Reproduction & Recovery - Energetics

Iteroparity & Semelparity

- **Iteroparity- (perennial) reproduces more than once.**



- **Semelparity- (annual) reproduces only once.**



Crespi, B.J. and R. Teo. 2002. Comparative phylogenetic analysis of the evolution of semelparity and life history in salmonid fishes. Evolution 56(5). 1008-1020.

- Which strategy evolved first?
- Lower degree of repeat breeding linked to higher reproductive investment.
- Tradeoff between high juvenile survival and adult survival…at least in salmonids.

Energy & Reproduction

- Evolution of diadromy (anadromy, catadromy, amphidromy)
- Energy investment
- Lifetime reproductive fitness

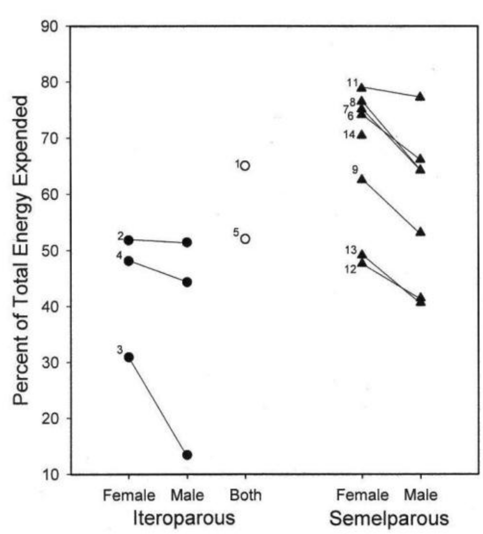
Fish Energy

- Lipid (26.4 kJ/g)
- Protein (20.1 kJ/g)
- Very little carbs

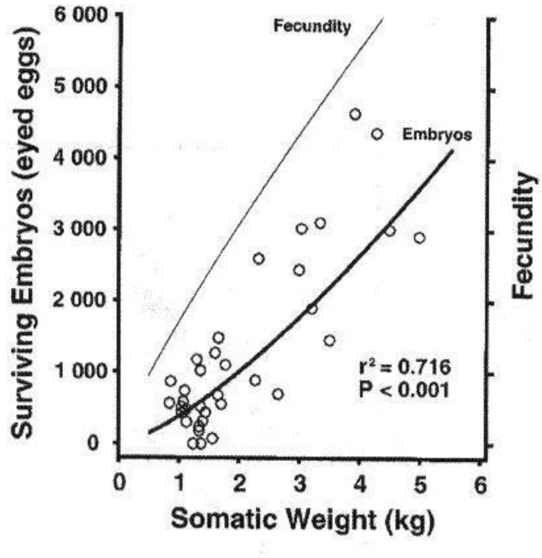
Lipid

Protein

Fleming, I.A. and J.D. Reynolds. 2004. Salmon breeding systems. Pages 264-294 *In* A.P. Hendry and S.C. Stearns. Evolution illuminated salmon and their relatives. Oxford University Press, USA.



Fleming, I.A. 1998. Pattern and variability in the breeding system of Atlantic salmon, with comparisons to other salmonids. Canadian Journal of Fisheries and Aquatic Sciences 55 (Suppl. 1):59-76



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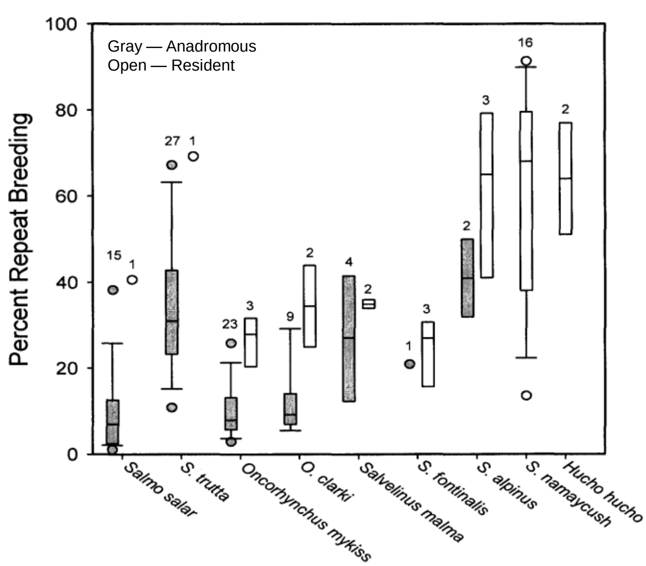


Anadromous vs. Resident

- **Why do you think some salmonid populations have both anadromous & resident individuals within the same population?**

Anadromous vs. Resident

- **Why do you think some salmonid populations have both anadromous & resident individuals within the same population?**

"All juveniles do not grow & accumulate [energy] equally in freshwater due to differences in genetics & environment."

"Get a fish fat enough and it won't move because the need has been quelled. In contrast, a hungry fish will move as far as necessary to get fat." J.R. McMillan

Costs of Reproduction

- **Gonadal maturation**
  - It costs more to build eggs than sperm
- **Migration**
- **Fasting**
- **Competition**
- **Guarding**

Post-spawning

- **Semelparity = no recovery**
- **Iteroparity = energy replacement via feeding**
- **Gonadal recrudescence (renewed activity)**

Rideout, R.M., and Tomkiewicz. 2011. Skipped spawning in fishes: More common than you might think. Marine and Coastal Fisheries Dynamics, Management, and Ecosystem Science 3:176-189.

- **Consecutive (annual) vs. skipped spawning**

Reasons for skip spawning:

1. **Sterility**
2. **Intersex** **(when it is not supposed to be)**
3. **Disease, parasites, etc.**
4. **Physiologically & energetically not ready**

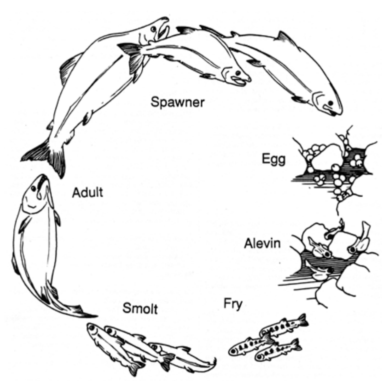
Skipped Spawning & Population Dynamics

- **Not accounting for skipped spawners could result in a overestimation of annual production (4 - 41%).**
- **Adjusting the SSB for skipped spawners in Atlantic cod did not improve the stock-recruitment relationship.**
- **Why?**

Physiology of Spawning & Recovery in Snake River Steelhead trout (*Oncorhynchus mykiss*)

Steelhead

- Anadromous
- Iteroparous
- Degree of iteroparity is highly variable (<1.0% to >70%)
- In Snake River <2.0%



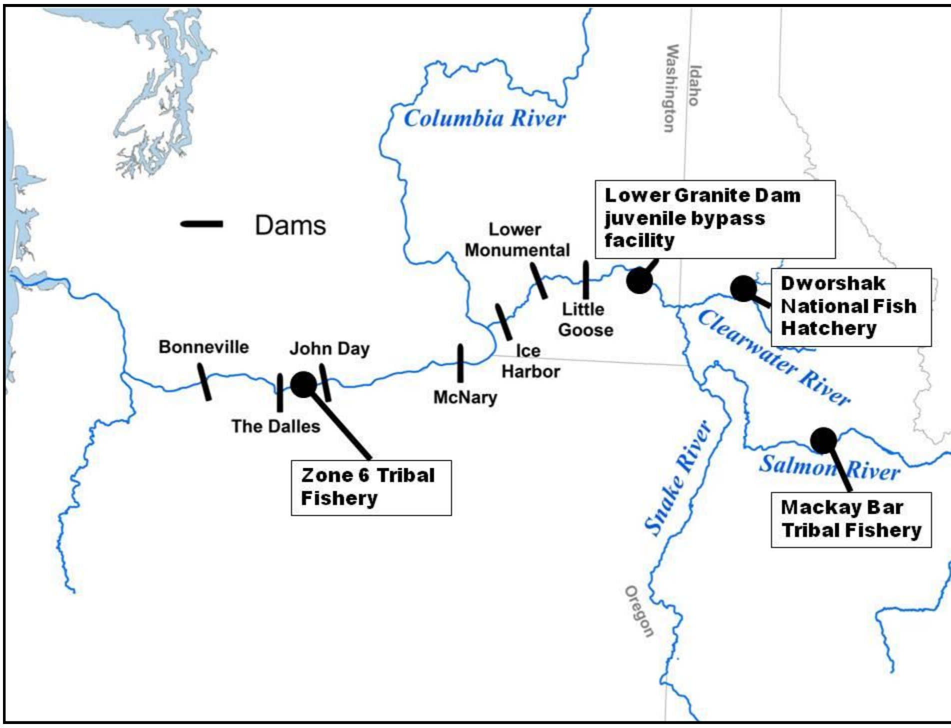
Steelhead Kelt Research

- Conservation tool
- Increase gene flow
- Reconditioning
- Historically low?

Energy Use & Recovery

Goal: Evaluate how much energy & what type of energy is used during reproduction.

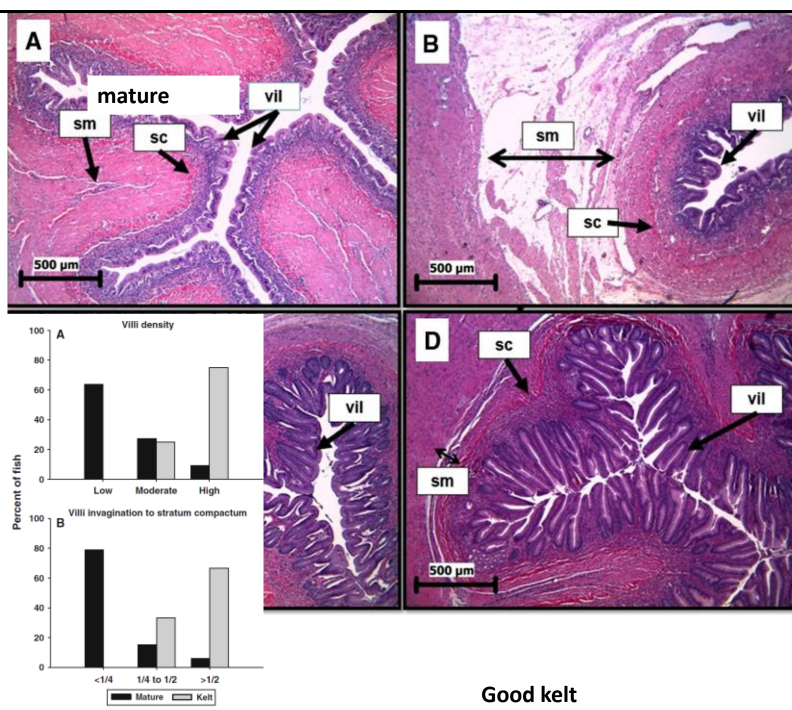
- Where is the bulk of energy used?
- How much energy remains?
- What is the physiological capacity for recovery?


Columbia River
Washington
Idaho
Dams
Lower Granite Dam juvenile bypass facility
Lower Monumental
Little Goose
Dworshak National Fish Hatchery
Clearwater River
Bonneville
John Day
Ice Harbor
McNary
The Dalles
Zone 6 Tribal Fishery
Snake River
Salmon River
Mackay Bar Tribal Fishery
Oregon

Energy use

Reproduction vs Feeding

- Many species, not just migratory fish reduce feeding at the time of reproduction
- Steelhead studies showed GI stasis and lack of structure for absorption at the time of maturity.



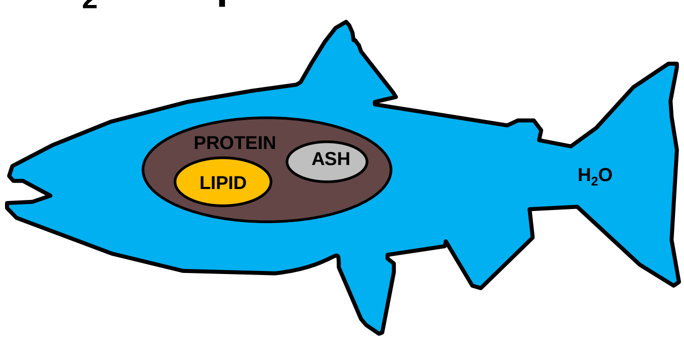
Good kelt

Profile of Energy Storage

- Use of destructive sampling of tissues
- Use of blood metrics – non lethal approach

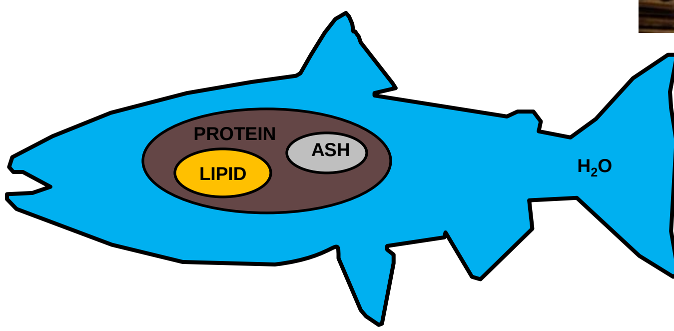
Proximate analysis

- **Mass Balance**
- **H_2O – Lipid – Protein – Ash**



Total energy

- Lipid + Protein



Predicting Energetic Status

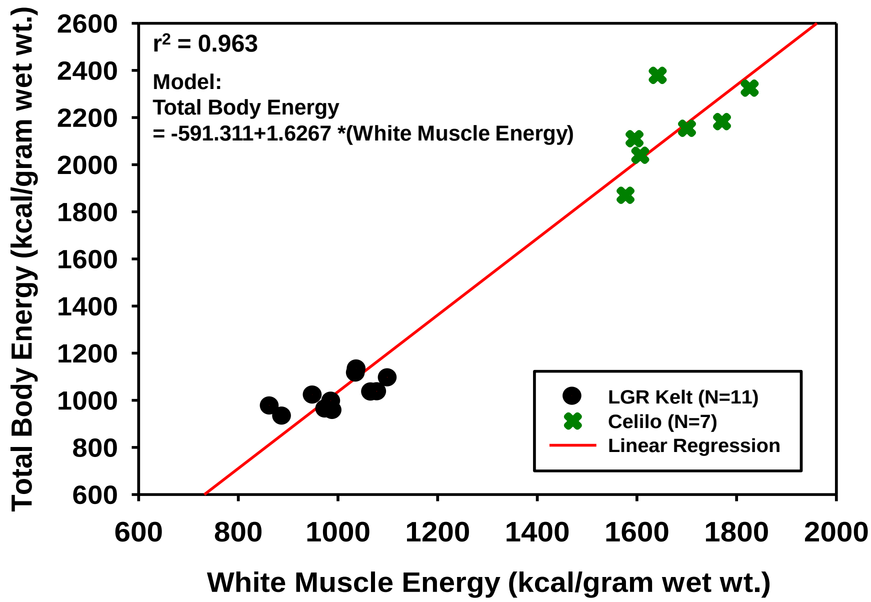
Model:

Total Body Energy = $\beta_0 + \beta_1$ * [White Muscle]

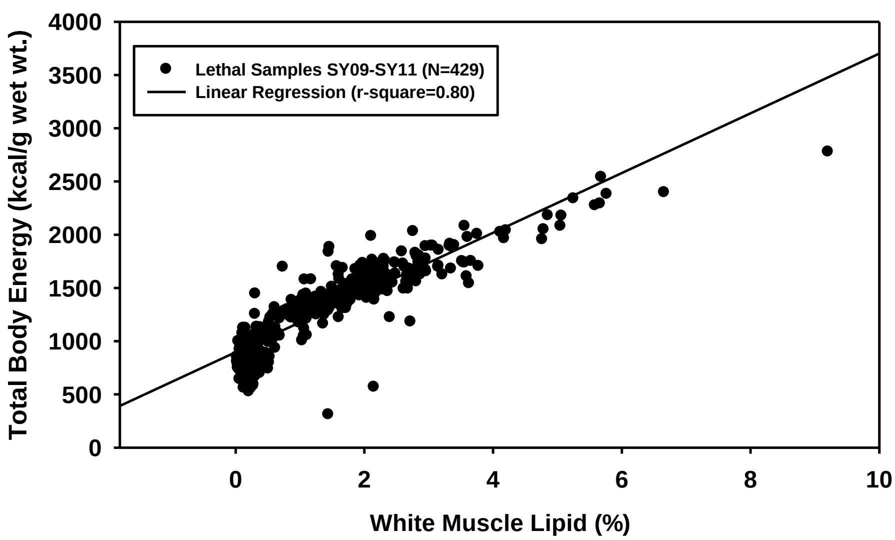
<u>Reconstructing Steelhead Bodies</u>

=

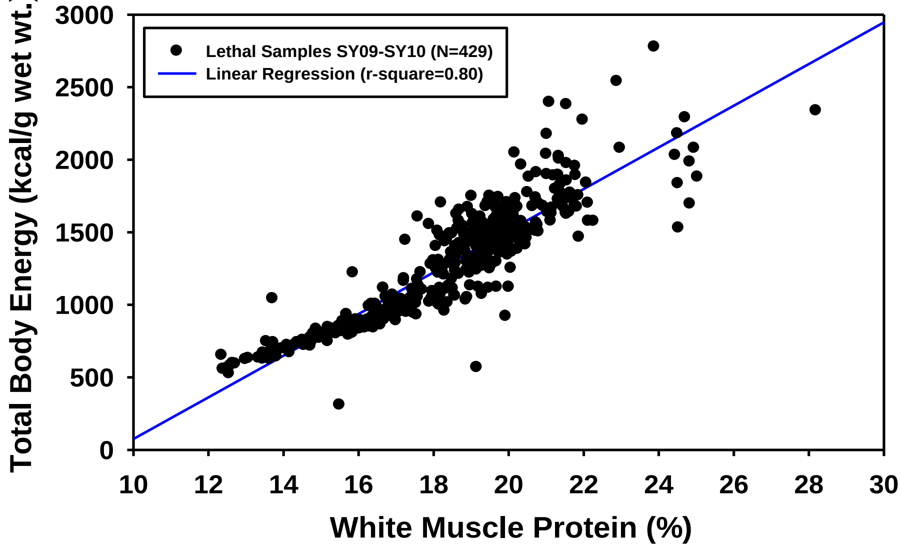
Total Body vs White Muscle Energy



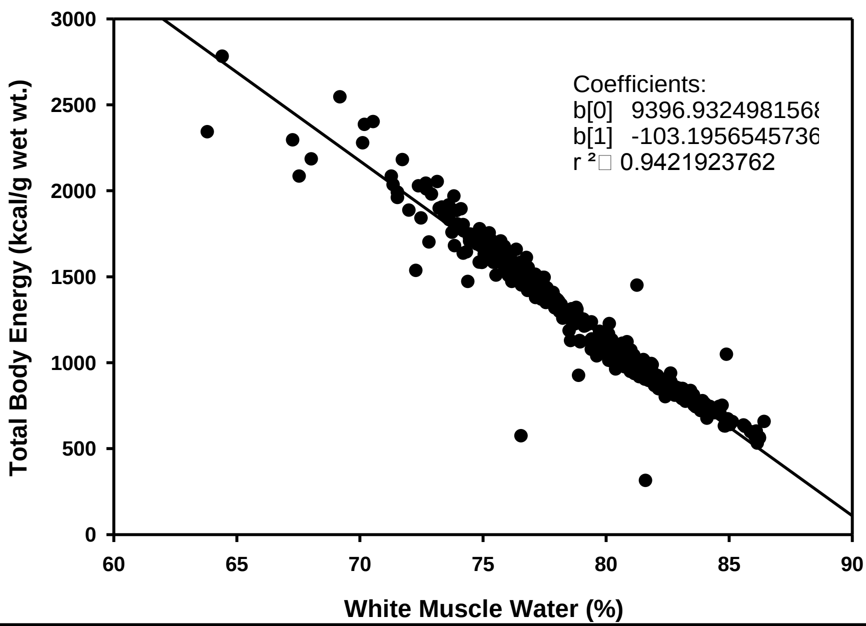
Total Body Energy vs. White Muscle Lipid



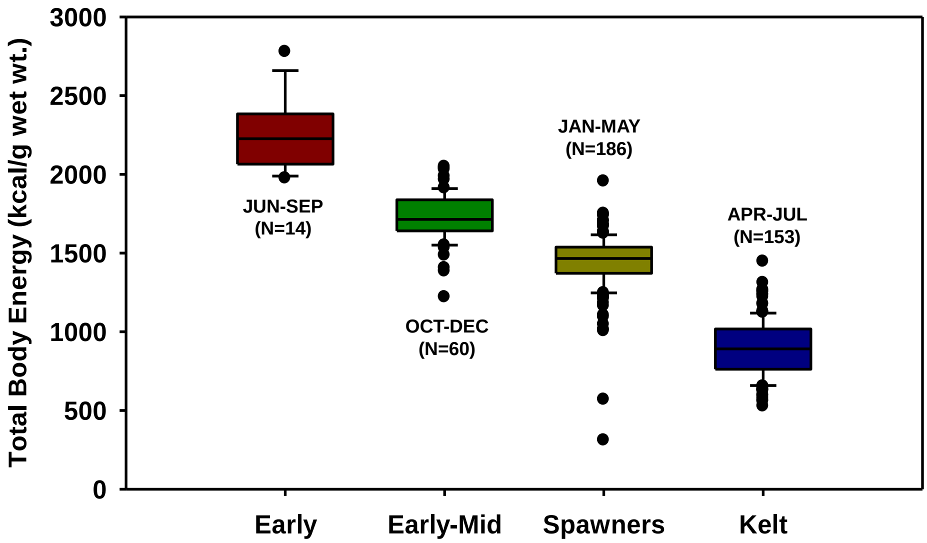
Total Body Energy vs. White Muscle Protein



Total Body Energy vs Water



Energy Profile By Phase

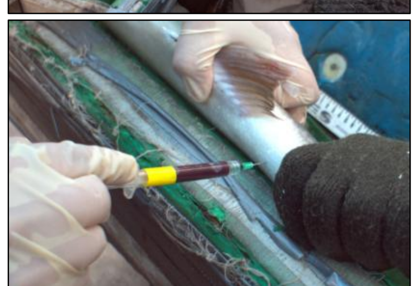


Blood

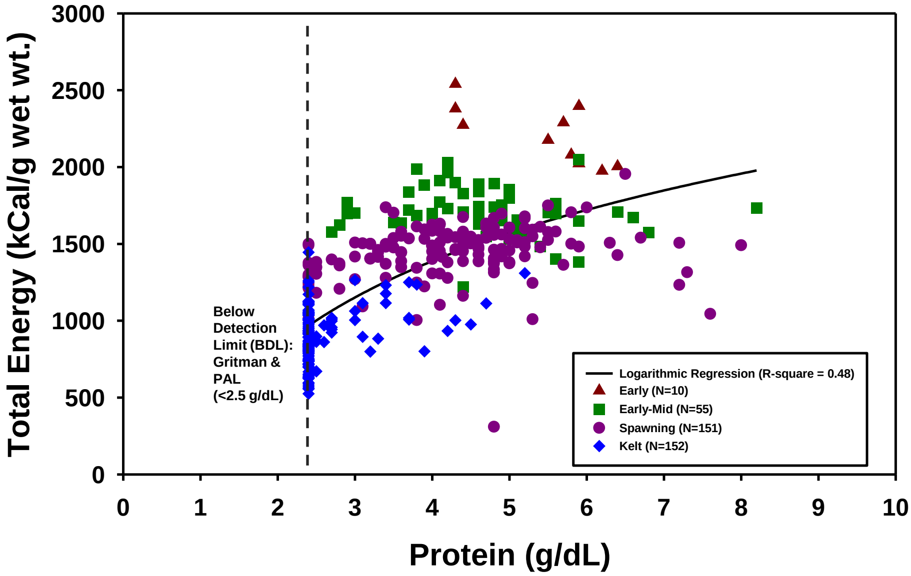
- Non-lethal

<u>**Plasma Factors:**</u>

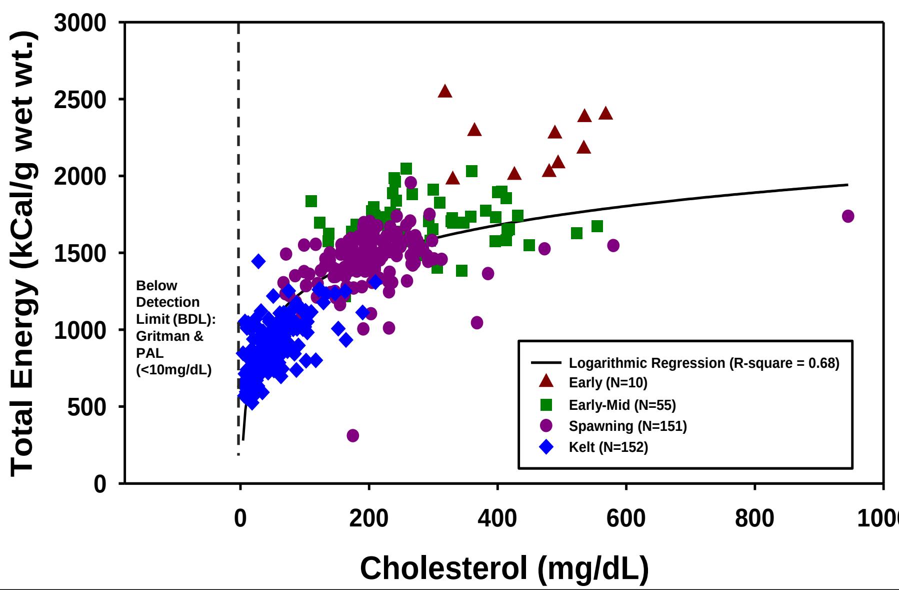
- Nutritional
- Stress
- Tissue Damage
- Electrolytes



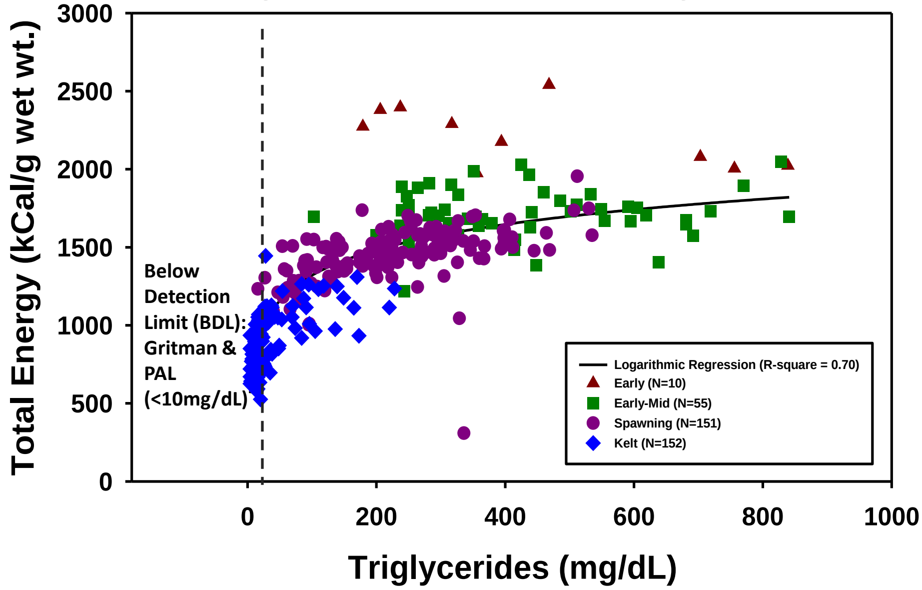
Total Energy vs. Plasma Protein



Total Energy vs Plasma Cholesterol



Total Energy vs Plasma Triglycerides

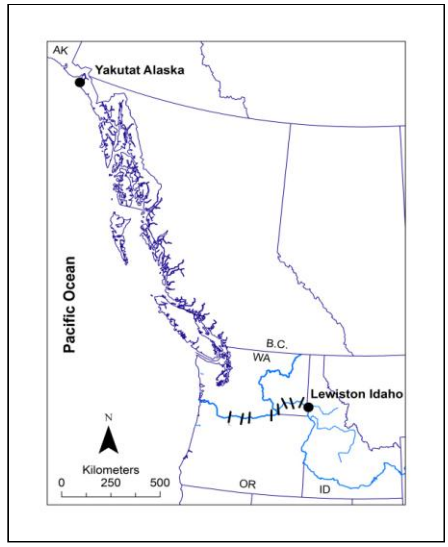


Selective comparison with shorter distance migratory stocks

Coastal vs Inland

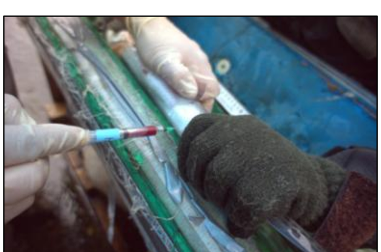
- Situk River, AK

- Snake River, WA & ID



Plasma Comparisons

- Good female kelts
- Natural origin (adipose intact)



System	N		Length (cm)
Snake	50	Median	60.5
		Range	52.0 - 83.0
Potlatch	47	Median	68.9
		Range	60.0 - 76.0
Clearwater	25	Median	75.0
		Range	62.0 - 81.0
Situk	24	Median	79.5
		Range	61.0 - 87.5

Tissue Sampling

- All sexes
- Fresh mortalities
- Poor condition kelts

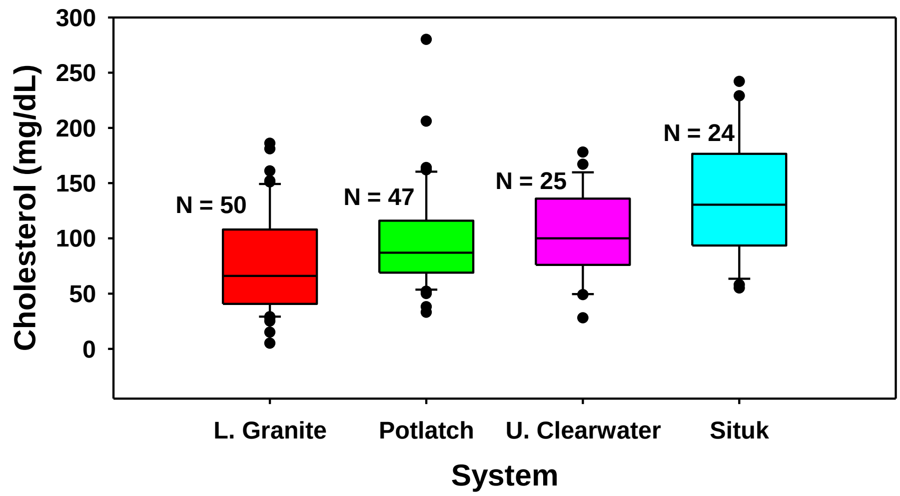
System	Poor condition kelts	Instream kelt mortalities
Situk	0	11
Potlatch	0	5
Upper Clearwater	0	0
Lower Granite Dam	31	0
Total	31	16



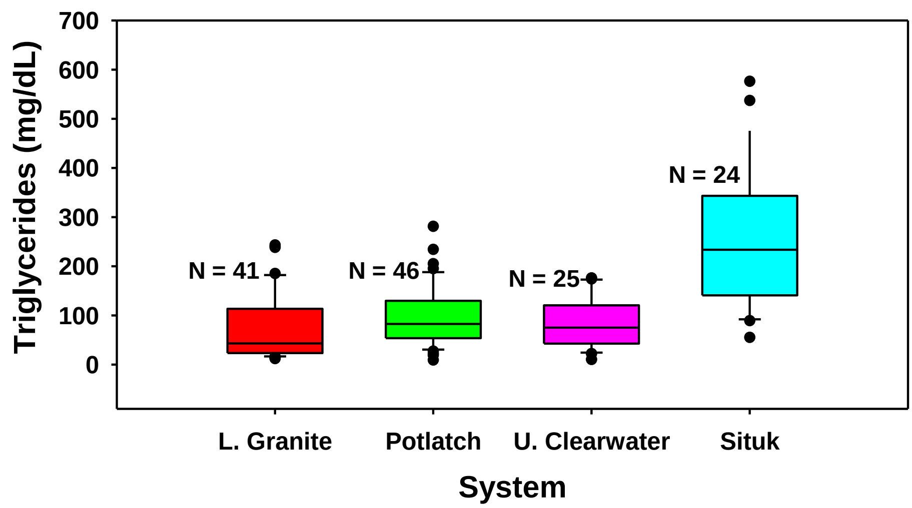
Plasma Protein (Chi-Square)

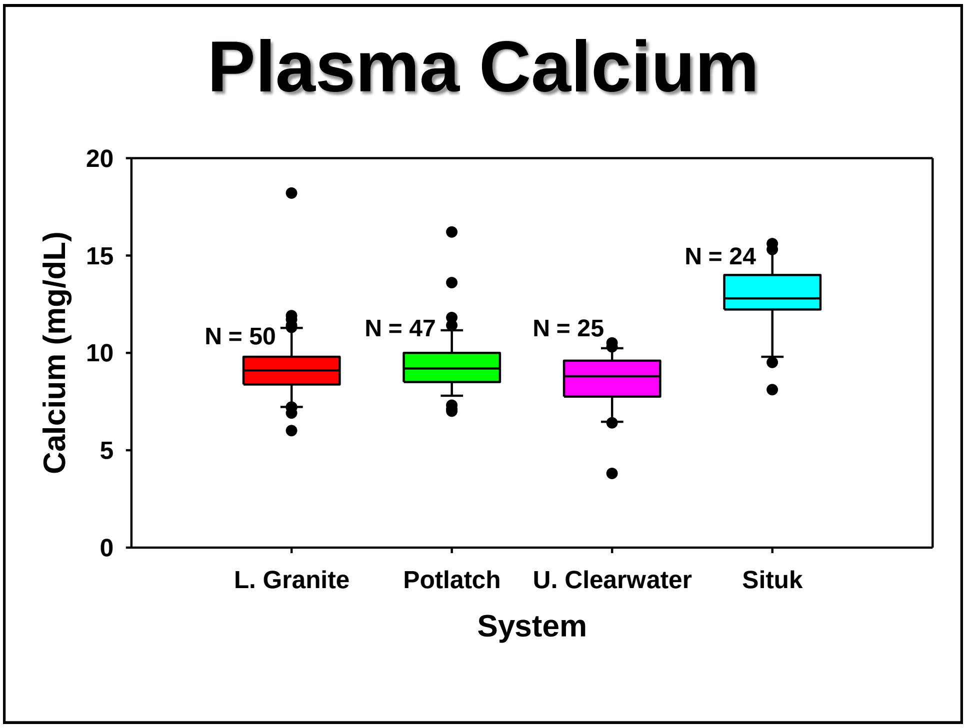
System	N	Above detection limits %	Below detection limits %	Significance $\alpha = 0.05$
Situk River	24	92	8	No difference
Upper Clearwater weirs	25	72	28	
Lower Granite Dam	50	26	74	No difference
Potlatch weirs	46	30	69	

Plasma Cholesterol

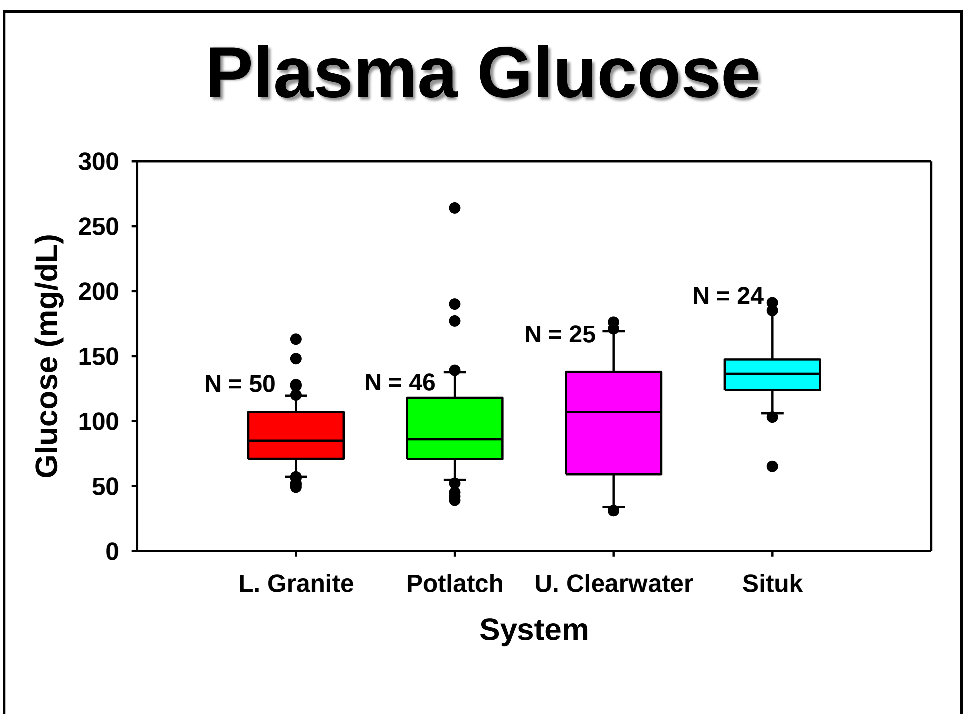


Plasma Triglycerides



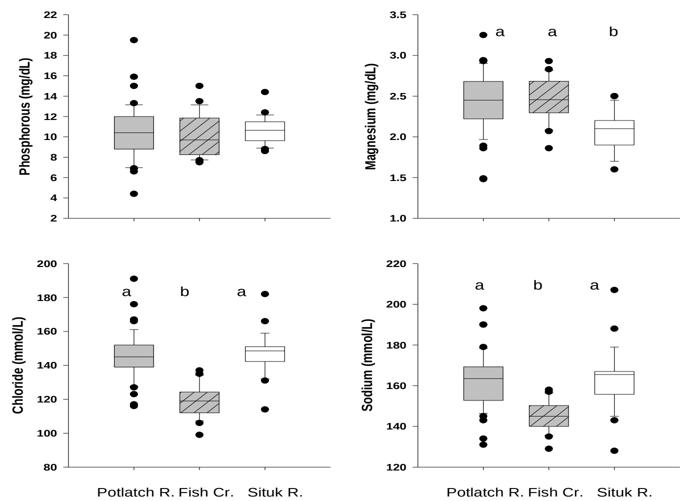


Plasma Calcium
Calcium (mg/dL)
20
15
10
5
0
N = 50
N = 47
N = 25
N = 24
L. Granite
Potlatch
U. Clearwater
Situk
System



Plasma Glucose
Glucose (mg/dL)
300
250
200
150
100
50
0
N = 50
N = 46
N = 25
N = 24
L. Granite
Potlatch
U. Clearwater
Situk
System

Electrolytes Comparison of Weir Fish



Migratory Mortality Snake vs Situk