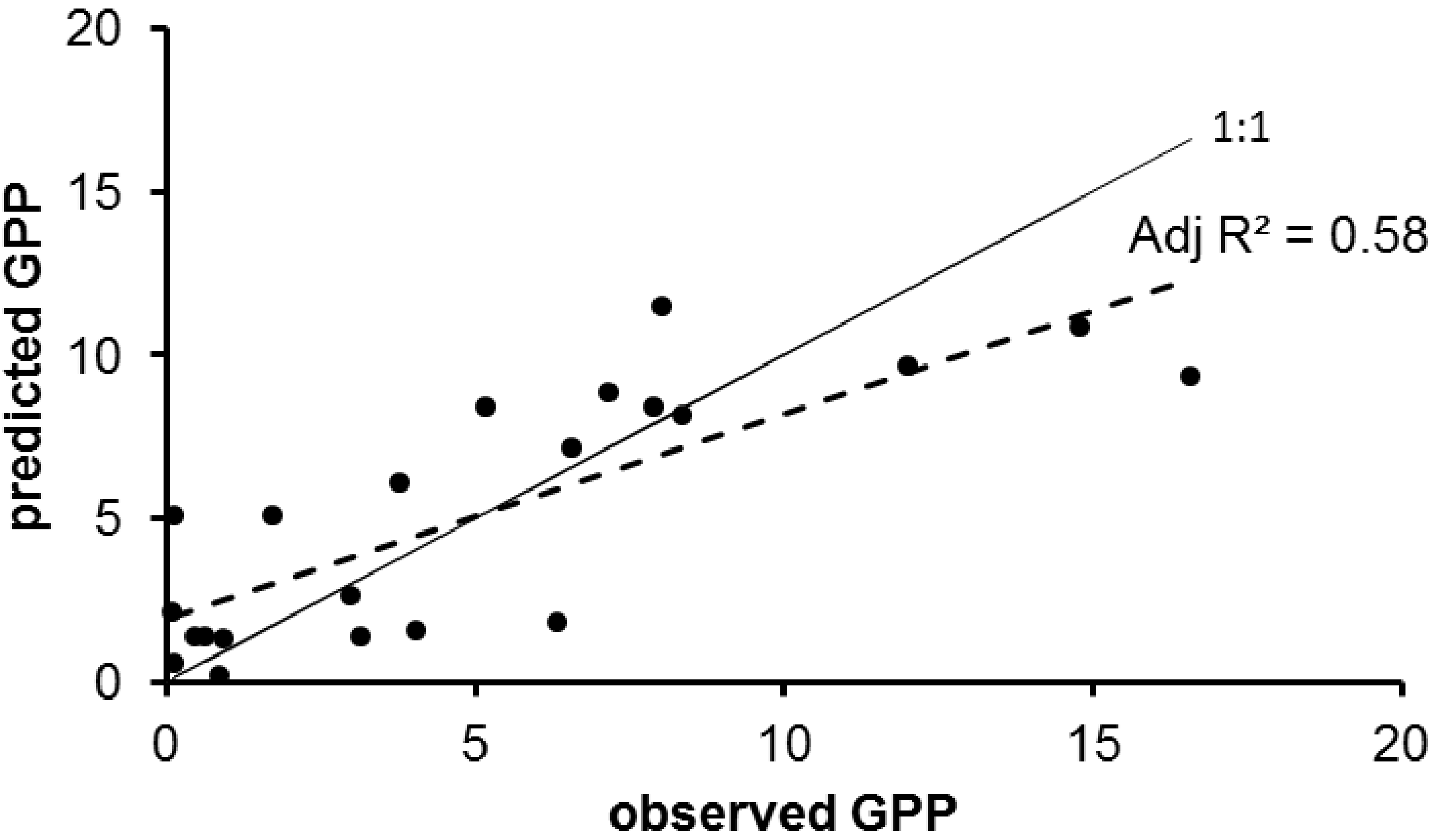


Fish abundance



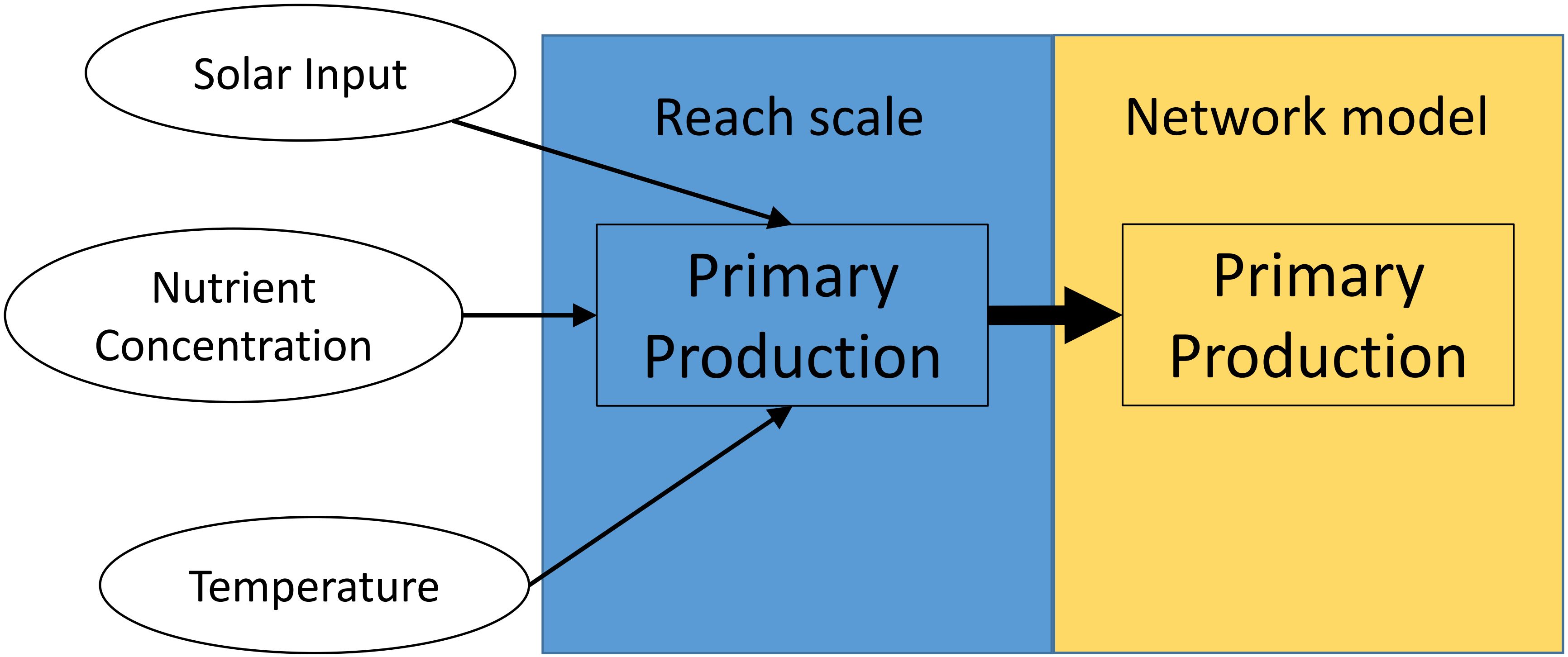
Site Scale Model of Gross Primary Production (from CHaMP)



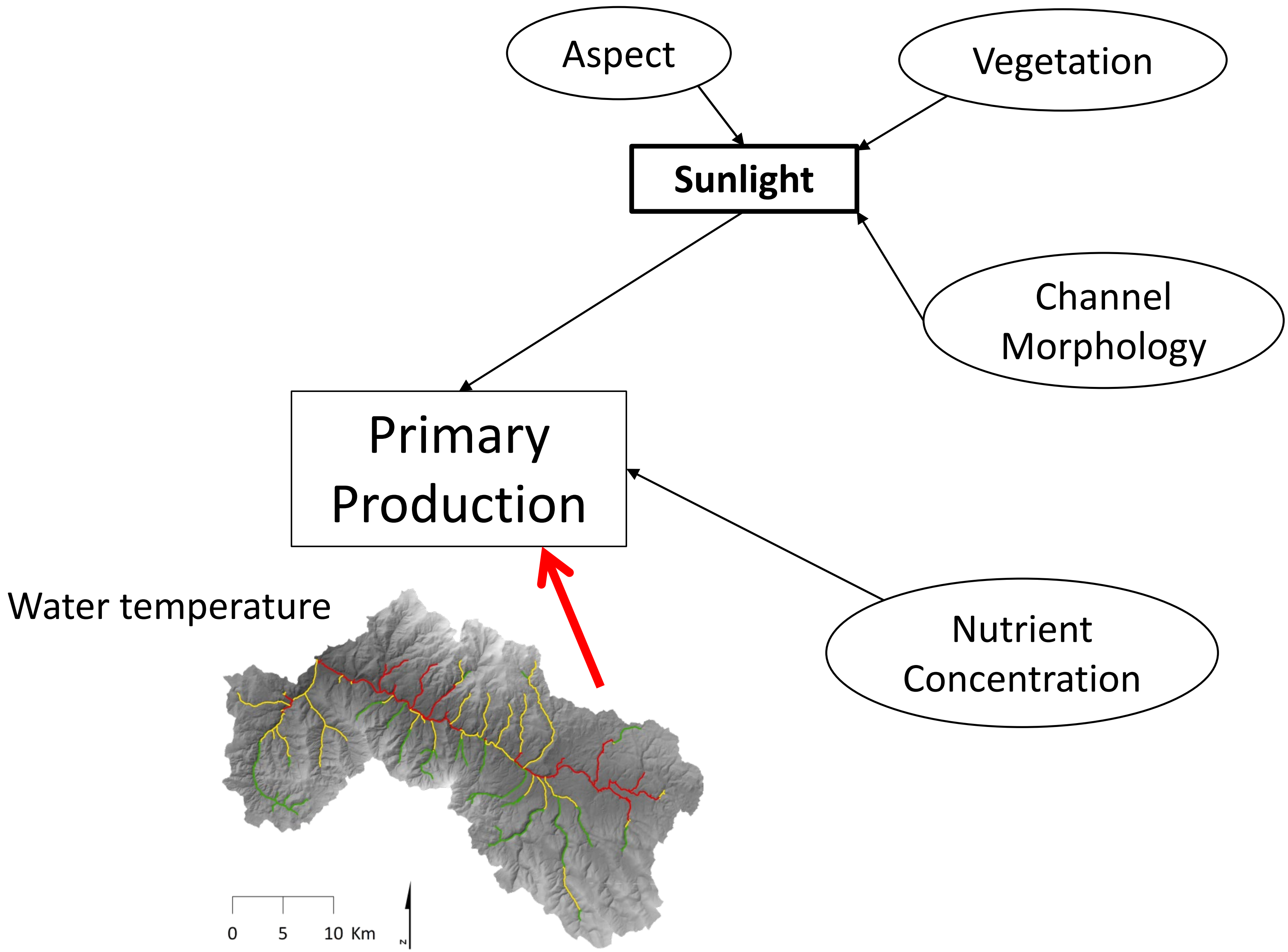


20
15
10
5
0
predicted GPP
1:1
Adj R² = 0.58
0
5
10
15
20
observed GPP

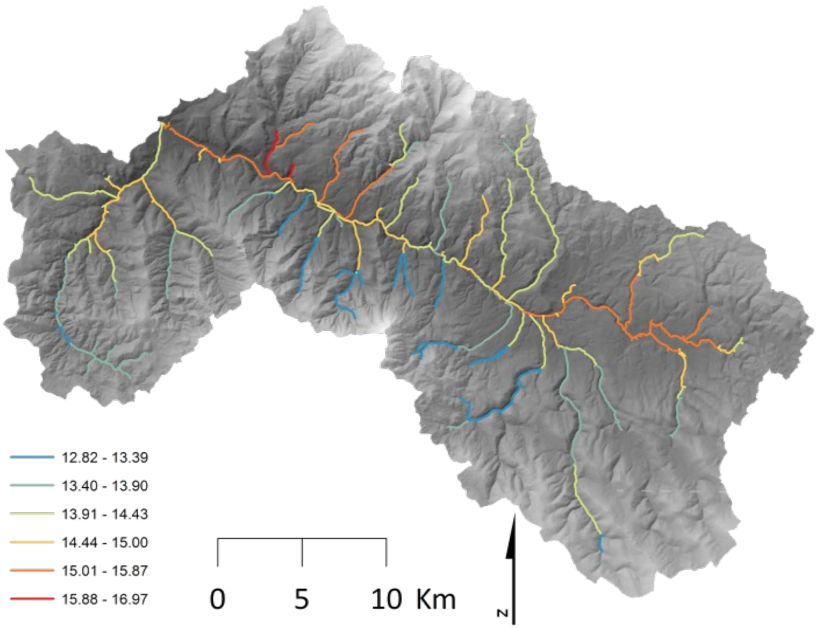
Watershed Scale Model of Primary Production



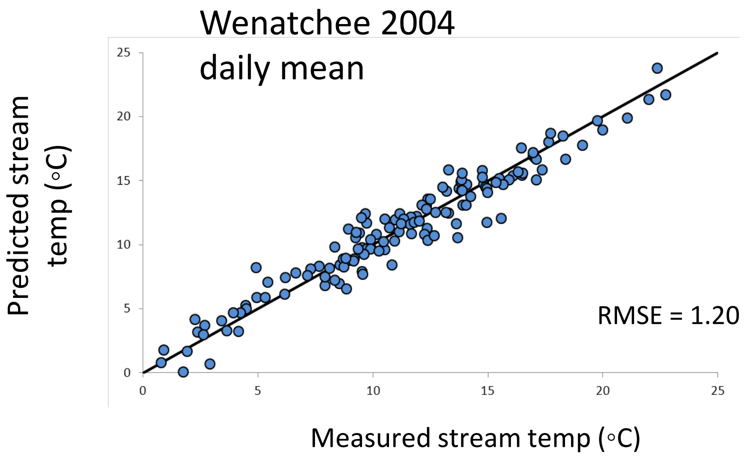
Watershed Scale Model of Primary Production

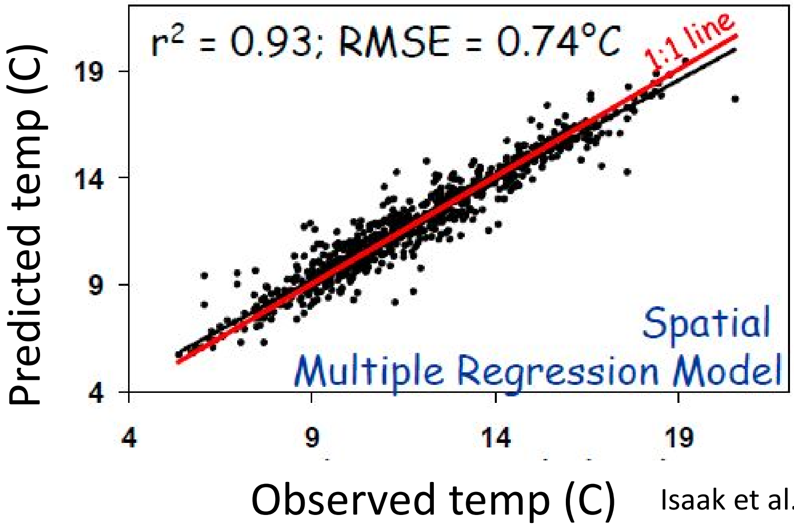


Stream temperature



MODIS Derived Stream Temp Predictions

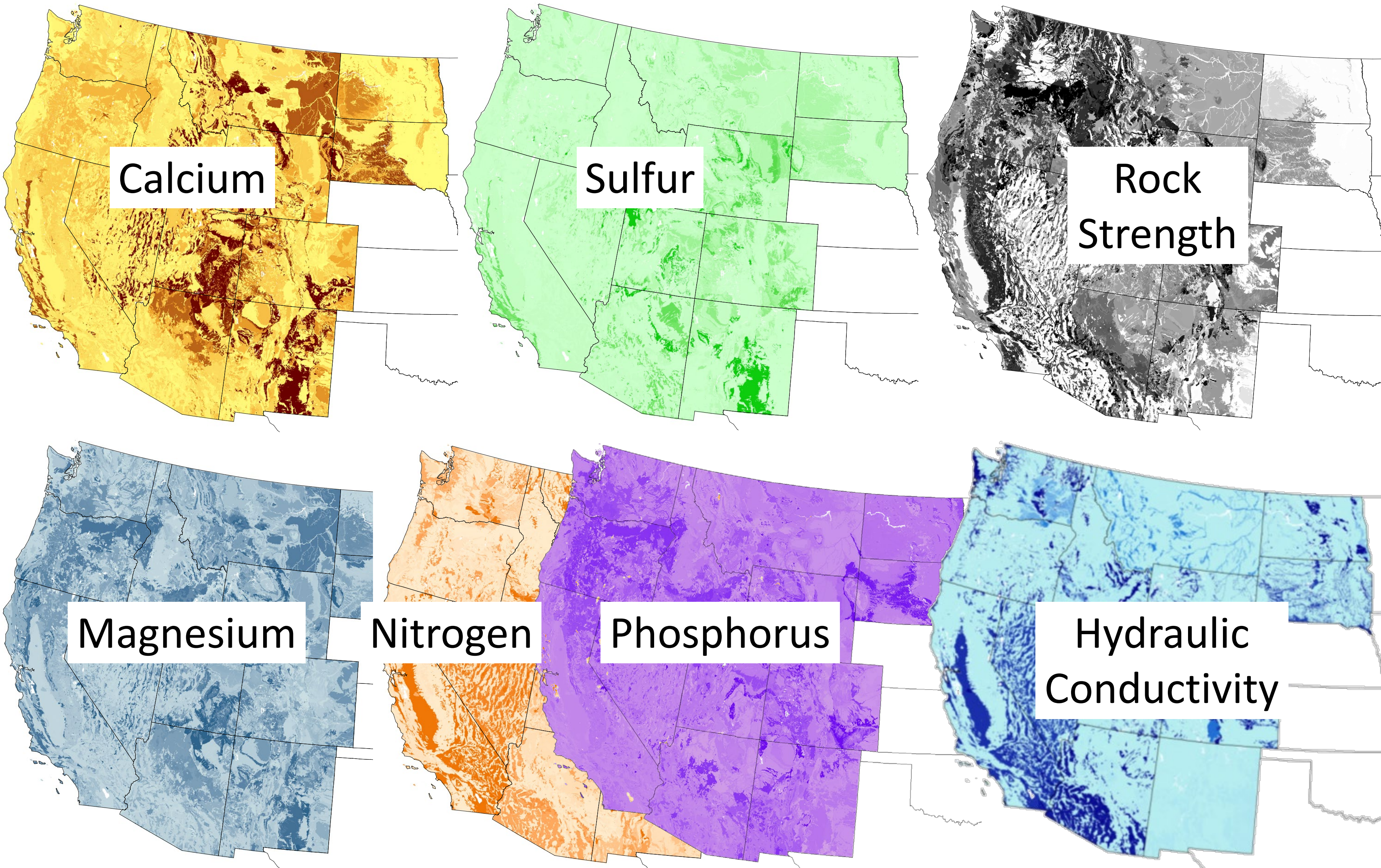




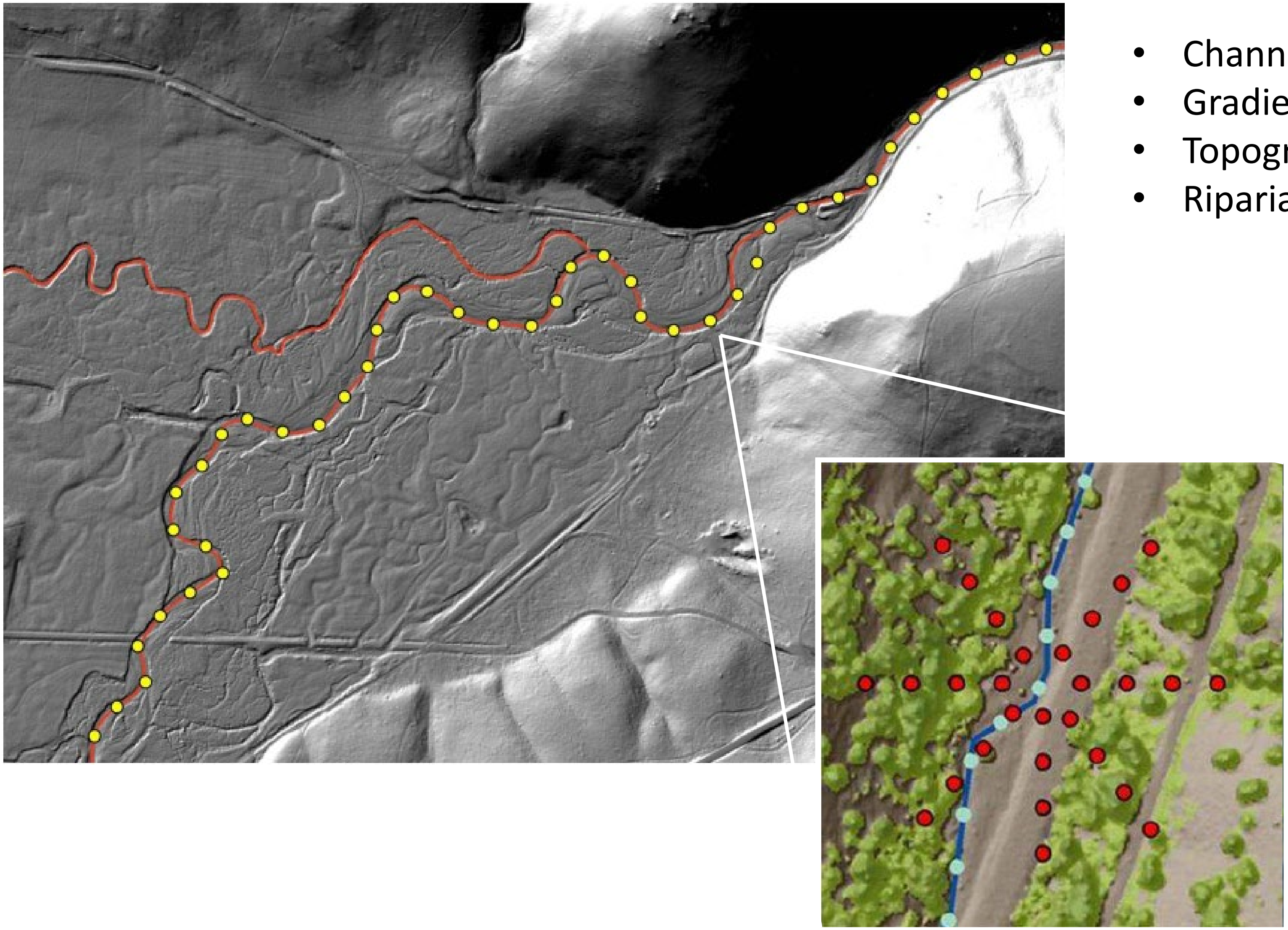
Isaak et al. 2010

Characterizing nutrients

From Olson and Hawkins 2012

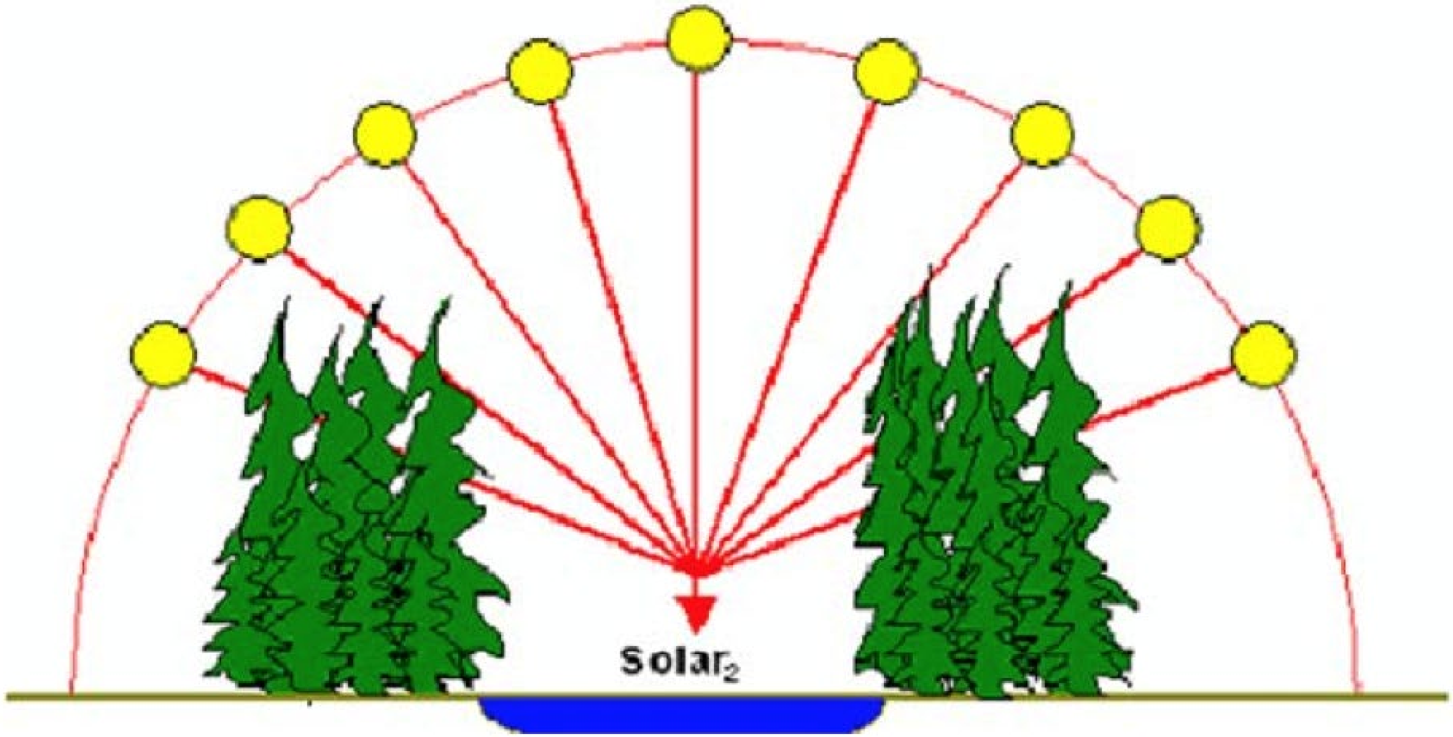


Solar input



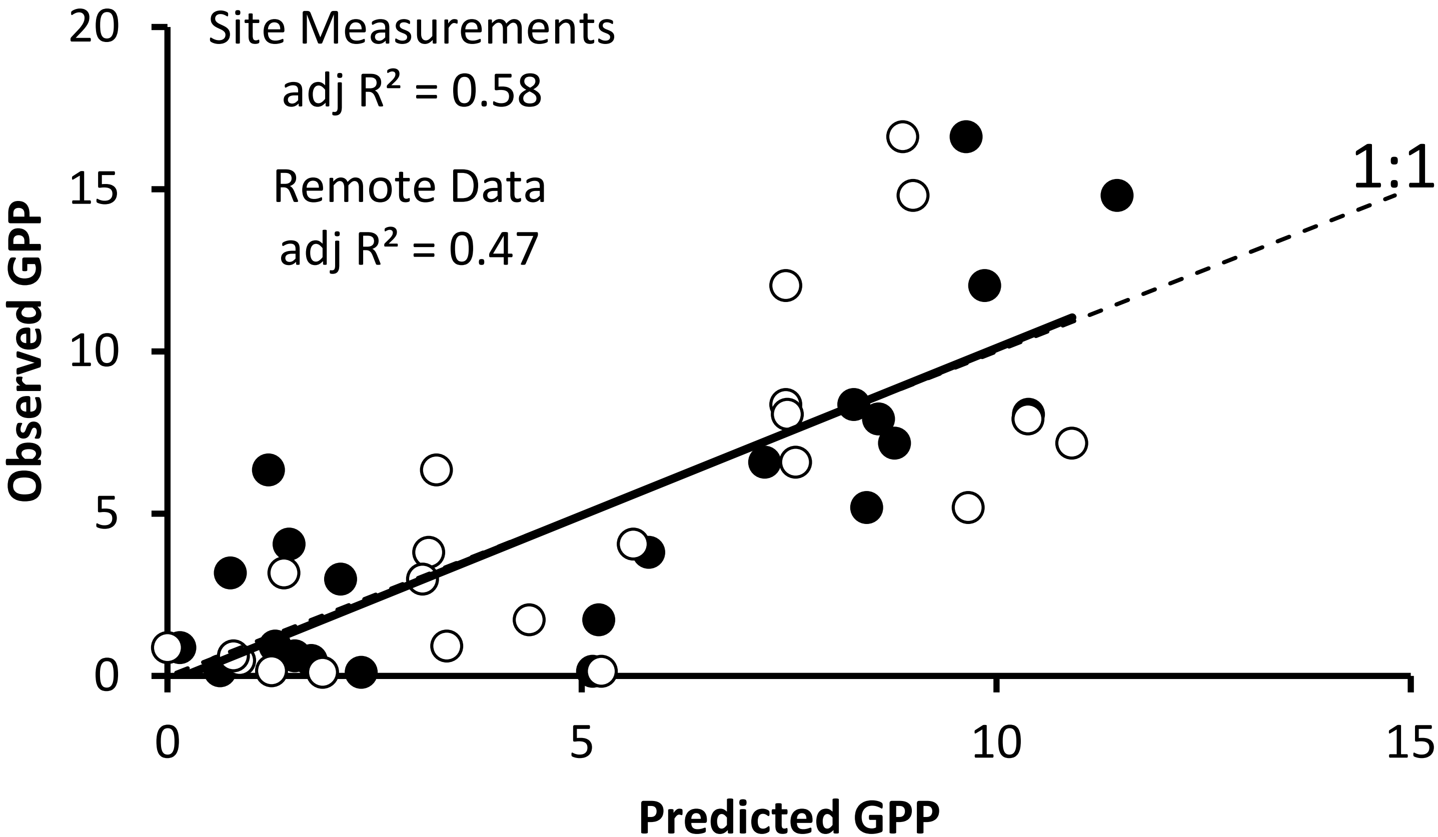
- Channel width
- Gradient
- Topographic shade
- Riparian shade

Effective shade

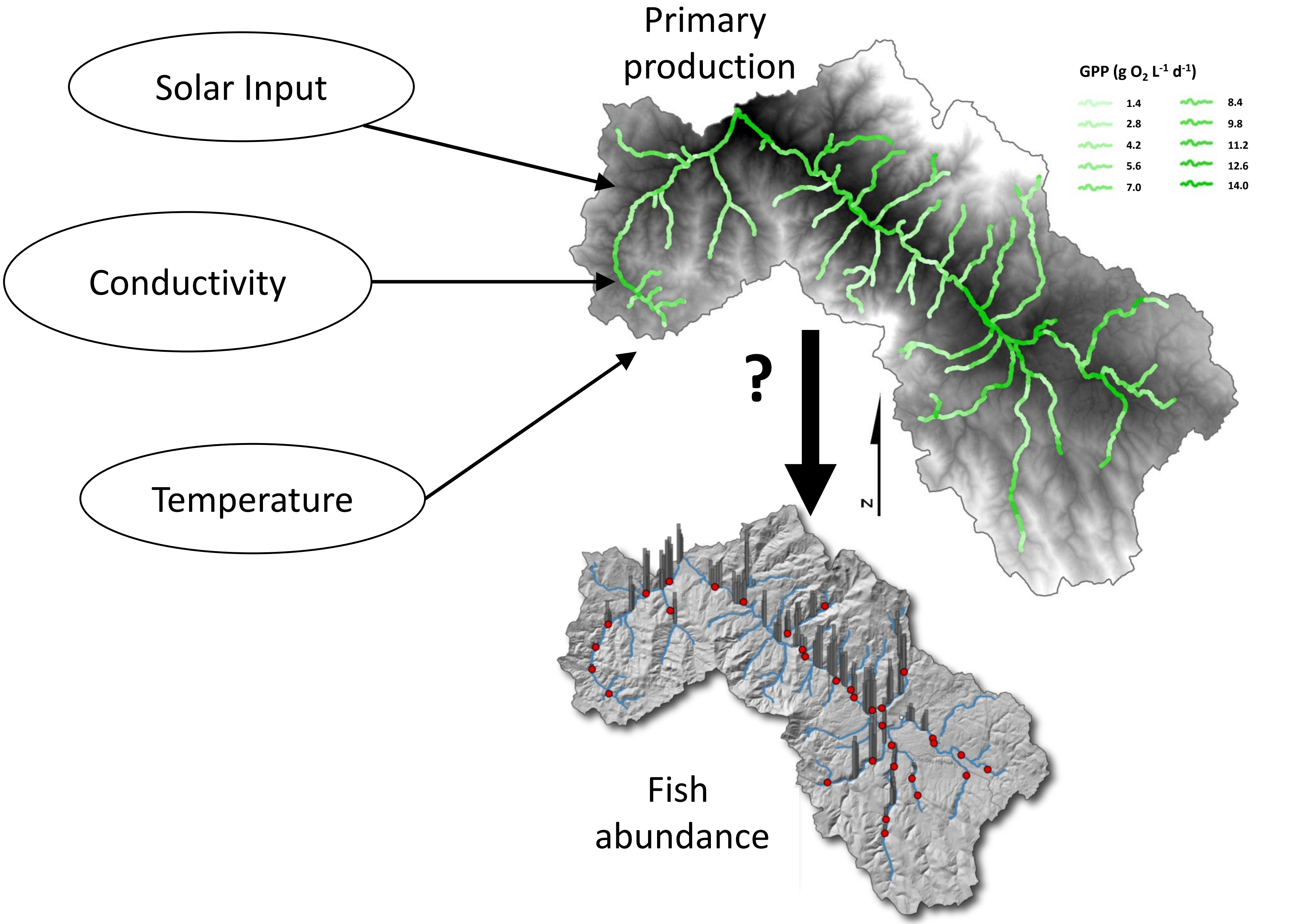


$$\text{Effective Shade} = \frac{(\text{Potential daily direct beam solar}) - (\text{Daily direct beam solar at stream surface})}{(\text{Potential daily direct beam solar})}$$

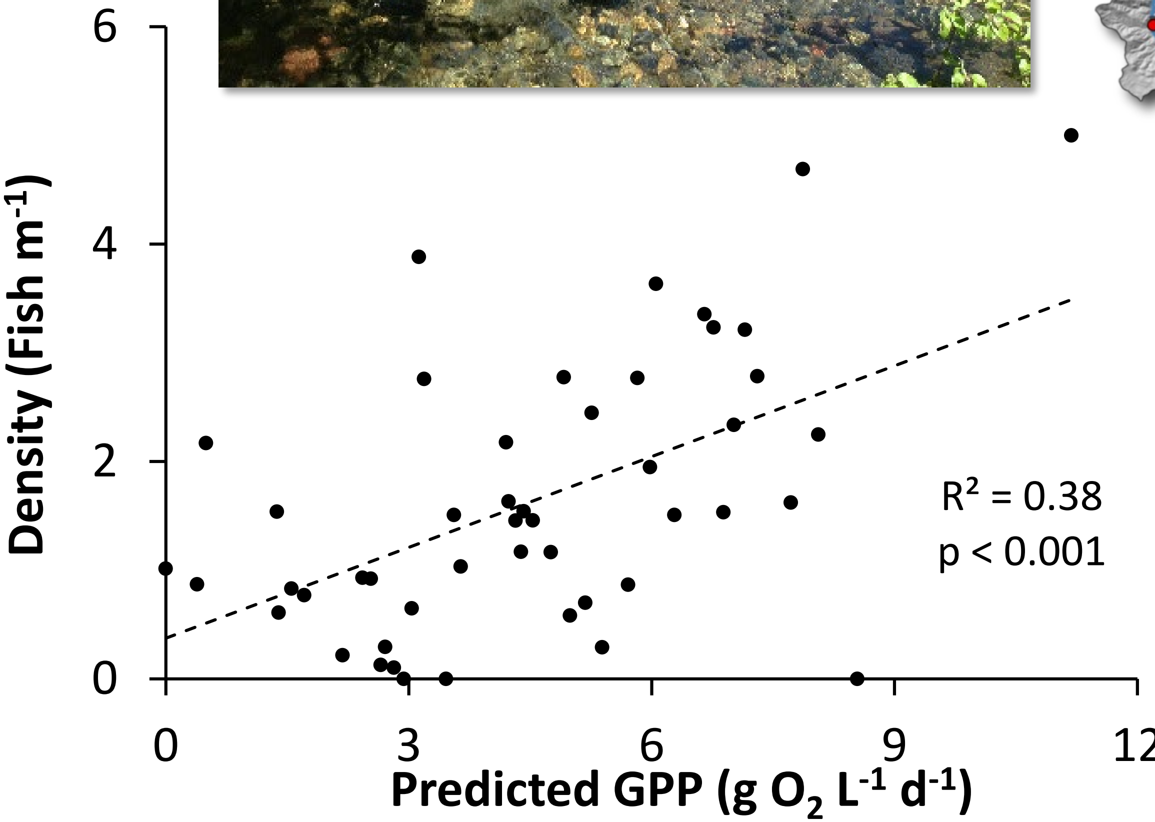
GPP from watershed scale inputs

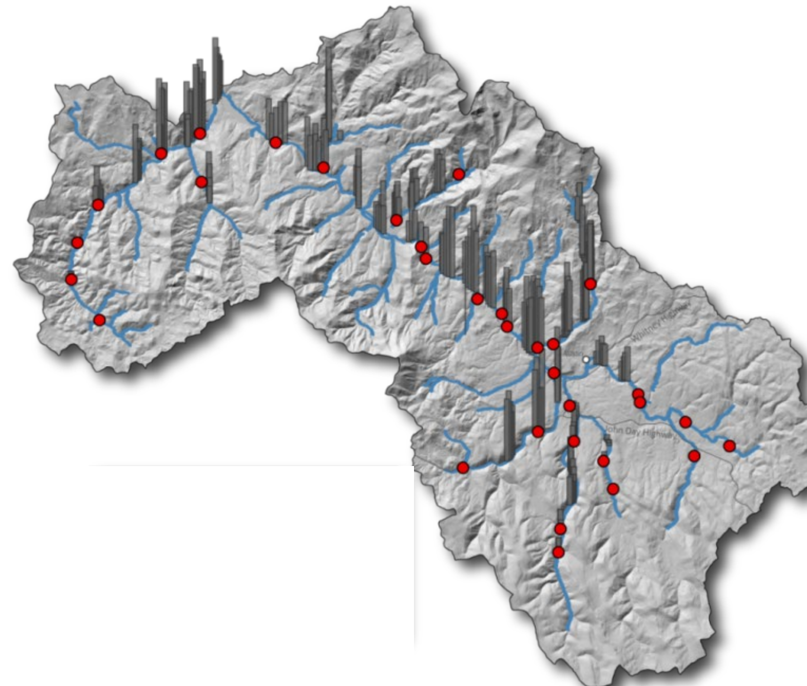


Network model of primary production



Network model GPP prediction of fish density





Summary

Measuring DO provides a fast, repeatable metric of reach productivity

Strongly correlated with measures of fish

Both site-scale and remotely derived predictors of GPP

Network GPP models accounted for substantial variation in fish abundance across semi-arid watershed

Summary

Network GPP models inform understanding of spatial structure of fish populations

Prioritize restoration /optimize monitoring

Understand response to disturbance / management actions