Weaver Creek
Chum Salmon Stream
Residence Time

Submitted to:

Gary Rosberg, Fisheries Management Instructor
Fish, Wildlife and Recreation Program
British Columbia Institute of Technology
Burnaby, BC

Sponsor
Sue Grant, Chum Salmon Biologist
Stock Assessment
Department of Fisheries and Oceans
New Westminster, BC

Submitted by:

Tim Wenman

Fish, Wildlife and Recreation Program
British Columbia Institute of Technology

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Summary

On October 8, 2003, British Columbia Institute of Technology (BCIT) entered into a joint project with Fisheries and Oceans Canada (DFO). This project, conducted by Tim Wenman, Michael Chimenti and Jeff Ambegia, in conjunction with Fisheries and Oceans' biologist Sue Grant, was to establish the stream residency time of chum salmon (*Oncorhynchus keta*) in the Weaver Creek spawning channel and the natural section of Weaver Creek above the spawning channel diversion fence. The study area was located in Harrison Mills, British Columbia approximately 150 km from Vancouver (Figure 1). This project was initiated in fulfillment of the course requirements of the Fish, Wildlife and Recreation program (FWR) as a year-long directed studies project for RENR courses 3230 and 4230.

The objective of this study was to generate a residence time estimate for chum salmon by gathering field data through foot surveys of the natural portion of Weaver Creek and the Weaver Creek spawning channel and to compare the results. Fish entered Weaver Creek and the spawning channel on October 8, 2003. Surveys began on October 15, 2003 and ended October 27, 2003 when chum salmon spawning was complete (no more live chum were in the spawning channel).

Because of high water events from October 15-22, 2003, foot surveys of the natural portion of Weaver Creek could not be performed and a residence time could not be calculated from this arm of the study. Study parameters were therefore modified to include two sets of dead recovery data collected by Weaver Creek staff for the spawning channel; one from 2002 and one from 2003. This data served to supplement the set of live count data collected by the study group.

Area-under-the-curve methodology was used to generate residence times. Three independent estimations of residence time were determined. The average of the three estimates, two estimates from the dead recovery counts combined with the foot survey estimate, yielded an average residence time of 5.73 days. The three values ranged from 4.82 to 6.73 days. All the residence times fall within the expected range of 3 to 10 days based on field estimates (Grant, pers. comm., 2003).

Acknowledgements

We would like to acknowledge the following individuals for their guidance and hard work in our project. A special thanks to Sue Grant, Assessment Biologist, with the Department of Fisheries and Oceans Canada whose considerable efforts in organizing and providing background and resources were essential to our project's success. Rick Stitt, DFO Operations Manager for the Weaver Creek Spawning Channel, was a critical information source throughout the period of data collection. Wayne Charlie, Weaver Creek Spawning Channel Supervisor, provided significant background information on the history of the Weaver Creek system and spawning channel. We would also like to thank Joe Tadey, Coho Biologist, DFO, and Ryan Galbraith, Program Head, Chinook and Coho Salmon, DFO for offering background information on study design, field data collection and project options. In addition, further thanks to Gary Rosberg, BCIT Fisheries Instructor, for his guidance on the report writing and background information on the Weaver Creek spawning channel. A final thanks to Dr. John Smith, BCIT Statistics Instructor, for his guidance on options for data and statistical analysis.

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1.0 Introduction

The importance of determining accurate escapement numbers has come to the forefront of fish stock management. Certain stocks have become dangerously low and accurate assessment of numbers has become paramount in assuring proper management decisions. A common method of estimating escapement is the area-under-the-curve method (Hilborn et al., 1999). Area-under-the-curve methodology has been documented in Ames and Phinney (1977), Pirtle (1977), Beidler and Nickelson (1980), Ames (1984), Johnson and Barrett (1988), English et al. (1992), Hill (1997), Quinn and Gates (1997), Bue et al. (1998) and (Hilborn et al., 1999) and this method is commonly used in the United States and Canada to determine Pacific salmon escapements (Hilborn et al., 1999).

This method defines escapement as the total number of fish-days divided by the stream residence time also referred to as “survey life” or “stream life” (Hilborn et al., 1999). Stream residence time is defined as the number of days that the average spawning fish is alive in the spawning area. Residence time can be estimated by dividing the cumulative fish days (derived from area-under-the-curve) by the number of fish known to be in the system. In order to derive a residence time, you must have a controlled and closed system to which absolute numbers of fish must be known. This is the case in systems where there are fish fence counts such as Weaver Creek and the Weaver Creek spawning channel.

Many studies have focused on estimating the total number of fish-days and have used a fixed predetermined value for stream residence time (Beidler and Nickelson 1980; Ames 1984). Recent research has found that establishing a residence time in one system and using it in another system to establish an escapement may introduce bias in the escapement estimate. The estimates of stream residence time should be site specific and time specific (Perrin and Irvine 1990). It is also thought that fish that enter the spawning area at different times may have different expected stream residence times (Lady and Skalski, 1998). The value of establishing a residence time for chum will be helpful in determining rough escapement estimates for other similar systems in the Fraser Valley of British Columbia.

The initial intent of this study was to measure the stream residence time for chum salmon in the Weaver Creek system as well as the spawning channel and to compare the two values. Due to a 200 year high water flood event, foot surveys of the natural portion of Weaver Creek were not possible. As a result, the study was altered to examine residence time in the spawning channel alone.

The Weaver Creek spawning channel is a continuously monitored system and a very important facility for sockeye enhancement in the Fraser Valley of British Columbia. As a result, a considerable amount of data is collected for the spawning channel. Dead recovery data are colleted daily for all three species of Pacific salmon (chum; pink, *Oncorhynchus gorbusha* and sockeye, *Oncorhynchus nerka*) present in the channel. In addition, total numbers of live fish entering the spawning channel are known from fence counts. Using dead recovery data in a manner similar to live counts, a residence time can also be established. Three independent calculations of residence time for the spawning channel were determined; two values from dead recovery data from 2002 and 2003 and one value obtained from live counts by foot survey in 2003. Residence times derived from year versus year and live versus dead counts were compared.

This study was proposed by the Department of Fisheries Oceans as a way to generate reliable data on the residence time of chum salmon, information which DFO does not currently have. Current field observations indicate chum residence time ranges from three to ten days (Grant and Charlie, pers. comm. 2003). This range is too broad to reliably estimate escapement numbers for this system or any other. With an accurate residence time, a more confident estimate of escapement can therefore be made.

Weaver Creek chum salmon begin their annual migration to their spawning grounds each fall. Their route from the ocean takes them up the Fraser River to the confluence of the Harrison and Fraser River systems. They migrate up the Harrison River and move into the Weaver Creek system in early October. The fish encounter two man-made fences that control their progress in the Weaver Creek system. These fences serve two purposes: to regulate the number of salmon that are allowed to move past a certain point in the Weaver system and to enumerate the number of salmon entering the system. The first fence is located below Morris Lake (Figure 3) and stops salmon movement into the lake. This is to ensure oxygen levels within the lake are not depleted by excessive numbers of fish holding in the lake area (Stitt, pers. comm., 2003). Fish are counted at the lower fence and are moved beyond the fence and into the lake. The fish then move through the lake and into Weaver Creek where they encounter a second fence just below the spawning channel. At an appropriate time in early October, the Weaver Creek spawning channel is filled with water from Weaver Lake via Weaver Creek. Once the spawning channel is full of water, fish are counted and diverted into either the Weaver Creek spawning channel, a holding area for First Nations, or a bypass into Weaver Creek proper. Once in either the spawning channel or Weaver Creek, chum salmon search for spawning habitat. The time spent within the final spawning destination is known as residence time.

2.0 Study Area

2.1 Directions to the Study Area

The Weaver Creek spawning channel is located near Harrison Mills in the Fraser Valley of British Columbia (Figure 1). To get to the study site from Vancouver, drive one hour east on Highway 1 (Trans Canada) and take exit 92 at Abbotsford. Drive to Mission via the Mission Highway. From Mission, drive east on Highway 7 for about 20 minutes until you pass Harrison Bay. Turn north onto Morris Valley Road (paved) at the Sasquatch Inn and the Hemlock Recreation area sign. Follow Morris Valley Road for 12 kilometers until you see the Weaver Creek spawning channel on you right hand side.

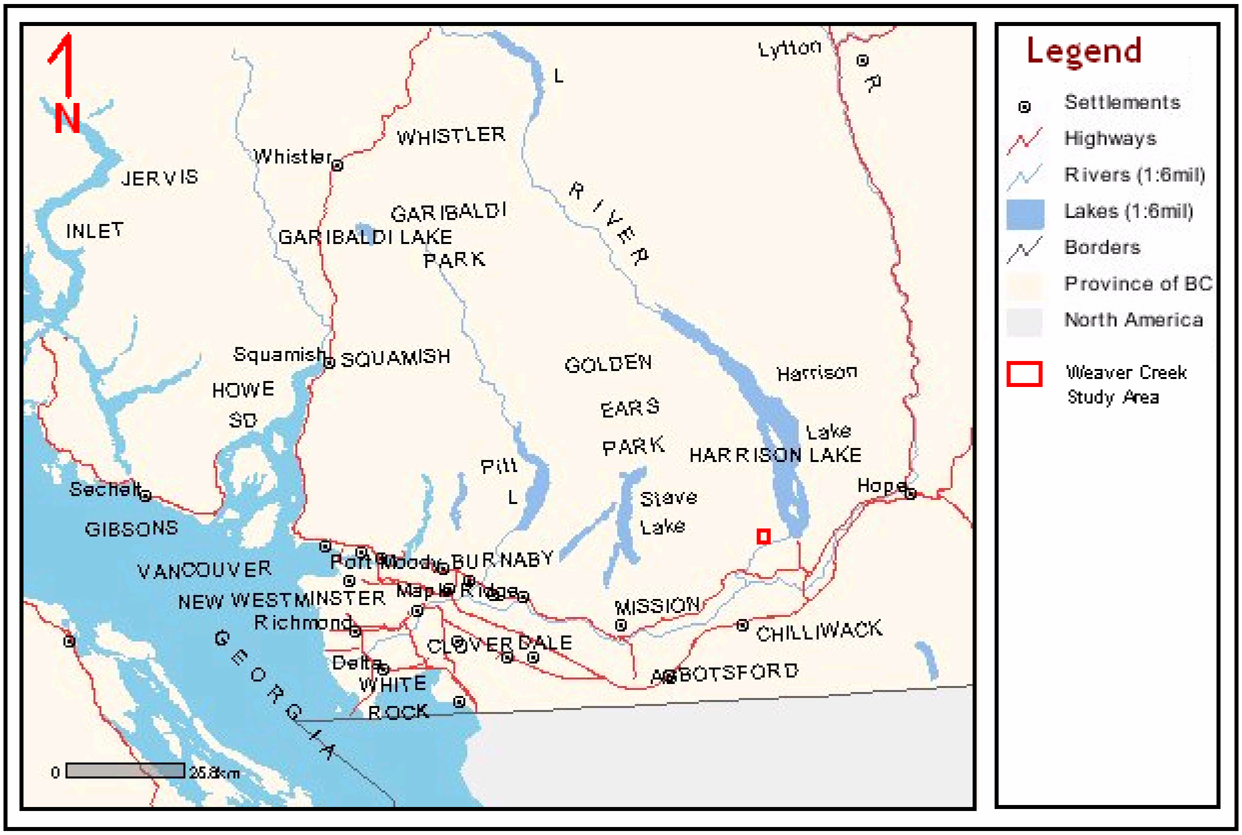


Figure 1 –A map of the Lower Mainland with special reference to the Weaver Creek study area in Harrison Mills, BC (source: Department of Fisheries and Oceans Map Creator).

2.2 Site Description

The study area is located west of Harrison Lake and north of the Harrison River (Figure 2). The study area consists of two watersheds: Sakwi Creek and Weaver Creek (Figure 3).

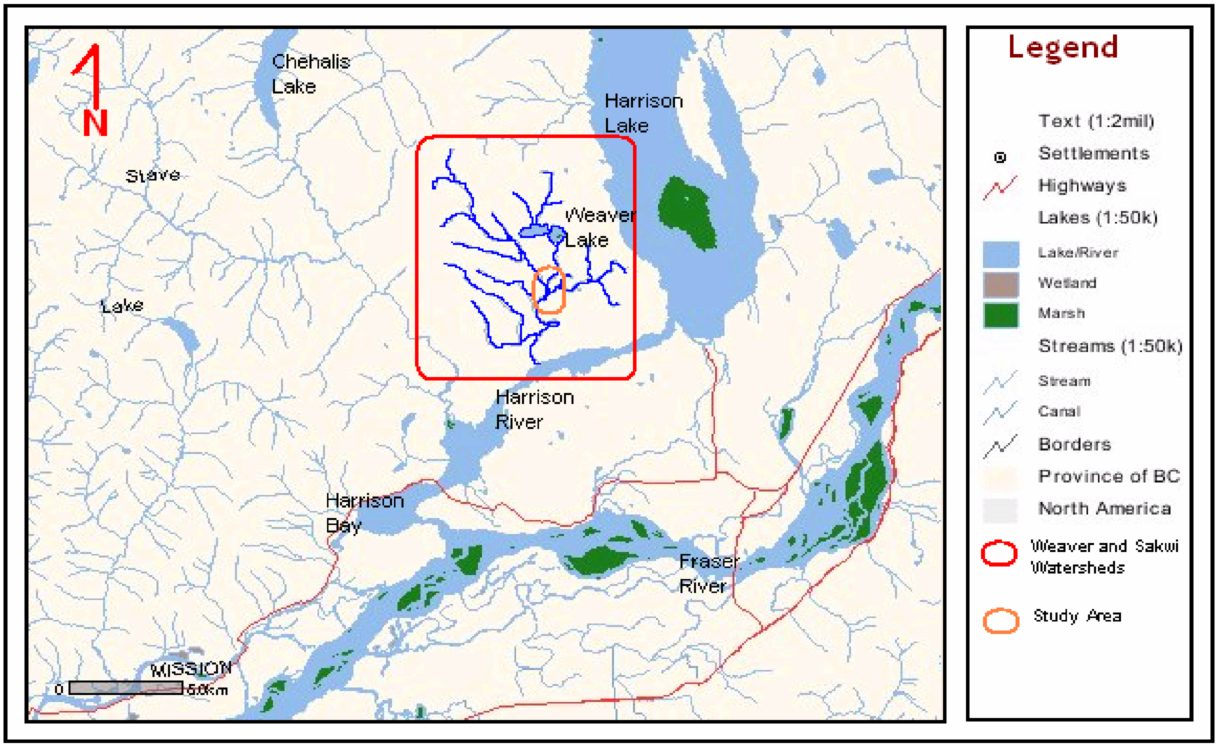


Figure 3 - A map of the Weaver and Sakwi Creek watersheds, Harrison Mills, BC (source: Department of Fisheries and Oceans Map Creator).

The natural section of Weaver Creek from the diversion fence at the bottom end of the spawning channel up to the waterfall approximately 4km upstream of the diversion fence was laid out into reaches. Weaver Creek was divided into 11 reaches (Appendix V). Sakwi Creek, from its confluence with Weaver Creek 300m upstream, was counted as a single reach. (Appendix V)

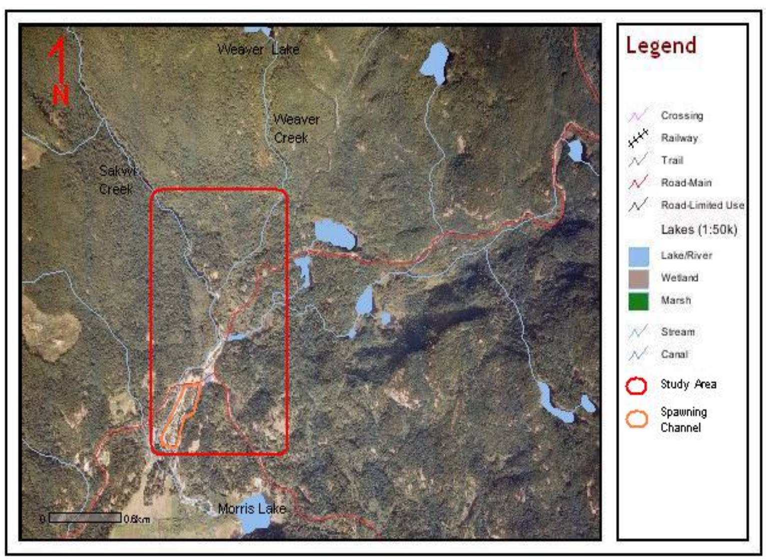


Figure 2 - An orthophoto view of the Weaver and Sakwi Creek watersheds showing the study area (source: Department of Fisheries and Oceans Map Creator).

Reaches divisions were chosen to keep counts contained to areas of similar water flow, character and visibility so as to facilitate and improve the accuracy of the visual counts. Reaches 1 and 7 on Weaver Creek were further subdivided into left and right bank sections to increase counting accuracy, a reflection of both their width and depth (Appendix V).

The study area also included the entire Weaver Creek spawning channel which is approximately 3km long. The spawning channel was divided into 26 different reaches (starting at reach 25, working upstream to reach 0). Reach boundaries were based on the reach breaks already in use by Weaver Creek staff (Figure 4).

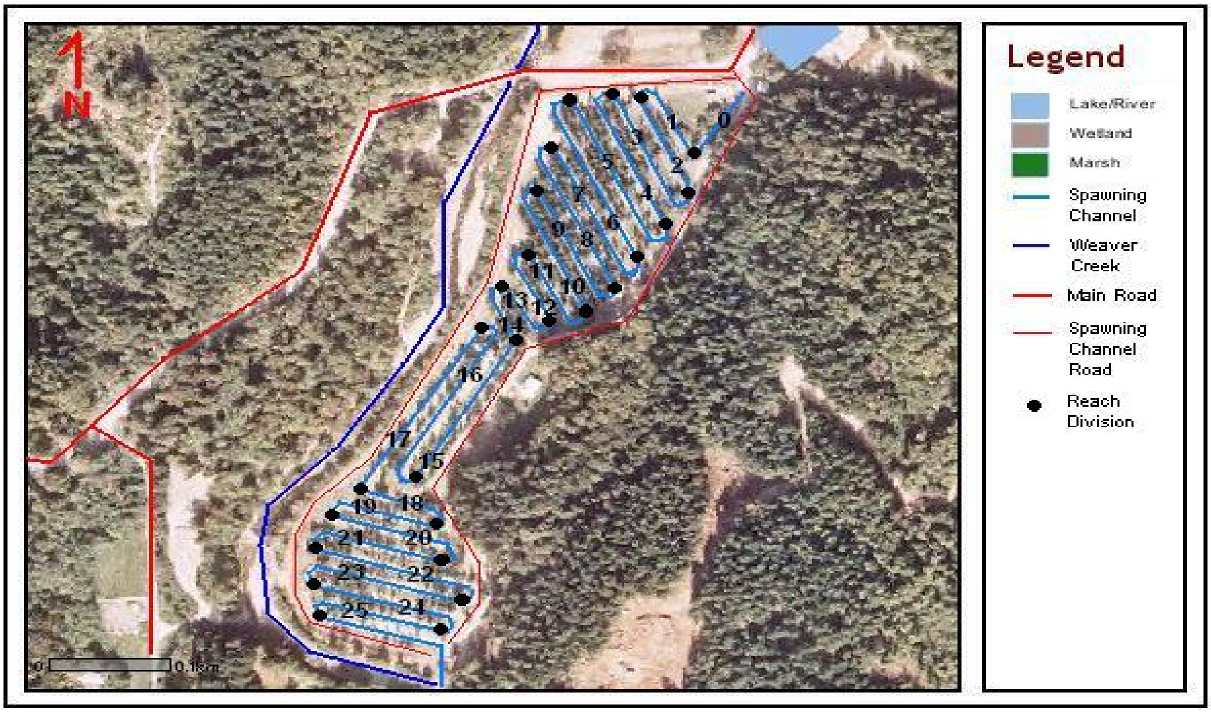


Figure 4 - A closer view of the Weaver Creek spawning channel study area broken into 26 reaches (source: Department of Fisheries and Oceans Map Creator).

2.3 Run Timing

The window of opportunity to study the chum salmon run of Weaver Creek varies from year to year. Fish arrive at the lower fence in early October and are put into the system around October 5th and have completed spawning in the channel by November 5th. In Weaver Creek, spawning will continue to mid-November. Peak numbers of fish arrive about October 15, with most spawning activity taking place over a ten-day period from October 15 to 25th (DFO, 2003).

3.0 Materials and Methods

The method of generating a residence time requires systematic visual counts of chum salmon over their spawning season. This requires counts before their arrival, during and after they have spawned and are all dead. The visual surveys were done twice a week on the spawning channel by a team of three people. Two crewmembers walked the left bank and the third walked the right. The project group counted the spawning channel and used the reaches already laid out by channel staff. There were 26 reaches laid out in the spawning channel; reach 25 began at the outlet of the intake pens, and a new reach began at each bend in the channel.

All reaches were surveyed in an upstream direction and observer efficiency (O.E.) was discussed and recorded at the end of each reach. Observer Efficiency is a subjective estimate of the surveyor’s count accuracy through a given reach. Surveyors decided on an accuracy percentage they were comfortable with and recorded this percentage along with the count result (Mahoney, pers. comm., 2003). The O.E. was used to expand the visual counts to account for environmental factors that lessened counting accuracy and resulted in less chum salmon being counted. Factors such as glare, turbidity, water depth, upstream/downstream movement of fish and large numbers of sockeye impeding counts of chum may contribute to an underestimation of chum numbers that would be accounted for using the observer efficiency as a correction factor.

As described previously, Weaver Creek was walked from the diversion fence to the upper falls and 11 reaches were laid out based on water flow characteristics. Larger pools were separated from runs/riffles due to lower O.E. in deep holding pools (Appendix V). Only one survey was completed before high water events prevented further data collection for this arm of the study.

Crew members required limited amounts of equipment for this study:

- leak proof chest waders
- polarized glasses
- tally whackers
- thermometers
- and field data recording sheets.

Counts by visual survey were expanded using the observer efficiency value for each reach and a total number of fish was calculated for the spawning channel. The corrected counts were plotted over time (days) and the area-under-the-curve (AUC) was calculated. Absolute abundance numbers were known for the spawning channel and were used in the calculation. The practicality of determining residence time (RT) may be useful in helping to predict chum salmon escapement in other similar systems in the Fraser Valley. Visual surveys in other systems coupled with residence time determined from this study, can help predict escapement numbers through the following relationship: **Abundance = AUC/ RT.**

AUC was calculated by plotting the curve representing the fish counts over the time of the survey in days. The area represented under the curve is most often calculated using trapezoidal approximation (English et al., 1992; Bue et al., 1998 cited in Hilborn et al., 1999). This method was used to calculate AUC in this study and was calculated using the following equation:

$$AUC = \sum_{i=2}^{n} (t_i - t_{i-1}) \frac{(x_i + x_{i-1})}{2}$$

- where t_i is the day of the year for the i survey and t_{i-1} is the day of the year of the previous survey
- and where x_i is the number of salmon observed for the i^{th} survey and x_{i-1} is the number of salmon observed for the previous survey (English et al. 1992; Bue et al. 1998 cited in Hilborn et al., 1999).

The areas of each polygon are added to estimate the AUC in fish-days. In order for this methodology to work, surveys are initiated prior to the presence of salmon in the survey area. This algorithm will fail if the first and last surveys do not begin and end with zero counts.

To facilitate calculations of an AUC value using trapezoidal approximation, an Excel template provided by DFO was used to plot the curve and to calculate the AUC value. Residence time was then calculated by manipulating the following equation: Abundance = AUC/ RT to become **RT= AUC/Abundance.**

4.0 Results/Discussion

The original intent of this project was to gather residence time data for chum salmon on the natural section of Weaver Creek and the spawning channel and to compare the data from the two. Due to record rainfalls from October 15-22, water levels in Weaver Creek rose several feet above normal (Figure 5).

Figure 5- A comparison of stream conditions on Weaver Creek during the high water events of October 15-22, 2003 compared to its normal levels before the study commenced on October 4, 2003.

Water levels exceeded the height of the diversion fence at the bottom of the spawning channel, thereby allowing upstream and downstream migration of fish to occur. The natural system of Weaver Creek was no longer a closed and contained system. Undocumented movement of fish upstream and downstream of the fence voided absolute abundance numbers recorded prior to the storm. This rise in water levels also made it impossible to perform visual foot surveys within the creek and forced the exclusion of the natural portion of Weaver Creek from the study. Without collection of AUC data for Weaver Creek, comparison between the creek and the channel was no longer possible. The data from the spawning channel will now serve as baseline data for chum residence time. The use of this data to describe other natural systems should be done with caution. It does not account for the variations and increased stresses chum salmon experience in natural systems.

4.1 Statistical Analysis

In order to determine the reliability of the residence time number generated from AUC methodology, a statistical analysis was employed. A fourth order polynomial trend line and equation was established to best represent the mean curve based upon the data collected. Due to the uncertainty associated with the established trend line actually representing the true mean, it was necessary to reduce the statistical reliability by 5 degrees of freedom; the value representing the statistical uncertainty of using a fourth order polynomial to establish the trend line (Smith, pers. comm.., 2004). A standard deviation was calculated between the ideal curve representing the mean and the curve generated from the survey event. A standard error (s_N) was then established through the following equation:

$$s_N = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \bar{x})^2}.$$

- where x_i is the number of salmon observed for the i^{th} survey
- where $\bar{x}$ is the sample mean from the trend line curve at sample i.
- where N is the number of sampling events
- and where $(N\text{-}t)$ is substituted for N and t represents the degrees of freedoms used to calculate the uncertainty of a forth order polynomial trend line representing the true mean (Smith, pers. comm.., 2004 and Weisstein, 2004).

The next portion of the analysis looks at the overall error taking into account the number of sampling occasions (N). A sampling error ($s_{\bar{x}}$) representing all sampling events (N) was then established through the following equation:

$$s_{\bar{x}} = \bar{x} \pm ts_N$$

- where $\bar{x}$ is the residence time mean calculated from the AUC
- and where t is the student's t-value calculated from the number of sampling occasions (N) equal to the degrees of freedom (N-1) multiplied by the standard error (s_N).

4.2 Summary of Residence Time Values and Sampling Error Limits

Table I is a summary of the residence time values calculated in the following sections. They include the value of the calculated sampling error as described in the previous section and the accompanying residence time limits.

Table I – This table is a summary of the residence times calculated from the dead recovery data in 2002 and 2003 and visual surveys in 2003.

Count Year	Count Method	Residence Time	Sampling Error	Residence Time Limits
2003	Live Count	4.82	± 0.74	4.08 – 5.56
2003	Dead Recovery	6.73	± 1.92	4.81 – 8.65
2002	Dead Recovery	5.65	± 0.50	5.15 – 6.15

The overall range of the residence time values considering their limits is between 4.08 and 8.65 days.

4.3 2003 Live Count Spawning Channel Residence Time

Counts generated by repeated systematic visual surveys of the spawning channel are represented in Table II. The expanded count was determined by taking the actual count obtained and increasing it to reflect the observer efficiency for that reach on that particular day. This was achieved by dividing the observed count by the percent observer efficiency represented as a decimal.

Table II– The numbers of chum salmon recorded by visual survey of the spawning channel on each of the respective dates in 2003. The expanded count represents the actual count increased to reflect the observer efficiency. The number of fish days was determined by calculating the AUC in Figure 6. The data source for this table is Appendix I.

Date Surveyed	Expanded Count	Fish days calculation	Area-under-the-curve (fish days)
04-Oct-03	0	0	12 371
08-Oct-03	93	372	
11-Oct-03	780	2619	
15-Oct-03	1476	9024	
18-Oct-03	1053	7587	
22-Oct-03	111	4656	
25-Oct-03	30	423	
27-Oct-03	0	60	

There were no counts performed on October 4, 2003 and October 11, 2003. The counts for these two dates were obtained from the channel loading figures (Appendix II) that kept track of the cumulative total of chum salmon loaded into the spawning channel. As there was no recorded dead chum up to October 11, 2003, the gross number of chum loaded into the channel was assumed to be a reflection of how many live chum were in the channel on that date. Figure 6 depicts the curve generated by plotting the number of live chum counted over the survey period.

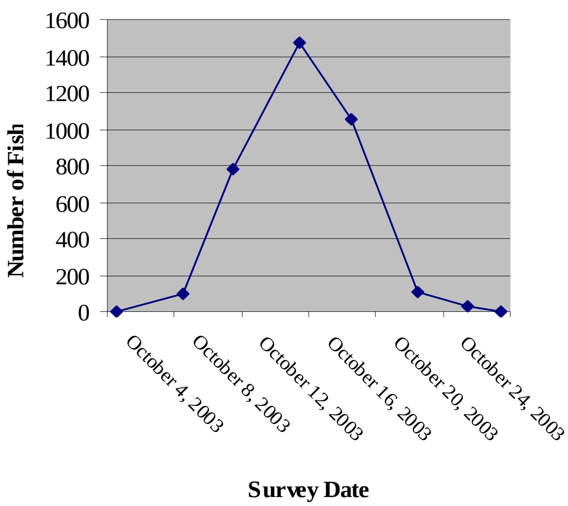


Figure 6 – A depiction of the number of live chum counted by visual survey in the spawning channel. The AUC is used to determine the total number of fish days over the study period.

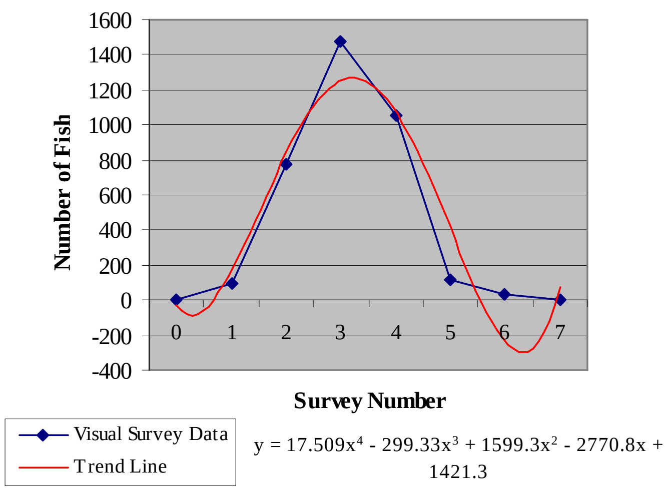


Figure 7 – A depiction of the best fit trend line in red representing the mean. The equation above was used in the statistical calculation to determine a sampling error from the data collected with a 95% level of confidence.

The AUC in Figure 6 was used to calculate the residence time. 12 371 fish days were calculated from the AUC. The number of chum salmon loaded into the spawning channel over the course of the study was 2566.

The residence time was calculated through the following relationship: RT= AUC / Abundance

The residence time was 4.82 days based upon visual surveys of the spawning channel. Figure 7 was used in the statistical analysis to determine a standard error. The sampling error at a level of confidence of 95% determined using the red trend line representing the mean in Figure 7, was 0.74 days. The residence time ranges from 4.08 to 5.56 days.

4.4 2003 Dead Recovery Spawning Channel Residence Time

Staff at the Weaver Creek spawning channel load primarily sockeye as well as some chum and some pink salmon into the spawning channel. Dead are removed daily so as to not overload the channel with nutrients from excessive decaying carcasses. Dead recovery data, including species and sex, is collected daily (Appendix II). Since the number of fish loaded daily into the channel is known and the number of dead recovered each day is known, a cumulative total of live fish left in the spawning area can be determined daily from the dead recovered . A curve can be plotted and a residence time determined.

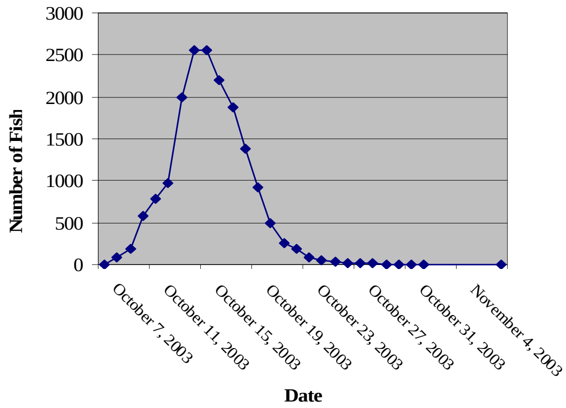
The Weaver Creek staff began loading chum into the spawning channel on October 8, 2003. Chum were loaded in daily until October 16, 2003 when loading was complete and the final number of 2 566 chum were loaded. The cumulative balance of live fish was determined daily based on fish being loaded into the spawning channel that day plus the previous day's total. The net balance of chum would be the cumulative live total minus the total of dead recovered on that day. The first dead were recovered on October, 16, 2003.

Dead recovery data collected in 2003 for chum salmon resulted in a net surplus of 210 live salmon. AUC methodology must begin and end with zero counts to determine the number of fish days. The net surplus of 210 salmon was not a reflection of what was actually left spawning. For the purposes of the AUC calculation, the final count was reduced to zero by determining the weighting of fish that were alive on a particular day over the course of the study. The percentage of the total of fish that were alive on that day was multiplied by 210 and the resulting number was subtracted from that day's total of live fish. This method of distributing the surplus balance of 210 was an unbiased means of reducing the final count to zero to allow for the AUC calculation.

Table III is a summary of the number of live fish calculated to be in the spawning channel. The curve was plotted and an AUC value was determined.

Table III - The numbers of live chum salmon recorded by dead recovery of the spawning channel on each of the respective dates in 2003. The number of fish days was determined by calculating the AUC in Figure 8. The data source for this table is Appendix II.

Date	Total LiveCount	Fish·days calculation	Area-under-the-curve (fish days)
7-Oct-03	0	0	17258
8-Oct-03	93	93	
9-Oct-03	181	274	
10-Oct-03	576	757	
11-Oct-03	780	1356	
12-Oct-03	976	1756	
13-Oct-03	1994	2970	
14-Oct-03	2560	4554	
15-Oct-03	2564	5124	
16-Oct-03	2195	4759	
17-Oct-03	1877	4071	
18-Oct-03	1372	3249	
19-Oct-03	924	2296	
20-Oct-03	497	1420	
21-Oct-03	262	759	
22-Oct-03	182	444	
23-Oct-03	82	264	
24-Oct-03	57	138	
25-Oct-03	36	93	
26-Oct-03	22	58	
27-Oct-03	10	32	
28-Oct-03	10	20	
29-Oct-03	2	12	
30-Oct-03	2	4	
31-Oct-03	2	4	
1-Nov-03	1	3	
7-Nov-03	0	7	



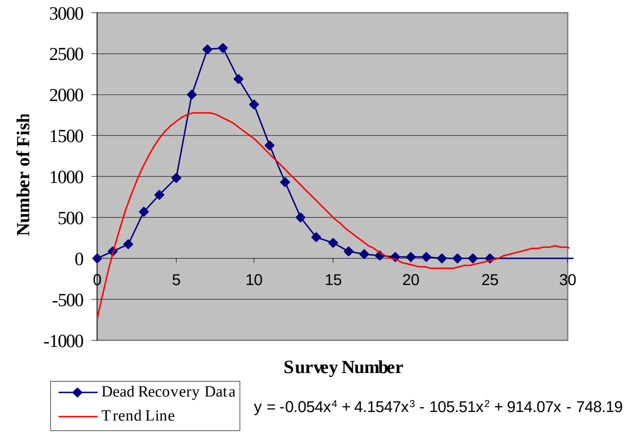


Figure 8 – A depiction of the number of live chum determined by dead recovery in the spawning channel. The AUC is used in determining the total number of fish days over the study period.

Figure 9 – A depiction of the best fit trend line in red representing the mean. The equation above was used in the statistical calculation to determine a sampling error from the data collected with a 95% level of confidence.

17 258 fish days were calculated from the AUC in Figure 8. The number of chum salmon loaded into the spawning channel over the course of the study was 2 566.

The residence time was calculated through the following relationship: RT= AUC / Abundance

The residence time was 6.73 days based upon dead recovery surveys of the spawning channel. Figure 9 was used in the statistical analysis to determine a standard error. The sampling error at a level of confidence of 95% determined using the trend line in Figure 9 was 1.92 days. The residence time ranges from 4.81 to 8.65 days.

There is a greater value range (4.81 to 8.65 days) associated with this data set versus the other two data sets because of the fit of the trend line curve in Figure 9. The result is a greater standard deviation with each sampling occasion and a greater standard error and sampling error overall.

4.5 2002 Dead Recovery Spawning Channel Residence Time

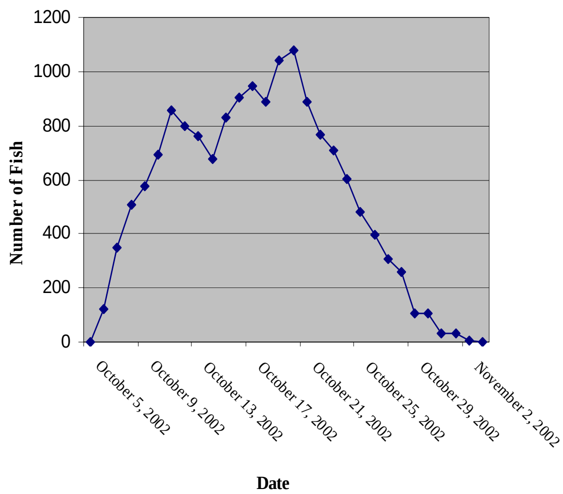
The means for determining the residence time in 2002 for the Weaver Creek spawning channel is similar to methods used in 2003. Dead recovery data collected in 2002 for chum salmon resulted in a net negative balance of 339 live salmon. The net negative balance of 339 salmon was not a reflection of what was actually left spawning. Again, the final count was reduced to zero by determining the weighting of fish that were alive on a particular day over the course of the study. The percentage of the total of fish that were alive on that day was multiplied by 339 and the resulting number was added to that day's total of live fish. This method of distributing the net negative balance of 339 was an unbiased means of reducing the final count to zero.

The Weaver staff began loading chum into the spawning channel on October 5, 2002. Chum were loaded in daily until October 24, 2003 when loading was complete and the final number of 2 566 chum were loaded. The cumulative balance of live fish was determined daily based on fish being loaded into the spawning channel that day plus the previous day's total. The net balance of chum would be the cumulative live total minus the total of dead recovered on that day. The first dead were recovered on October 8, 2003.

Table IV is a summary of the number of live fish calculated from the dead recovery data assumed to be in the spawning channel on each of the respective dates. The curve was plotted and an AUC value was determined.

Table IV- The numbers of live chum salmon recorded by dead recovery of the spawning channel on each of the respective dates in 2002. The number of fish days was determined by calculating the AUC in Figure 10. The data source for this table is Appendix III.

Date	Total Live Count	Fish days calculation	Area-under-the-curve (fish days)
05-Oct	0	0	15735
06-Oct	121	121	
07-Oct	348	469	
08-Oct	507	855	
09-Oct	576	1082	
10-Oct	693	1269	
11-Oct	857	1550	
12-Oct	799	1656	
13-Oct	763	1562	
14-Oct	677	1441	
15-Oct	831	1508	
16-Oct	905	1736	
17-Oct	948	1854	
18-Oct	889	1837	
19-Oct	1044	1932	
20-Oct	1080	2124	
21-Oct	889	1969	
22-Oct	766	1655	
23-Oct	709	1475	
24-Oct	605	1314	
25-Oct	480	1085	
26-Oct	399	879	
27-Oct	306	705	
28-Oct	260	566	
29-Oct	105	365	
30-Oct	105	210	
31-Oct	34	139	
01-Nov	34	68	
02-Nov	4	38	
03-Nov	0	4	



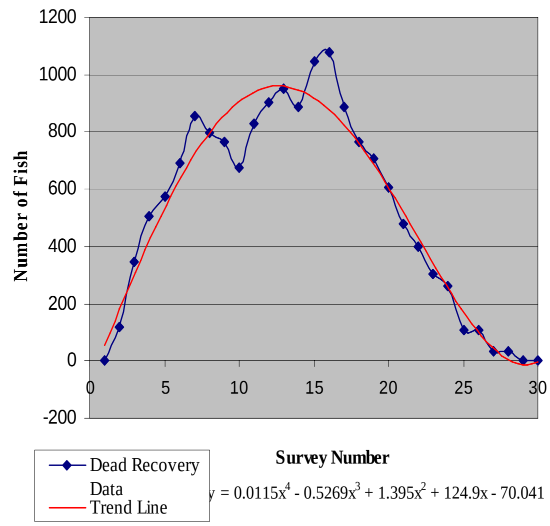


Figure 10 – A depiction of the number of live chum determined by dead recovery in the spawning channel in 2002. The AUC is used in determining the total number of fish days over the study period.

Figure 11 - A depiction of the best fit trend line in red representing the mean. The equation above was used in the statistical calculation to determine a sampling error from the data collected with a 95% level of confidence.

15 735 fish days were calculated from the AUC in Figure 10. The number of chum salmon loaded into the spawning channel over the course of the study was 2 783.

The residence time was 5.65 days based upon dead recovery surveys of the spawning channel. Figure 11 was used in the statistical analysis to determine a standard error. The sampling error at a level of confidence of 95% determined using the red trend line representing the mean in Figure 11 was 0.50 days. The residence time ranges from 5.15 to 6.15 days.

4.6 Differences between residence time values

The differences in residence time values can be attributed to a number of factors including the difficulties surrounding accurate counts at the peak of spawn time. The most difficult visual counts coincided with peak of spawn. On this occasion, within the spawning channel, there were pink, sockeye and chum totaling more than 36,900 fish in 3 km of spawning channel. Large numbers of fish made counting difficult due to 'stacking' of fish in the water column. Figure 12 illustrates the difficulties of counting fish in areas where fish were 'stacked up'.

Figure 12 – A view of the difficulties associated with both fish stacking and glare that made visual surveys difficult at peak spawn time in mid-October 2003.

Figure 12 also demonstrates the difficulties associated with glare. The uncertainty associated with glare was reduced with the use of polarized glasses. Glare could not be reduced to zero and varied in intensity based on the sun's position and the surveyor's aspect to the sun. Time of day and weather also impacted the effects of glare on a particular day.

There were also difficulties associated with differentiation between species, particularly chum versus sockeye. Figure 13 points out how size and color of chum and sockeye in a multi-species system makes identification difficult. There are also a small percentage of sockeye/chum hybrids that further cloud the process of identification (Grant, pers. comm., 2003).

Figure 13 – A photo demonstrating the overlap in size and coloration that can make identification of chum and sockeye difficult. Females are compared on the left of the photo and males on the right. Chum are located in the upper portion of the photo and sockeye in the lower portion. The yellow field book, used for scale, is 20cm long.

4.7 Differences between 2002 and 2003 residence time values

Factors that may have resulted in residence time differences between years may have been associated with weather conditions affecting water quality, temperature and level. This information was not collected as part of this study and is only speculative. One might hypothesize that water property differences could affect fish and cause changes in spawning behavior. The consistency of a spawning channel such as Weaver Creek would remove much of the natural variation caused by weather particularly water level fluctuations and turbidity.

The chemical properties of the water would, however, vary from year to year. Certainly temperature, pH and dissolved oxygen levels would fluctuate and might result in the residence time fluctuations noted in figure 14.

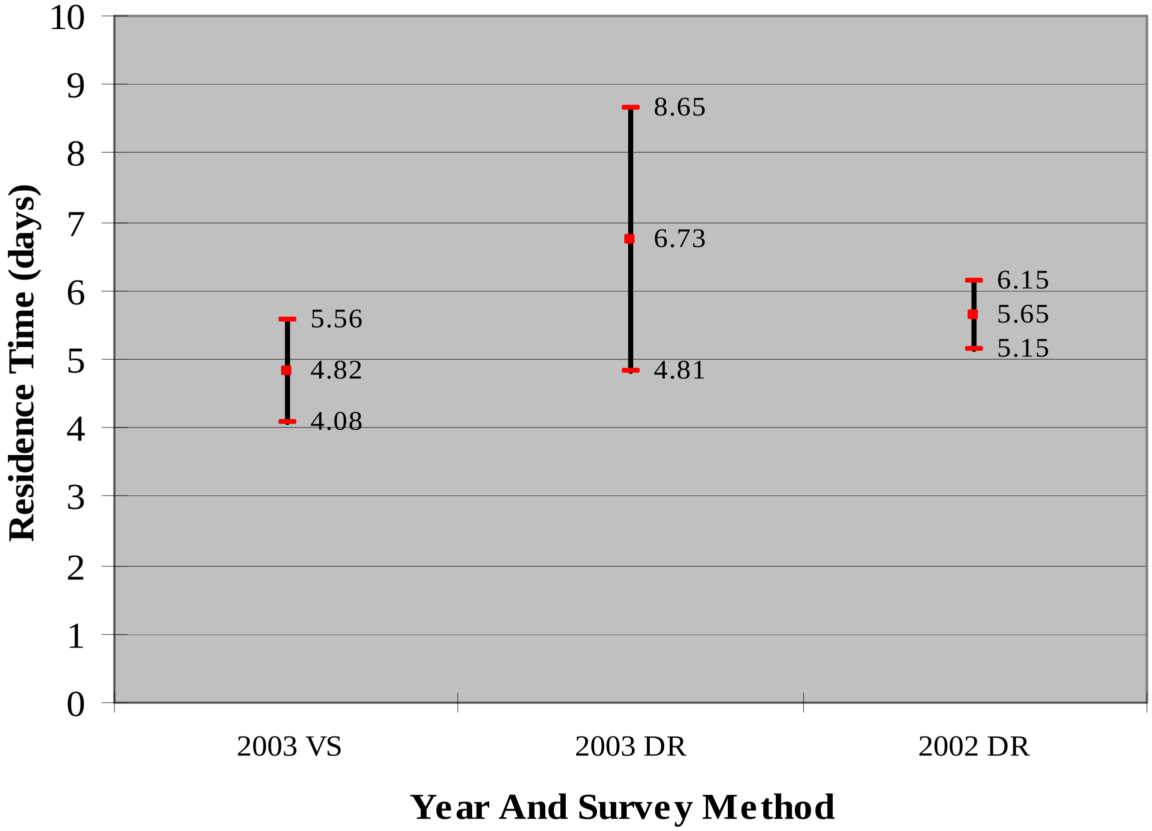


Figure 14– A representation of the three residence time values determined by visual survey (VS) and dead recovery (DR) in 2002 and 2003. The three values for each survey represent the mean (•) and the corresponding upper and lower confidence limits (–).

Figure 14 illustrates the three residence time values, their upper and lower limits and how all three values with their corresponding sampling error overlap from 5.15 to 5.56 days.

4.8 Differences between visual survey and dead recovery data in determining residence time values for 2003

Values between dead recovery and live counts in 2003 were most likely the result of an underestimation of fish at the peak of spawn. Because of the difficulty of counting chum at this time, there was likely an underestimation of live counts of fish in the spawning area.

Figure 15 compares dead recovery data in blue and live counts in red from the spawning channel for 2003. Ideally the two curves should be the same if counts are done accurately. It is evident that when the two curves are superimposed, the greatest differences in count values are seen at peak spawn. Up to and just after peak spawn the curves are almost identical. The number of fish days calculated between dead recovery data and live count data is 17 258 versus 12 371, a difference of 4 887 fish days or 28%.

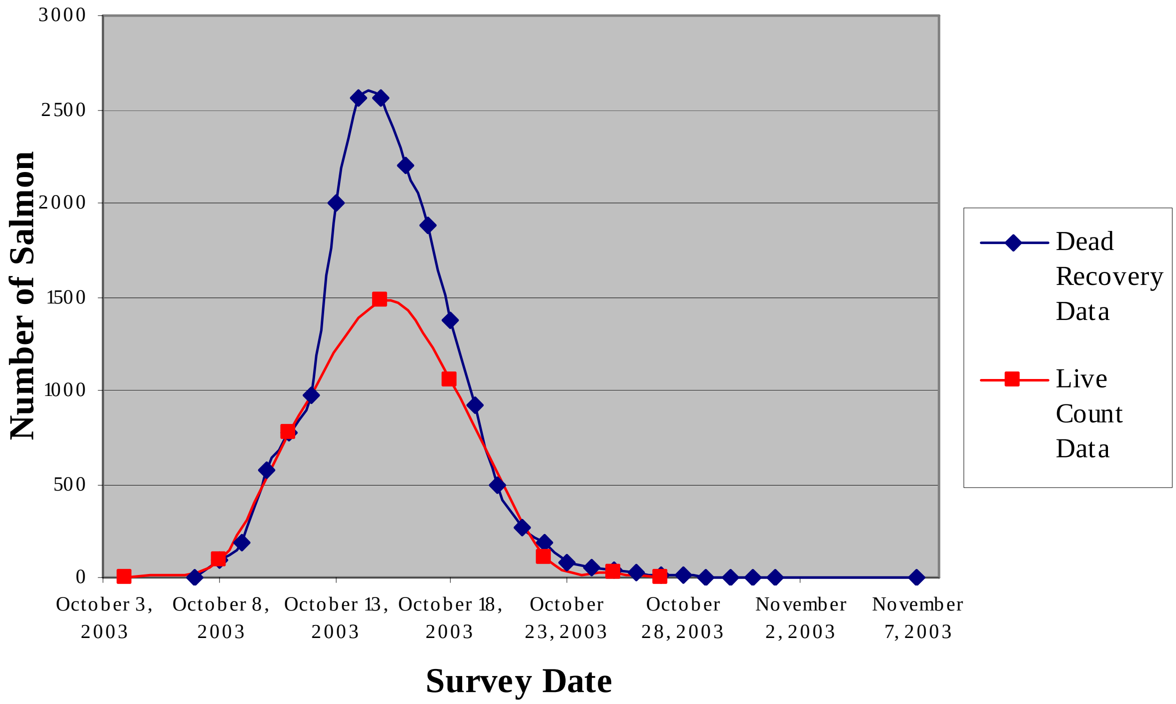


Figure 15 – A comparison of curves generated from live count and dead recovery data in 2003 on the Weaver Creek spawning channel.

The result is likely an underestimation of residence time with the live count data of 4.82 days. The value obtained from the dead recovery data of 6.73 days is more likely to be closer to the true value. From this data, it is safe to say that the real value lies somewhere between 4.82 and 6.73 days.

5.0 Conclusion

Three independent residence time values were determined from this study. The mean values for the three residence times calculated fell within the range of 4.82 to 6.73 days. The average of the three residence time estimates was 5.73 days, a value that is consistent with the expected result of a residence time ranging from 3 to 10 days (Grant, pers. comm., 2003).

Statistical weighting of the discrepancies in the data provided by the Weaver Channel staff allowed for the development of two additional residence time estimates. The averaging of three different estimates of residence time for the same system bolsters the confidence of the result. It may, however, be problematic to take an average from these three values because they were derived from two different methods over two different years. The three residence time values and their upper and lower limits values overlap from 5.15 to 5.56 days. It may be that the true value lies somewhere within this range.

A special note should be made that this estimate was derived from data collected in a controlled and closed system. Caution should be exercised in using this estimate to assess escapement numbers in other systems. Natural systems are exposed to fluctuations in habitat quality and environmental stresses that were not addressed in this study. In order to develop a more defendable estimate of chum residence time, a similar study must be performed on a natural system and compared to the estimates calculated in this study. This will allow for a direct comparison of natural versus man made systems and determine if there are differences in resident times between these two system types.

6.0 Recommendations

In order to give validity and confidence to the residence time data derived from the spawning channel, a similar study must be performed on a natural system and compared. The differences between the complexities of a natural versus man-made system may account for differences in residence time values. Future study in the form of a head to head comparison is necessary to evaluate whether there is a significant difference between natural and man-made systems.

The level of confidence in the residence time that was derived from visual surveys of the creek and spawning channel was not very high due to difficulties with observation. These difficulties are primarily glare and fish stacking. Although polarized glasses did help to reduce glare, it is recommended that visual survey of the creek or spawning channel be conducted at the earliest hours of the day to maximize the use of flat light. Stacking of fish or the congregation of fish in confined areas was also problematic for the accuracy of counts and is best avoided by taking counts with more than one crew member and calculating an average.

To this end, should the Weaver Creek project be conducted in the future, it is recommended that four people conduct the counts. Two on the natural portion of Weaver Creek and two along the spawning channel. Counts must certainly be done every three to four days and be commenced no later than three days after the first chum is put into the system. Close communication with the hatchery staff will ensure that the project will run smoothly. To improve the accuracy of the results, the study team might consider adding extra surveys near peak of spawn.

Training by a DFO technician in fish identification and visual survey techniques would be an asset to ensure consistency among surveyors. Overlap between sockeye and chum salmon in size as well as coloration can make identification challenging. Proper training will certainly improve this area of the study.

7.0 References

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8.0 Appendices

8.1 Appendix I - Weaver Creek Spawning Channel Live Counts by Visual Survey, 2003

Reach	Date of Expanded Count				
	Oct-15	***Oct-18***	***Oct-22***	***Oct-25***	***Oct-27***
25	8	10	1	1	0
24	25	21	7	4	0
23	19	16	7	1	0
22	22	16	9	5	0
21	28	14	5	3	0
20	39	47	31	14	0
19	29	8	0	0	0
18	35	17	0	0	0
17	41	28	3	0	0
16	51	52	2	0	0
15	143	109	5	0	0
14	77	66	4	0	0
13	58	83	1	2	0
12	29	27	1	0	0
11	16	8	1	0	0
10	57	34	2	0	0
9	21	17	0	0	0
8	74	34	2	0	0
7	72	35	2	0	0
6	86	49	5	0	0
5	60	59	4	0	0
4	80	62	3	0	0
3	91	68	4	0	0
2	110	64	1	0	0
1	102	55	5	0	0
0	103	55	6	0	0
Total Channel Count	**1476**	**1053**	**111**	**30**	**0**

8.2 Appendix II - Chum Loading and Dead Recovery, Weaver Channel, 2003

	Channel Loading			Channel Dead Recovery			Live Balance
Date	*Male/jacks*	*females*	*Total*	*Male/jacks*	*females*	*Total*	
08-Oct	43	50	93				
09-Oct	46	42	181				
10-Oct	187	208	576				
11-Oct	84	120	780				
12-Oct	66	130	976				
13-Oct	439	579	1994				
14-Oct	265	301	2560				
15-Oct	2	2	2564				
16-Oct	2	0	2566	158	183	341	2225
17-Oct			2566	142	150	633	1933
18-Oct			2566	208	255	1096	1470
19-Oct			2566	199	213	1508	1058
20-Oct			2566	201	191	1900	666
21-Oct			2566	132	83	2115	451
22-Oct			2566	43	31	2189	377
23-Oct			2566	54	38	2281	285
24-Oct			2566	15	8	2304	262
25-Oct			2566	9	10	2323	243
26-Oct			2566	5	8	2336	230
27-Oct			2566	4	7	2347	219
28-Oct			2566	0	0	2347	219
29-Oct			2566	2	5	2354	212
30-Oct			2566	0	0	2354	212
31-Oct			2566	0	0	2354	212
01-Nov			2566	0	1	2355	211
07-Nov			2566	0	1	2356	210

8.3 *Appendix III - Chum Loading and Dead Recovery, Weaver Channel, 2002*

2002	**Channel Loading**				**Channel Dead Recovery**				*Live Balance*	
	Daily		*Accum. total*		*Daily*		*Accum. total*			
Date	*Male/jacks*	*Females*	*Male/jacks*	*Females*	*Male/jacks*	*Females*	*Male/jacks*	*Females*	*Male/jacks*	*Females*
03-Oct			0	0			0	0	0	0
04-Oct			0	0			0	0	0	0
05-Oct			0	0			0	0	0	0
06-Oct	56	50	56	50			0	0	56	50
07-Oct	100	100	156	150			0	0	156	150
08-Oct	70	69	226	219			0	0	226	219
09-Oct	43	43	269	262	18	11	18	11	251	251
10-Oct	87	96	356	358	60	31	78	42	278	316
11-Oct	71	73	427	431			78	42	349	389
12-Oct	31	33	458	464	79	52	157	94	301	370
13-Oct	24	45	482	509	57	57	214	151	268	358
14-Oct	13	13	495	522	62	54	276	205	219	317
15-Oct	92	145	587	667	58	58	334	263	253	404
16-Oct	82	109	669	776	75	68	409	331	260	445
17-Oct	72	79	741	855	69	60	478	391	263	464
18-Oct	20	25	761	880	64	47	542	438	219	442
19-Oct	89	136	850	1016	51	50	593	488	257	528
20-Oct	108	118	958	1134	111	110	704	598	254	536
21-Oct	30	19	988	1153	83	164	787	762	201	391
22-Oct	22	39	1010	1192	89	103	876	865	134	327
23-Oct	77	92	1087	1284	105	145	981	1010	106	274
24-Oct	51	22	1138	1306	71	116	1052	1126	86	180
25-Oct			1138	1306	53	72	1105	1198	33	108
26-Oct			1138	1306	33	48	1138	1246	0	60
27-Oct			1138	1306	43	50	1181	1296	-43	10
28-Oct			1138	1306	22	24	1203	1320	-65	-14
29-Oct			1138	1306	107	48	1310	1368	-172	-62
30-Oct			1138	1306	0	0	1310	1368	-172	-62
31-Oct			1138	1306	48	23	1358	1391	-220	-85
01-Nov			1138	1306	0	0	1358	1391	-220	-85
02-Nov			1138	1306	9	21	1367	1412	-229	-106
03-Nov			1138	1306	2	2	1369	1414	-231	-108

Note: The channel ended up with a discrepancy gain of 108 female and 231 male chum.
This was due to:
(1) improper installation of the holding pens and
(2) the night crew not closing the channel entrance gate while sorting surplus.

8.4 Appendix IV – Weaver Creek Reach Divisions

Reach/Feature	Start	Finish	Length	Description	Landmark
1	0	80	80	Pool	Dug out pool above fence
2	80	188	108	Riffle/Pool	Near first bend
3	188	248	60	Pool	Chum bypass enters
4	248	646	398	Riffle	First bridge crossing
5	646	1127	481	Riffle/Run	Sakwi/Weaver Creek confluence
	1167				Second bridge crossing
6	1127	1197	70	Narrow, low slope falls	Spawning channel intake
7	1197	1317	120	Pools	
	1593				Third bridge crossing
8	1317	1692	375	Riffle	Old foot bridge
9	1692	1814	122	Riffle	Braid
10A	1814	2362	548	Heavy Riffle	Braid
10B	NM	NM	NM	Heavy Riffle	Braid
11	NM	NM	NM		Start of sloped boulder section

NM: No measurement

8.5 *Appendix V – Layout of Reaches on the Natural Portion of Weaver Creek above the Spawning Channel Diversion Fence*