Aquatic Ecosystems Branch

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Synthesis of Empirical Anadromous Coastal Cutthroat Smolt Abundance and the Prediction of Wild Smolt Production at the Watershed or Sub-Basin Level

CCT smolt FL = 200 mm

200mm

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Talk Outline

- Goal
- Known Coastal Cutthroat Trout (CCT) distribution with focus on the anadromous ecotype (sea-runs)
- Methods
- Results
- Conclusions
- Future applications
- Recommendations
- Acknowledgements

Goal →fill the data gap

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Species by ecotype threat assessment, regional habitat and fisheries management planning requires estimates of the capacity of watersheds to produce salmonids. The goal was to formulate a predictive model to estimate the potential of streams to produce anadromous CCT smolts.

Serious data gaps from British Columbia's management perspective suggested a high ranking for smolt yield (Griswold 2006) in the Coastal Cutthroat Trout Science Workshop. The average number of cutthroat smolts produced annually by a stream is a fundamental metric for a stream's potential to sustain a healthy anadromous adult cutthroat trout fishery. It tells the story of how well we manage land and water at a large scale to sustain valued salmon resources.

Known CCT Distribution and Range

The study area includes selected coastal drainage basins (Salish Sea, Coast Range, Cascades, Klamath Mountains) of southern British Columbia, Washington, Oregon, and Northern California

Methods

Data Sources and Analysis

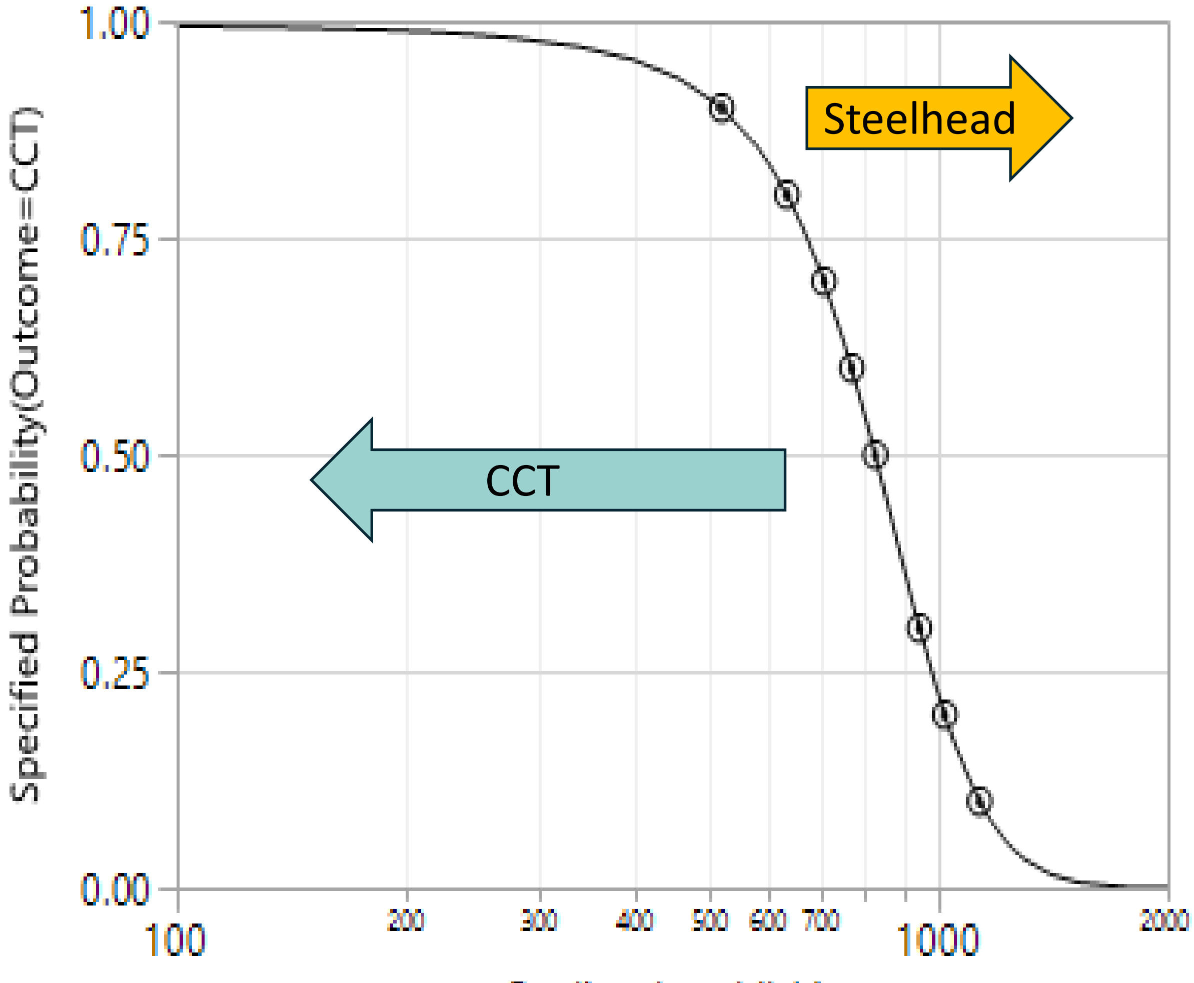
- I collected data from studies that contained estimates of the total annual CCT smolt abundance for one or more years (Appendix 1). As others have approached their research on steelhead or coho directed smolt production studies, I only considered estimates that were from calibrated index traps, rotary screw traps, or fences.

CCT distribution in small streams and large rivers

- The natural distribution of CCT fry and parr assumed the upper stream gradient was limited to <20% slope which was verified by the author's focused field trials in the steep-sided Bella Coola River valley (Burt and Horchik 1998). In cases located in WA state, the upstream limit mapped for coho was assumed to apply to CCT; see https://apps.wdfw.wa.gov/salmonscape/map.html. In addition, https://www.arcgis.com/home/item.html?id=1e56a648718543ab952e75ff9971f086

- The downstream limit for CCT dominance was approximated using the high-resolution logistic equation (Ptolemy 2013). See following Slides.

Methods continued



Logistic probability curve for CCT dominance at the reach scale. Razor edge result over a narrow band in LT mad (L/s)

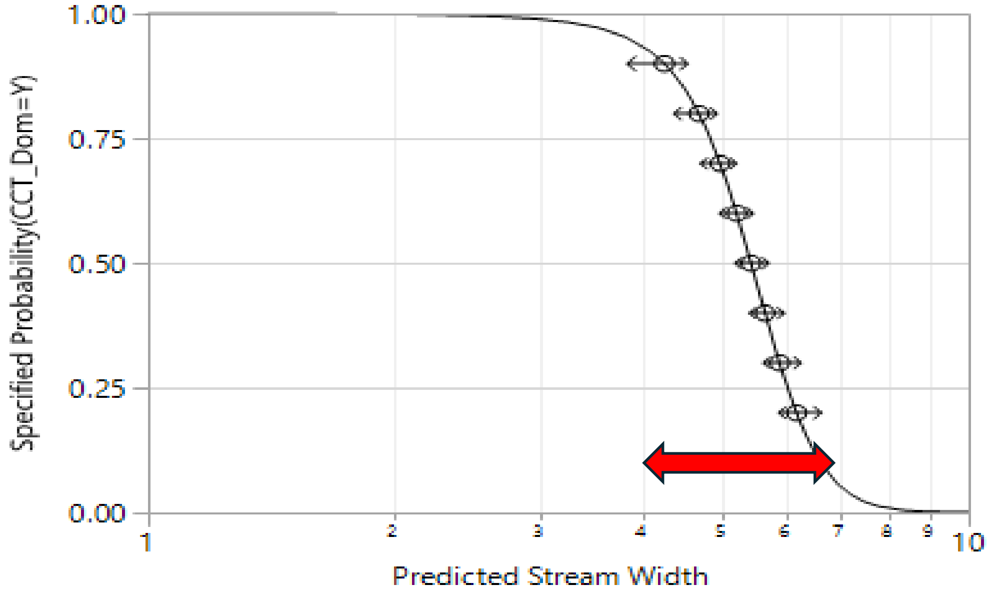
Stream width at 1000 L/s = 6.0 m
Stream width at 500 L/s = 4.2 m

Juvenile Steelhead out-compete CCT in larger streams

Methods continued

Inverse Prediction

Specified Probability(CCT_Dom=Y)	Predicted Stream Width	Lower 95%	Upper 95%
0.9000000	4.259465	3.832563	4.551063
0.8000000	4.692059	4.371701	4.941191
0.7000000	4.979590	4.709030	5.221513
0.6000000	5.215287	4.967767	5.469082
0.5000000	5.431585	5.189957	5.711526
0.4000000	5.647882	5.399102	5.967014
0.3000000	5.883579	5.615494	6.256929
0.2000000	6.171110	5.868281	6.621792



For those not familiar with Litres per second on X-axis as in previous Slide…

Again, note the rapid change in Probability of CCT dominance with mean wetted reach width (m)

Critical width range is 4 to 7 m.

Methods continued

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Accessible Stream Length

- In a qualifying stream or tributary confirmed to be dominated by CCT, available CCT habitat is restricted by both physical limitations (barriers, gradient, and discharge, water quality, dissolved oxygen, turbidity, and temperature) and evolutionary distribution factors.
- All open-source information on barriers, contours and gradient within each watershed were used to restrict CCT distribution in systems. The sources of information on barriers included Fisheries Information Summary System data (BC Ministry of Environment, 2014), Aquatic Biophysical Maps (MOE 1977) and barrier information layer in https://apps.wdfw.wa.gov/salmonscape/map.html
- Fortunately, the length of permanent stream available for spawning and rearing upstream of the trapping site was often described in the source report **although this data may be subject to some uncertainty**. Mapping of the upper distribution of coho assisted in many cases where detailed basin maps were provided; this was particularly useful for the upstream limits. **Stream lengths were measured with a digitizing tablet**. **Link to Brooke Penaluna's upper extent talk.**

Methods continued

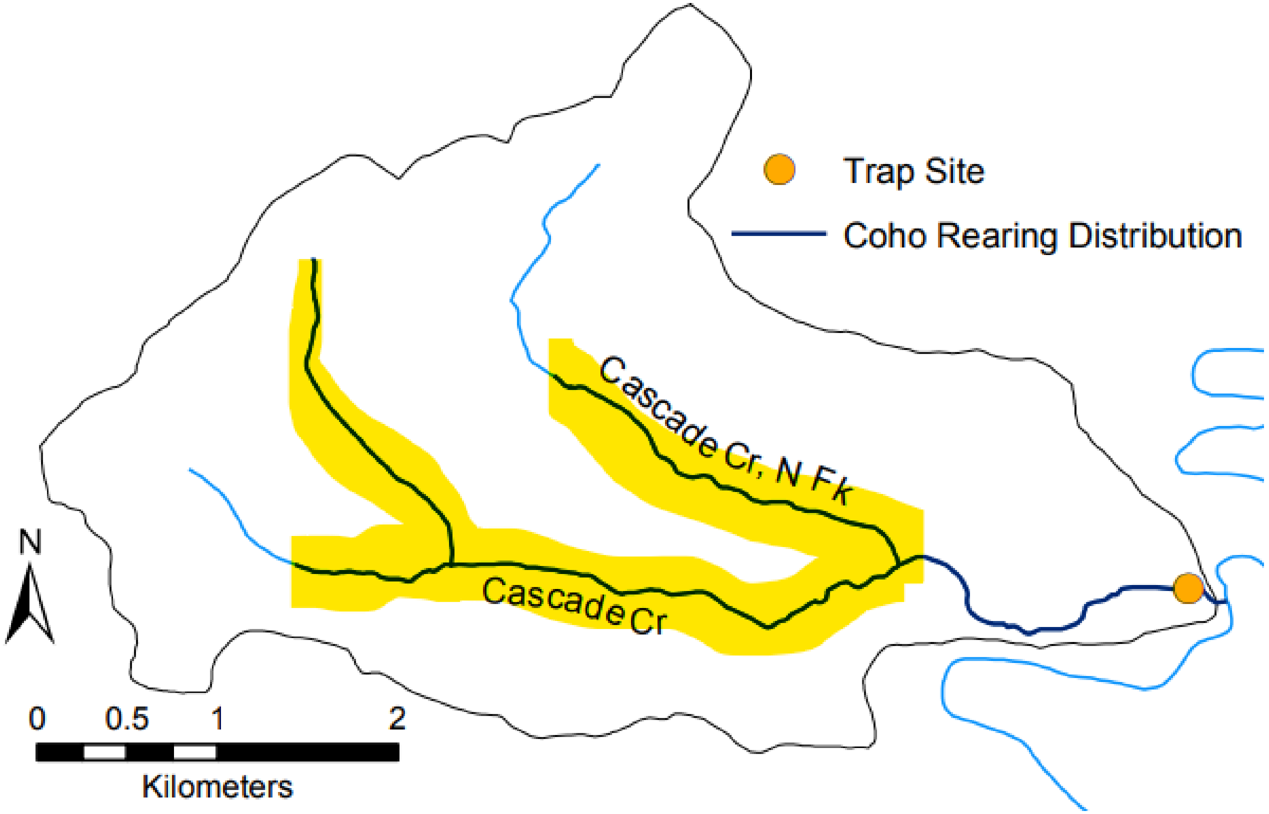

Figure 21. Cascade Creek showing the trap site and extent of coho rearing distribution.

- Tributary to Alsea River (OR)
- Drainage Area = 14.5 km^2
- LT mad = 670 L/s
- Width = 4.9 m
- CCT Length = 12 km
- CCT smolts/km = 146
- CPSF = 7%LT mad
- Suring et al. 2015

Methods continued

Stream gradient

- The mean gradient of a stream used for spawning and rearing was calculated from contour lines on the topographic map; usually 1:20,000 scale or larger. In the case of very low gradient streams or reaches where the slope was 0.000 $m \cdot m^{-1}$ or 0%, these lengths were not included in the CCT-bearing stream length due to the empirical findings of de Leeuw and Stuart (1982). BC stream data on stream order, magnitude and gradient utilized layers in Habitat Wizard application. Gradients of <0.2% should be dismissed based on empirical parr data.

Discharge

- For my analyses (Appendix 2, TABLE A1.2) I sought estimates of the long-term mean annual discharge (natural LT mad, L/s) based on the location of the smolt trap and not where CCT parr occurred. For larger British Columbia streams, these flows were usually obtained from gauging station summaries (Environment Canada 2023, https://wateroffice.ec.gc.ca/search/historical_e.html). Discharge data for gauged USA streams were found in USGS (2023), https://waterdata.usgs.gov/nwis/sw. Discharge data were occasionally available in the original reports of CCT smolt abundance. Proximate gauging stations to fish traps were aided with "mapper" or the like (iMap BC) such as https://maps.waterdata.usgs.gov/mapper/index.html and https://maps.gov.bc.ca/ess/hm/imap4m/. I was aware of the baseflow differences in gauged large rivers and ungauged small tributaries which could seriously bias the analyses. Actual measures of summer baseflows on small tributaries were instructive.

Methods continued

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Food Supply, Riffle Health, and Water Chemistry

- For my analyses (Appendix 2), I sought proxies for food supply based on summer baseflow water chemistry. I had previously found that Total Alkalinity (mg/L $CaCO_3$) accounts for the large variation in maximum salmonid biomass per unit area by Species and Age (Ptolemy 2008; Ptolemy 2023).
- For British Columbia streams, these data were usually obtained from synoptic stream studies or the Provincial EMS database (https://www2.gov.bc.ca/gov/content/environment/research-monitoring-reporting/monitoring/environmental-monitoring-system). Water quality data for gauged US streams were found in USGS (2023), https://waterdata.usgs.gov/nwis/sw.

Data Analysis

- **All variables were $\log_e$-transformed** because variability in smolt abundance increased with the mean (Bradford et al. 1997; Burns 2016). I used simple and multiple regression to search for predictors of mean smolt abundance but was aware of the approach and success of predicting coho smolt abundance using stream length for a "small streams" species (Rosenfeld et al. 2000) that often co-occurs with CCT (Lister 1968; Marshall and Britton 1990; Bradford et al. 1997; Korman and Tompkins 2014; Noble et al. 2015).

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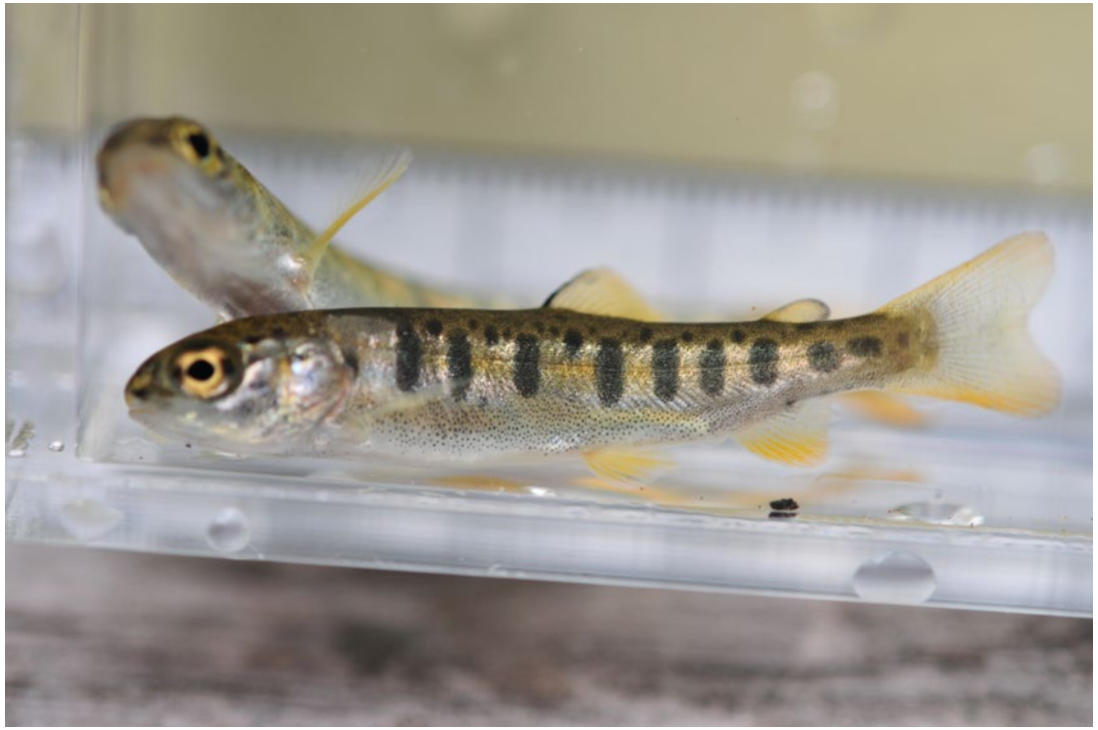
Methods continued---CCT ID issues

CCT Fry



RB Fry

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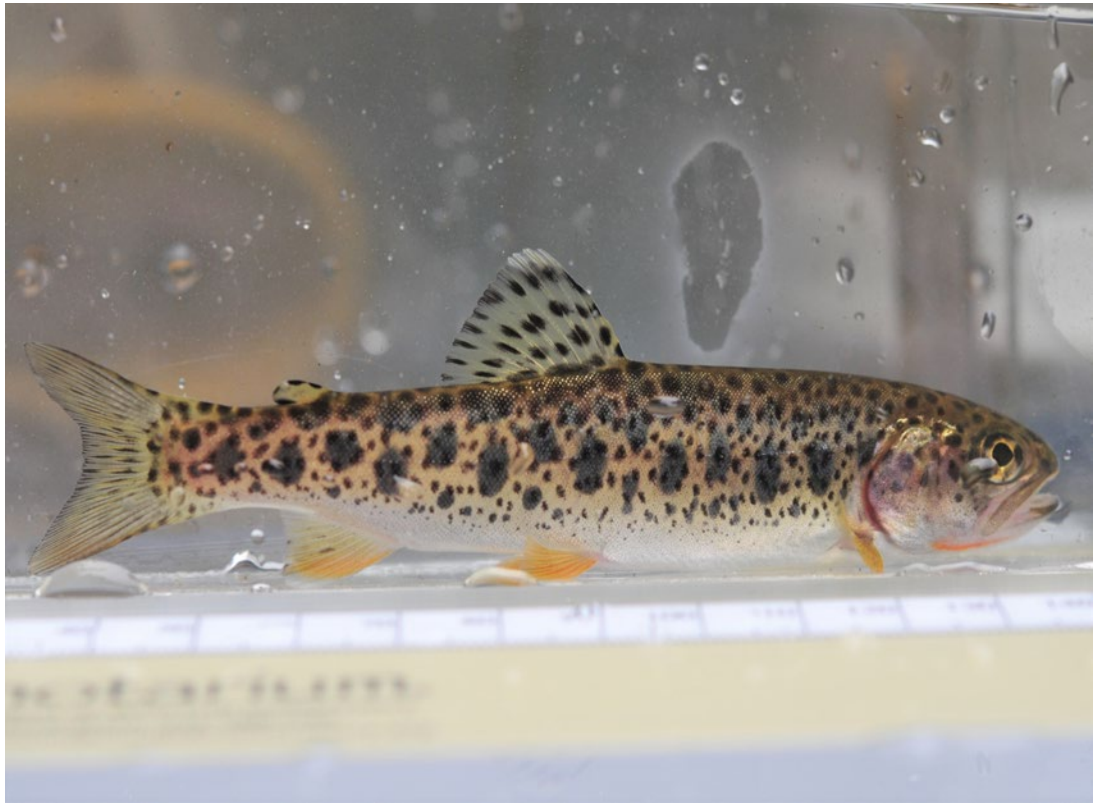
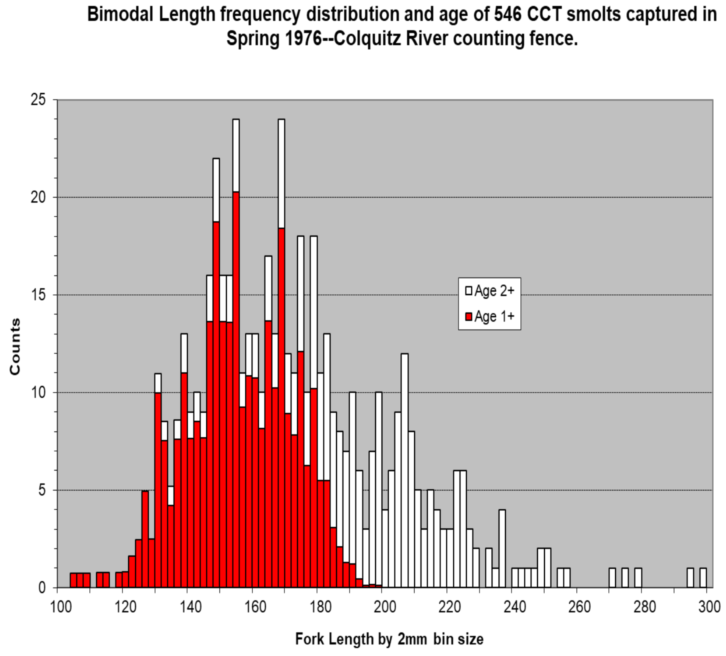
Methods continued---more CCT ID issues



Results

Mean CCT Smolt Size and Age

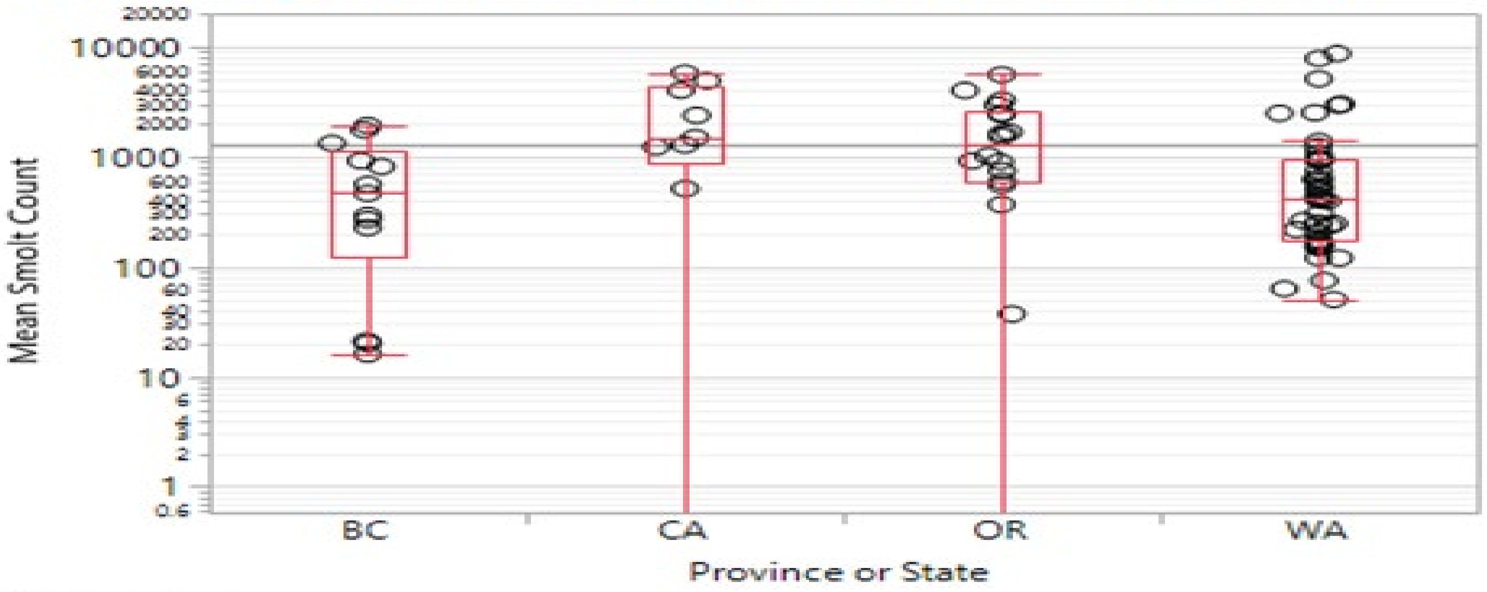
- Cutthroat smolt size averaged 161 mm FL across all streams; individuals ranged in size from 120-300 mm. The smallest mean size of 141 mm came from Carnation Creek (BC) while the largest mean size of 182 mm came from Coweeman River (WA). Example from Colquitz River below.



Smolt Age (yr) varied from a low of 1.4 years on streams with a long Growth Season (G7, days ≥ 7°C per annum) such as Colquitz to 5 years in Alaska (G7 = 85 days/annum). Smolt age = 425/G7. G7 was not used in modelling smolt yield and maybe an important factor. Smolt composition on Colquitz is 60% with 1 winter annulus and 40% with 2 winter annulus. Math is 0.6*1+ 0.4*2 or 1.4 years.

Results continued

Oneway Analysis of Mean Smolt Count By Province or State

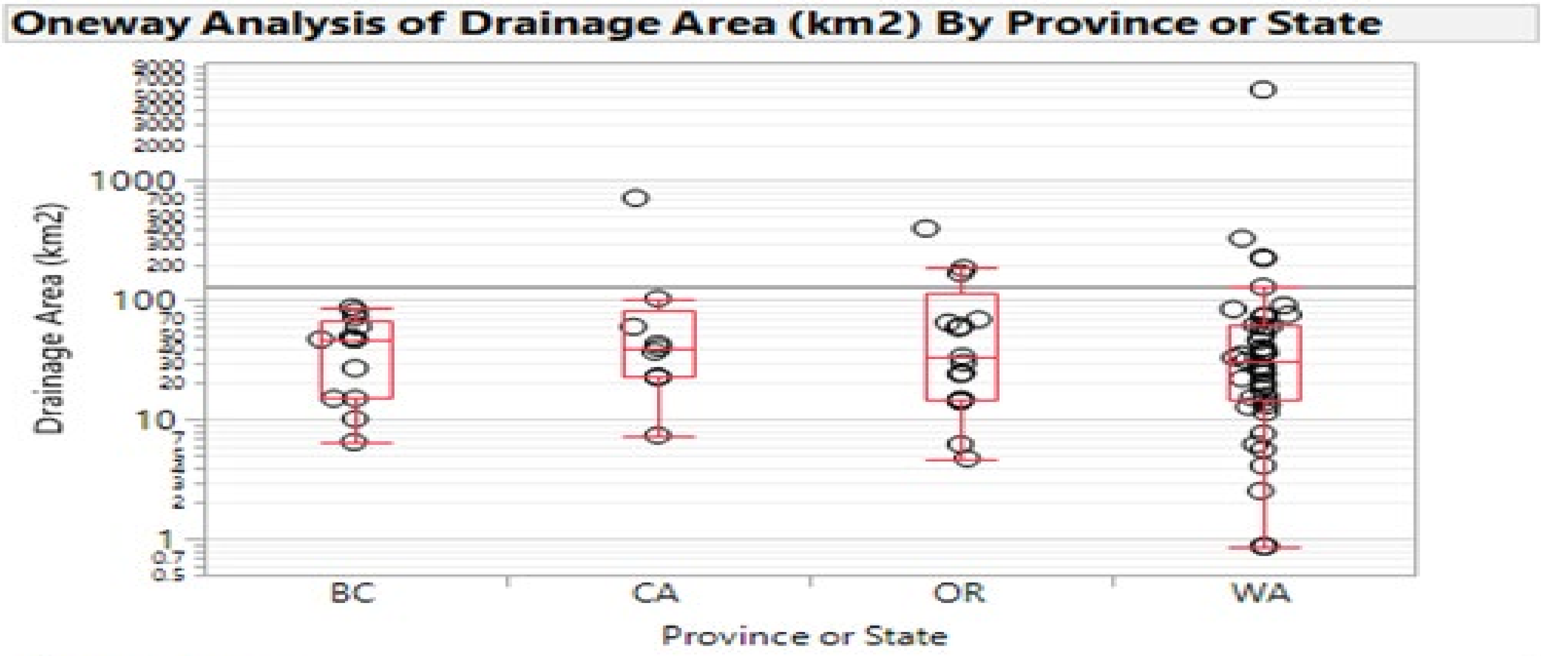


Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
BC	16	17.6	124	464	1120.5	1848	1916
CA	0	0	869.5	1487	4441.5	5769	5769
OR	0	33.3	586.5	1271	2588	4142.8	5545
WA	50	120.6	172	408	948	2955.6	8698

Missing Rows 3

Results continued



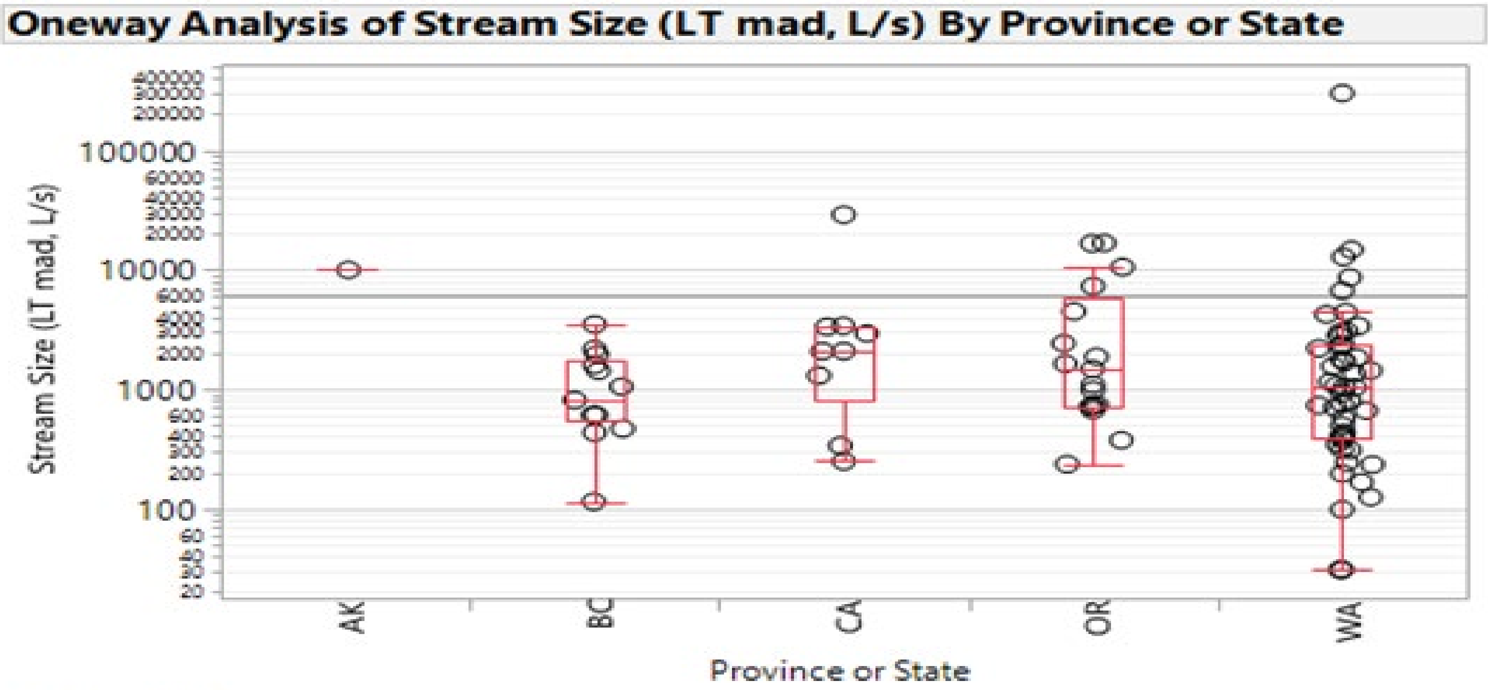
Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
BC	6.5	7.94	15	47	66	84.52	87
CA	7.36	7.36	22.75	40	81.5	717	717
OR	4.7	5.9	14.65	33.8	117	227.8	399
WA	0.87	5	14.685	31.2	61	166.6	5796

Missing Rows 4

Each open circle represents a data source or trap site. The sample size is very large (N = 83 streams). There are total of 862 annual estimates of smolt abundance

Results continued



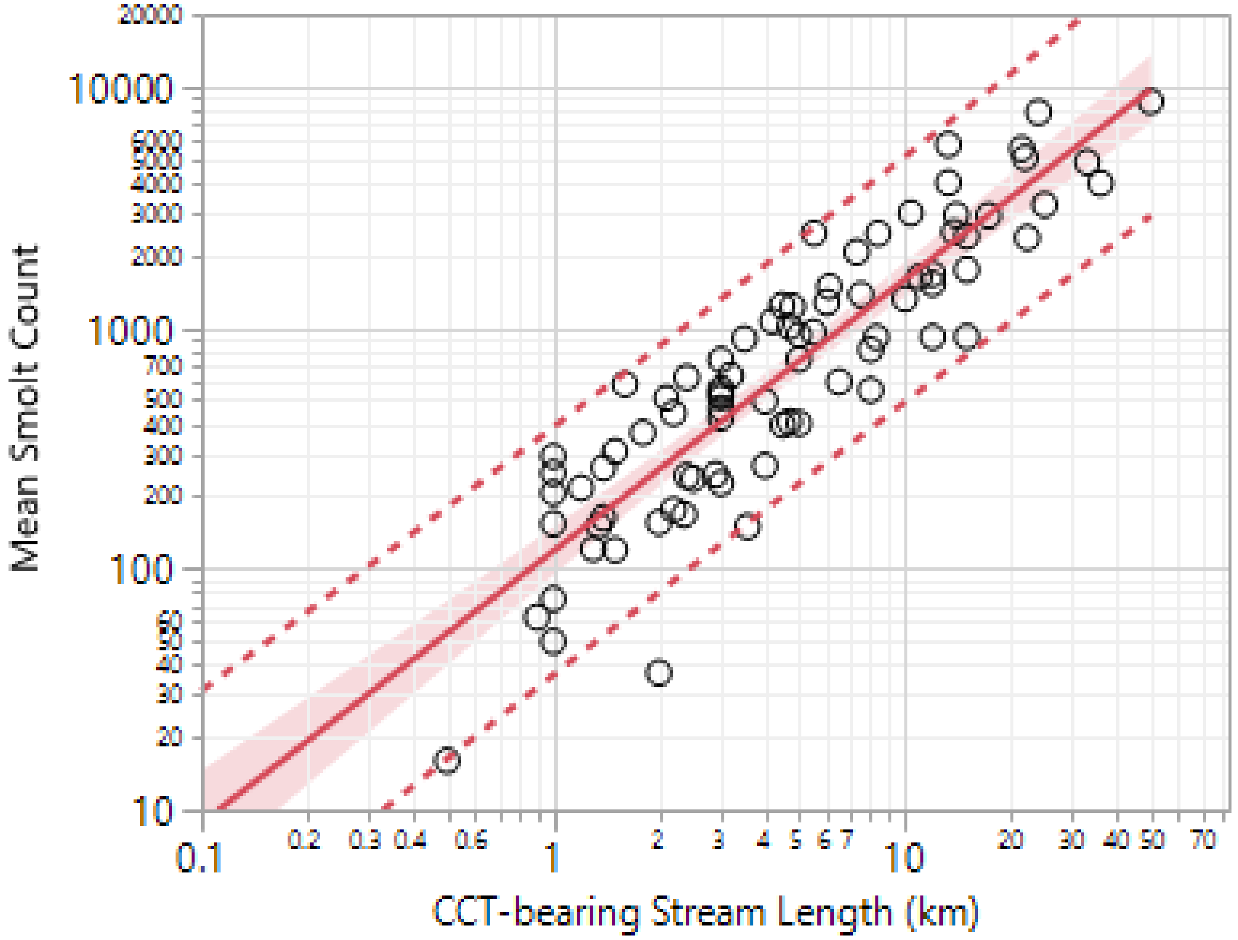
Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
AK	10000	10000	10000	10000	10000	10000	10000
BC	115	243	539.5	814	1780	2967.2	3500
CA	250	250	822	2091	3369.5	29000	29000
OR	237	348.2	725	1488	5896.5	16671.6	16758
WA	31	158.6	384	1040	2392	7086	301392

Missing Rows 1

Larger streams and rivers where LT mad>1000 L/s or >35 cfs saw the use of rotary screw traps.

Results continued

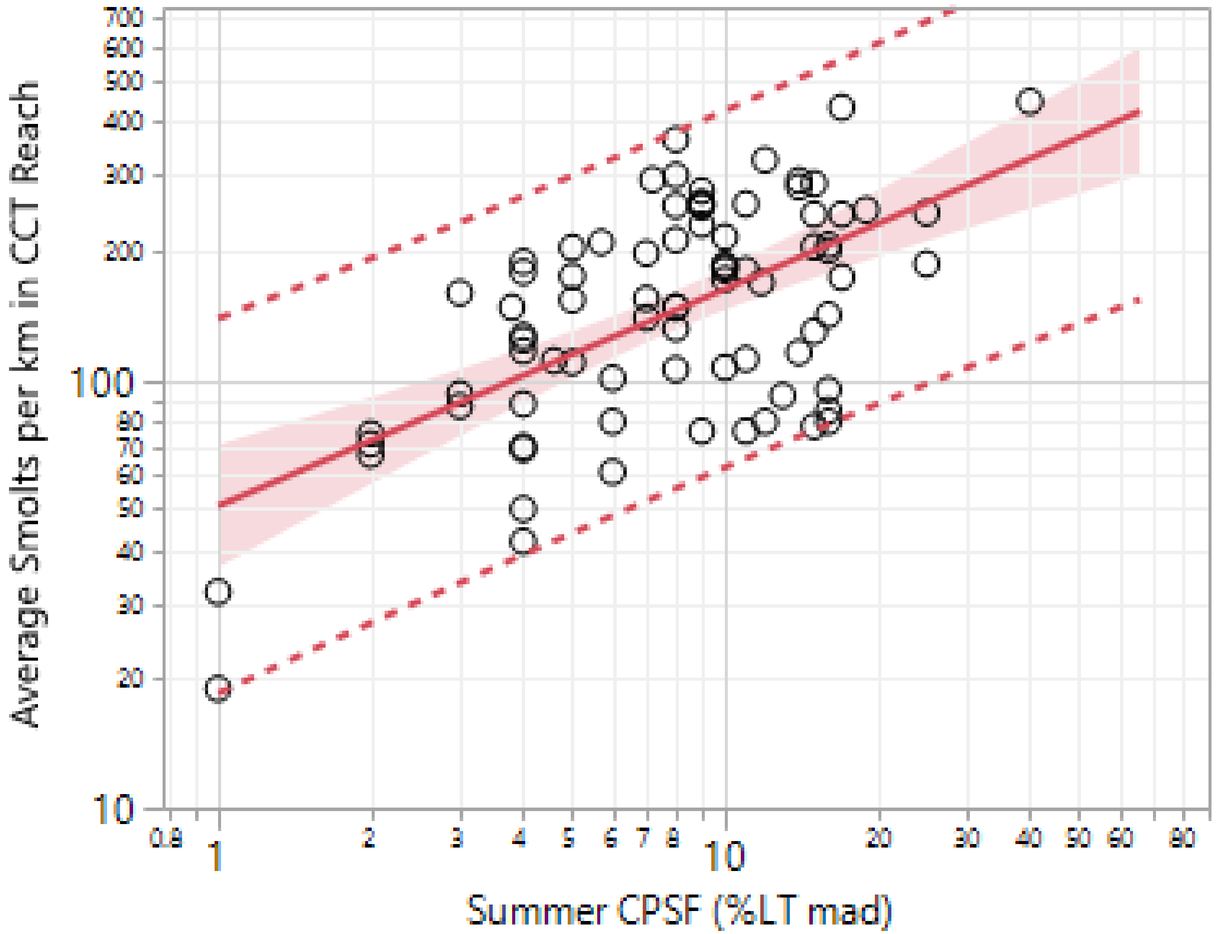


Log(Mean Smolt Count) = 4.7744245 + 1.1279767*Log(CCT-bearing Stream Length (km))

Summary of Fit

RSquare	0.800102
RSquare Adj	0.797572
Root Mean Square Error	0.583728
Mean of Response	6.483165
Observations (or Sum Wgts)	81

Results continued



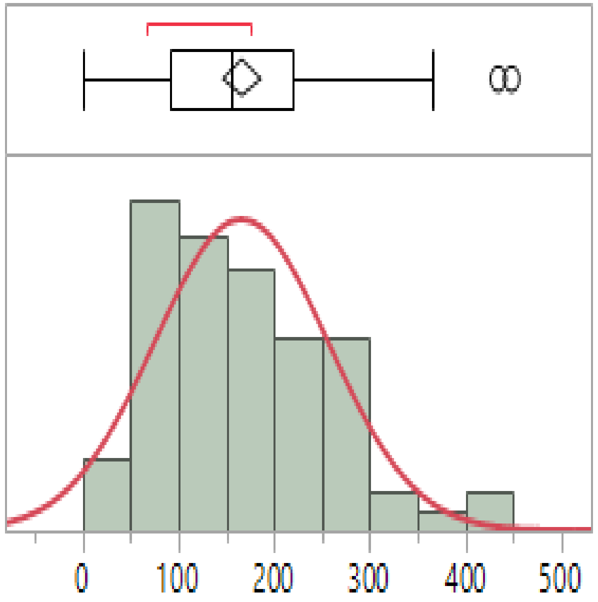
Log(Average Smolts per km in CCT Reach) = 3.9275018 + 0.5070778*Log(Summer CPSF (%LT mad))

Summary of Fit	
RSquare	0.357327
RSquare Adj	0.349192
Root Mean Square Error	0.478811
Mean of Response	4.968934
Observations (or Sum Wgts)	81

Results continued

Distributions

Average Smolts per km in CCT Reach



Normal(165.805,90.4801)

Quantiles

100.0%	maximum	448
99.5%		448
97.5%		428.825
90.0%		286.5
75.0%	quartile	219.75
50.0%	median	154.5
25.0%	quartile	91
10.0%		69.3
2.5%		19.975
0.5%		0
0.0%	minimum	0

Summary Statistics

Mean	165.80488
Std Dev	90.480124
Std Err Mean	9.9918582
Upper 95% Mean	185.68554
Lower 95% Mean	145.92421
N	82

Fitted Normal

Parameter Estimates

Type	Parameter	Estimate	Lower 95%	Upper 95%
Location	μ	165.80488	145.92421	185.68554
Dispersion	σ	90.480124	78.436776	106.92706

-2log(Likelihood) = 970.547272381986

Goodness-of-Fit Test

Shapiro-Wilk W Test

W	Prob<W
0.956940	0.0077*

Note: Ho = The data is from the Normal distribution. Small p-values reject Ho.

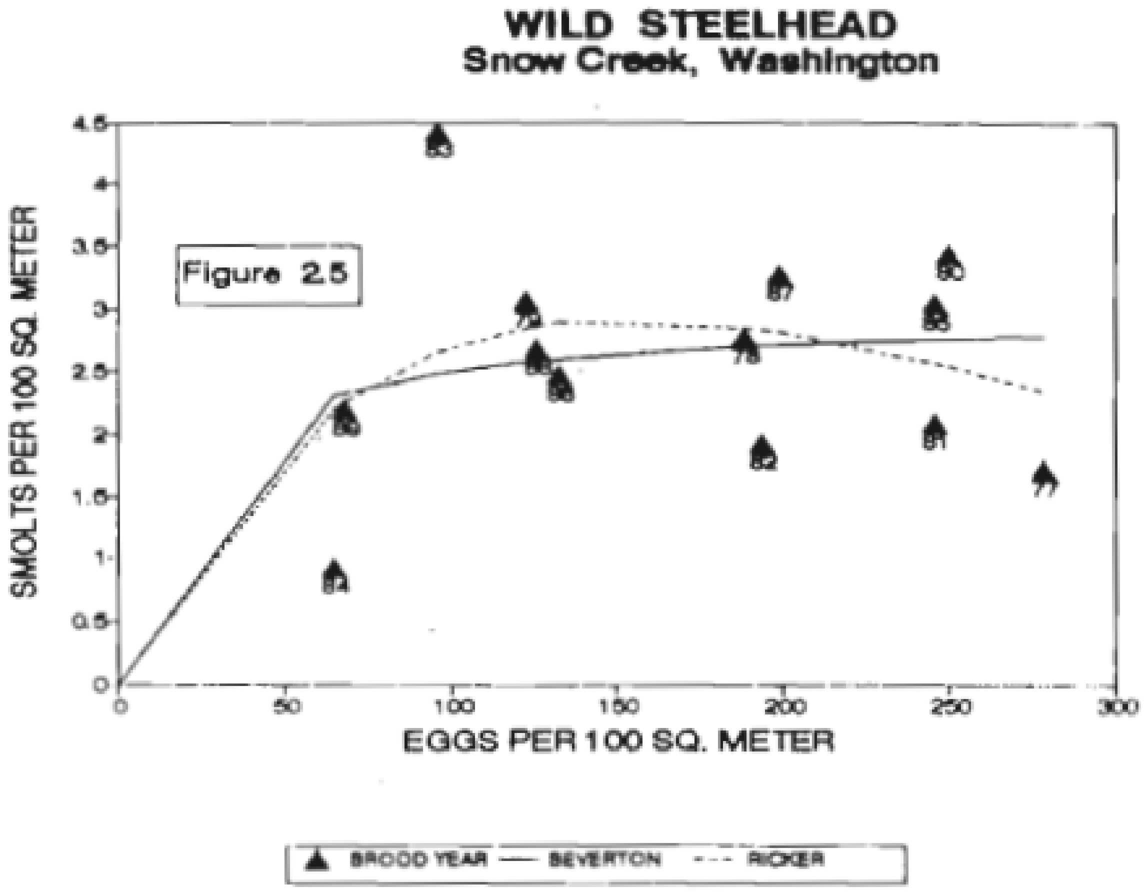
Conclusions

1. There is a surprising amount of competent CCT smolt data despite the species and anadromous ecotype not being the focus of intensively studied watersheds or salmonid life-cycle monitoring. **Incidental data.**
2. Most of the CCT smolt data originates from **WA**.
3. Both CCT-bearing stream length (km) and summer baseflows are good predictors of watershed or sub-basin carrying capacity. **Novel models**.
4. Given the characterization of CCT streams and model results, **threats to small streams** is likely to be much greater in the Georgia Depression EcoProvince than elsewhere in B.C. **Link to threats assessment with Sierra Sullivan**.
5. Smolt capacity is **NOT** a fixed quantity and inter-annual variation (CV) is high (40%).
6. The most productive stream with highest wild smolt yield (448 smolts/km) was **Minter Creek (WA)** which had a high summer baseflow (40%LT mad), high Total Alkalinity, and elevated N+P enrichment. 448 smolts/km may form an upper limit.
7. BC's most productive CCT streams reside in the Southern Gulf Islands ecosection. Productive but summer flow challenged; **link to Russ Barsh's Lyall Creek talk**. Most if not all extinct CCT populations are from the "**Lost Streams** of Vancouver, etc.." in the Georgia Depression EcoProvince. Water abstractions, urbanization, road crossings (i.e., culverts and not bridges), pollution, and agriculture are major threats.

Future Application---Spawner Needs

Application of Johnson and Cooper's (1992) Snow Creek WA 13-year average egg-to-smolt survival of 1.8% to 154 smolts/km, suggests the cutthroat egg deposition requirement is in the magnitude **of 8,600 eggs per km or 9 females/km** with a mean fecundity of 1000 eggs (Pauley et al. 1989; Bates 2000) and **sensitive** to female size. Larger females (55 cm FL) in Bates study contained upwards of 1829 eggs. Snow Creek is small (LT mad = 1040 L/s) and is more relevant to CCT stream structure suggesting adopted freshwater survival estimates (egg-to-smolt) maybe appropriate.

Smolt production as a function of Egg Deposition (Snow Creek Example). Stock recruit curve application to small stream CCT dimensions.



- The long-term mean annual discharge for Snow Creek is 1040 L/s or 37 cfs. Its small size makes it a good proxy for CCT population dynamics.
- Mean wetted width near the fish counting fence is 6 m or 20 feet.
- Very few CCT smolts (50) here; produces 1334 steelhead smolts annually on average.

Recommendations

1. Further refinements of habitat dimensions (upper distribution limits, lower limits dominance by steelhead parr, barrier locations, stream gradients, summer baseflow discharge, water quality) should be entertained by agencies, First Nations and others. We need good watershed profiles to complete fair comparisons and expectations.
2. Validation of various models should be made using independent data perhaps from new or existing smolt trapping sites that have not yet published CCT data.
3. Emerging, competing models should challenge this study’s novel results.
4. Planned field trip to Cascade Creek (OR) may provide good contextual insights on its habitat character and limitations. Its average CCT smolt production rate is 146 smolts/km (near the global median).

Acknowledgements

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This research would not have been possible without the collective hard work and dedication of fisheries management agencies, NGOs, and Indigenous group staff collecting emigrant data in the Pacific Northwest. I am very grateful for the generous support (50+ years) from my British Columbia mentors with a determined interest in anadromous cutthroat trout conservation; namely, **George Reid, Gerry Taylor, Dr. Art Tautz, Pat Slaney, Dr. Dave Narver, Dave Hurn, Ted Burns,** and **Charlie Lyons**. There are many other notable colleagues that have supported me.