Evolution and ecology of partial migration in a salmonid fish *(Oncorhynchus mykiss)*

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California Chapter, Society of Freshwater Science

Suzanne Kelson[1]

skelson@berkeley.edu

PhD Candidate, University of California, Berkeley

Michael Miller[2], Stephanie Carlson[1]

[2]UC Davis, Dept. of Animal Sciences, [1]UC Berkeley, Dept. of Environmental Science, Policy, and Management

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

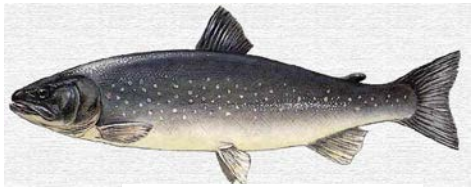
Pleuronectidae– Plaice

Cyprinidae – Common Roach

Partial Migration in Salmonids

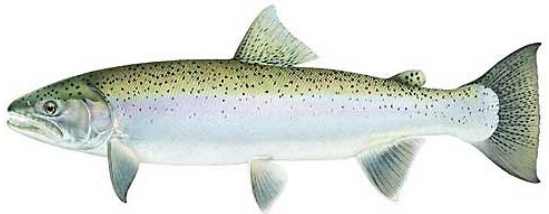
- Migration in salmonids has genetic underpinnings (Pearse et al. 2014, Abadía-Cardoso et al 2011, Nichols et al.2008)
- Offspring can express a different life history than their parents (e.g., Thrower et al. 2004, Hodge et al. 2016)
- Migration in salmonids is often considered a threshold trait – individuals 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 fish in streams?

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

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- **How are genotypes distributed in the stream?**

Partial Migration in *Oncorhynchus mykiss*

Juveniles

Resident fish

Smolts

Migratory fish

Ocean

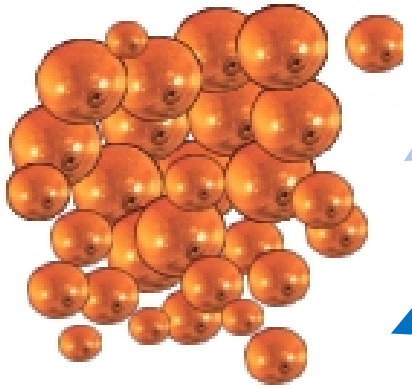
Adults

Steelhead trout

Rainbow trout

Adults

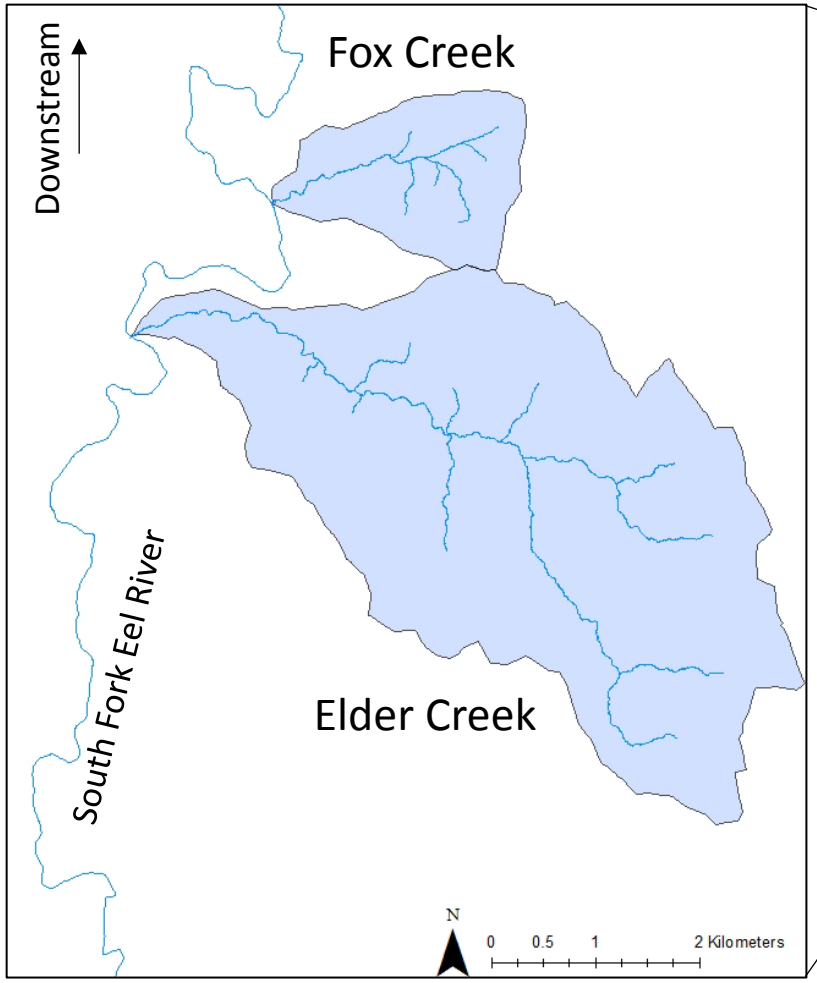
Freshwater

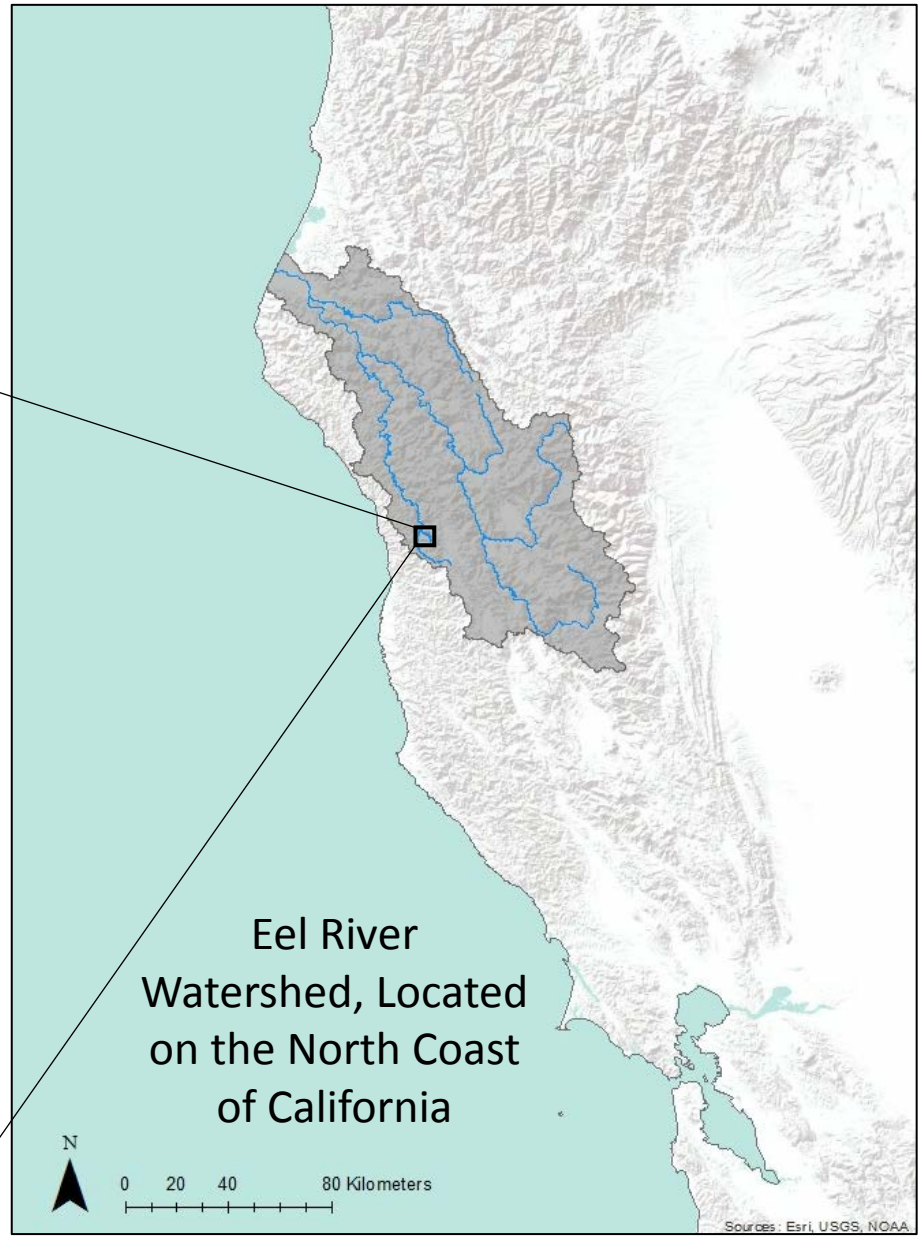


Embryos

Slide modified from Todd Seamons

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

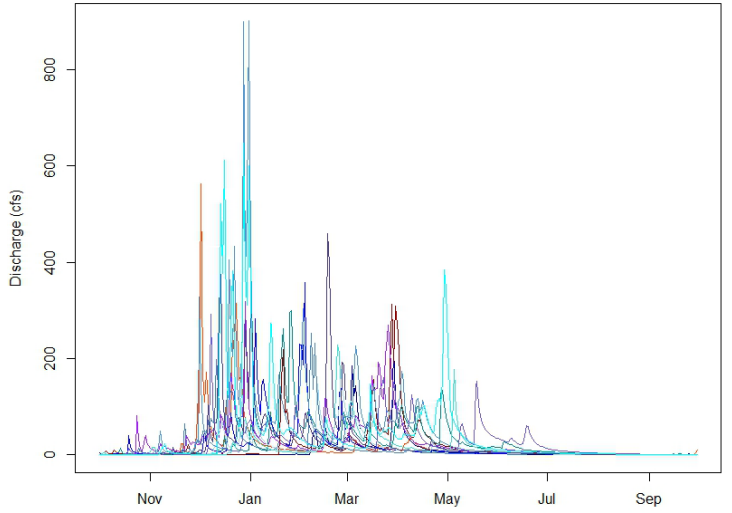




Waterfalls: barriers to migration

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

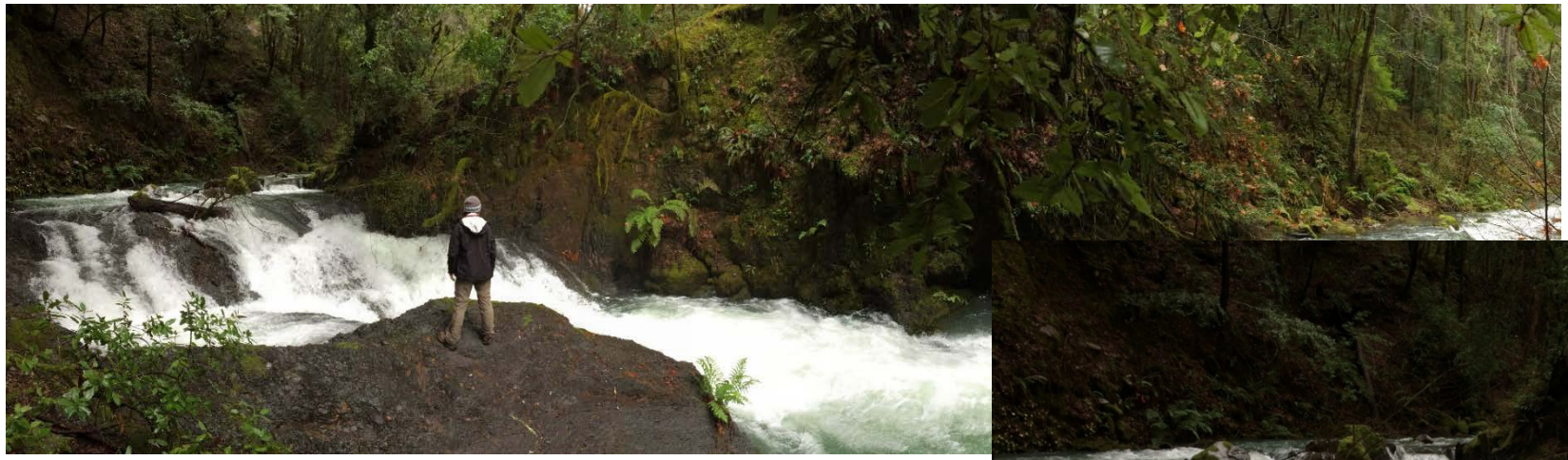


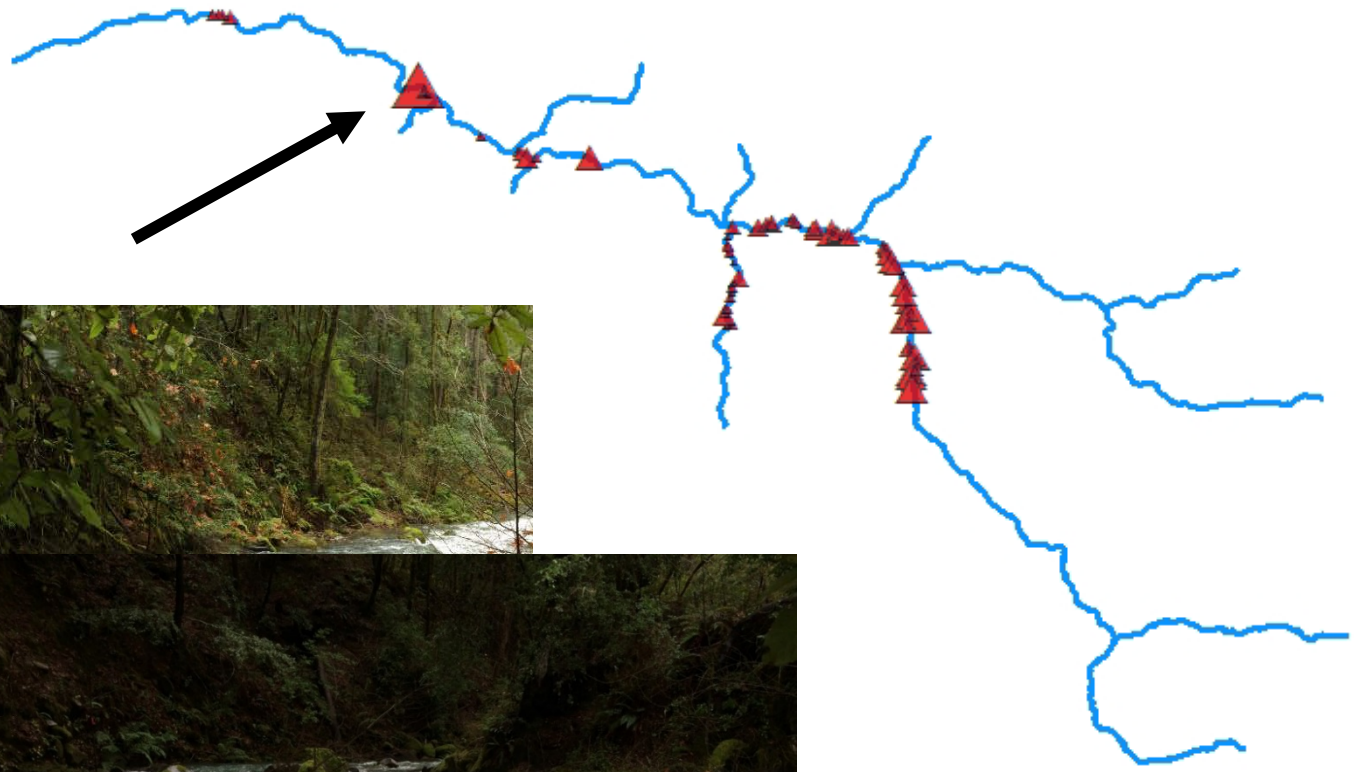
Inter-annual **variation** in **precipitation** (timing and magnitude) influence the strength of selection at waterfalls and spatial distribution of genotypes

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

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

Elder Creek Falls: 3.1m high from bedrock to crest

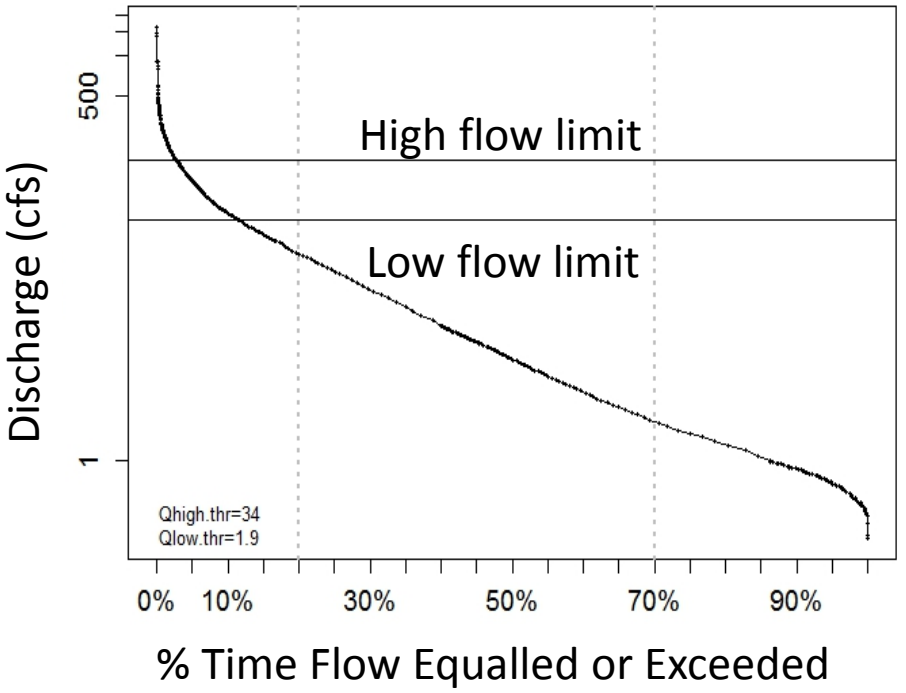




Inter-annual variation in the amount of time that Elder Creek Falls is passable during the steelhead spawning season (Dec-April)

- This waterfall was passable **<u>0-78</u>** <u>days each year</u> between December and April from 1967 to 2015, following flows suggested by Trush 1991 (60 – 170 cfs)

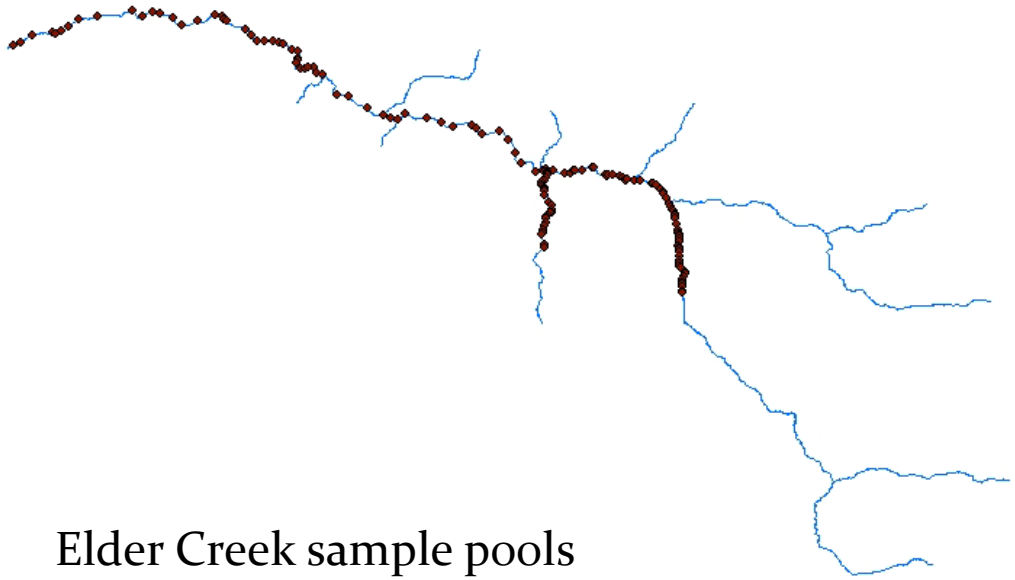
Elder Creek Flow Duration Curve,
Dec – Apr, 1967-2014



Methods: Sample collection

- We sampled for fin clips in Fox Creek and Elder Creek in July - August 2014, 2015, & 2016
- 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

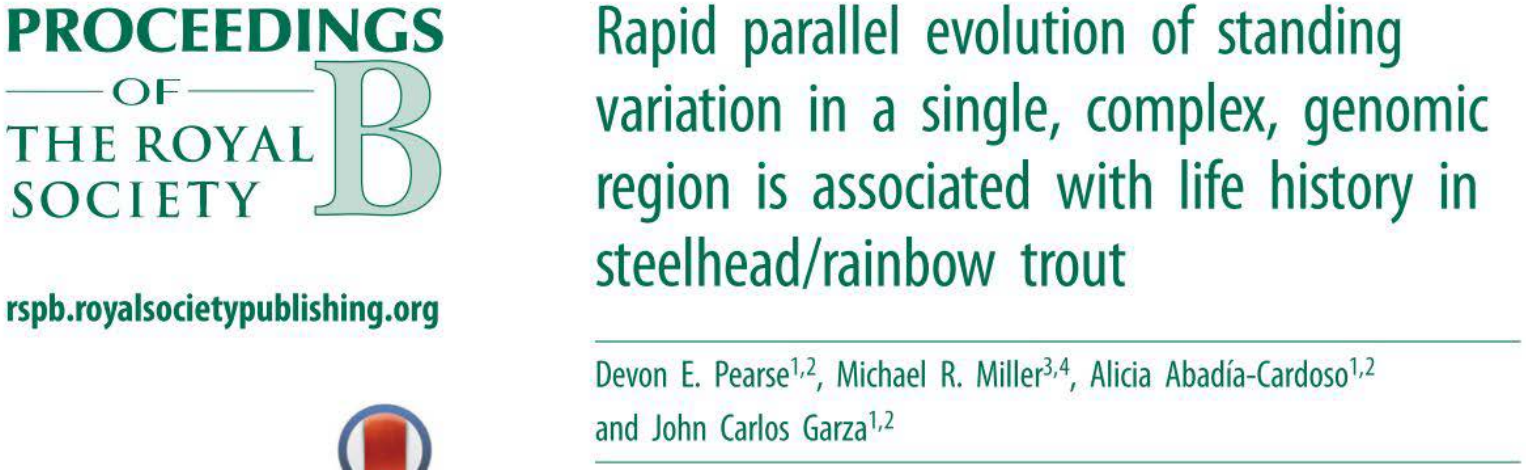


Elder Creek sample pools

Methods: Genotyping

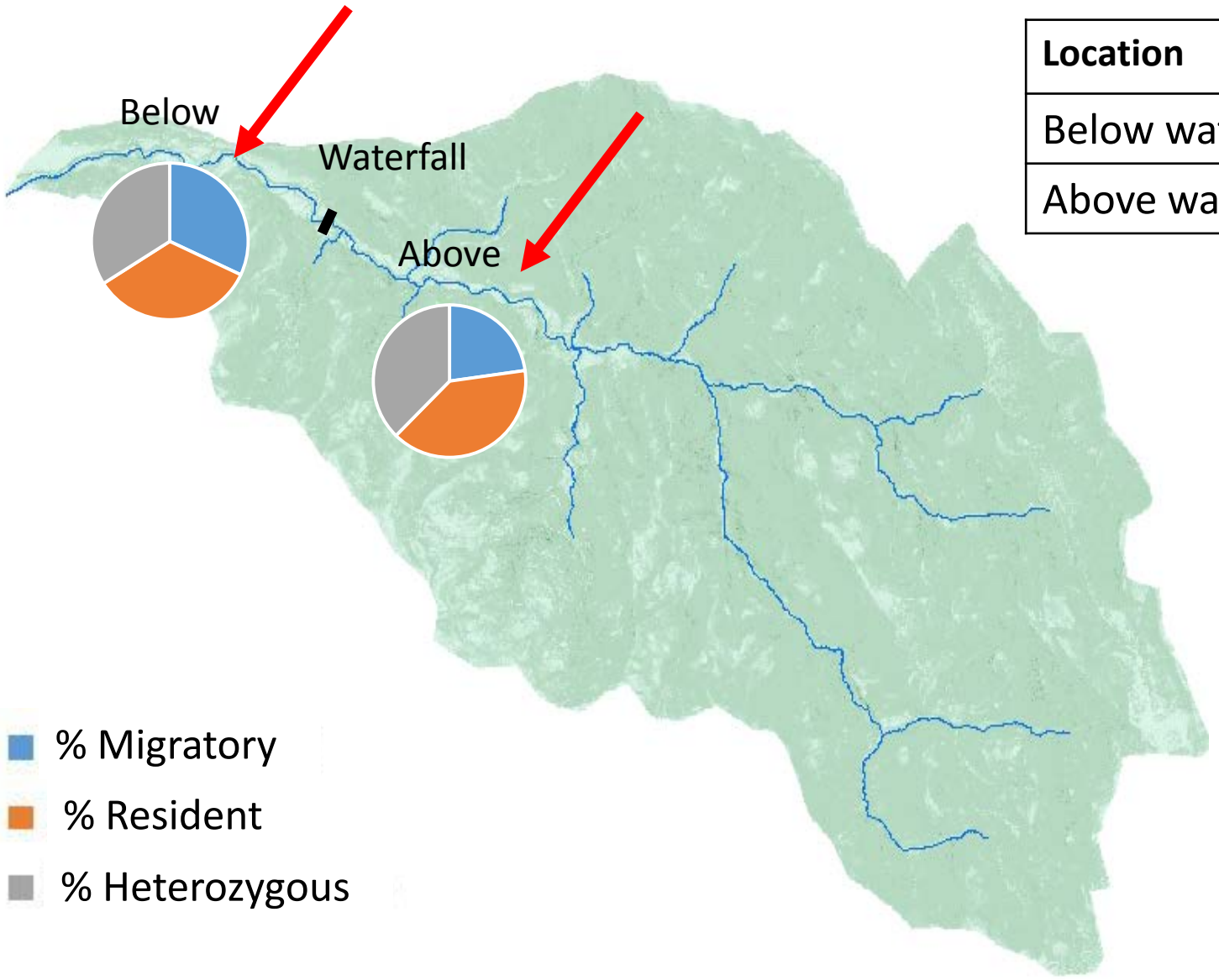
- Samples were sequenced using RAD capture (Ali et al. 2016)

- Focus on SNPs on Omy5, a region of the genome that is linked to life history diversity in *O. mykiss* (Pearse et al. 2014)



- **Today** – preliminary results from 10 SNPs on Omy5 from fish captured in 2014 (dry year)

Frequencies of Migratory vs. Resident Genotypes in July 2014



Location	Migratory	Resident	Heterozygous
Below waterfall	32%	34%	34%
Above waterfall	23%	40%	38%

- Migratory genotypes decrease above the waterfall

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?

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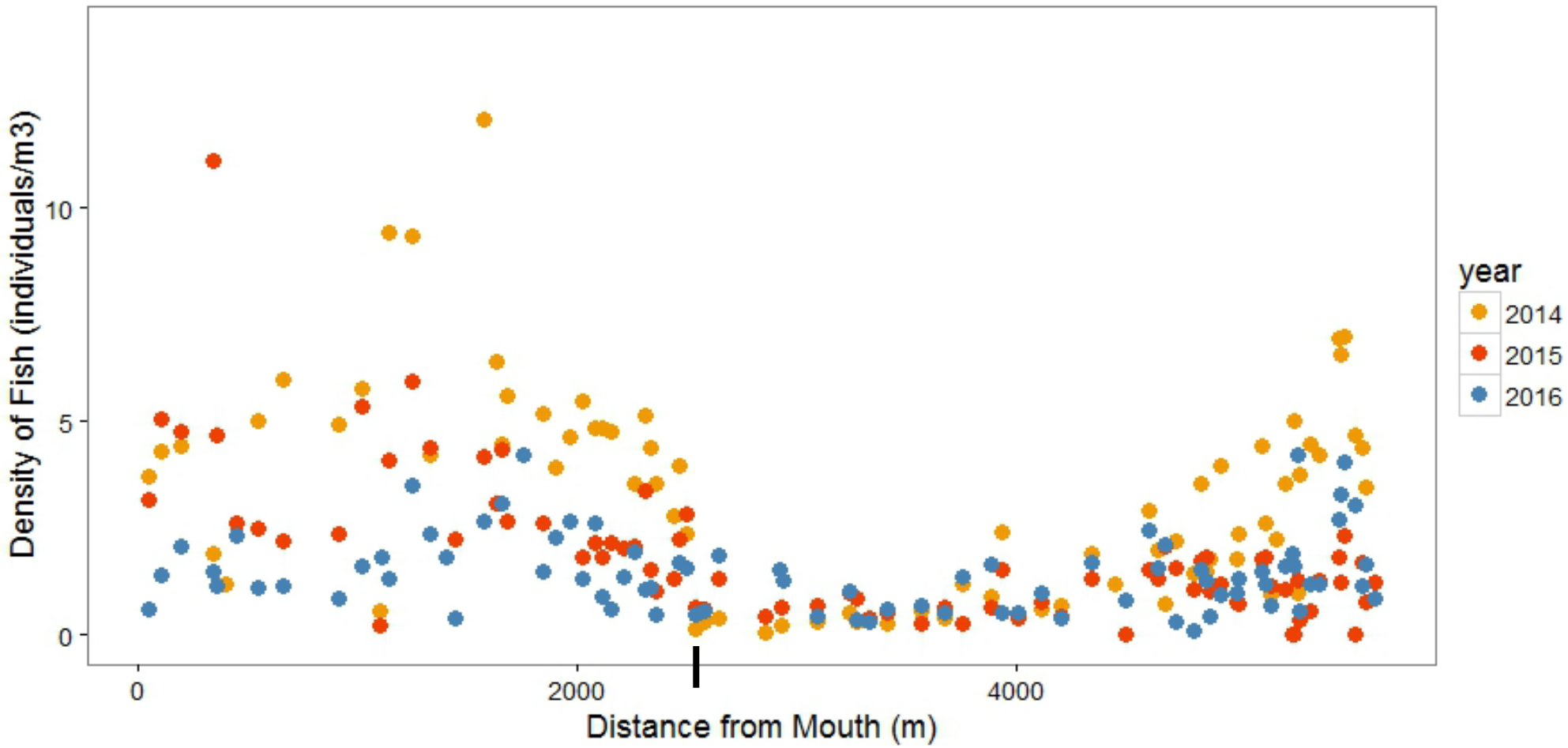
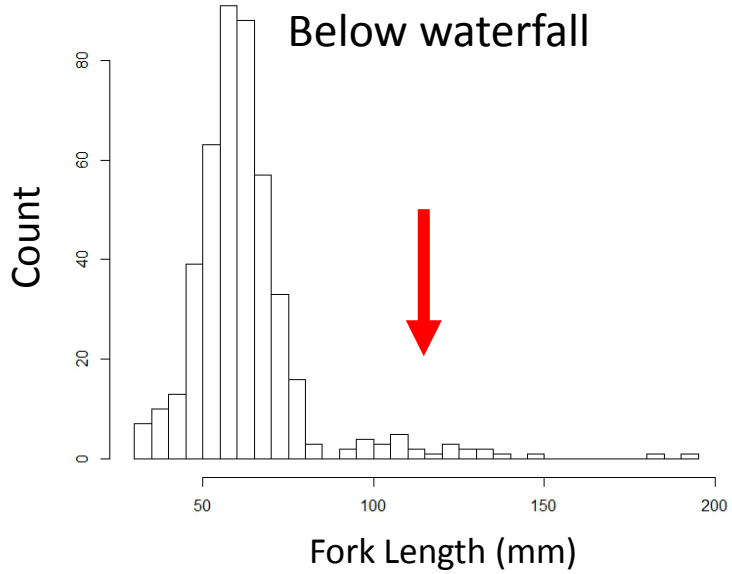
- **Density of fish**

Longitudinal patterns in density in Elder Creek

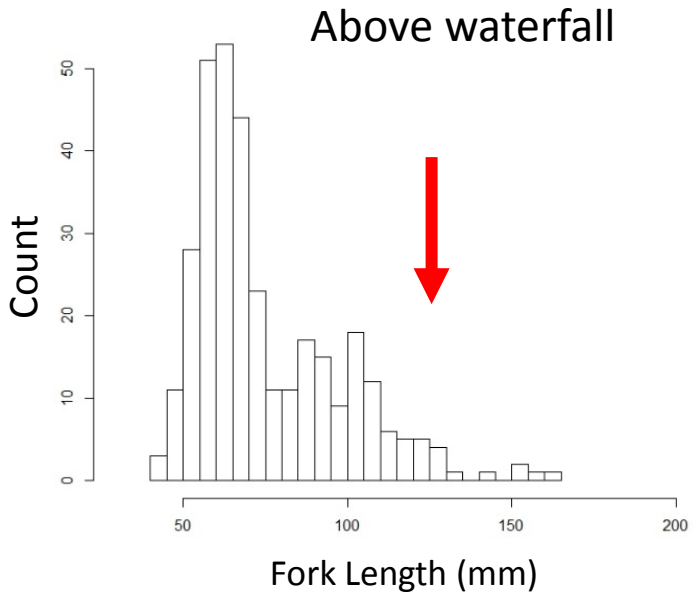


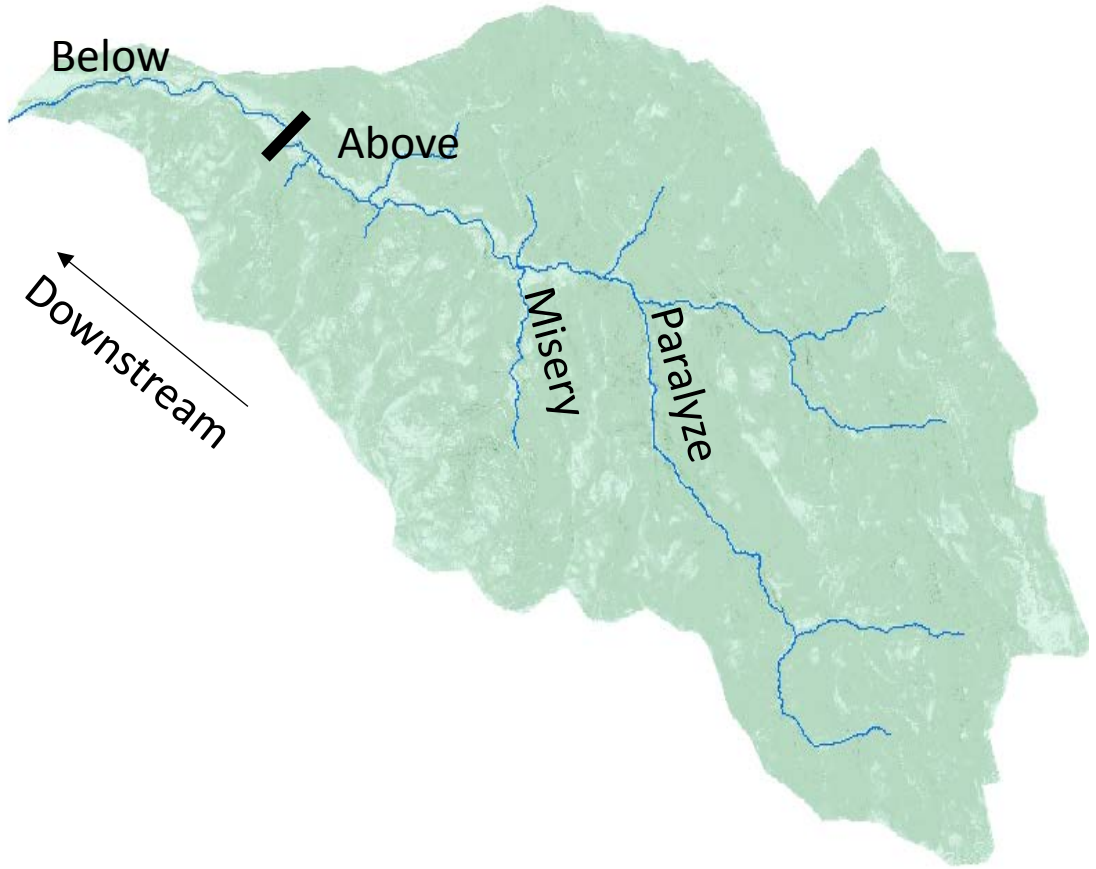
Spatial variation in size structure

Migratory regions:



Resident regions:





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

Fish in one pool below waterfall

Fish in one pool above waterfall

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 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 ecological variables in the resident habitat

Thanks!

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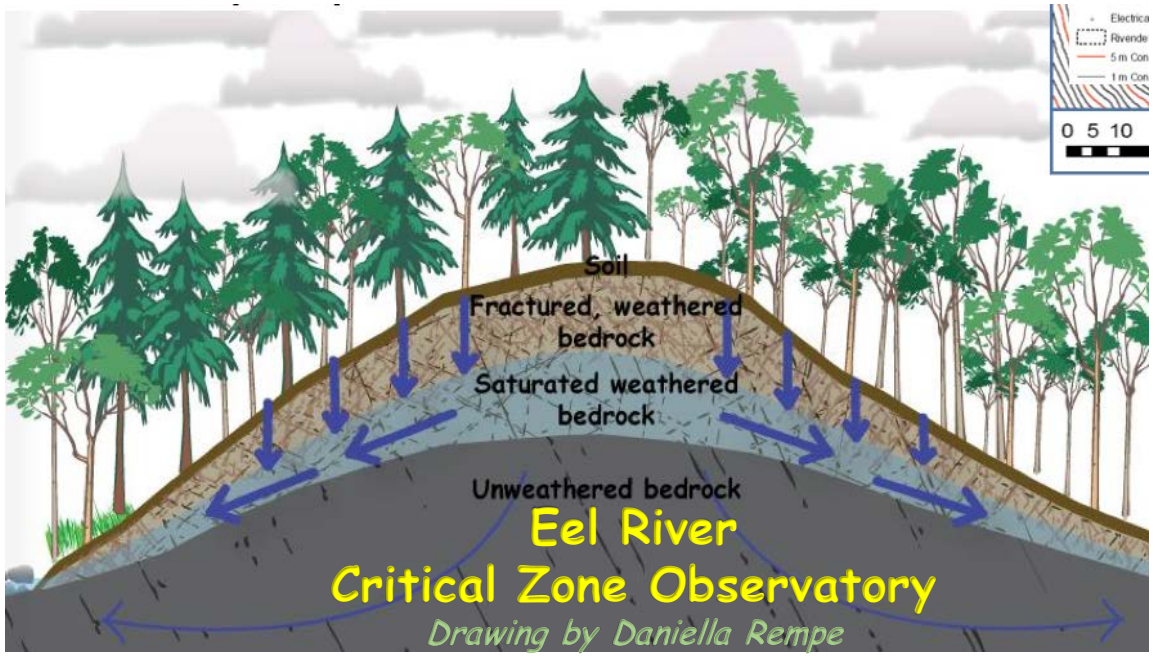
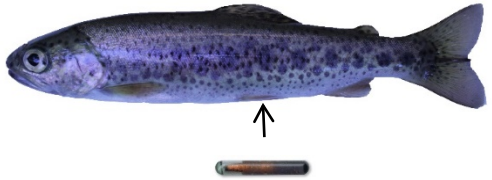


Mark and recapture study of *O. mykiss* in Elder and Fox creeks

Migratory fish are detected at stationary antenna

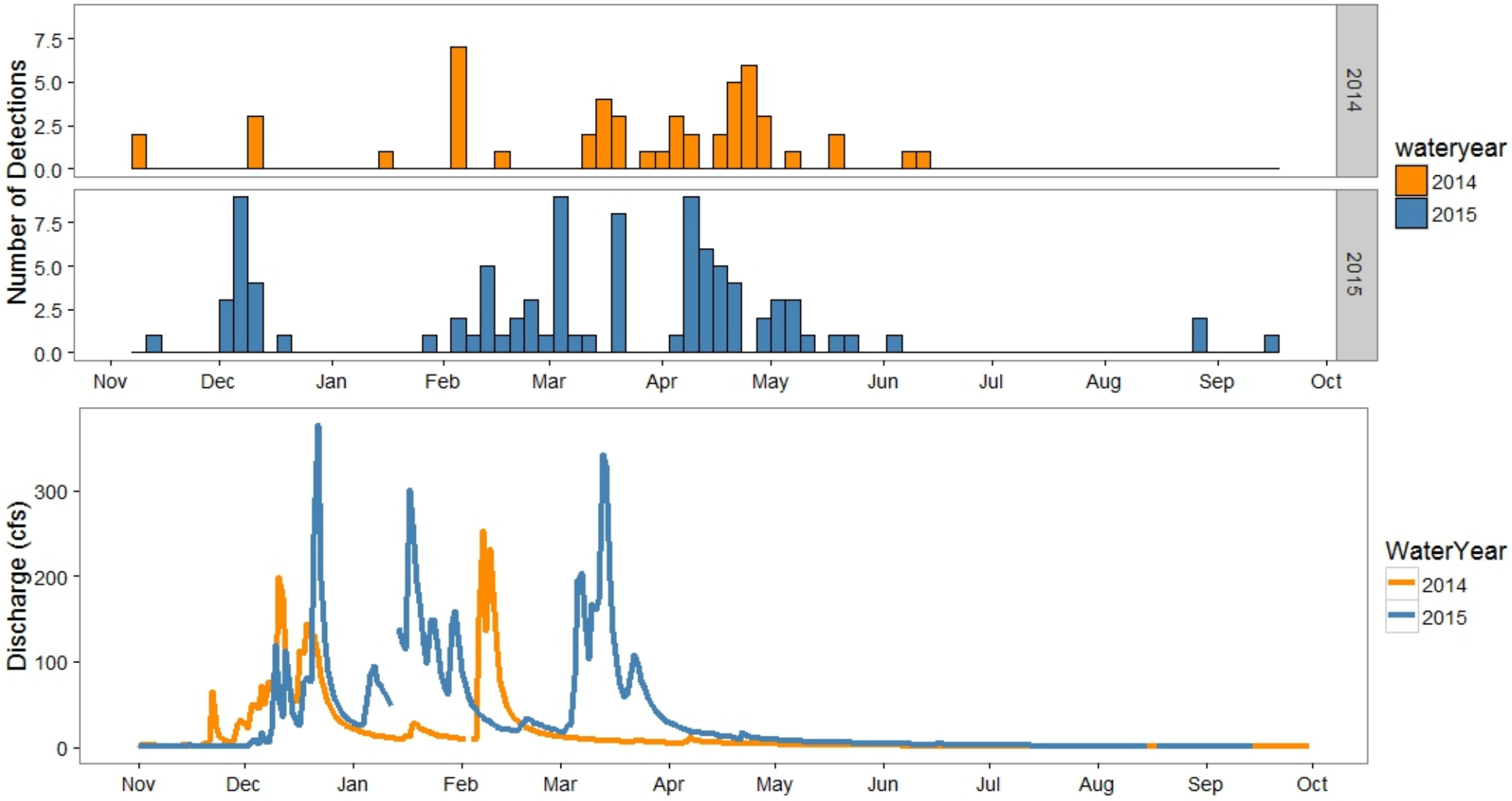


- n = 97 migratory fish have been detected out-migrating from Fox and Elder Creeks

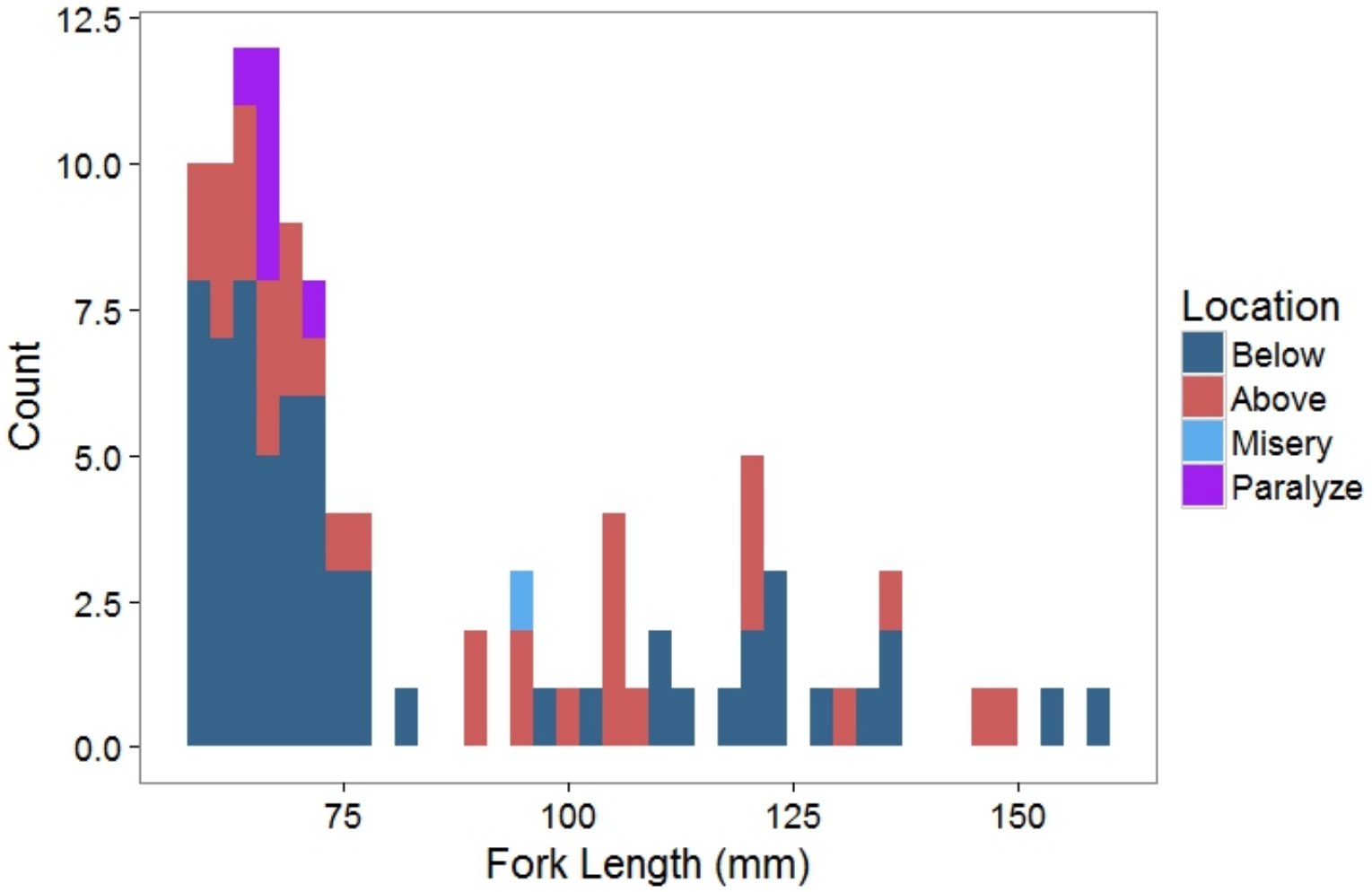
Resident fish are over 170 mm fork length at capture

- n = 44 residents assigned based on size threshold between Elder and Fox

Most fish are migrating from Elder Creek in the spring, February through May



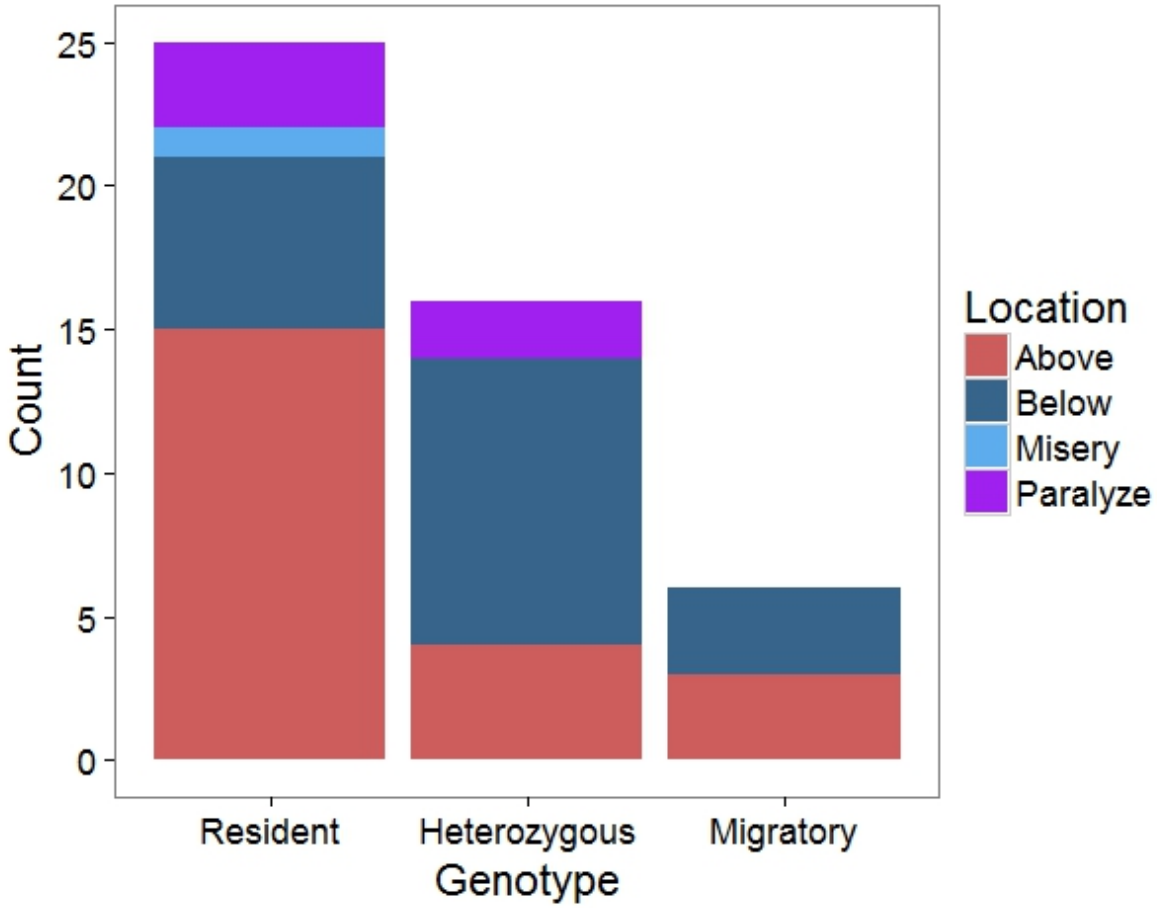
Migratory *O. mykiss* in Elder Creek (detected at the stationary antenna)



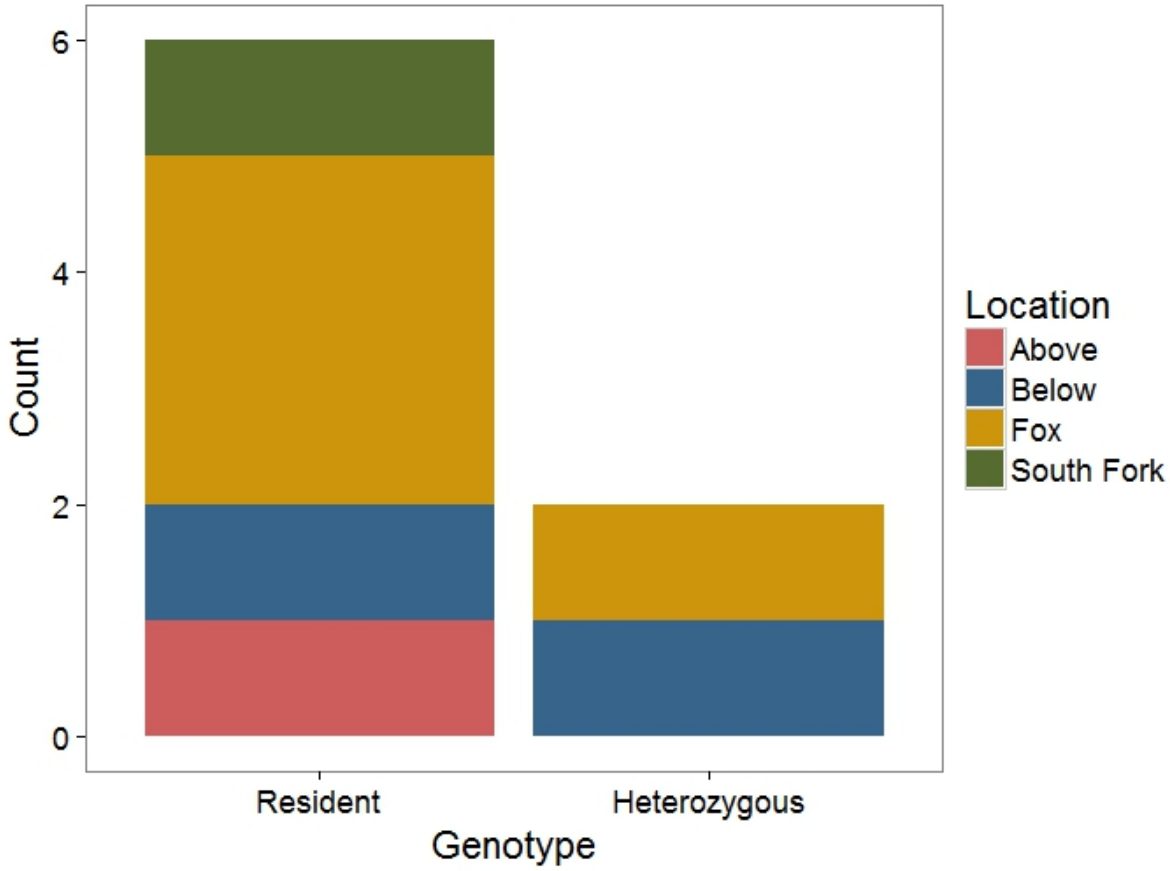
- Most fish detected out-migrating were originally captured below the waterfall (59 out of 97 detections)
- Most out-migrating fish are one-year-olds

Does genotype (SNPs on Omy5) accurately predict **migratory behavior** in a partially migratory population?

Out-migrating fish



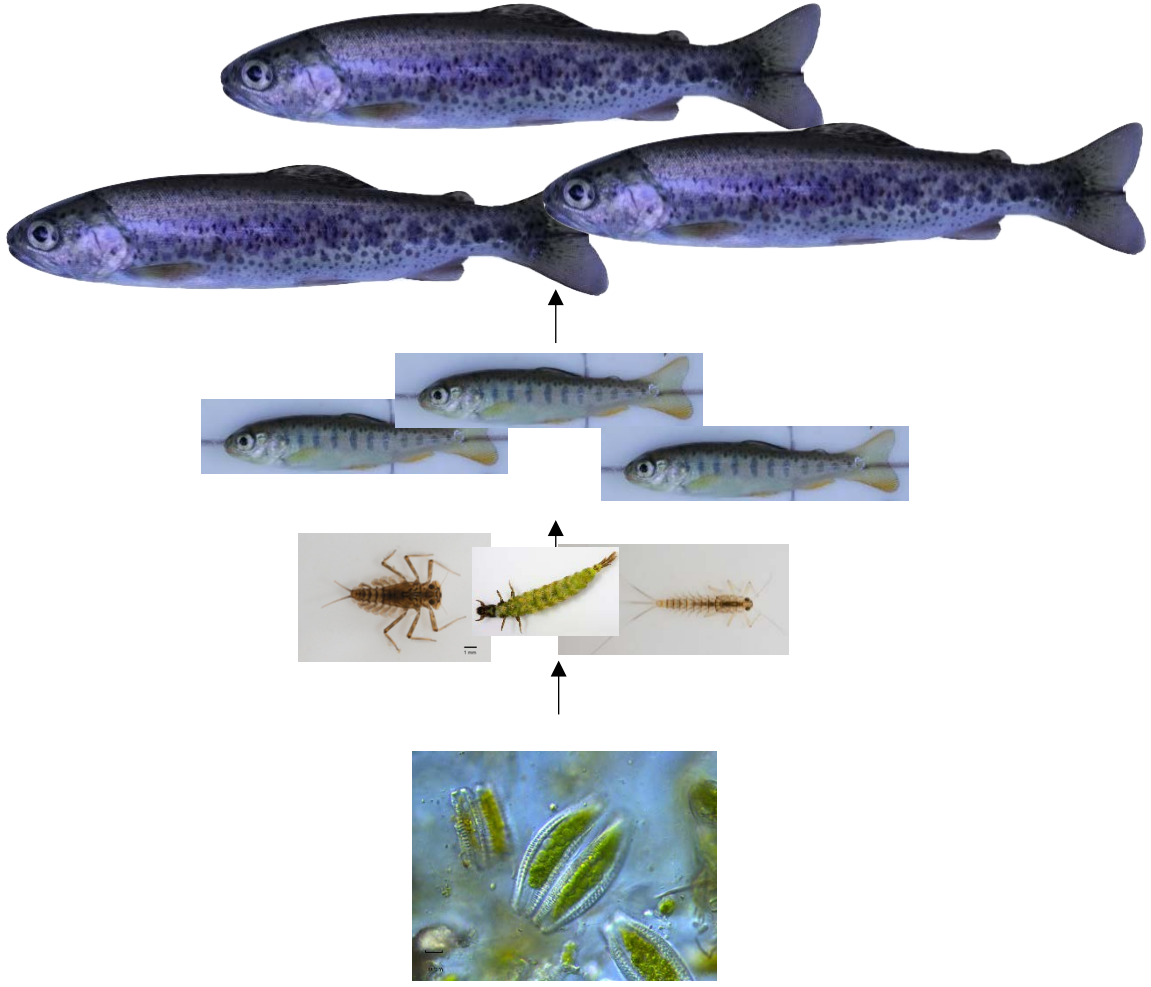
Resident fish



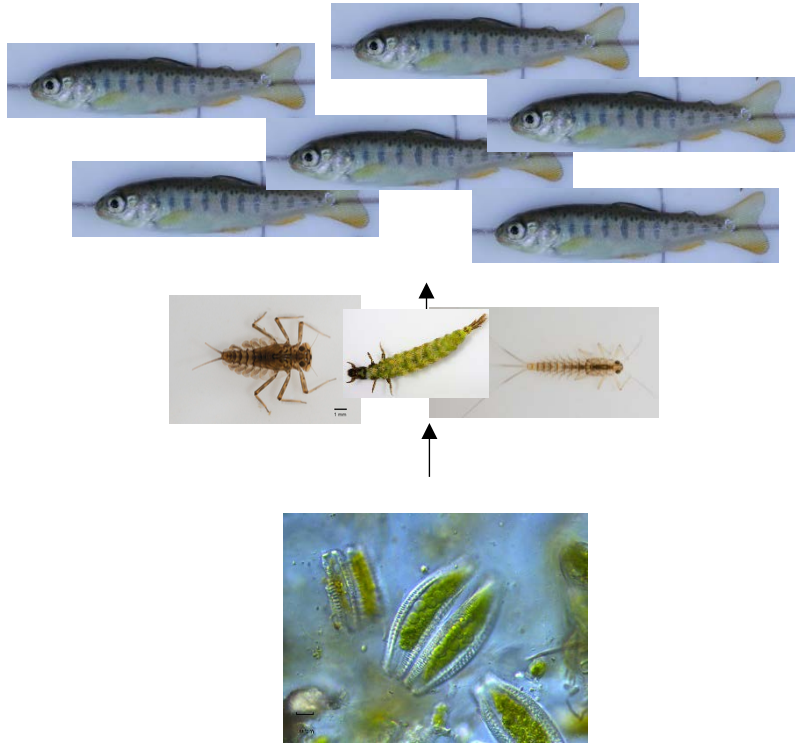
Next steps: Inter-annual variation in the correlation between phenotype and genotype

Can size structure influence number of trophic levels?

4-level food web

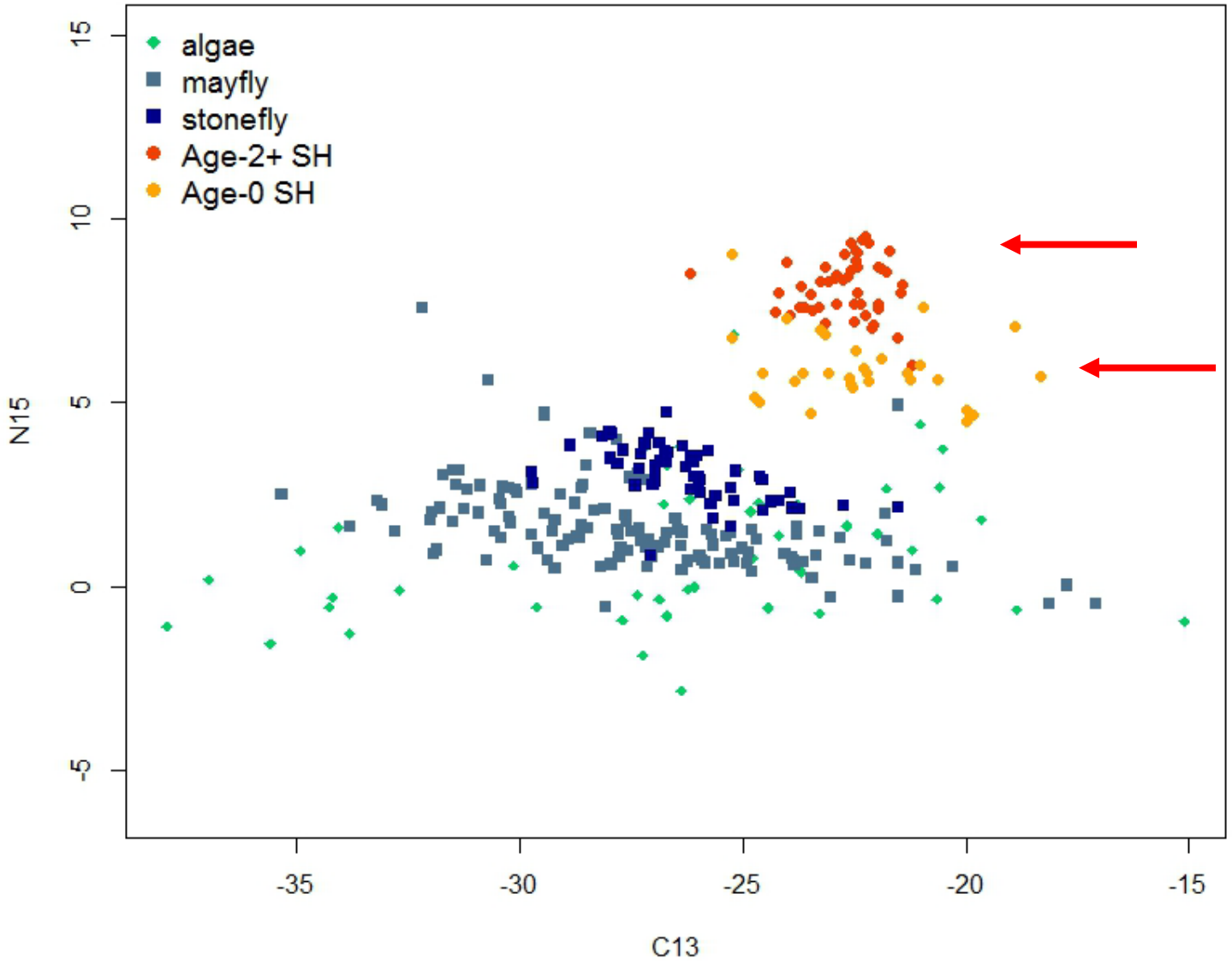


3-level food web



Invertebrate photos: Shelley Pneh, Epithemia photo: Rex Lowe

Can size structure influence number of trophic levels?



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