The ecology of ferox trout

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SFG - Stirling University

My PhD

- Part of a large lab group working across Scotland, Ireland and Northern Ireland.
- The lab was tasked with investigating numerous areas of interest across freshwater, estuarine and coastal waters.
- Projects consisted of investigating species important to aquaculture, hydro, commercial and recreational fisheries.
- Projects also had an important evolutionary theme.
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IBIS - SCENE

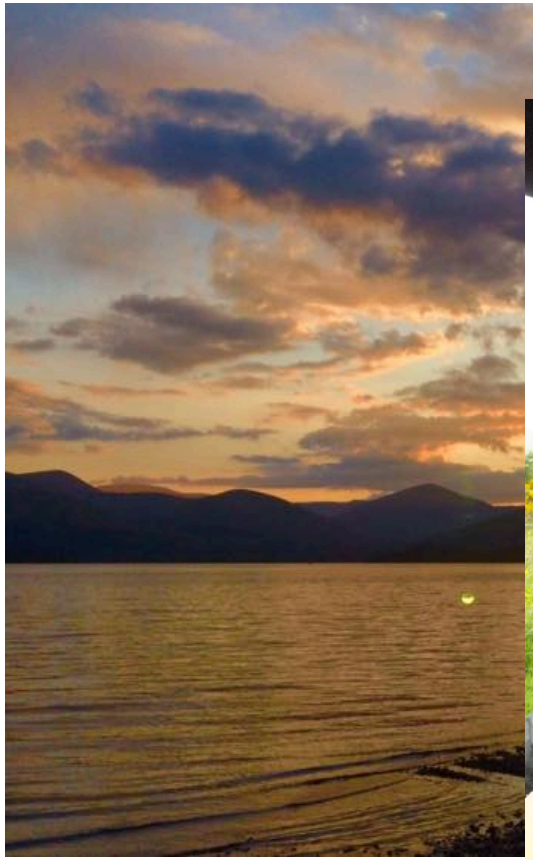









My PhD

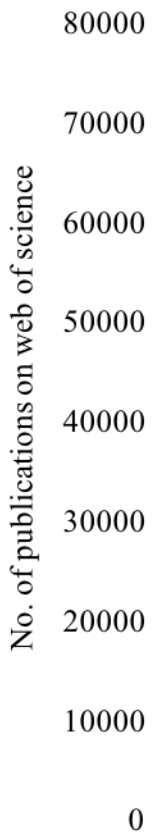


Ferox trout vs Brown trout

Ferox trout

- Large, long-lived, piscivorous brown trout.
  - Large - heaviest in UK was about 15kilos.
  - Old - oldest in the UK was 23 years old.
  - Apex predators - Known to eat other brown trout but mainly Arctic charr.

Consult the literature

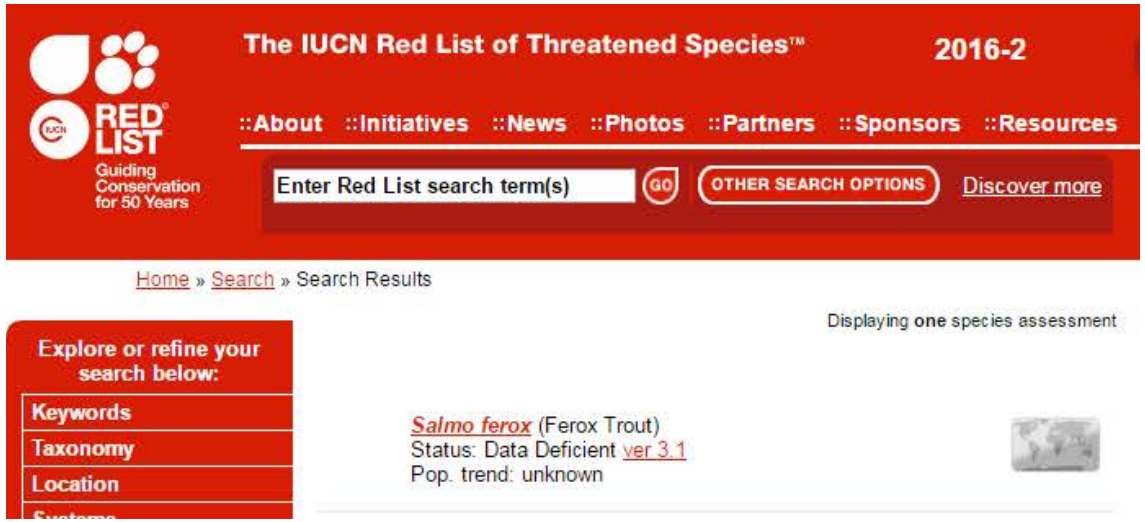


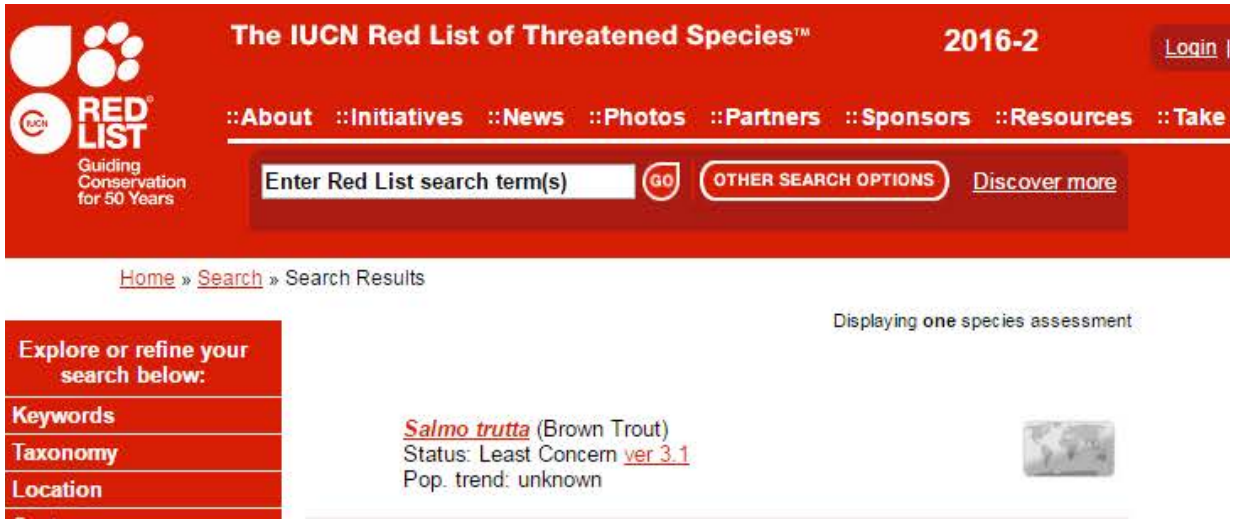
From the literature

- 58 sites in Scotland described with ferox trout by Campbell (1979).
- Strong suggestion of relationship between ferox trout and Arctic charr and large lake size.
- Genetically distinct from sympatric populations in Melvin, Laggan and Awe. Spawn in ferox only rivers.
- Delayed maturation in ferox trout.
- Considered distinct in some areas and a life-history strategy in others.

What we knew cont…

- As a result ferox trout are on the IUCN Red List of Threatened Species as Salmo ferox - “Data deficient” compared with Salmo trutta -“Least concern”.





Management Questions

- How rare are these fish? - Produce a modern estimate on ferox distribution in Scotland.
- What are the ecological parameters associated with ferox trout?
- Can we measure differences in wild populations using non-lethal methods?

Broad Evolutionary Questions

- How can ferox trout maintain isolation while living in sympatry with brown trout.
- Do ferox and brown trout differ physiologically?
- If distinct do ferox/brown trout hybrids exist?

Thesis outline

- Chapter 1 – Ferox distribution
- Chapter 2 – Growth rates between lakes
- Chapter 3 – Common Garden Experiment
- Chapter 4 - Behavioral Study
- Chapter 5 – Telemetry Study

Chapter 1. Ferox distribution

- First, we wanted to just get a number for the amount of lakes we have evidence of ferox trout populations.
- Secondly, we wanted to look at the abiotic and biotic characteristics associated with lakes that contain a ferox trout population.
- Thirdly, we wanted to generate a probability on the number of ferox trout lakes.

Methods

- Extensive literature review of over 20 angling books over the past 400 years.
- Lakes that had records of ferox or large trout >5lbs we recorded and added multiple entries for a single lake into a database.
- Using Murray and Pullar bathymetry data on lake abiotic characteristics and Arctic Charr data from Peter Maitland and Colin Adams we constructed a series of binomial logistic models.
- We also produced a probability model to predict the amount of lakes in Scotland that may have ferox based on a single abiotic measure (area).

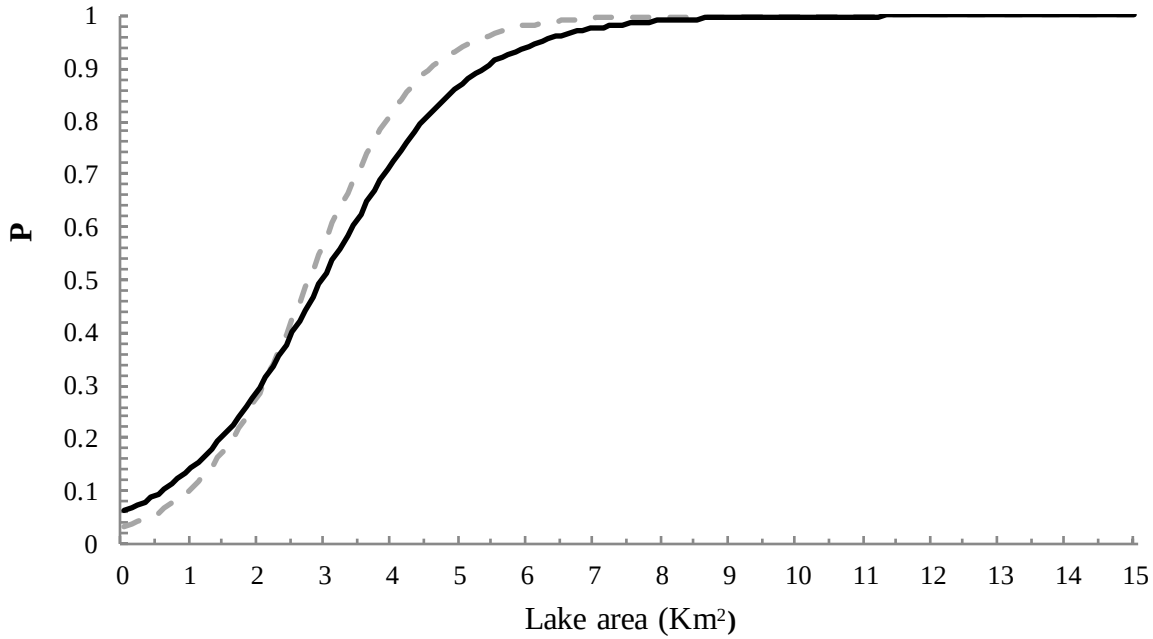
Results

- We found records of ferox trout in 192 lochs in Scotland.

Characteristic	Estimate	Std.Error	z-value	p
Mean Depth	0.04	0.02	2.15	0.032
Area	0.01	0.01	4.76	<0.001
Catch	0.01	0.01	3.97	<0.001
Charr	1.72	0.39	4.39	<0.001
Area*Charr	-0.01	0.01	-3.13	<0.01

Results

Km²	Number of Lakes	Probability (%)	Estimate of ferox lakes
0.125	2973	7	208.11
0.38	417	9	37.53
0.75	209	12	25.08
1.5	83	21	17.43
3	54	51	27.54
6	27	94	25.38
12	12	99	11.88
24	9	100	9
51.5	4	100	4
Total	3788		365.95



Discussion

- Ferox trout populations are rare considering the amount of habitats they could exist in and don’t.
- Even if they inhabit all 366 lakes predicted by our model, this is still an extremely low number given the thousands of lakes available.
- Rare, apex predators, potentially vulnerable.

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Lake bathymetry and species occurrence predict the distribution of a lacustrine apex predator

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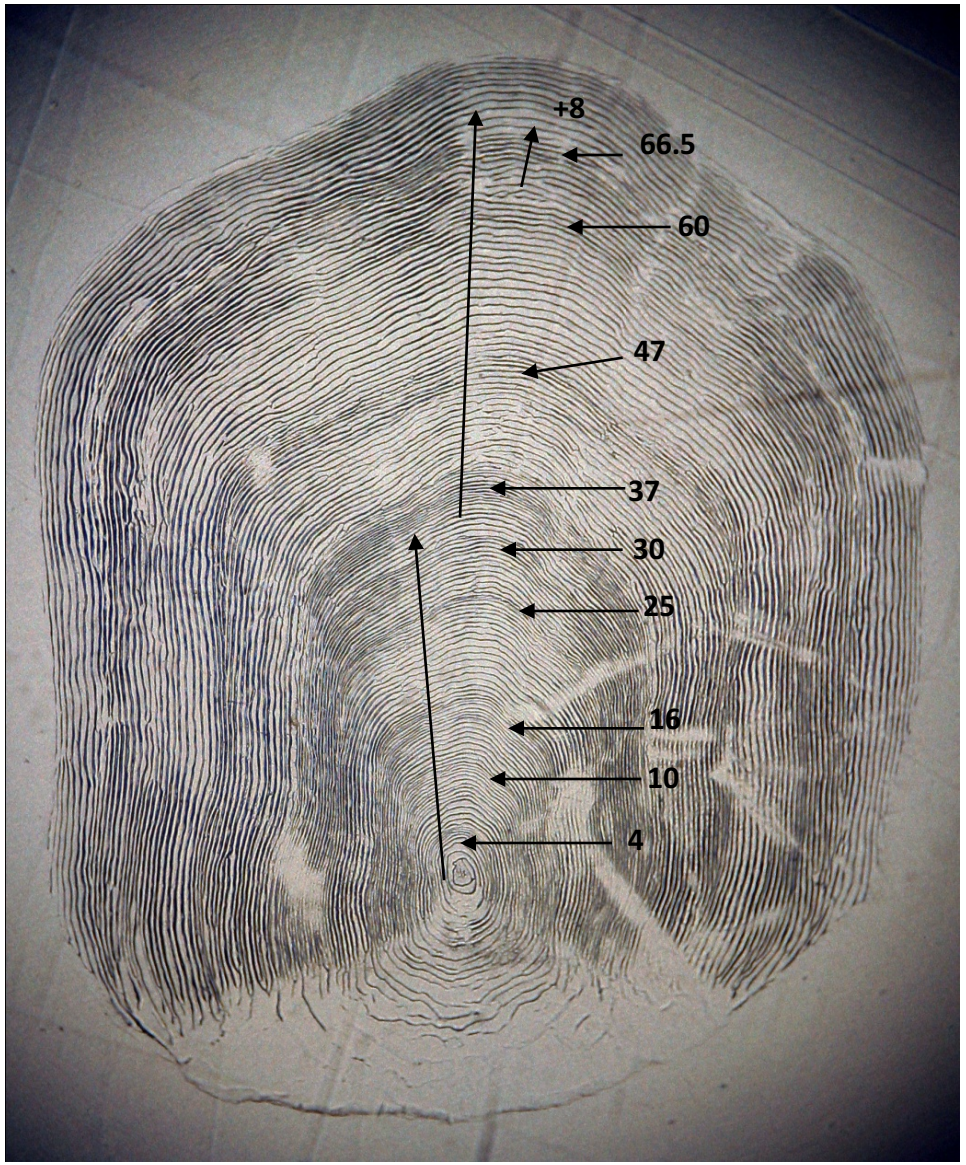
Chapter 2. Growth Rates of Sympatric Populations

- Do ferox trout and brown trout from the same lake have alternative growth strategies?

- Is the increased growth rate of ferox trout:
  - (1) an extension of normal brown trout growth?
  - (2) Or do ferox trout have a distinct trajectory from a young age?

Growth Rates using non-lethal methods



- Back-calculation of scale samples.
- Length at age
- Von Bertalanffy Growth Function (VBGF)
- Calculate growth curves
- Compare growth rates

Discussion

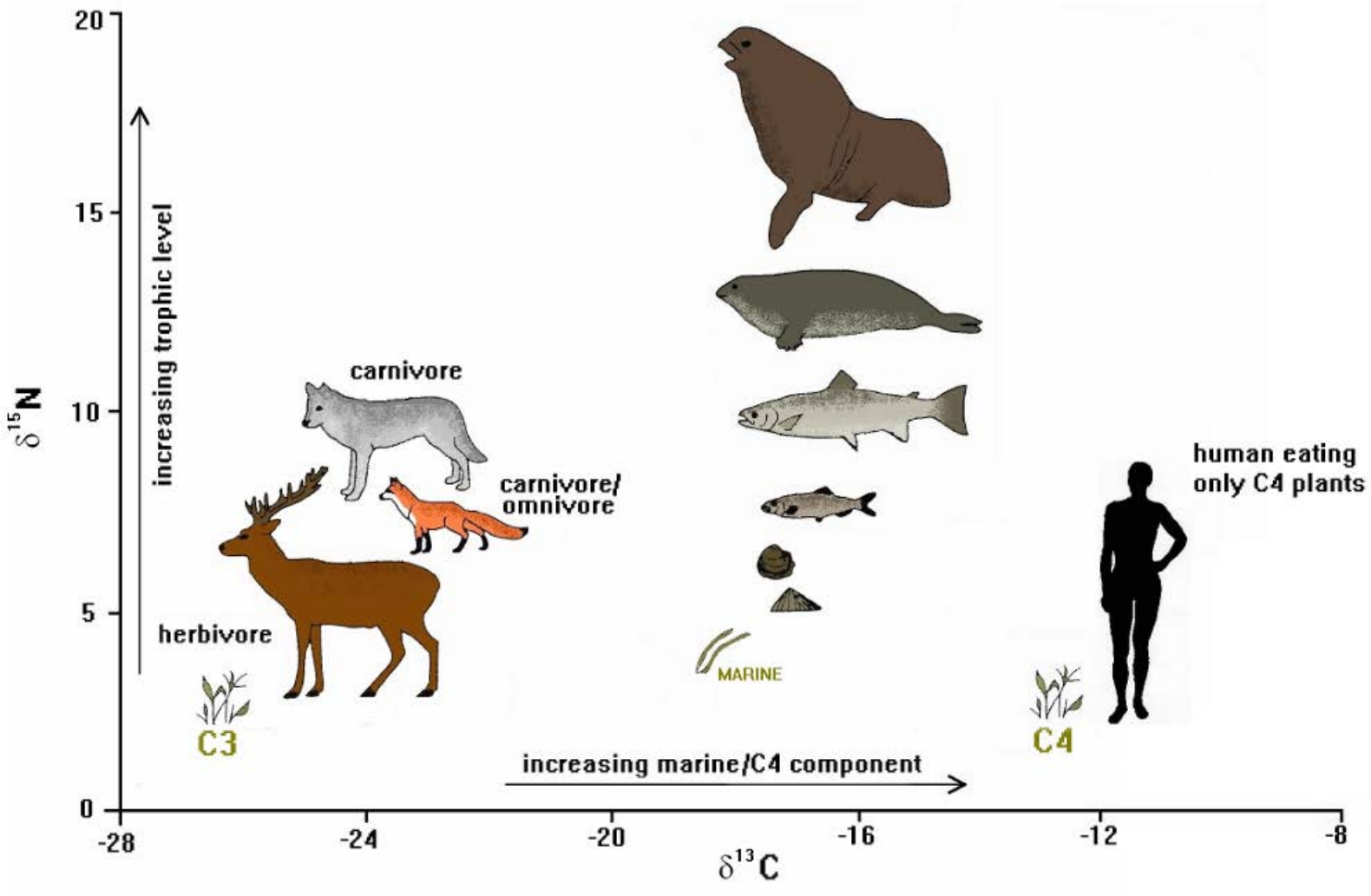
- Three different growth trajectories.
- Although the two fish look the same in Loch Awe and Loch Rannoch, the journey they took to get there is quite different.
- Loch Awe are fast growers from a young age, likely some genetic basis.
- Loch Rannoch ferox grow like normal brown trout and growth extends beyond the “normal” population, similar to Campbells description, likely an adopted life history strategy.
- Na Sealga appears to be a single population, although piscivores are slightly older.

Chapter 3. Common Garden Experiment

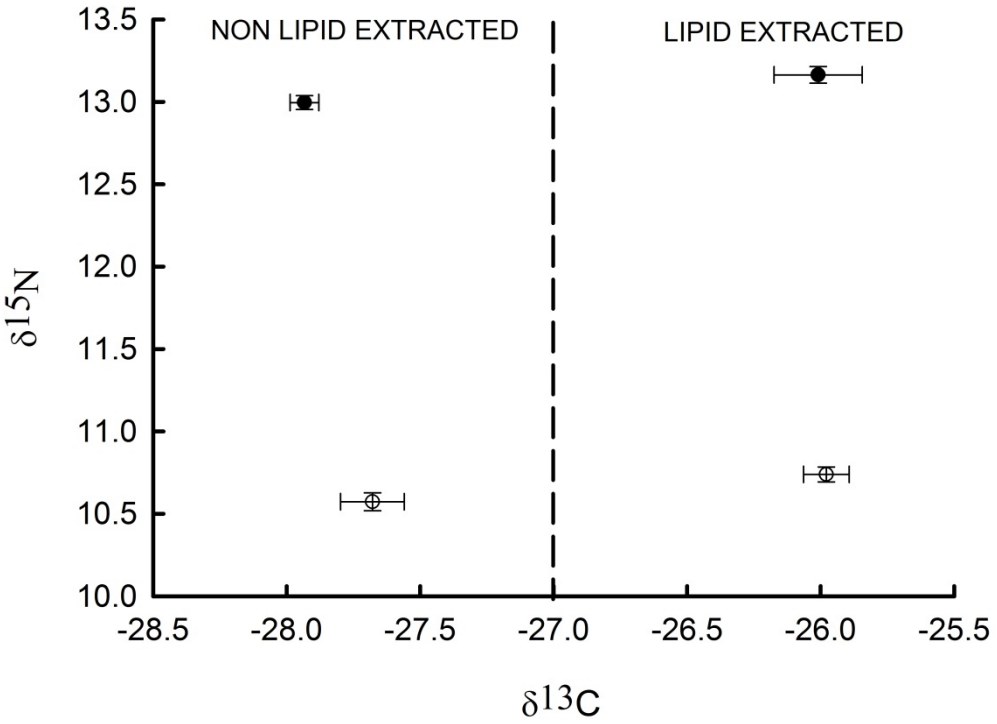
- The most obvious solution to answer some of the problems posed would be compare biological traits in offspring of ferox trout and offspring from brown trout from the same lake system.
- Easier said than done…

Wester Ross

Stable Isotope Analysis



Ferox classification



Family	Morph	δC13(%)	δN15(%)
1	Ferox trout	-28.04 ± 0.06	12.9 ± 0.02
2	Ferox trout	-27.82 ± 0.05	13.09 ± 0.04
5	Brown trout	-27.68 ± 0.12	10.45 ± 0.03
6	Brown trout	-27.93 ± 0.06	10.7 ± 0.05

Brown trout eggs (n = 8) were significantly more depleted in $\delta^{15}N$ (t = -35.4, df = 13.1, P <0.01) than ferox trout eggs (n = 8).

There was no significant difference in $\delta^{13}C$ (t = 1.4, df = 12.3 P = 0.2) between brown trout and ferox trout eggs.

Early development

- In salmonids, important developmental stages such as eye pigmentation, hatch time and swim-up (full yolk absorption) are dictated by temperature and genetics.

- Fish that emerge earlier have been shown to have a competitive advantage over later emerging fish, believed in part to be due to a ‘prior residency’ effect.

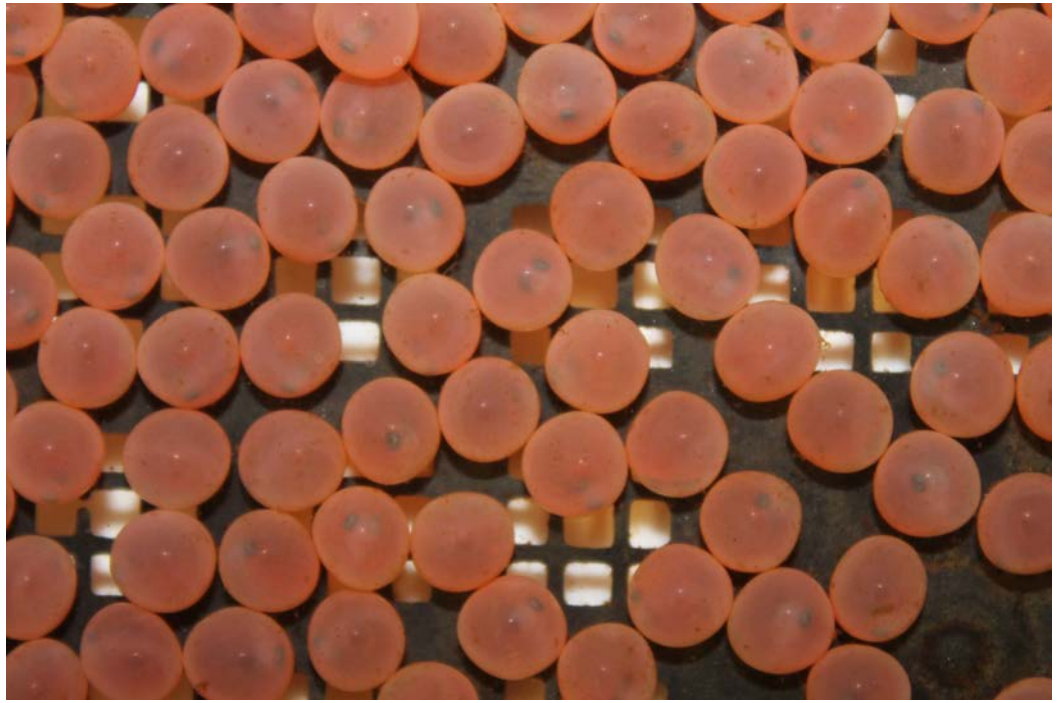
- Thus, early emergence increases foraging ability, which will influence growth and ultimately life history strategy.

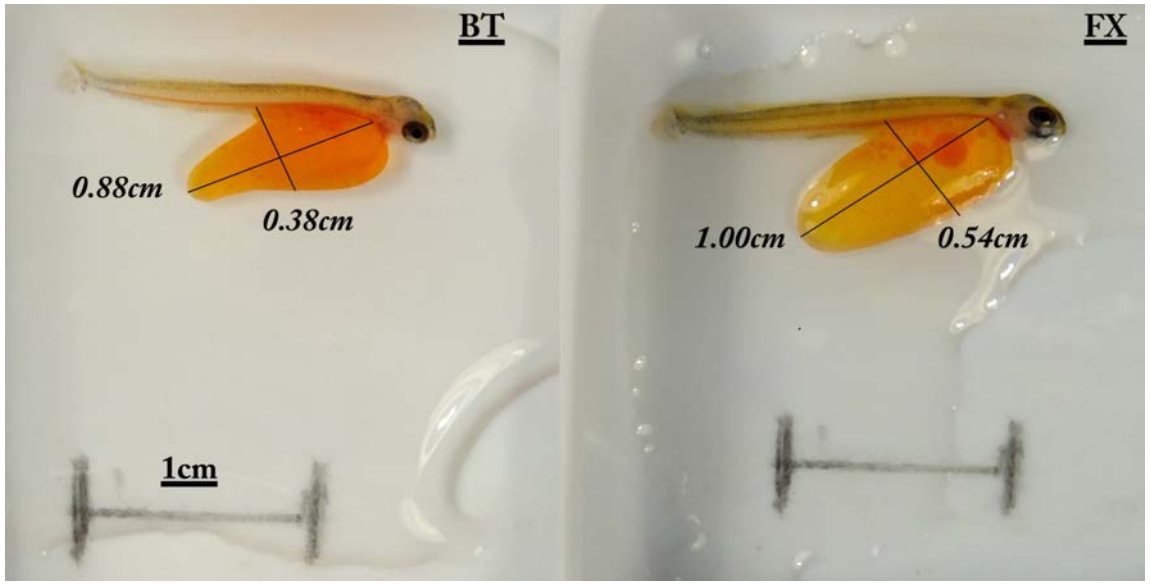
Early development

Family	Life History	Eyed-egg stage	Hatch	Swim-Up
1	FX	239.1	492.9	852.2
2	FX	239.1	468.9	843.2
3	PC	246	508.4	877.8
4	MC	239.1	492.9	869.4
5	BT	227.5	484.8	869.4
6	BT	239.1	461	861

- No significant differences in pace of development among all families ($P < 0.05$)

Egg and yolk sac size



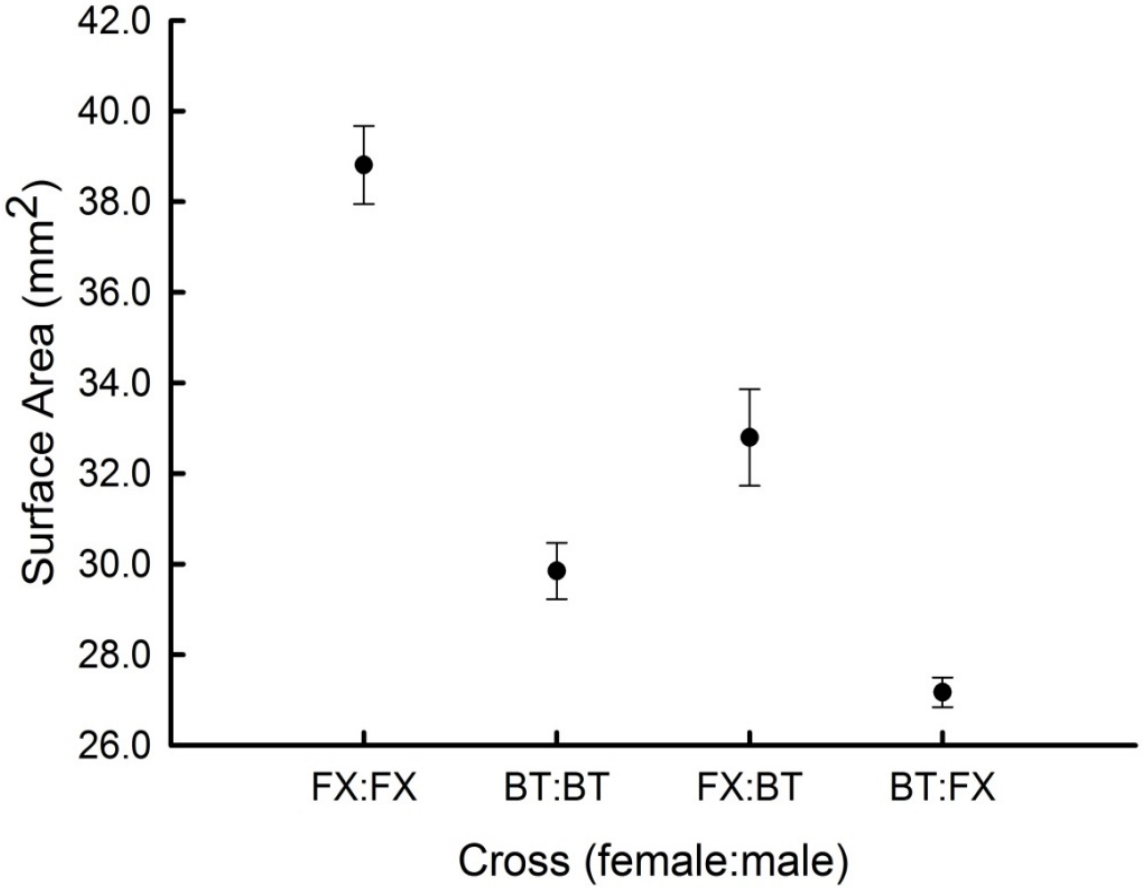


Egg size and yolk size

Family	Life History	Egg Number	Egg Area (mm^2) ± S.E.
1	FX	122	30.67 ± 0.17
2	FX	267	32.45 ± 0.18
3	PC	392	25.24 ± 0.19
4	MC	402	29.73 ± 0.18
5	BT	328	30.44 ± 0.19
6	BT	462	26.83 ± 0.21

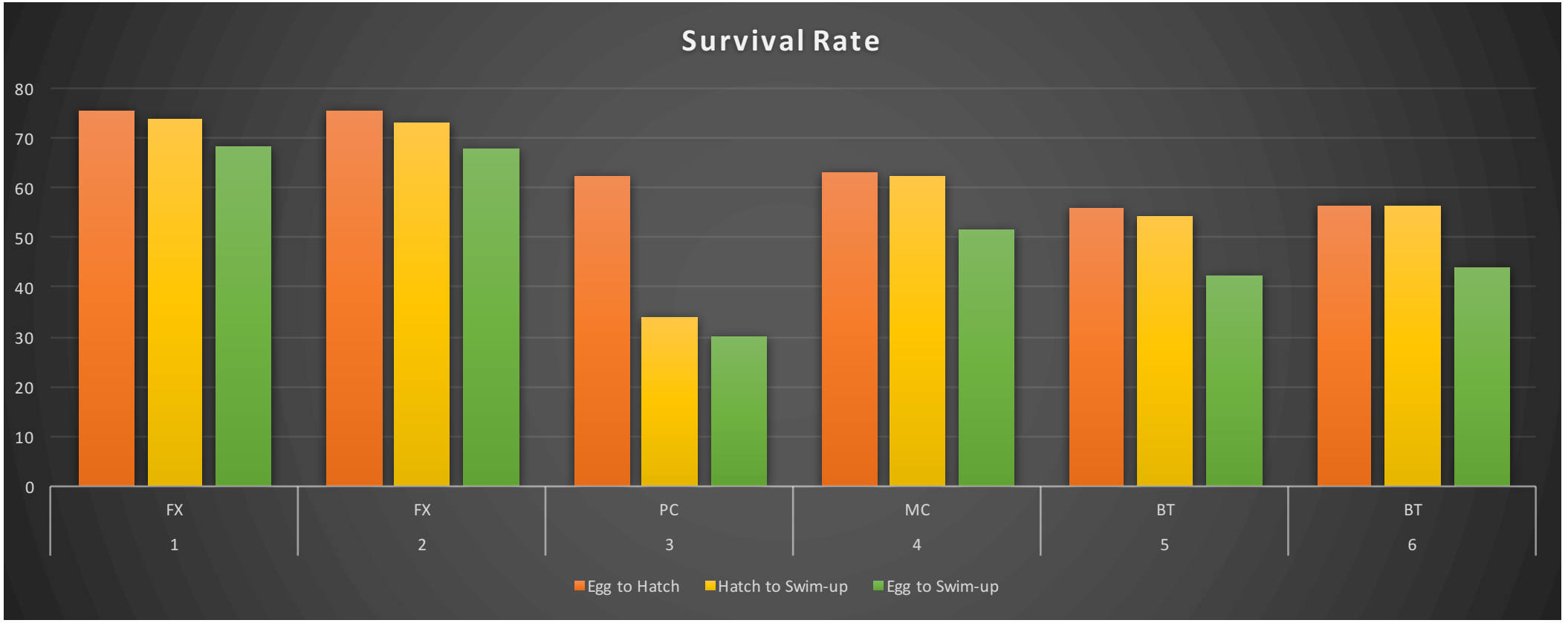
- There was a significant difference in egg surface area between life history type ($F_{3, 296} = 104.2$, $p < 0.001$).

Egg size and yolk size



- Overall there was a significant difference in yolk sac size between offspring type ($F_{3,57} = 40.71$, $P < 0.001$)

Survival Rate



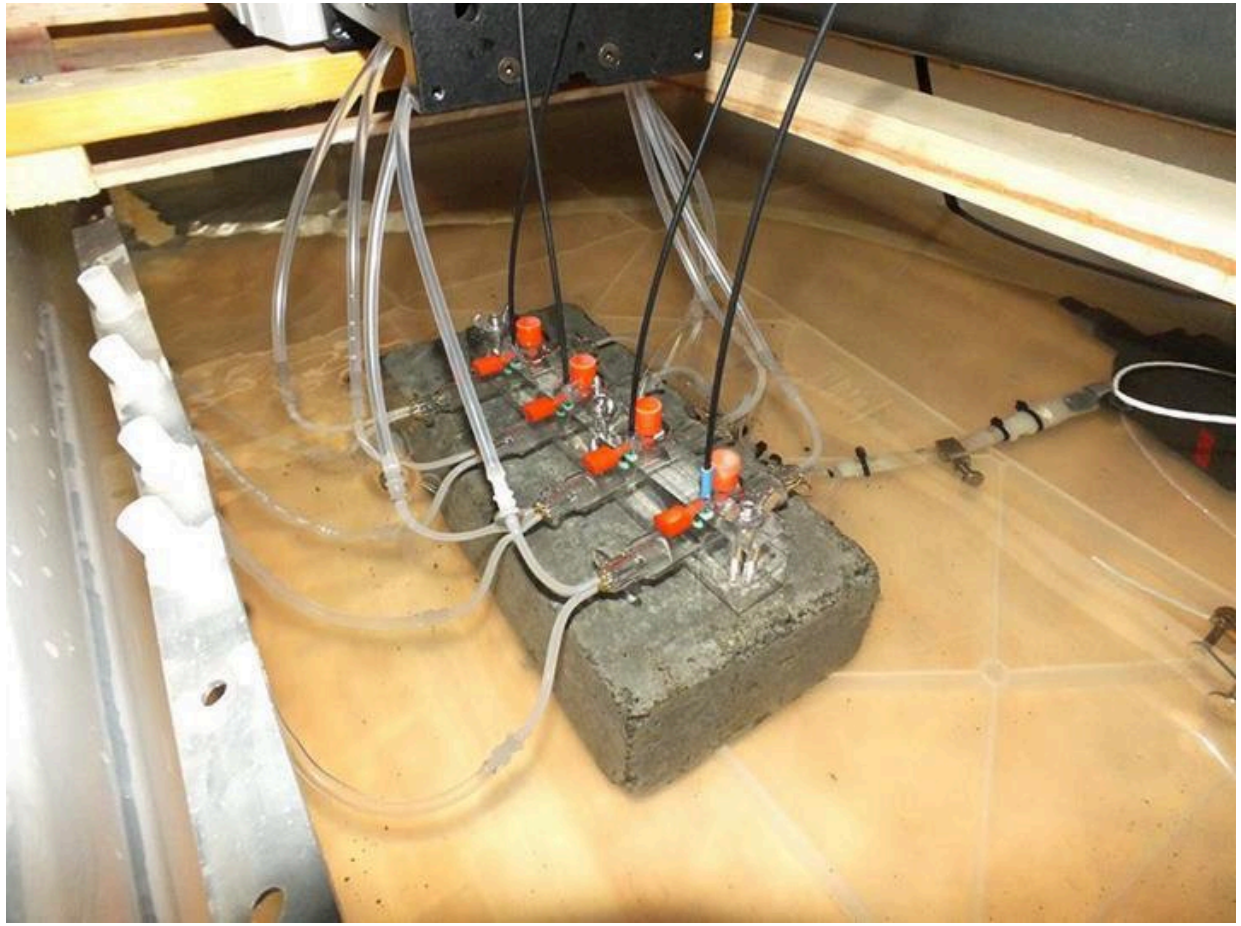
Metabolism

- Metabolic rate is an important physiological measure, particularly in salmonids.

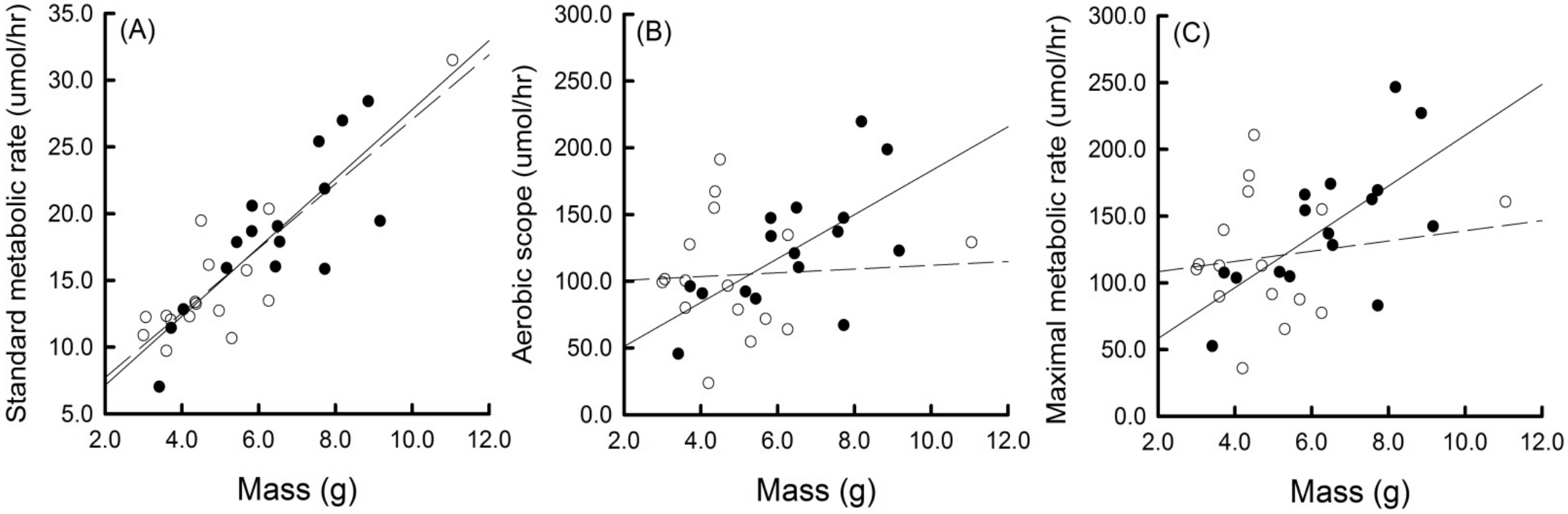
- Metabolic rate has been demonstrated to affect growth rate, time of smolting and dominance behaviour in salmonids.

- Standard metabolic rate (SMR),Maximum metabolic rate (MMR) and scope (AS) represents the difference between SMR and MMR.

Metabolism



Metabolism

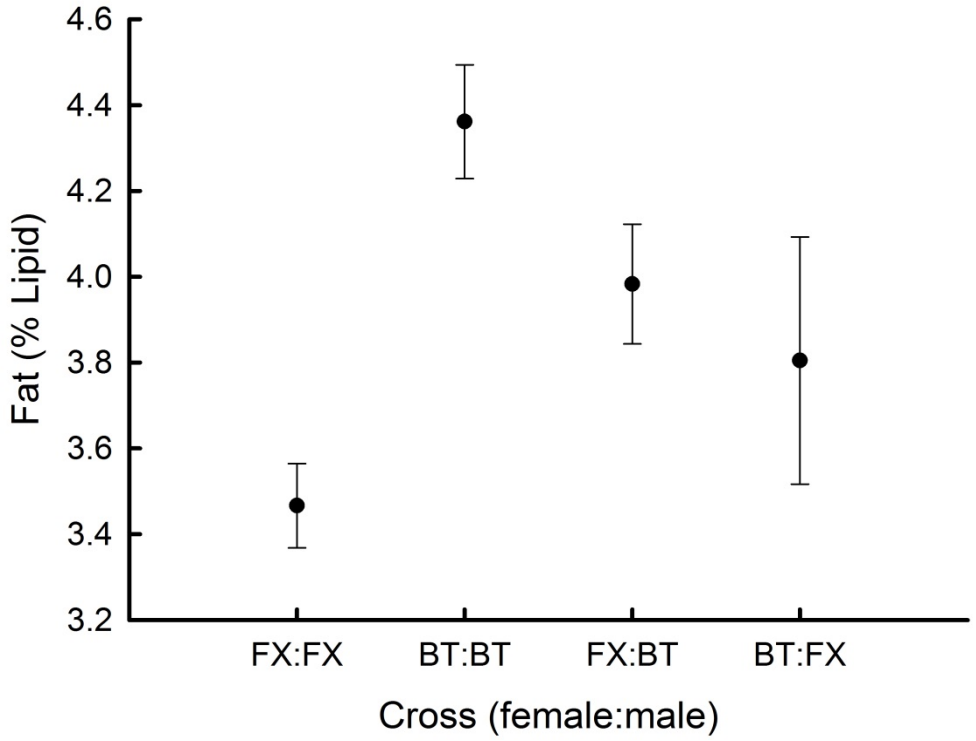


- There was no difference in SMR ($F_{2,28}$=0.9, p=0.4427), AS ($F_{2,28}$=1.48, p=0.3474) or MMR ($F_{2,28}$=0.7, p=0.4914).

Lipid Deposition

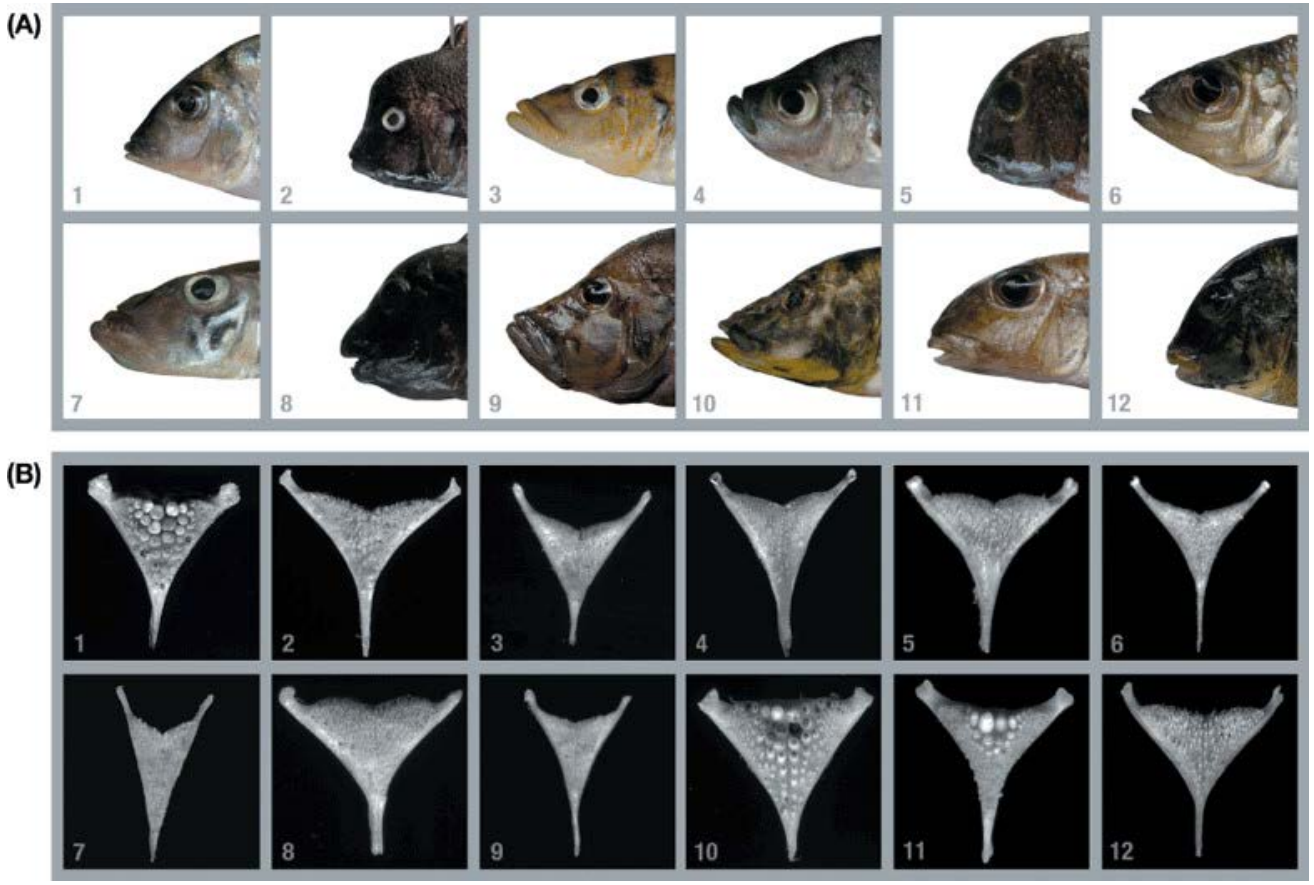
- Related to metabolism is lipids or fatty acids.
- Fish lack carbohydrates so lipids act as the main source of energy in fish.
- Lipid levels in salmonids is of particular interest to maturation.
- Numerous studies have demonstrated lipid level thresholds exist which dictate if a salmon will return from sea to spawn or if a juvenile will smolt.

Lipid Deposition

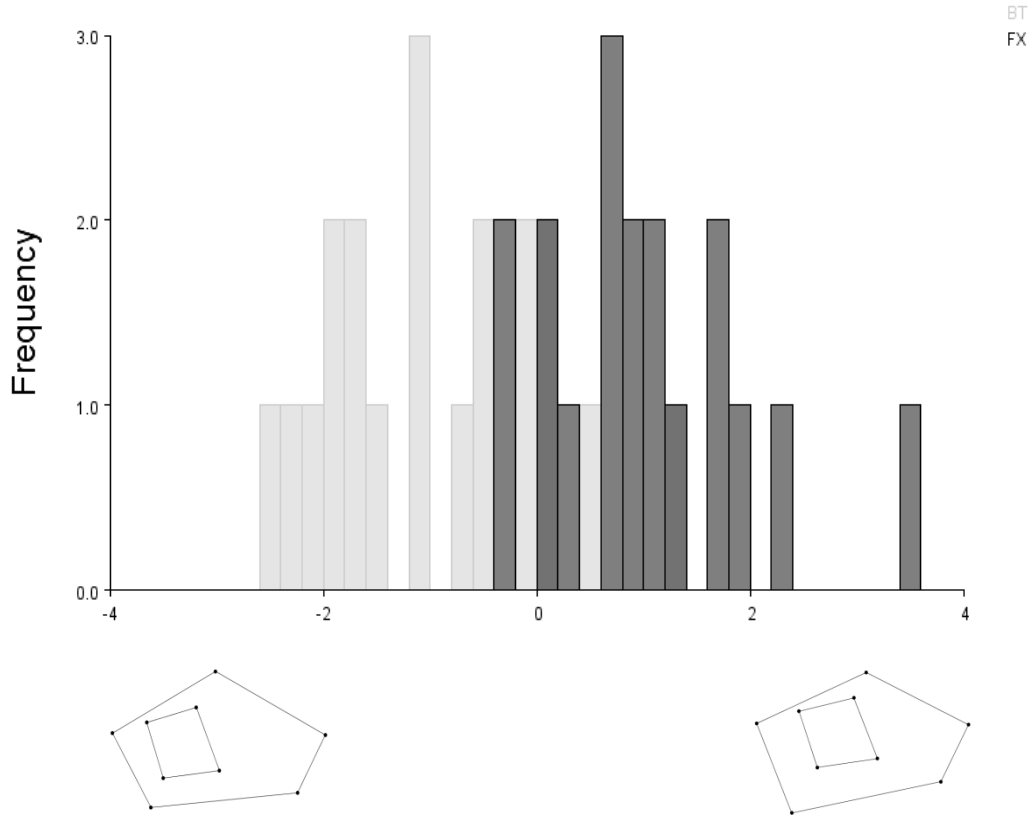


- There was a significant difference in % body fat between offspring of alternative life-history (ANOVA; $F_{3, 821,} = 10.49$, $P<0.001$)

Geometric Morphometrics



Morphology

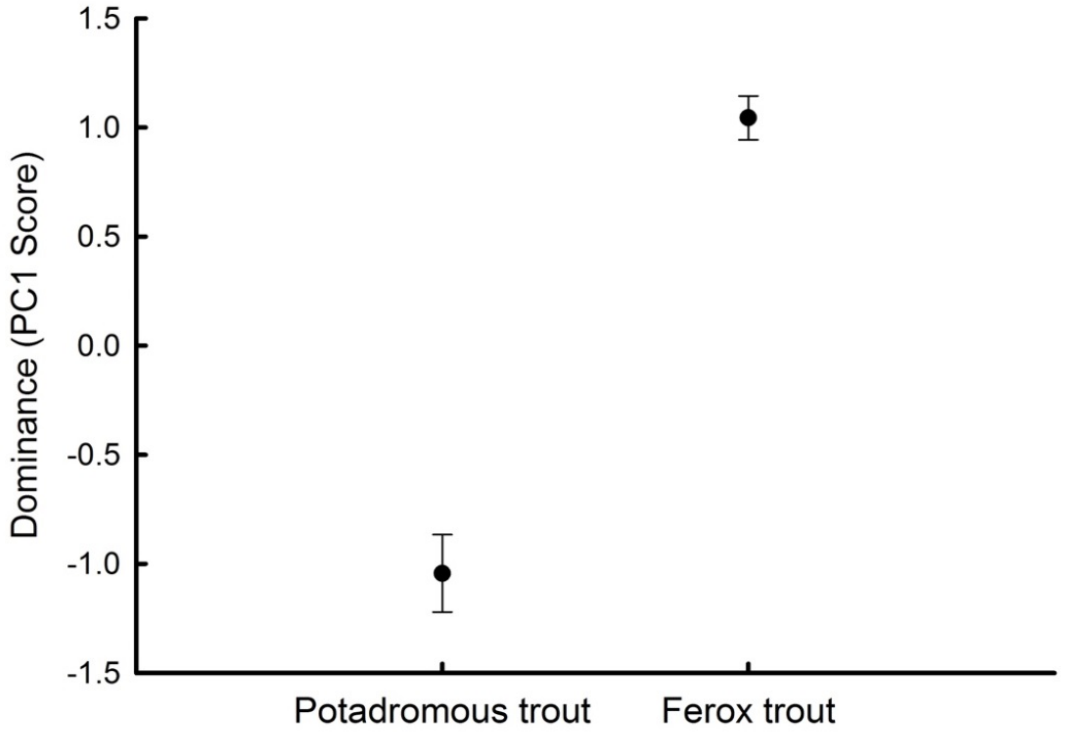


Basic trout behaviour

- Brown trout establish territories within these streams as juveniles.
- Dominant individuals more likely to acquire more food and therefore more likely to reach sexual maturity and reproduce.
- Brown trout return to natal streams to spawn as adults.

Behaviour

Behaviour


1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
Dominance (PC1 Score)
Potadromous trout
Ferox trout

Management Questions

- How rare are these fish? - Produce a modern estimate on ferox distribution in Scotland.
    - 192 sites in Scotland.
- What are the ecological parameters associated with ferox trout?
    - Strong statistical evidence of relationship between ferox trout and Arctic charr, large lake size and lake depth.
- Can we measure differences in wild populations using non-lethal methods?
    - Yes, scale reading and examination of juveniles through common garden exps.

Broad Evolutionary Questions

- How can ferox trout maintain isolation while living in sympatry with brown trout.
    - Potentially behavioural mechanisms, operate at different trophic levels.
- Do ferox and brown trout differ physiologically?
    - Different maternal provisioning, lipid levels, morphologies, and survival rate. Not metabolism or developmental pace.

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