Evaluation of Cause - Decline in Upper Fording River Westslope Cutthroat Trout Population

Effects of Capture and Handling on Westslope Cutthroat Trout in the Upper Fording River: A Brief Review of Cope (2020) and Additional Calculations

August 2021

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(Subject Matter Expert for the Upper Fording River Westslope Cutthroat Trout Evaluation of Cause)

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1 Introduction

Capture and handling of Westslope Cutthroat Trout (WCT) in the upper Fording River (UFR) for scientific studies and salvage operations has the potential to impact the population. Estimates of juvenile and adult abundance in the UFR from 2019 were well below estimates from 2017 and signal a substantive decline in both these components of the population. An evaluation of cause (EoC) effort was undertaken to identify the potential causes of the population decline. A Fish Handling report (Cope 2020a) addressed whether fish capture and handling (hereafter referred to as handling) could have caused or contributed to the population decline. Cope (2020a) summarized the annual number of fish handled for scientific studies and salvage operations, and applied assumed handling mortality rates to these captures to estimate how many WCT potentially die due to handling. These estimates were then divided by estimated abundances of the population to calculate the proportion of the population that could potentially die due to handling (hereafter referred to as the population mortality rate). Cope (2020a) came to three basic conclusions about handling effects from this analysis. First, losses due to handling were not great enough to be a primary cause of the decline of the WCT population between 2017 and 2019. Second, handling effects could reduce productivity and therefore contribute to the cumulative impact of mining-related and natural stressors on the population. Finally, there is merit to the concern that the combined impact of handling associated with scientific studies and salvage operations may be unsustainable for the WCT population.

As part of the EoC process we were asked to provide a review of the Fish Handling report (Cope 2020a). The main points from this review and some alternate calculations of handling mortality were provided in presentations given to participant reviewers on October 15, 2020 and January 21, 2021. Questions and comments from participants following the presentations led to further correspondence via email, adjustments to the mortality calculations and additional consideration of salvage activities during the Decline Window. The objective of this memorandum is to document our interpretation of the Fish Handling report, present additional analyses using a revised approach to estimate handling mortality and the population mortality rate, and to address questions and comments that came up following the presentations. In particular, this report will: 1) describe the general approach used in Cope (2020a) to estimate handling effects; 2) present the main data and estimates of the population mortality rate due to handling used in Cope's (2020a)assessment; 3) provide additional estimates of population mortality rate using the same data as Cope (2020a) but based on different calculations; 4) provide conclusions based on the revised estimates and compare them to those in Cope (2020a); and 5) calculate handling impacts separately for scientific studies and salvage operations, to support future discussions on monitoring.

2 Approaches used to Estimate Mortality and Population Mortality Rates Approach used to Estimate Mortality and Population Mortality Rates in Cope 2020a.

Cope (2020a) used a two-step approach to calculate the proportion of the UFR WCT population that potentially die due to capture and handling. In the first step the total number of mortalities caused by capture and handling ('mortalities') was calculated using,

Equation 1)

mortalities = captured * per_capita_mortality_rate

where 'captured' represents the total number of fish caught in scientific studies and from salvage operations, and 'per_capita_mortality_rate' (PCM) is the proportion of fish handled that are assumed to die either immediately or after release (Cope 2020a). Per capita mortality rates for different handling scenarios were derived from the literature and professional judgement. The estimated PCM associated with scientific studies (7%) was much lower than for salvage operations (27%) (Table 5, Cope 2020a). The number of individuals handled using the two different methods (scientific studies and salvage operations) were summed multiplied by either low (scientific) or high (salvage) PCMs to estimate a range of handling-related mortalities (Equation 1) (p. 19, Cope 2020a).

In the second step, Cope (2020a) calculated the population mortality rate due to handling using,

Equation 2)

population_mortality_rate[t] = mortalities[t1]/population_abundance[t2]

where, 'mortalities' is calculated using Equation 1, 'population abundance' is the annual estimate based on the sum of estimates from juvenile and adult components of the population and "t1" and "t2" denote a year or set of 2 years (Cope 2020a). In Cope (2020a) capture years and abundance years could differ (i.e., $t1 \neq t2$ or $t1=t2$); captures from 2018 (max), 2016 – 2018 (avg) and 2017 (low) were used with abundance estimates from 2019 and 2017 to represent expected minimum and maximum values (Table 1, reproduced here from Cope 2020a Table 6). Two abundance estimates were calculated for each year based on different assumptions about the amount of suitable rearing habitat for juveniles.

3 Review of Population Mortality Rate Calculations (Cope 2020a)

There are issues with the derivation and application of the per capita mortality rates as well as the estimates of the proportion of population handled both of which are components of the Cope 2020a population mortality rate calculation (see Section 2 above). These issues and a revised approach are provided below.

3.1 Per Capita Mortality Rate Calculations

3.1.1. Combination of Captures from Scientific Monitoring and Salvage Operations

In Cope (2020a) (p. 19), either a low (scientific) or high (salvage) PCM was applied to the combined scientific and salvage captures to calculate the population mortality rate using Equation 1 (see Section 2.1 above). This leads to over- or under-estimates of the number of handling-related mortalities. In examples where the scientific PCM (7%) is applied to total captures, the total number of mortalities is underestimated. In examples where the salvage PCM (27%) is applied to the total captures, the total number of mortalities is overestimated.

The revised approach, presented in Revised Equation 1, reduces the bias associated with those estimates by applying the PCM for each handling type (i.e., scientific or salvage) to the number of fish handled by type, and then summing the two to estimate total handling related mortalities.

Revised Equation 1)

$$mortalities_{scientific} = captured_{scientific} * per\_capita\_handling\_mortality\_rates_{scientific}$$
$$mortalities_{salvage} = captured_{salvage} * per\_capita\_handling\_mortality\_rates_{salvage}$$
$$mortalities_{total} = mortalities_{scientific} + mortalities_{salvage}$$

3.1.2. Calculation of Mortality from Capture and Handling

The salvage per capita mortality rate of 27% is based on combined effects of immediate handling due to capture and handling (2%), latent electrofishing and handling effects (5%), salvage inefficiency (10%), and relocation effects (10%) (Table 5, Cope 2020a). Cope's (2020a) PCM for salvage was incorrectly calculated as 27% (i.e., 27 = 100 * (0.02 + 0.05 + 0.1 + 0.1)) by adding mortality from different sources (Cope 2020a, Table 5). Mortality from capture and handling is sequential, which needs to be accounted for in the calculation of total mortality. For example, a fish killed by capture cannot be killed again by later handling effects (e.g., from tagging). Thus, mortalities associated with capture and later handling effects cannot be simply added together as done by Cope (2020a). In addition, mortality associated with salvage inefficiency should be applied only to the fish left behind as discussed further in Section 3.1.3.

Using the revised approach, a sequential calculation of mortality using the same components as in Cope (2020a) would be 25.2% (i.e., 25.2 = 100 * (1-(1-0.02)*(1-0.05)*(1-0.1)*(1-0.1)). These differences are modest but would be much greater if mortality rates were higher. The revised PCM for salvage of fish captured was calculated as 16.2 %

(i.e., 16.2 = 100*(1-(1-0.02)*(1-0.05)*(1-0.1)) which accounts for sequential mortality. The revised PCM also removes salvage inefficiency of 10% which was used in the Cope (2020a) mortality calculation and is included in the revised approach as a separate term (Section 3.1.3).

3.1.3. Use of Salvage Inefficiency Term in PCM

One of the terms included in the PCM for salvage in Cope (2020a) is the 10% used for salvage inefficiency. This component of the PCM should be calculated separately from handling effects as it should be applied to fish left behind after salvage and not those that were captured and handled. The basis for the 10% salvage inefficiency term was not provided in Cope (2020a), but it is an assumption rather than estimated from data.

In the revised approach two terms, capture efficiency and mortality rates, were used to estimate mortality associated with salvage inefficiency for fish left behind after salvage. The salvage inefficiency estimate is based on the premise that not all fish are captured during salvage. Some of the uncaptured fish may die either due to effects from salvage operations and in-water activities subsequent to the salvage (e.g., dewatering, increased sedimentation) or other latent effects associated with electrofishing (e.g., an increased time in the electric field, physical disturbance of fry in gravels; assumed by Cope 2020a to be 5%). Capture efficiency is influenced by factors including salvage methods, intensity of efforts and habitat. Mortality rates for fish left behind are expected to vary based on the salvage operation. For example, capture efficiency using multiple techniques (e.g., electrofishing, hand salvage, fyke nets) over several days in a stream reach that is gradually being dewatered would be higher than in complex habitat that is not being dewatered.

In the Upper Fording River Operations area, extensive effort was made when there was planned dewatering or emergency salvage. For example, to increase capture efficiency, multiple salvage methods were used and crews returned multiple days to hand salvage as dewatering proceeded (e.g., Swift Creek 2018, [Hemmera Envirochem Inc. 2019], Kilmarnock 2018, [Teck Coal Limited 2019a and 2019b]). In these scenarios, hypothetically, there may be a high capture efficiency and a high mortality rate for fish left behind post-salvage. In contrast, where salvage activities took place in complex habitat that was not subsequently dewatered (e.g., Smith Creek 2018 [Hemmera Envirochem Inc. 2019]), both capture efficiencies and mortalities are unknown but expected to be much lower than in a dewatering scenario.

Lacking salvage specific data on capture efficiency or mortality rates, the following assumptions were used in the revised approach.

- Based on a review of salvage reports between 2017 and 2019, approximately half of salvages ended in dewatering, although the actual numbers vary from year to year. On this basis two capture efficiency rates were used to estimate the number of fish left behind after salvage. A low capture efficiency rate of approximately 50%, which was estimated for juveniles in the UFR based on electrofishing studies (Thorley et al. 2021), was assumed to apply where habitat was not dewatered during salvage, and a high 90% capture efficiency rate, based on the descriptions of intensive sampling and subsequent dewatering, were each applied to half of the total of number of fish salvaged in a given year.

- A mortality rate of 25% was applied in the low capture efficiency scenario based on the assumption that there may have been latent electrofishing effects of 5%, as assumed by Cope et al 2020a. Although there are no data to support an assessment of additional mortalities that may have resulted from in-stream activities post-salvage (e.g., operations related), we assumed an additional 20% mortality for a total of 25% mortality in the low capture efficiency scenario. For the scenario with high capture efficiency, which assumes there was dewatering after salvage, the revised approach assumes 100% mortality for fish left behind. There are not data to support the mortality rates rendering them uncertain; however, they provide a range of potential conditions that could occur post-salvage.

These assumptions were applied in the revised approach to calculate a population mortality rate for fish left behind after salvage using the Revised Equation 2 as summarized in Table 2

Revised Equation 2)

$$\text{Total fish}_{\text{before salvage}} = \text{Fish salvaged/CE}$$
$$\text{Total fish}_{\text{left behind after salvage}} = \text{Total fish}_{\text{before salvage}} - \text{Fish salvaged}$$
$$\text{Salvage inefficiency mortality} = \text{Total fish}_{\text{left behind after salvage}} * \text{Mortality rate}$$

Where:
CE_{low} = 50% and CE_{High} = 90%
$Mortality_{Low}$ =25% and $Mortality_{High}$ = 100%

3.2 Different Years of Handling and Abundance Used to Compute Proportion of Population Handled

The most significant issue with the calculations used in Cope (2020a) to determine the proportion of the population handled is that different years were used for captures and population estimates. This approach relies on the assumption that mortalities are independent of abundance. That is, it is assumed that captures from scientific studies or salvage operations will not be higher in years when abundance is higher. Using this assumption, the number of fish captured (used to estimate mortalities) and population abundance do not have to be from the same year. Using these assumptions, the estimates of the proportion of the population handled in Cope (2020a) range from a low of 7% (slightly too low because scientific study captures not included) to a high of 51% (Table 1). The latter value likely overestimates the proportion of the population handled because it is calculated using the ratio of the number of fish handled in a high abundance year (2018) to the abundance following the population decline (2019), which was a very low abundance year.

The revised approach assumes there is a relationship between the number of fish captured and population abundance. That is, the number of fish caught in salvage operations and for scientific studies should in part depend on the abundance of the population when those events occur. Using the revised approach, the proportion of population handled is calculated by dividing the estimate of mortalities due to captures and handling by the population abundance estimate from the same year (e.g., 2017 captures are divided by 2017 abundance) using, Revised Equation 3)

$$\text{Population mortality rate} = \text{mortalities}_{\text{total}}[t] / \text{population abundance}[t]$$

where t=year). For 2018, which had a high number of fish salvaged but no abundance data, abundance was assumed to be the same as in 2017 because the population decline likely occurred after scientific studies and salvage operations occurred in 2018 (i.e., decline likely occurred in the winter of 2018-2019) (Evaluation of Cause Team, 2021).

4 Estimates of Handling Losses and Population Mortality Rate using the Revised Approach

Cope (2020a) calculated that the population mortality rate from handling could be as high as 13.8%. This maximum value (based on 2018 captures and 2019 abundance with habitat suitability adjustment, Cope 2020a, p. 22) is important because it supports the main conclusions that handling from both salvage and scientific monitoring could have been a modest contributor to the population decline and provides partial support for the notion that the population is being negatively impacted by the combined effect of scientific studies and salvage operations.

As discussed above, a revised approach was developed to refine the population mortality rate reported in Cope (2020a). Five adjustments were made in the calculations including (1) handling type specific PCMs were used to calculate mortalities (Revised Equation 1, Section 3.1.1), (2) mortality was calculated sequentially (section 3.1.2), (3) the salvage mortality rate was revised to exclude mortality related to salvage inefficiency and to correct errors in how mortality rates were combined (Section 3.1.3), (4) the salvage inefficiency term was calculated separately based on estimates of fish left behind (Revised Equation 2, Section 3.1.3) and (5) the proportion of population handled was calculated using paired handling and low and high abundance estimates (Cope 2020a) from the same year where data were available. Abundance data were not available for 2018 therefore 2017 abundance data were used for the 2018 calculation (Section 3.2).

The range of population mortality rates (minimum and maximum) calculated using the revised approach with paired data was 2.2 – 2.9% for 2017 and 5.2 – 8.2% for 2019 (Table 3). The range of population mortality rates in 2018 were 4.8 – 6.3%, which was based on 2018 captures and 2017 abundance. We used the 2017 rather than 2019 abundance for the population mortality rate for 2018 because there is evidence that the decline happened in the winter of 2018-2019, which is after scientific studies and salvage operation occurred in 2018. The maximum population mortality rate calculated with the revised approach (8.2%) is considerably lower than Cope’s (2020a) maximum value of 13.8%. All estimates are based on the same data used in Cope (2020a).

Aside from providing a more logical structure to compute estimates of population mortality rate, the calculations using the revised approach allow separation of mortality due to scientific studies and salvage operations. This is a useful separation, since only the scientific studies-related mortalities should be relevant to concerns about the effects of monitoring on the population. Estimates of the population mortality rate due to scientific studies ranged from 0.1-0.5% (Table 3). The impacts of scientific studies on the population are very modest.

5.0 Conclusions

The three main conclusions (in *italics*) drawn in the Fish Handling report (Cope 2020a) are revisited below with comments relevant to the new estimates calculated in this memo.

Capture and Handling Was Not a Significant Contributor to the Population Decline

We agree with the conclusion that capture and handling was not a significant contributor to the population decline between 2017 and 2019 given that the population mortality rate calculated using either the revised approach (a maximum of 8.2%) or the higher rate in Cope (2020a, 13.8%), are simply too low to cause the sudden ~75% reduction in the juvenile population, and ~90% reduction in the adult population. Moreover, the nature of the observed decline is not consistent with an impact that would be observed due to salvage, which largely affects juvenile fish (Cope 2020a). If the salvage-related mortality of juveniles was somehow much higher than estimated by Cope (2020a) or the revised approach, the effects would appear as a progressive decline in the abundance of adults, and not the sudden decline in adults that occurred in 2019.

Handling Effects Have the Potential to Contribute to Reduced Productivity and May Contribute to a Cumulative Impact

Any increase in mortality resulting from handling will reduce productivity, but what is relevant is whether capture and handling mortality results in a meaningful effect on productivity. A simple population model was used to estimate the potential effects of the estimated population mortality rates (due to handling) under different scenarios, specifically: 1) no recruitment, 2) a level of recruitment that would result in a consistent population abundance over time, and 3) an increase in the population over time by adding 1000 recruiting fish to the population each year.

A natural survival rate of 38% for juveniles (to age-2) and 61% for adults (age 3+) was assumed in the population dynamics model recently developed for the UFR (i.e., a natural mortality rate of 62% and 39%, respectively; Ma and Thomson 2021). The natural mortality rate and the population mortality rate were used to model population growth for juveniles and adults. Each scenario began with 500 age-0 fish. As the additional mortality from capture and handling cannot simply be added to the natural morality rate, in this model we assume that natural mortality and mortality associated with capture/handling effects (including fish left behind after salvage) are concurrent processes, resulting in overall mortality rates of 65% for juveniles and 44% for adults using a population mortality rate of 8.2% (Table 3) and overall mortality rates of 67% for juveniles and 47% for adults using a population mortality rate of 13.8% (Cope 2020a)).

The simplest population projection (Fig. 2a) assumes no recruitment, and hence quantifies the effect of handling on the rate of population decline. The second projection (Fig. 2b) adds sufficient recruitment to balance the population and keep the abundance stable over time, and the third (Fig. 2c) adds an annual recruitment of 1000 fish, and hence quantifies the effects of handling on the rate of population recovery. Mortality due to capture and handling were then added to these baseline scenarios. There were negligible effects of the additional capture and handling mortality to population trajectories (Fig. 2).

There is Merit to the Assertion that the Combined Impact of Handling Associated with Scientific Studies and Salvage Operations may be Unsustainable for the WCT Population

There is no evidence to support the idea that scientific monitoring or salvage activities are causing substantive reductions in abundance, or will substantively slow population recovery. Prior to 2019, both juvenile and adult populations were increasing in spite of increases in the number of fish salvaged and with ongoing scientific studies (Fig. 1, Cope 2020b). Modeling of population abundance does not indicate a substantive change in the trajectory of the population under the estimated population mortality rates due to capture and handling (Fig. 2).

Reviewers expressed specific concern about the potential impact of scientific studies on the WCT. The majority of capture and handling, and the majority of the population mortality rate, is driven by salvage, therefore separating out these components is important in addressing this concern. Maximum population mortality rates for scientific monitoring are very low (0.1-0.5%), indicating no support for the concern that the population is being negatively impacted by scientific studies.

6.0 References

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Table 1. Copy of Table 6 from the Fish Handling report (Cope 2020a).

Table 6. Population abundance scenarios illustrating a range of captures and the proportion of the population sampled to illustrate the potential for a population level effect.

Year	Juv and Adult Popn Est.	Salvage apture 2018 (Max)	Salvage Captures 2016-2019 (Avg)	Salvage Captures 2016 (low)	Scientific Captures 2017 (Max)	Scientific Captures 2016-2019 (Avg)	Scientific Captures 2016 (low)	Combined Captures 2018 (Max)	Combined Captures 2016-2019 (Avg)	Combined Captures 2016 (low)
2019	12,335	3,696	2,119	1,861	1,291	594	263	3,959	2,713	1,861
% Popn		30	17	15	10	5	2	**32**	22	**15**
2019*S.I.	7,727	3,696	2,119	1,861	1,291	594	263	3,959	2,713	1,861
% Popn		48	27	24	17	8	3	**51**	35	**24**
2017	26,924	3,696	2,119	1,861	1,291	594	263	3,959	2,713	1,861
% Popn		14	8	7	5	2	1	**15**	10	**7**
2017*S.I.	20,562	3,696	2,119	1,861	1,291	594	263	3,959	2,713	1,861
% Popn		18	10	9	6	3	1	**19**	13	**9**

Table 2. Population mortality rates for fish left behind after salvage using revised Equation 2. As detailed in Section 3.1.3, for each year, we assumed that half of the total number of fish captured in salvage operations were caught at a low capture efficiency (50%), and half at a high capture efficiency (90%). Low and high population abundance estimates are based on not adjusting and adjusting for juvenile habitat availability, respectively (2017: low population estimate = 20,562 and high = 26,924; 2019: low population estimate = 7,727 and high = 12,335 [Cope 2020a]).

	# Fish	Per Capita Mortality Rate (PCM)	# of Mortalities (# Fish*PCM)	Population Mortality Rate (# mortalities/population abundance)	
				Low Abundance	High Abundance
2017[a]					
Fish Captured in Salvage Operations[d]	1482				
Fish Left Behind (Low 50% Capture Efficiency)	741	25%	185	0.9%	0.7%
Fish Left Behind (High 90% Capture Efficiency)	82	100%	82	0.4%	0.3%
Total Left Behind	823		268	1.3%	1.0%
2018[b]					
Fish Captured in Salvage Operations[d]	3696				
Fish Left Behind (Low 50% Capture Efficiency)	1848	25%	462	2.2%	1.7%
Fish Left Behind (High 90% Capture Efficiency)	205	100%	205	1.0%	0.8%
Total Left Behind	2053		667	3.2%	2.5%
2019[c]					
Fish Captured in Salvage Operations[d]	1758				
Fish Left Behind (Low 50% Capture Efficiency)	879	25%	220	2.8%	1.8%
Fish Left Behind (High 90% Capture Efficiency)	98	100%	98	1.3%	0.8%
Total Left Behind	977		317	4.1%	2.6%

[a] Calculated with 2017 # fish captured and 2017 abundance

[b] Calculated with 2018 # fish captured and 2017 abundance as 2018 abundance data are not available

[c] Calculated with 2019 # fish captured and 2019 abundance

[d] # of fish from Teck Coal 2019c; Cope 2020a

Table 3. Calculations used to determine the number of mortalities and the population mortality rate for Westslope Cutthroat Trout in the Upper Fording River caused by capture and handling using the revised approach. Low and high population abundance estimates are based on not adjusting and adjusting for juvenile habitat availability, respectively (2017: low population estimate = 20,562 and high = 26,924; 2019: low population estimate = 7,727 and high = 12,335 [Cope 2020a]). Revised Equations 1 and 3 are used to compute the number of mortalities and the population mortality rate, respectively.

Method	# Fish	Per Capita Mortality Rate (PCM)	# of Mortalities (# Fish Captured*PCM)	Population Mortality Rate (# mortalities/population abundance)	
				Low Abundance	High Abundance
2017[a]					
Scientific Studies[d]	1200	7.0%	84	0.4%	0.3%
Salvage Operations[e]	1482	16.2%	240	1.2%	0.9%
Fish Left Behind After Salvage	823	**	268	1.3%	1.0%
Total				2.9%	2.2%
2018[b]					
Scientific Studies[d]	300	7.0%	21	0.1%	0.1%
Salvage Operations[e]	3696	16.2%	599	2.9%	2.2%
Fish Left Behind After Salvage	2053	**	667	3.2%	2.5%
Total				6.3%	4.8%
2019[c]					
Scientific Studies[d]	500	7.0%	35	0.5%	0.3%
Salvage Operations[e]	1758	16.2%	285	3.7%	2.3%
Fish Left Behind After Salvage	977	**	317	4.1%	2.6%
Total				8.2%	5.2%

[a] Calculated with 2017 # fish captured and 2017 abundance

[b] Calculated with 2018 # fish captured and 2017 abundance as 2018 abundance data are not available

[c] Calculated with 2019 # fish captured and 2019 abundance

[d] # fish is approximate, exact values not reported in Cope (2020a)

[e] # of fish from Teck Coal 2019c; Cope 2020a

**See Table 2. Per capital mortality rate is 50% for the low capture efficiency and mortality scenario and 90% for the high capture efficiency and mortality scenario.

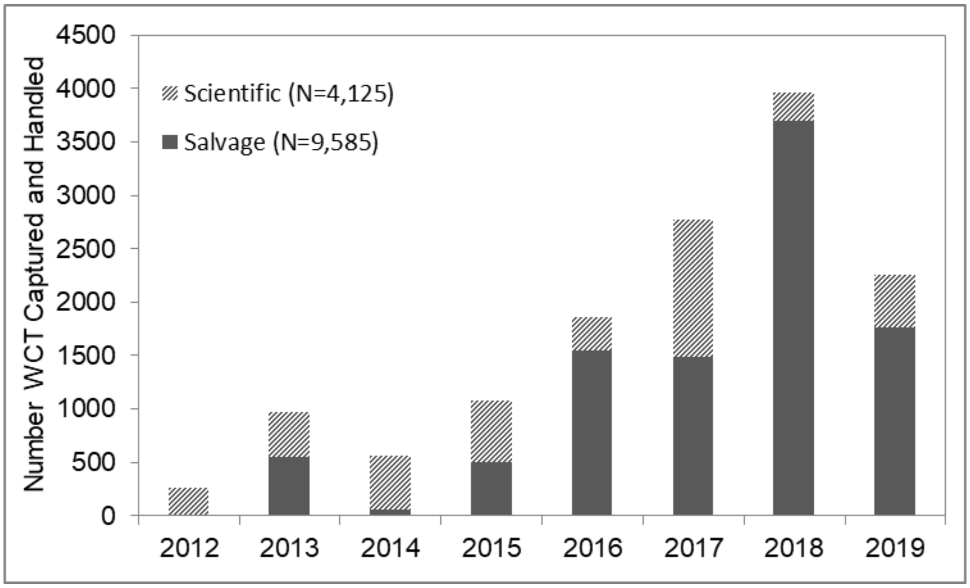
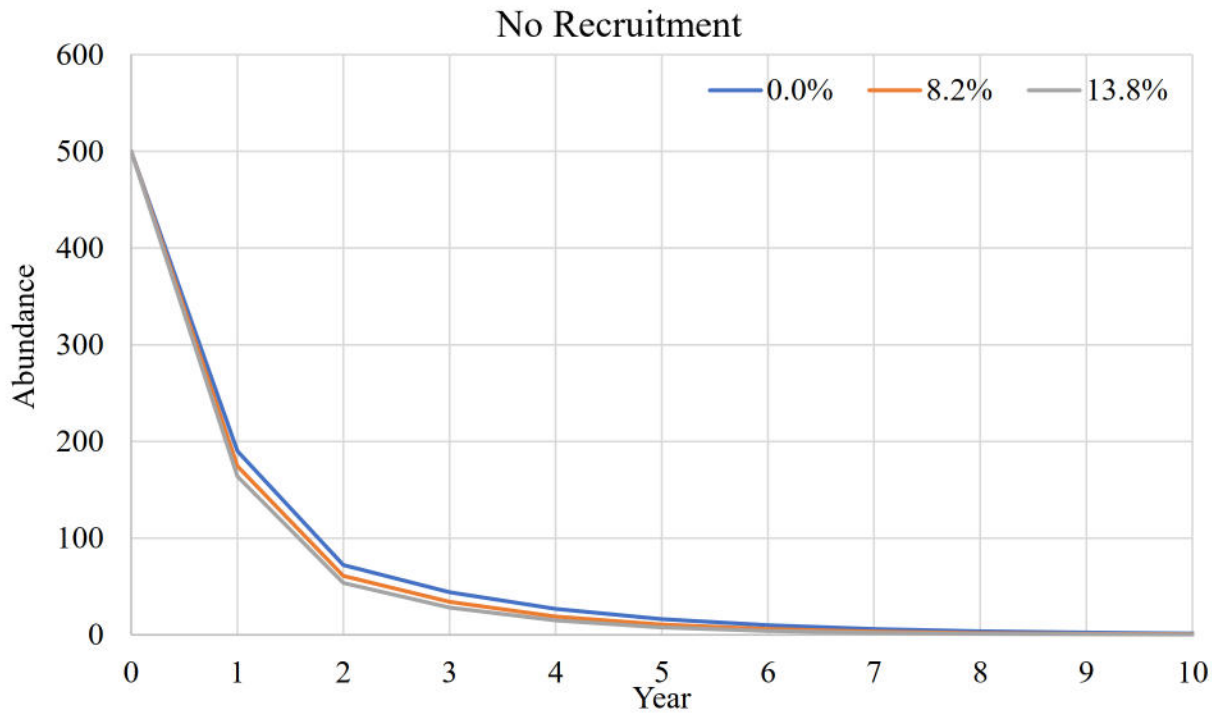
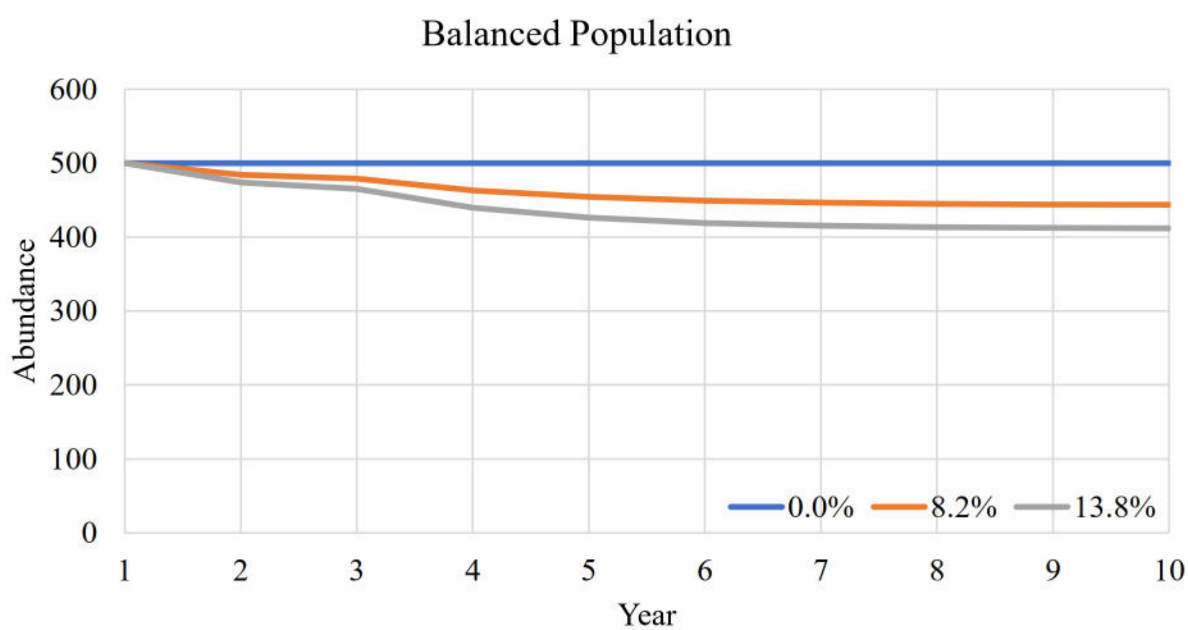


Figure 1. Reproduction of Figure 4 from Cope (2020a) showing the total numbers of Westslope Cutthroat Trout captured and handed within the upper Fording River watershed through both salvage and scientific collection purposes.

a.


No Recruitment
600
500
400
300
200
100
0
Abundance
0.0%
8.2%
13.8%
0
1
2
3
4
5
6
7
8
9
10
Year

b.


Balanced Population
600
500
400
300
200
100
0
Abundance
0.0%
8.2%
13.8%
1
2
3
4
5
6
7
8
9
10
Year

c.

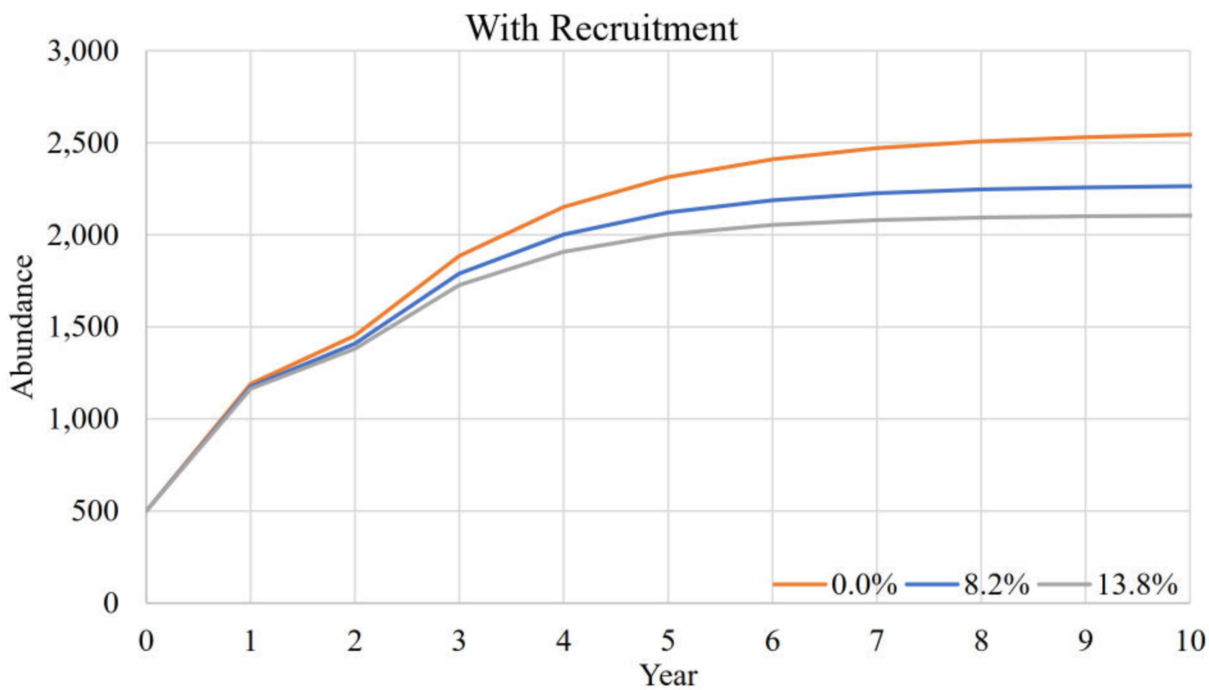


Figure 2. Projected abundance over time of a population based on a natural survival rate of 38% for juveniles and 61% for age 3+ (Ma and Thomson 2021) with handling population mortality rates of 0.0%, 8.2% and 13.8%. Panel a) shows a scenario with no recruitment and Panel b) shows a scenario with a balanced population (i.e., not growing) without capture and handling mortality and Panel c) shows a scenario for a population that is recovering due to an annual recruitment of 1000 fish/year. All scenarios begin with 500 age-0 fish.

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