Weight, Length, and Growth in Cutbow Trout (*Oncorhynchus mykiss x clarkii*)

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Background: The cutbow trout (*Oncorhynchus mykiss x clarkii*) is a fertile hybrid of rainbow and cutthroat trout. Little published length-weight data is available for this hybrid, and a standard weight curve is not established. Eleven Mile Reservoir is a clear mountain reservior in Colorado with a surface area of 13.4 square kilometers, an average depth of 10 m, and a maximum depth of 41 m. 80,000 cutbow trout were stocked through the ice in late winter before samples were taken.
Materials and Methods: Angling provided 171 samples which were weighed and measured (total length and fork length). Dressed weight was also determined with the scales, head, and entrails removed. Estimates of parameters a and b in the model, $W(L) = aL^b$, were obtained by both linear least-squares (LLS) regression ($\log(W) = \log(a) + b \log(L)$) and non-linear least-squares (NLLS) regression, where W is weight in kg and L is length in cm. Parameter estimates of an improved model, $W(L) = (L/L_1)^b$, were also determined by NLLS regression; the parameter L_1 is the typical length of a fish weighing 1 kg. The resulting best-fit parameters, parameter standard errors, and covariances are compared between the two models. Average weight and length are considered for each month from June through October to estimate growth rates for fish stocked over the winter. Standard weights (relative to the rainbow trout and cutthroat trout standard weight curves) are also determined, along with the ratio of total length to fork length and typical dressed weight percentage.
Results: The improved model parameter estimates were b = 2.662 and L_1 = 45.32 cm, with correlation coefficient r = 0.969. From June to October, mean relative weight decreased from 101.5% to 93.6% relative to the rainbow trout standard weight and 114.5% to 103.2% relative to the cutthroat trout standard weight as mean total lengths increased from 34.4 cm to 41.9 cm and the mean weights increased from 0.505 kg to 0.830 kg. Typical dressed weight is 71% of the total weight.
Conclusion: Eleven mile reservoir is an excellent trout fishery, capable of producing large numbers of cutbow trout in good condition. The cutbow trout is well suited to this kind of mountain reservoir and grows fast. As might be expected, the weights of cutbow trout of a given length tend to fall between the standard weights of the rainbow and the cutthroat. For the season, the average relative weight was 97.0% relative to the rainbow trout, and 108.3% relative to cutthroat trout.

Key Words: Length, Weight, Cutbow trout, Rainbow trout hybrid, Standard Weight, Relative Weight

Introduction

If there are prejudiced biases in the fisheries literature against types of fish, then the cutbow trout hybrid (*Oncorhynchus mykiss x clarkii*), a fertile hybrid of rainbow and cutthroat trout, might be near the top of the list of fishes subjected to deliberate ignorance regarding life history information generally regarded as important for good management. The cutbow trout hybrid is found in eleven states in the western United States as well as New Zealand. It occurs both as the result of natural hybridization and is widely stocked. (Fuller 2011) The hybrid is fast-growing and is often very satisfying to sport anglers. (Ross 1997, Behnke and Tomerelli 2002, Montgomery and Bernstein 2008) Unlike other purposeful hybrids which are widely stocked and important in fisheries management, including the splake (*Salvelinus namaycush x fontinalis*), tiger muskellunge (*Esox masquinongy x lucius*) and saugeye (*Stizostedion vitreum x canadense*), no standard weight curve is established for this hybrid,(Gerow et al. 2005, Blackwell et al. 2000) and there is little published data regarding length-weight relationships, growth rates, and yield. Life history information is key for stock assessment and good management. (Anderson and Neumann 1996, Carlander 1969) One might hypothesize about an unspoken conspiracy to exclude key life history information regarding this vigorous hybrid, lest fisheries managers realize the utility of this hybrid in overcoming certain management challenges.

It is widely recognized that introgression of rainbow trout (*Oncorhynchus mykiss*) genetics into native cutthroat trout (*Oncorhynchus clarkii*) populations has negative consequences for biodiversity and survival of cutthroat trout subspecies throughout their native range. (Weigel et al. 2003) However, concerns of genetic introgression have largely overshadowed promising possibilities of fast growth and high angler satisfaction for cutbow trout in lentic systems that already include a large component of rainbow trout genetics. (Rohrer and Thorgaard 1986, Montgomery and Bernstein 2008)

Eleven Mile reservoir is a clear mountain reservoir in Colorado with a surface elevation of approximately 2621 m above sea level, surface area of approximately 13.4 square kilometers, an average depth of approximately 10 m, and a maximum depth of 41 m. It was created in 1932 by damming the South Platte River, a notable trout fishery, to create a reserve water source for the cifty of Denver. A variety of cutthroat trout, rainbow trout, and kokanee salmon (*Oncorhynchus nerka*) are stocked annually. The reservoir also contains significant numbers of naturally reproducing brown trout (*Salmo trutta*) and northern pike (*Esox lucius*) from previous stockings. In late winter 2010, 80,000 cutbow trout of length 25-30 cm were stocked through the ice.

This paper presents results from measuring total length (TL), fork length (FL), total weight, and dressed weight in samples taken from Eleven Mile reservoir from June through October 2010. Length-weight parameters are presented, along with a month by month analysis of length and weight to study the growth of the cohort of cutbow trout hybrids that were in the 25-30 cm length range when stocked the previous winter.

Method

A total of 171 samples of cutbow trout obtained via sport angling were measured from June through October. Cutbow trout in this reservoir had a generic grey/silver appearance with spots, without any of the vivid coloration often associated with rainbow trout, cutthroat trout, or cutbow hybrids. There was not any significant color variation to suggest how much rainbow vs. cutthroat genetics are present in a given specimen. Weights were determined on a scale with an accuracy of 3 g. Fork and total lengths were measured by a tape measure to 2 mm. After weighing and measuring, fish were dressed (head, scales, and entrails removed), and the dressed weight was also recorded.

Length-weight relationships in fish traditionally employ the model, $W(L) = aL^b$, where L is length and W is weight. The parameters a and b were obtained by both linear least-squares (LLS) regression ($\log(W) = \log(a) + b \log(L)$) and non-linear least-squares (NLLS) regression. Best-fit parameters of an improved model, $W(L) = (L/L_1)^b$, were also determined by NLLS regression; the parameter L_1 is the typical length of a fish weighing 1 kg. The resulting best-fit parameters, parameter standard errors, and covariances were compared between the two models. The relative weight of each fish was computed (relative to the standard weights) for both the rainbow trout and the cutthroat trout standard weight curves, (Anderson and Neumann 1996) and monthly means for the relative weights were computed to document month to month changes over the sample period (June-October). Monthly means for weight and length were also analyzed to determine average growth rates each month for weight and length.

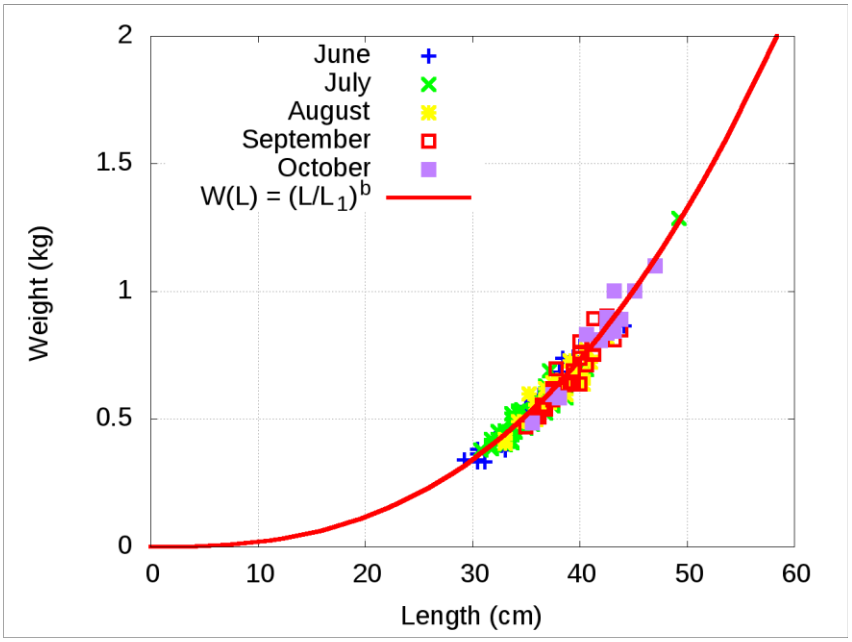

Figure 1: Weight vs. length (total length) data for cutbow trout, along with best-fit weight-length curve.

NLLS	**L_1 (cm)**	**45.3190**
improved	L_1 error	0.36%
$W(L)=(L/L_1)^b$	b	2.6621
	b error	1.87%
	covariance	0.8520
	r	0.9688
NLLS	**a**	**3.8974E-5**
traditional	a error	18.10%
$W(L)=aL^b$	b	2.6621
	b error	1.85%
	covariance	-1.0000
	r	0.9688
LLS	**a**	**4.5211E-5**
traditional	a error	4.44%
$W(L)=aL^b$	b	2.6206
	b error	2.04%
	covariance	-1.0000
	r	0.9678

Table 1: Best-fit length-weight parameters.

Results

Figure 1 shows the monthly data for total weight vs. length in cutbow trout, along with the best fit model curve for all 171 samples. It is evident that the fish are growing, because in the later months, most of the data points are higher along the curve, except for one large specimen caught in July which was the biggest fish in the sample at 49.2 cm. This is the only sample which was probably stocked in 2009, and was not included in the July data when computing growth rates (Tables 3 and 4). Table 1 shows the results of non-linear least squares (NLLS) fitting of cutbow trout data to both the traditional length-weight model and an improved model. The improved model has about the same correlation coefficient and estimated uncertainty in the parameter b as the traditional model, but the uncertainty in L_1 is much smaller (0.36%) than the estimated uncertainties in a using either the NLLS regression of linear least-squares (LLS) regression of log(W) vs. log(L). The covariance between parameters in the improved model is also smaller in magnitude than the covariance between parameters in the traditional model.

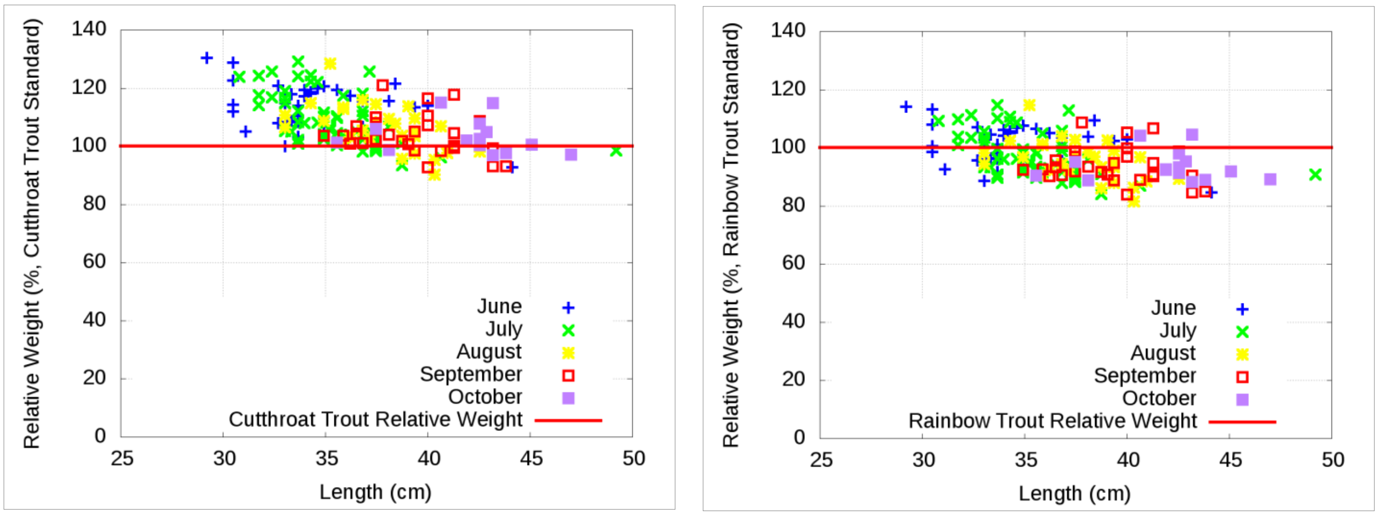

Figure 2: Cutbow trout relative weights compared with the cutthroat (left) and rainbow trout (right) standard weights. (Anderson and Neumann 1996)

Figure 2 shows the cutbow trout relative weights as a percentage of the standard weight curves for the cutthroat and rainbow trout. Most cutbow specimens are above the standard weight for cutthroat trout, but are well distributed both above and below the standard weight for rainbow trout. There is a definite trend in both graphs for the relative weight to decrease with increasing length. Table 2 shows the relative weights for the cutbow trout, compared with the standard weight curve of the cutthroat and rainbow trout for each month in the study period. There is a clear trend toward smaller relative weights between June and October.

	W_r RBT %	uncertainty %	W_r CTT %	uncertainty %
June	101.51	1.09	114.47	1.27
July	97.17	0.93	108.89	1.09
August	95.59	1.32	106.48	1.52
September	93.82	1.16	104.08	1.30
October	93.61	1.32	103.21	1.48

Table 2: Mean relative weights (W_r) for cutbow trout relative to the standard weight curves (Anderson and Neumann 1996) for rainbow trout (RBT) and cutthroat trout (CTT).

Monthly relative weights are shown in Table 2, relative to both the rainbow trout and cutthroat trout standard weight curves. Relative to the cutthroat trout standard weight curve, (Anderson and Neumann 1996) the relative weight decreased from 114.47% in June to 103.21% in October. Relative to the rainbow trout standard weight curve, the relative weight of the cutbow trout in the sample decreased from 101.51% to 93.61% from June to October. Compared with isometric growth (b = 3.0) or the standard weight curves for rainbow (b = 2.990) and cutthroat (b = 3.086) length growth outpaced weight growth over the course of the season.

Month	Mean Date (month)	Mean L (cm)	Mean W (kg)	uncertainty L (cm)	uncertainty W (kg)	Samples
June	6.500	34.410	0.502	0.530	0.022	37
July	7.355	35.232	0.509	0.318	0.009	62
August	8.710	37.692	0.613	0.496	0.019	28
September	9.700	39.291	0.684	0.497	0.024	28
October	10.194	41.889	0.830	0.785	0.043	15

Table 3: Mean lengths, weights, and dates of catch for each months sampling of cutbow trout.

Mean monthly lengths and weights are shown in Table 3. Since the cohort of trout stocked over the winter were in the 25-30 cm range at the time of stocking (February and March), mean lengths from 34.410 cm in June increasing to 41.889 cm in October represent significant increases in length. The uncertainties reported in the mean monthly lengths and weights represent the standard deviations in the monthly groups divided by the square roots of the number of samples, added in quadrature with the measurement uncertainty of each specimen. Over the sampling period, the mean length increased by 21.73% which would suggest a weight increase by a factor of $(1.2173)^3$ = 1.804, or 80.4% had the growth been isometric. In contrast, the length-weight curve through the mean (L,W) endpoints of the interval, June (34.410 cm, 0.502 kg) and October (41.889 cm, 0.830 kg), has an exponent b = 2.5566, and an L_1 = 45.06 cm.

Time Interval	Growth rates Length (cm/month)	Weight (kg/month)	Length (%/month)	Weight (%/month)	b equivalent
June-July	0.962	0.008	2.762	1.512	0.547
July-August	1.815	0.077	4.979	13.768	2.765
August-September	1.614	0.071	4.194	11.021	2.628
September-October	5.264	0.295	12.970	39.012	3.008

Table 4: Month to month growth rate estimates for length and weight in cutbow trout, along with equivalent exponent, b, computed as weight percent change per month divided by length percent change per month.

Table 4 shows growth rate estimates, computed as the difference in the mean weights and lengths divided by the difference in mean catch date for each month. Assuming that there was no sampling bias between months, there was much more growth in the interval from September to October than there was in the earlier months. It is unclear whether this is because surface water temperatures after September 16 were back below 15°C after having been warmer all summer, or because sport angling had reduced the trout population sufficiently that remaining trout could optimally use the available forage in late summer and early autumn. Figure 3 shows the measured surface water temperatures over the course of the season. Detailed catch rates are not available, but the local officials were reporting excellent angling all season for these trout, and many anglers were reporting catching their limit (4 fish per angler) as they passed through the boat inspection leaving the boat ramp.

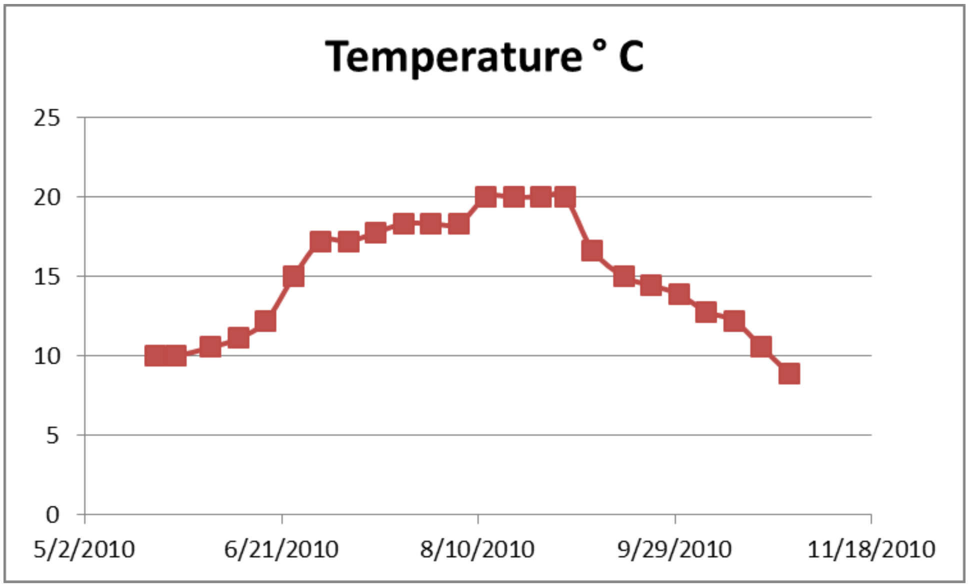

Figure 3: Surface water temperatures for the season.

A linear regression (zero intercept) of total length (TL) vs. fork length (FL) gave the best-fit equation of TL = 1.03575 FL with a standard error of 0.11% in the slope and a correlation coefficient r = 0.989. Linear regression of dressed weight (head, entrails, and scales removed) vs. total weight (zero intercept) on a sample size of 89 gave a slope of 0.7178 with a standard error of 0.90% and r = 0.994.

Discussion

The improved length-weight model, $W(L) = (L/L_1)^b$, produced smaller uncertainty in the non-exponent parameter and smaller covariance. The parameter L_1 = 45.32 cm has a clear physical meaning as the typical length of a fish weighing 1 kg. In this case, the best-fit estimate of b = 2.662, suggesting allometric growth, which is confirmed by analysis of the month to month increases in average length and weight.

The greatest loss of relative weight occurred between June and July when the relative weight compared to the cutthroat trout standard weight curve (Anderson and Neumann 1996) decreased from 114.47% to 108.89%. Analysis of growth between June and July suggest this is because the average length increased by 2.76% but the average weight only increased by 1.51% over this interval. Isometric growth (Pauly 1984, Froese 2006) requires a weight increase by about 3% for each 1% increase in length. Growth remained allometric ($b < 3.0$) through the summer months and did not become isometric again until the September-October interval when the increase in average length was 12.97% and the increase in average weight was 39.01%.

To the authors' knowledge, this paper reports the first detailed study of length, weight, and growth of cutbow trout over the course of a season. Whether the slow growth in the June to July period was due to overstocking or warm water temperatures remains a question for future study.

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