Influence of waterfalls and hydrology on the spatial zonation of *O. mykiss* life histories

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Partial Migration in Fishes

- Partial migration is very common in a diversity of fishes (Jonsson and Jonsson 1993)

- Migration is often phenotypically plastic, ongoing trade-offs include individual growth and predation risk (Chapman et al. 2012)

- Migration strategy is often linked to body size, with smaller-bodied individuals often expressing the less-fit strategy (Chapman et al. 2012)

Clupeidae - Atlantic herring

Moronidae - White perch

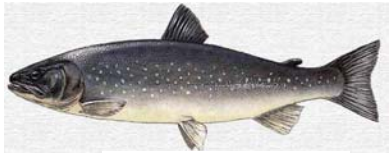
Pleuronectidae– Plaice

Cyprinidae – Common Roach

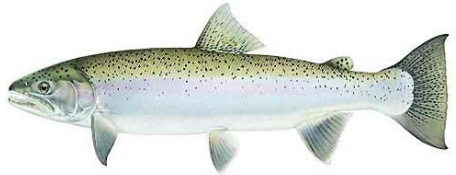
Partial Migration in Salmonids

- Migration in salmonids has genetic underpinnings (Pearse et al. 2014, Abadía-Cardoso et al 2011, Nichols et al.2008)
- Offspring can express a different life history than their parents (e.g., Thrower et al. 2004, Hodge et al. 2016)
- Migration in salmonids is often considered a threshold trait – individuals migrate once they reach a certain body size (Dodson et al 2013)
  - The threshold size can very between populations (Phillis et al. 2016)
- Migration has consequences for nutrient transfer between marine and freshwater ecosystems (e.g., Helfield and Naiman 2001)


Bull trout


Arctic charr

Sockeye/kokanee

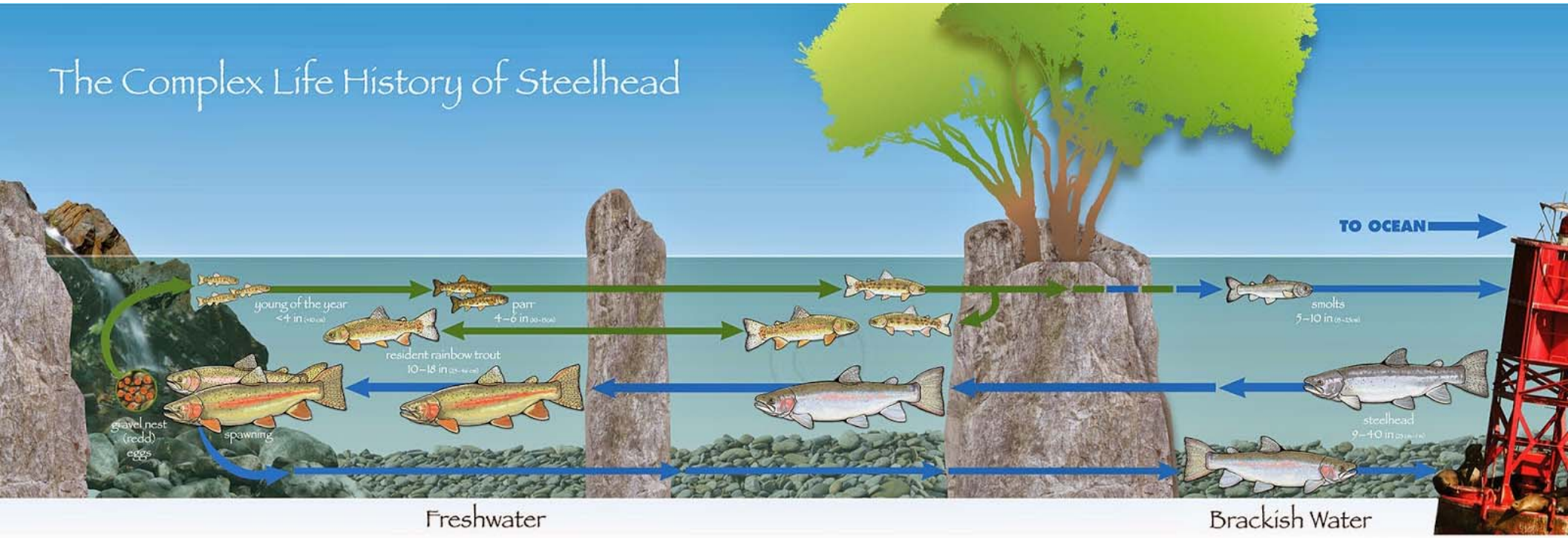

Steelhead/rainbow trout

A few outstanding questions for partial migration in salmonids:

1) What are the geographical features that determine the spatial zonation of resident vs. migratory genotypes in streams?

2) What are the consequences of life history zonation for stream ecology?

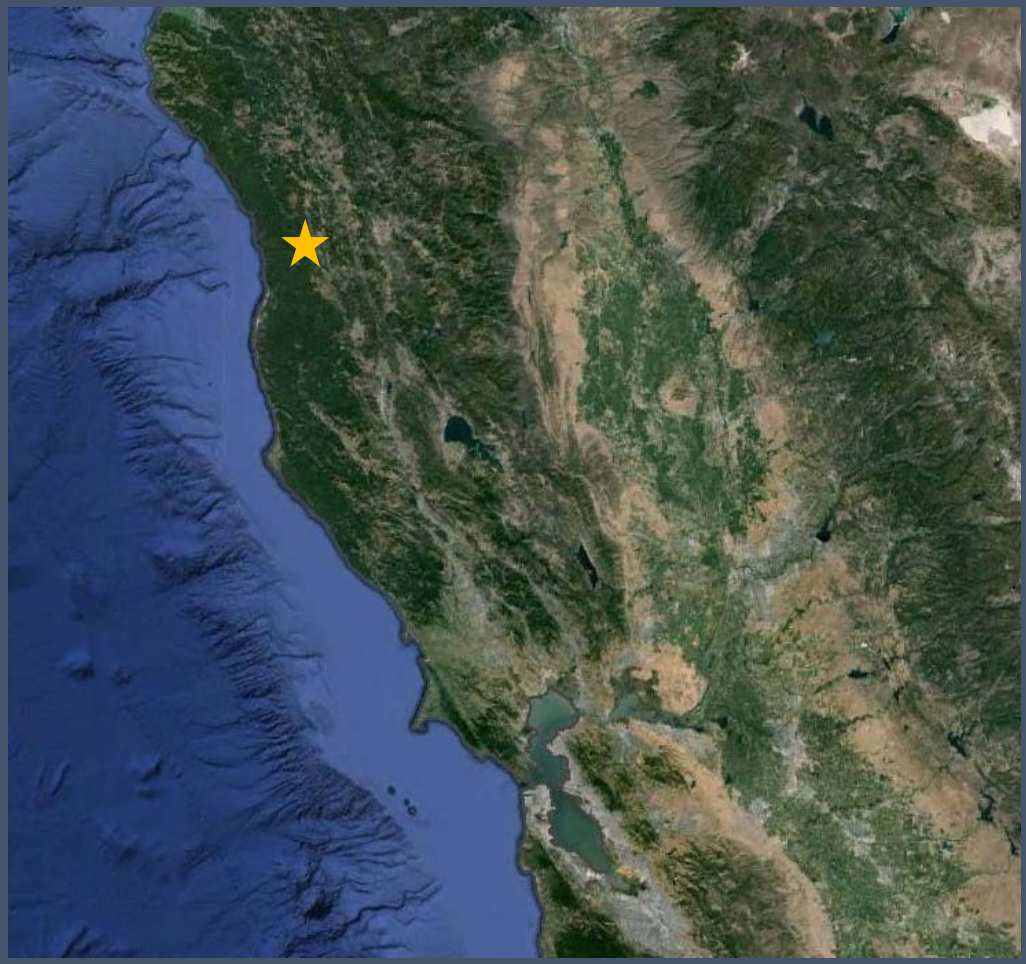
Partial migration in steelhead/rainbow trout (*Oncorhynchus mykiss*)



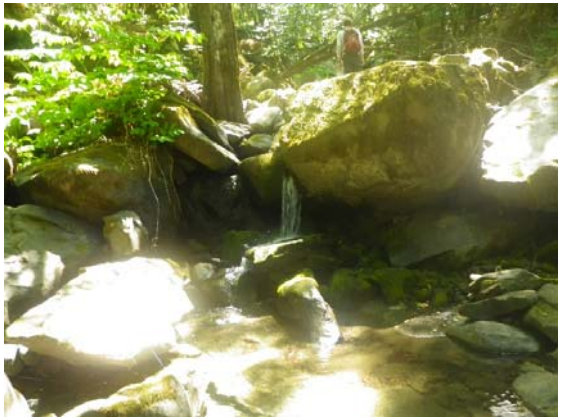
http://changewindsink.blogspot.com/

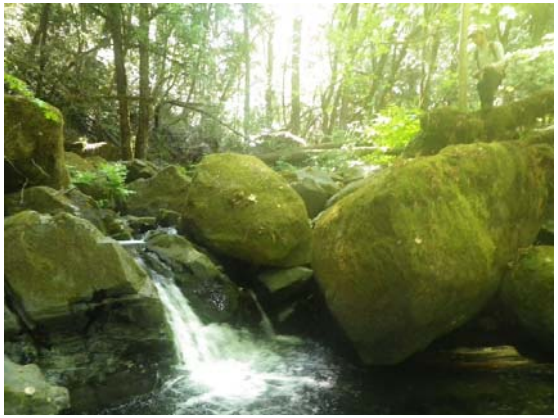
Green arrows: resident life history, **Blue arrows:** migratory life history

Migratory and resident fish co-occur in many coastal watersheds, including in tributaries to the South Fork Eel River

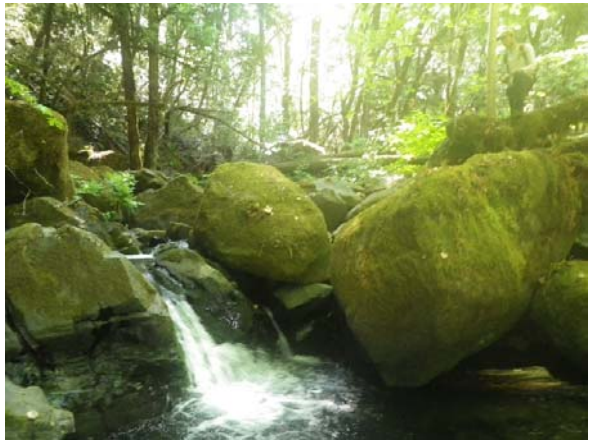


Waterfalls: barriers to migration

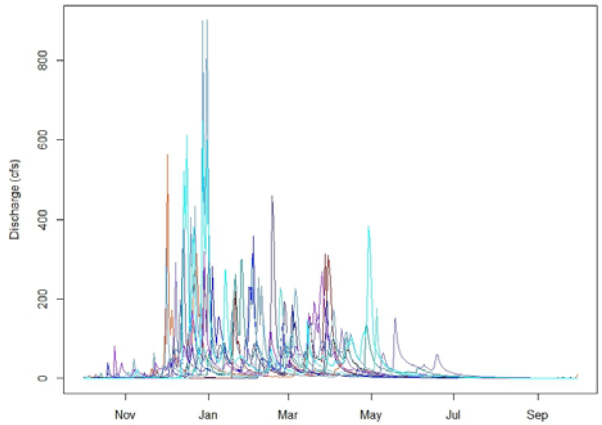




How do **waterfalls** and **hydrology** interact to influence the longitudinal distribution of *O. mykiss* life histories in streams?



Discharge from 1967 – 2014 at Elder Creek



Inter-annual **variation** in **precipitation** (timing and magnitude) influence the strength of selection at waterfalls and spatial distribution of genotypes

- **Dry years:** Waterfalls will exert a greater selection against migratory adults in dry years, decreasing the spatial extent to which the life history forms overlap

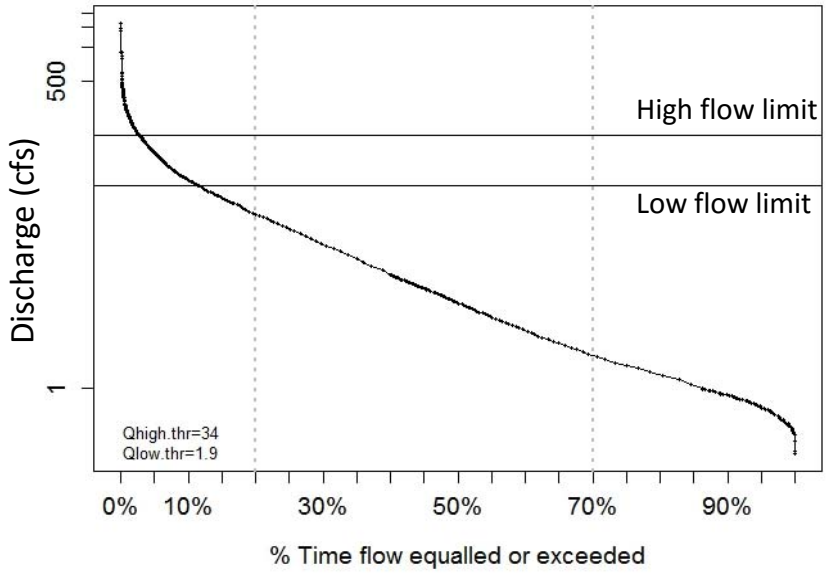
- **Wet years:** More migratory adults will be able to ascend waterfalls in the winter, increasing the spatial extent to which the life history forms overlap

Elder Creek Falls: 3.1m high from bedrock to crest

Inter-annual variation in the amount of time that Elder Creek Falls is passable during the steelhead spawning season (Dec-April)

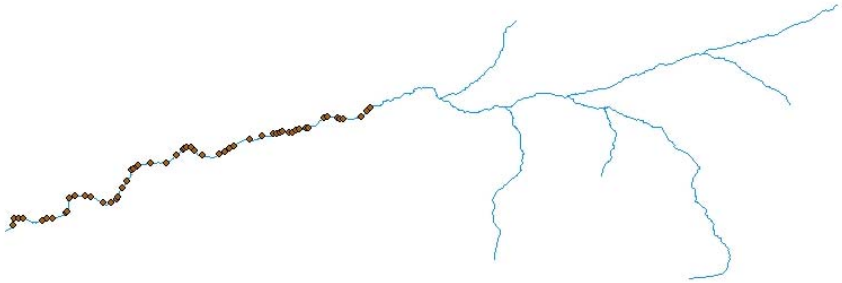
- This waterfall was passable **0-78** days each year between December and April from 1967 to 2014, following flows suggested by Trush 1991 (60 – 170 cfs)

Elder Creek Flow Duration Curve, Dec – April, 1967-2014

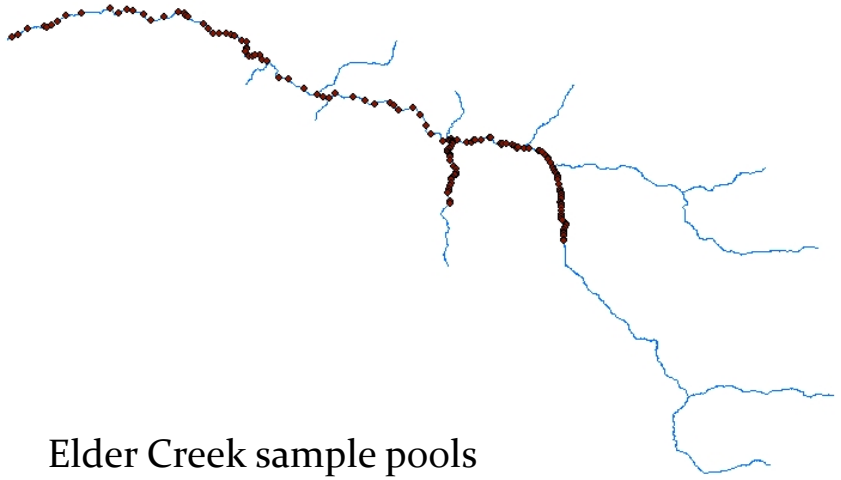


Methods: Sample collection

- We sampled for fin clips in Fox Creek and Elder Creek in July - August 2014 & 2015
- Fish were captured longitudinally from mouth to the upper extent of fish, in ~20% of the pools, which were randomly chosen



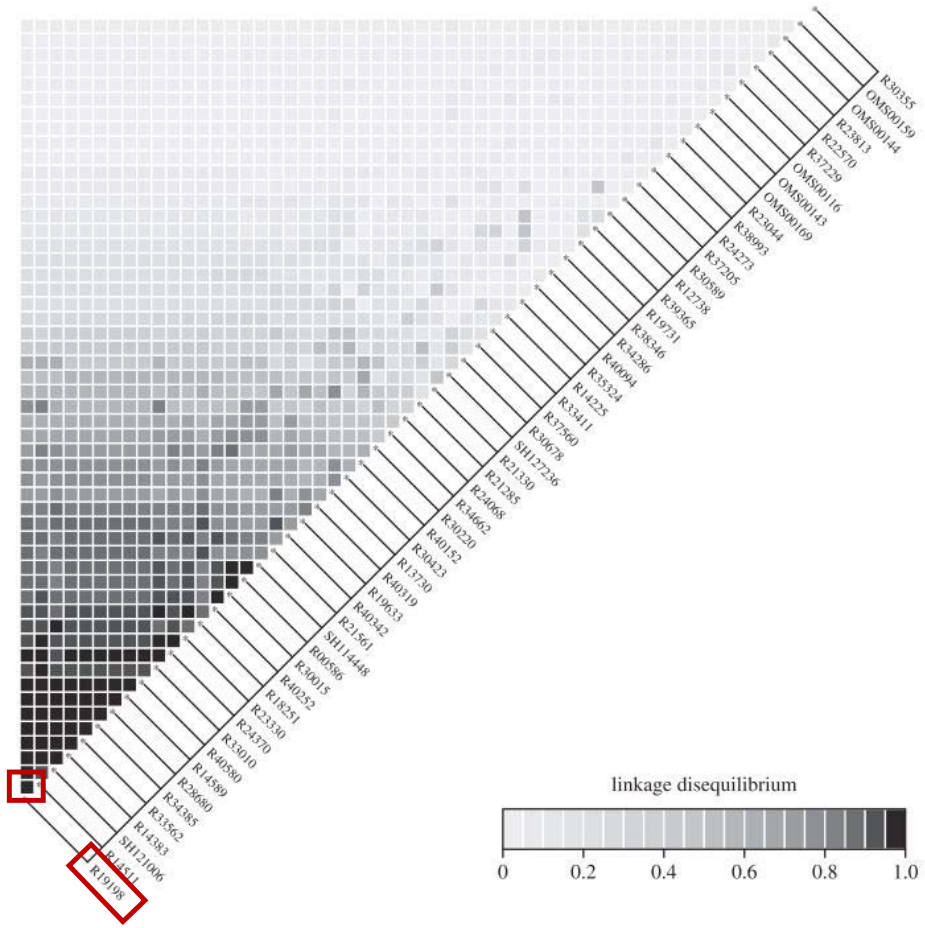
Fox Creek sample pools



Elder Creek sample pools

Methods: Genotyping

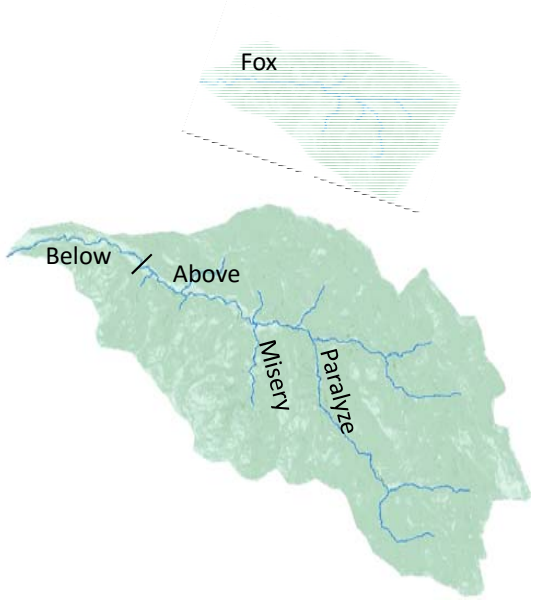
- Samples were sequenced using RAD capture (Ali et al. 2016)
- Here we are interested in SNPs on Omy5, a region of the genome that is linked to life history diversity in *O. mykiss* (Pearse et al. 2014)
- We were able to sequence one SNP on OMy5, R19198, in high linkage disequilibrium for adult anadromous steelhead (Pearse et al. 2014)



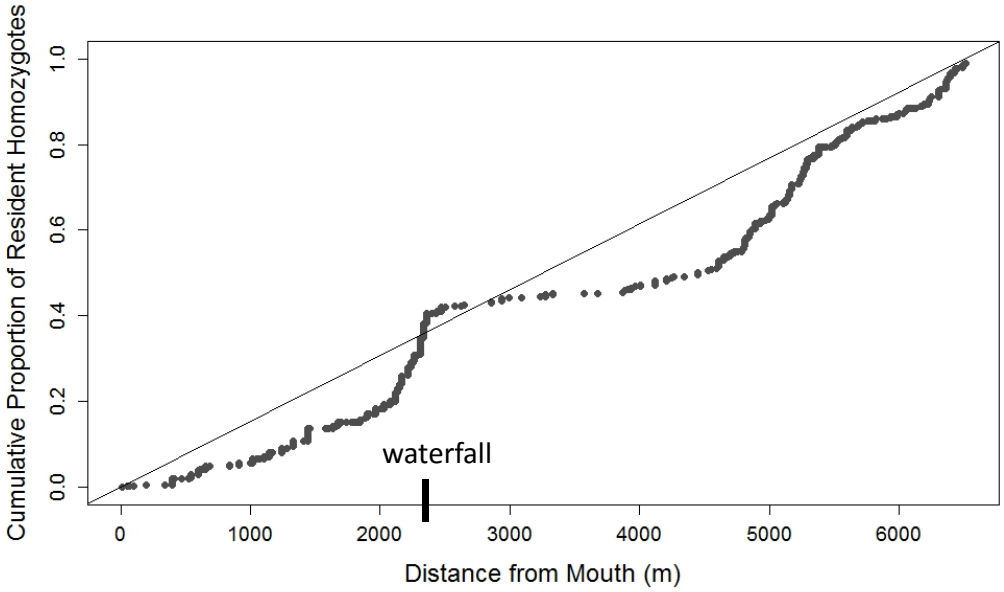
Frequencies of Alleles at R19198

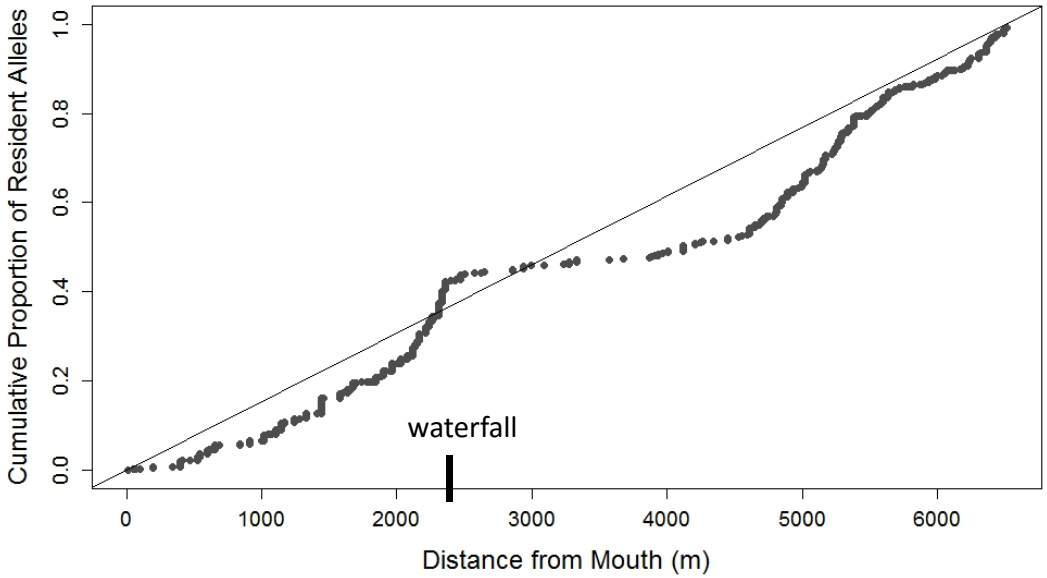
Regions that are over 50% migratory are in blue, dominant frequency is bolded

Location	Frequency T (Migratory)	Frequency C (Residency)
Elder-Below waterfall	**0.56**	0.44
Elder – Above waterfall	0.48	**0.52**
Misery	0.29	**0.71**
Paralyze	**0.52**	0.48
Fox	0.35	**0.65**
South Fork Eel R	**0.88**	0.12



Preliminary Results: Longitudinal patterns of resident genotypes at R19198 in Elder Creek in summer 2014





- Line is the null model: the rate of increase of resident homozygotes (left) or alleles (right) remains constant moving upstream

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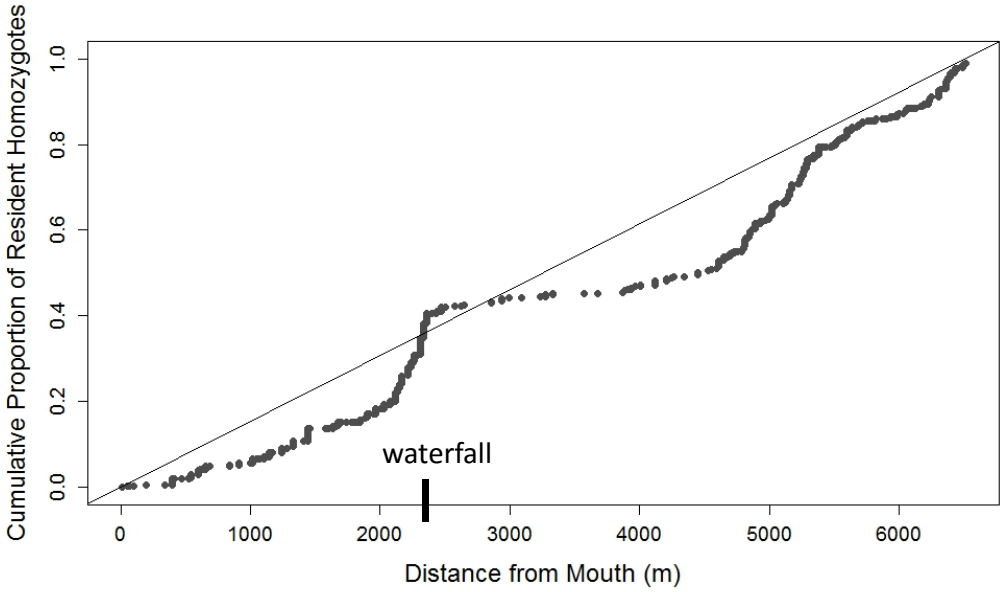

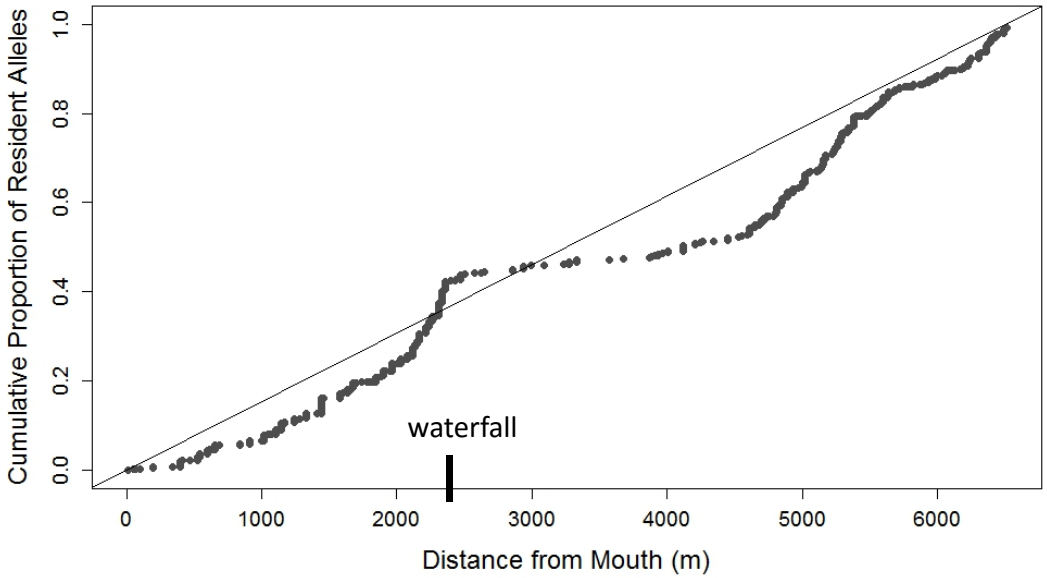

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1) What are the geographical features that determine the spatial zonation of resident vs. migratory genotypes in streams?

2) What are the consequences of life history zonation for stream ecology?

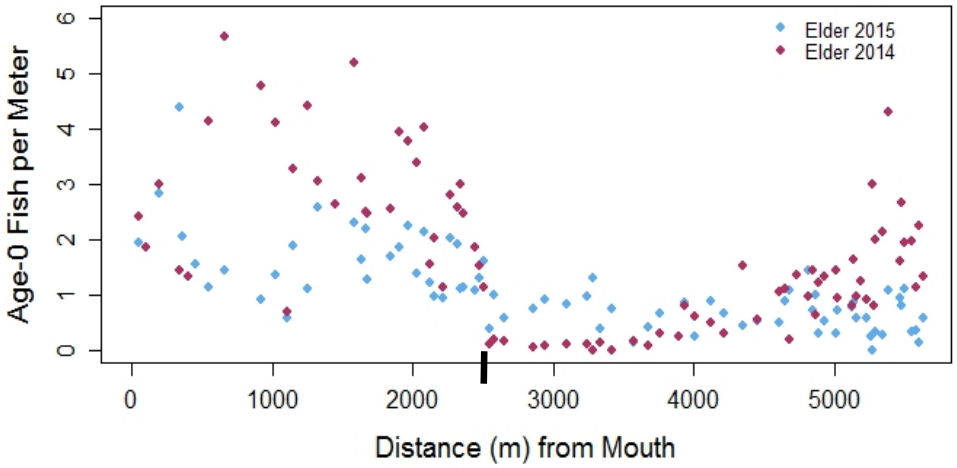
1) What are the geographical features that determine the spatial distribution of resident vs. migratory genotypes and phenotypes?

2) What are the consequences of life history zonation for stream ecology?

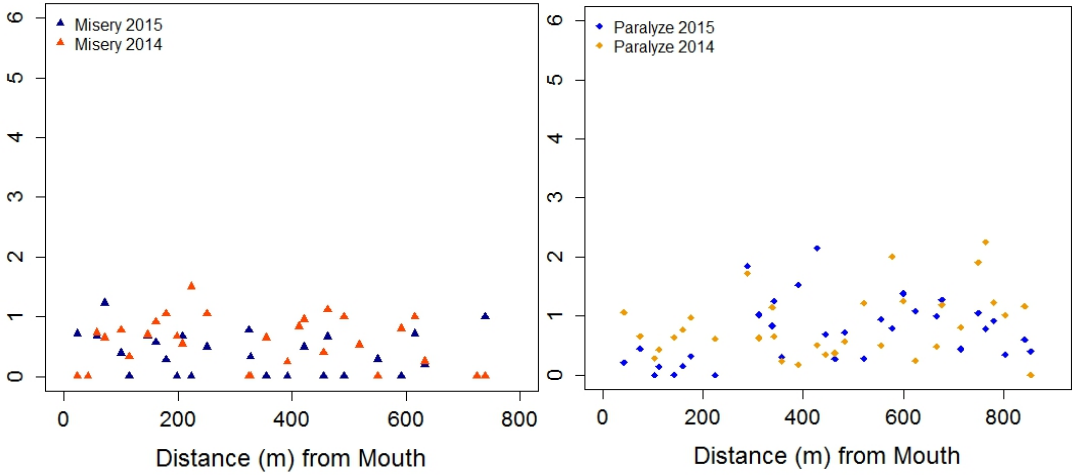
- What are the effects of life history on:
  - density
  - size structure
  - food web characteristics

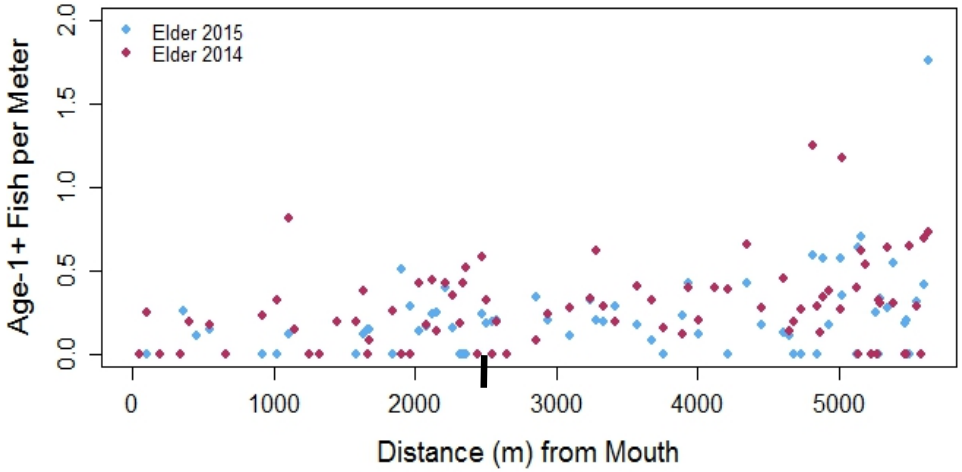
Longitudinal patterns in density in Elder Creek

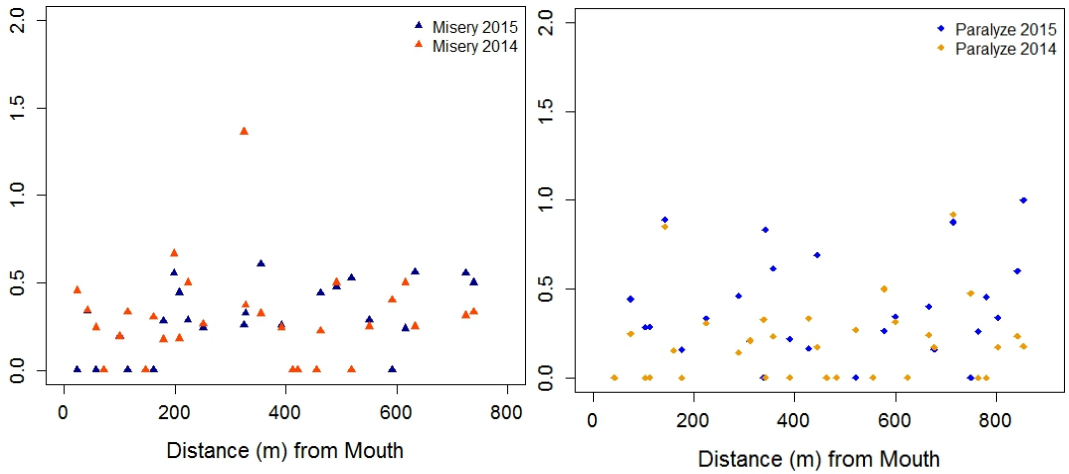
Elder Creek



Elder Creek tributaries – Misery and Paralyze







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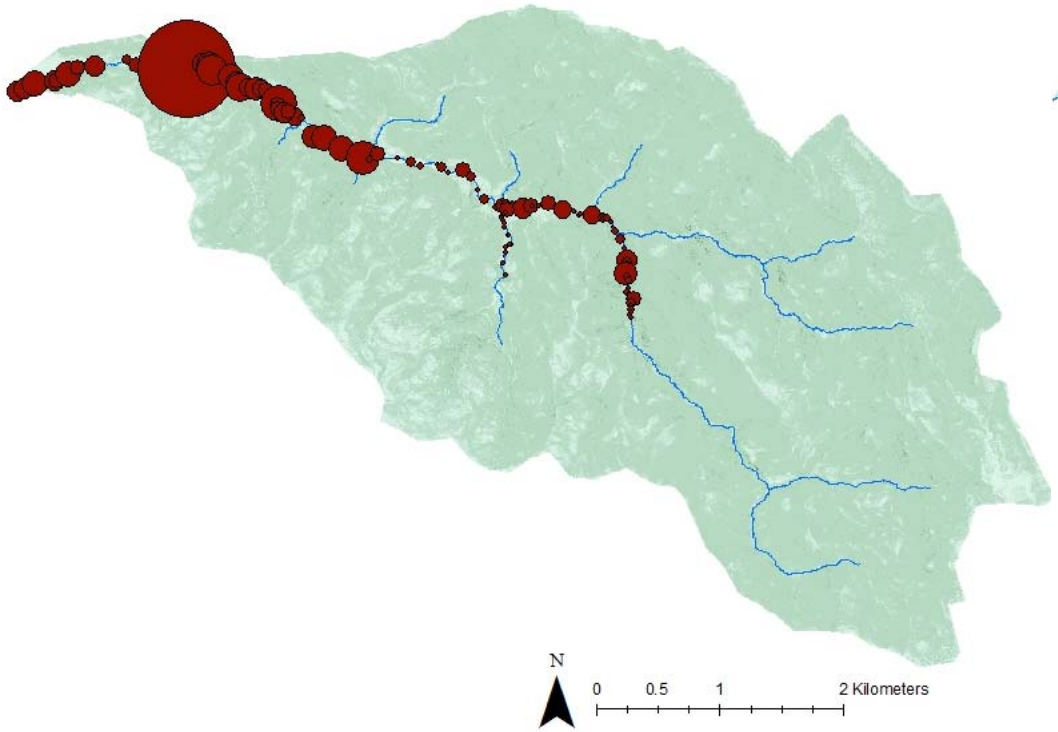
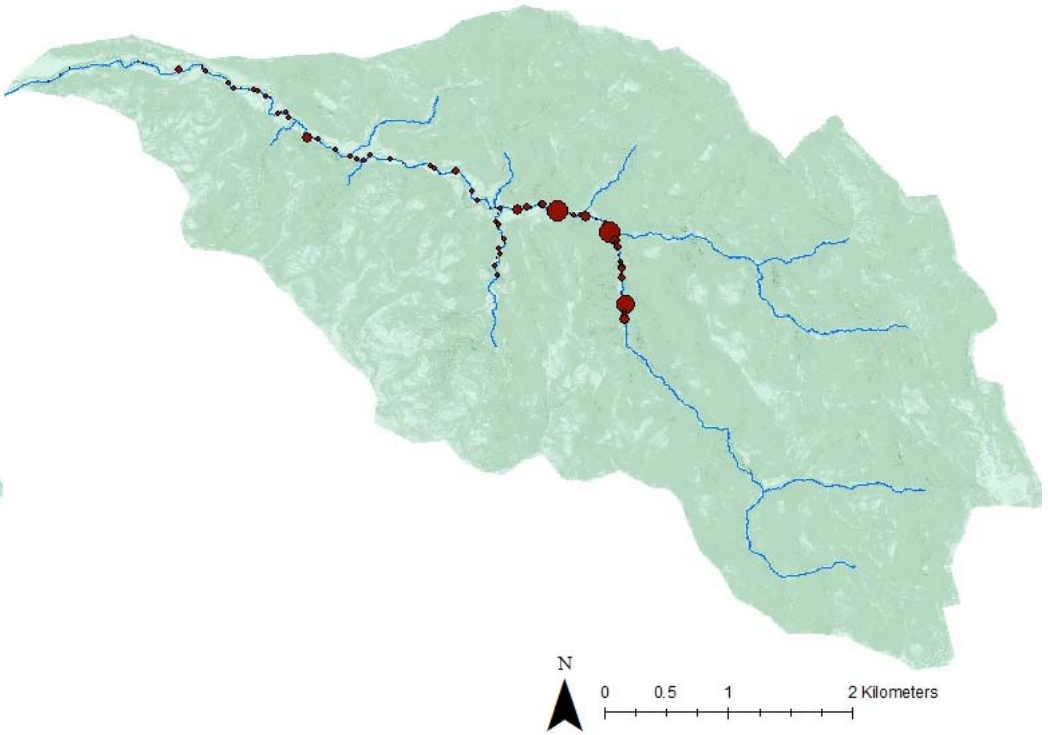
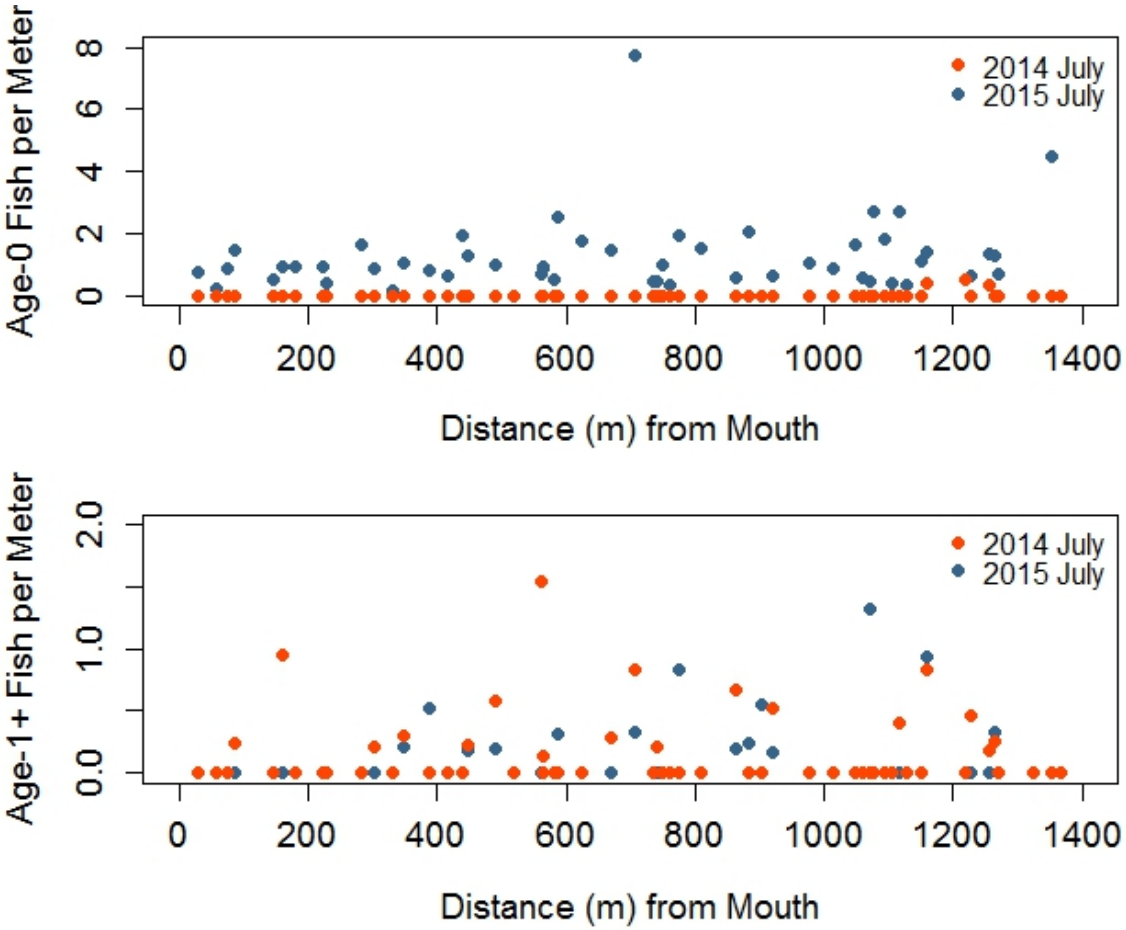


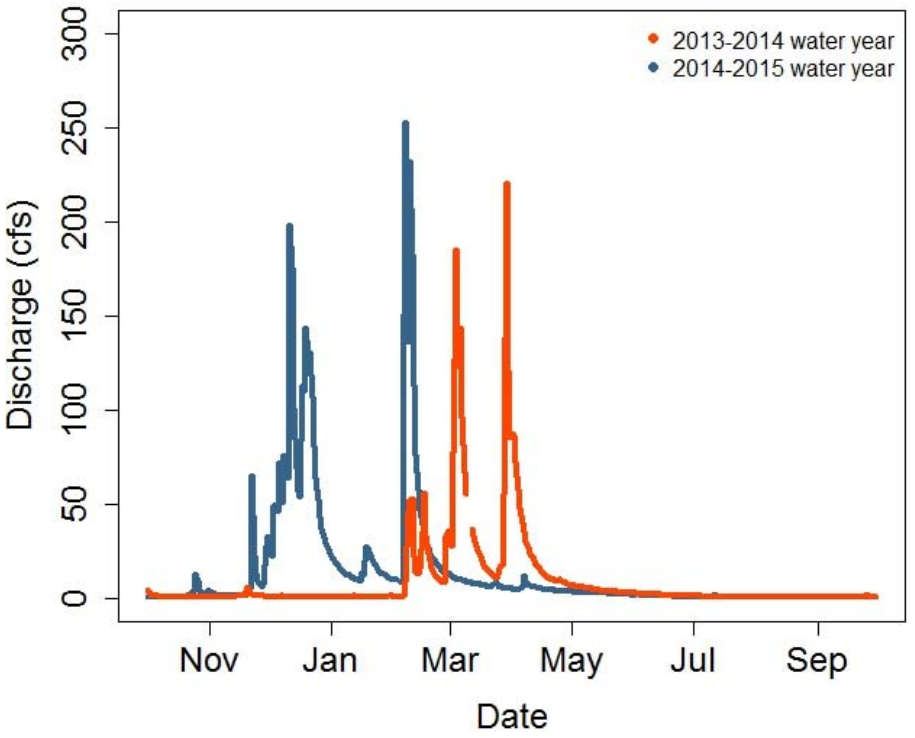
Age-0 fish in Elder Creek



Age-1+ fish in Elder Creek

Patterns in density in Fox Creek in 2014 and 2015





In 2014, the frequency of resident alleles was 64% in Fox Creek

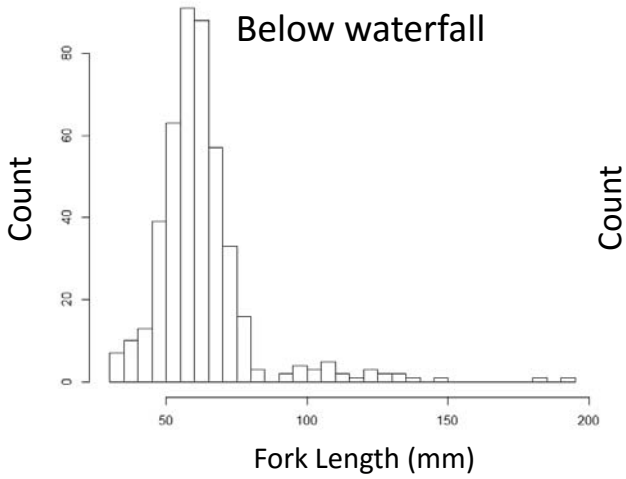
Longitudinal patterns in **size structure** in Elder Creek

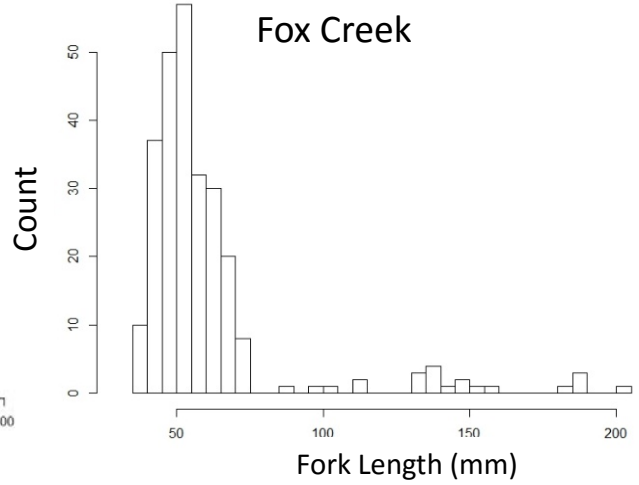
Fish in one pool below waterfall

Fish in one pool above waterfall

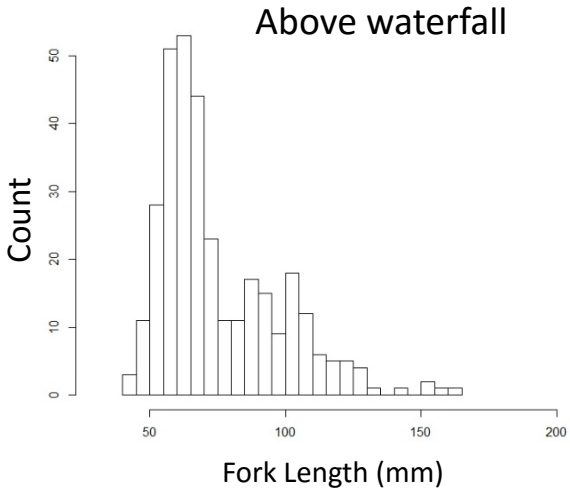
Spatial variation in size structure

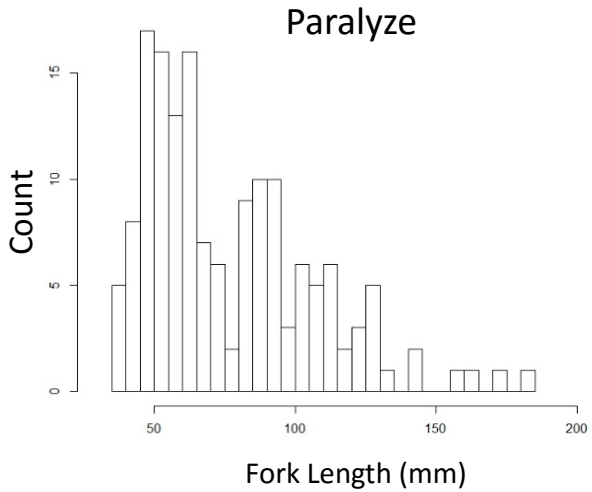
Migratory regions:

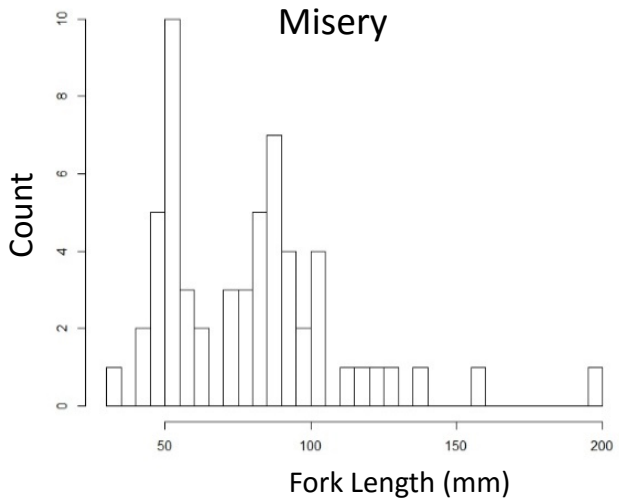




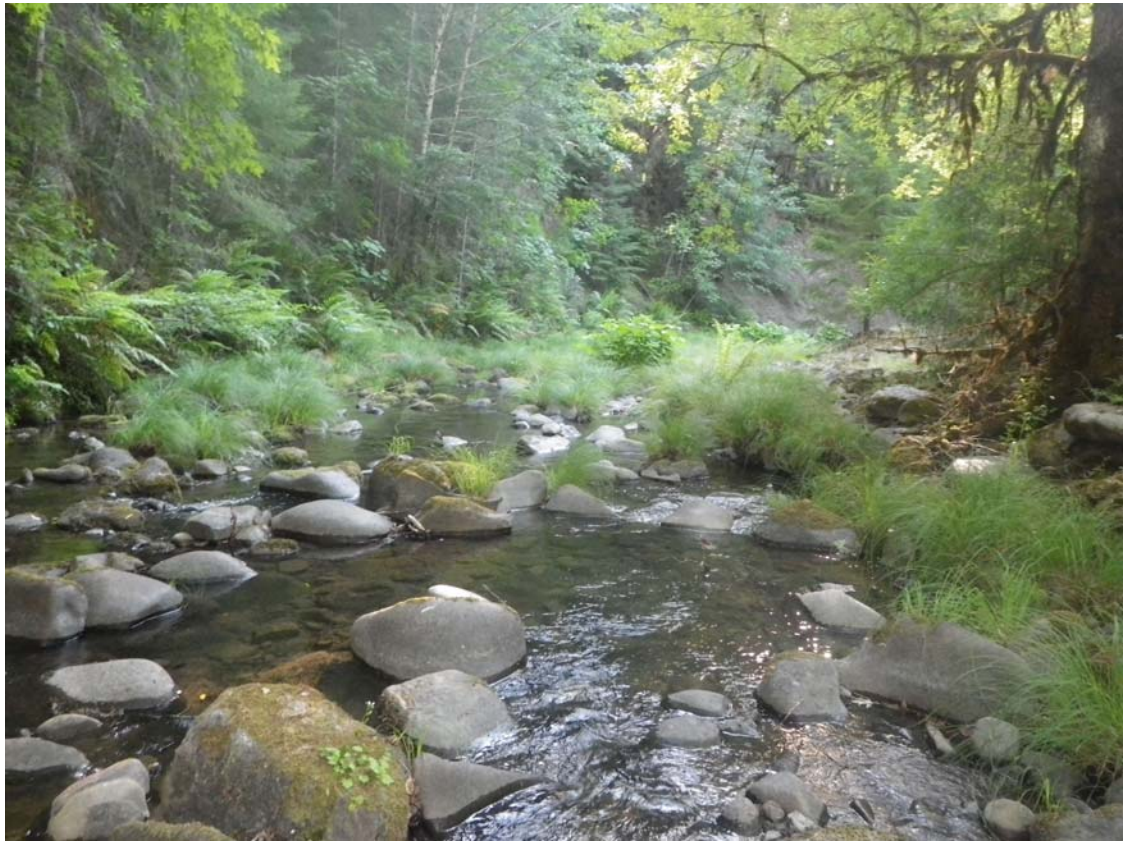
Resident regions:

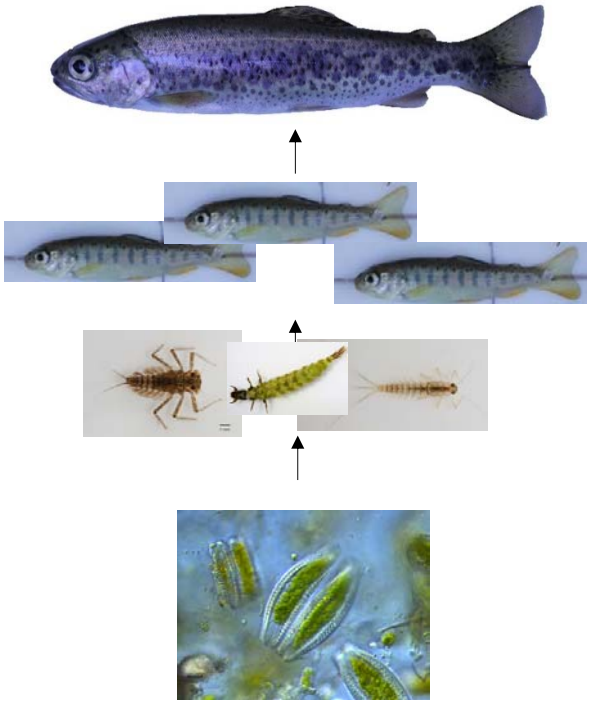






Food web ecology in shaded tributaries

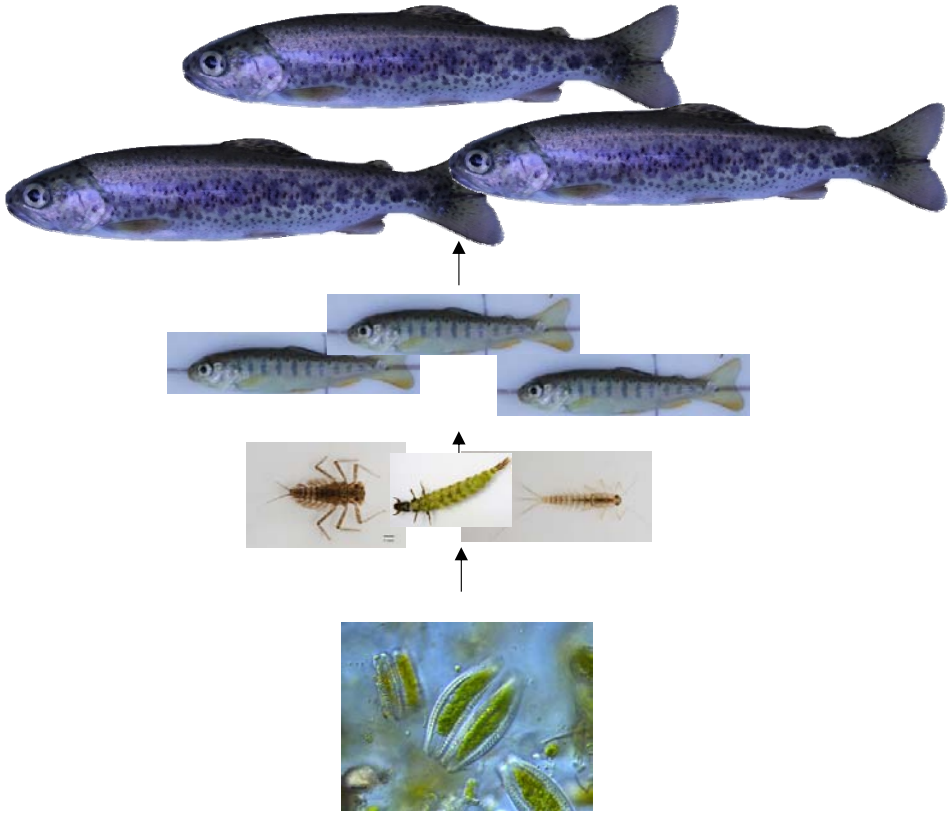




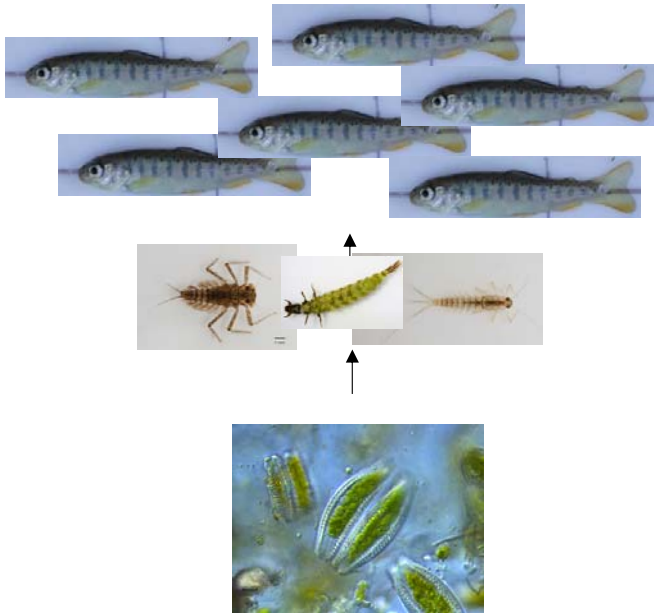
Invertebrate photos: Shelley Pneh, Epithemia photo: Rex Lowe

Can size structure influence number of trophic levels?

4-level food web



3-level food web



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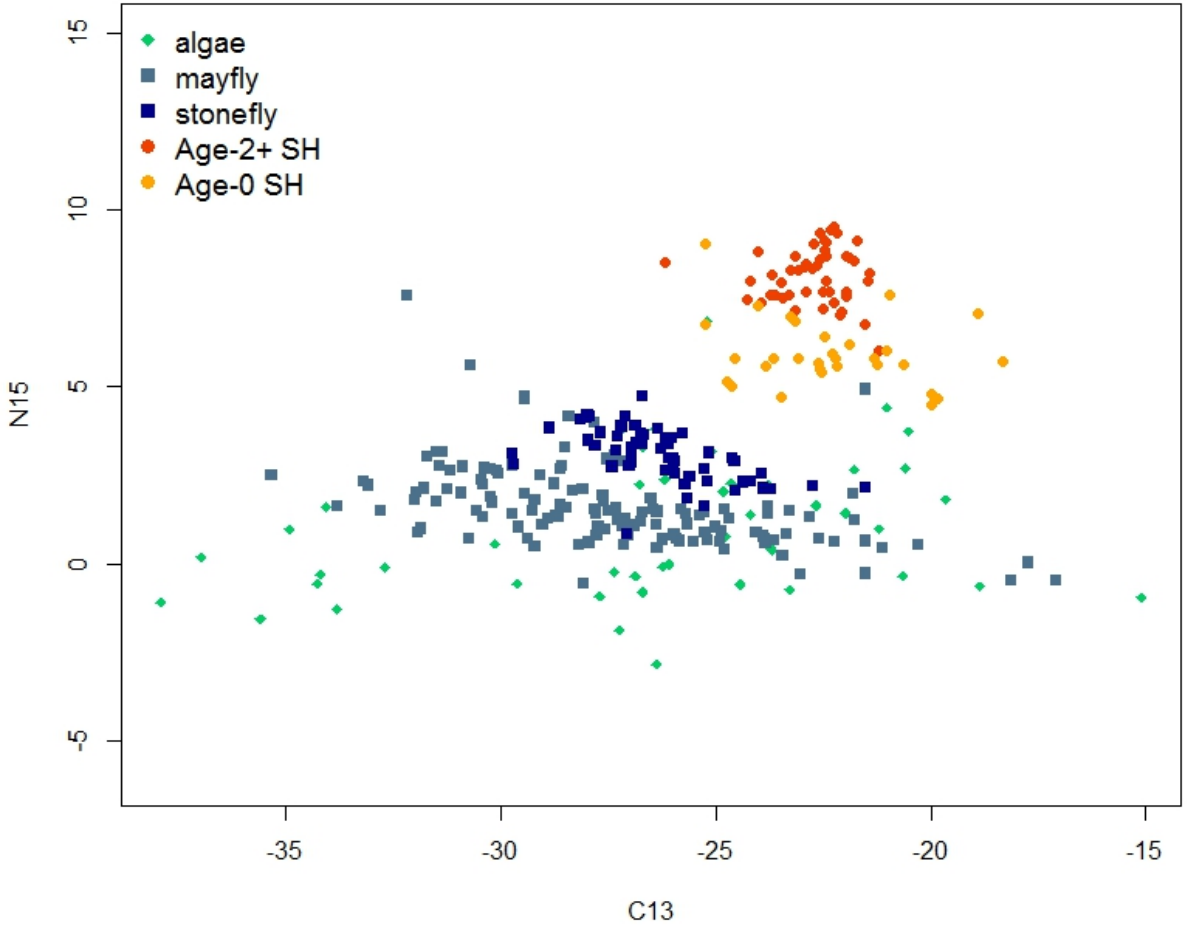

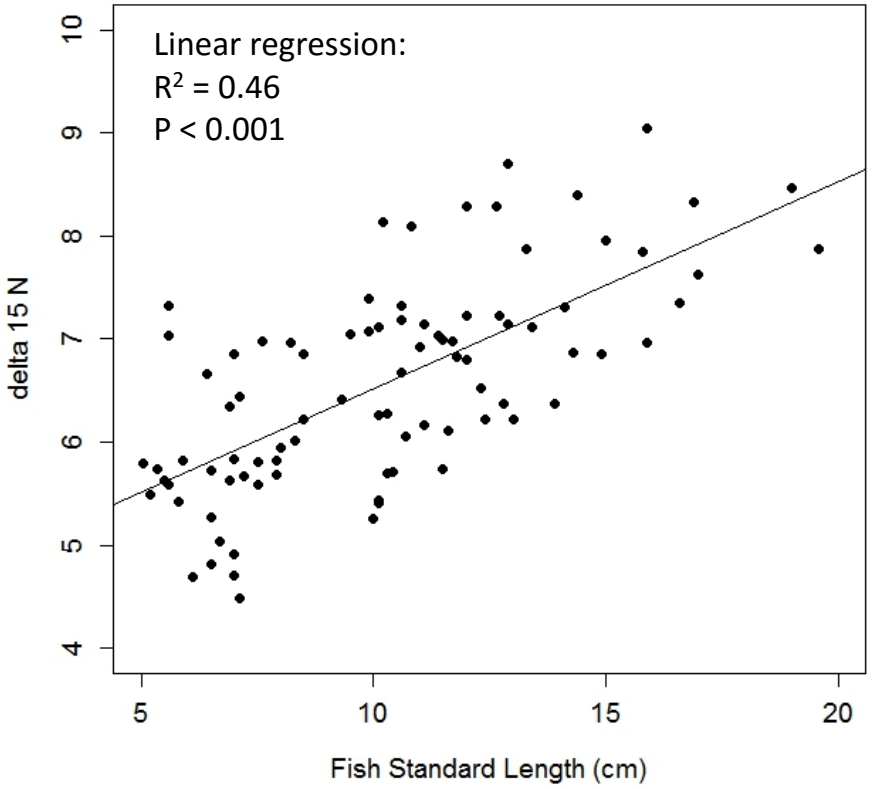

Algae, mayfly, stonefly, and age-0 data courtesy of J. Finlay, 1997-1999, age-2+ fish from August 2014 and 2015

Conclusions

1) Small waterfalls may influence the spatial zonation of migratory and resident life histories

-Migratory alleles persist in the furthest upstream reaches of a partially migratory population

2) Changes in density and size structure, which correlate with a shift towards more resident fish, may have implications for stream food webs

Implications for partial migration

-Partial migration can be influenced by geographical features in addition to ecological interactions

-Partial migration can have consequences for food web structure in the resident habitat

Thanks!

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Natural Reserve System

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