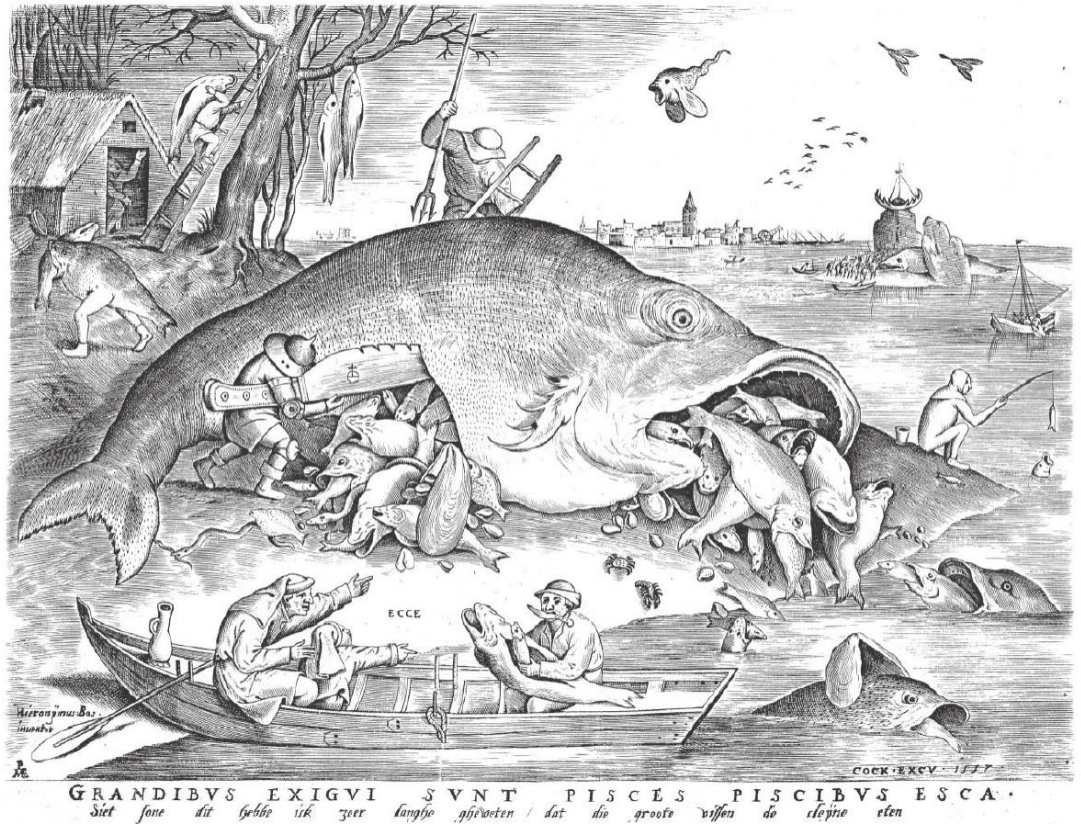
More than the Sum of the Parts: Integrating Nature's Complexity into Climate Change Impact Assessments



Ryan Bellmore and Rick Edward

Pacific Northwest Research Station, Forest Service, Juneau, AK

Nature‘s Complexity

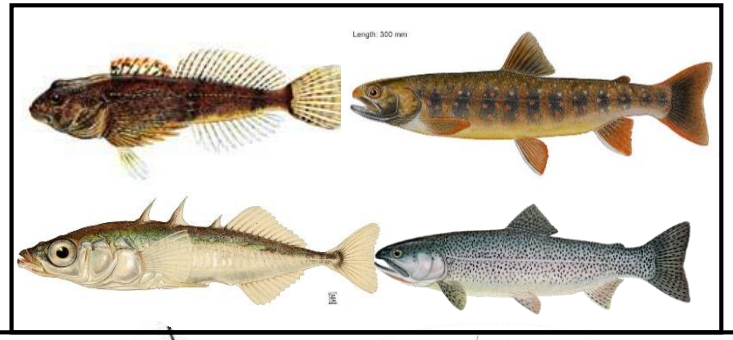
“I have yet to see any problem, however complicated, which, when looked at in the right way, did not become still more complicated.”

—Poul Anderson

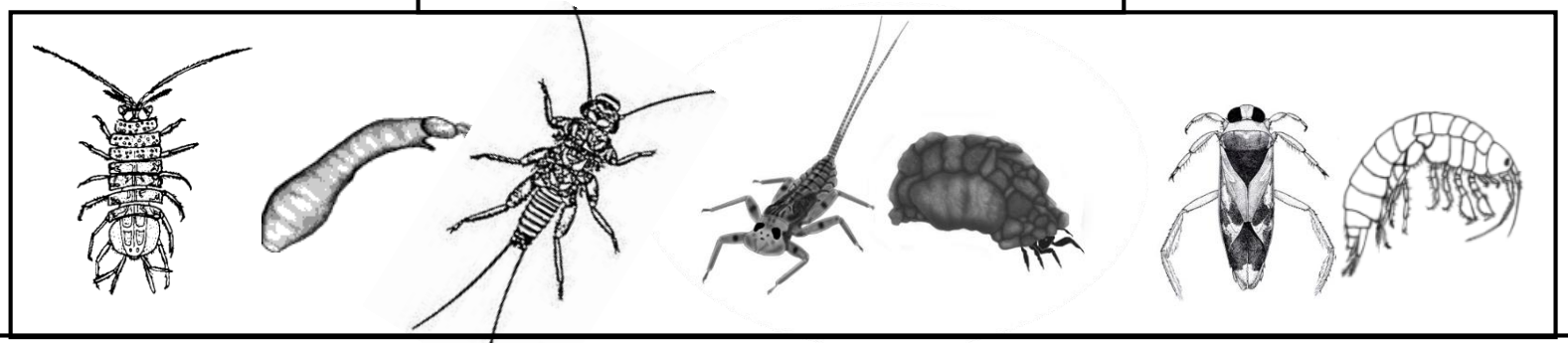
Nature‘s Complexity

Photo Credit: Jonny Armstrong

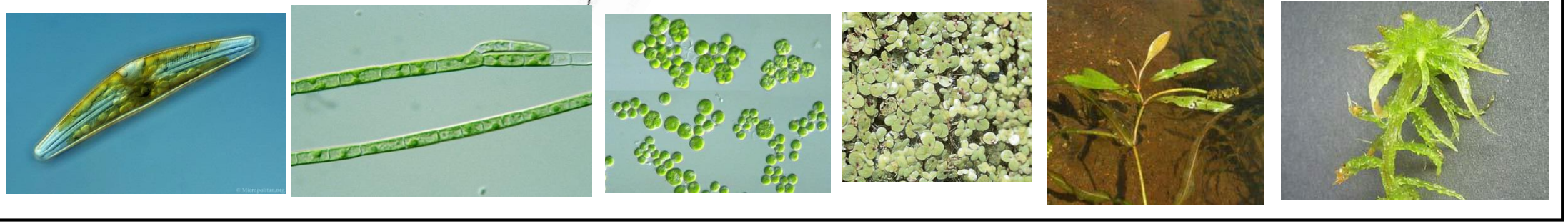
Nature‘s Complexity



10^1



10^2



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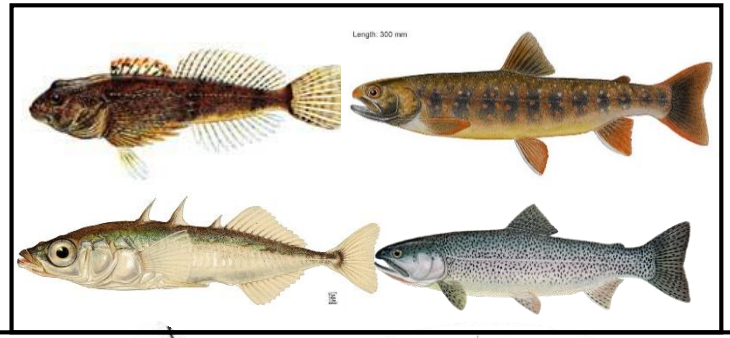
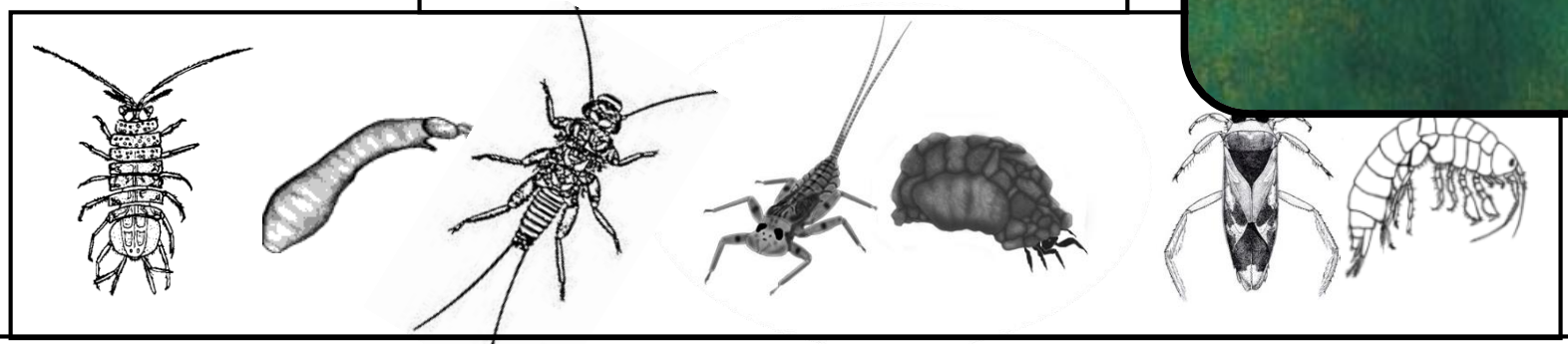
Nature‘s Complexity

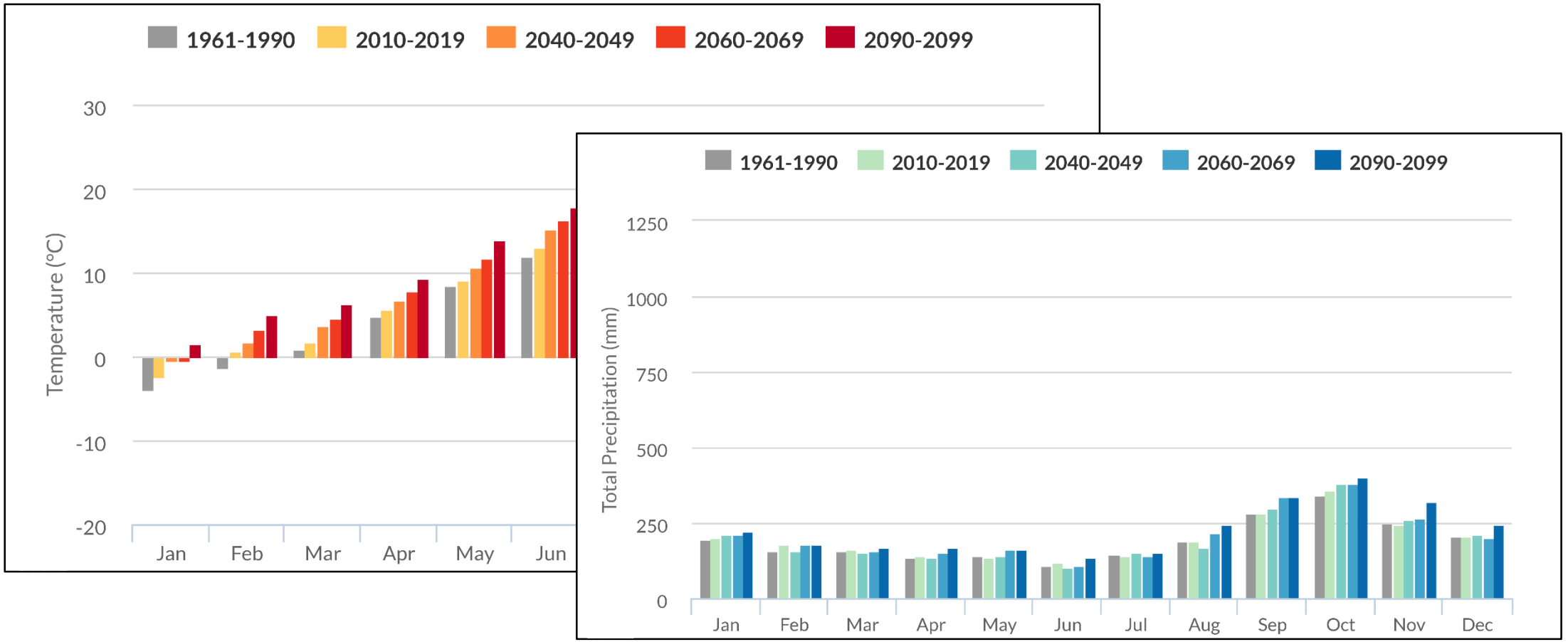




10^2

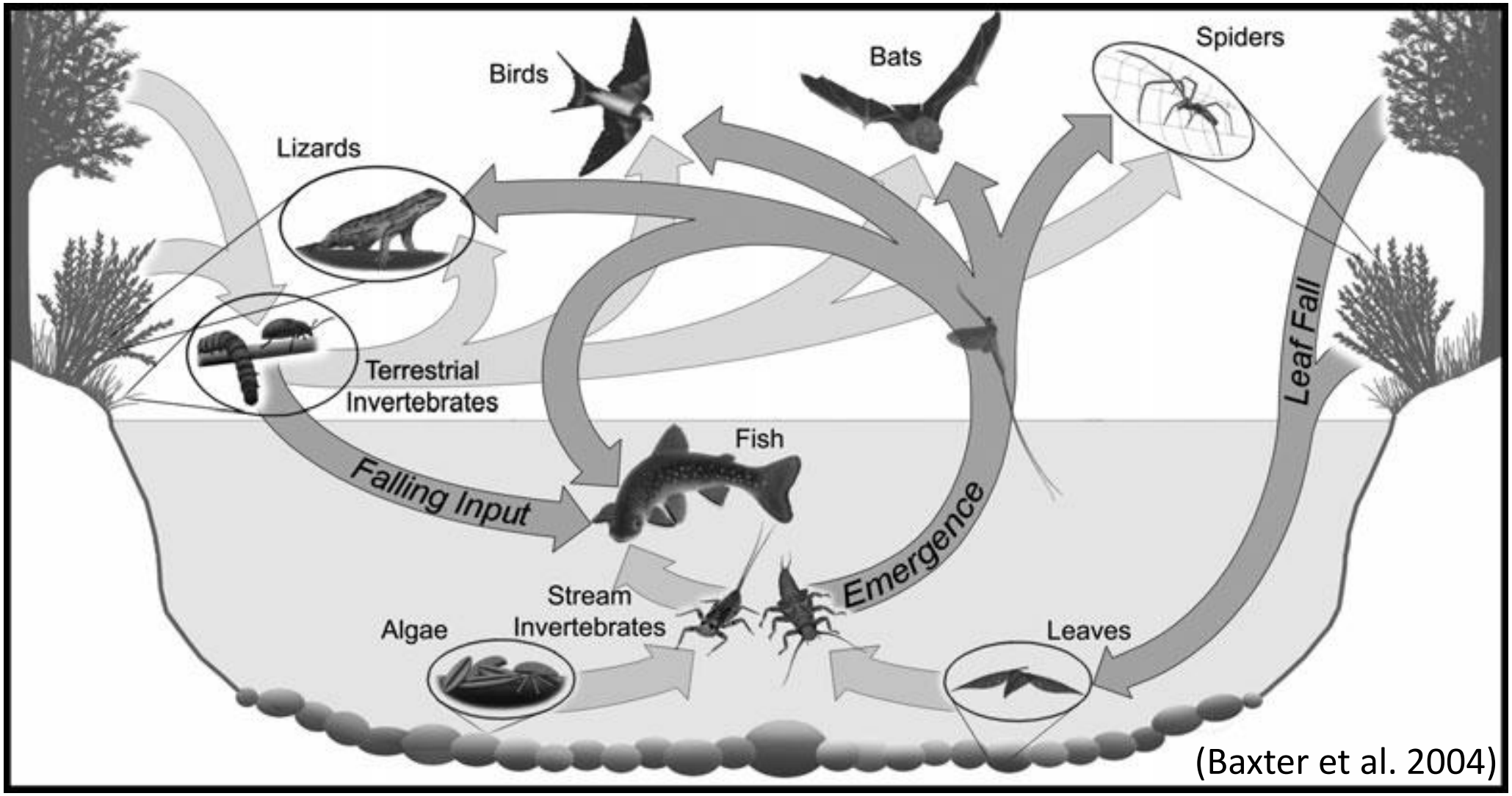
10^3

Climate Change Projections



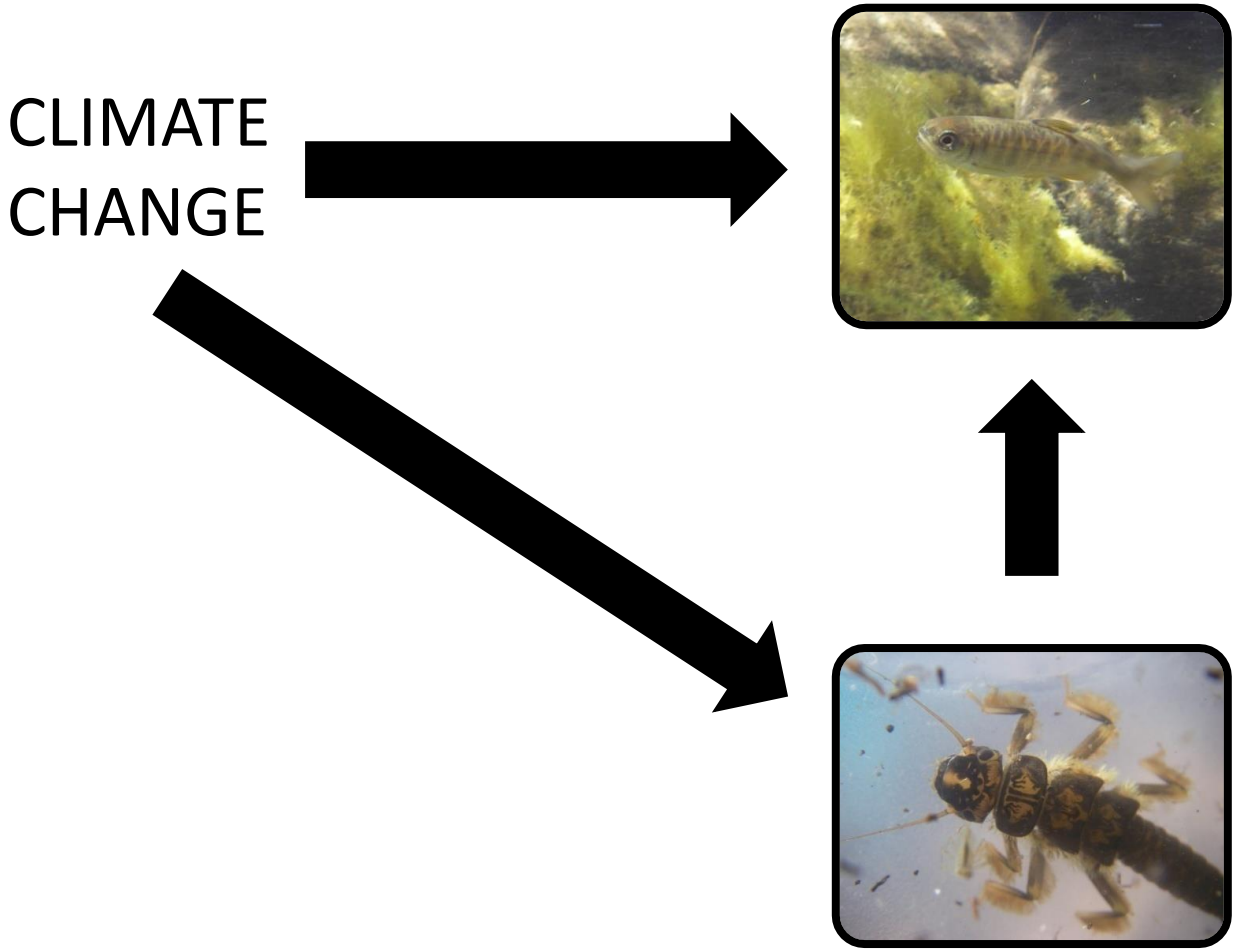
SNAP

Species Interactions and Climate Change



(Baxter et al. 2004)

Species Interactions and Climate Change

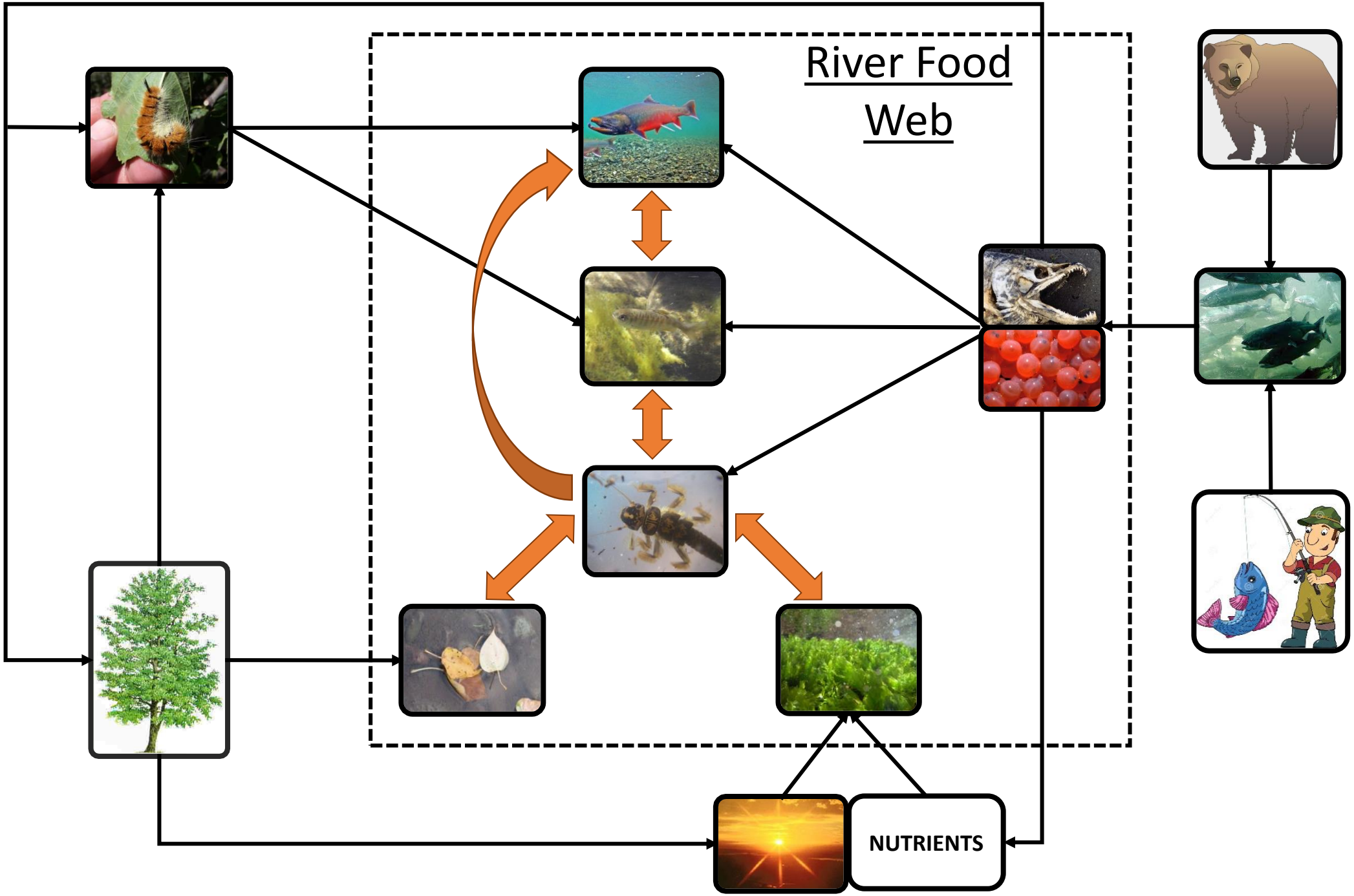


Outline

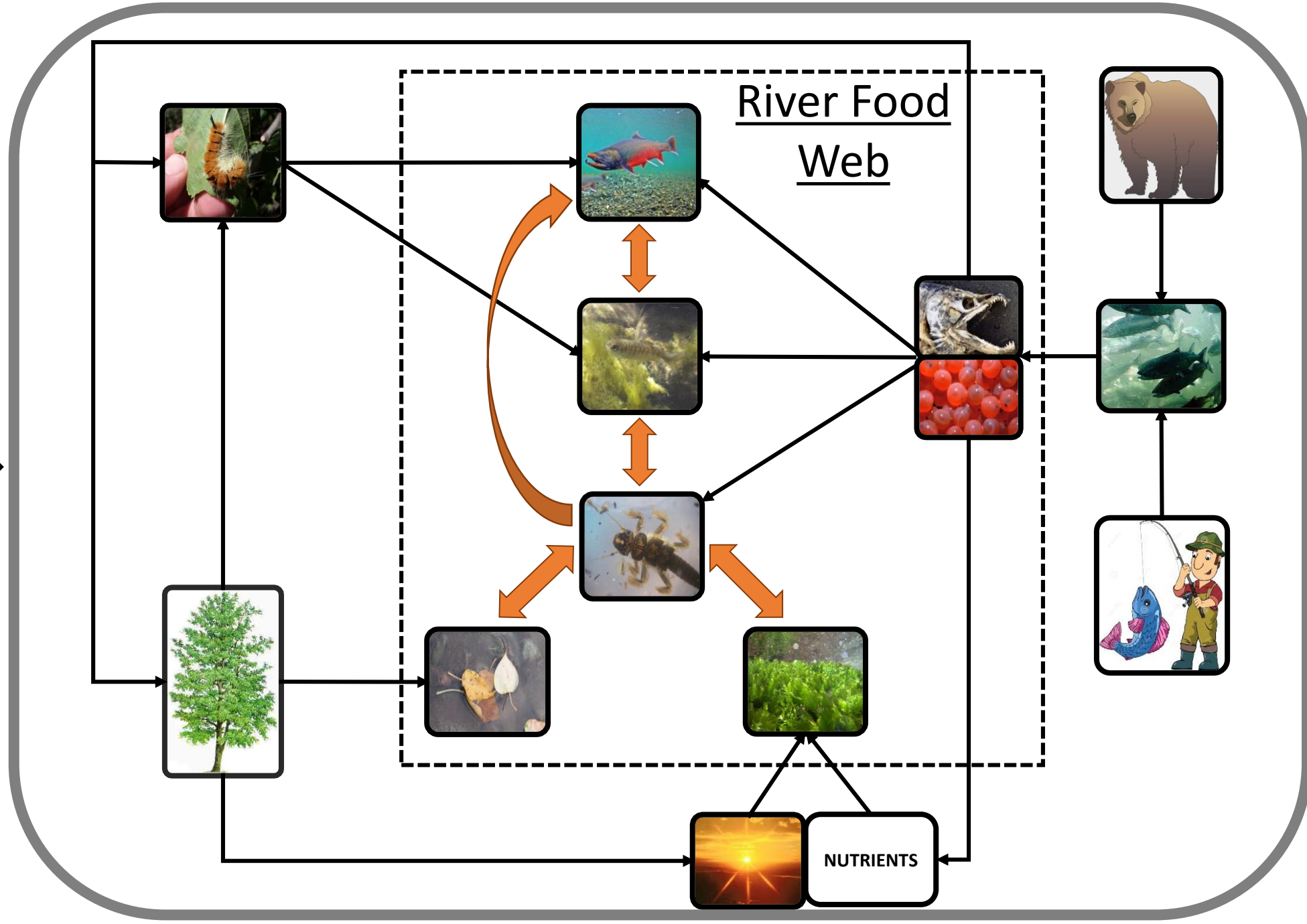
1) How do salmon fit within the larger freshwater ecosystem or food web, and how might climate change influence these webs?

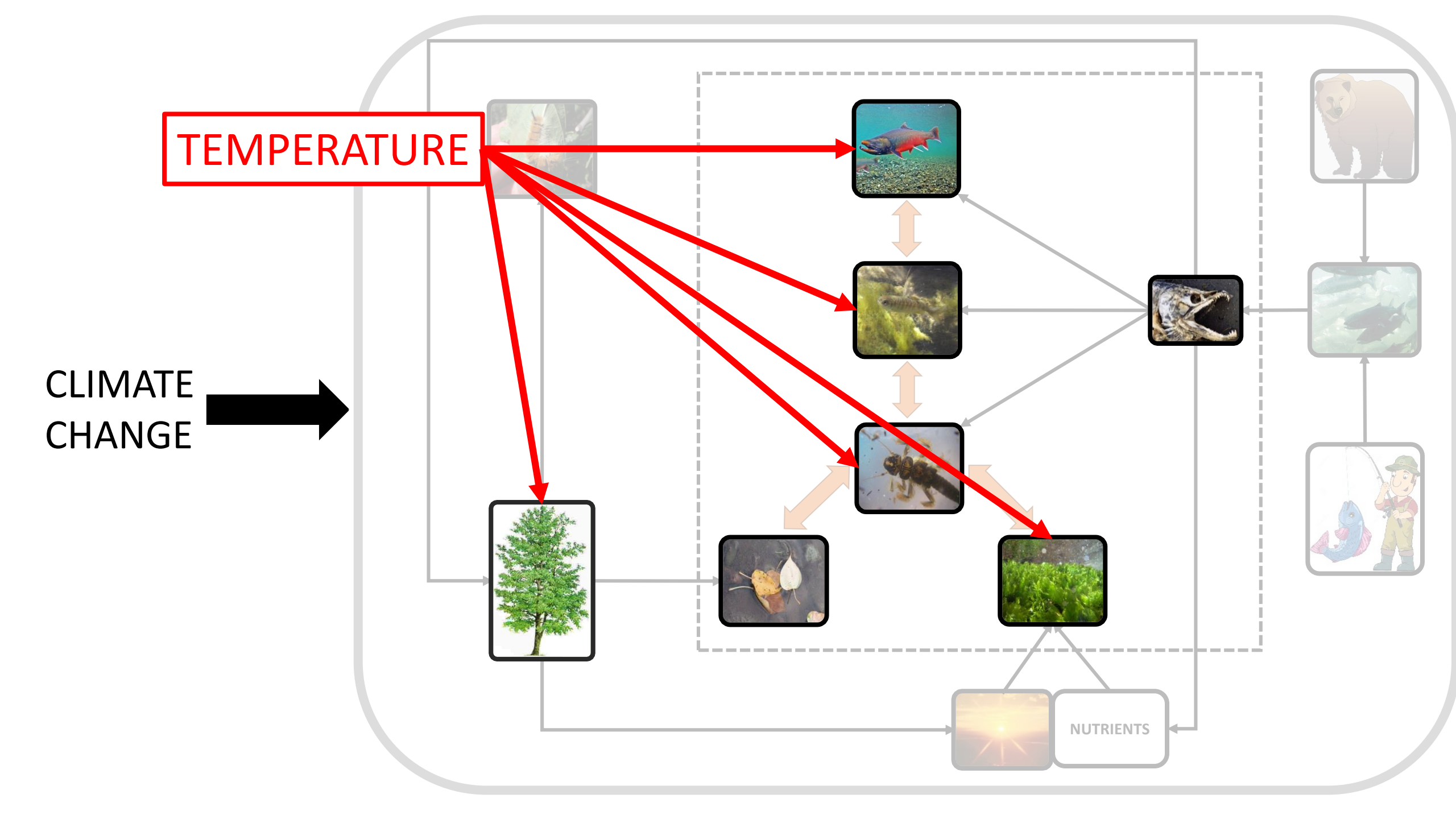
1) What approaches exist for understanding these complex interactions and projecting climate change influences?

2) What are the guiding principles for managing for this complexity in the face of climate change?

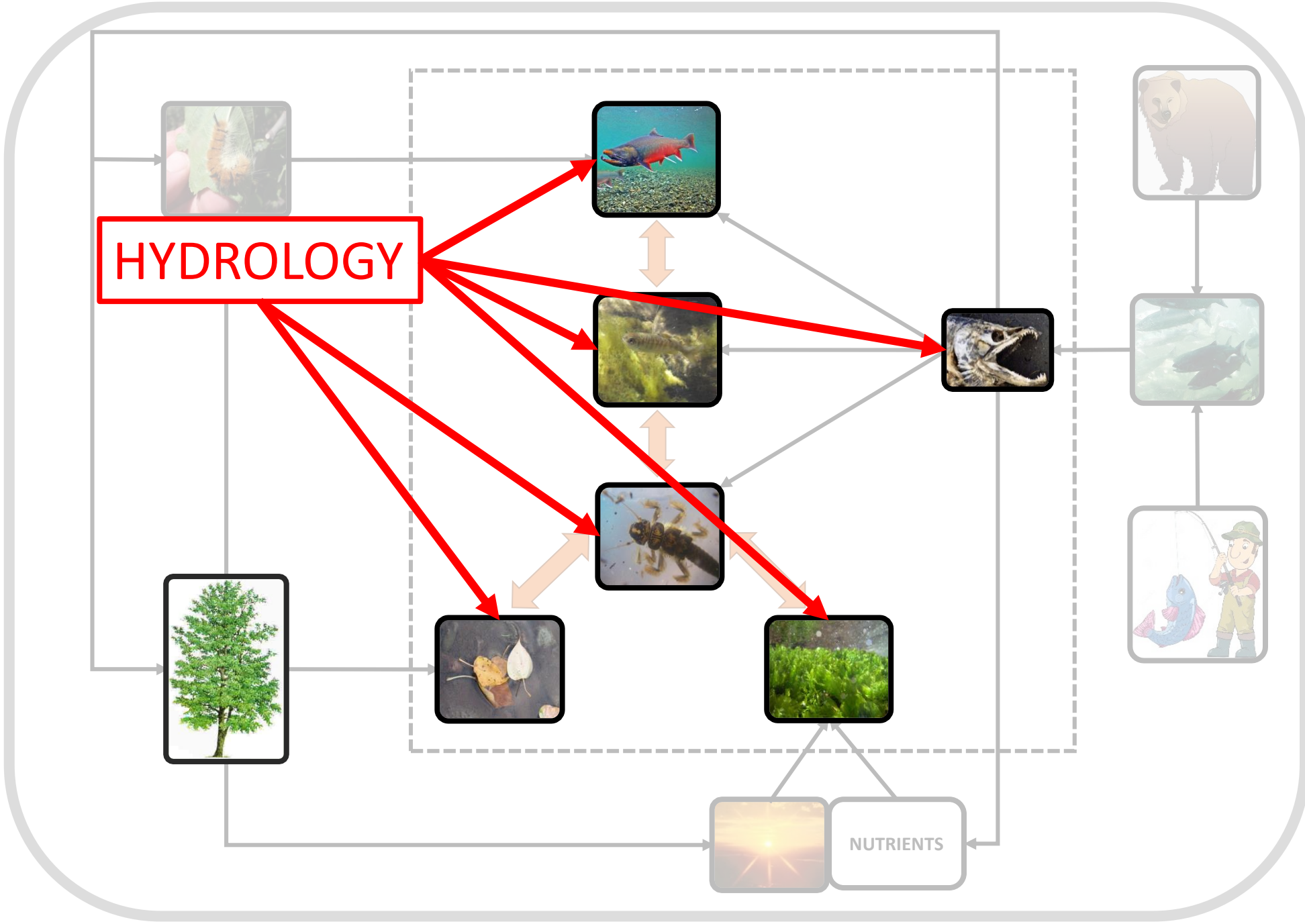

River Food Web
NUTRIENTS

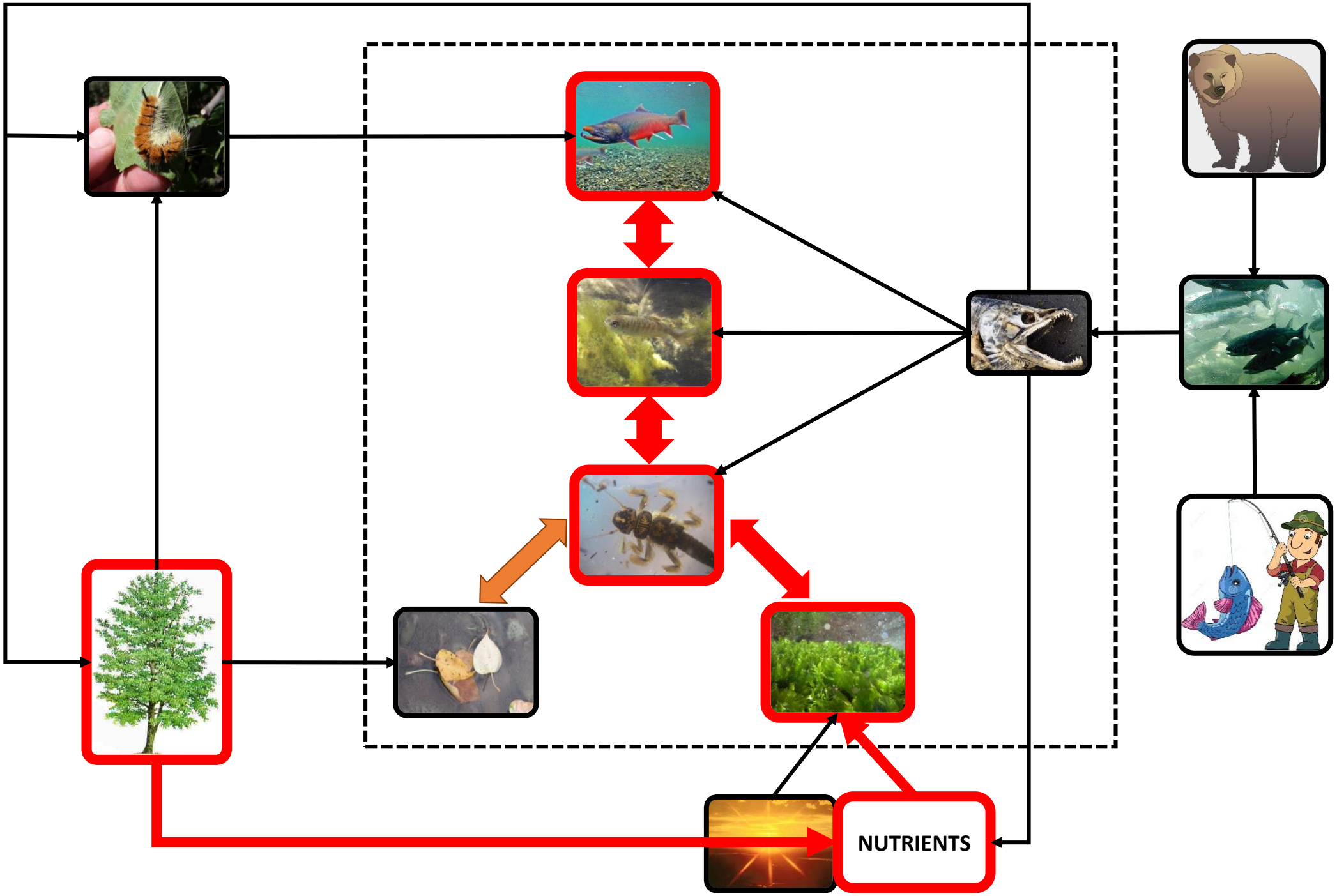
CLIMATE CHANGE




TEMPERATURE
CLIMATE
CHANGE
NUTRIENTS

CLIMATE CHANGE




NUTRIENTS

Outline

1) How do salmon fit within the freshwater food web, and how might climate change influence these webs?

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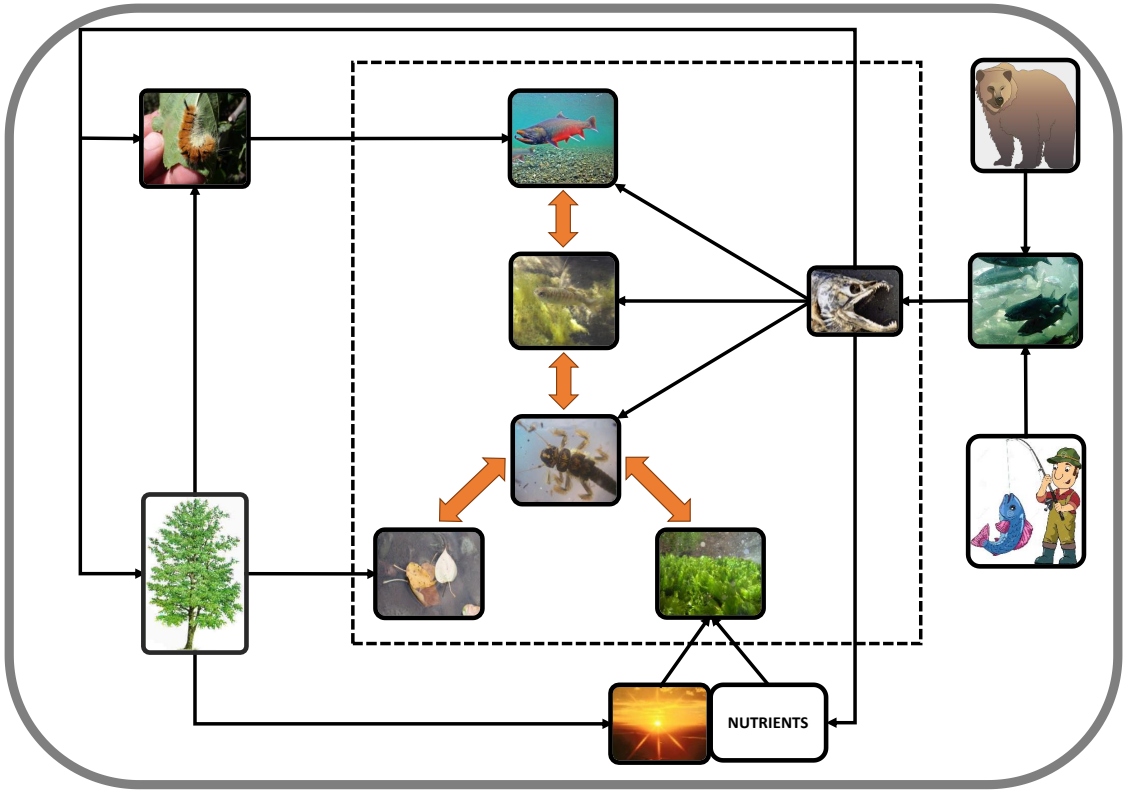
Modeling Approaches

Conceptual Model



Mathematical Model

$$\frac{dBiomass}{dt} = Assimilation - (Respiration + Predation + Mortality)$$

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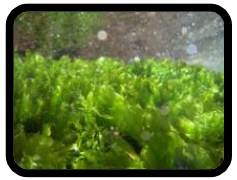
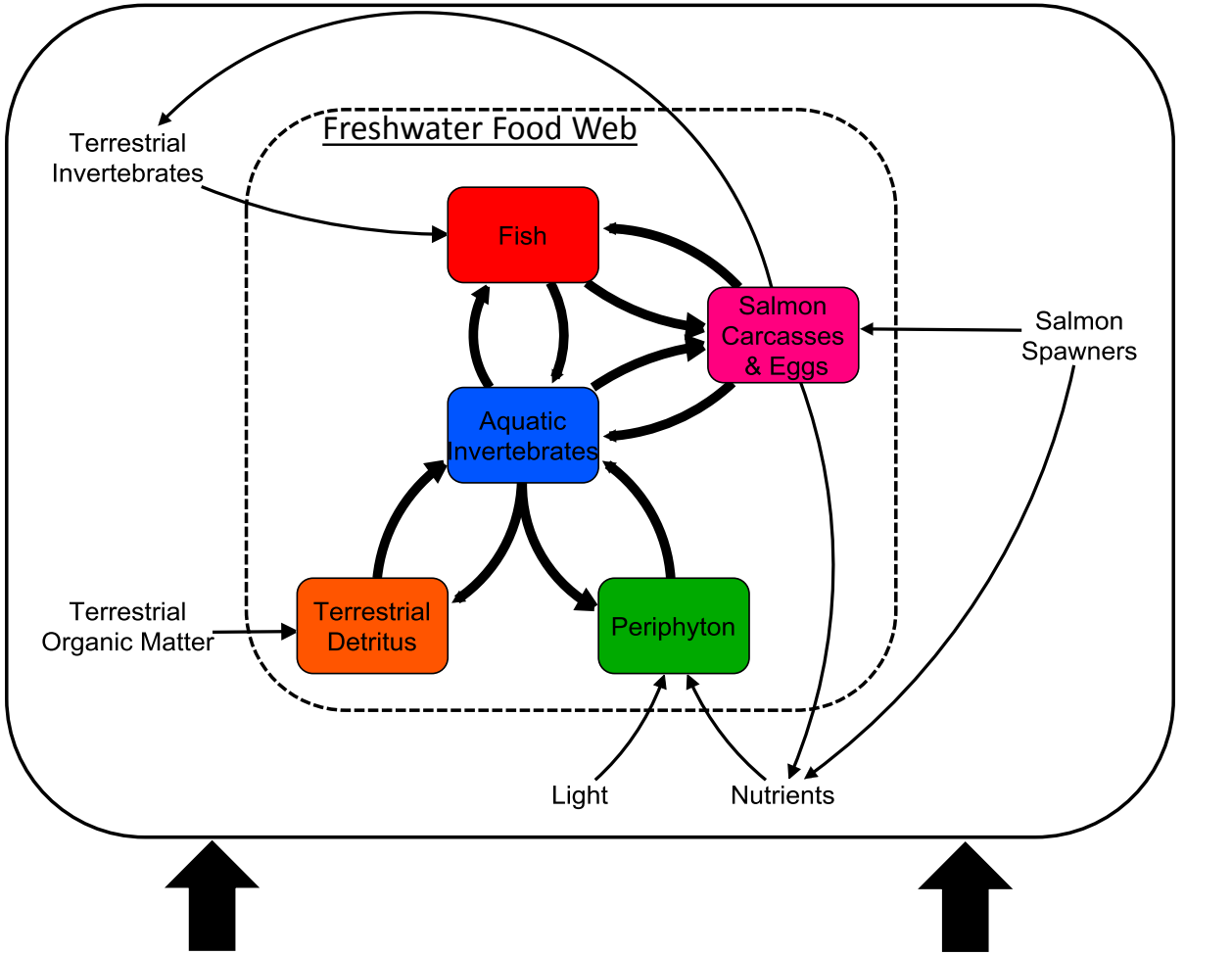


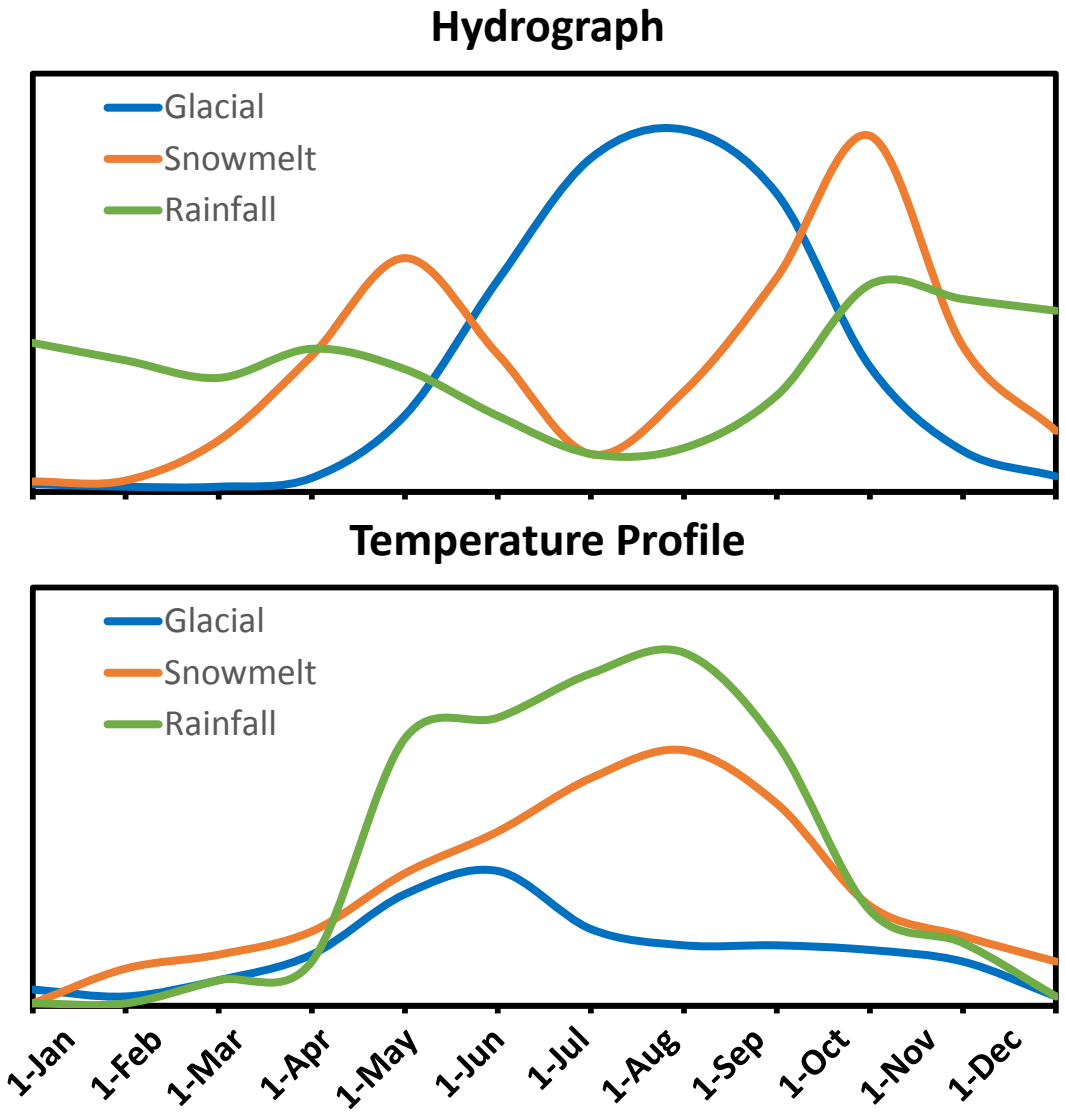
$$\frac{dBiomass}{dt} = Production - (Respiration + Predation + Mortality)$$

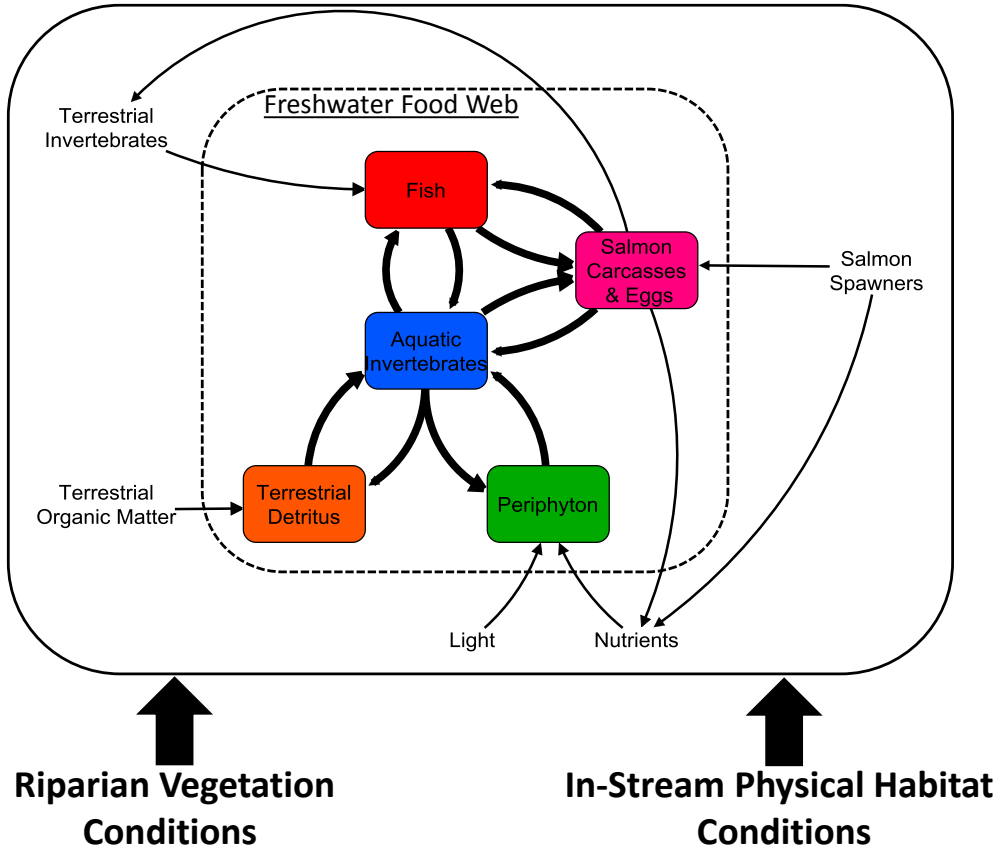
Modeling Approaches



(Bellmore & Benjamin, In Review)

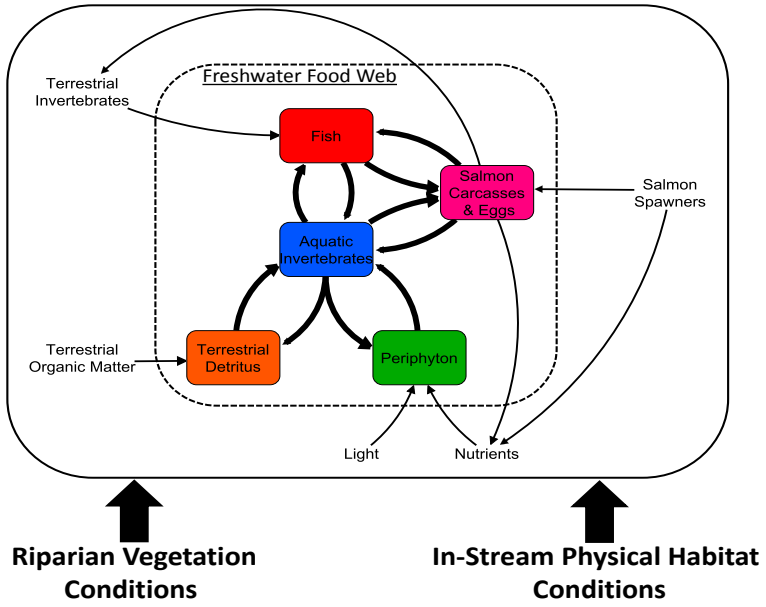
Modeling Approaches

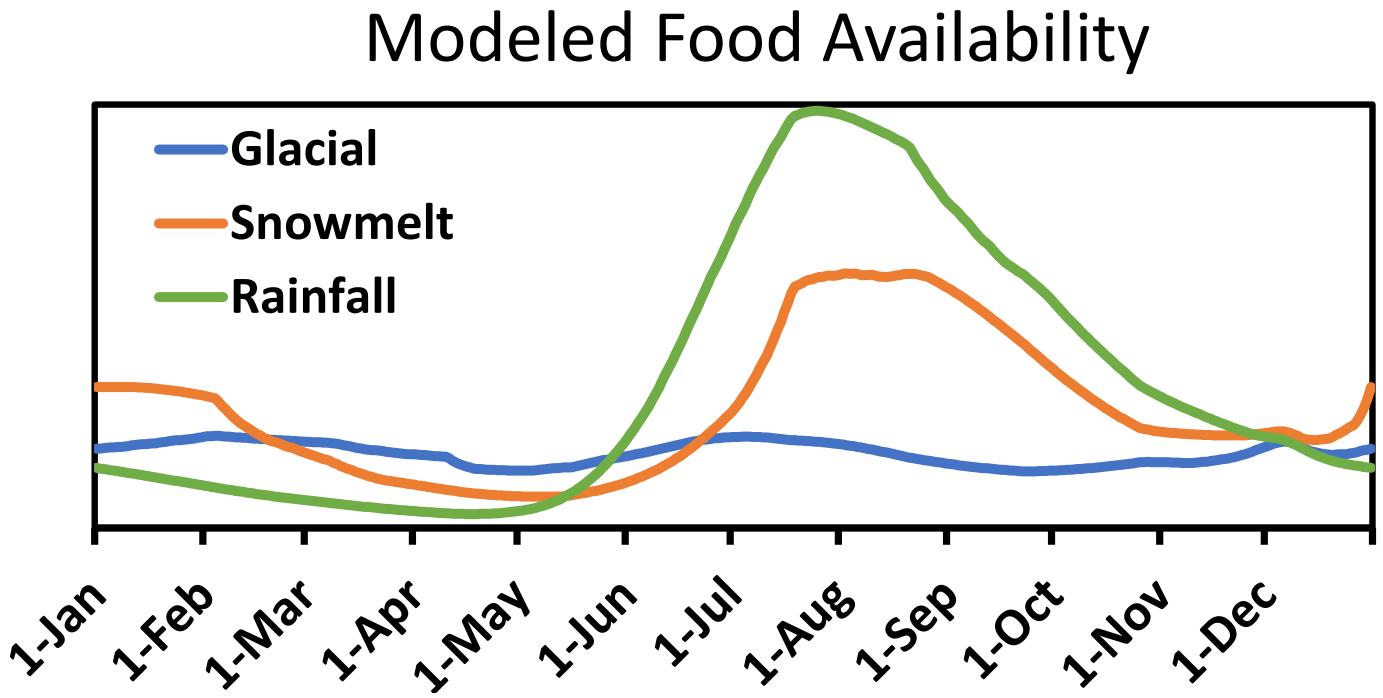


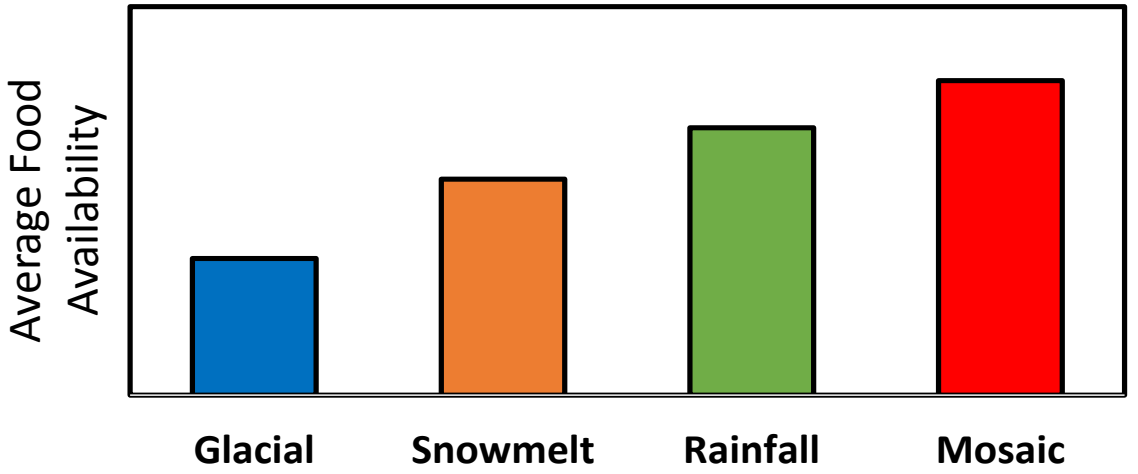


(Edwards et al. 2013, Shanley et al. 2015)

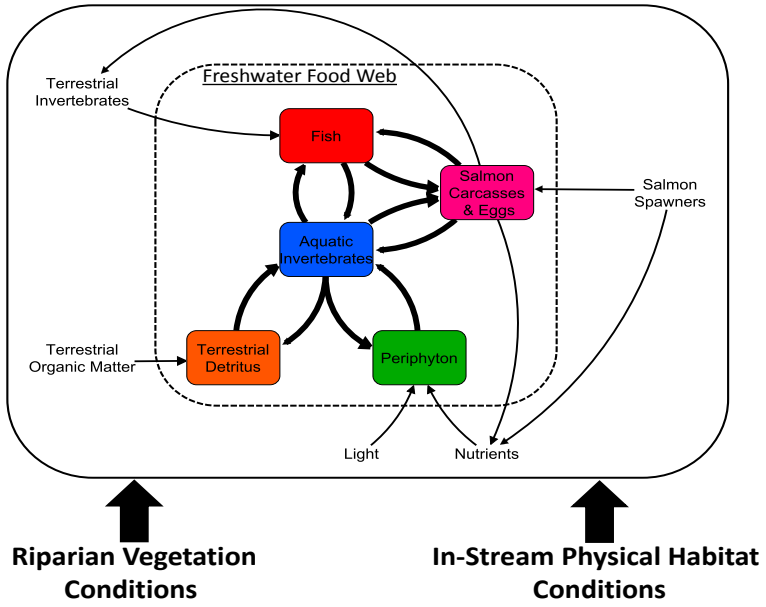
Modeling Approaches

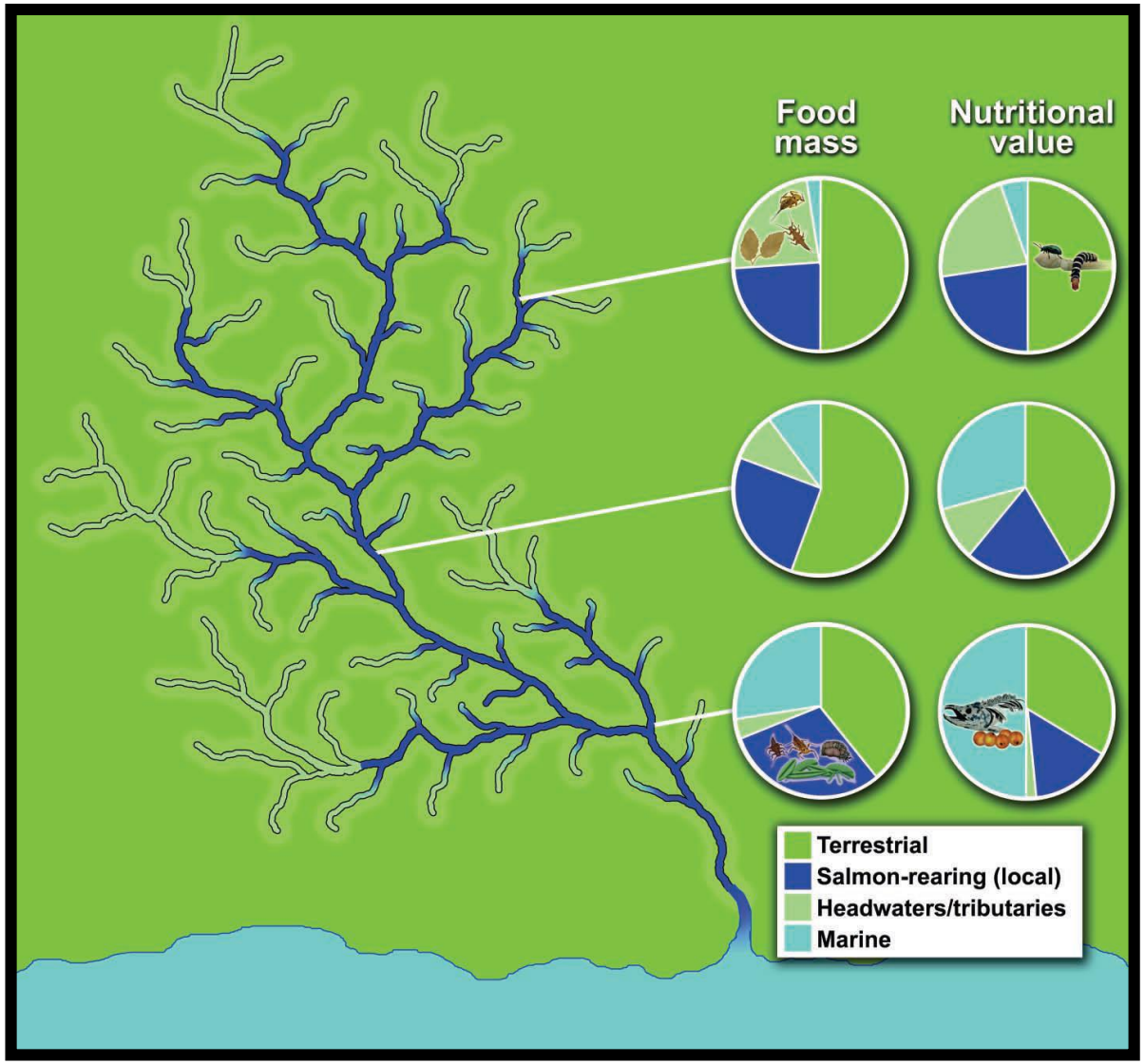






Modeling Approaches

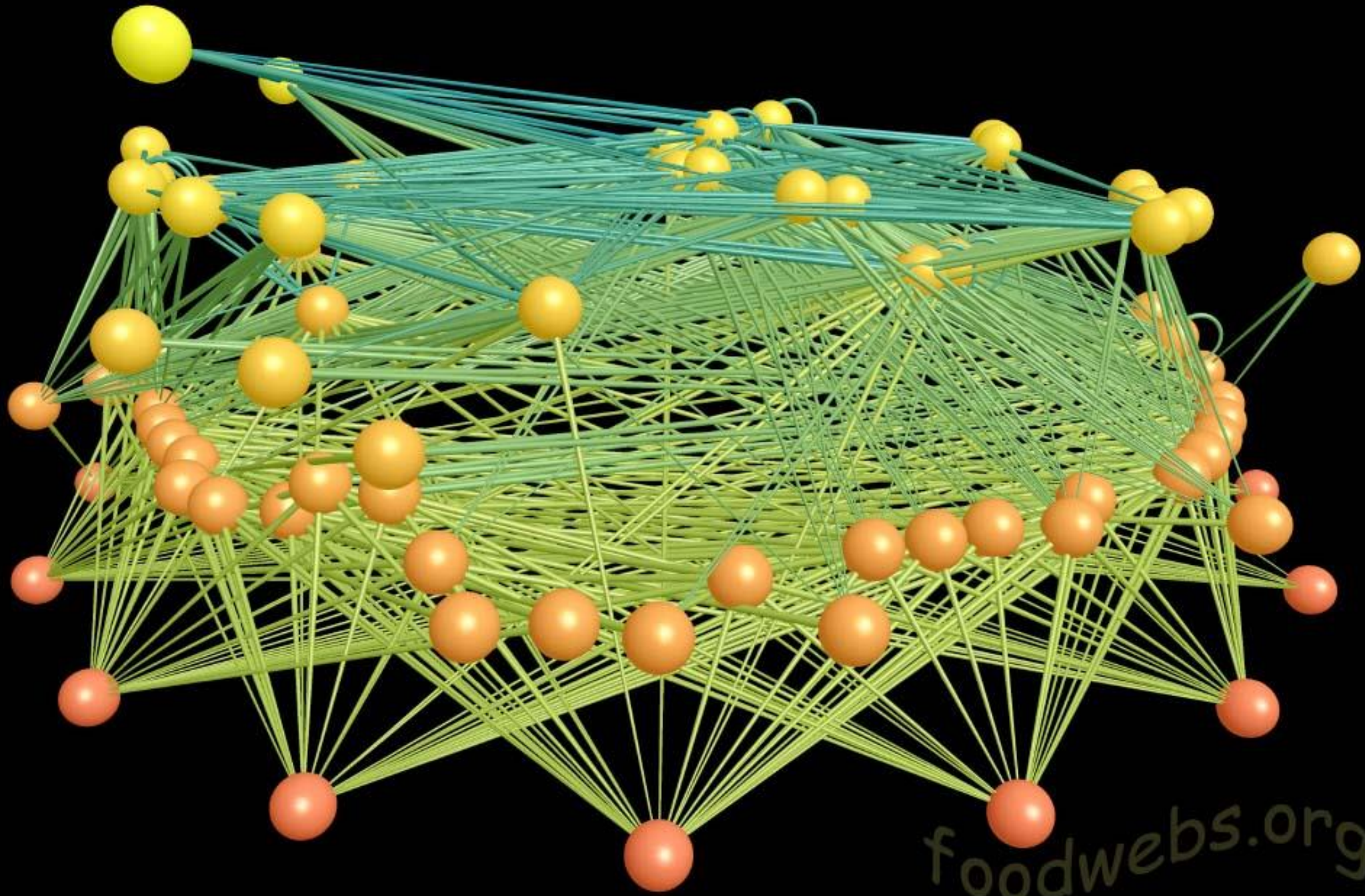




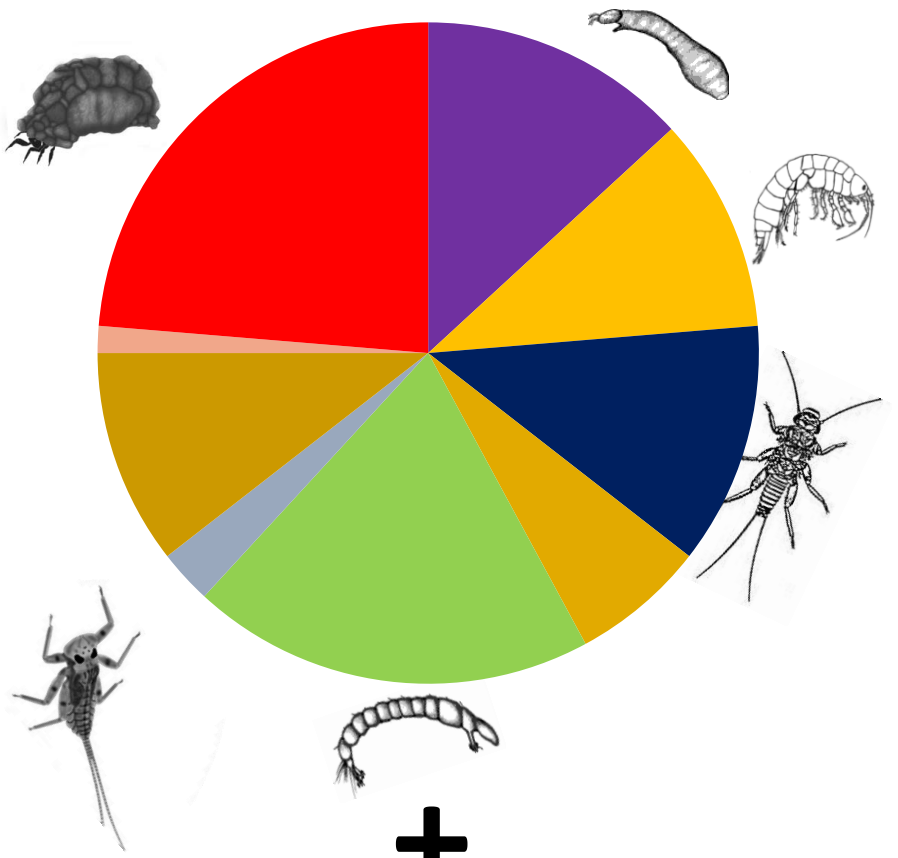
(Wipfli and Baxter 2010)

Need to model these interaction at the watershed scale!

Empirical Approaches


foodwebs.org

Trophic Basis of Production

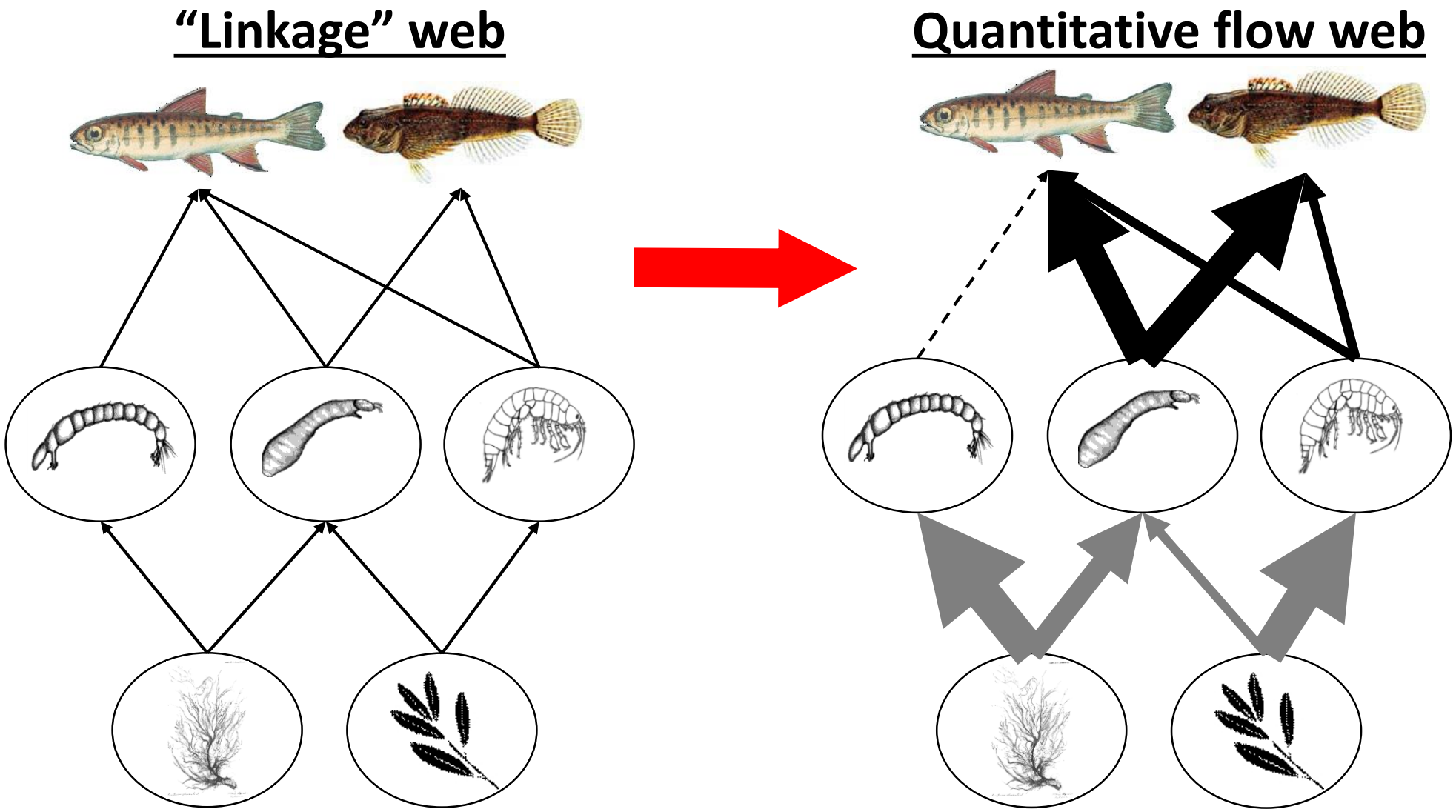


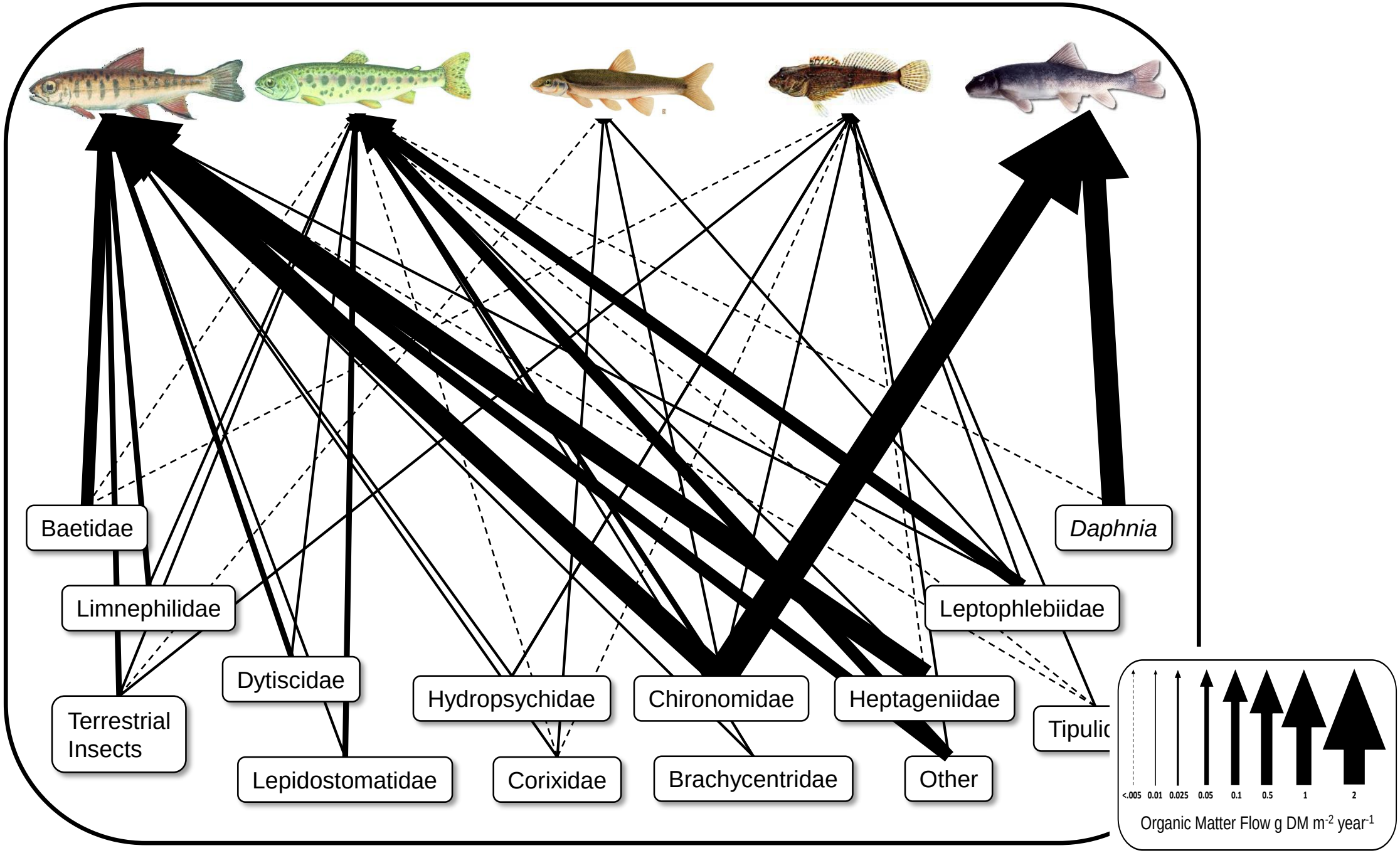
+

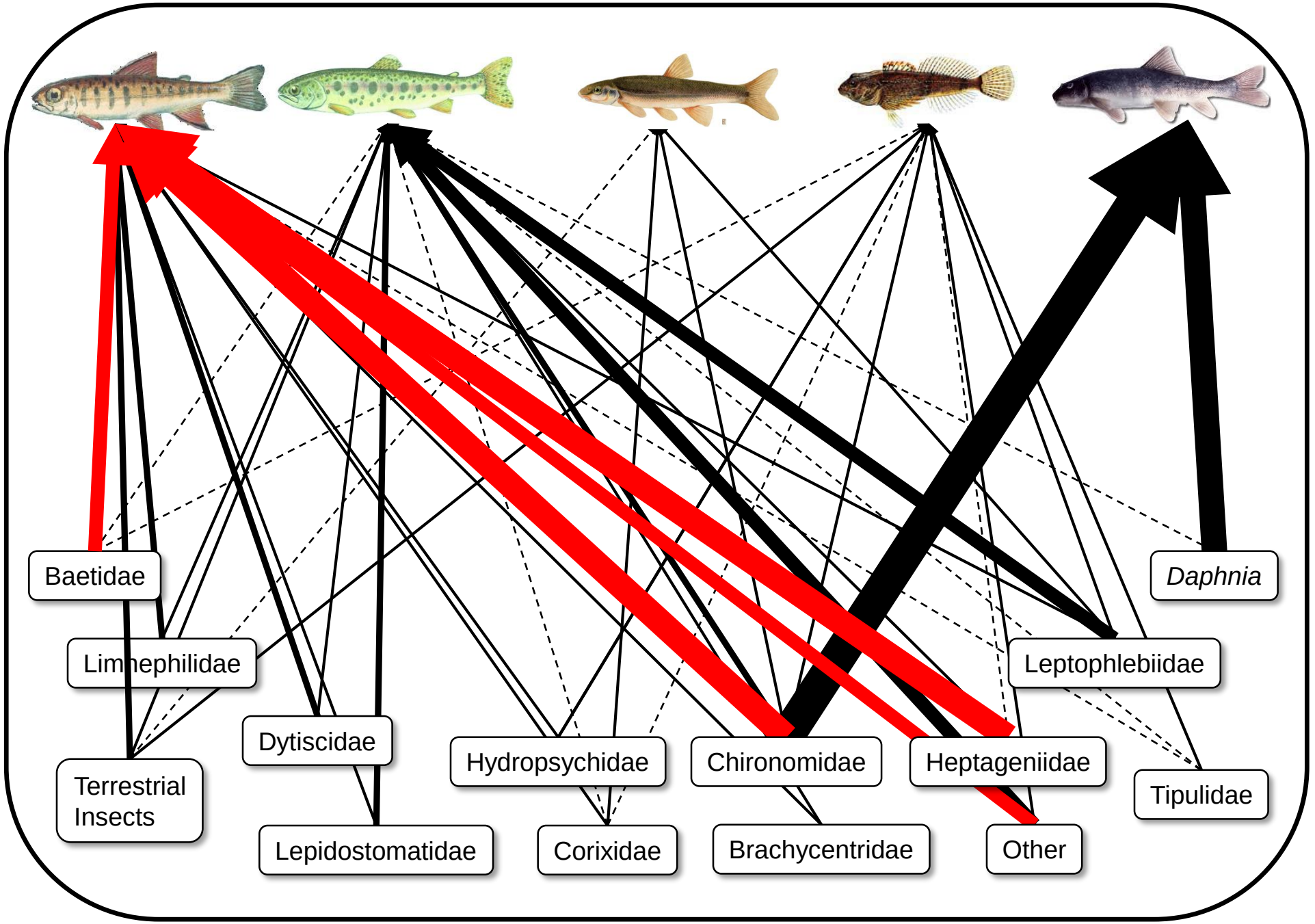
- **Rates of Production (mass/time)**
- **Bioenergetic information**

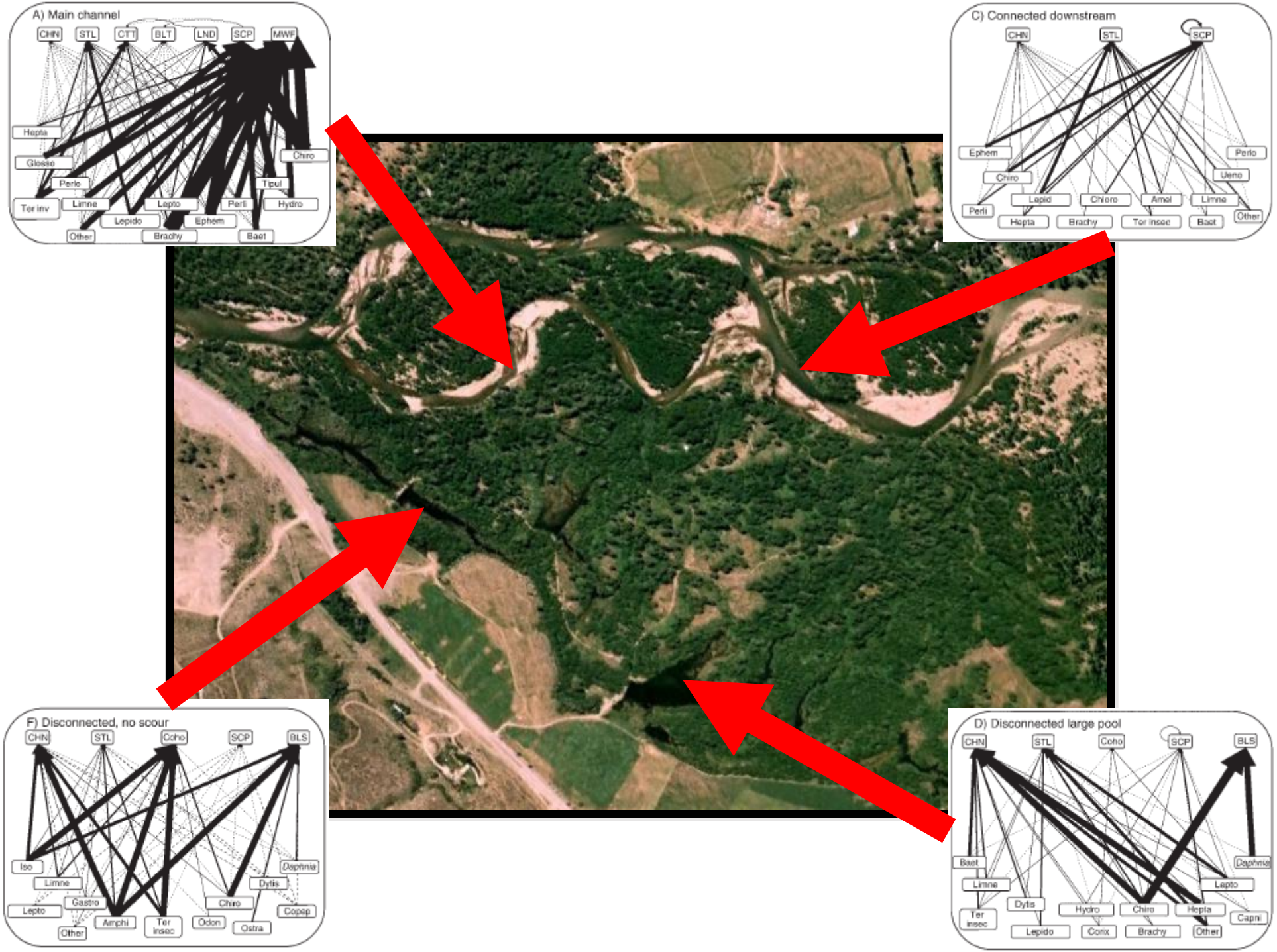
(Benke and Wallace 1997, Ecology)

Quantitative Food Webs




Baetidae
Limnephilidae
Terrestrial Insects
Dytiscidae
Lepidostomatidae
Hydropsychidae
Corixidae
Chironomidae
Brachycentridae
Heptageniidae
Other
Leptophlebiidae
Tipulic
Daphnia
<.005
0.01
0.025
0.05
0.1
0.5
1
2
Organic Matter Flow g DM m-2 year-1


Baetidae
Limnephilidae
Terrestrial Insects
Dytiscidae
Lepidostomatidae
Hydropsychidae
Corixidae
Chironomidae
Brachycentridae
Heptageniidae
Other
Leptophlebiidae
Tipulidae
Daphnia


A) Main channel
CHN
STL
CTT
BLT
LND
SCP
MWF
Hepta
Glosso
Chiro
Perlo
Tipul
Ter inv
Limne
Lepto
Perli
Hydro
Lepido
Ephem
Other
Brachy
Baet
C) Connected downstream
CHN
STL
SCP
Ephem
Perlo
Chiro
Ulmo
Lepid
Chloro
Amel
Limne
Perli
Hepta
Brachy
Ter insec
Baet
Other
F) Disconnected, no scour
CHN
STL
Coho
SCP
BLS
Iso
Daphnia
Limne
Dytis
Gastro
Chiro
Lepto
Copep
Amphi
Ter insec
Odon
Ostra
Other
D) Disconnected large pool
CHN
STL
Coho
SCP
BLS
Baet
Daphnia
Limne
Lepto
Dytis
Hydro
Chiro
Hepta
Ter insec
Capni
Lepido
Corix
Brachy
Other

Outline

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Guiding Principles

Maintain biodiversity

An insurance policy for an uncertain future

Guiding Principles

Maintain Heterogeneity

Diverse, complex, and connected habitats support biological diversity

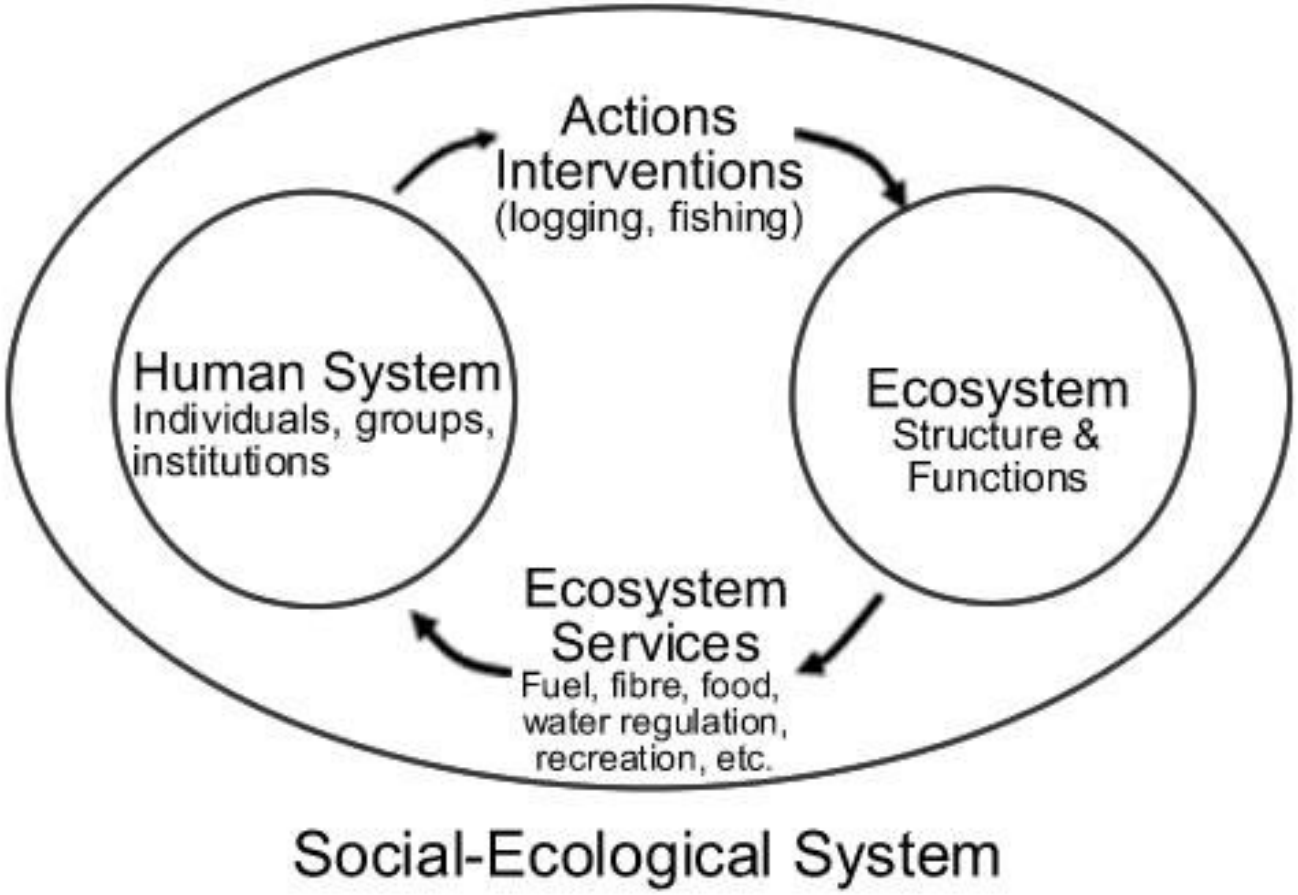
Guiding Principles

Maintain Natural Process

Disturbances create heterogeneity

Guiding Principles

Ecosystem will adapt. Can we?



Embrace Complexity

"Let's face it, the universe is messy. It is nonlinear, turbulent, and chaotic. It is dynamic. . . .It self-organizes and evolves. It creates diversity, not uniformity. That's what makes the world interesting, that's what makes it beautiful, and that's what makes it work."

-Donella Meadows, *Thinking in Systems*

Acknowledgements

Thanks for the inspiring conversations!

Anne Beaudreau, Allison Bidlack, Ron Britton, Buck Bryant, Dave D'Amore, Rick Edwards, Jason Feldman, Liz Graham, Deborah Hart, Paul Hennon, Eran Hood, John Hudson, Shiela Jacobson, Di Johnson, Justin Koller, Dana Kuntzsch, Don Martin, Robin Mulvey, Wayne Owens, Chris Sergeant, Neil Stichert . . . . . .