Text S1: Additional description of bioenergetics model used to estimate weight loss

The Wisconsin Bioenergetics Model is, at its core, an energy budget equation in which energy consumed is balanced by energy expended for metabolism (respiration, active metabolism and specific dynamic action), waste (egestion, excretion), and growth (somatic and gonad) (Deslauriers et al. 2017).

$$C = (R + A + SDA) + (F + U) + (SG + GG) \qquad \textit{(eq. S1)}$$

Consumption of prey C is balanced against metabolism (which is made up of three components; respiration (resting metabolism) R, active metabolism A, and specific dynamic action (energy required for energy assimilation and use, modelled as a proportion of consumption) SDA), waste (which is made up of egestion (fecal waste) F and excretion (nitrogenous waste) U) and growth (which is made up of somatic SG and gonad GG growth). Energy is allocated in the order of the equation with metabolism and waste first, with any remaining energy being allocated to growth. Each process (metabolism, waste, and growth) is determined by temperature and body size. Therefore each process and sub-process is described by a set of temperature and mass-specific functions with parameters developed for various species during controlled laboratory conditions (Tyler and Bolduc 2008).

The equations are associated parameters which are species- and life-stage specific. We used the equations for juvenile rainbow trout, as no other juvenile salmon species was available (Hanson et al. 1997, Tyler and Bolduc 2008). We assumed 0 g of food was consumed (i.e., food deprivation), which represents an extreme condition. In general, bioenergetic equations for the Wisconsin Bioenergetics Model were created using experiments in which fish were fed. During starvation, metabolic processes change, and thus the metabolic equations developed for feeding fish may be inaccurate for starving fish (McCue 2010). However, equations for fed fish represent the closest approximation that is available.

By setting consumption to zero, the Wisconsin Bioenergetics Model is simplified as excretion, egestion, and specific dynamic action are modelled as a proportion of consumption. Additionally, juvenile salmon are not yet investing in gonadal growth so that term can also be set to 0. Resulting in a simplified equation:

$$0 = (R + A) + (SG) \qquad \textit{(eq. S2)}$$

$$-SG = (R + A) \qquad \textit{(eq. S3)}$$

Thus, respiration (in (g O_2/g fish/d; oxy-caloric coefficient 13,560 J/g O_2), and active metabolism will result in energy loss (negative somatic growth). The rate of energy loss will be temperature and size dependent.

$$R = RA * W^{RB} * F(T) * ACTIVITY \quad \textit{(eq. S4)}$$

Where RA and RB are the intercept (specific mass of oxygen (g O_2/g/d) consumed by a 1-gram fish at 0°C) and slope for the allometric mass function, and W is the mass of the fish. Water temperature $F(T)$ is described by the function:

$$F(T) = e^{(RQ*T)} \quad \textit{(eq. S5)}$$

Where RQ approximates the Q10 (the rate at which the function increases over relatively low water temperatures) and T is temperature.

Active metabolic rate, $ACTIVITY$ in eq. S4 for salmon is described by the function:

$$ACTIVITY = e^{(RTO*VEL)} \quad \textit{(eq. S6)}$$

$$VEL = ACT * W^{RK4} * e^{(BACT*T)} \quad \textit{(eq. S7)}$$

Where RTO is the coefficient for swimming speed dependence of metabolism (s/cm), $RK4$ is the mass dependence coefficient for swimming speed at all water temperatures, and $BACT$ is the water temperature dependence coefficient of swimming speed. If swimming speed is a constant then $RK4$ and $BACT$ are set to 0, and ACT is set to the desired velocity (cm/s) (Deslauriers et al. 2017).

We ran the Wisconsin Bioenergetics Model using R statistical computing environment (v 3.6.3) (R Core Team 2020) using RStudio GUI (v 1.2.5033, 2019) and Fish Bioenergetic 4.0 (Deslauriers et al. 2017). Fish Bioenergetic 4.0 uses parameters from juvenile rainbow trout (Tyler and Bolduc 2008) to estimate daily energy difference and estimates daily weight. Since we set the model to 0 g consumption, we observed daily weight that decreased through time. We compared predicted weight loss by the Wisconsin Bioenergetics model to observed weekly weight loss for sockeye salmon held without food (Fig. S2). In general, the Wisconsin Bioenergetics Model over-estimated weight loss, especially for weeks 4 – 7. Over estimated weight loss could be due to the model's assumption of average activity, ascribed to ACT. Fish held in the laboratory experiment did not move much, and so used less energy than predicted (Simpkins et al. 2003). However, in 'natural' environments fish would be expected to move, such that the observed weight loss might be less than expected in the 'natural' environment. The predicted weights were much lower than observed during weeks 4 – 7, possibly due to unaccounted for changes in metabolism due to starvation (McCue 2010). The Wisconsin Bioenergetics model was parameterized for feeding fish, with likely higher metabolic rates compared to starving fish. Therefore, it is likely that the predicted weight loss is over-estimated and thus starvation resistance estimates may be underestimated/conservative.

Table S1: Migration timing, smolt condition, and estimates of annual number of emigrating sockeye salmon smolts from three freshwater lakes – Kitwanga, Slamgeesh, and Babine Lake.

Population - year	5% cumulative migration date	50% cumulative migration date	95% cumulative migration date	Smolt abundance estimate	Mean FL (mm) (SD)	Mean Weight (g)(SD)	Condition Factor (K)	Lipid Content (%) (SD)
Kitwanga – 2014[1]	Apr 26th	May 3rd	May 8th	46.955	104.1 (7.0)	11.0 (2.2)	NA	NA
Kitwanga – 2015[2]	April 21st	May 2nd	May 8th	12,165	112.0 (5.7)	13.5 (2.2)	NA	NA
Kitwanga – 2017[3]	May 2nd	May 8th	May 17th	11.915	NA	NA	NA	NA
Kitwanga – 2018[4]	April 27th	May 3rd	May 12th	6,920	104.0 (6.4)	11.0 (2.0)	NA	NA
Kitwanga – 2019[4]	April 23rd	May 3rd	May 8th	22,083	105.4 (7.0)	11.7 (2.0)	NA	NA
Kitwanga – 2020[5]	May 1st	May 5th	May 10th	23,753	107.4 (8.7)	12.4 (2.9)	NA	NA
Slamgeesh – 2003[6]	May 10th	May 12th	May 28th	37,672	99.7	8.6	NA	NA
Slamgeesh – 2004[7]	May 6th	May 13th	May 20th	18,938	112.4	12.6	NA	NA
Slamgeesh – 2005[8]	May 6th	May 11th	May 18th	10,326	107.1	10.7	NA	NA
Slamgeesh – 2009[9]	May 12th	May 15th	May 23rd	30,254	104.8	NA	NA	NA
Slamgeesh – 2010[10]	NA	NA	NA	14,485	NA	NA	NA	NA
Slamgeesh – 2011[10]	NA	NA	NA	9,245	NA	NA	NA	NA
Babine – 2014[11]	May 8th	May 24th	Jun 5th	94,707,541	81.8 (10.7)	4.8 (9.3)	NA	NA
Babine – 2015[12]	May 7th	May 21st	May 31st	21,715,205	83.9 (8.9)	4.9 (1.6)	NA	NA
Babine – 2016[13]	May 6th	May 16th	May 25th	57,455,570	82.5 (9.2)	5.0 (1.6)	0.88	NA
Babine – 2017[14]	May 12th	May 27th	Jun 6th	109,386,225	83.5 (11.4)	5.2 (2.0)	0.87	NA
Babine – 2018[15]	May 10th	May 18th	Jun 1st	217,518,451	83.5 (7.0)	5.1 (1.8)	0.84	2.9 (0.8)
Babine – 2019[16]	May 12th	May 25th	Jun 3rd	94,966,284	83.0 (6.1)	4.9 (1.2)	0.85	3.0 (1.5)

[1] McCarthy & Kingston 2015 http://www.gitanyowfisheries.com/images/uploads/docs/2014%20Smolt%20Final%20Report_Feb%202_2015.pdf
[2] McCarthy & Kingston 2016 http://www.gitanyowfisheries.com/images/uploads/docs/2015_GFA_Annual_Smolt_Report_Final.pdf
[3] Beblow, J. 2019 http://www.gitanyowfisheries.com/images/uploads/docs/2018_GFA_Smolt_Report_FINAL.pdf
[4] Beblow, J. 2020 - http://www.gitanyowfisheries.com/images/uploads/docs/2019_GFA_Smolt_Report_Final.pdf
[5] Beblow, J. 2021 - http://www.gitanyowfisheries.com/images/uploads/docs/2020_GFA_Smolt_Report_Final.pdf
[6] Hall, P.E.D, and Gottesfeld, A.S. 2004. Slamgeesh Lake salmon project 2003. Gitksan Watershed Authorities, Hazelton
[7] Hall, P.E.D, and Gottesfeld, A.S. 2005. Slamgeesh Lake salmon project 2004. Gitksan Watershed Authorities, Hazelton
[8] Hall, P.E.D, and Gottesfeld, A.S. 2006. Slamgeesh Lake salmon project 2005. Gitksan Watershed Authorities, Hazelton
[9] Hooper, A., and Gottesfeld, A.S.2010. Slamgeesh Lake salmon project 2009. Gitksan Watershed Authorities, Hazelton
[10] Pacific Salmon Explorer - https://www.salmonexplorer.ca/#!/skeena/sockeye/slamgeesh&pop=SMOLT_SURVEYS&pop-detail=1
[11] Doire, J. Macintyre, D. 2015. 2014 Babine Lake Watershed Sockeye Smolt Population Estimation Project – Mark-Recapture, Lake Babine Nation Fisheries, Burns Lake
[12] Doire, J. Macintyre, D. 2016. 2015 Babine Lake Watershed Sockeye Smolt Population Estimation Project – Mark-Recapture, Lake Babine Nation Fisheries, Burns Lake
[13] Tiley, M., Rosenberger, A., Bergen-Sweeney, E., Macintyre, D. 2017. 2016 Babine Lake Watershed Sockeye Smolt Enumeration Project – Mark-Recapture, Lake Babine Nation Fisheries, Burns Lake
[14] Tiley, M., Rosenberger, A., Mason, E., Macintyre, D. 2018. 2017 Babine Lake Watershed Sockeye Smolt Enumeration Project – Mark-Recapture, Lake Babine Nation Fisheries, Burns Lake
[15] Tiley, M., Rosenberger, A., Ewaschuk, M., Macintyre, D. 2019. 2018 Babine Lake Watershed Sockeye Smolt Enumeration Project – Mark-Recapture, Lake Babine Nation Fisheries, Burns Lake
[16] Tiley, M., Rosenberger, A., Enright, S., Macintyre, D. 2020. 2019 Babine Lake Watershed Sockeye Smolt Enumeration Project – Mark-Recapture, Lake Babine Nation Fisheries, Burns Lake

Table S2: p values for Bonferroni pairwise comparisons of **fork lengths (mm)** of populations of sockeye salmon smolts captured in the Skeena River **estuary**, α=0.00625. Significance is indicated by bold letters.

	Alastair	**Babine**	**Johnston**	**Kalum**	**McDonnell**	**Nanika**	**Salix/Bear**
Babine	1.0						
Johnston	0.0066	**<0.0001**					
Kalum	0.33	**<0.0001**	0.84				
McDonnell	1.0	1.0	0.26	1.0			
Nanika	1.0	1.0	0.02	1.0	1.0		
Salix/Bear	**0.0013**	**<0.0001**	**<0.0001**	**<0.0001**	0.024	**0.00019**	
Sustut	1.0	1.0	**0.00081**	0.020	1.0	1.0	**<0.0001**

Table S3: p values for Bonferroni pairwise comparisons of **weight (g)** of populations of sockeye salmon smolts captured in the Skeena River **estuary**, α=0.00625. Significance is indicated by bold letters.

	Alastair	**Babine**	**Johnston**	**Kalum**	**McDonnell**	**Nanika**	**Salix/Bear**
Babine	1.0						
Johnston	0.043	**0.0038**					
Kalum	1.0	0.018	1.0				
McDonnell	1.0	1.0	1.0	1.0			
Nanika	1.0	1.0	0.12	1.0	1.0		
Salix/Bear	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	
Sustut	1.0	1.0	**0.0058**	0.099	1.0	1.0	**<0.0001**

Table S4: p values for Bonferroni pairwise comparisons of **lipid content (%)** of populations of sockeye salmon smolts captured in the Skeena River **estuary**, α=0.00625. Significance is indicated by bold letters.

	Alastair	**Babine**	**Johnston**	**Kalum**	**McDonnell**	**Nanika**	**Salix/Bear**
Babine	1.0						
Johnston	1.0	1.0					
Kalum	1.0	0.56	1.0				
McDonnell	1.0	1.0	1.0	1.0			
Nanika	1.0	1.0	1.0	1.0	1.0		
Salix/Bear	0.031	**0.0002**	0.056	**<0.0001**	0.25	0.37	
Sustut	0.92	0.13	0.92	**0.004**	1.0	1.0	1.0

Table S5: p values for Bonferroni pairwise comparisons of **water content (%)** of populations of sockeye salmon smolts captured in the Skeena River **estuary**, α=0.00625. Significance is indicated by bold letters.

	Alastair	**Babine**	**Johnston**	**Kalum**	**McDonnell**	**Nanika**	**Salix/Bear**
Babine	1.0						
Johnston	1.0	1.0					
Kalum	1.0	1.0	1.0				
McDonnell	1.0	1.0	1.0	1.0			
Nanika	1.0	0.42	1.0	1.0	1.0		
Salix/Bear	1.0	**<0.0001**	0.11	**0.00063**	1.0	1.0	
Sustut	1.0	**<0.0001**	0.59	0.014	1.0	1.0	1.0

Table S6: p values for Bonferroni pairwise comparisons of **protein content (%)** of populations of sockeye salmon smolts captured in the Skeena River **estuary**, α=0.00625. Significance is indicated by bold letters.

	Alastair	**Babine**	**Johnston**	**Kalum**	**McDonnell**	**Nanika**	**Salix/Bear**
Babine	0.022						
Johnston	1.0	1.0					
Kalum	1.0	0.090	1.0				
McDonnell	1.0	1.0	1.0	1.0			
Nanika	1.0	0.35	1.0	1.0	1.0		
Salix/Bear	1.0	**<0.0001**	1.0	0.97	1.0	1.0	
Sustut	1.0	**<0.0001**	1.0	1.0	1.0	1.0	1.0

Table S7: p values for Bonferroni pairwise comparisons of **energy density (MJ/kg)** of populations of sockeye salmon smolts captured in the Skeena River **estuary**, α=0.00625. Significance is indicated by bold letters.

	Alastair	**Babine**	**Johnston**	**Kalum**	**McDonnell**	**Nanika**	**Salix/Bear**
Babine	1.0						
Johnston	1.0	1.0					
Kalum	1.0	1.0	1.0				
McDonnell	1.0	1.0	1.0	1.0			
Nanika	1.0	1.0	1.0	1.0	1.0		
Salix/Bear	0.077	**<0.0001**	0.011	**<0.0001**	0.19	0.22	
Sustut	1.0	**<0.0001**	0.31	**0.0022**	1.0	1.0	1.0

Table S8: p values for Bonferroni pairwise comparisons of **Fulton's condition factor** of populations of sockeye salmon smolts captured in the Skeena River **estuary**, α=0.00625. Significance is indicated by bold letters.

	Alastair	**Babine**	**Johnston**	**Kalum**	**McDonnell**	**Nanika**	**Salix/Bear**
Babine	1.0						
Johnston	1.0	1.0					
Kalum	1.0	**0.0019**	0.90				
McDonnell	1.0	1.0	1.0	0.33			
Nanika	1.0	1.0	1.0	1.0	1.0		
Salix/Bear	1.0	0.058	1.0	1.0	0.65	1.0	
Sustut	1.0	0.038	1.0	1.0	0.76	1.0	1.0

Table S9: p values for Bonferroni pairwise comparisons of **days to death** of populations of sockeye salmon smolts captured in the Skeena River **estuary**, α=0.00625. Significance is indicated by bold letters. Days to death measured with median temperature profile.

	Alastair	**Babine**	**Johnston**	**Kalum**	**McDonnell**	**Nanika**	**Salix/Bear**
Babine	1.0						
Johnston	1.0	1.0					
Kalum	1.0	**<0.0001**	0.018				
McDonnell	0.56	1.0	1.0	**0.0058**			
Nanika	1.0	0.19	0.33	1.0	0.089		
Salix/Bear	1.0	**<0.0001**	0.0061	1.0	**0.0021**	1.0	
Sustut	1.0	**<0.0001**	0.053	1.0	0.016	1.0	1.0

Table S10: p values for Bonferroni pairwise comparisons of **fork lengths (mm), weight (g)** of populations of sockeye salmon smolts captured in the freshwater smolt fences, α=0.00625. Significance is indicated by bold letters.

	Babine	Kitwanga
Fork length		
Kitwanga	**<0.0001**	
Slamgeesh	**<0.0001**	**<0.0001**
Weight		
Kitwanga	**<0.0001**	
Slamgeesh	**<0.0001**	**<0.0001**
Lipid content		
Kitwanga	**<0.0001**	
Slamgeesh	**0.0022**	**<0.0001**
Water content		
Kitwanga	**<0.0001**	
Slamgeesh	**<0.0001**	**<0.0001**
Protein content		
Kitwanga	**<0.0001**	
Slamgeesh	**<0.0001**	0.25
Energy density		
Kitwanga	**<0.0001**	
Slamgeesh	**<0.0001**	**<0.0001**
Condition factor		
Kitwanga	**<0.0001**	
Slamgeesh	1	**<0.0001**
Days to death		
Kitwanga	**<0.0001**	
Slamgeesh	1	**<0.0001**

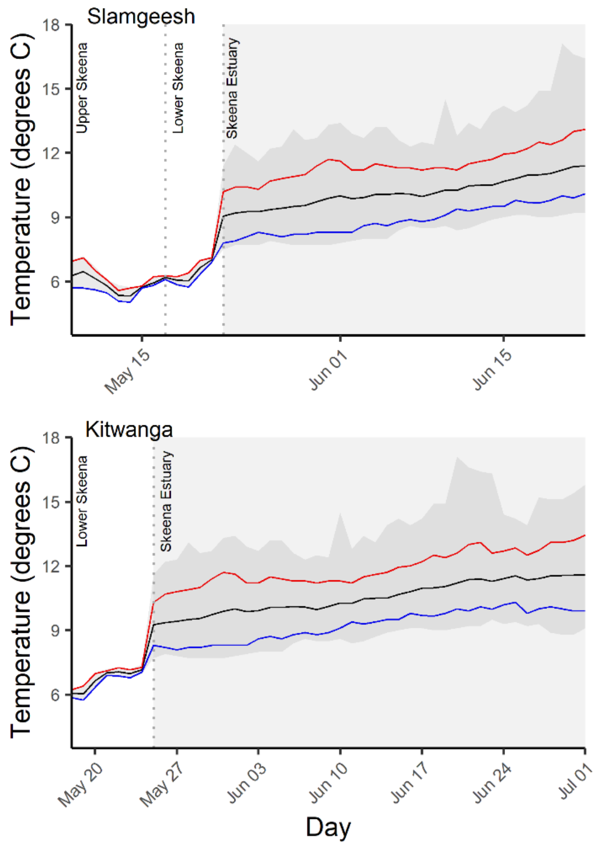

Figure S1: Temperature profiles used to predict weight loss for fish captured at the Slamgeesh Lake fish fence (top left), Babine Lake fish fence (top right), Kitwanga Lake fish fence (bottom left) and in the Skeena River estuary (bottom right). Lines indicated 50% (black) 90% (red) and 10% (blue) data quantiles. Dark shaded region indicates range of temperature data observed. Light shaded region indicates anticipated presence in estuary or near shore coastal marine waters, vertical lines indicate migration milestones. X axis changes based on migration timing and duration.

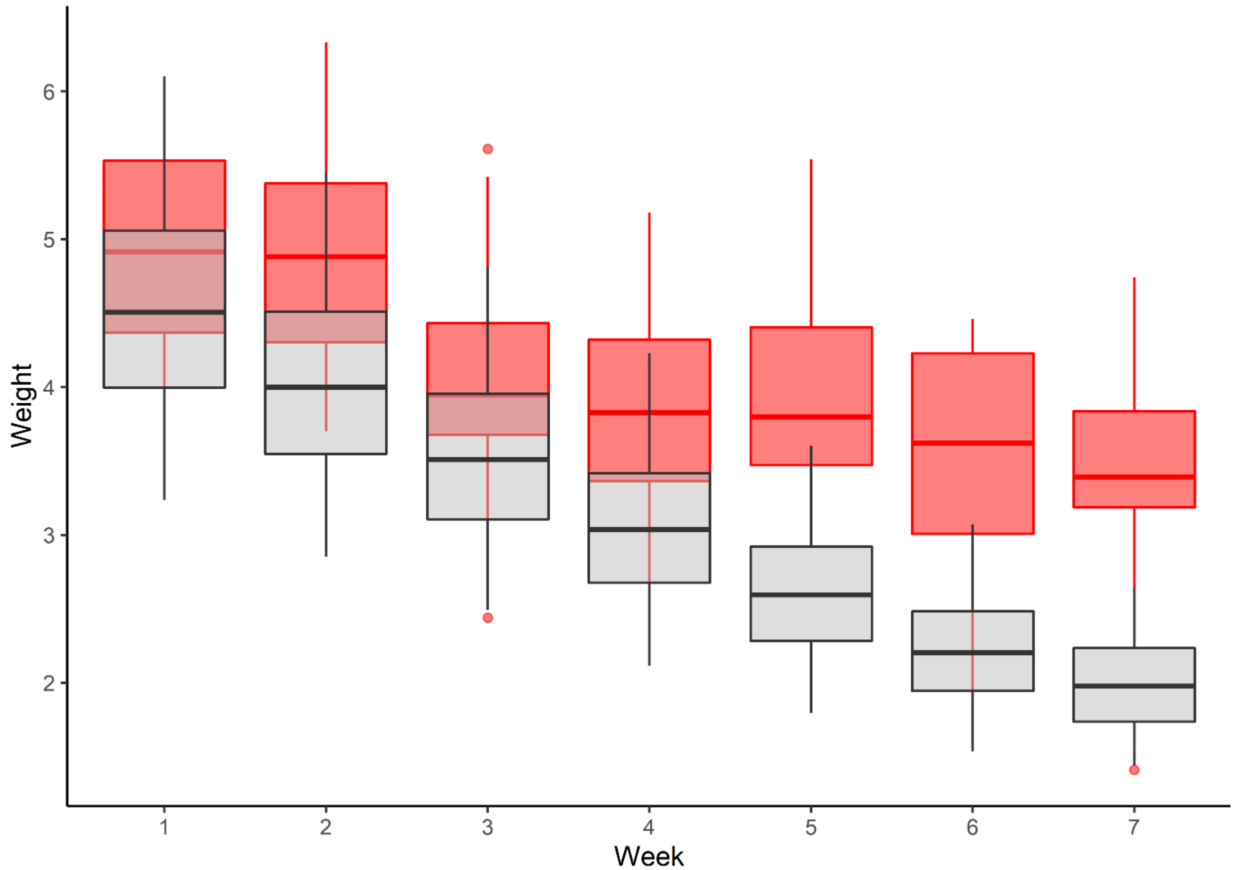

Figure S2: Weight of Chilko Lake sockeye salmon that were experimentally held and food deprived (red) compared to modelled weight loss of Chilko Lake salmon smolts beginning before food deprivation (black). Modelled weights used the Wisconsin Bioenergetics Model for juvenile rainbow trout, zero consumption, and temperatures from the controlled experiment. Though predicted weights are consistently lower than observed, experimentally held fish did not move, and thus observed weight loss was expected to be lower than in 'natural' conditions. After three weeks observed weight loss vs. predicted weight loss begin to differ more substantially, possibly due to metabolic changes from starvation that the Wisconsin Bioenergetics model does not account for. Boxplots show the 25th, median and 75th percentiles.

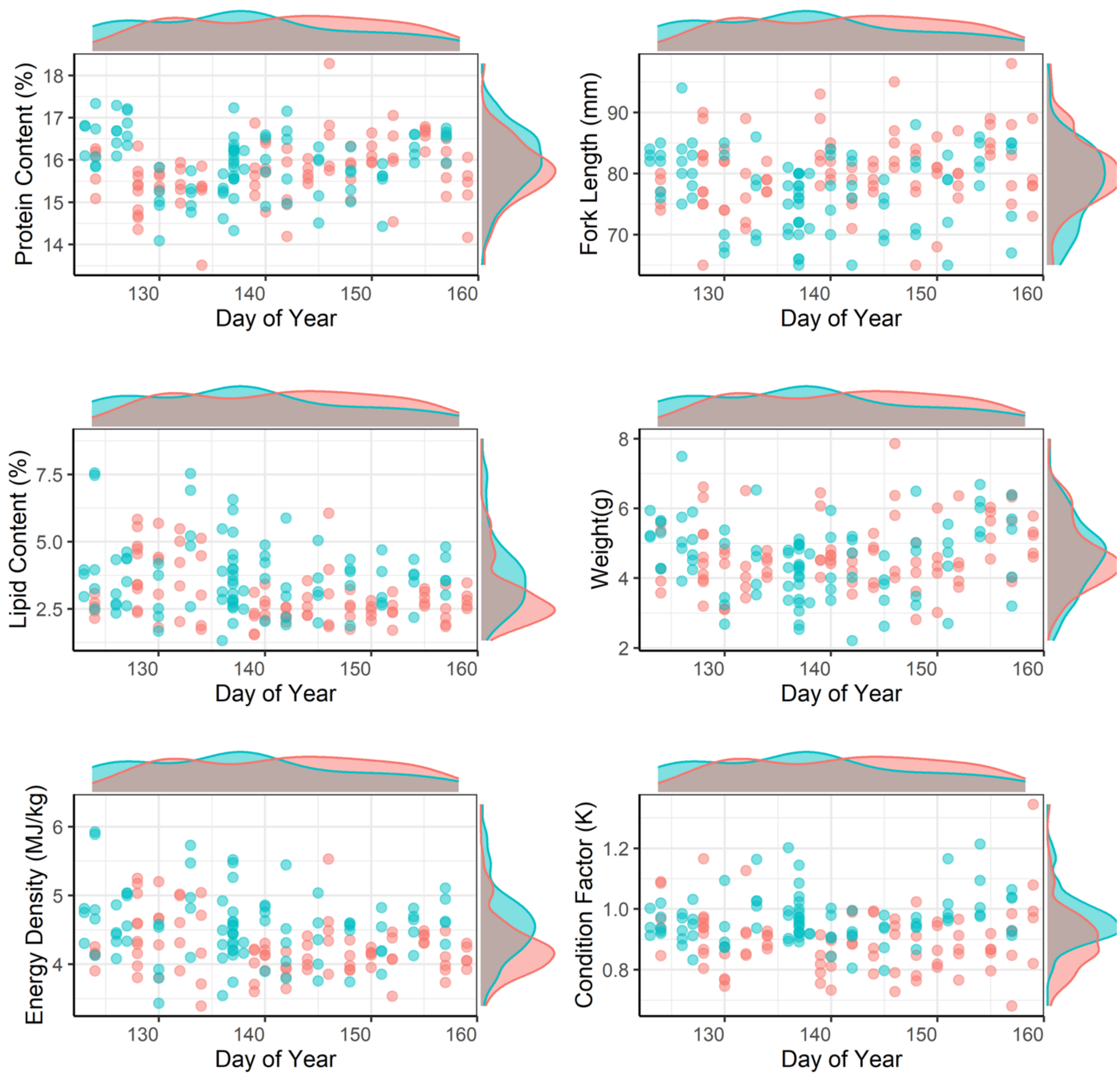

Figure S3: Physical and energetic condition metrics for juvenile sockeye salmon collected leaving Babine Lake in 2015 (pink) and 2016 (blue) throughout the migration period. Curves represent density plots.

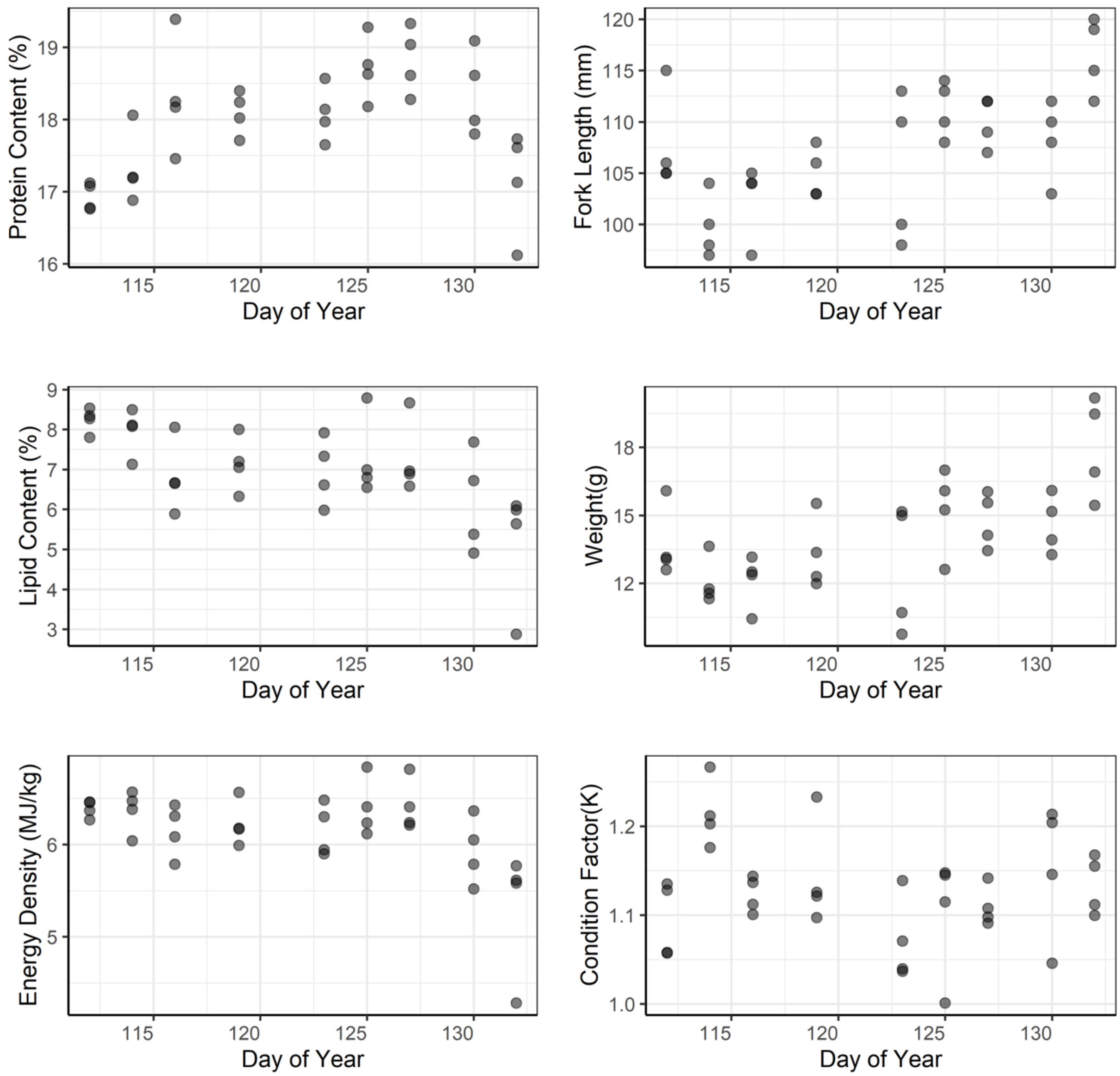

Figure S4: Physical and energetic condition measurements for juvenile sockeye salmon collected leaving Kitwanga Lake in 2016.

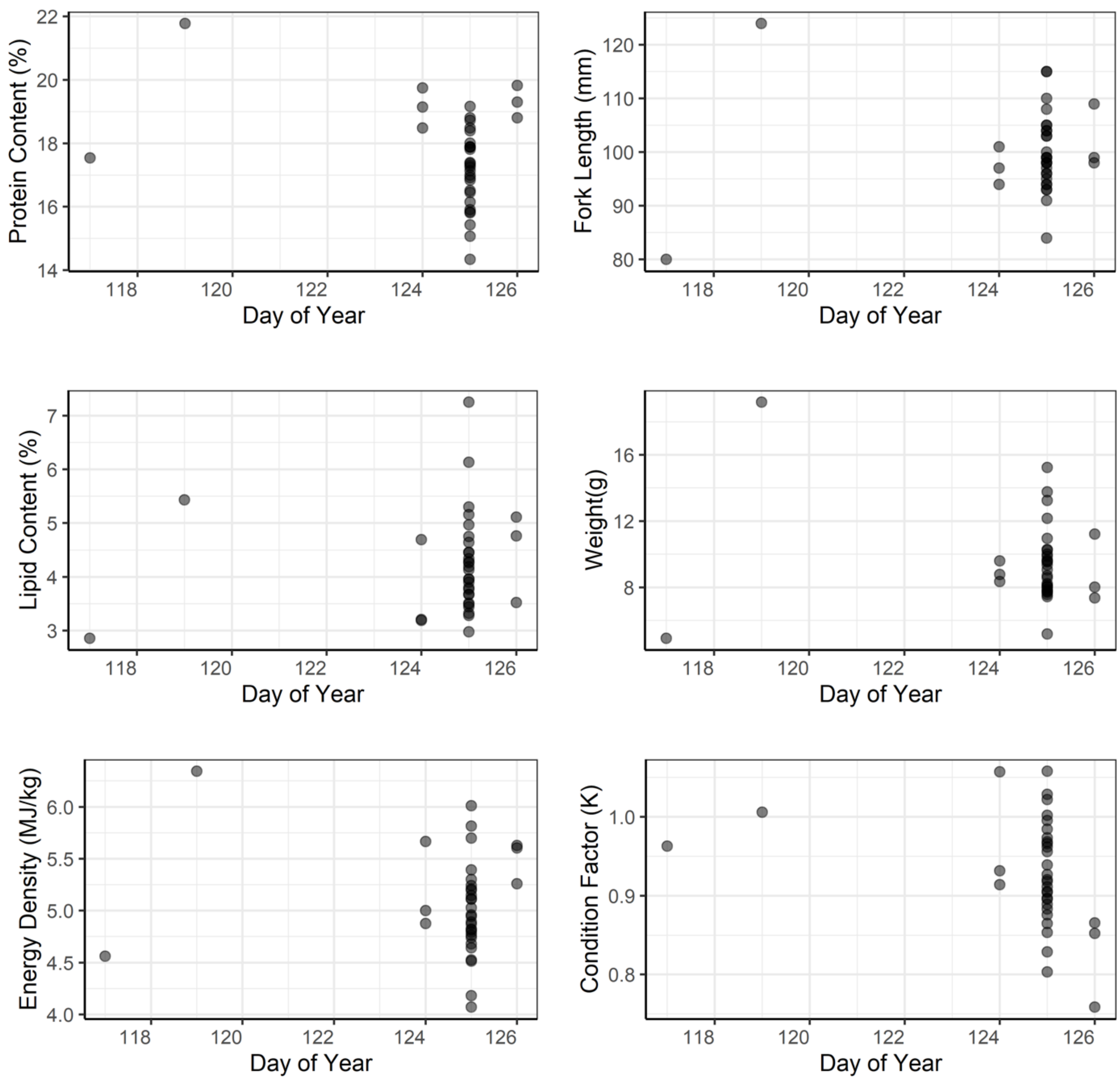

Figure S5: Physical and energetic condition measurements for juvenile sockeye salmon collected leaving Slamgeesh Lake in 2016.

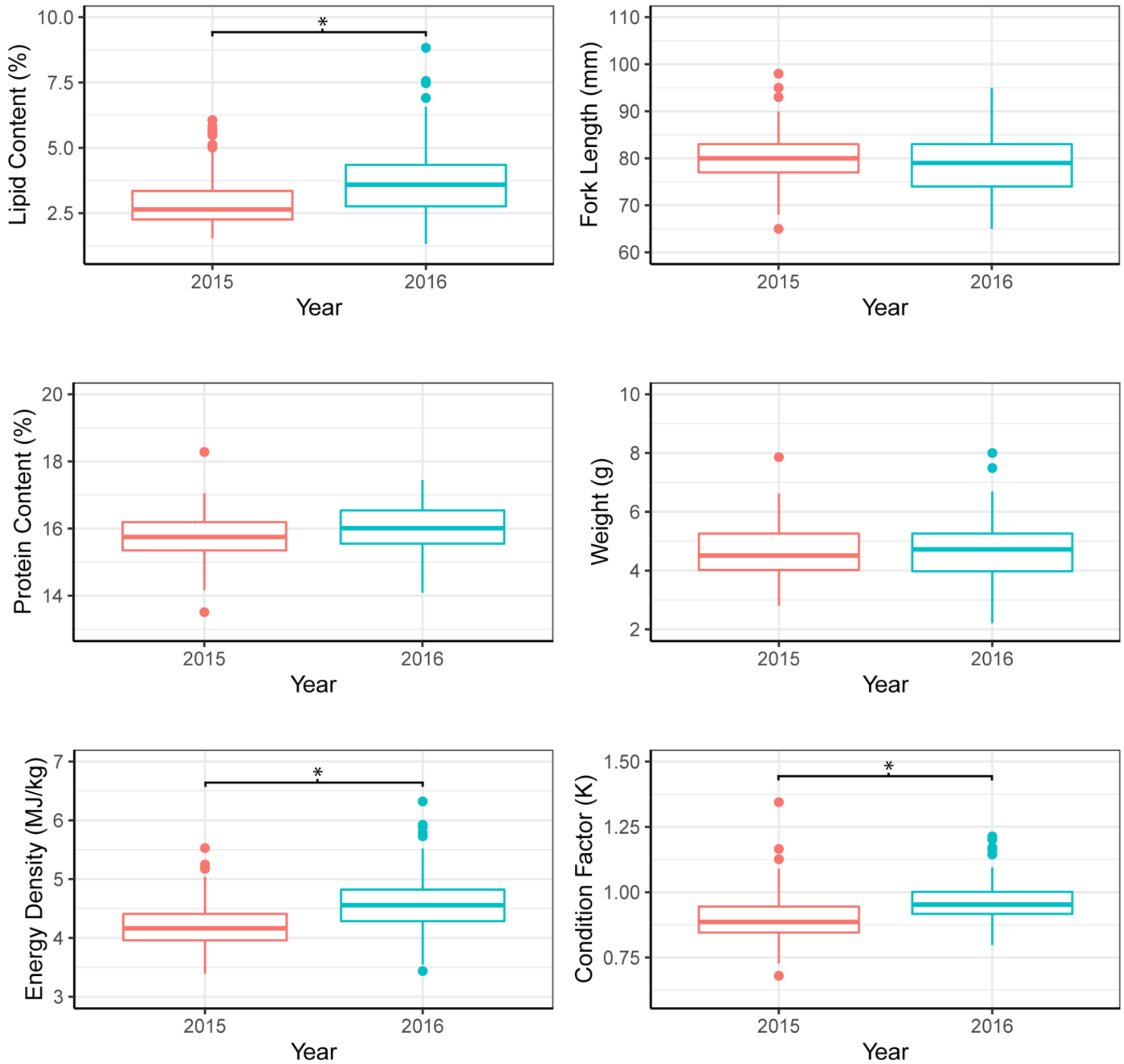

Figure S6: Physical and energetic condition metrics for juvenile sockeye salmon collected leaving Babine Lake in 2015 (pink) and 2016 (blue). * indicates significance of p<0.0001

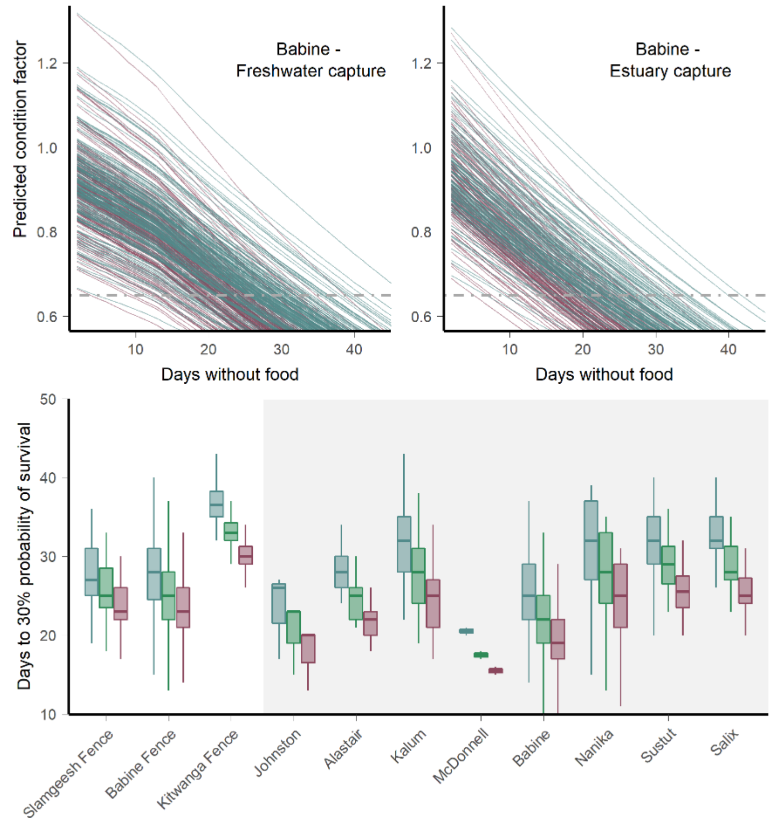

Figure S7: Top – Predictions of condition factor based on predicted weights from Wisconsin bioenergetic model output for fish captured at fence sites (left) and in the estuary (right), for three different temperature scenarios (90%, 50% and 10% quantiles of historic temperatures). Bottom - Number of days to 30% prediction of survival using swim performance model, for fish captured at fence sites or in the estuary and three different temperature scenarios. Red indicates predictions with 90% quantile temperatures, green indicates predictions with median temperature, blue indicates predictions with 10% quantile temperatures. Grey shaded region represents estuary residence. Boxplots show the 25th, median and 75th percentiles, whiskers extend to 1.5 x interquartile range.