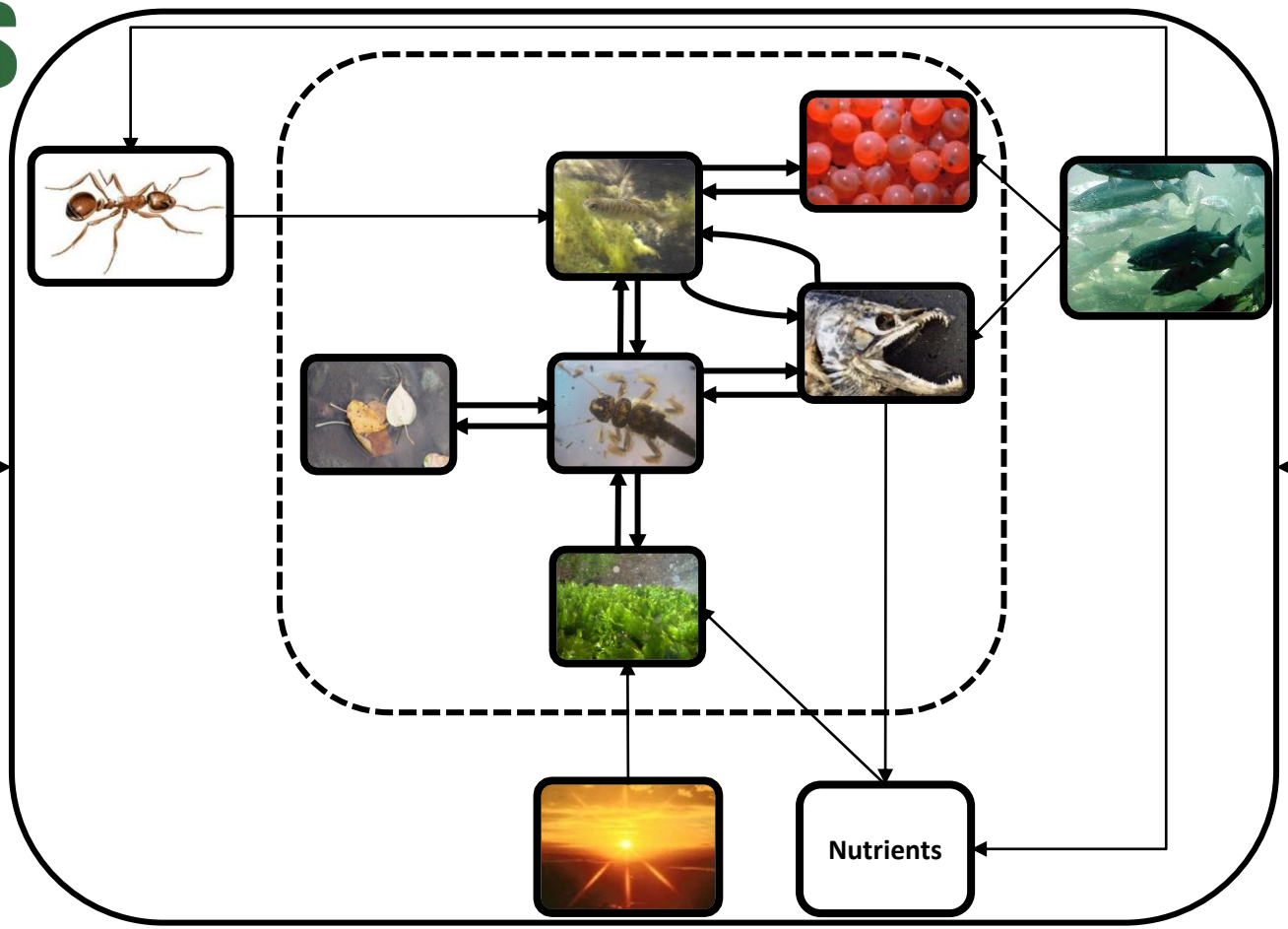
The Aquatic Trophic Productivity Model:
Incorporating Food Webs into Salmon Recovery Science

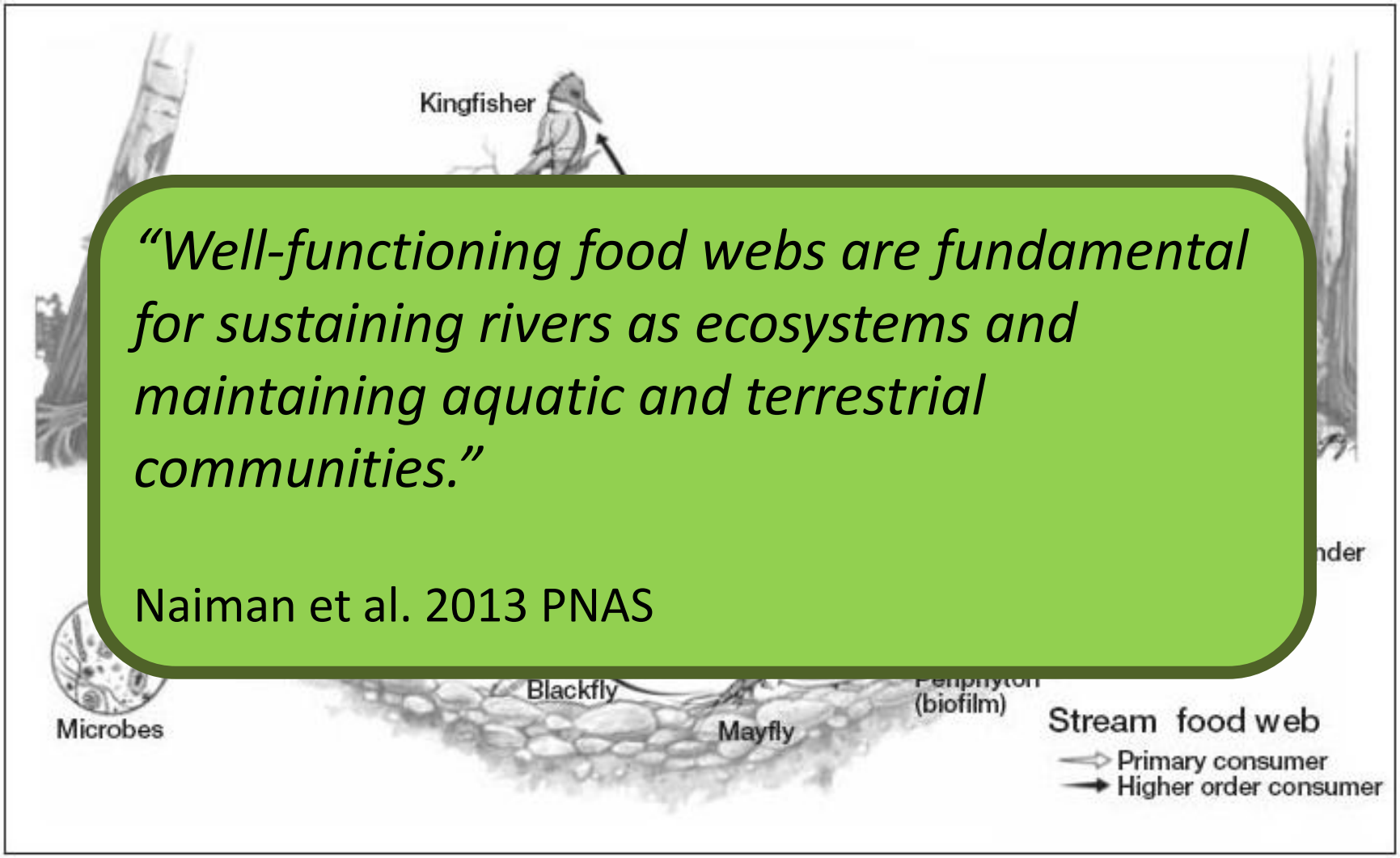
Ryan Bellmore (USGS), Michael Newsom (BOR), Alex Fremier (WSU), Pat Connolly (USGS),
John Jorgensen (Yakama Nation)



Riparian Conditions

Physical Conditions

Why food webs?

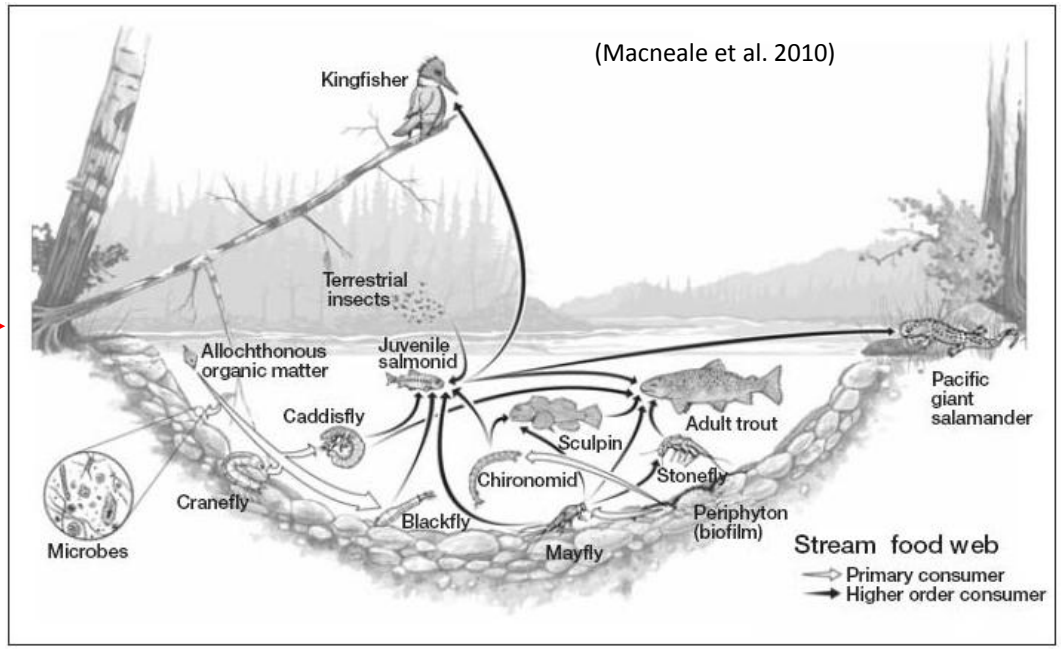


"Well-functioning food webs are fundamental for sustaining rivers as ecosystems and maintaining aquatic and terrestrial communities."

Naiman et al. 2013 PNAS

(Macneale et al. 2010)

Why food webs?



The Trophic Productivity Model

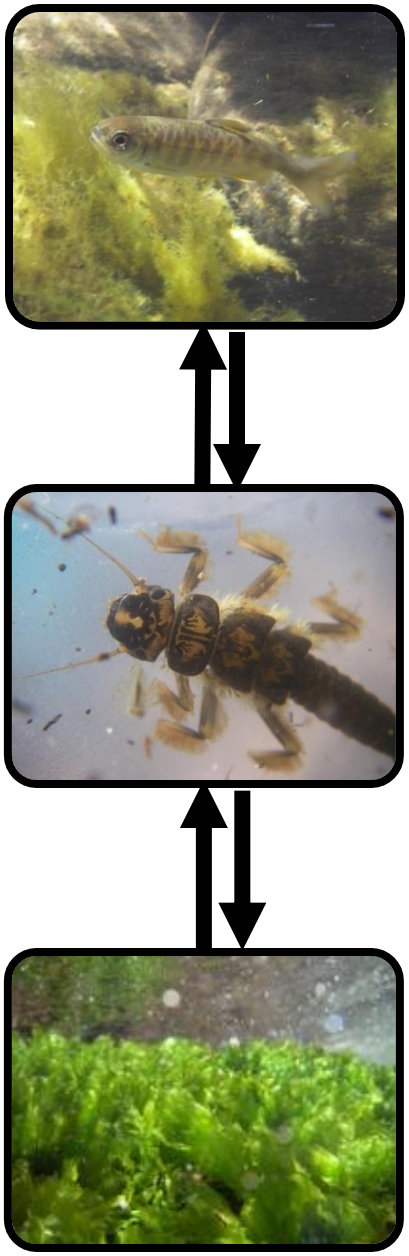
To Address this Need. . .

We constructed a mechanism-based simulation model to explore how restoration strategies (and environmental changes) might influence food webs, and the capacity to sustain fish.

Here we will:

1. Provide a brief overview of this model, termed the "**Trophic Productivity Model**"

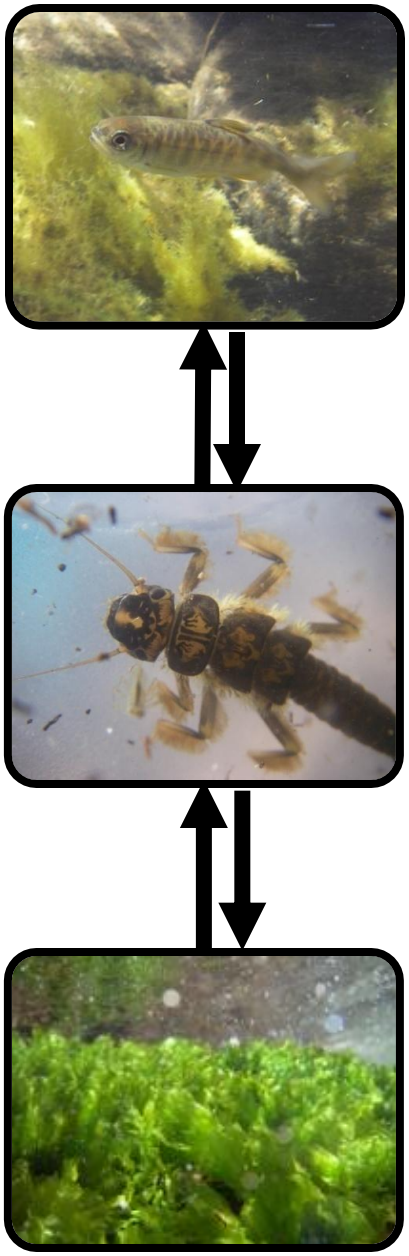
2. Present a series of simulations to demonstrate model capability



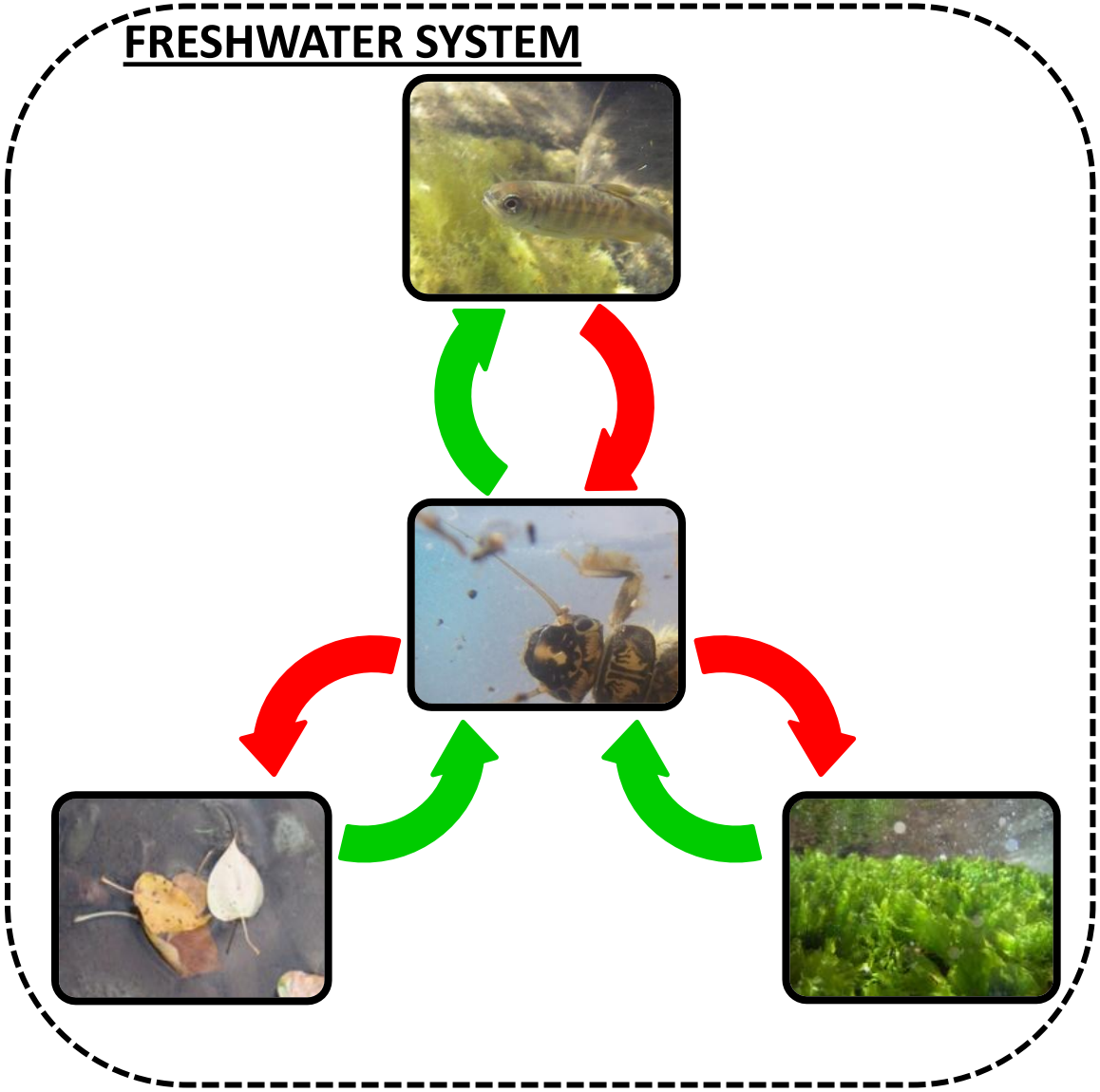
The Trophic Productivity Model

What is the Trophic Productivity Model?
It is a dynamic food web model, whereby fish production is explicitly tied to transfers of organic matter between different components of a simplified river food web.

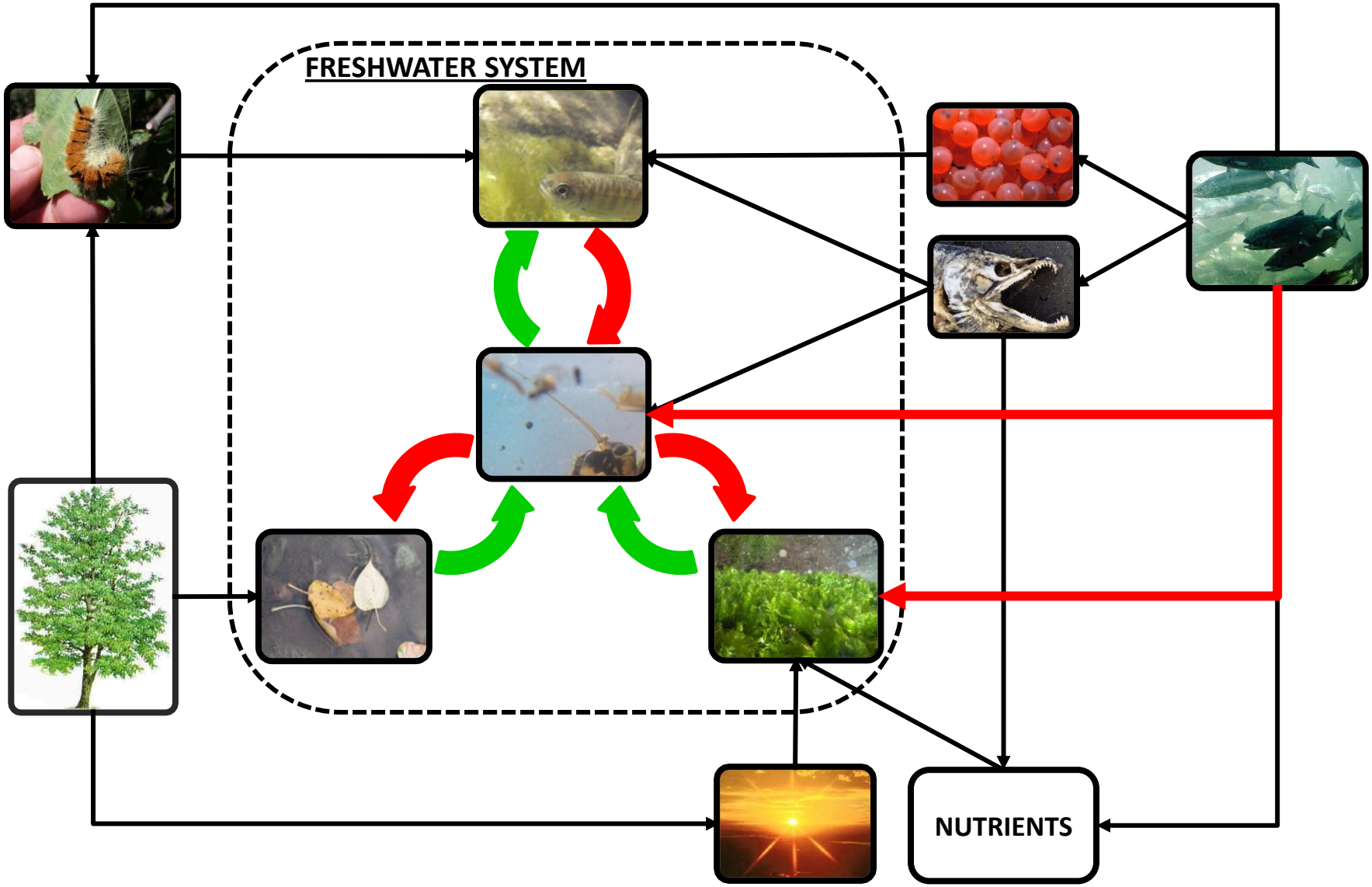
- Built upon previous stream ecosystem models (e.g., McIntire and Colby 1978, Power et al. 1995, D'Angelo et al. 1997)



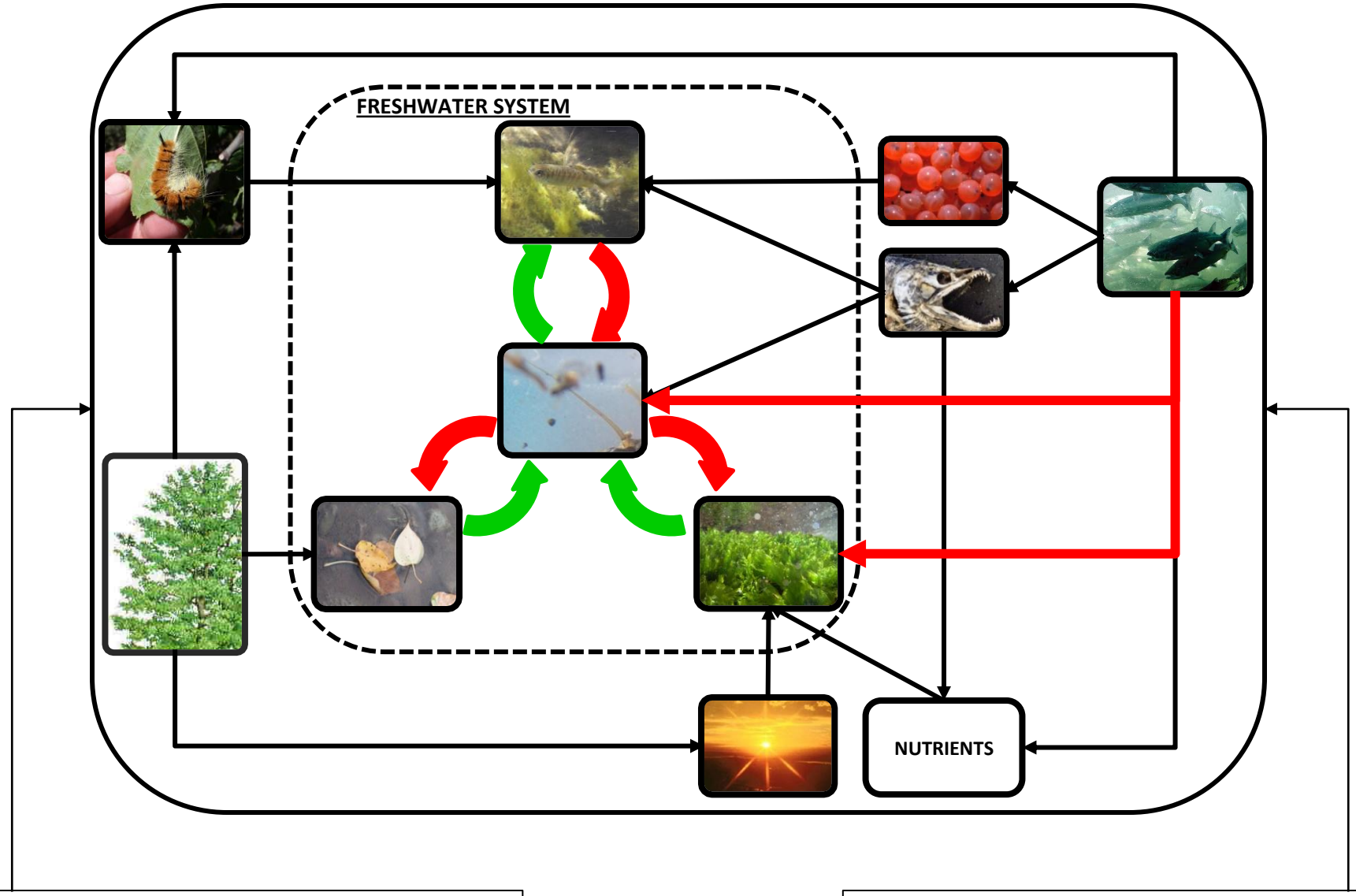
Model Structure



Model Structure



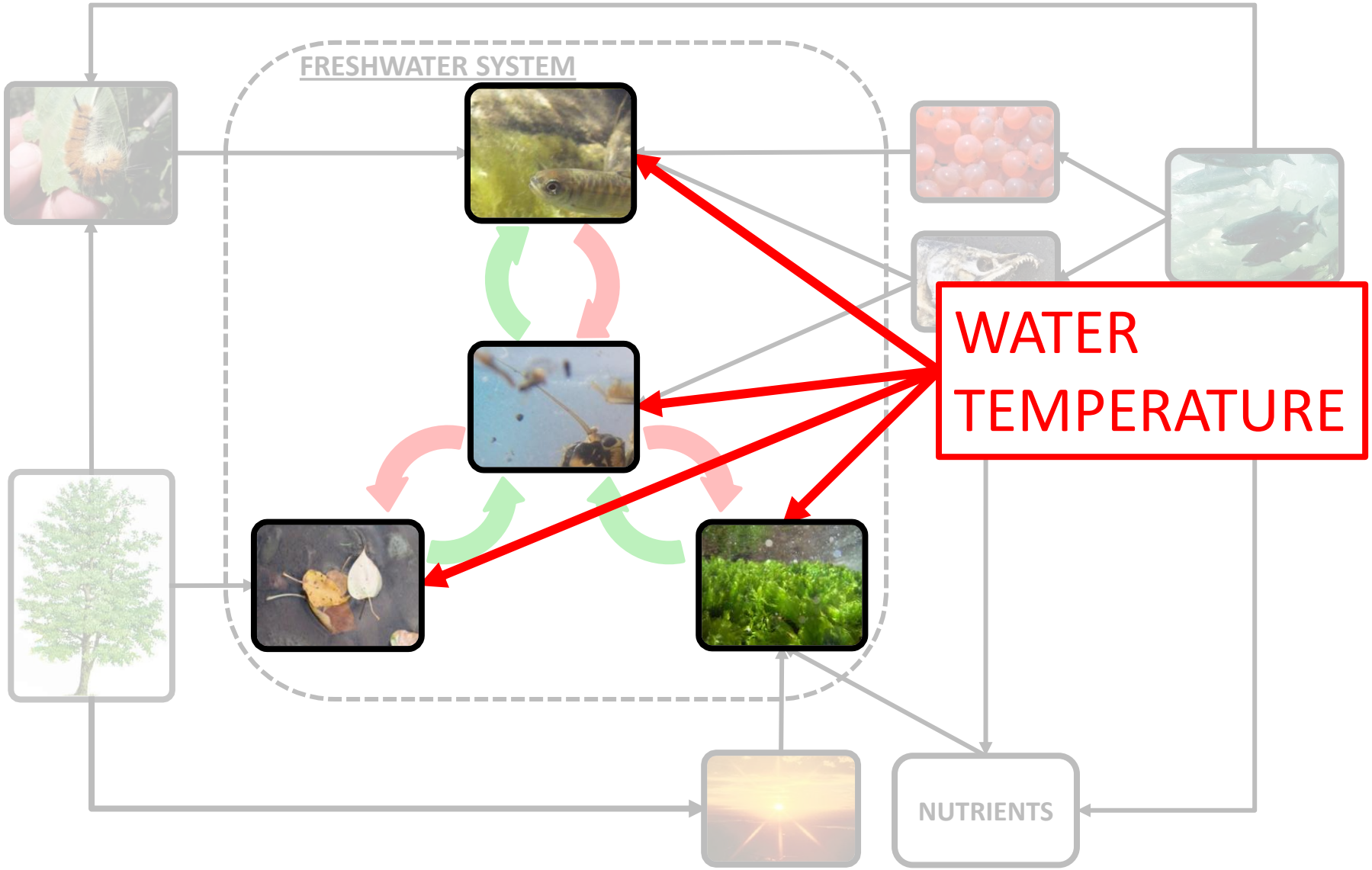
Model Structure



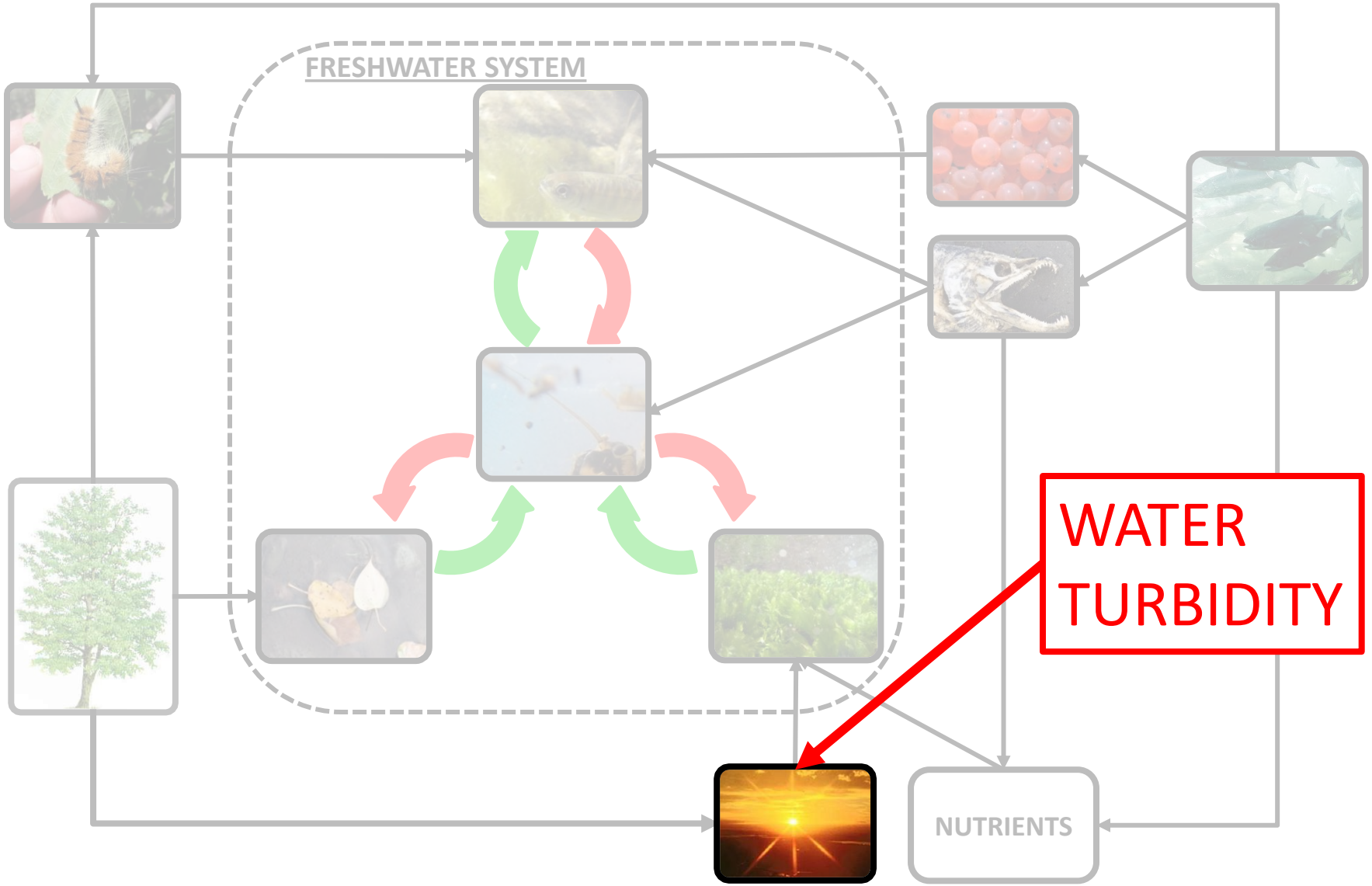
Riparian Conditions

Physical Conditions

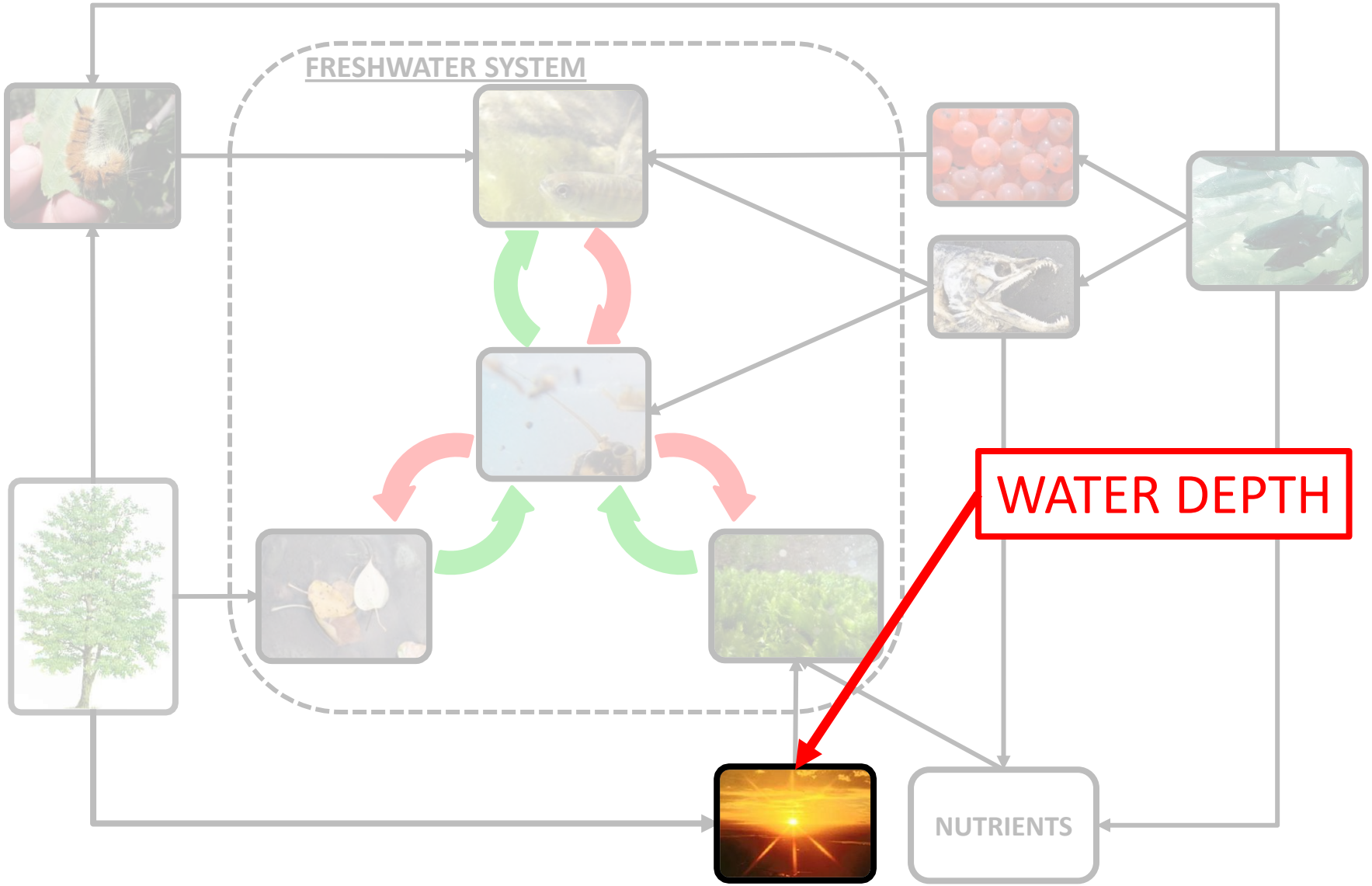
Model Structure



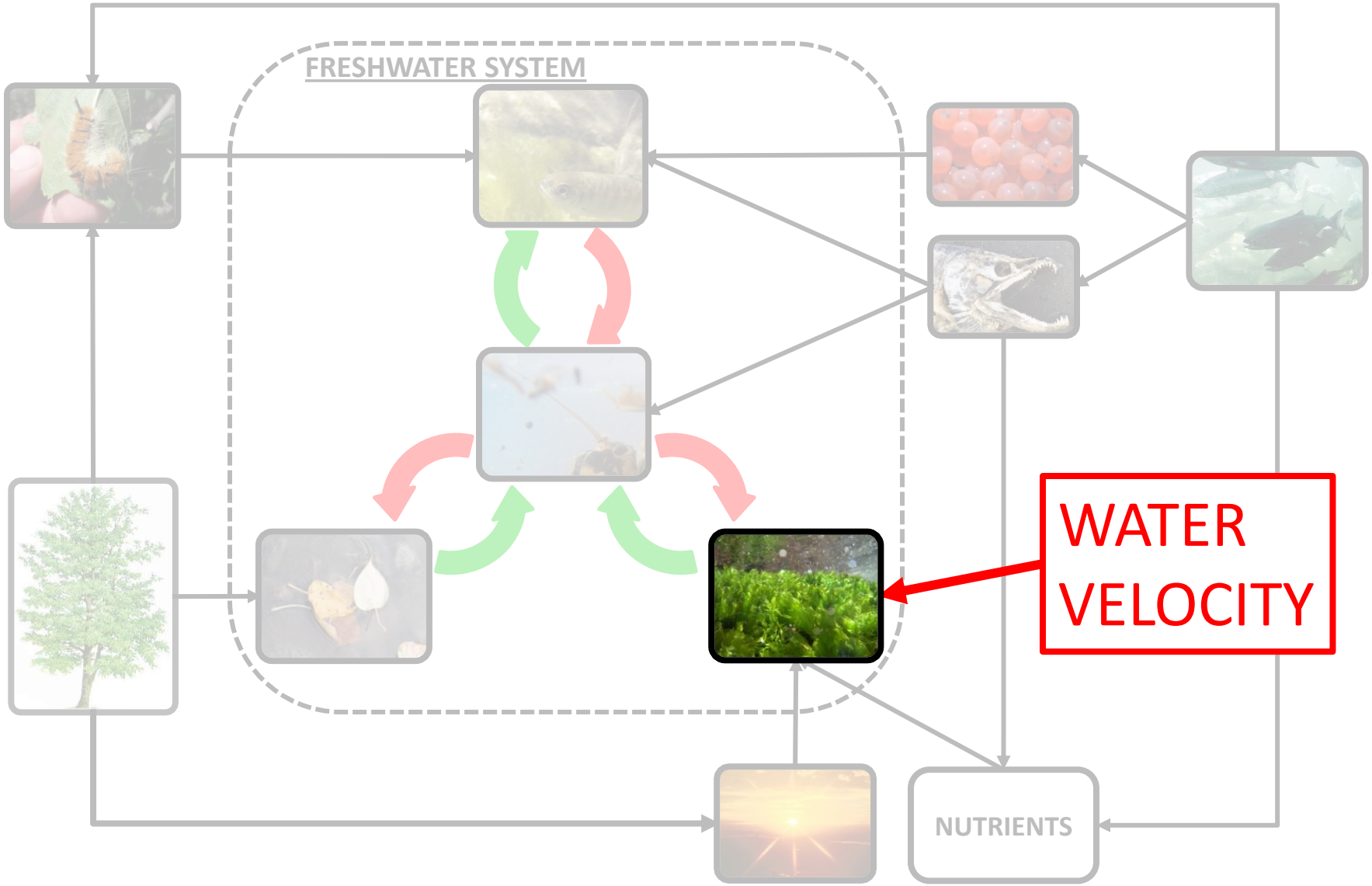
Model Structure



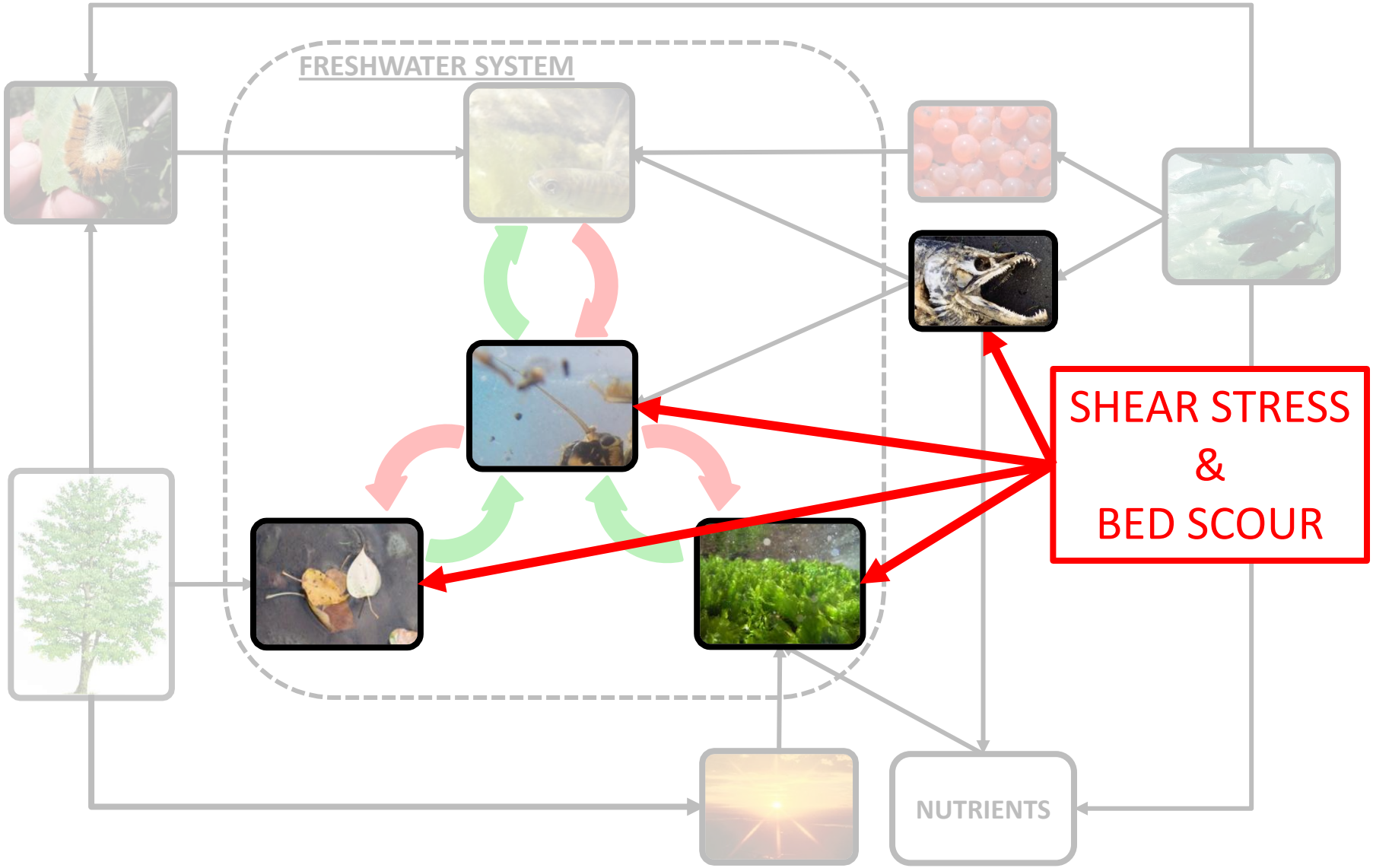
Model Structure



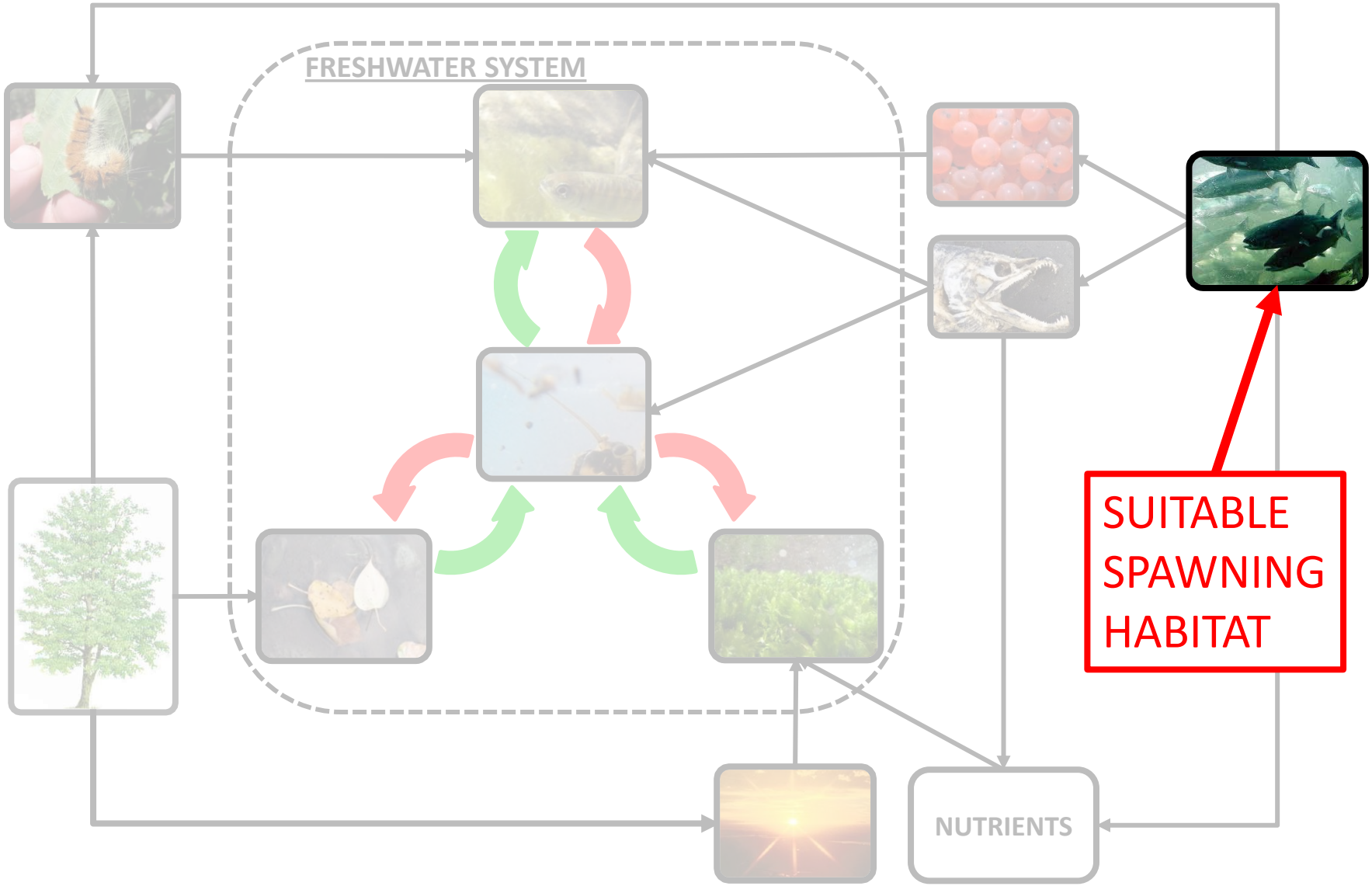
Model Structure



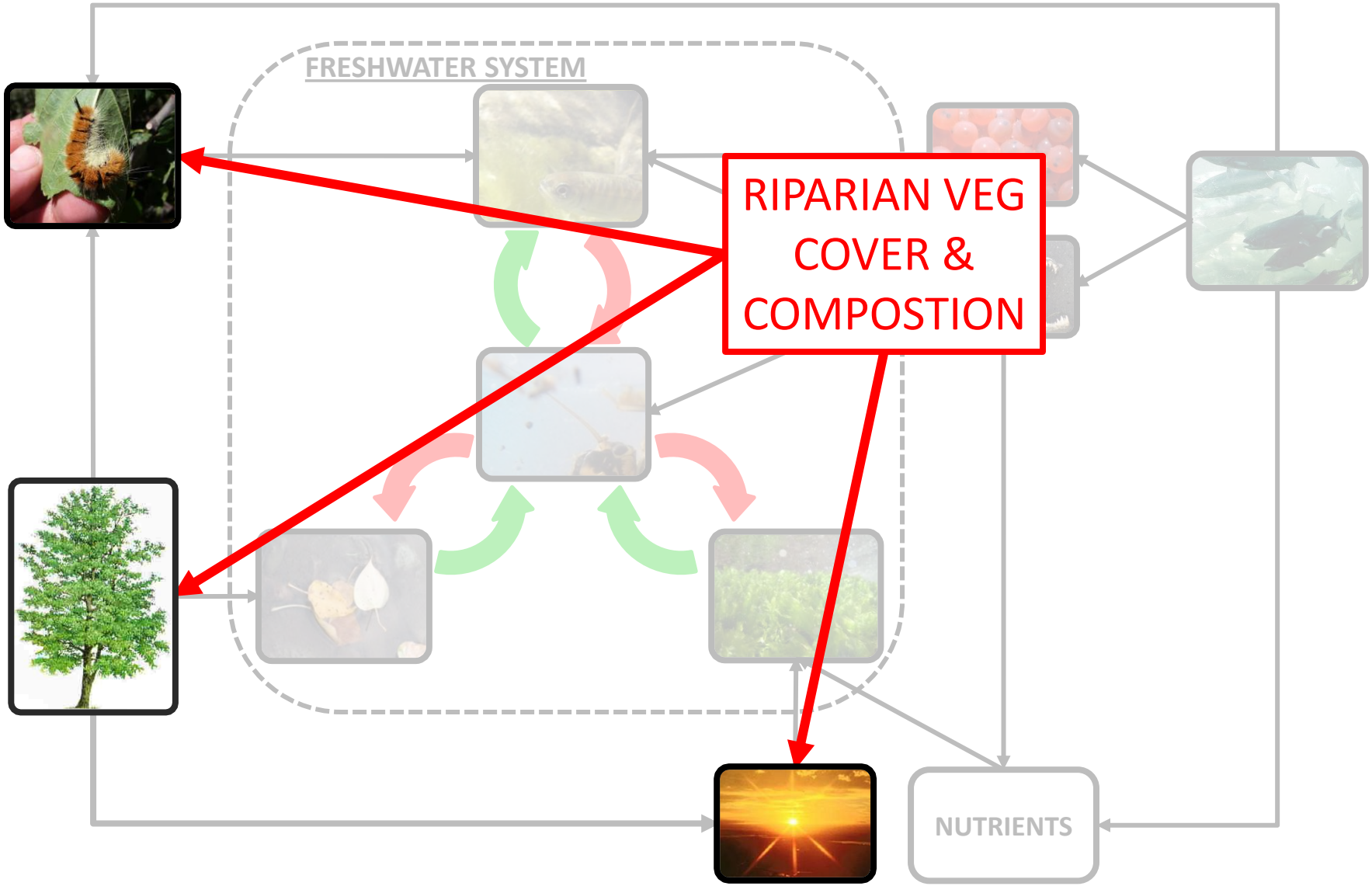
Model Structure



Model Structure



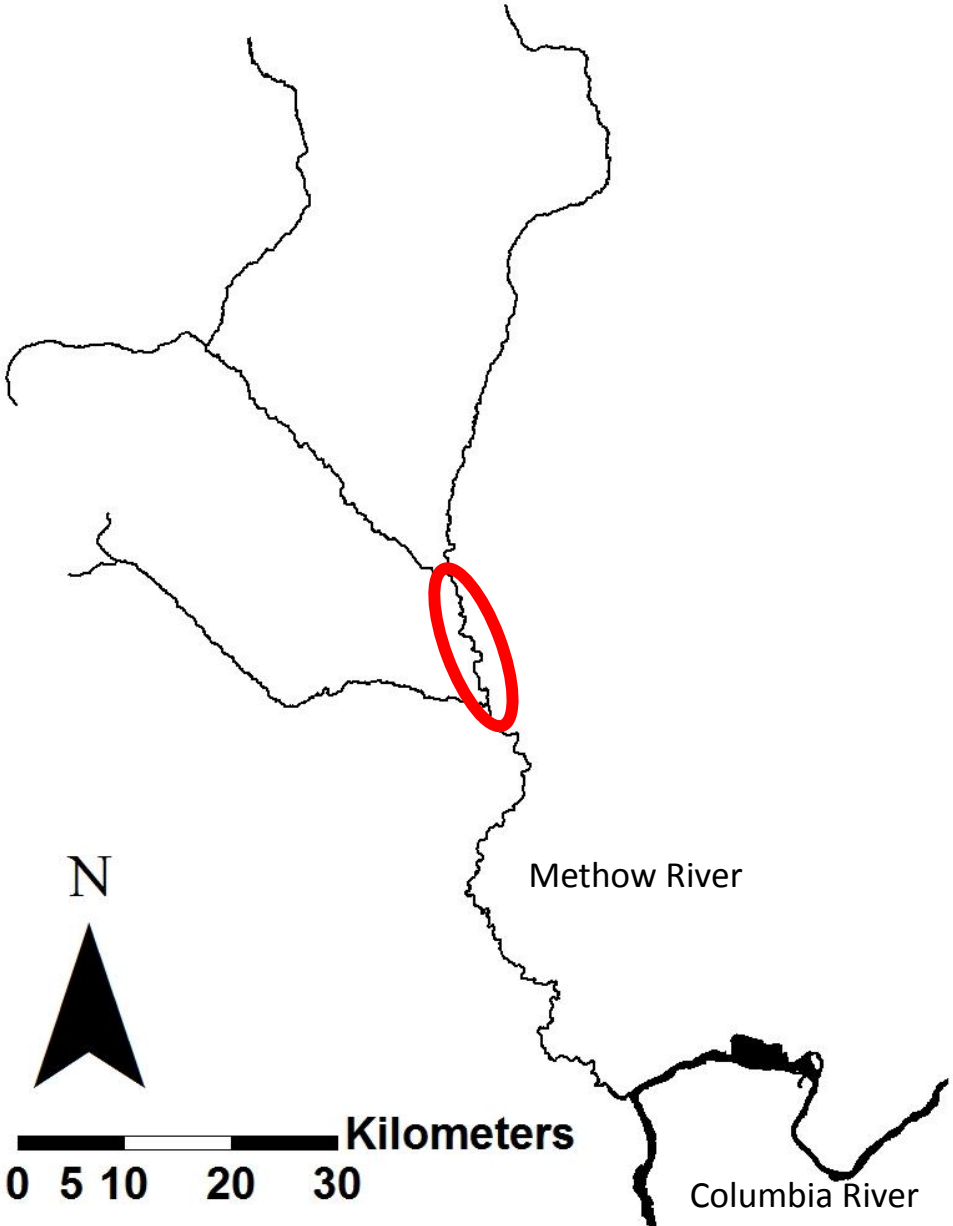
Model Structure

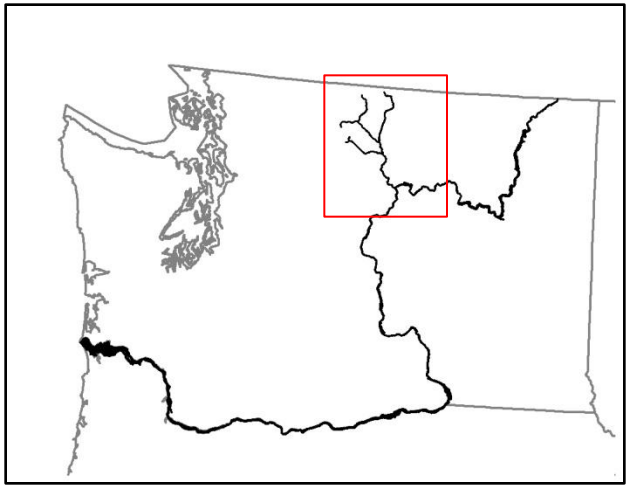


Model Inputs

- Discharge (flow regime)
- Temperature (air and water)
- Photosynthically active radiation (PAR)
- Riparian cover & shading
- Water turbidity
- Nutrient concentrations (NO3, NH4, SRP)
- Number of salmon spawners
- Substrate sizes
- Channel gradient
- Channel morphology (bankfull width & depth, bank angle)
- Floodplain width

Model Test: Methow River





Model Test: Methow River

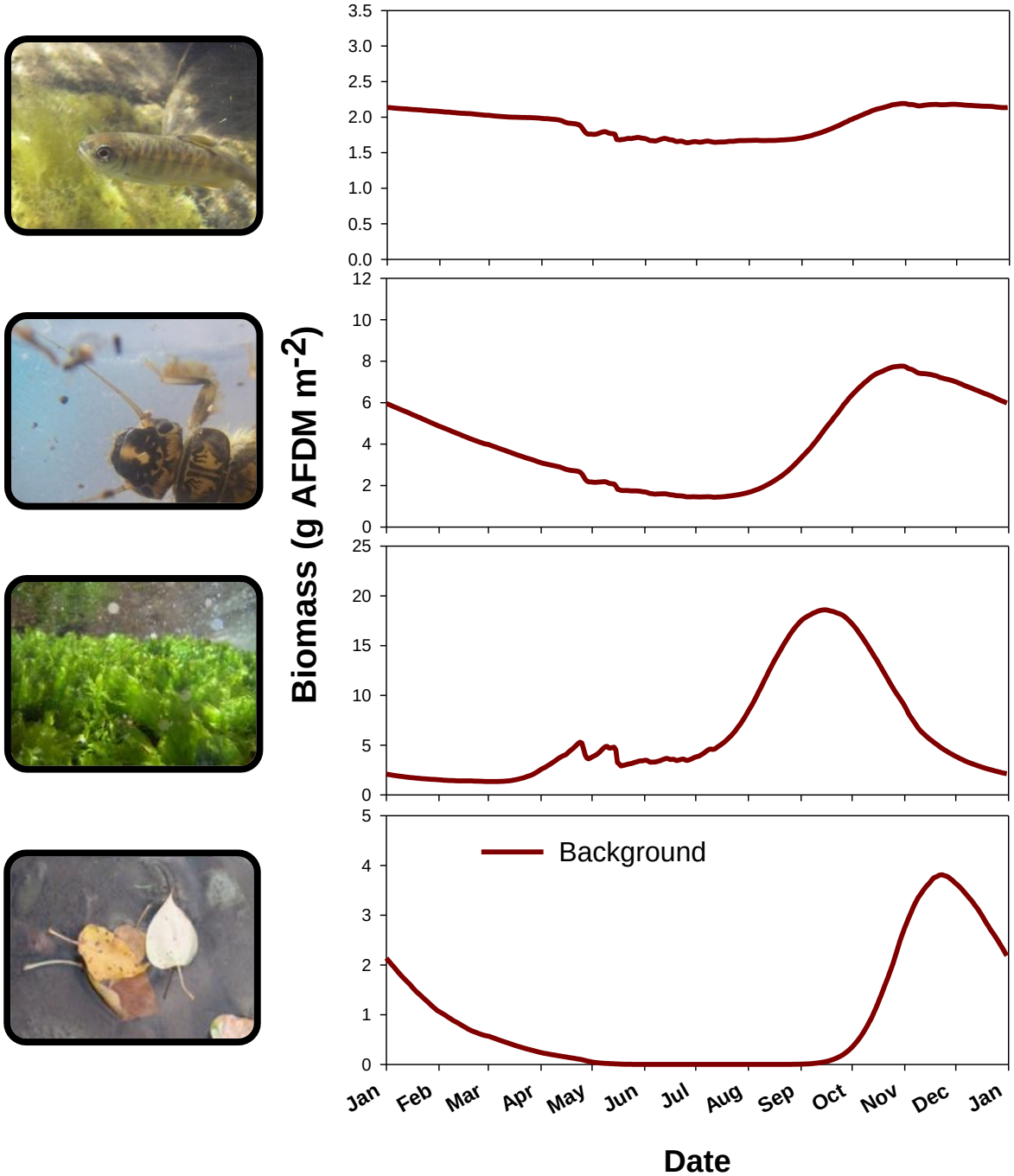
Simulations:

1. **No Treatment – Background Conditions**

2. **Nutrient Addition (phosphorus)**

3. **Salmon Carcass Addition**

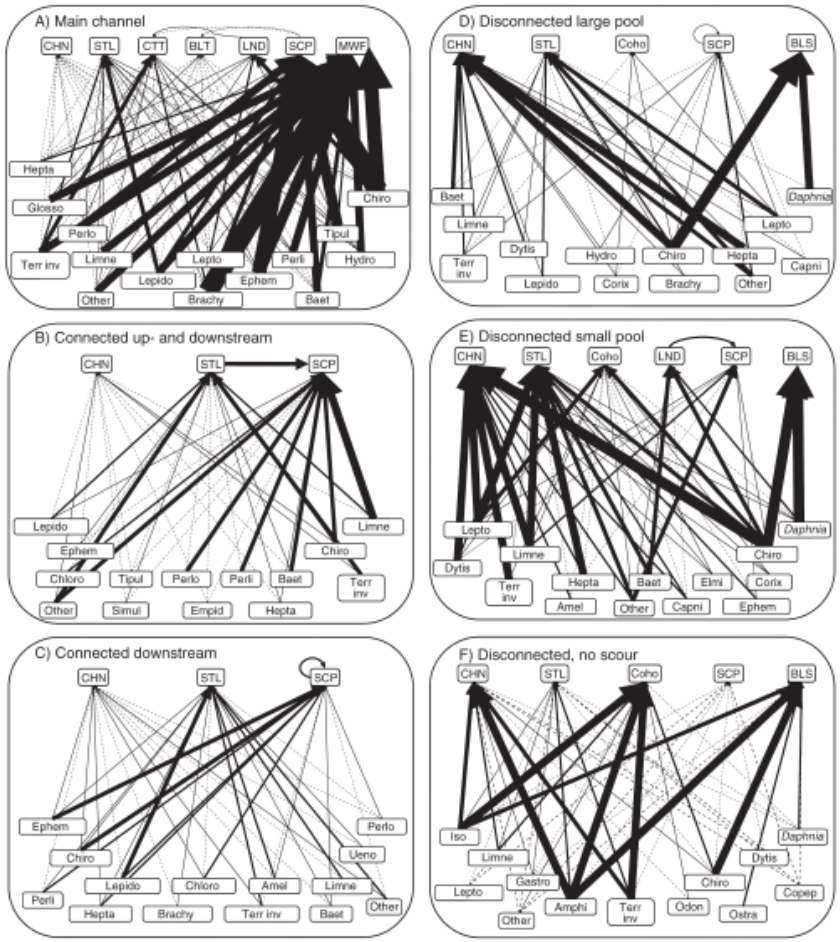
4. **Habitat Restoration (floodplain restoration)**

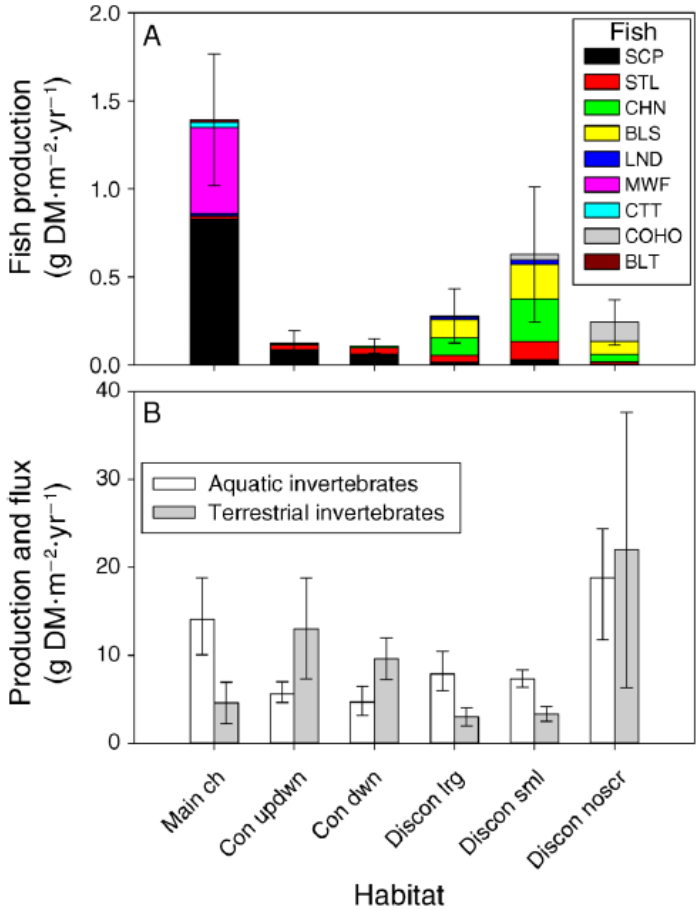

Biomass (g AFDM m-2)
Background
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Date

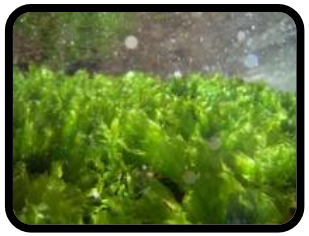
Ecological Applications, 23(1), 2013, pp. 189–207
© 2013 by the Ecological Society of America

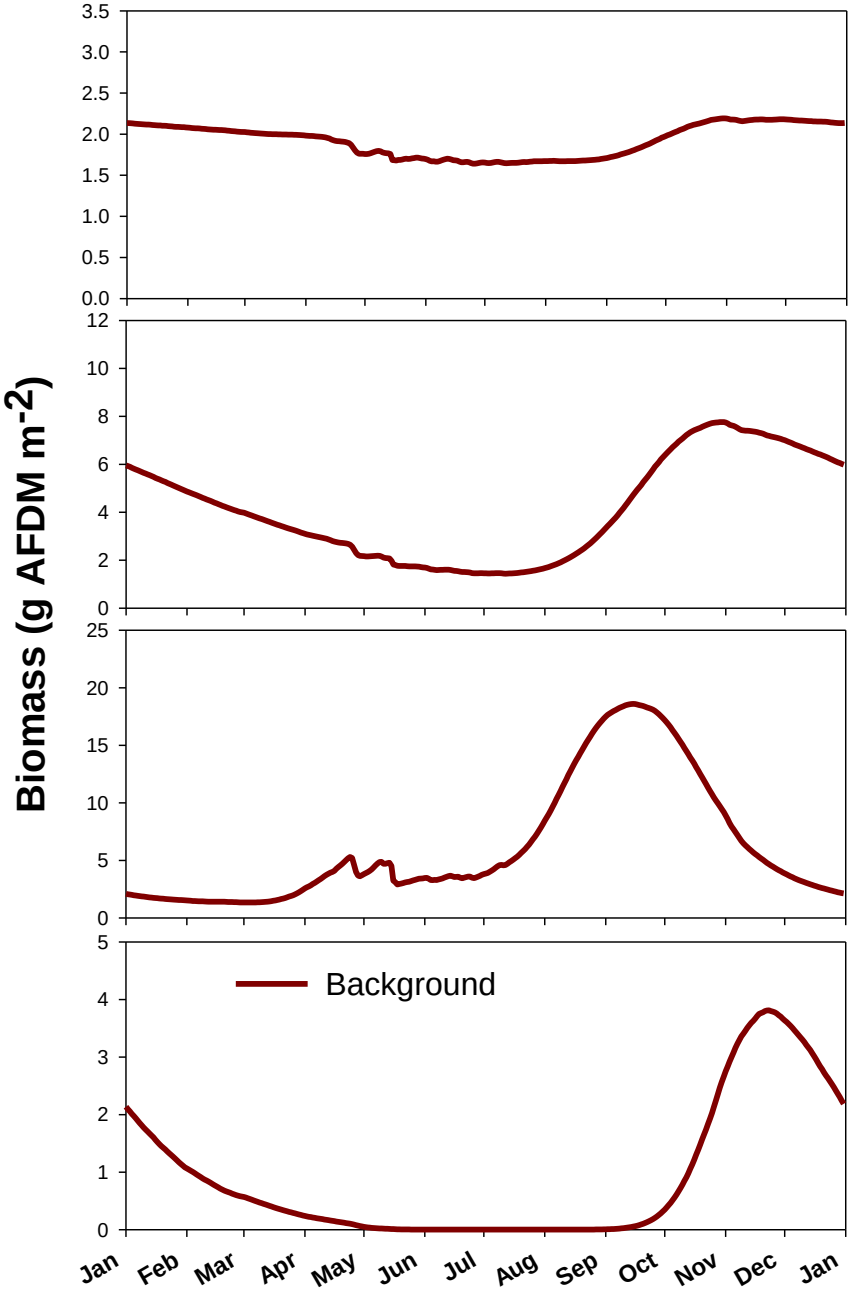
The floodplain food web mosaic: a study of its importance to salmon and steelhead with implications for their recovery

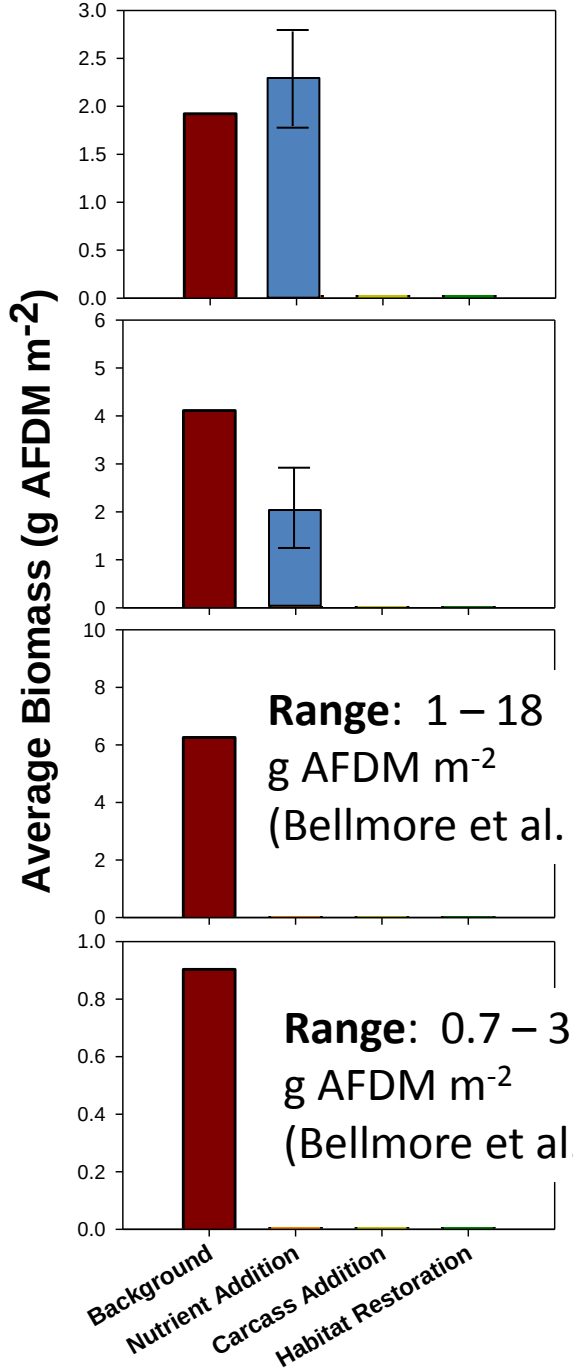
J. Ryan Bellmore,[1,2,3] Colden V. Baxter,[2] Kyle Martens[1] and Patrick J. Connolly[1]











Range: 1 – 18 g AFDM m^{-2} (Bellmore et al. 2012)

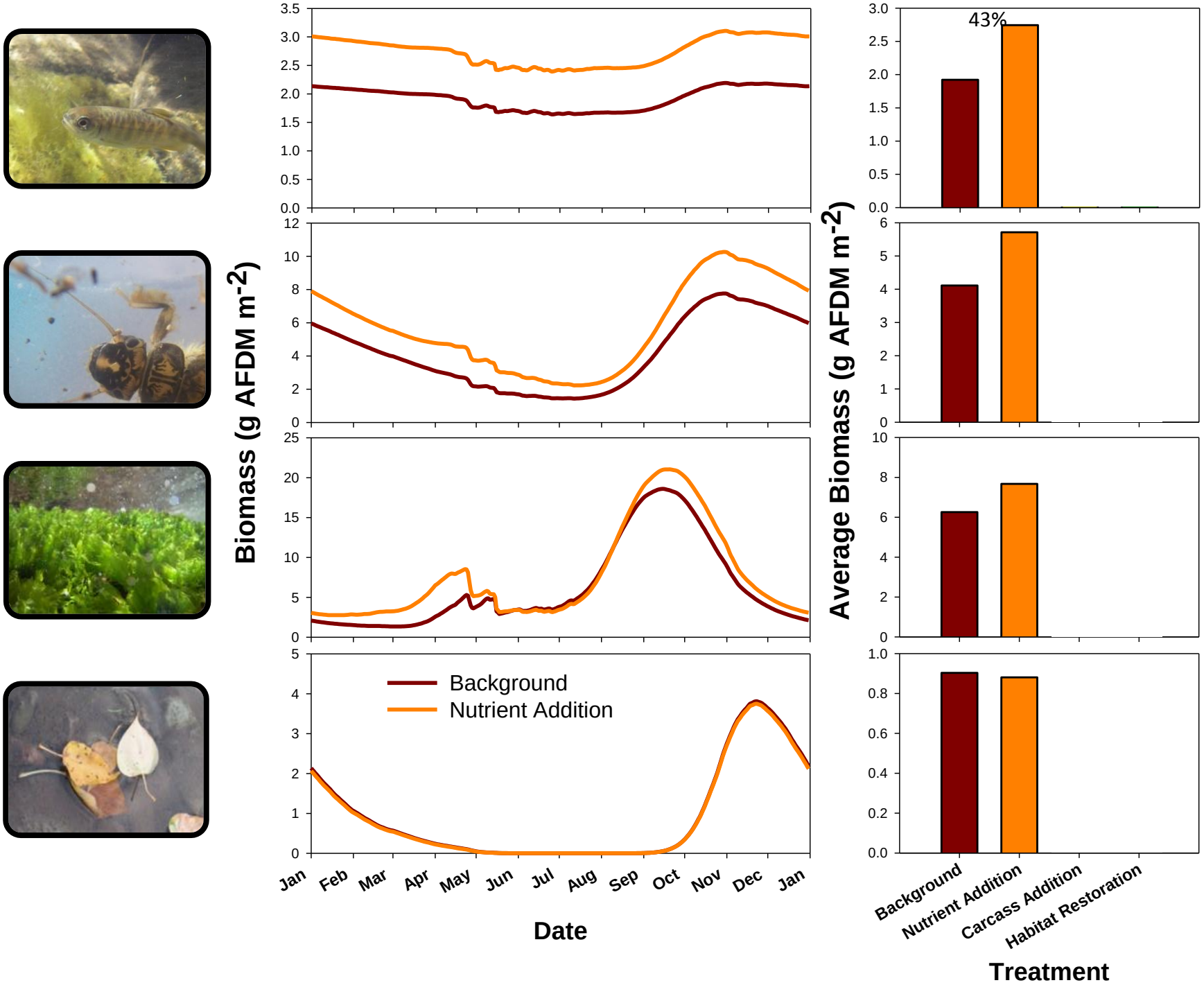
Range: 0.7 – 33 g AFDM m^{-2} (Bellmore et al. 2012)

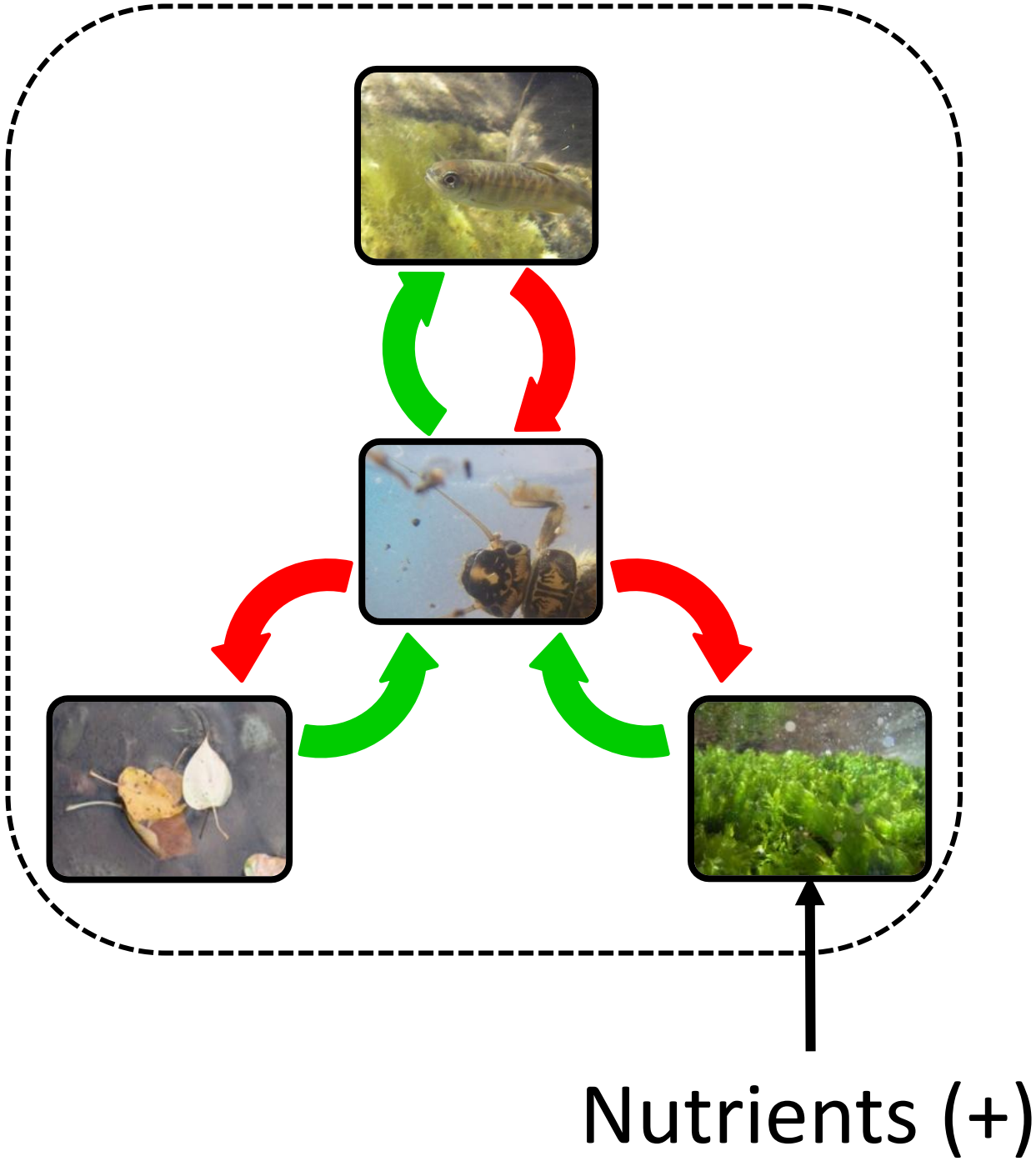
Model Test: Methow River

Simulations:

2. Nutrient Addition (phosphorus)

- 2 kg of orthophosphate (PO_4) daily
- Raises dissolved phosphorus concentration (SRP) by approx. 50%


Biomass (g AFDM m-2)
Average Biomass (g AFDM m-2)
43%
Background
Nutrient Addition
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Date
Background
Nutrient Addition
Carcass Addition
Habitat Restoration
Treatment

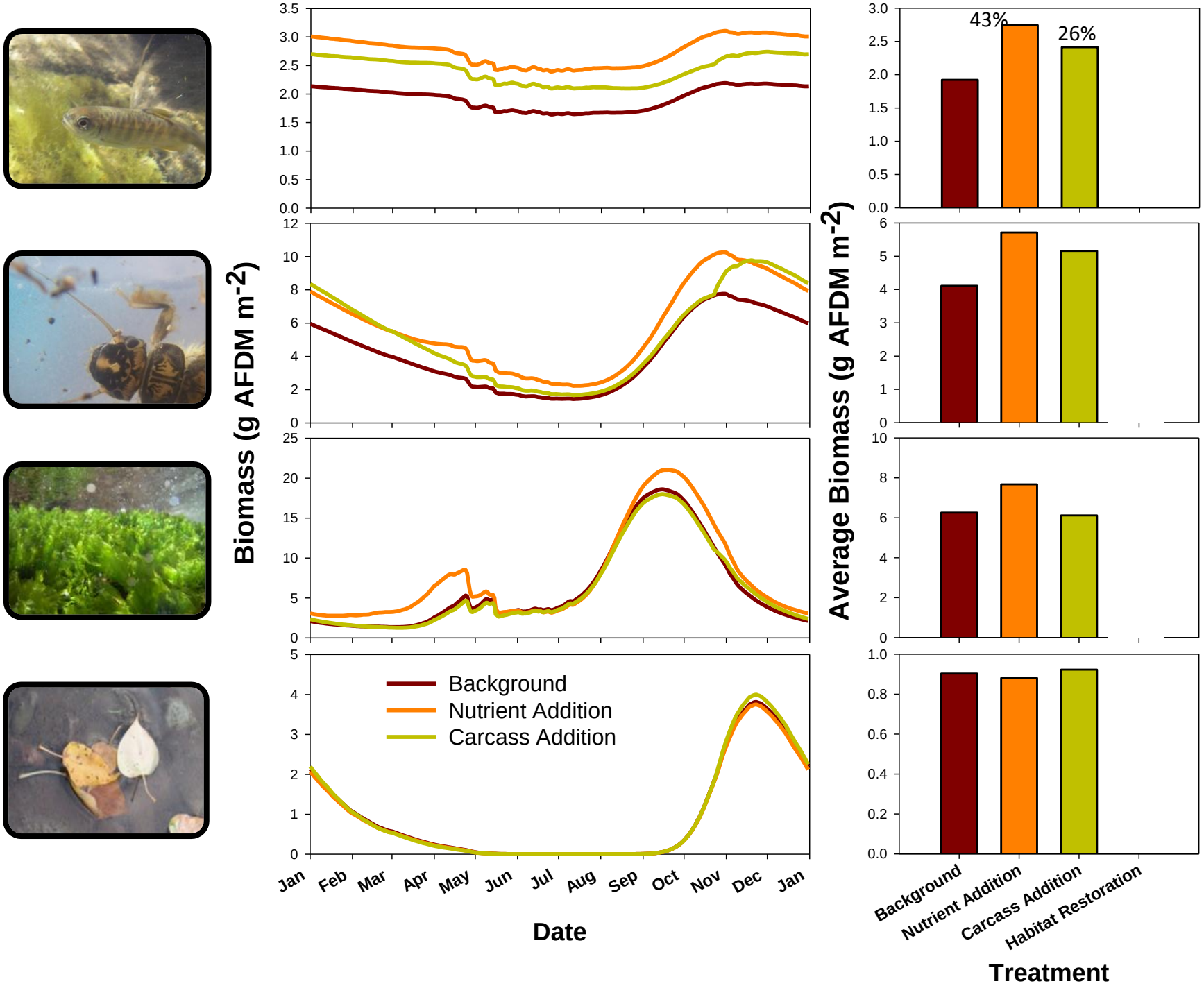

Nutrients (+)

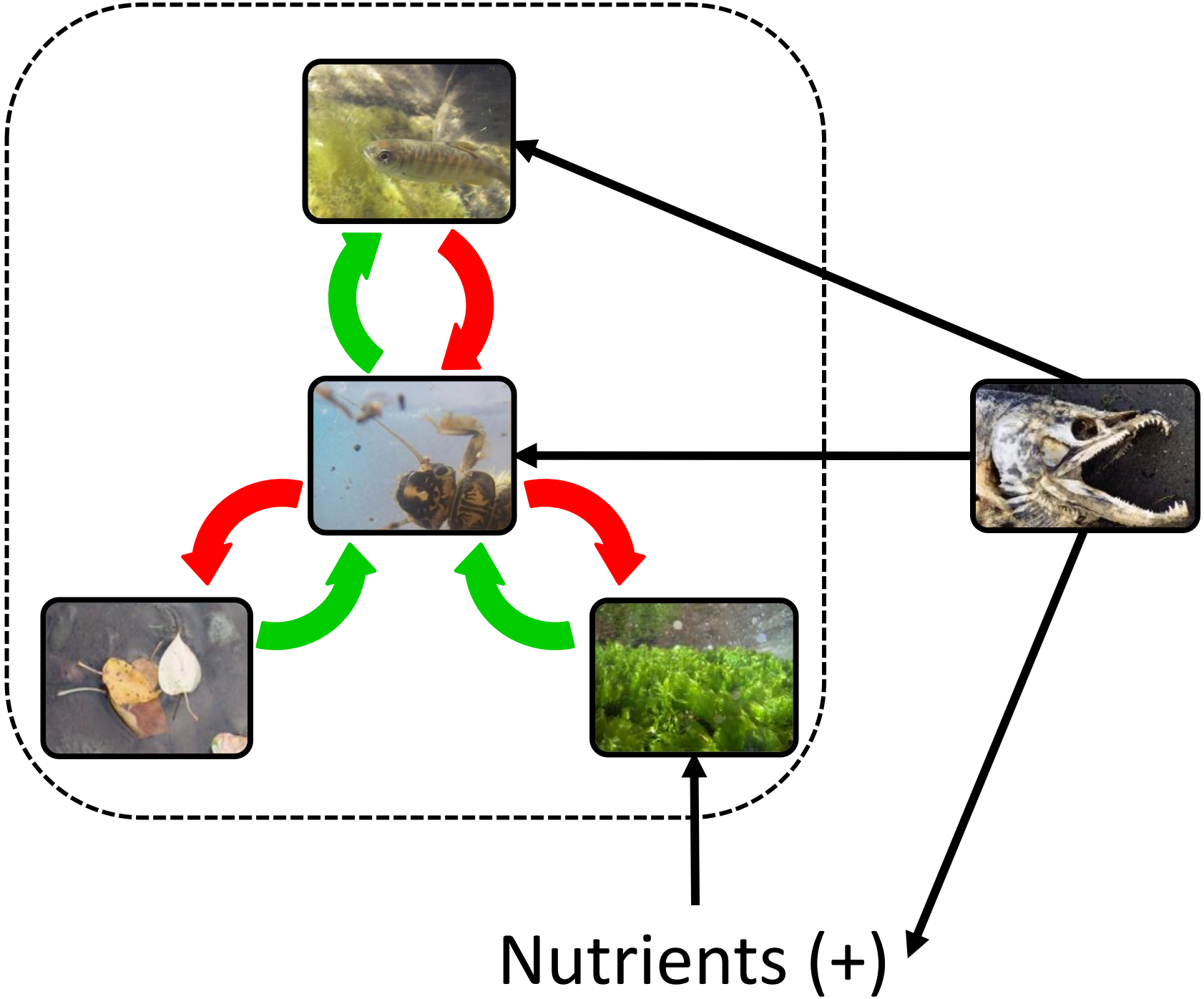
Model Test: Methow River

Simulations:

3. Salmon Carcass Addition

- 10,000 carcasses added to segment
- 0.01 carcasses / meter^2


Biomass (g AFDM m-2)
Average Biomass (g AFDM m-2)
43%
26%
Background
Nutrient Addition
Carcass Addition
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Date
Background
Nutrient Addition
Carcass Addition
Habitat Restoration
Treatment

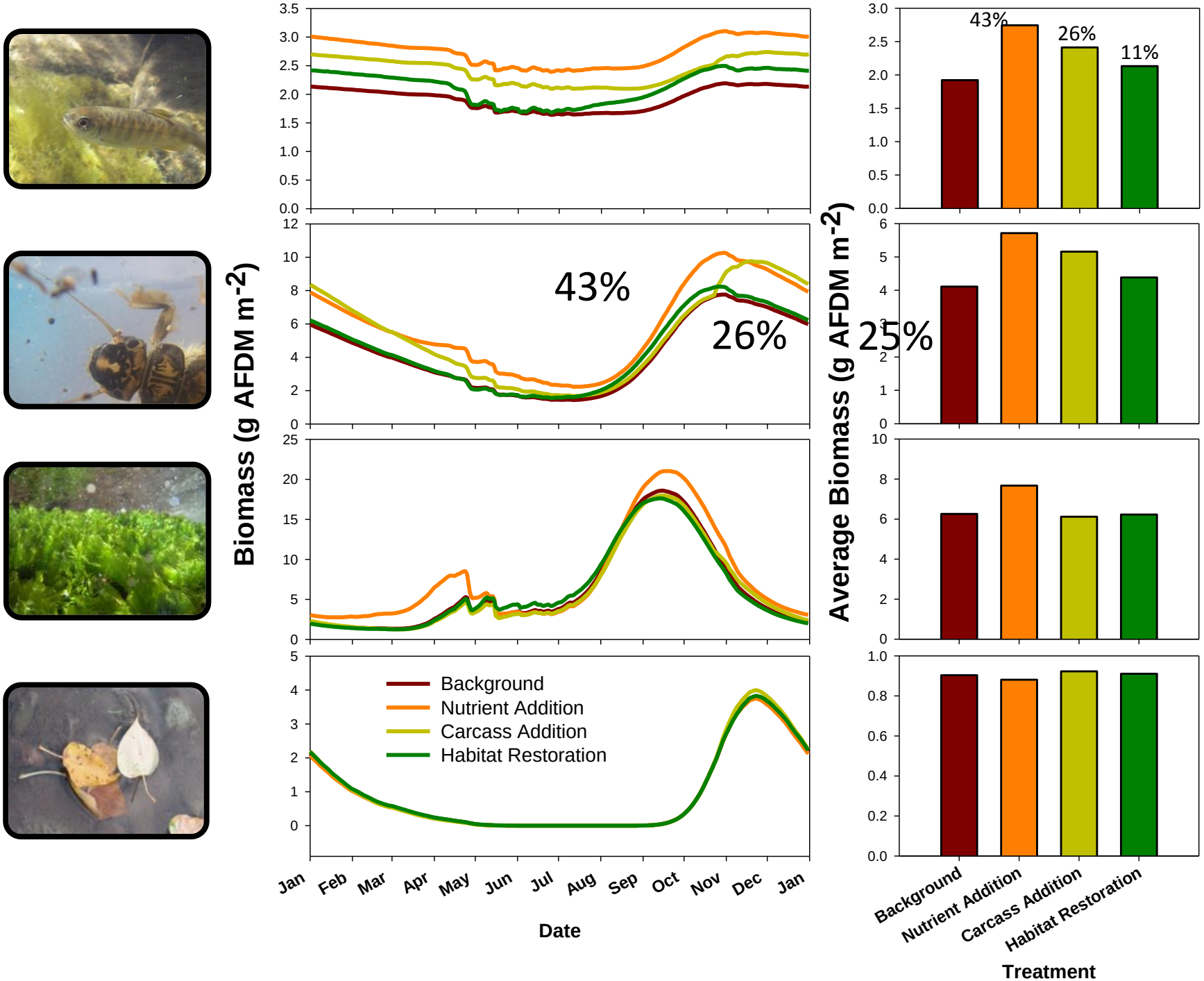

Nutrients (+)

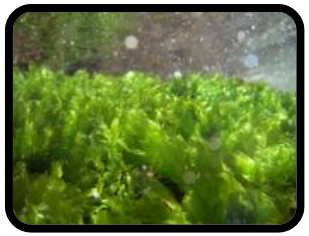
Model Test: Methow River

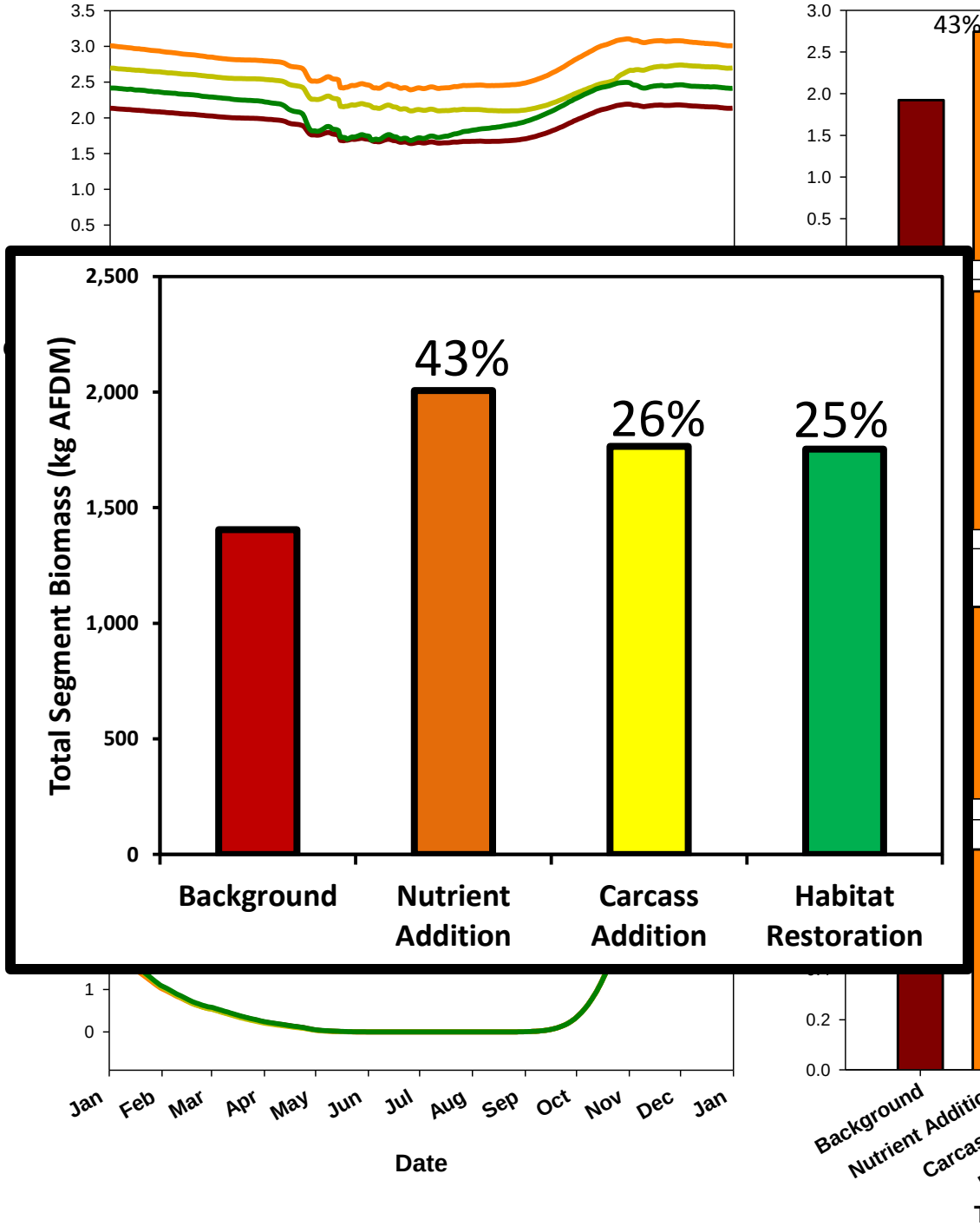
Simulations:

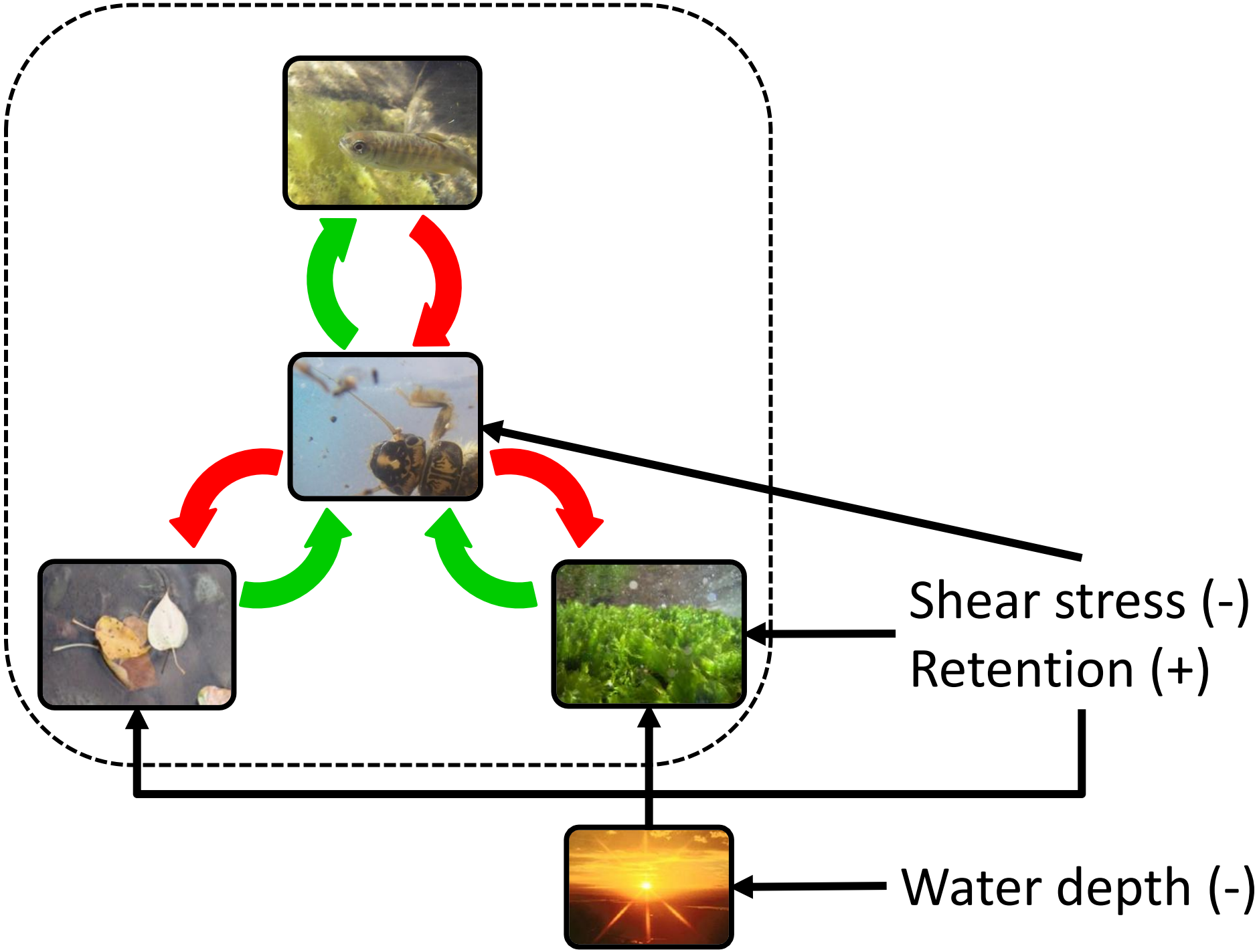
4. Habitat Restoration (floodplain restoration)

- increase bankfull width (20%)
- decrease bankfull depth (20%)
- increase total floodplain width (50%)
- decrease stream gradient (20%)


Biomass (g AFDM m-2)
Average Biomass (g AFDM m-2)
43%
26%
11%
43%
26%
25%
Background
Nutrient Addition
Carcass Addition
Habitat Restoration
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Date
Treatment



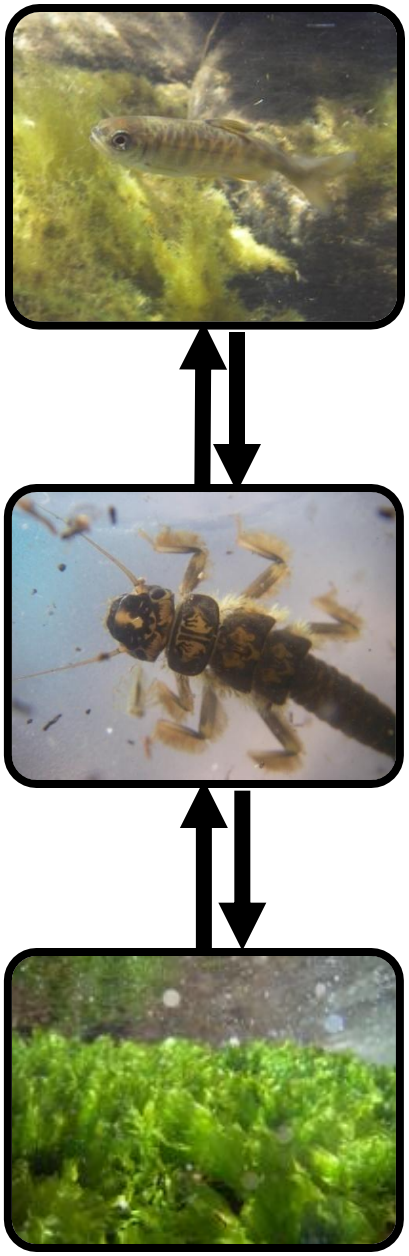

3.5
3.0
2.5
2.0
1.5
1.0
0.5
1
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Date
43%
26%
11%
0.2
0.0
Background
Nutrient Addition
Carcass Addition
Habitat Restoration
Treatment
2,500
2,000
1,500
1,000
500
0
Total Segment Biomass (kg AFDM)
43%
26%
25%
Background
Nutrient Addition
Carcass Addition
Habitat Restoration

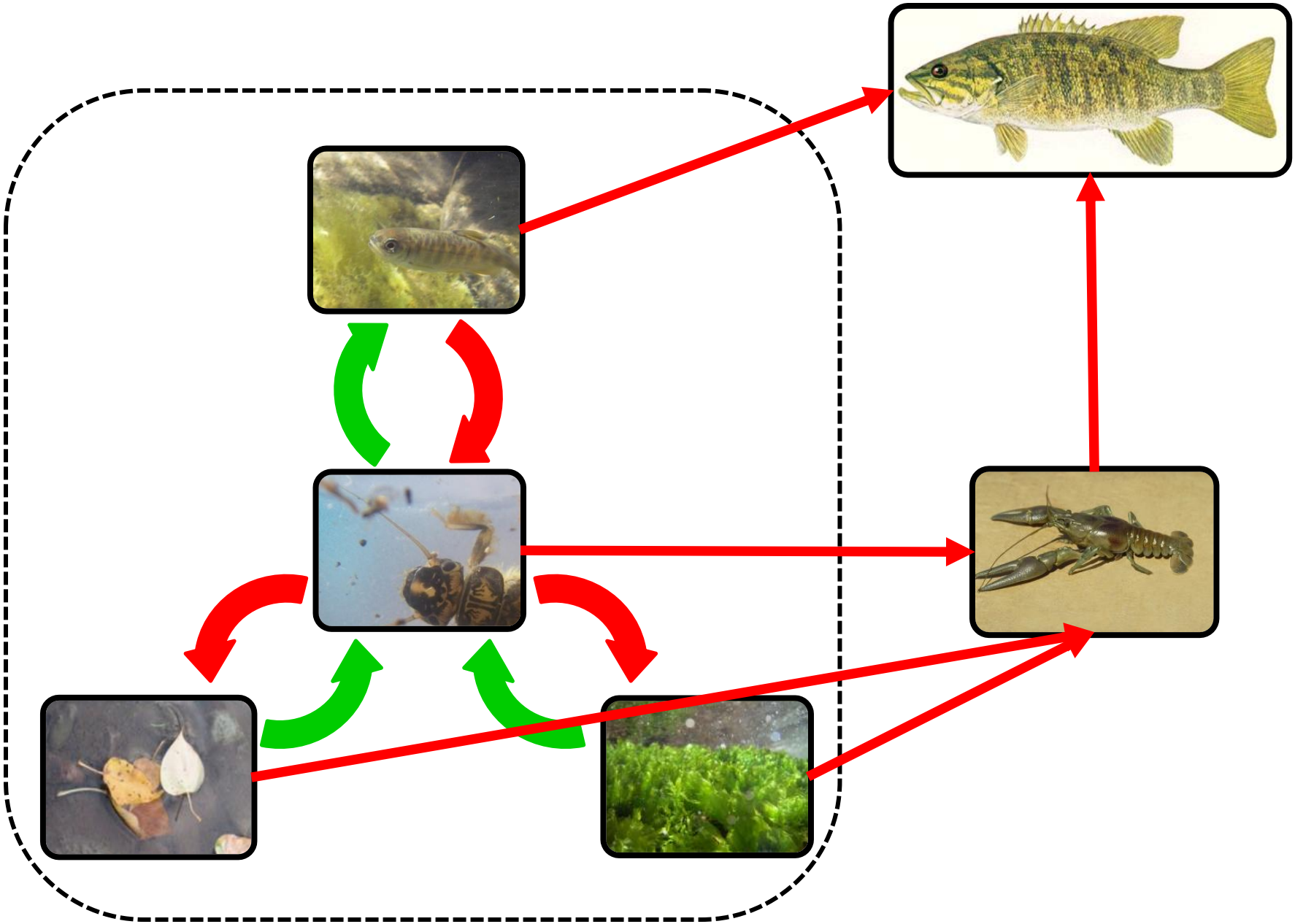

Shear stress (-)
Retention (+)
Water depth (-)

Summary

- The "*Trophic Productivity Model*" is a simplified food web model that *mechanistically* links trophic dynamics to physical habitat, riparian condition, and marine derived nutrients.

- Can be used to explore the potential outcomes of alternative restoration strategies:
  - Nutrient addition
  - Salmon carcass addition
  - Habitat restoration
  - Riparian planting, hatchery supplementation, etc.



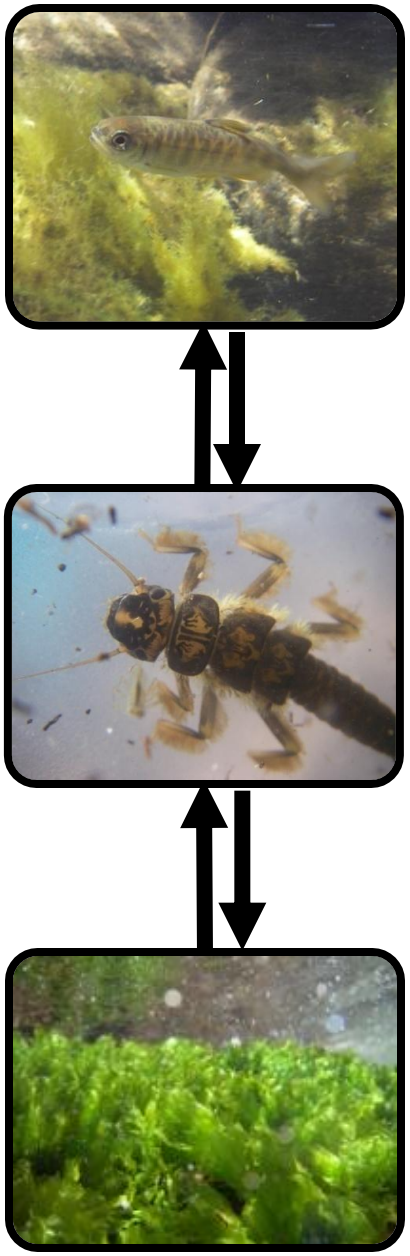


Summary

- Goes beyond the fish response. . .

- Can use this approach to explore how changes to the system modify ecosystem processes:
  - Primary production
  - Secondary invertebrate production
  - Organic matter dynamics
  - Ecosystem production and respiration

- How might salmon restoration modify the "heart beat" or the health of stream ecosystems?



Acknowledgements

-Andy Ford, Francine Mejia & Adrianne Zuckerman (Washington State University)

-John Jorgensen (Yakama Nation)

-Joe Benjamin (Quantitative Consultants)

-Russ Perry & Jason Romine (USGS)

-Dana Warren, Stan Gregory & Dave McIntire (Oregon State University)

-Colden Baxter & Scott Collins (Idaho State University)

-Funding and Support, Bureau of Reclamation