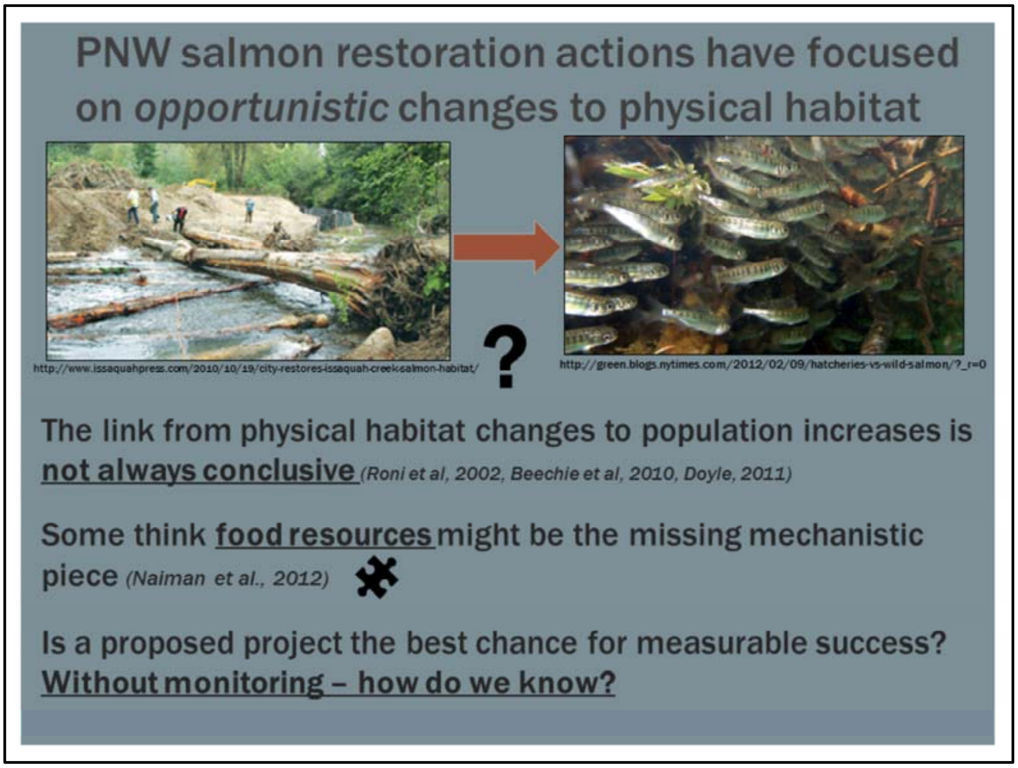
1. Thank you for staying around until the end!
2. My name is Adrianne Grimm and I work as a hydrologist Geosystems Analysis in Hood River, OR
3. I’m going to be talking about a study I worked on in the Methow River Basin as part of my graduate work at the University of Idaho

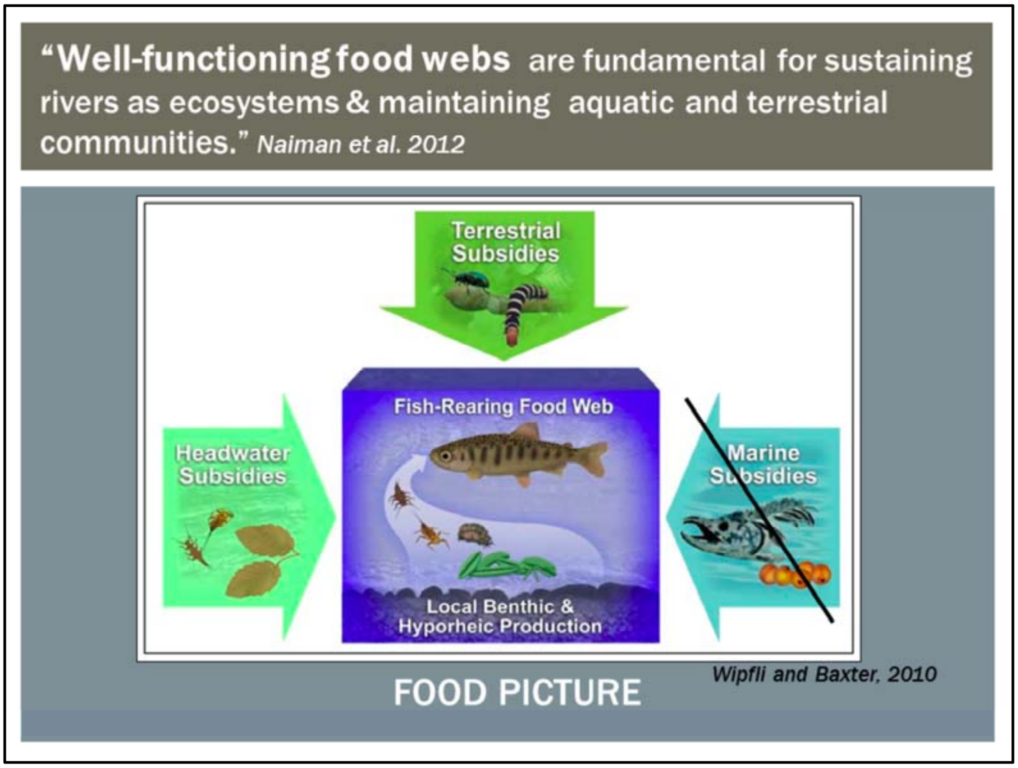


Changing the physical habitat is common approach to address decline, hoping the biological response follows

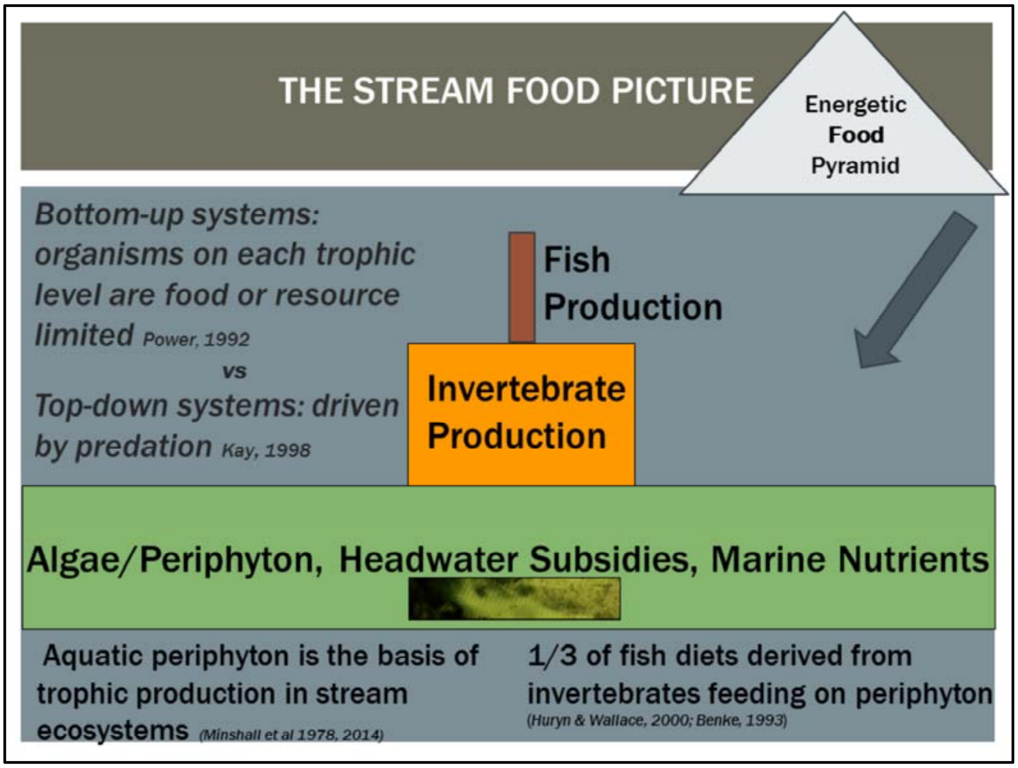
However the term "Habitat" comprises both physical space & FOOD

Is the biological response always observed? Why or why not?

Monitoring results is imperative to the success of salmon recovery – should be critical moving forward



1. With the potential missing link of food resources identified, we designed a study to look at food resources in aquatic foodwebs
2. We looked at local benthic and hyporheic food – namely algae
3. We looked at terrestrial subsidies, such as invertebrates falling into the stream from the riparian canopy
4. We looked at headwater leaf material falling and either becoming entrained in the substrate or being moved downstream

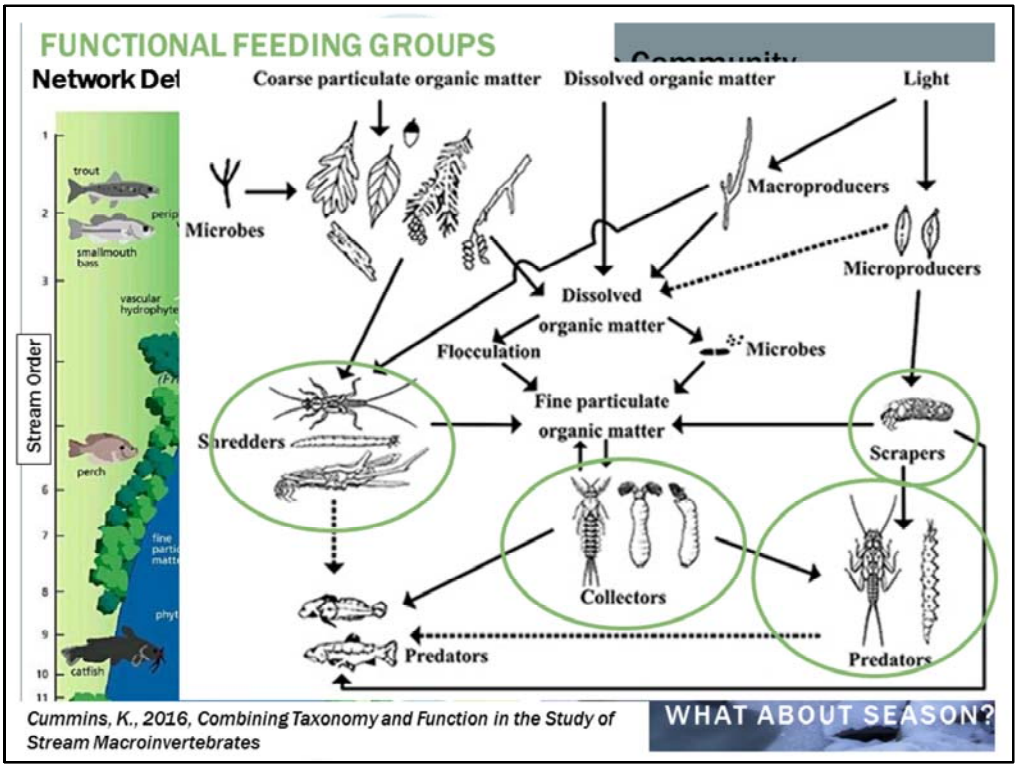


1. The base of the food web is comprised of photosynthesizing algae from single celled diatoms to rooted aquatic plants. In this presentation, they are all lumped under the umbrella of Periphyton – “green stuff on the stream bottom”

2. The food pyramid concept illustrates the approximate proportions of food resources required to support the next trophic level.

3. In ecology, there are two contrasting principles important for this study, whether a location is food limited, that is, production on the next tropic level is constrained by the amount of food - which dictates movement and behavior OR whether patterns are controlled from the top down, by predation. Endangered fish in this study are thought to be food limited.

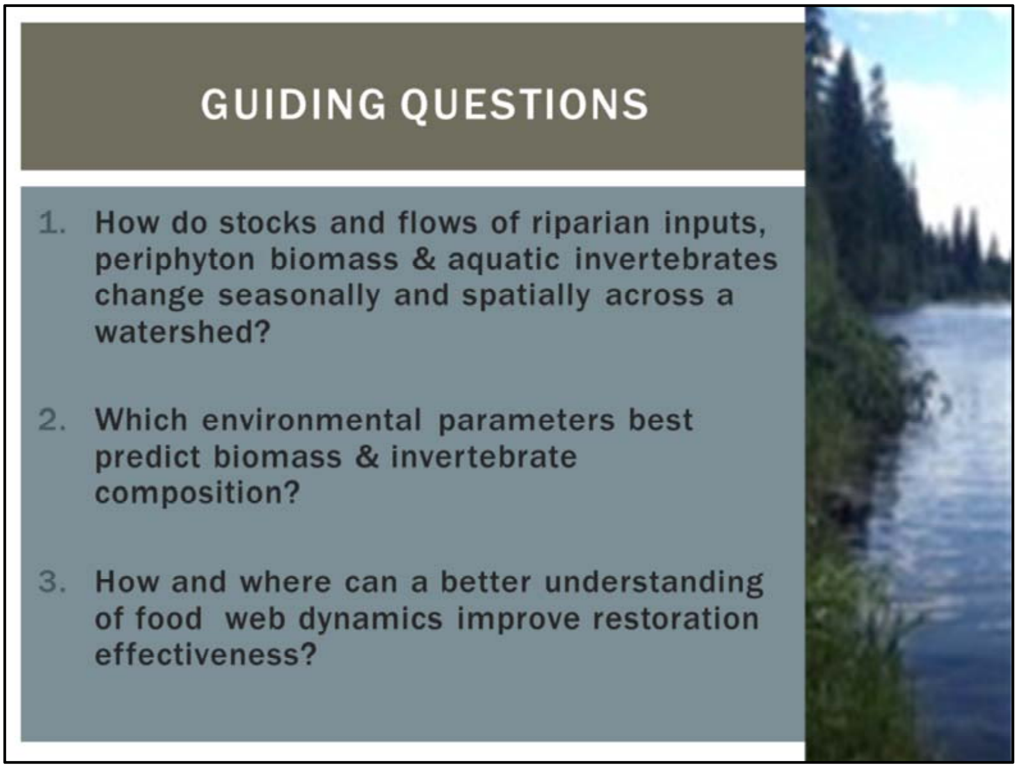
4. What is driving the population in the stream you are thinking of?



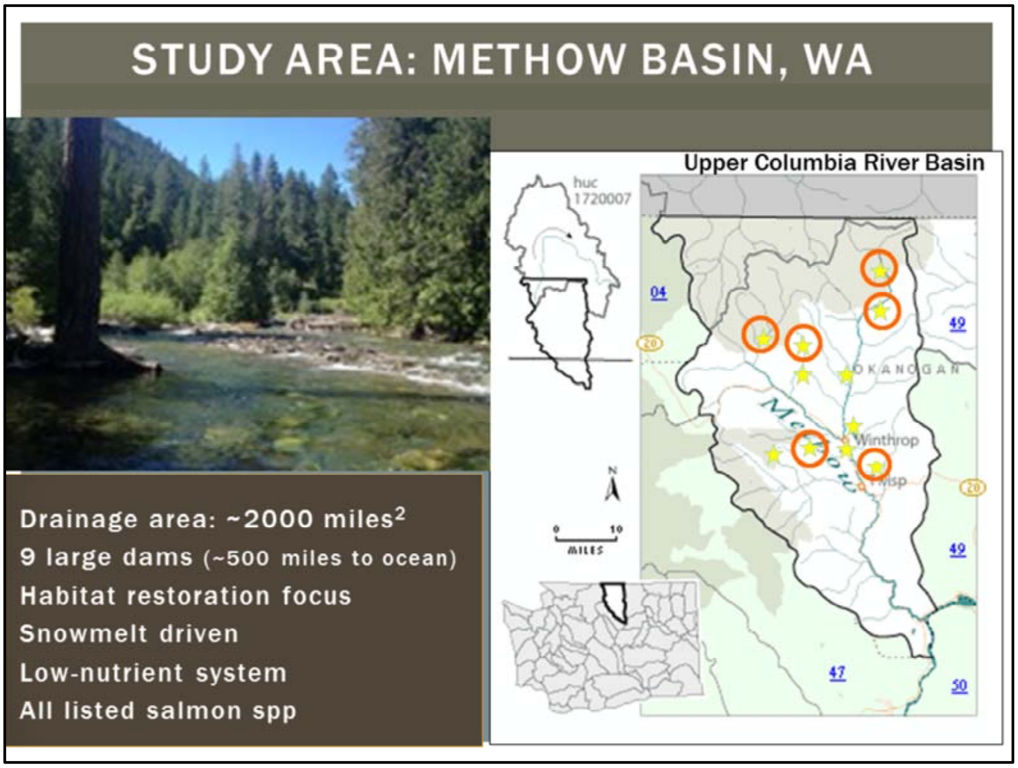
1. Our study tested and a finer resolution to the River Continuum Concept – most simply, the location in the stream network determines the community

2. Of particular interest is the evolution of feeding behaviors developed by invertebrates based on location they occupy in the network. Each has an important role in processing those upstream inefficiencies or using them to make their cases or homes

3. However, we wondered if this theory applied across all seasons and locations in the watershed?

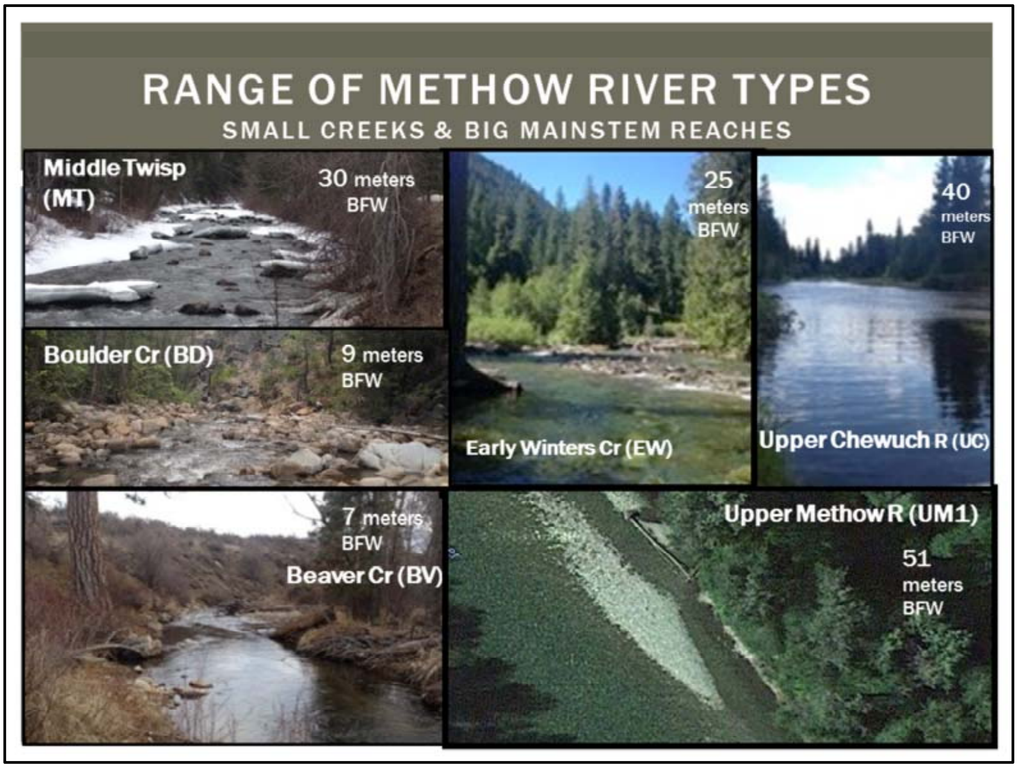


1. We wanted to know the effect of season across the watershed, from headwaters to mainstem
2. We wanted to know if expected drivers of photosynthesis (light and nutrients) were upheld
3. We wanted to see if the concept of food resource availability could be predicted to inform restoration projects

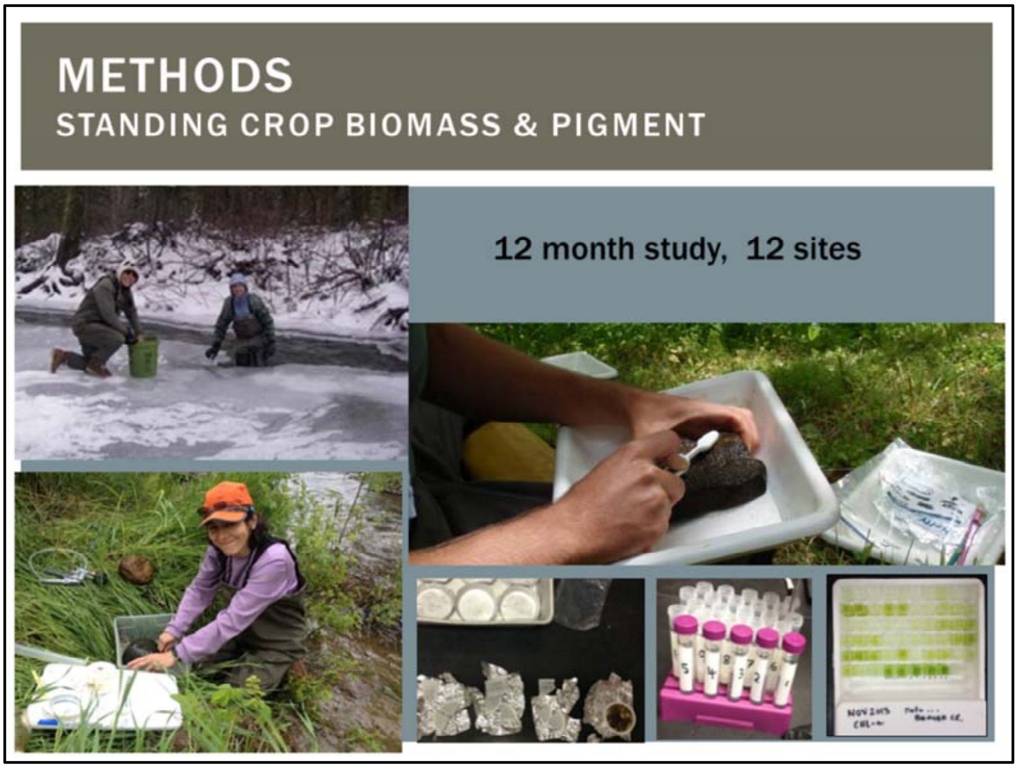


1. Large watershed located above **9** Columbia River mainstem Dams
2. Predominantly free flowing, so effort has focused on addressing salmon decline through restoration actions
3. Snowmelt is major disturbance in May and June
4. In general, a low nutrient system –relatively pristine, generally low levels periphyton and invertebrate production – in strong contrast to the nutrient rich Klamath system, the Methow has granitic geology, not high phosphorous volcanic geology found in high nutrient systems
5. Supports all listed salmon spp

6. The map shows 12 sites used in the periphyton and a separate stream metabolism study, the circles were monitored for terrestrial and invertebrate dynamics.



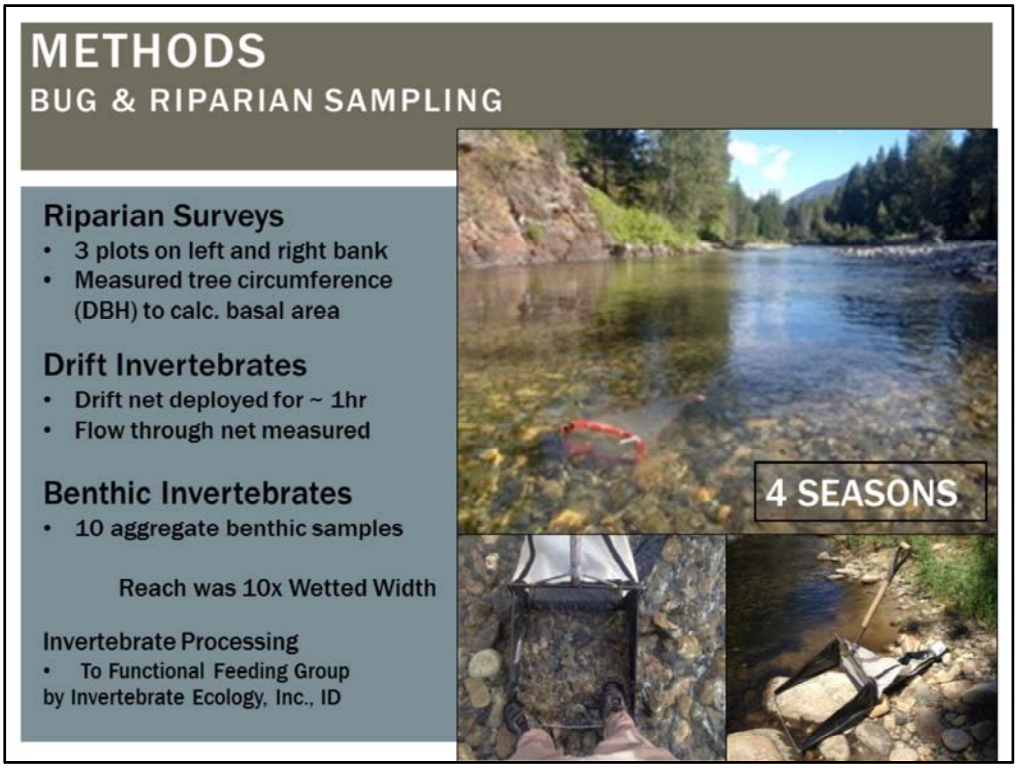
1. Here are the approximate sizes of reaches monitored in the riparian component of the study
2. Names as well as Bankfull width are shown above
3. Sites ranged from small tributaries to large mainstem reaches.



1. Selected 12 sites based on Columbia Habitat Monitoring Protocol (CHAMP) sites because annual or frequent topographic surveys are collected as well as numerous other environmental parameters.

2. Visited each month and collected 5 rocks from the thalweg on each visit

3. Processed 720 samples in the lab for Periphyton biomass and chlorophyll a pigment



1. To understand resources flows in and out of a study reach,

2. We conducted measurements in 4 seasons (summer, early fall, late fall (after) leaf abscission, and spring)

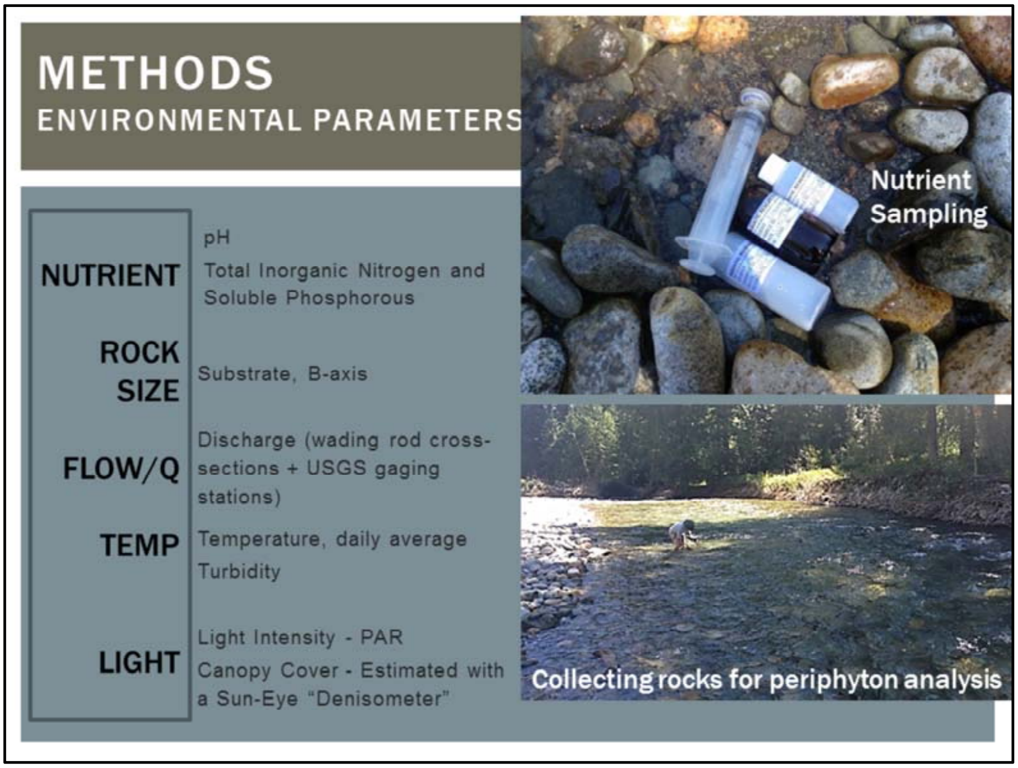
3. Drift nets were deployed for one hour at the up and downstream extents of reaches

4. Reaches were 10 times the wetted width of the stream BFW as measured previously.

5. 10 aggregate benthic samples were collected on each visit

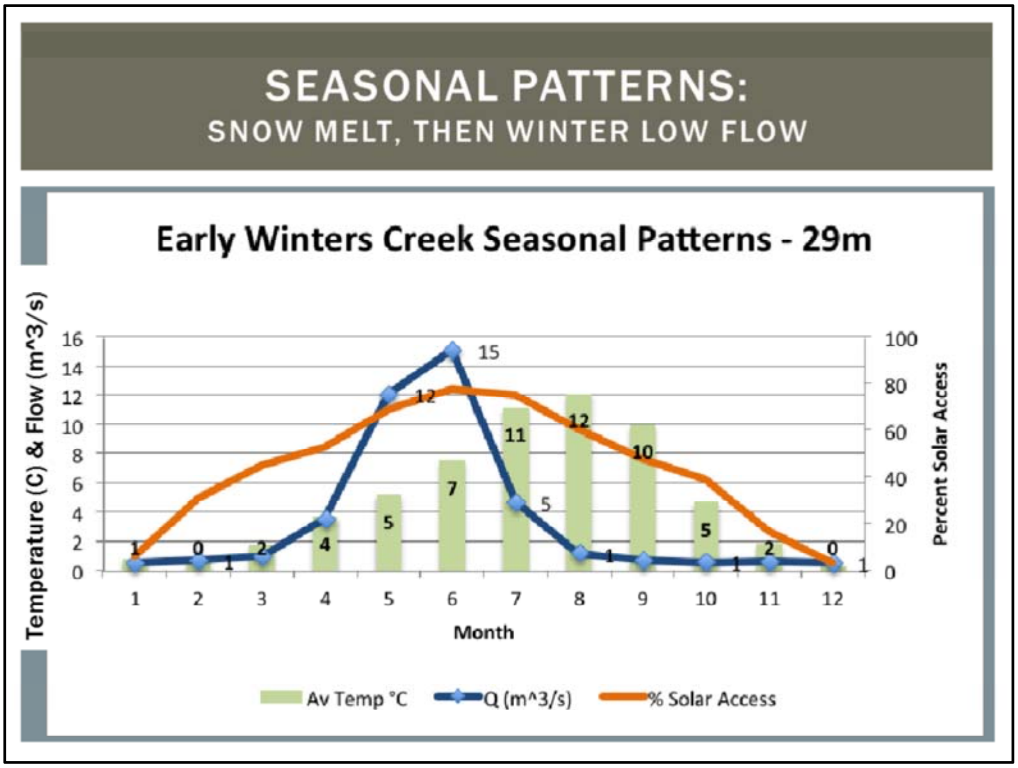
6. Drift and Benthic bug samples were processed to the taxonomic level of Functional Feeding Group by a firm in Idaho.

7. Dissolved organic carbon was measured at 5 times through the study period.

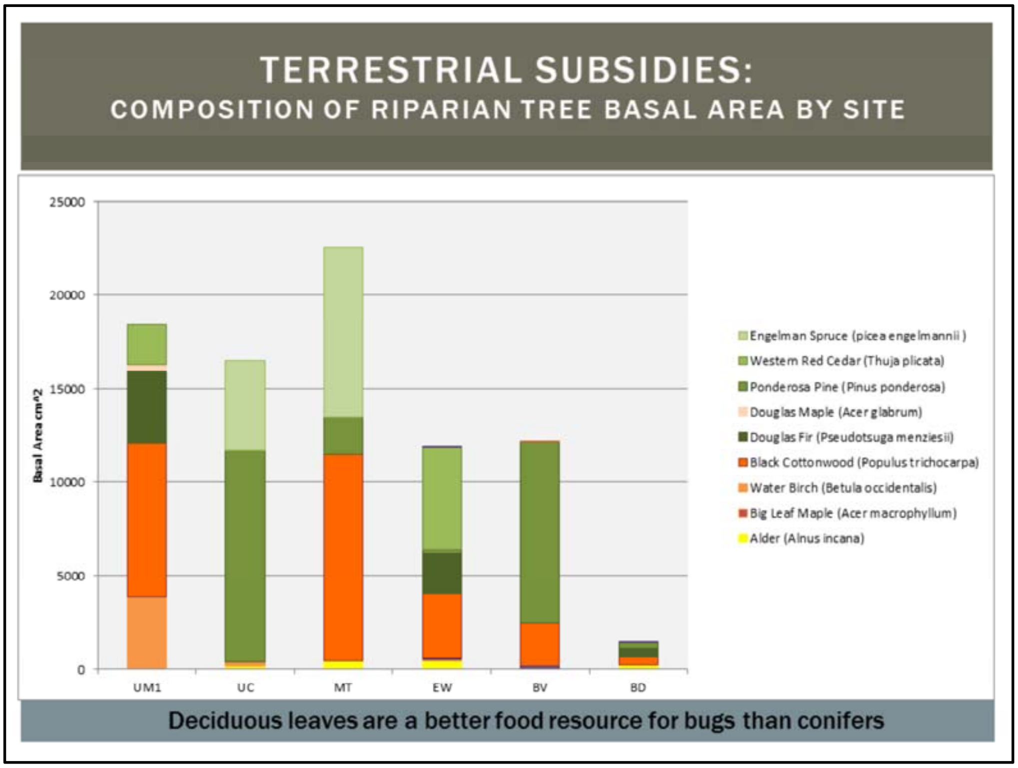


1. We also sampled numerous environmental parameters each month of the year
2. Nutrient levels: Total inorganic nitrogen and phosphorous
3. Pebble counts and b axis of all periphyton rock samples
4. Discharge
5. Hourly temperature and turbidity
6. Light intensity and riparian shading at three locations along each sampled reach.

This is an overview of the results we'll talk about next



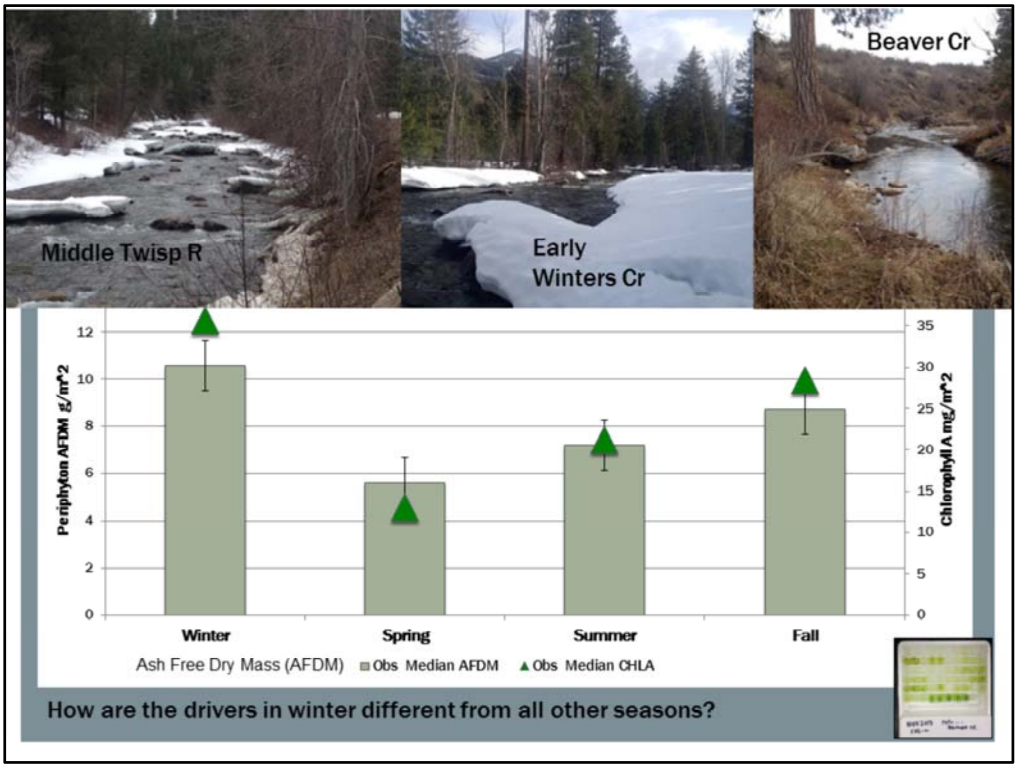
1. Flow peaks in May and June – major disturbance and annual reset for biological communities
2. Low flow throughout winter
3. Winter stream temperatures hover around freezing
4. This watershed does not have high temperature problems.



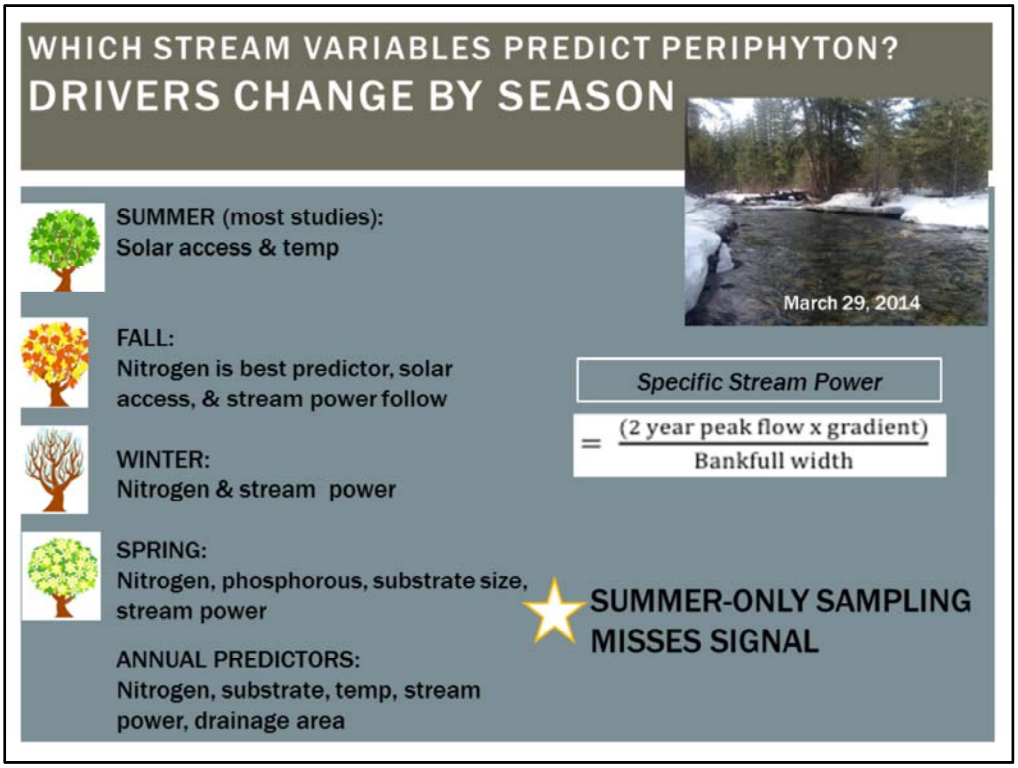
1. Riparian survey results indicated that the sites were generally conifer dominated, with the deciduous cover dominated by of black cotton wood, big leaf maple, willow, and less alder than expected. We quantified expected annual leaf contribution from each tree spp.

2. Alder is critical - it fixes atmospheric nitrogen, and is a preferable food source for invertebrates because it can be more quickly conditioned by microbes and consumed by invertebrates.

3. Additionally, as species common in primary succession, alder is able to colonize more disturbed sites, quickly providing shade and building soil to support later successional species like riparian conifers.

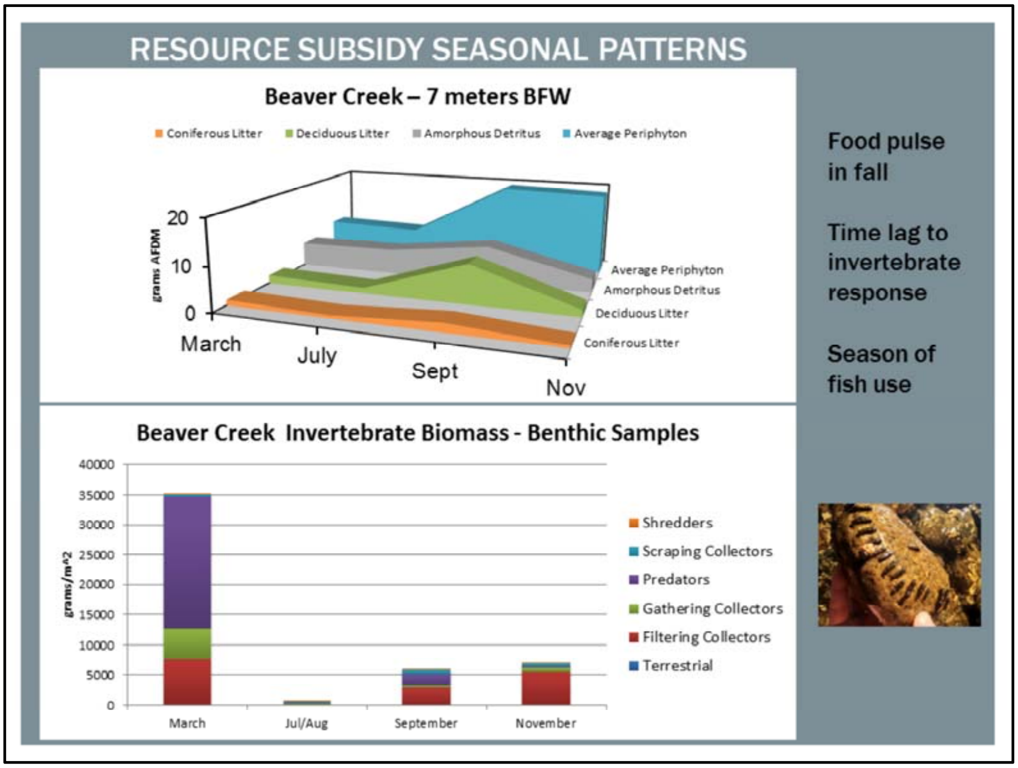


1. Biomass peaks in winter, despite cold temps
2. What explains this pattern?
3. Winter is longest time since spring disturbance, more time for growth and reproduction of periphyton communities, also low flow limits sunlight obstruction the stream bed.
4. **Cold Adapted spp**

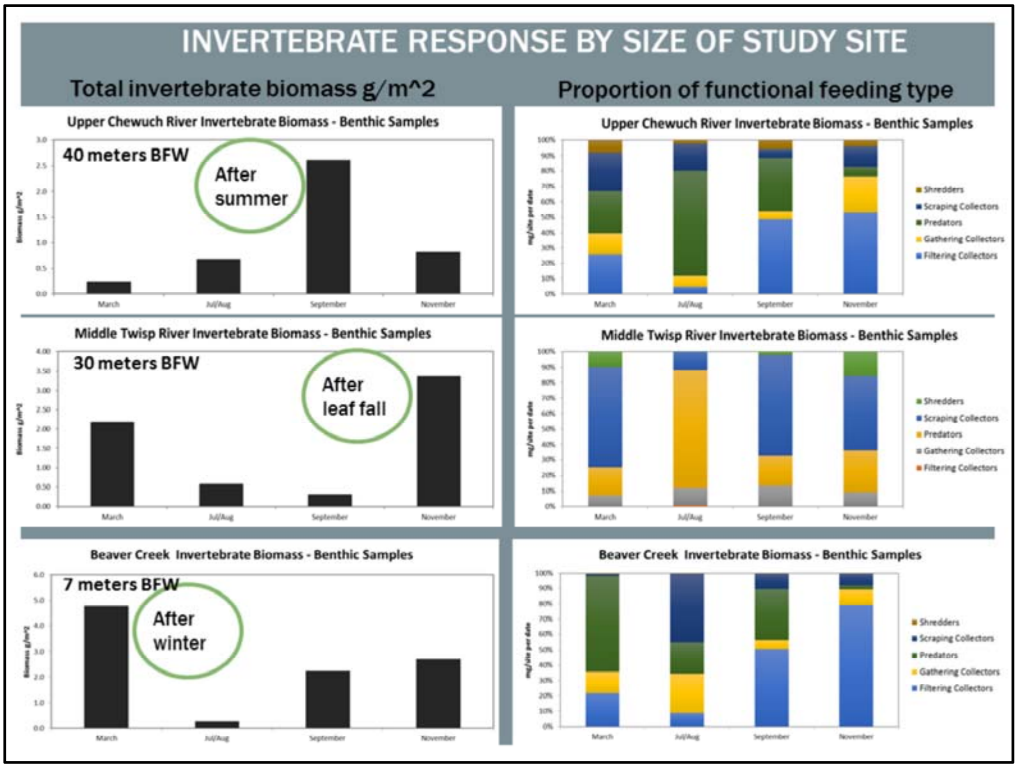


1. We used a multiple linear regression analysis and model selection to determine the drivers of periphyton growth in each season
2. Nitrogen is an important predictor of biomass year round, except in summer
3. Specific stream power is also an important predictor in all seasons except summer
4. Summer only sampling misses important annual predictors of the food abundance.
5. The take home here is that nutrients are critical for a robust food landscape… surprising no one, but still important to reiterate in systems that have low salmon returns. A big piece of the missing nutrient input was likely previously supplied by abundant salmon carcasses.

Think about nutrient sources and patterns at your sites.
Are there abundant alder? Is there heavy wildlife use? Beaver or elk?
Cattle or dairy land uses or phosphorous rich sediment inputs from volcanic soil layer?



1. I'm showing these charts to demonstrate the asynchronous pattern we observed in the data
2. At this site, take a look at periphyton abundance in blue – highest from Sept – Nov, then
3. Look at the invertebrate response, not until months later in early spring, coinciding with the emergence of early instars of invertebrates.
4. This may all be a coincidence, but observing the food pulse, then time lag to invertebrate response, and thinking about how this corresponds to the season of fish use is pretty cool
5. We know fish use smaller streams to escape high flows, this data also demonstrates they use smaller streams because of food availability in early spring



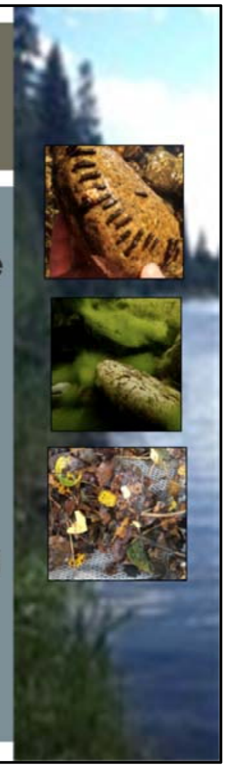
1. These show the invertebrate response by size of creek.
2. Generally speaking this pattern happens at all sites:
Fall (September invertebrate biomass levels are higher in larger streams.

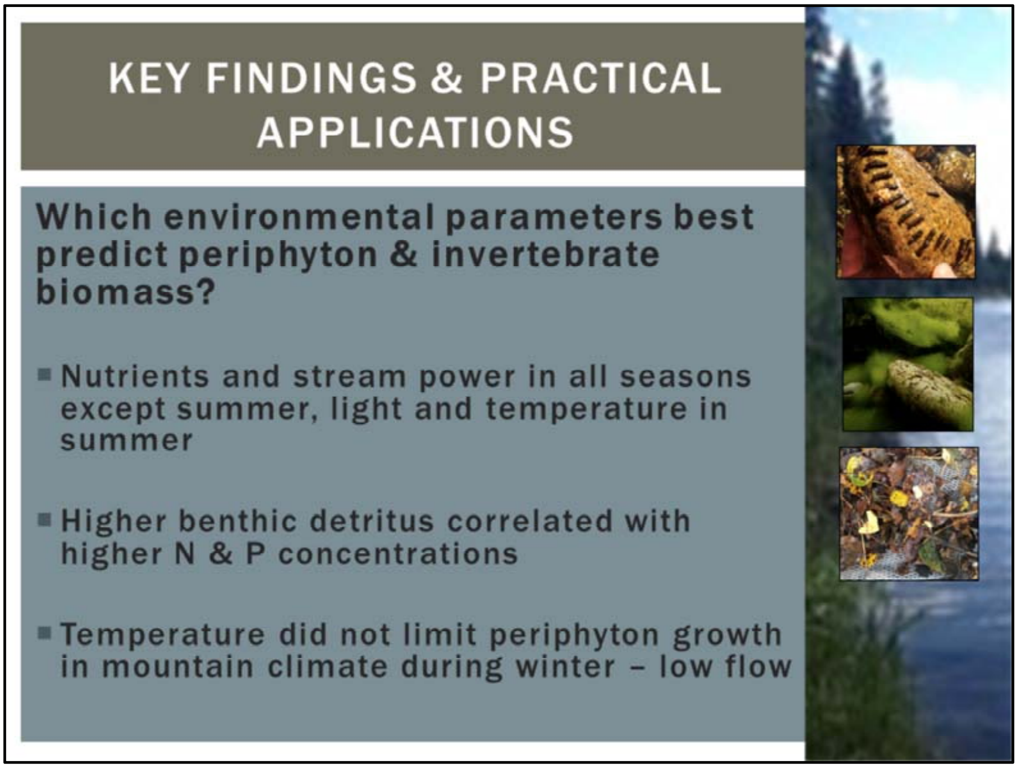
3. Increase in invertebrate biomass occurring after summer in large river (greater periphyton)
4. In reaches that fell in the middle of all the study sites, invertebrate biomass was highest in November, correlating with leaf fall, and invertebrate life cycle
5. After winter in smaller stream – lower flow, lower turnover, more decay of riparian leaf litter and consumption/growth by invertebrates/early instars
6. What does this mean for restoration practioners?

KEY FINDINGS & PRACTICAL APPLICATIONS

How do riparian inputs, periphyton biomass & aquatic invertebrates change seasonally and spatially across a watershed?

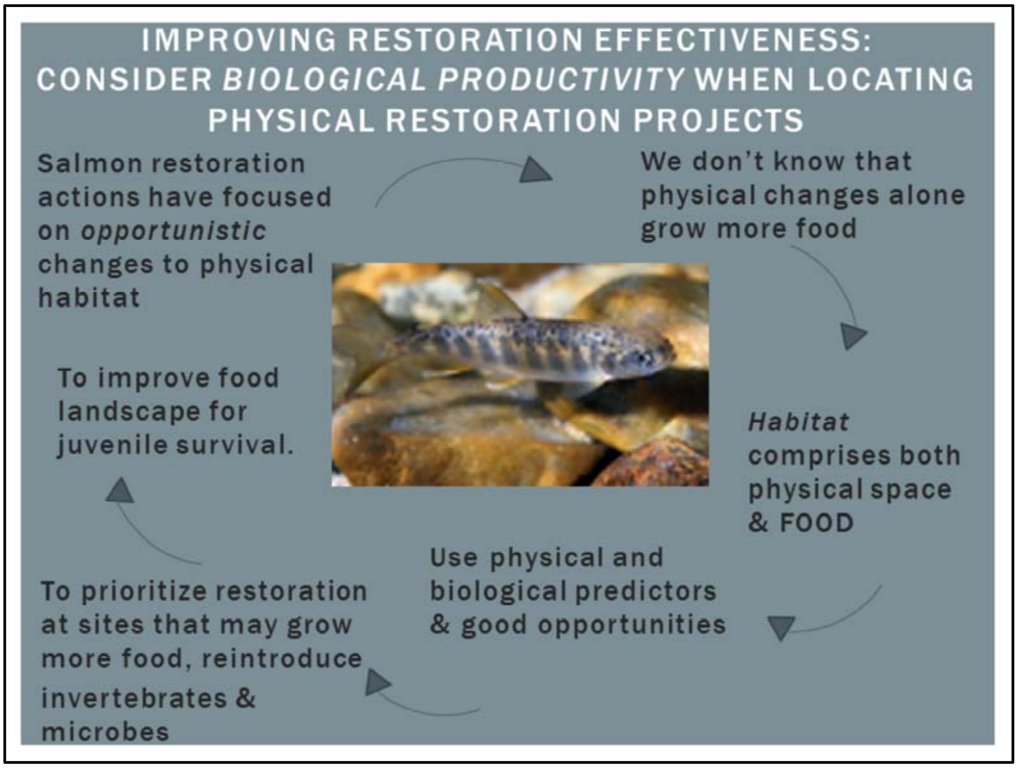
- Can't only look at summer data – different drivers
- Large streams have more invertebrates in fall, small streams have more in early spring
- Location in the network determines input type, season, retention





3. (due to increased winter light)

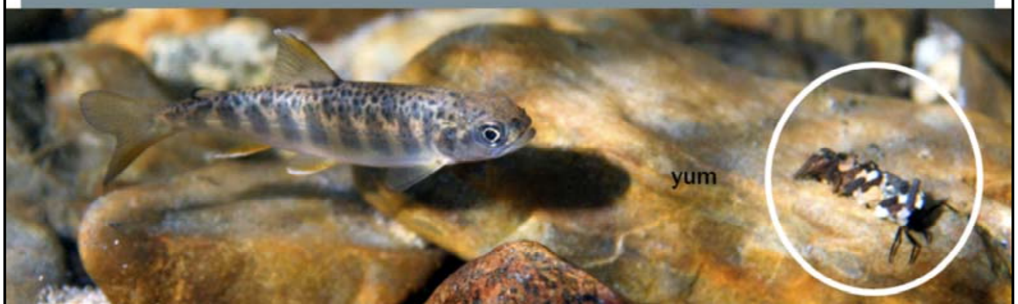
1. I was thrilled to hear about the idea to inoculate restoration projects with local, native, stream invertebrates and microbes from an appropriate reference reach, and especially that the inoculation effort collected samples in ALL seasons from the reference reach.


IMPROVING RESTORATION EFFECTIVENESS:
CONSIDER BIOLOGICAL PRODUCTIVITY WHEN LOCATING PHYSICAL RESTORATION PROJECTS
Salmon restoration actions have focused on opportunistic changes to physical habitat
We don't know that physical changes alone grow more food
Habitat comprises both physical space & FOOD
Use physical and biological predictors & good opportunities
To prioritize restoration at sites that may grow more food, reintroduce invertebrates & microbes
To improve food landscape for juvenile survival.

1.

1. Empirical data collected during this study was used to calibrate a model that can be used to predict the success of different restoration approaches – the publication will be in Ecological Applications at the end of the month.
2. Model parameters included geomorphic and topographic information collected at all Columbia Habitat Monitoring Protocol sites mentioned a few time previously this week.
3. A few other parameters are needed to use the model – namely nutrient information – so I encourage all restoration practitioners to start evaluating the nutrient landscape of their chosen systems.

PRIORITIZE RESTORATION AT SITES THAT MAY GROW MORE FOOD & MONITOR FUNCTIONAL RESPONSE TO PROJECTS



ACKNOWLEDGEMENTS

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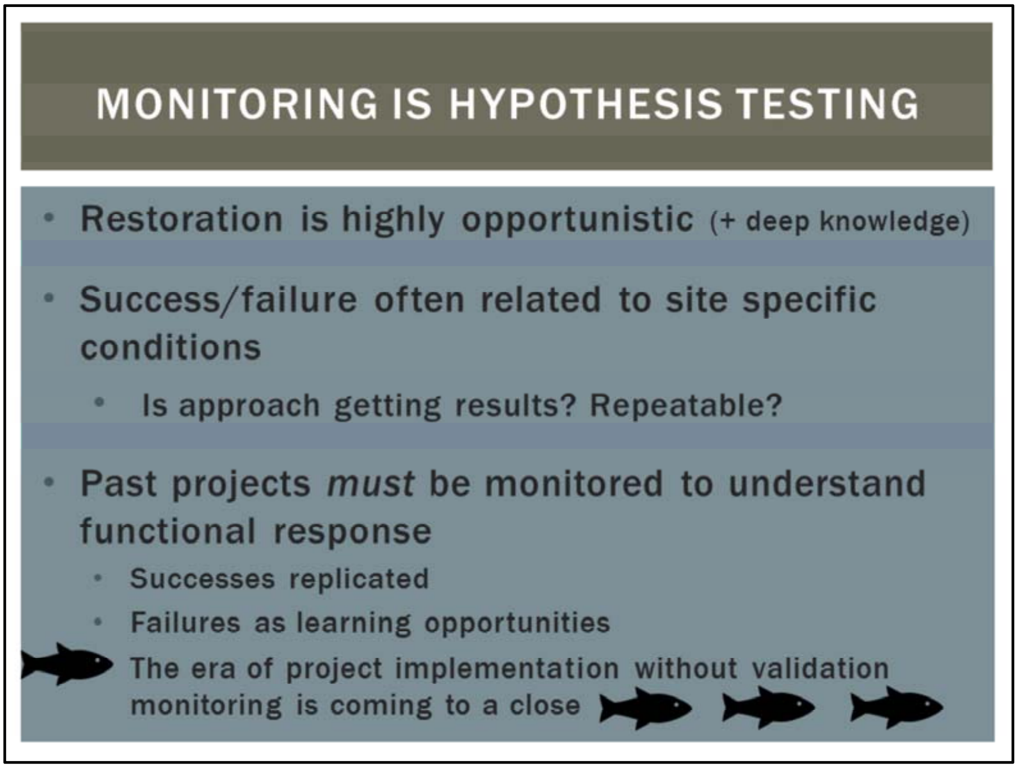
- Dr. J. Ryan Bellmore, USGS, now USFS
- Dr. Francine Mejia, USGS
- Michael Newsom, Bureau of Reclamation, retired
- Grace Watson, USGS Twisp/Methow Salmon
- CHaMP Data, PNAMP & Monitoring Methods
- Fremier Lab Group


QUESTIONS?
GSA GeoSystems Analysis, Inc.
Innovations in Hydrology
USGS
science for a changing world
University of Idaho
Washington State University
RECLAMATION
Managing Water in the West



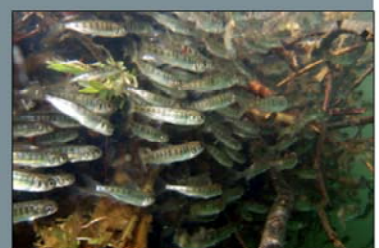
NOD your head

Funding, landowner willingness, access, material cost – LWD or potential donation, pubic opinion, the need to address other identified limiting factors that drive the project, consideration of future climate change impacts.
All need to line up
One approach may not be a good fit in a different location
Know what works and critically – why it worked where applied
Monitoring of the functional response, in addition to the number of trees planted and stream miles treated needs to be a funded component of restoration project implementation, without it, success is difficult to replicate.

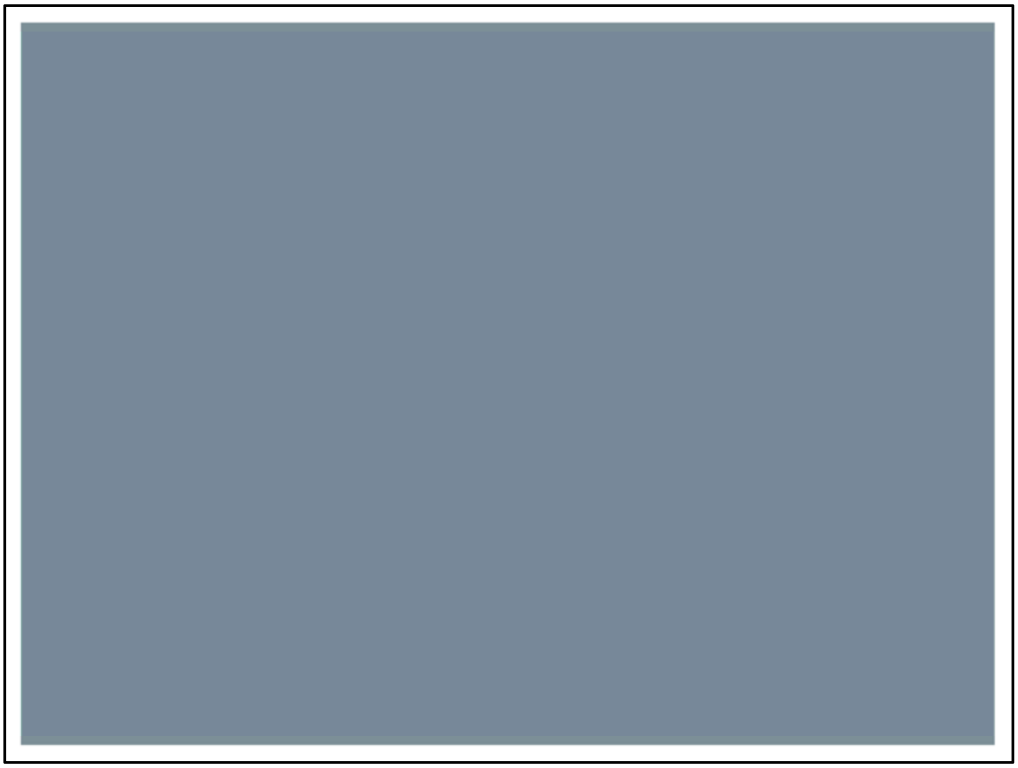
The novel ecosystem acknowledgement – that restoration projects are experimentation in new scenarios is important, but if our objective is to grow more fish and restore critically endangered populations units, we need to get results, and the first step in understanding what works is monitoring our projects and implementing adaptive management to correct observed issues.

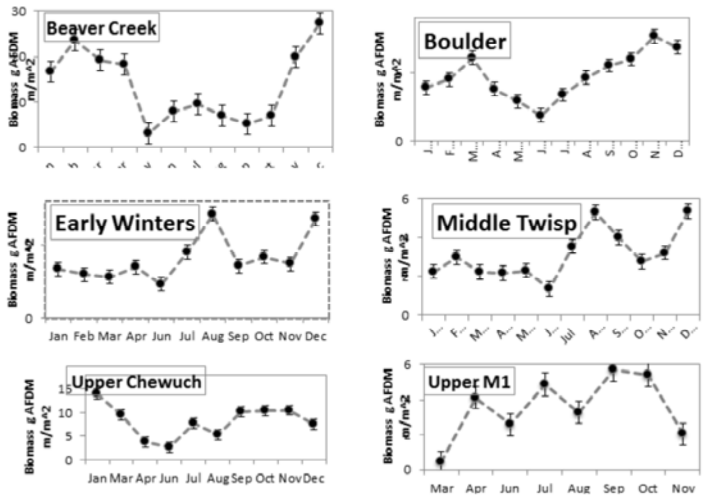
CONCLUSIONS & IMPLICATIONS:

- Sites with high shading can produce high quantities of invertebrates
- Seasonal changes: Benthic & detritus drift detritus
- Bug Food resource varies through the year
- Detritus levels are weakly correlated with benthic periphyton & invert biomass
- Leaf on – leaf off cycle of deciduous dominant river reaches affects observed periphyton & invert biomass, however not in a clear way.



http://green.blogs.nytimes.com/2012/02/09/hatcheries-vs-wild-salmon/?_r=0



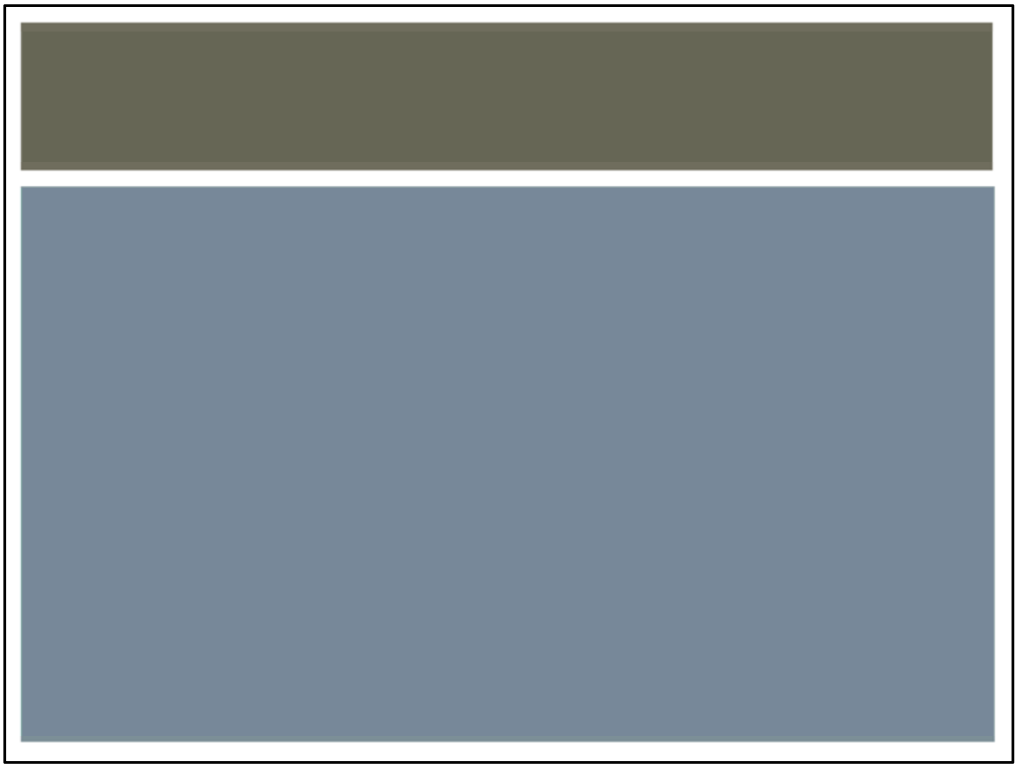


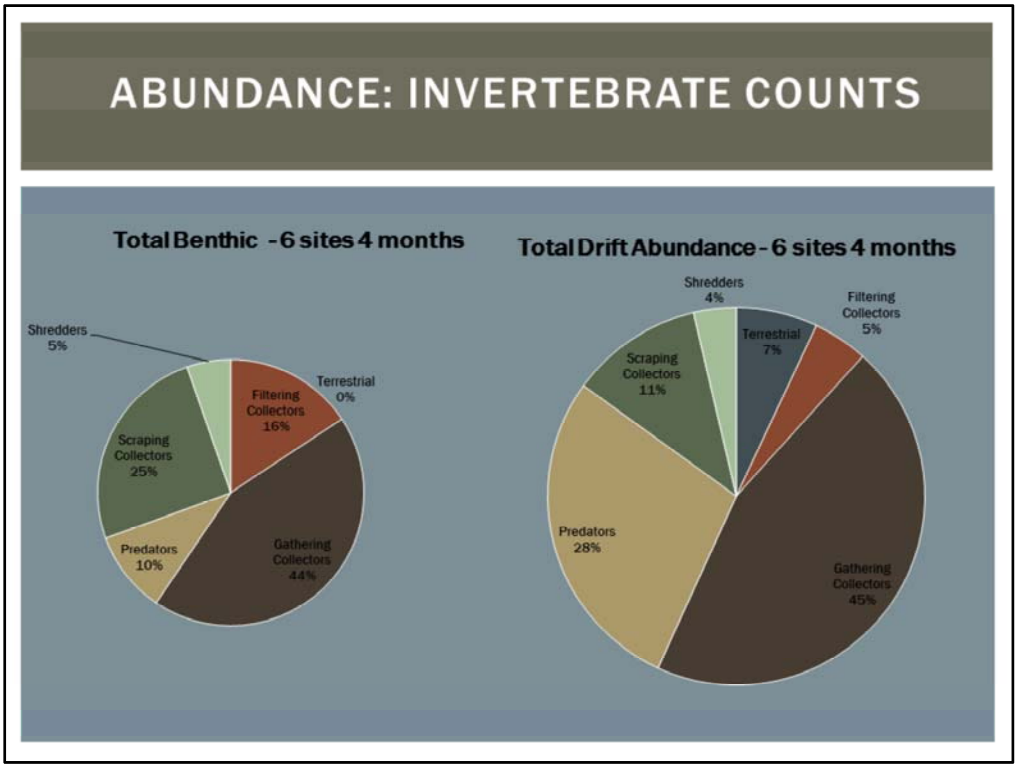
Sites arranged as:
Top: Small Streams
Mid: mid Streams
Bottom: Rivers

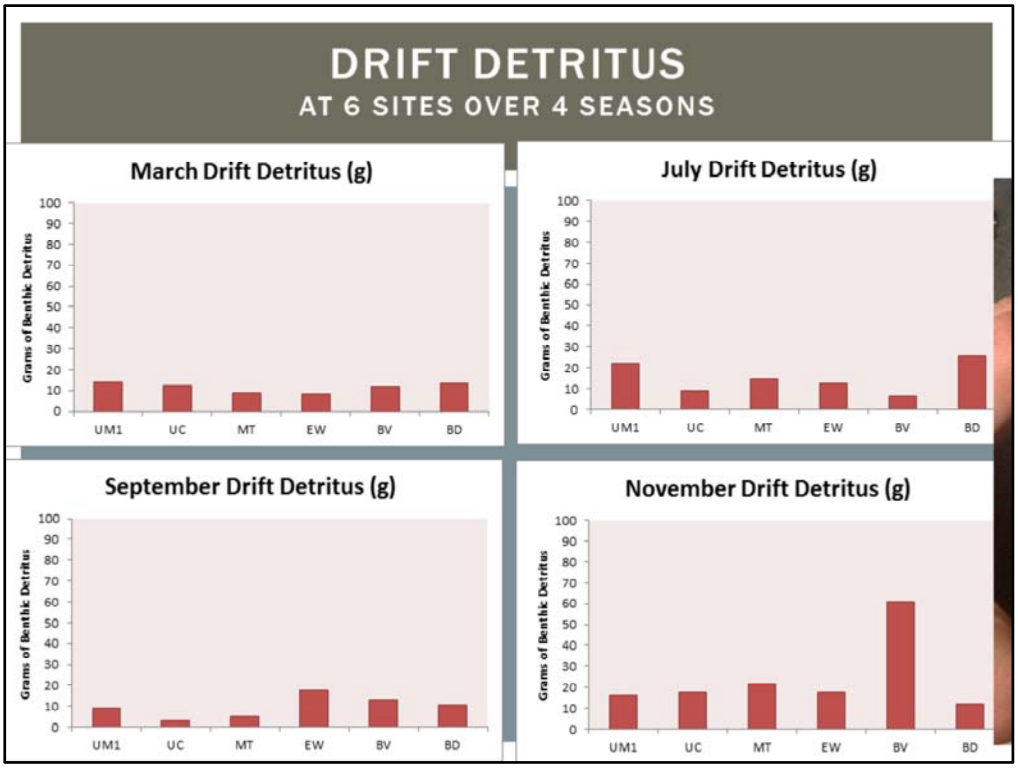
Observations:
Small Streams: Low point occurs earlier in BV (my vs June) compared to BD due to location lower in watershed. Both have winter high, with peak in late fall
(is this due to invertebrate life cycle? Die off in fall? Low water in winter? Biomass varies based on site conditions (nutrients)

Mid Streams: Peak in Aug – what we normally expect to see via RCC, ANOTHER PEAK IN DEC – due to invert life cycle?

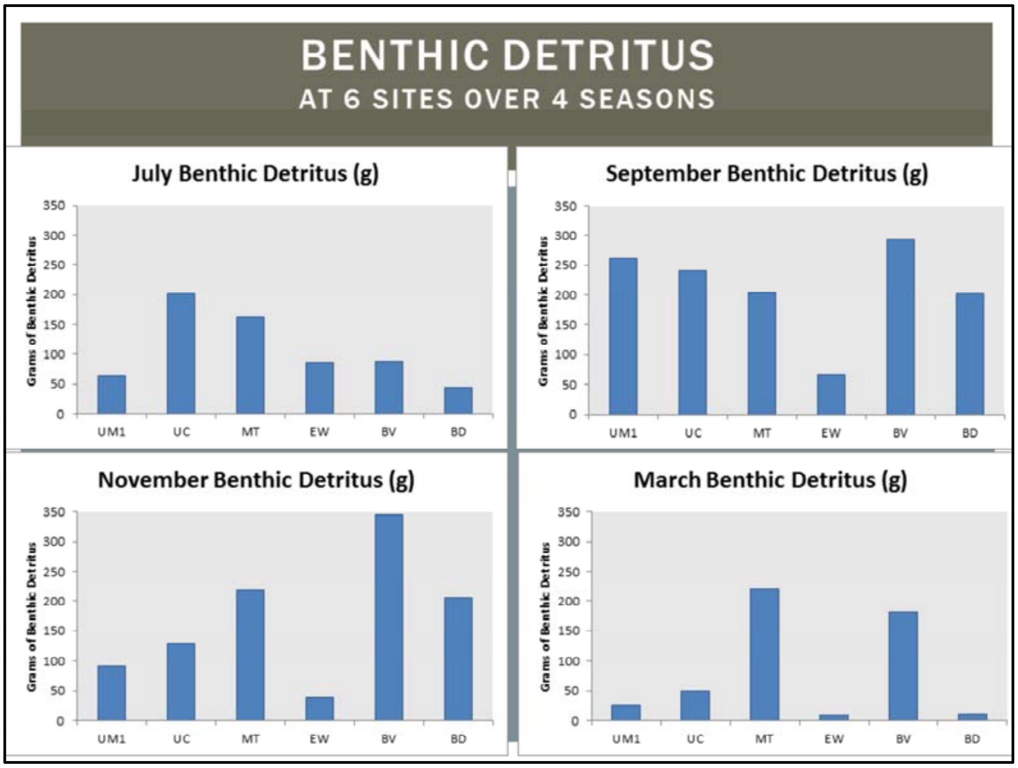
Big streams: Winter peak in Upper Chewuch - more silimar to mid sized streams, Aug decrease – what is causing this? other effects moderated.

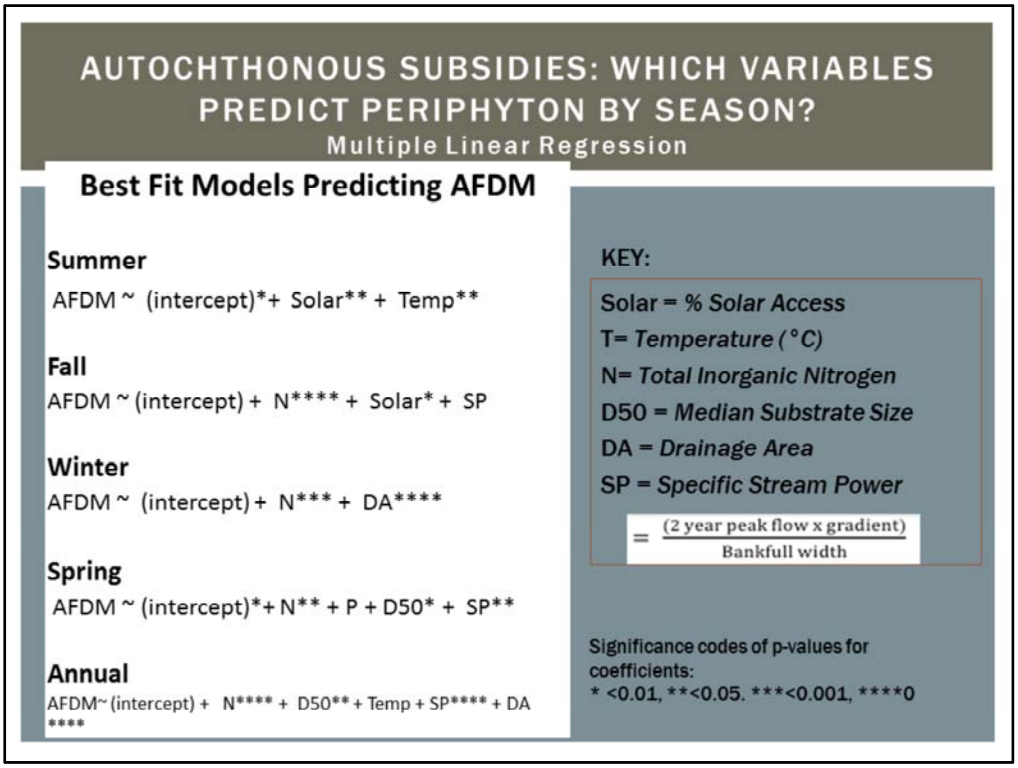



ABUNDANCE: INVERTEBRATE COUNTS
Total Benthic - 6 sites 4 months
Shredders 5%
Terrestrial 0%
Filtering Collectors 16%
Scraping Collectors 25%
Predators 10%
Gathering Collectors 44%
Total Drift Abundance - 6 sites 4 months
Shredders 4%
Filtering Collectors 5%
Terrestrial 7%
Scraping Collectors 11%
Predators 28%
Gathering Collectors 45%



Bugs were removed
Detritus samples – proportion of each type of detritus was identified and material was ashed and weighed

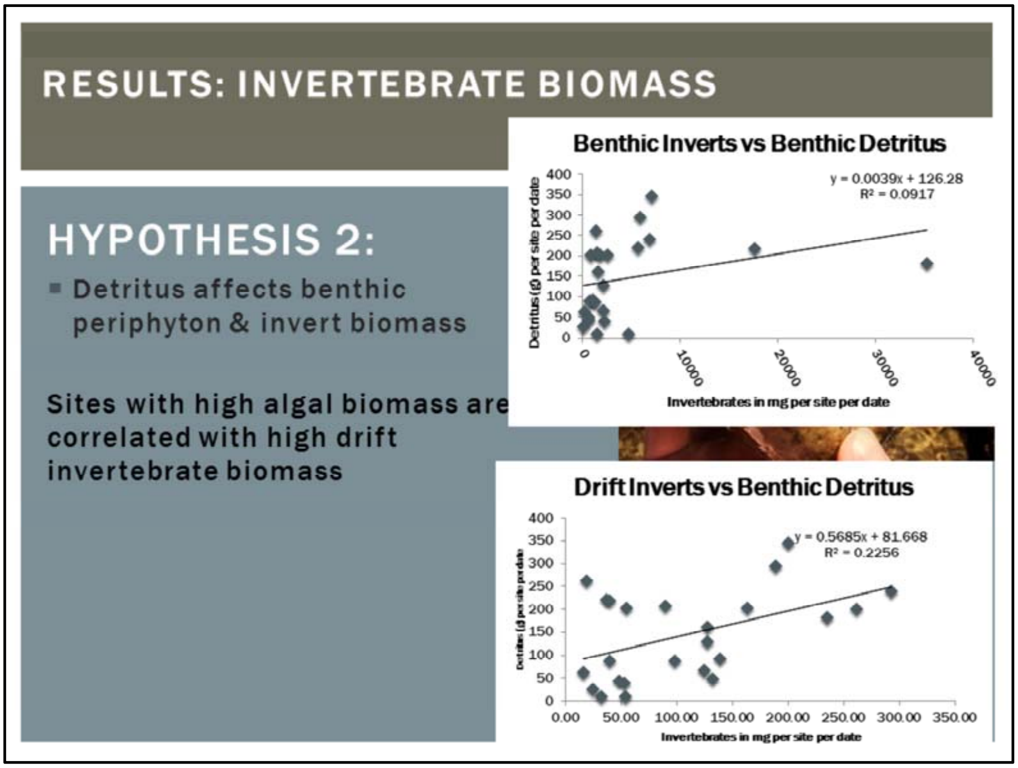

BENTHIC DETRITUS
AT 6 SITES OVER 4 SEASONS
July Benthic Detritus (g)
September Benthic Detritus (g)
November Benthic Detritus (g)
March Benthic Detritus (g)
Grams of Benthic Detritus
0
50
100
150
200
250
300
350
UM1
UC
MT
EW
BV
BD



1. Drivers change through the seasons

1. Biomass peaks in winter, despite cold temps

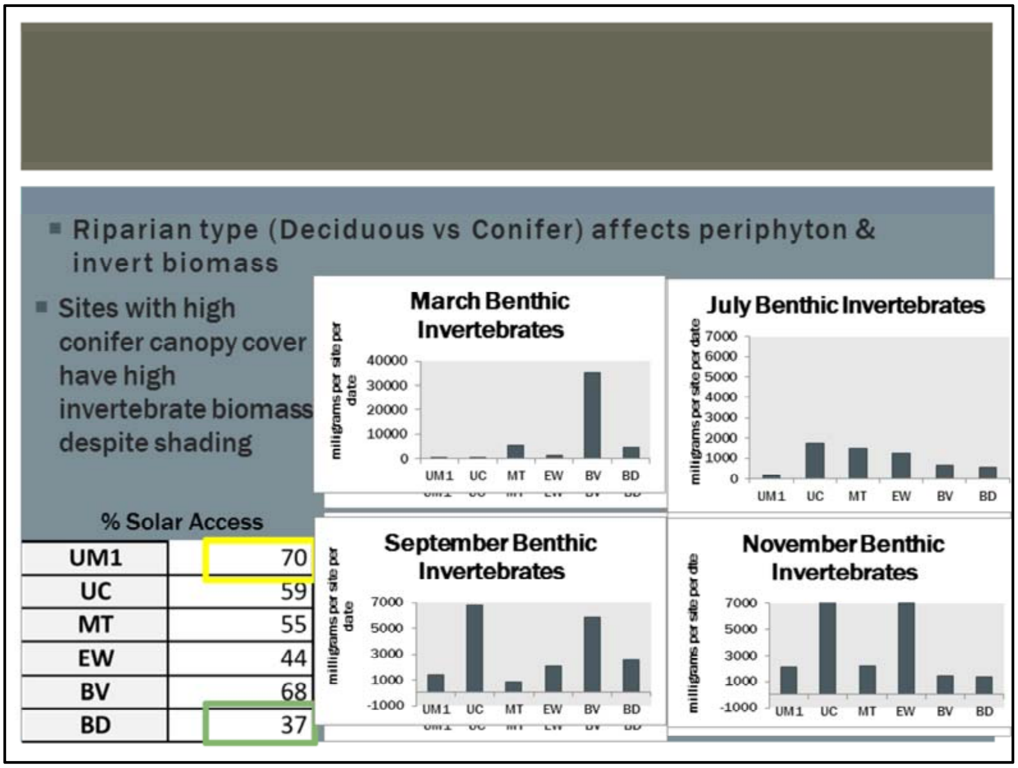
2. Nitrogen is a very important predictor of biomass year round, except in summer



Invertebrate data tends to match the periphyton, and high canopy sites do not seem to decrease the abundance of grazers or filtering collectors.

As with the biomass and chlorophyll a data – there are complex interactions happening here, perhaps with pigment efficiency increasing under low light conditions of dense canopy sites.

Still, these interactions are hard to isolate and statistical analysis can demonstrate similarly inconclusive results if interactions are not accounted for.



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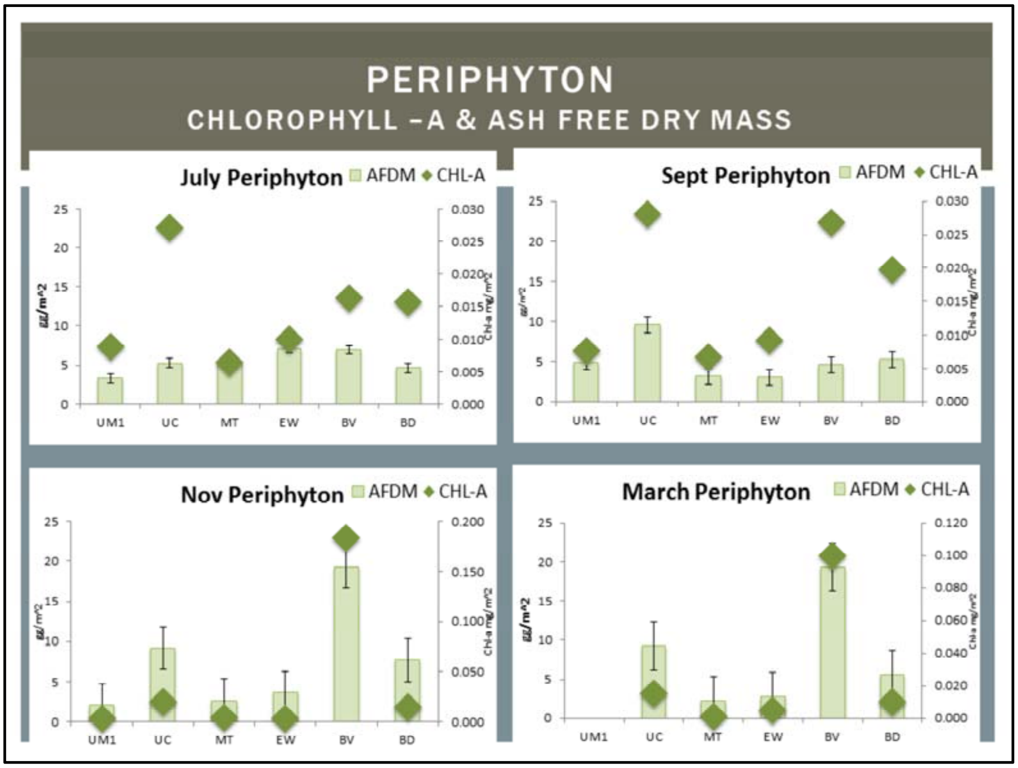
As with the biomass and chlorophyll a data – there are complex interactions happening here, perhaps with pigment efficiency increasing under low light conditions of dense canopy sites.

Still, these interactions are hard to isolate and statistical analysis could demonstrate similarly inconclusive results if interactions are not accounted for.

We are getting into the analyses here as more of the data sets we measured are finalized, shortly.



1. Biomass peaks in winter, despite cold temps

2. Nitrogen is a very important predictor of biomass year round, except in summer
3. Drivers change through the seasons\

Primary productivity*:* rate of organic matter created via photosynthesis by autotrophic organisms (e.g., algae, macrophyes, bryophytes).

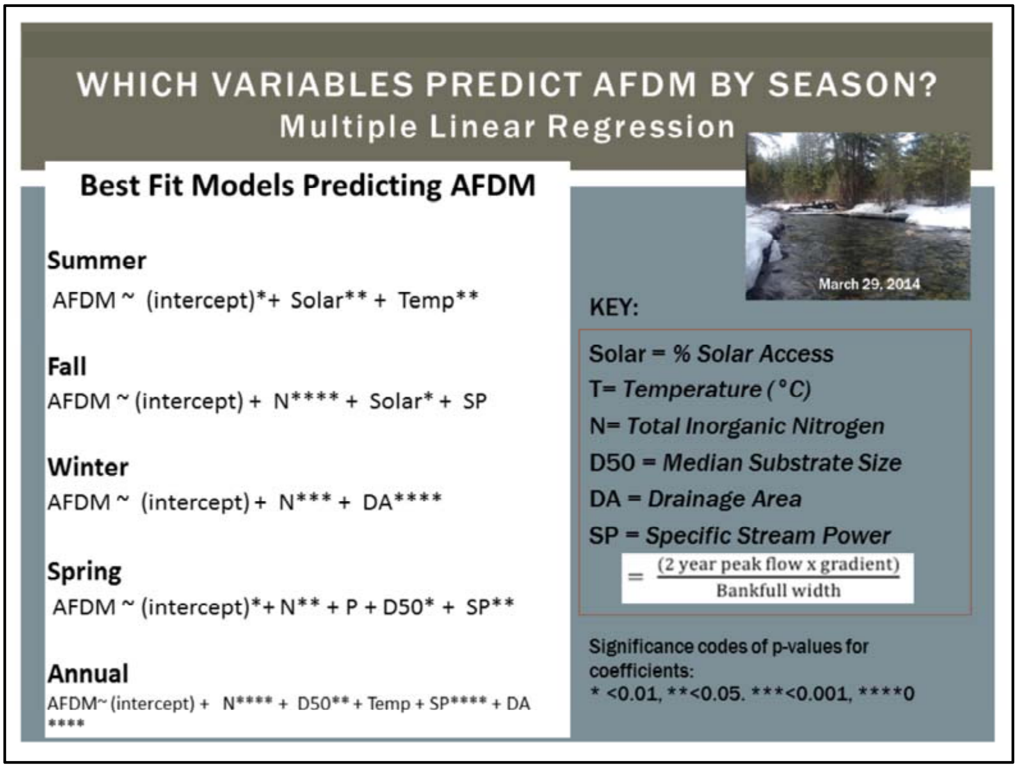
✧ Light
  •Riparian or topographic shading

✧ Temperature

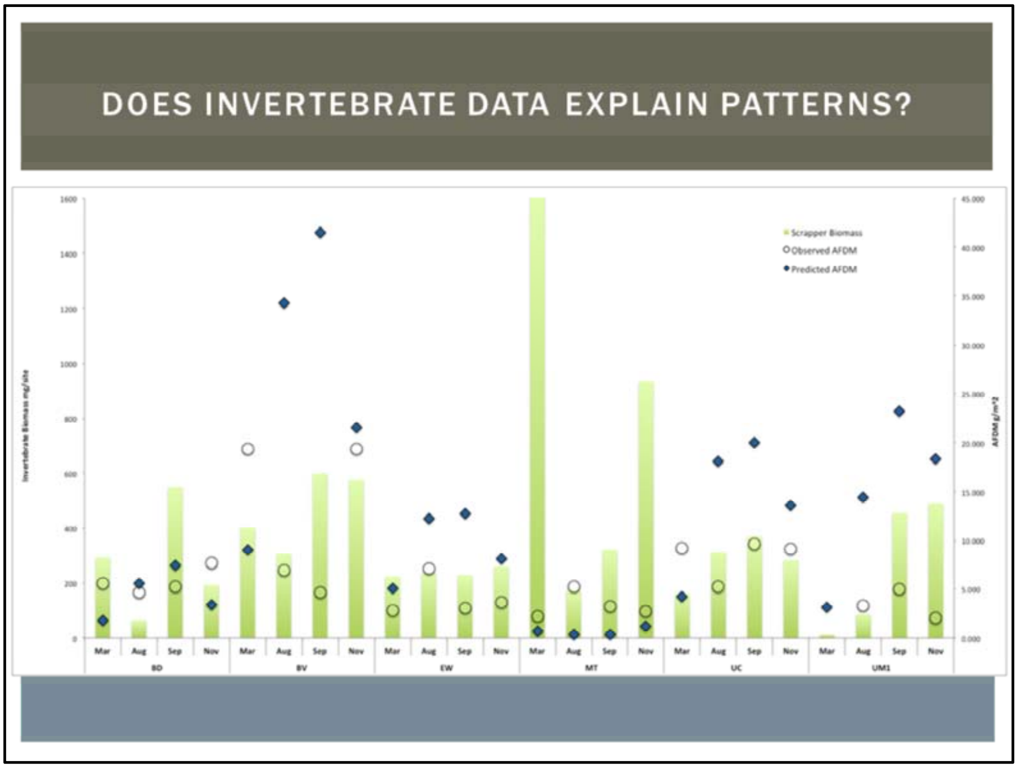
✧ Nutrients

✧ Watershed position

Other Factors:
Disturbance
Density Dependent Growth?



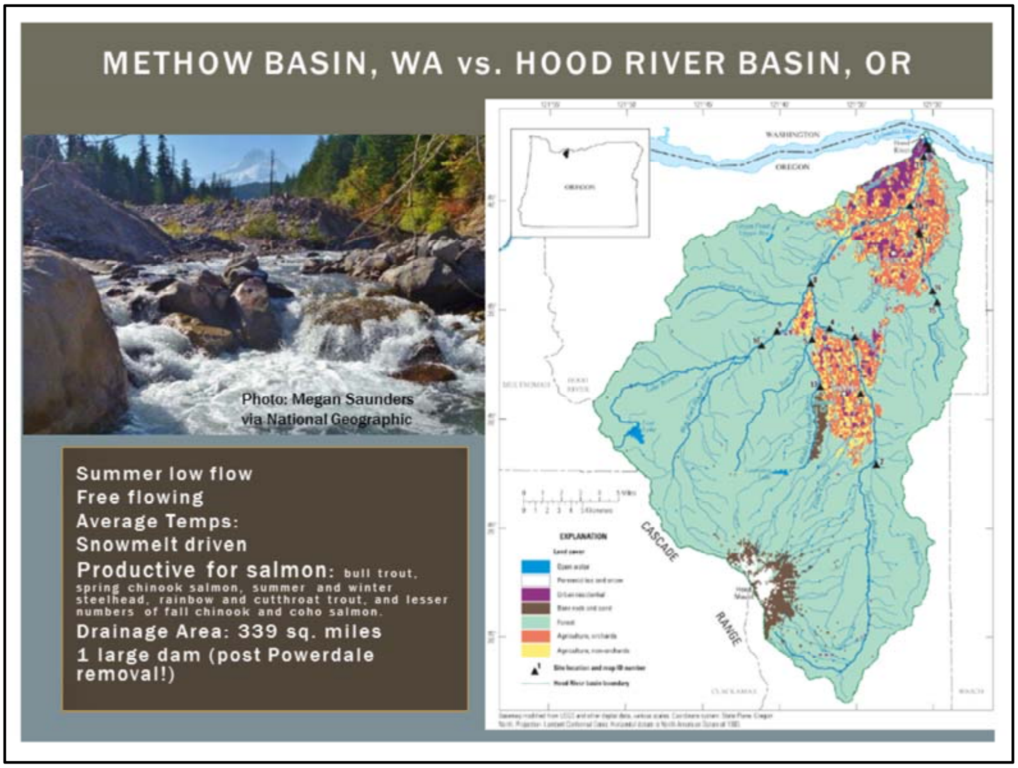
Nitrogen is an important predictor of biomass year round, except in summer



Biomass of invertebrates classified as part of the functional feeding group scrappers at all sample sites over all dates in comparison with Chlorophyll–a values. The site with the highest invertebrate biomass (Middle Twisp) consistently had the lowest AFDM and Chl-a biomass in empirical samples. This graph indicates efficiency of invertebrates at MT.

The site with the highest invertebrate biomass (Middle Twisp) consistently had the lowest AFDM and Chl-a biomass in empirical samples. This graph indicates efficiency of invertebrates at MT.

Frequently, but not always, the ATP Model (diamonds) over predicts periphyton biomass compared to observed biomass (circles). Invertebrate consumption can help explain this over prediction. Though not all feeding types directly consume biomass, all invertebrates benefit from higher biomass (though filtering consumption or as predators feeding on direct consumers). This important finding demonstrates model the needs to be calibrated using modifiers that account for the affect of grazing.

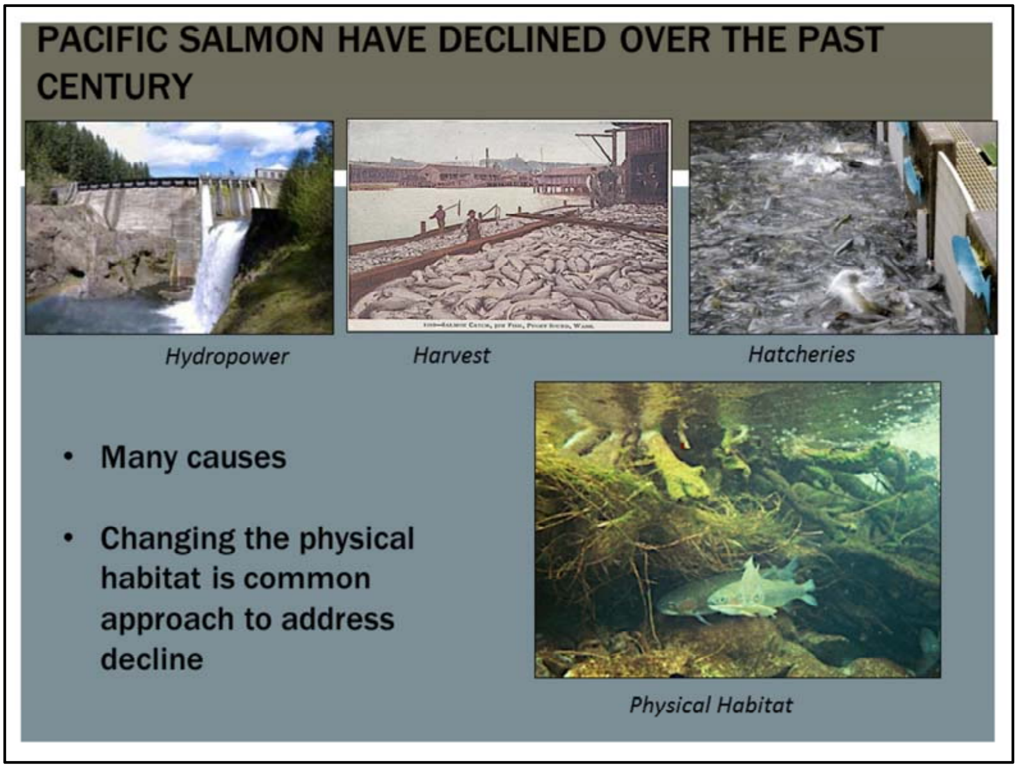


Free flowing

All listed salmonids,
Located above **9** Columbia River Dams

Elevation: 9,000 - 805 ft
Watershed area: 1805 mi^2

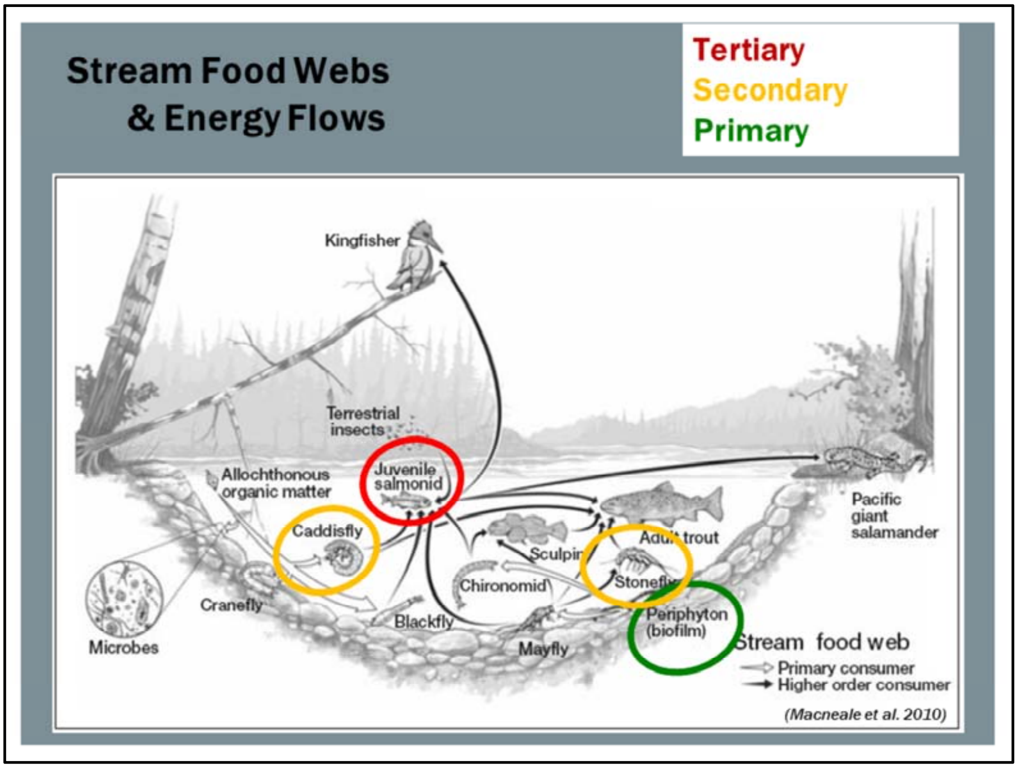
Oligotrophic system



In the PNW we know pacific salmonids are imperiled and we point to 4 key reasons for this imperilment.

4 H's – Harvest Levels: enormous catch rates in the early part of the century diminished adult numbers spawning in natal streams and overtime, populations over all,
Hatchery Production has introduced diseases and is interbreeding between hatchery and wild stocks has reduced the resilience of wild
A Hydropower System that block upstream passage, pummels juveniles as they swimming downstream over dams, slows or confuses upstream passage though fish ladders where predators are abundant.
Pause
The endangered species act of 1973 requires action to increase and maintain salmon populations under many human driven constrains, and as a result

Efforts to improve freshwater and estuary habitats have come into focus with Habitat labeled as the 4th H.
Numerous habitat project address upstream passage, like this culvert replacement, while other projects address water quality issues such as temperature or sedimentation, and other projects seek to address physical channel shape, instream cover or river hydraulics.

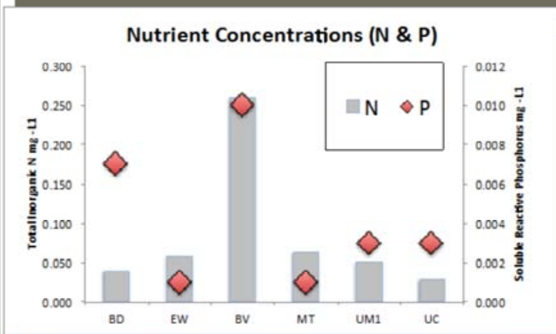


Stream Food Webs & Energy Flows
Tertiary
Secondary
Primary
Kingfisher
Terrestrial insects
Juvenile salmonid
Allochthonous organic matter
Caddisfly
Cranefly
Microbes
Blackfly
Chironomid
Sculpin
Adult trout
Stonefly
Periphyton (biofilm)
Mayfly
Pacific giant salamander
Stream food web
Primary consumer
Higher order consumer
(Macneale et al. 2010)

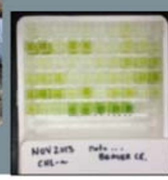
I Looked at:
Deciduous v Conifer Riparian Cover
Timing of inputs
Drift vs Standing Crop Benthic

Other Ecological Drivers that contribute to the patterns we see:
Temp
Nutrient Concentration
Light
Stream Power/Channel Shape and the Disturbance Regime

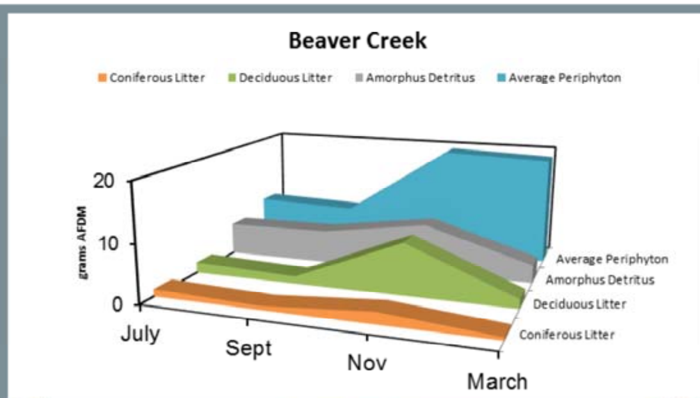
OVERALL: COARSE ORGANIC MATTER & BENTHIC DETRITUS MAY HELP RETAIN NUTRIENTS

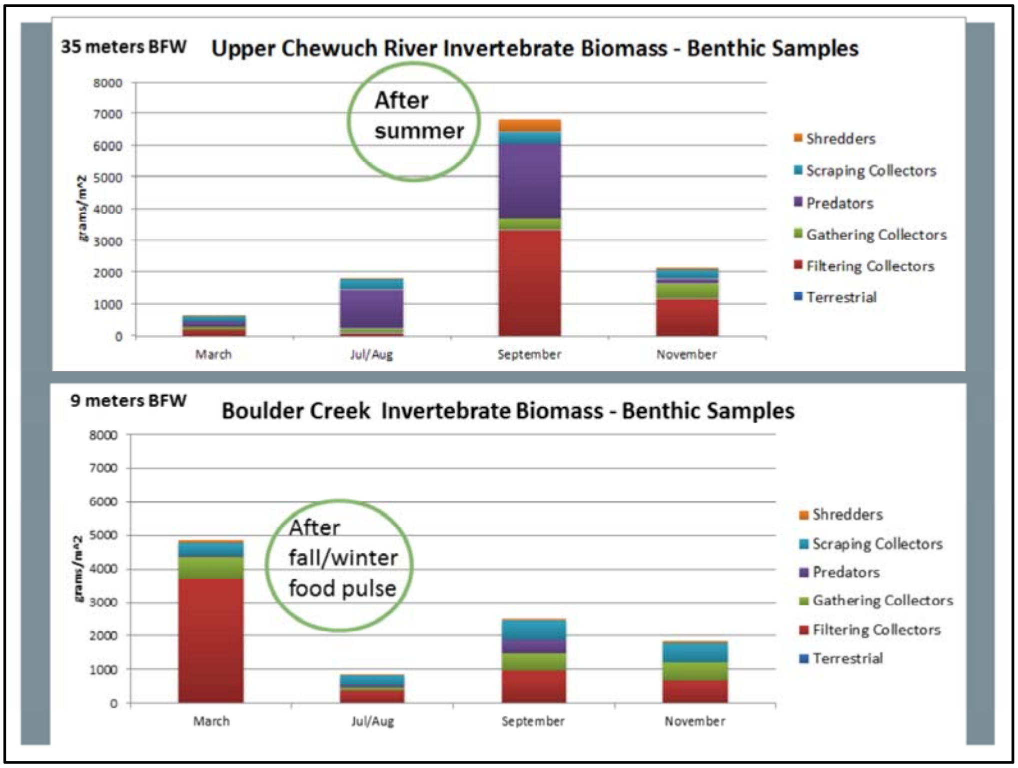


N= Total Inorganic Nitrogen, P = Soluble Reactive Phosphorous



STREAM RESOURCES BY SEASON



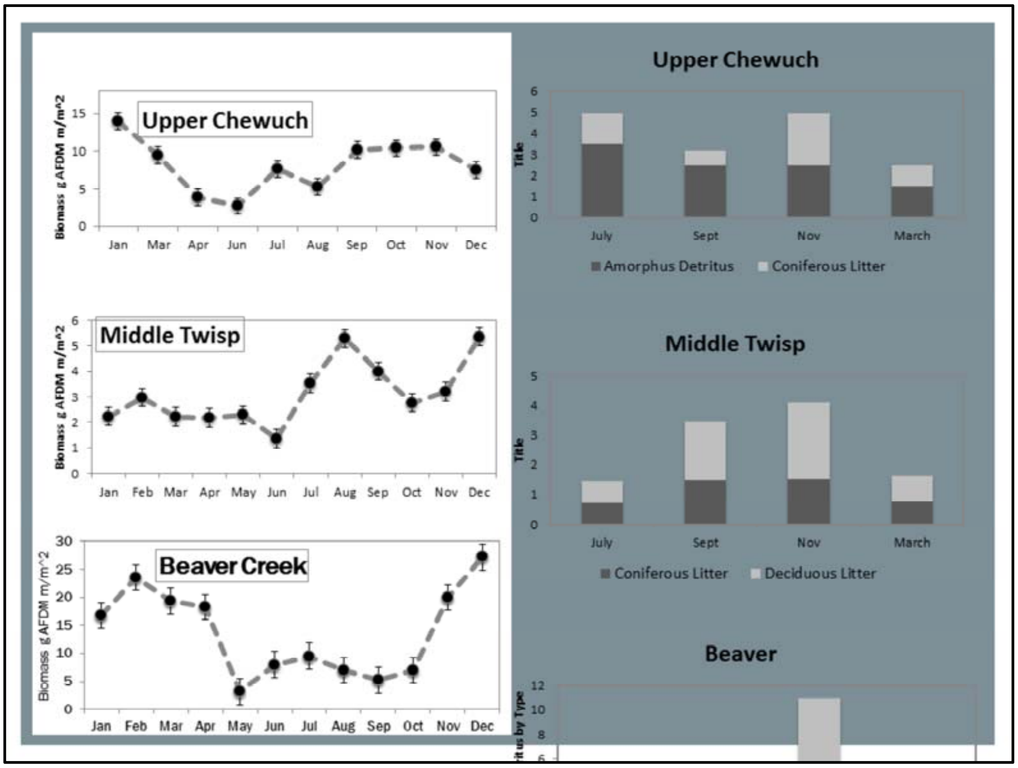


1. These show the invertebrate response by size of creek.
2. Generally speaking this pattern happens at all sites:
Fall (September invertebrate biomass levels are higher in larger streams.
In smaller tributries, benthic invertebrate biomass levels were higher in early spring.

1. Increase in invertebrate biomass occurring after summer in large river (greater periphyton)

2. After winter in smaller stream – lower flow, lower turnover, more decay of riparian leaf litter and consumption/growth by invertebrates.

3. Overall, sites with high conifer canopy cover also had high invertebrate biomass despite shading


Upper Chewuch
Biomass g AFDM m/m^2
Jan Mar Apr Jun Jul Aug Sep Oct Nov Dec
Middle Twisp
Biomass g AFDM m/m^2
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Beaver Creek
Biomass g AFDM m/m^2
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Upper Chewuch
Title
July Sept Nov March
Amorphus Detritus
Coniferous Litter
Middle Twisp
Title
July Sept Nov March
Coniferous Litter
Deciduous Litter
Beaver