Adult Salmon Bioenergetics

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Background

- Adult salmon have finite energy reserves.
- Physiological challenges during upstream migration.
- Difficult passage environment increases risk that adult salmon will expend all their available energy before successfully spawning.
- Temperature and flow both affect energy use of salmonids.

Recognized Issue

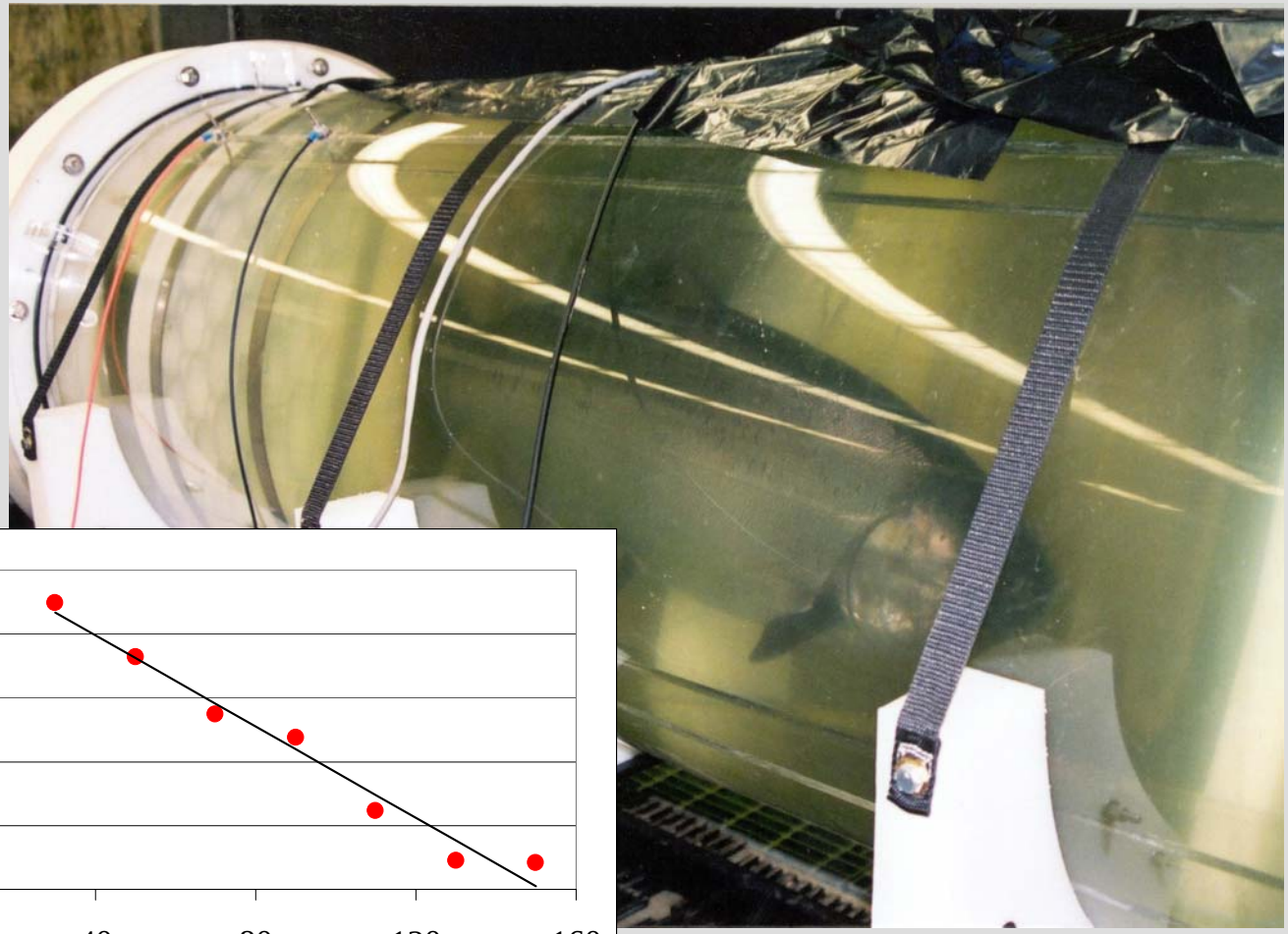
- "Many questions remain about the effects of delay or extra energy expenditure en route upstream on the ultimate ability of adults to spawn successfully." (Independent Science Advisory Board 1999).
- 2000 Biological Opinion directed Agencies to fund research for the purposes of evaluating the relationship between energy expenditure and pre-spawning mortality of adult salmonids migrating through the FCRPS (Sec. 9.6, Actions 107 and 118)

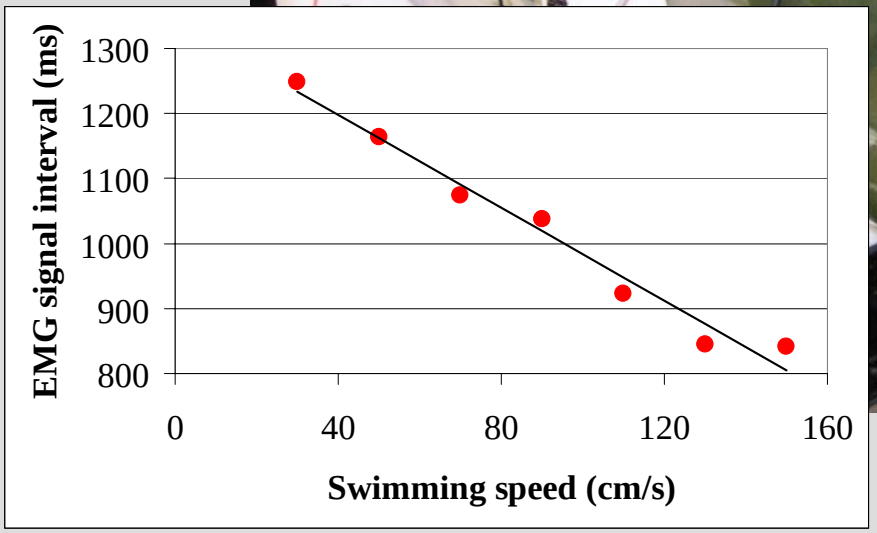
Energy Expenditure of Adult Fall Chinook Salmon Using EMG Telemetry

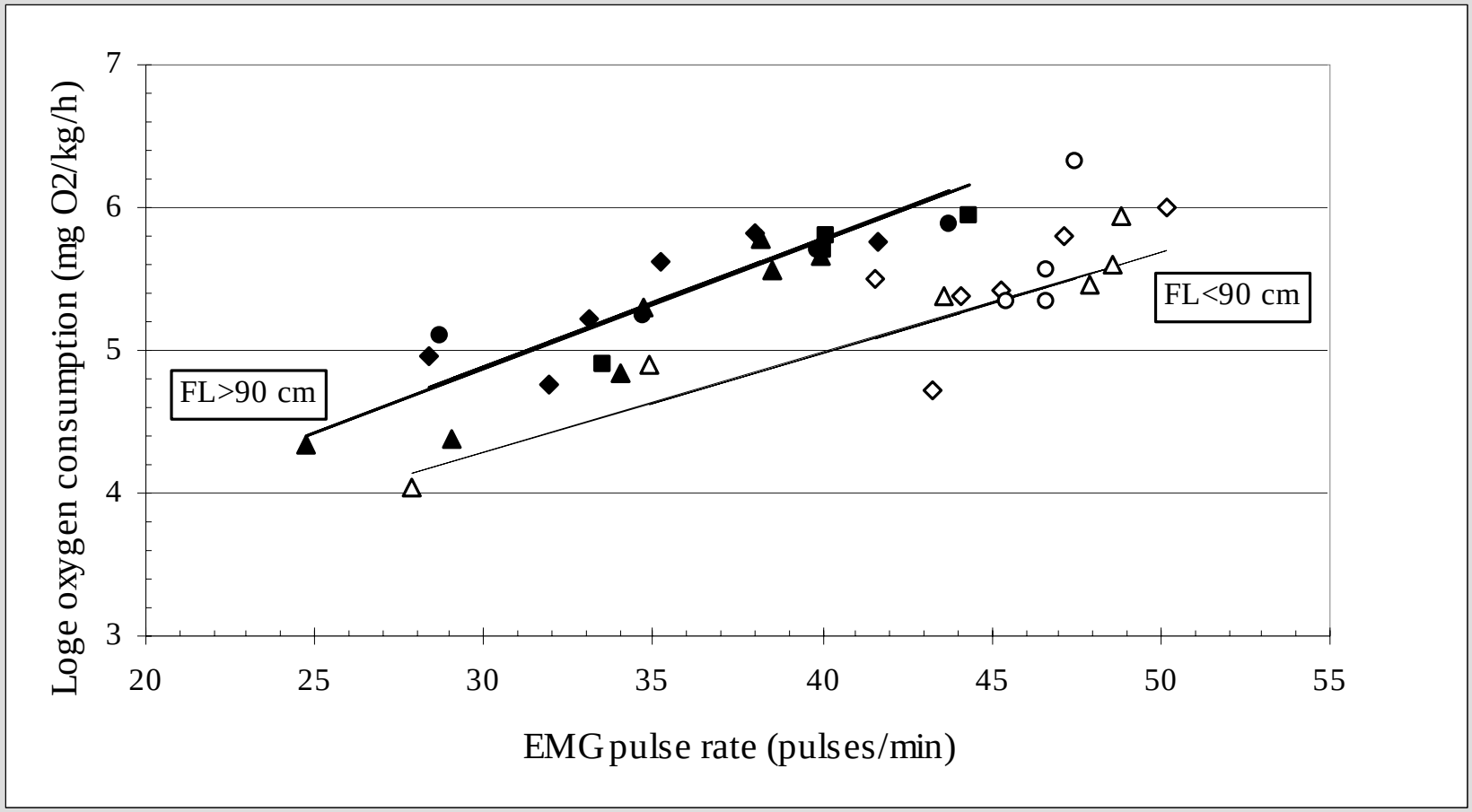
- Objective of study was to evaluate electromyogram (EMG) telemetry as a means to estimate energy expenditure of adult salmon.
- EMG telemetry uses electrical signals of muscle tissue as a correlate of swimming and oxygen consumption.

Surgically Implant EMG Tag

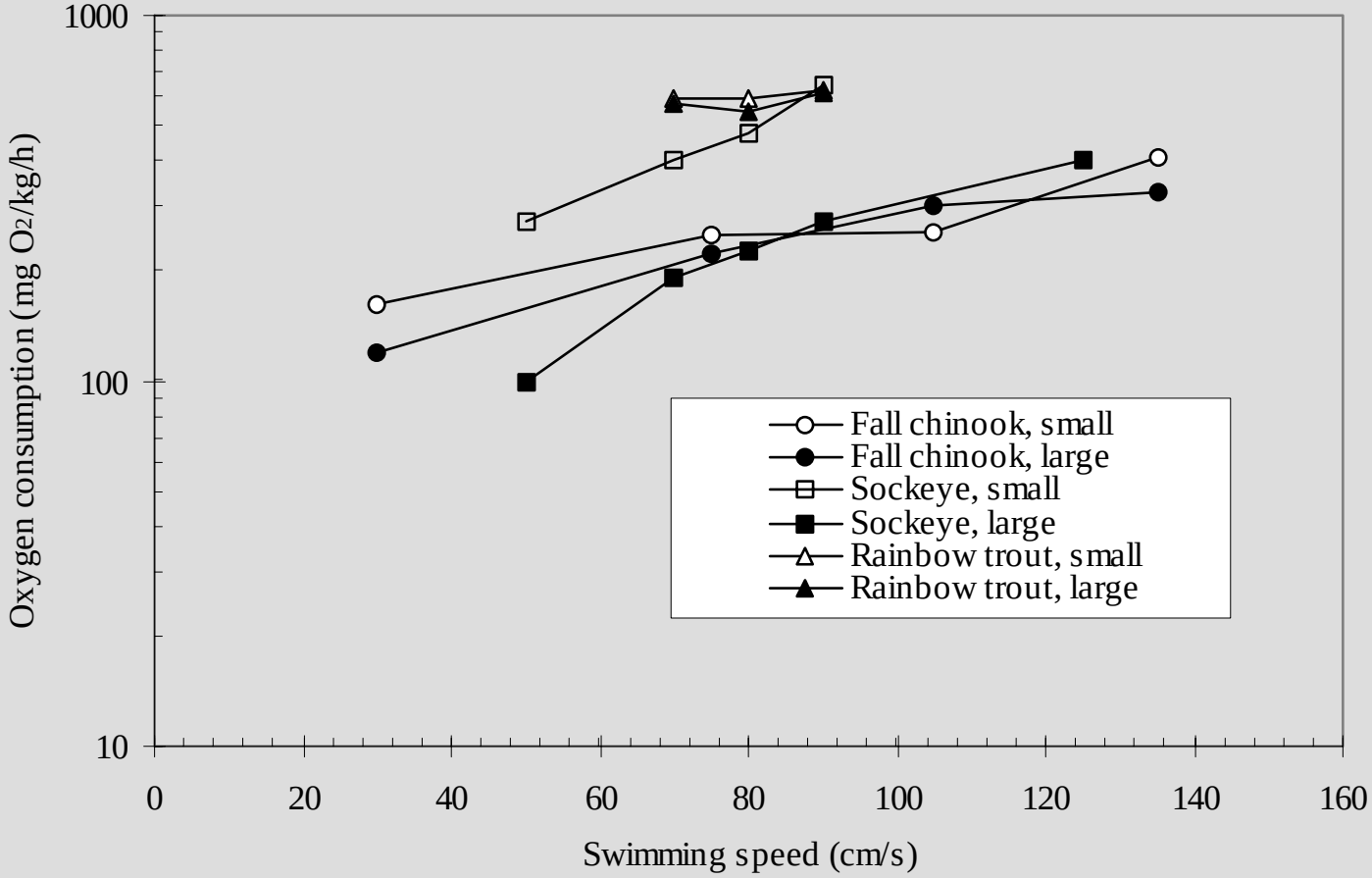
Calibration of EMG Tag







Source: Geist et al. 2000. TAFS 129:126-135.



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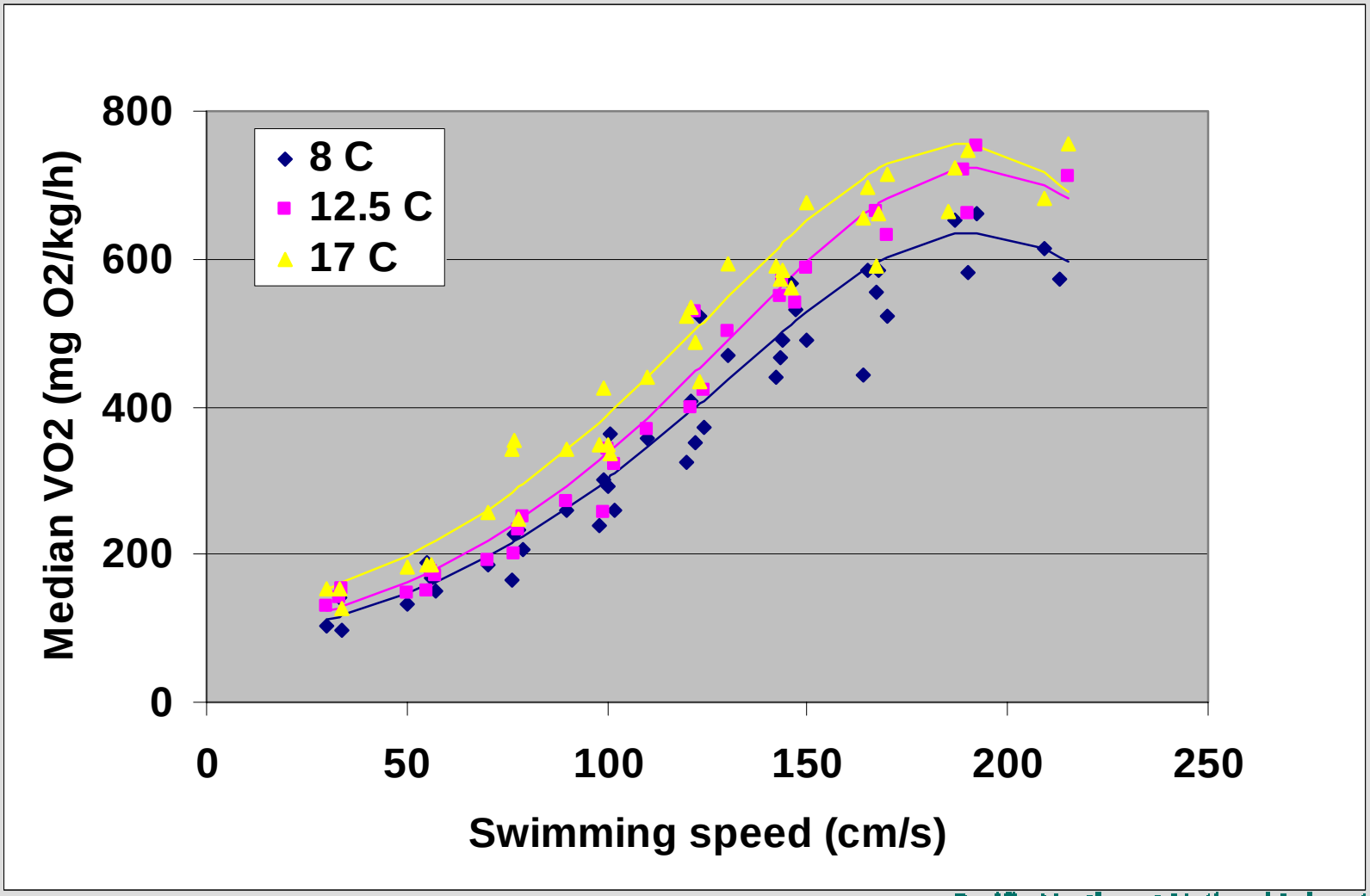
Delay period per dam and reservoir (days)	Energy used for all eight dams and reservoirs (kcal)	Total migration time (days)
0	3,176	15
1	4,736	23
3	7,856	39
5	10,976	55
7	14,096	71
10	18,776	95

Source: Geist et al. 2000. TAFS 129:126-135.

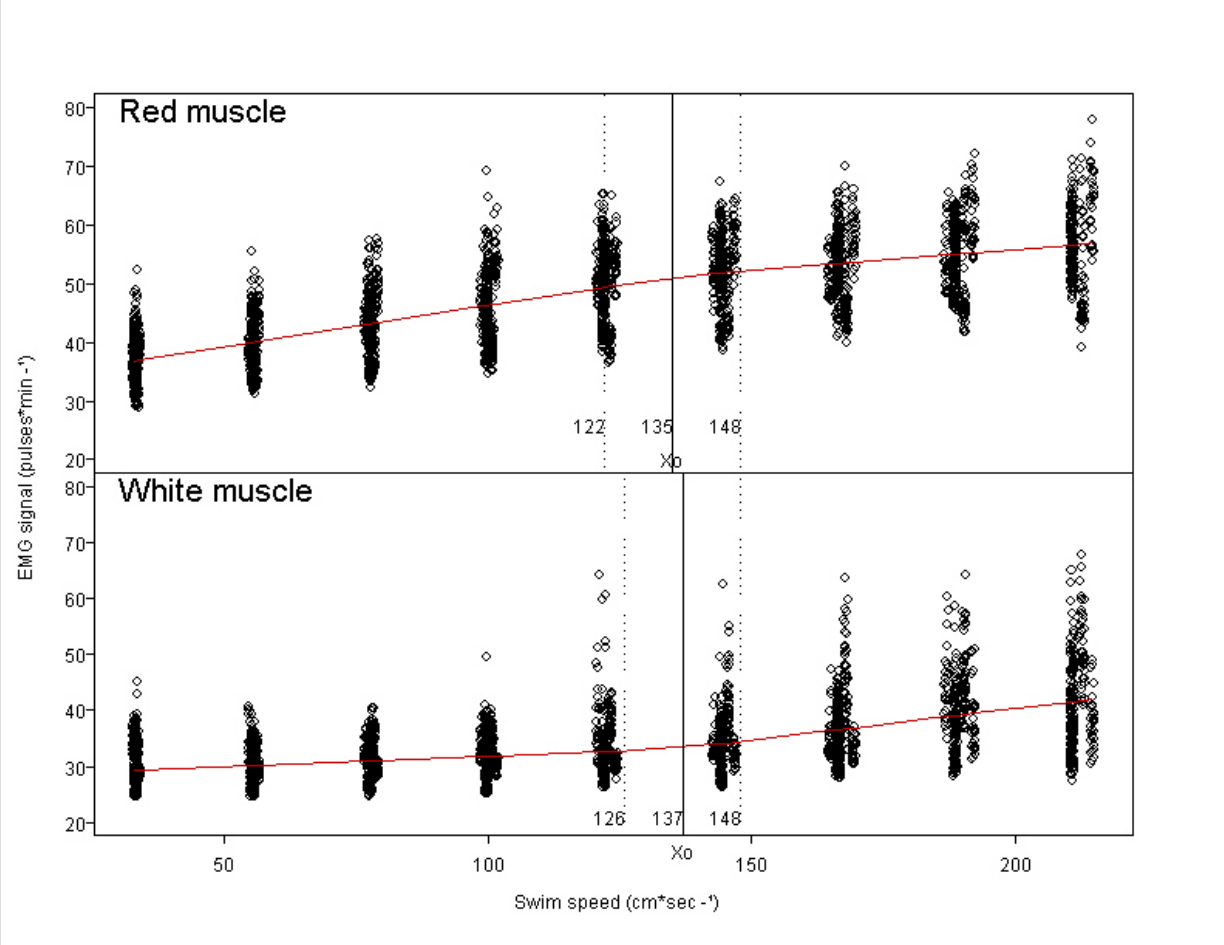
Use of EMG Telemetry to Estimate Energetics of Dam Passage

- Goal of study was to estimate energy expenditure of upstream migrating adult salmon and steelhead to assess the potential influence of delay, fallback, water temperature, and dam operations on migration energetics and reproductive performance.
- Cooperative study with USGS.

Spring Chinook Salmon

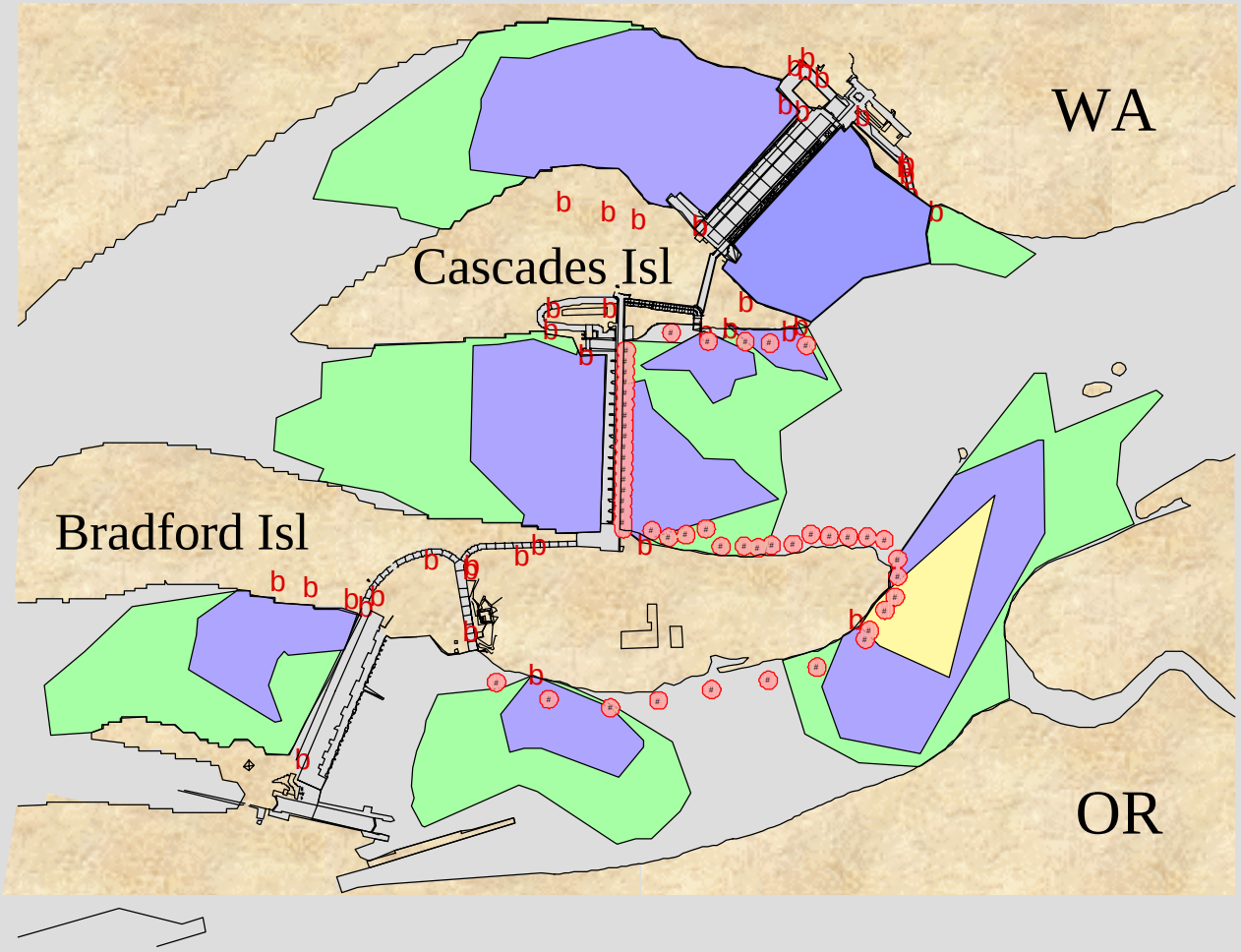


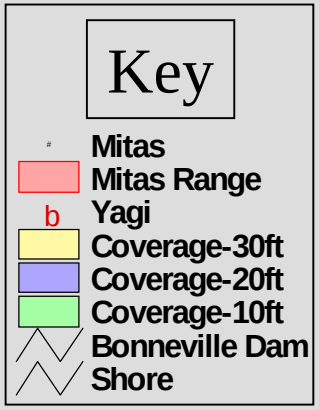
Muscle Type Determines Bioenergetics



Source: Geist et al. 2003. JFB 63:970-989.

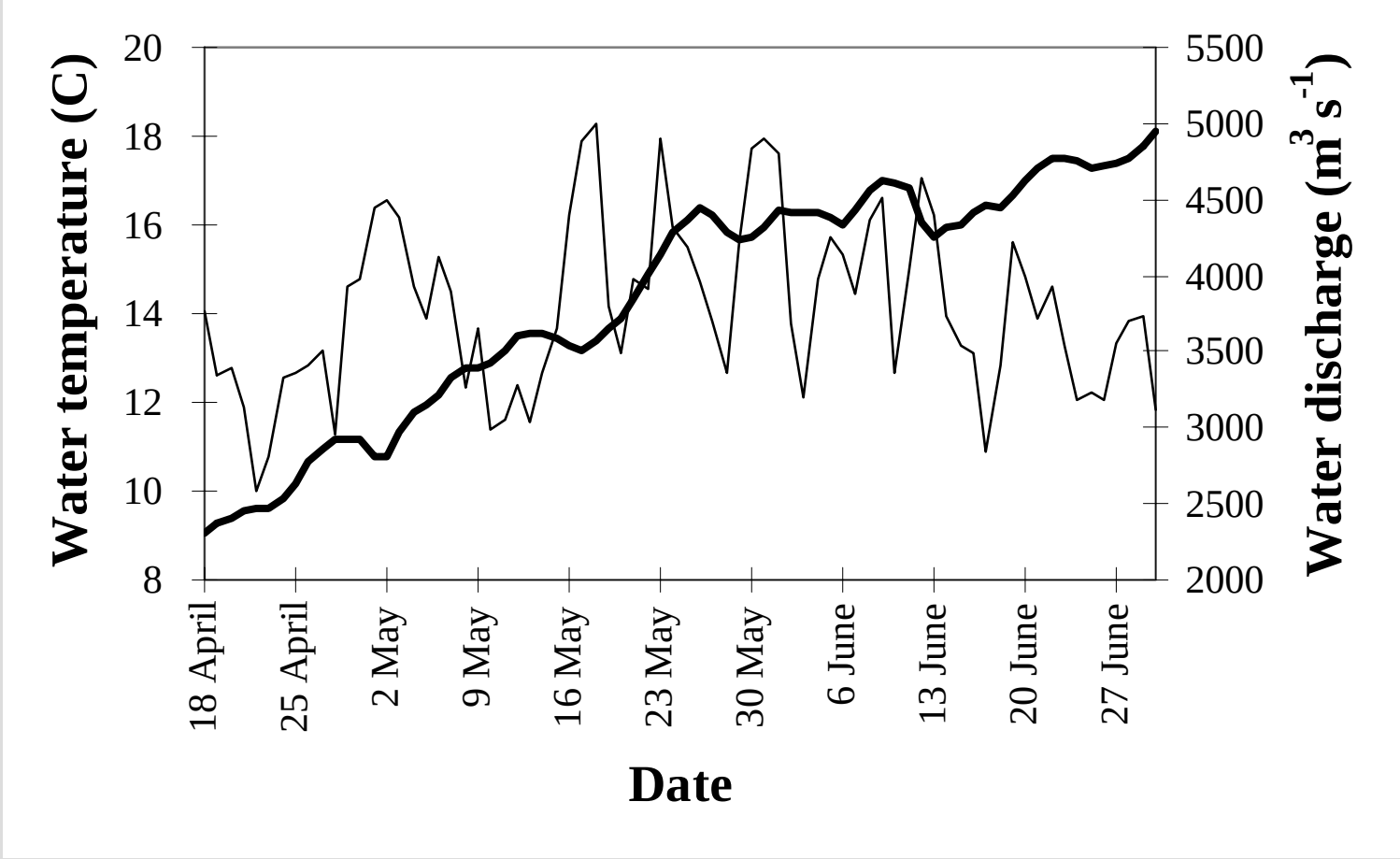
Study Conducted at Bonneville Dam





96 EMG-Tagged and Calibrated Salmon Released Below Bonneville Dam

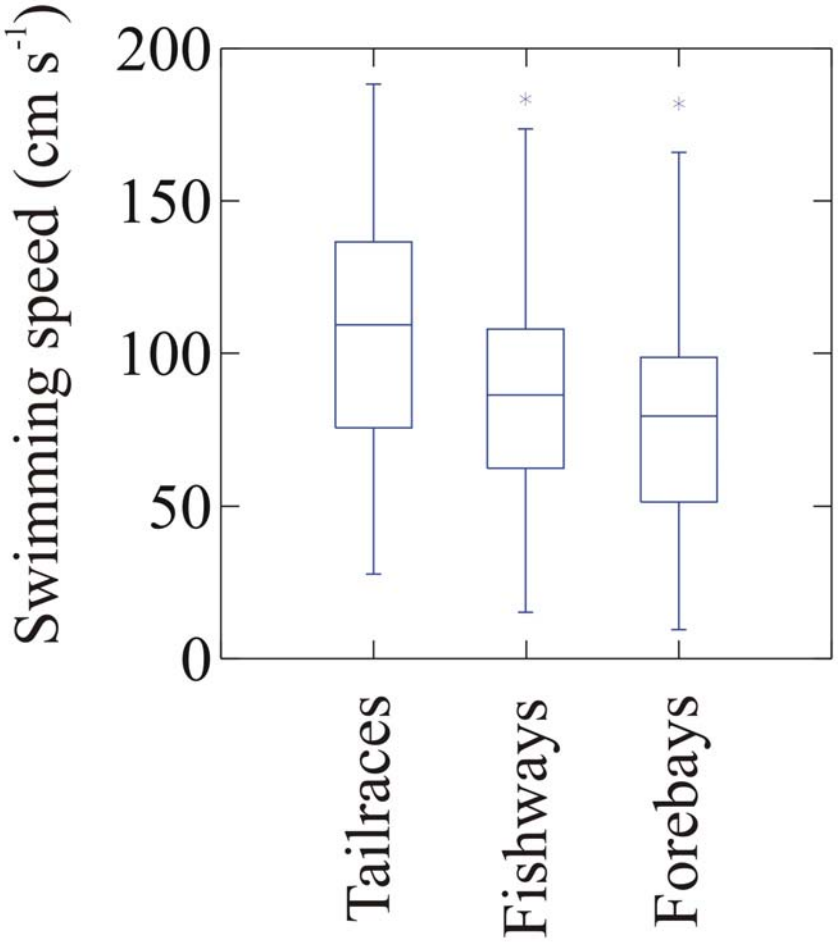
2001 Water Temperature and Flow Bonneville Dam



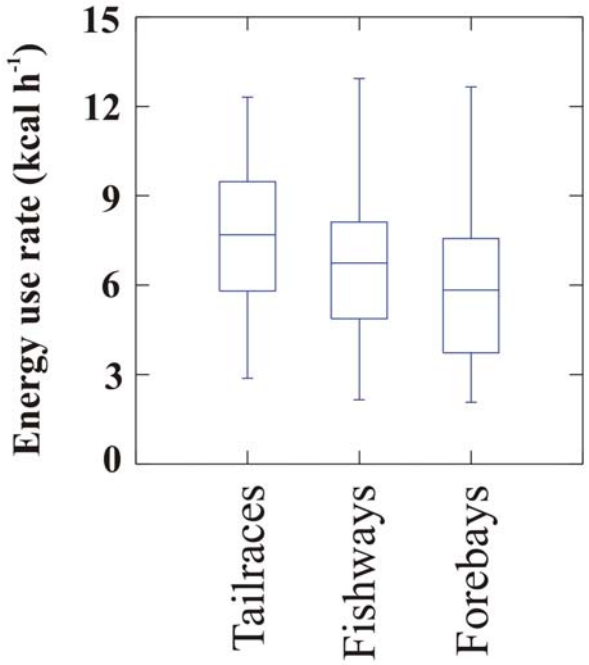
Spring Chinook Salmon Bioenergetics at Bonneville Dam

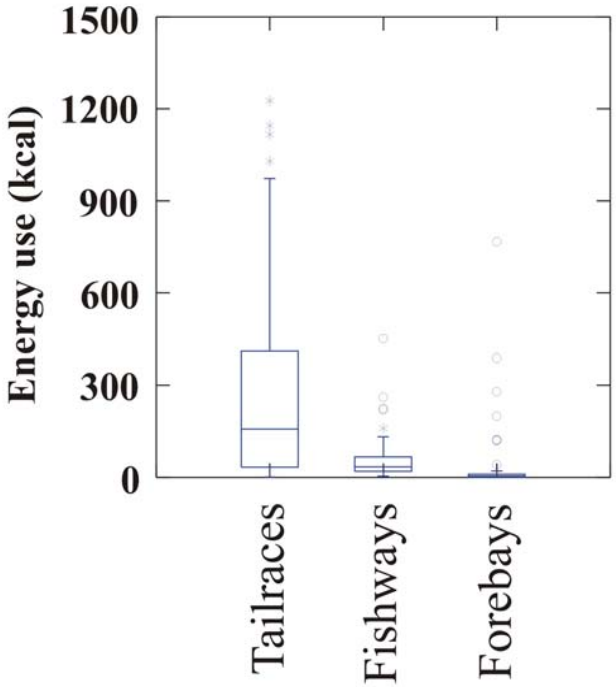
- Median fish took 26.8 h to migrate over Bonneville Dam.
- Expended 31.7 kcal/g, or 190 kcal for an average 6 kg fish.
- Anaerobic energy not accounted for, but could be substantial as considerable time was spent swimming at speeds which were $\geq$ 80% of Ucrit.

Swimming Speeds Highest In Tailrace



80% of Aerobic Energy Used In Tailrace



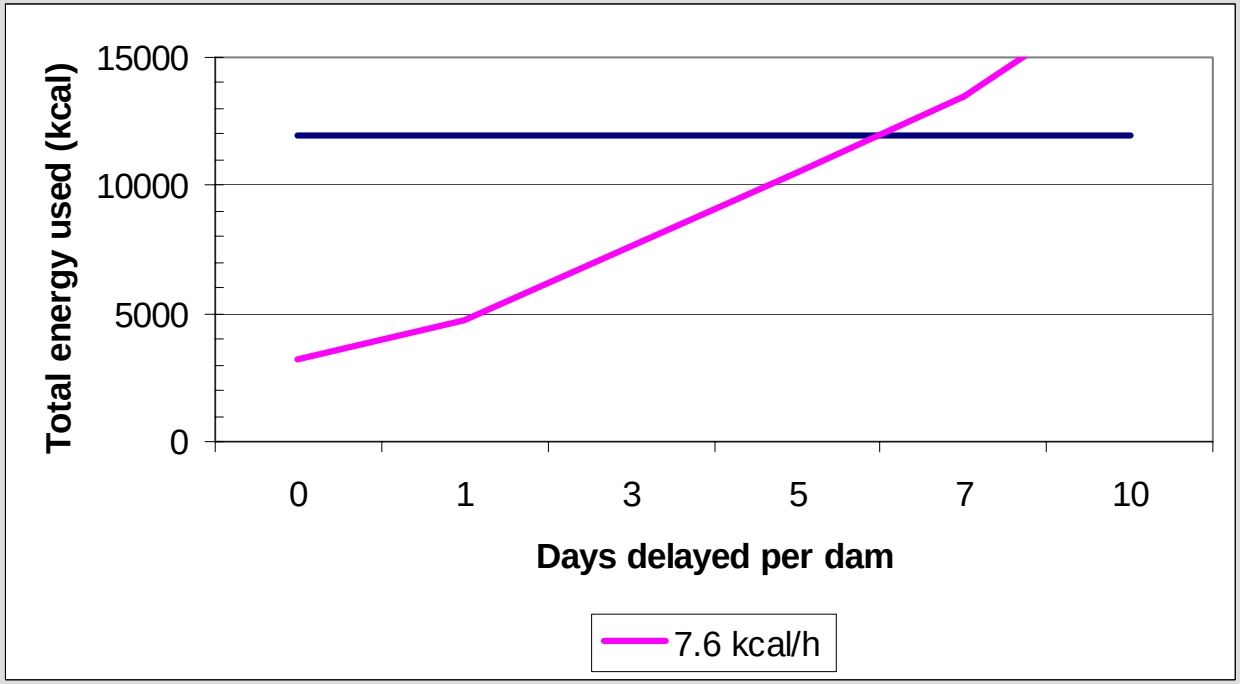


BEGINNING ENERGY
6 kg Sp Chnk
15,870 kcal
•19.7% fat
•19.4% prot

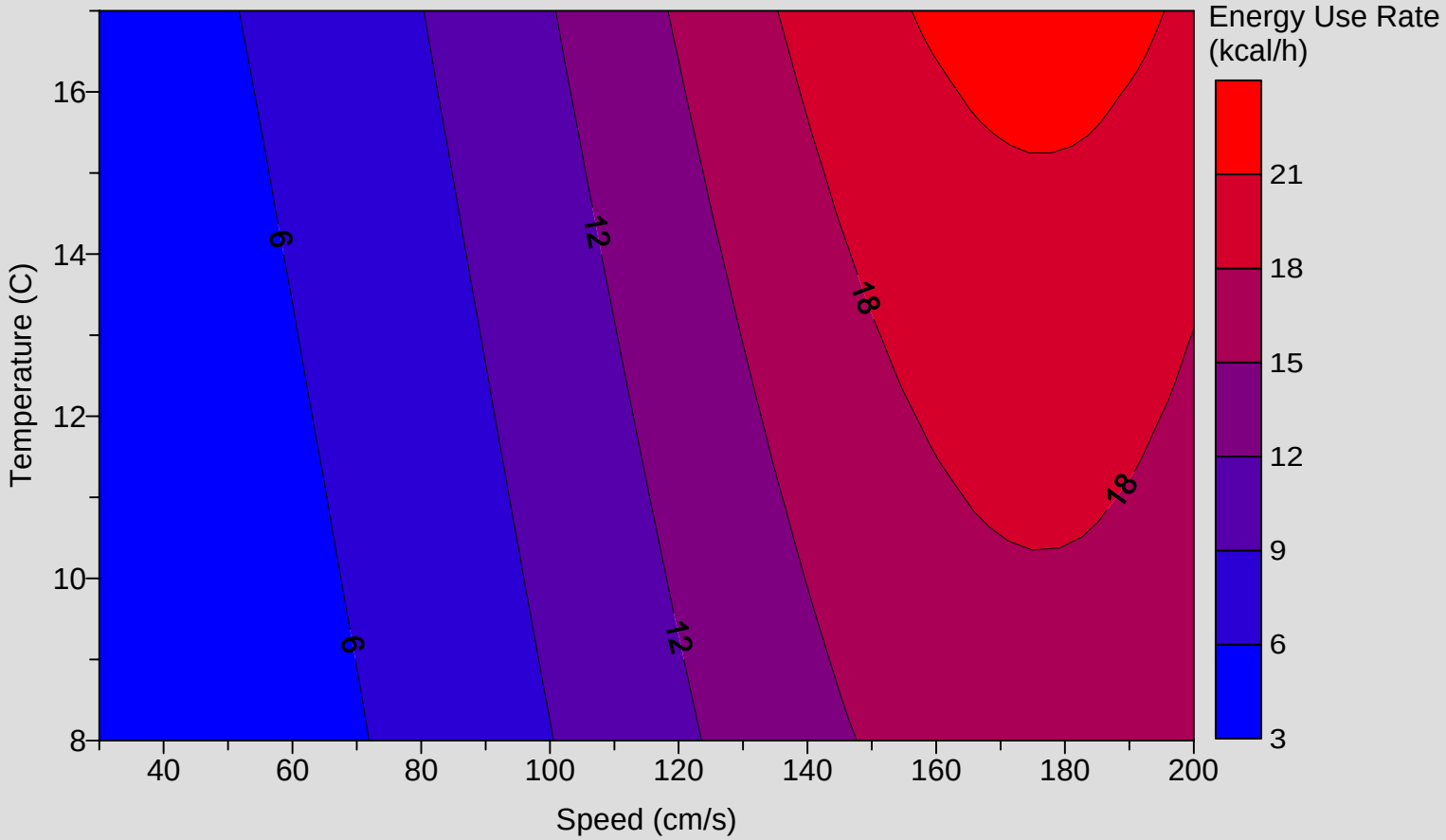
Gonad growth/development
2,280 kcal
•380 kcal/kg

Standard metabolism
1,600 kcal
•7.8 kcal/d

Remaining
11,990 kcal
for migration and spawning



How Might Temperature and Flow Affect Adult Salmon Bioenergetics?



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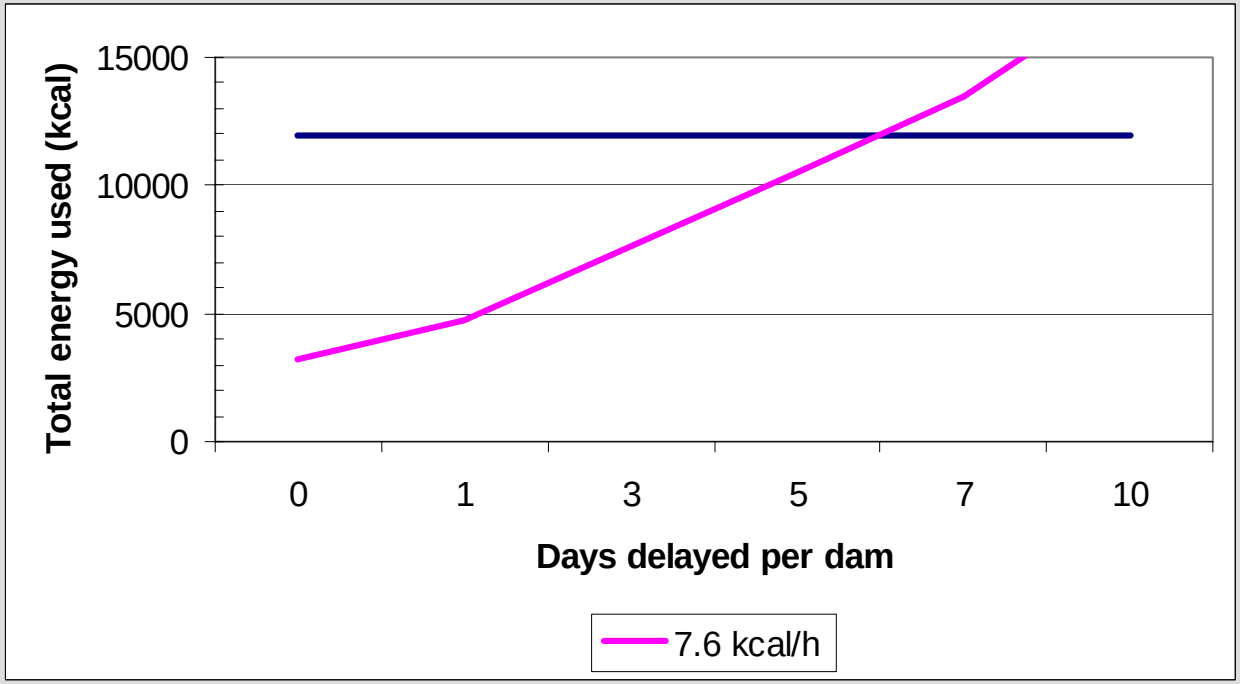

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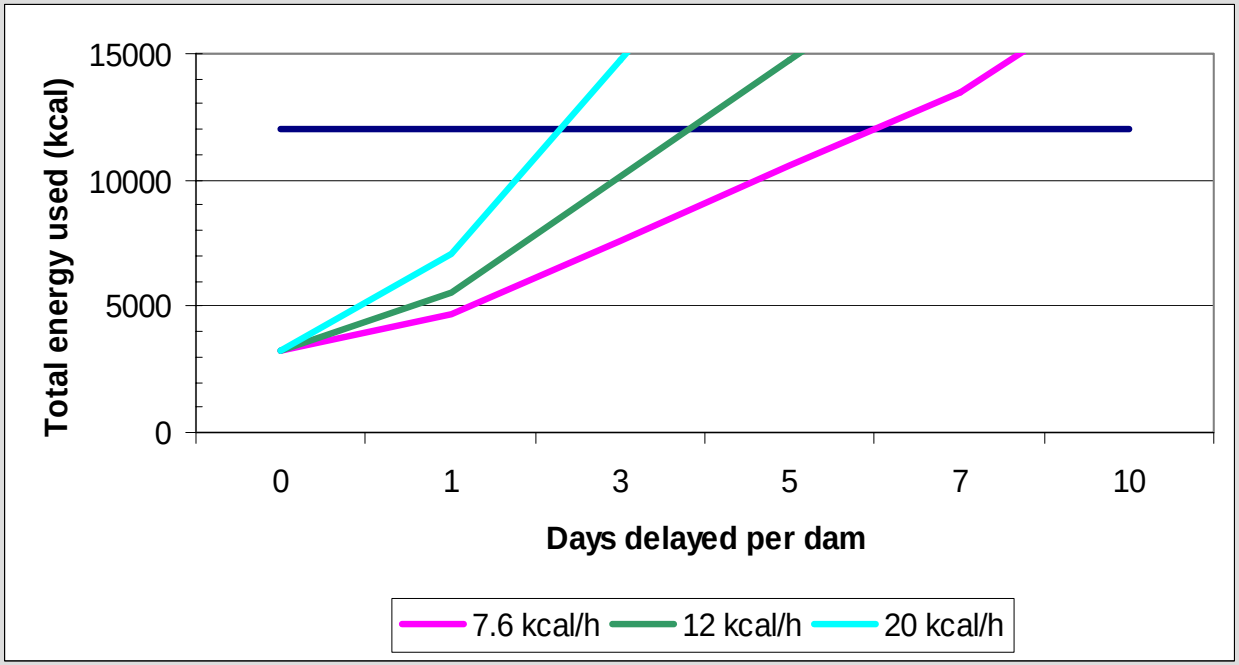

Conclusions

- Delays at hydroelectric projects can contribute to excessive energy use in adult salmon migrating upstream to spawning areas.
- The impacts would be exacerbated if water temperatures or flows were higher.
- Little work has been done on fall Chinook salmon which migrate later in the year when water temperature is warmer.
- Future work should include considerations of anaerobic metabolism and non-intrusive means of measuring energy content.