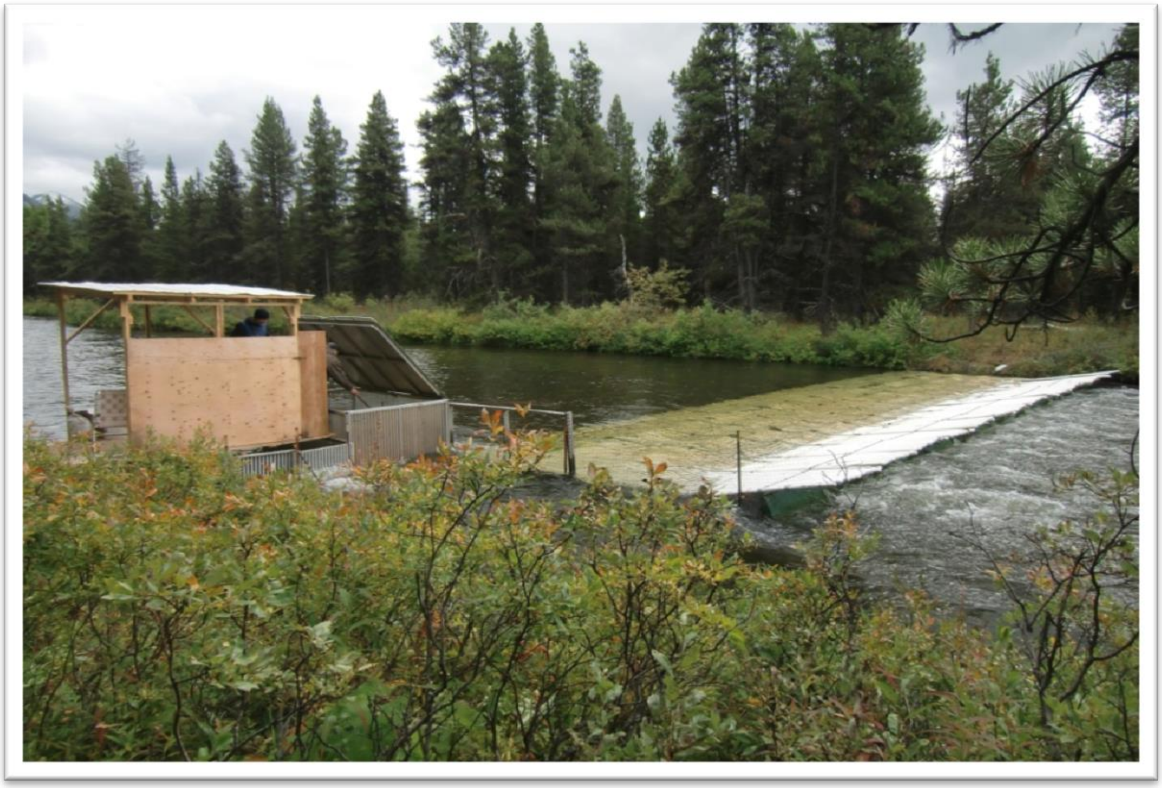
Enumeration of Adult Steelhead in the Upper Sustut River
2016



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Executive Summary

From August 1 to September 30, 2016, a fish weir was in operation on the upper Sustut River. This weir is used to count migrating summer-run Steelhead (*Oncorhynchus mykiss*) and provides annual monitoring information for this species. One thousand, five hundred and thirty two (1532) Steelhead were counted passing the weir during this project in 2016. This is the highest recorded escapement over the past twenty-three years and is 99% higher than the historical average annual count for this project (*n*=772).

The first Steelhead migrated through the weir on August 8 and by September 1, 50% of the Steelhead had passed the weir. Approximately 67%, (*n*=1029) of Steelhead counted crossed the weir in five days, on August 28 (*n*=208), August 31 (*n*=200), September 1 (*n*=345), September 2 (*n*=126) and September 26 (*n*=150). Steelhead were counted on 50 days of this 63 day project.

Of the 1532 Steelhead that migrated past the weir, 1019 (67%) were female and 513 (33%) were male resulting in a F:M sex ratio of 1.99:1.

Over the course of the project, 302 Steelhead were sampled for nose-fork length; 110 males and 192 females. Male displayed a wider range of lengths (590 to 930 mm) and significantly larger mean length ($\overline{x}$=778, SD=66, *n*=110) than females (645 to 870 mm, $\overline{x}$=732, SD=43, *n*=192).

Gillnet scars were present on 3% (*n*=52) of all Steelhead that passed through the weir in 2016. Fish with gillnet scars arrived at the weir between August 28 and September 29, and were fairly evenly distributed across this time period. Thirty seven of the Steelhead observed with net scars were female and fifteen were male, a ratio of 2.5:1.

Water temperature at the weir ranged between 3.4°C and 13.5°C, averaging 9.47°C. Water levels ranged from a low of 0.13 m to a high of 0.55 m and averaged 0.25 m. Comparison of mean water levels at the weir after 2015 to historical measurements was not possible as the staff gauge was moved 100 m upstream from its former position in 2015.

Recommendations of this report include suggestions to enhance management and conservation of the upper Sustut River Steelhead population, potential improvements to study design, evaluation of methods for collecting environmental variables and the potential for juvenile assessments to create a comparison to carrying capacity estimates.

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1.0 Introduction

Since 1994, the upper Sustut River Steelhead (*Oncorhynchus mykiss*) population has been monitored in a standardized manner at a counting weir during the months of August and September. This information provides insight into annual adult escapement for the stock and is believed to demonstrate trends in the abundance of all early summer-run Steelhead in the Skeena watershed. Perpetual concerns exist regarding the conservation of early summer-run Steelhead stocks in the Skeena watershed as their run timing coincides with marine mixed stock commercial fisheries for Chinook (*O. tshawytscha*) Sockeye (*O. nerka*) and Pink (*O. gorbuscha*) salmon where they are incidentally captured (Ward *et al*, 1993; Cox-Rogers, 1994). Due to the long distance of their freshwater migration, Sustut River Steelhead are exposed to multiple sources of natural mortality, as well as added mortality from First Nations and recreational fisheries.

Upper Sustut River Steelhead are a unique population within the Skeena River watershed. Over-wintering, spawning and rearing occur at high elevations in the Sustut Lake (1306 m) and Johanson Lake (1448 m) watersheds. The short growth season in this region prolongs the rearing component of their life-history. The mean smolt age for upper Sustut River Steelhead is 4.5 years (Tautz *et al*, 1992). In comparison, most British Columbia Steelhead populations produce smolts that range from two to three years of age (McPhail, 2007).

The Sustut River is designated as a Class 1 Classified Water from September 1 to October 31. Angling is prohibited from January 1 to June 15 and in a zone above the BC Railway bridge near the Bear-Sustut river confluence (all year) to protect overwintering and emigrating Steelhead. There is no access to the section of river below the railway bridge via road; anglers most commonly reach this area by helicopter or jet boat from fishing lodges on the lower Sustut River.

The objectives of the upper Sustut River Steelhead enumeration project are to:

1. enumerate the upper Sustut River summer-run Steelhead population
2. examine the biological characteristics of Steelhead throughout the run
3. investigate the number and distribution of gillnet scarred Steelhead throughout the run
4. examine the effect of water level and temperature on Steelhead migration
5. examine the relative run timing of male and female Steelhead

Although the objectives of the project relate to Steelhead, other species are enumerated during weir operation. Data for Chinook, Sockeye, Coho (*O. kisutch*), Bull Trout (*Salvelinus confluentus*), Rocky Mountain Whitefish (*Prosopium williamsoni*) and Rainbow Trout are also recorded during operation of the Sustut weir. Salmon data is forwarded to Fisheries and Oceans Canada for analysis and archiving (Appendix Table 1).

2.0 Study Area

The Sustut River is a tributary of the upper Skeena River, located in north central British Columbia (Figure 1). It originates in the Omineca Mountains approximately 200 km north of Smithers, B.C. and flows for approximately 108 km from the outlet of Sustut Lake to the Skeena River. The mainstem section of river from Sustut Lake downstream to, and including, Johanson Creek form the primary spawning areas for Steelhead in the upper Sustut River (Bustard, 1993). This river drains approximately 3,574 km^2 and has seven main tributaries including Birdflat Creek, Bear River, Asitka River, Red Creek, Two Lake Creek, Moosevale Creek and Johanson Creek.

Fish species known to inhabit the upper Sustut River include Steelhead, Chinook, Sockeye, Coho, Bull Trout, Dolly Varden (*S. malma*), Rocky Mountain Whitefish and Burbot (*Lota lota*) (Bustard, 1993). The area that defines the upper Sustut River Steelhead population is the Sustut River upstream of the Bear River confluence including Johanson Creek and Sustut and Johanson Lakes (Spence *et al*, 1990; Figure 2). The area that defines the lower Sustut River Steelhead population is the Sustut River downstream of the Bear River confluence, including Bear River and Bear Lake (Spence *et al*, 1990).

3.0 Methods

3.1 Steelhead Enumeration

A floating fish weir constructed from 3.8 cm PVC pipe was installed in the Sustut River 600 m upstream of the Moosevale Creek confluence (Figures 2 and 3), approximately 97 km upstream from the confluence of the Skeena and Sustut rivers. It is important to note that as a result of localized erosion, the weir was repositioned in 2015, to a new location approximately 100 m upstream (Figures 3 and 4).

The weir was in operation between August 1 and September 30, 2016. Upon arriving at the weir, fish were directed into an aluminum trap box where they remained until a gate was opened allowing upstream migration to continue (Figures 5, 6 and 7). The total count of Steelhead migrating past the weir between August 1 and September 30 has historically reflected the majority of the upper Sustut River Steelhead population that spawns upstream of the weir. The count recorded during this time period is used for comparison amongst years. This information is believed to demonstrate trends in Steelhead abundance for other upper Skeena River tributaries. A count of Steelhead crossing the weir after September 30 is periodically recorded, in addition to Steelhead holding below the weir upon its removal. This information is not added to total counts as it is not consistently measured. In some years, water clarity is limited and accurate visual counts are not possible.

During operation, the weir was inspected a minimum of three times a day. Debris was removed and repairs were made as necessary. The trap box was checked in the morning, afternoon and evening during low levels of fish migration. At peak migration, the weir was checked in the morning and a member of the project crew remained on site throughout the afternoon and evening. Experience indicates that human activity around the weir often delays or halts migration (Ron Steffey pers. comm.). Therefore, the removal of debris and carcasses from the weir was limited to avoid affecting fish migration.

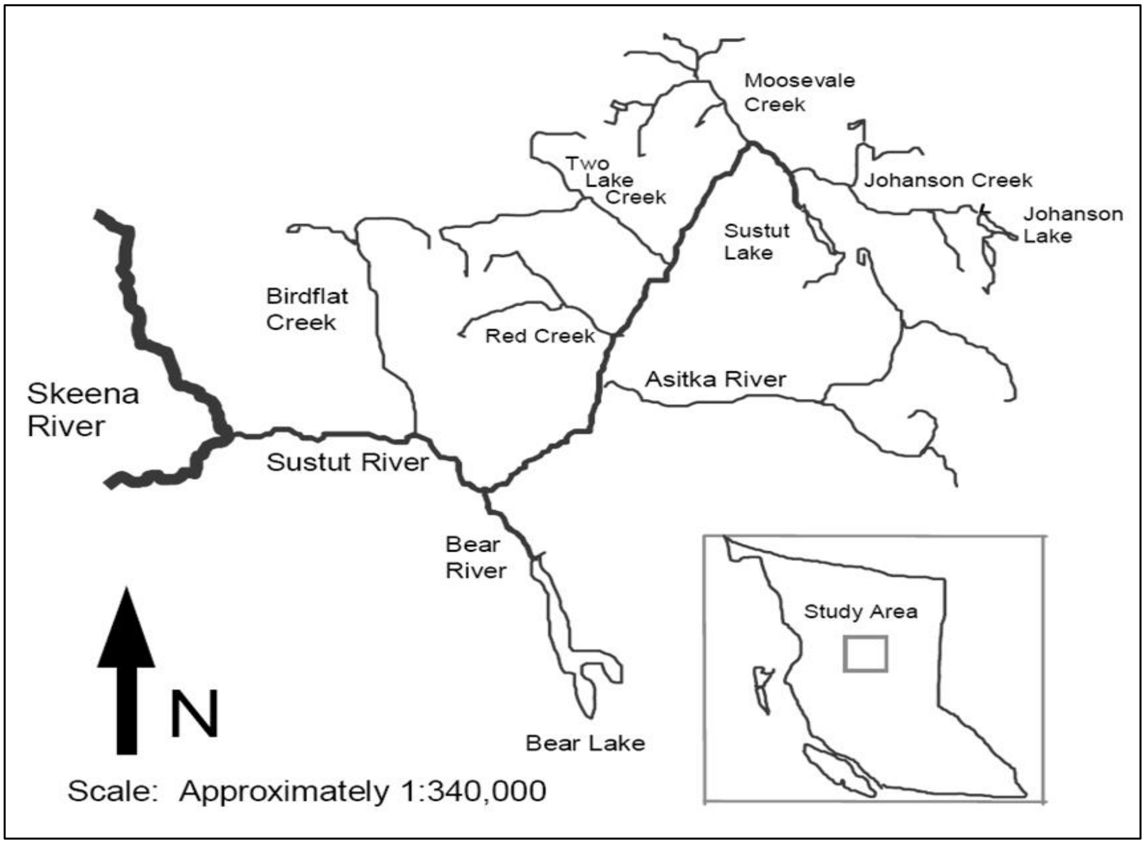

Figure 1. Sustut River and surrounding tributaries (Saimoto, 1995)

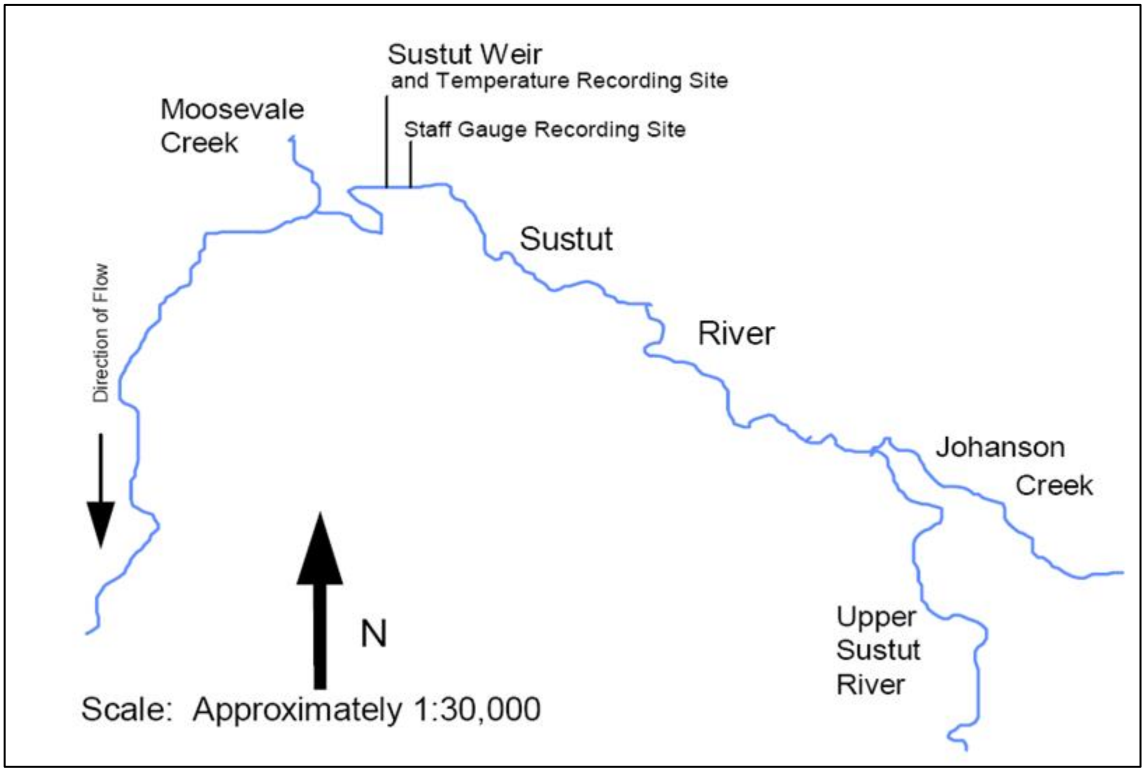

Figure 2. Sustut enumeration weir location on the upper Sustut River

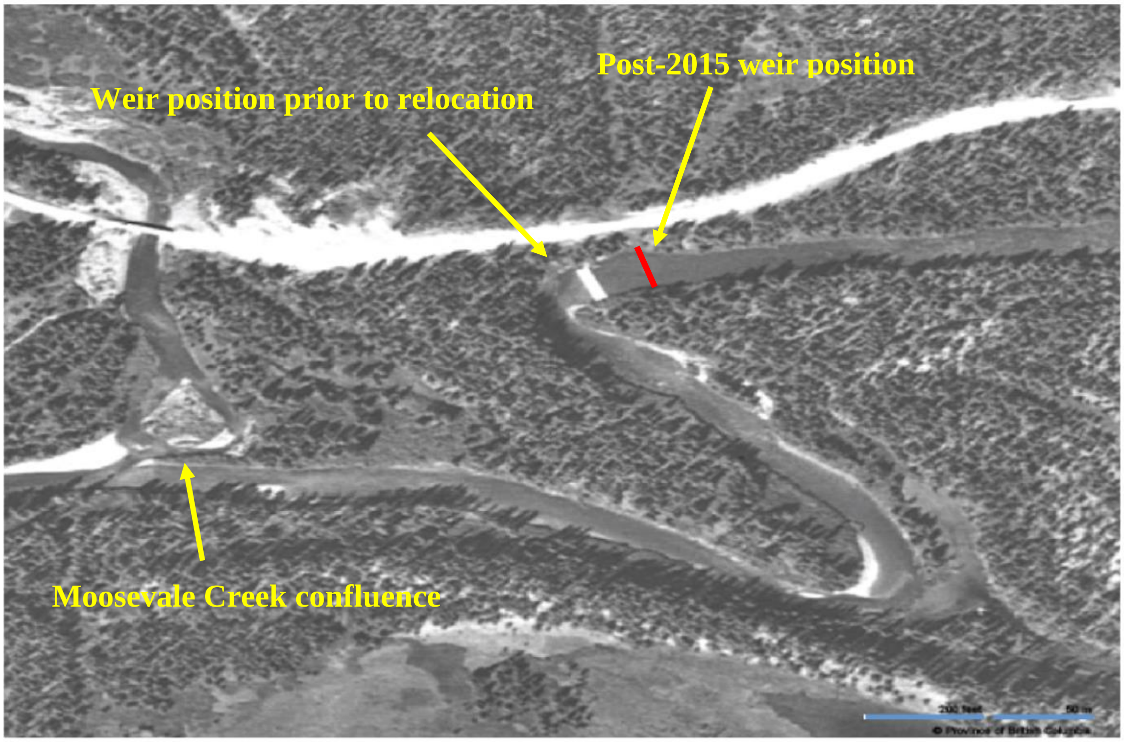

Figure 3. Aerial view of Sustut enumeration weir relocation

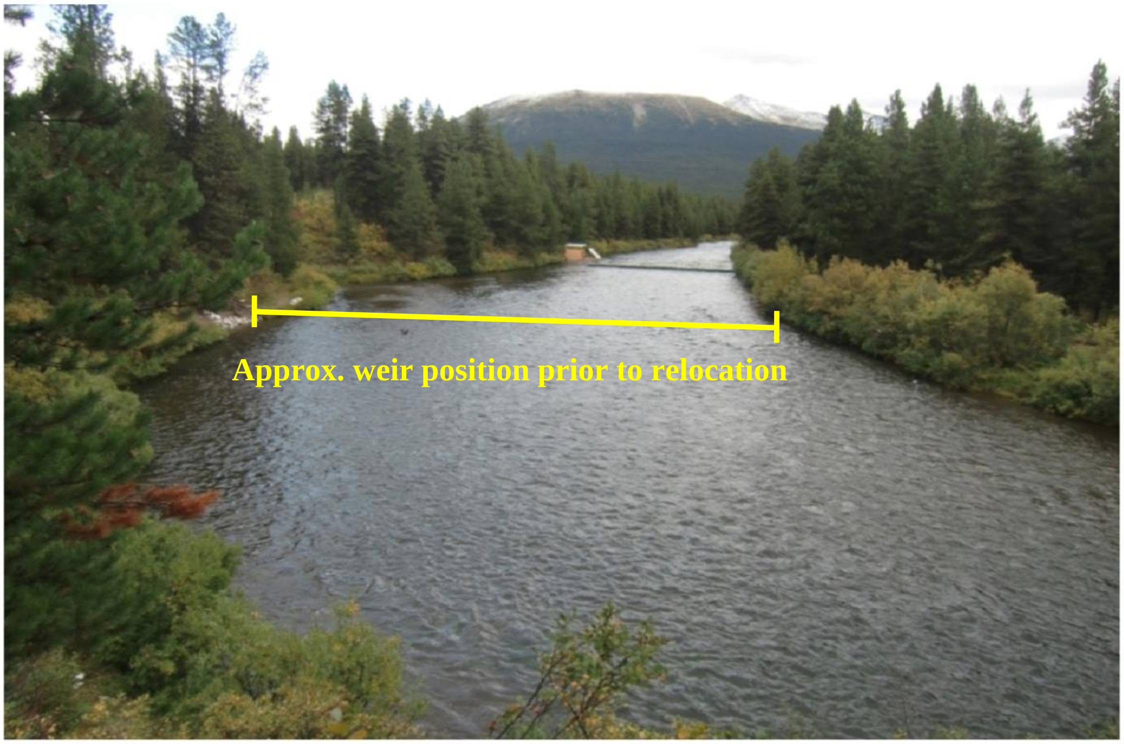

Figure 4. Ground view of Sustut enumeration weir relocation
Photo courtesy of Mark Beere

Figure 5. Sustut enumeration weir looking downstream
Photo courtesy of Mark Beere

Figure 6. Sustut enumeration weir looking upstream
Photo courtesy of Mark Beere

Figure 7. Sustut enumeration weir trap box entrance
Photo courtesy of Mark Beere

Figure 8. Staff gauge location upstream of the repositioned Sustut enumeration weir
Photo courtesy of Mark Beere

3.2 Management Framework

The upper Sustut Steelhead stock is managed according to *A Conceptual Framework for the Management of Steelhead, Oncorhynchus mykiss* (Johnston *et al*, 2002). This framework identifies stock specific biological reference points for Steelhead conservation. These include a minimum target reference point (TRP) and a limit reference point (LRP) to describe desired and highly undesired states for fish abundance (Figure 9).

For the purposes of this study, TRP was defined as 0.25**B* (the asymptotic maximum recruitment) as this value approximates the spawner abundance that produces the maximum long-term yield. If a stock falls below the TRP, it is considered overfished. LRP was defined as 0.15**B*, the spawner abundance from which the population will recover to the TRP in one generation in the absence of harvest.

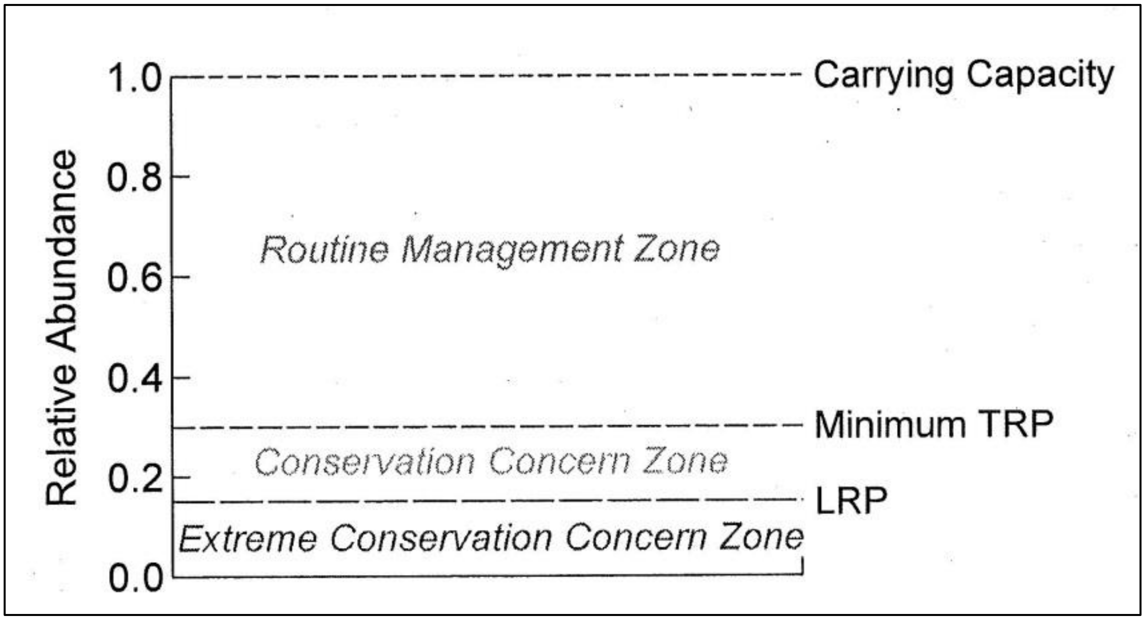

Figure 9. Management framework for the upper Sustut River Steelhead population (Johnston *et al* 2002)

Below, between and above these thresholds are three management zones described as the Routine Management Zone, Conservation Concern Zone and the Extreme Conservation Concern Zone (Figure 9). These zones and their corresponding management actions are discussed in detail in Johnston *et al* (2002).

Abundance estimates and Steelhead carrying capacity were determined using a habitat based productivity model developed by Tautz *et al* (1992). This model indicates an adult production potential of 1036 Steelhead for the upper Sustut River. Annual Steelhead counts were compared to this value, enabling abundance to be assessed relative to management thresholds.

While alternate adult production estimates exist for the upper Sustut River Steelhead population (884; Lessard, 2005), the value of 1036 was selected for this report. This value yields a more precautionary Target Reference Point (TRP) which enhances the ability to protect the unique attributes of the upper Sustut Steelhead stock including early run timing, distance and elevation gained during migration ("mile high" Steelhead) and the unique genetic heritage associated with these traits.

3.3 Steelhead Biological Information

Experienced personnel using the visual characteristics described in Scott & Crossman (1973) and McPhail & Carveth (1994) identified all fish passing the weir by species. This information was recorded and summarized daily. A plexiglass viewing box was used to identify fish by species and sex and to observe scars, wounds and general condition. Approximately 20% of all male and female Steelhead passing through the weir were sub-sampled for nose-fork length and scale ageing, 21% and 19% respectively.

Steelhead lengths were collected by netting fish from the trap box (Figure 7) and measuring their nose-fork length to the nearest half centimeter. For age determination, five scales were collected from sampled fish mid-laterally between the dorsal and anal fins. Any mortalities recovered from the weir were also measured for nose-fork length and had scale samples collected.

To determine whether a difference in nose-fork length existed between males and females sampled during the study, an independent t-test assuming unequal variances was used.

A total of 302 scale samples were analyzed by Birkenhead Scale Analyses who determined length of freshwater and ocean residency and incidence of spawning events. FLNRO staff then filtered the scale ages by condition, including condition codes 1, 5, 5a, 6, 8 and 9 in the analysis. A total of 10 scale samples (3%) were not included in the analysis as they were in poor condition (code 2). No scale samples were assigned codes 3, 4, 7 or 8 in 2016. See Appendix Table 2 for full scale condition code descriptors.

For scales identified as condition code 6 (regenerated, n=53), all salt water (SW) ages were included in the analysis (total SW ages n=292). Excluding all code 6 scales from the analysis would have negatively biased the reported repeat spawning rate. Approximately 17% of code 6 scales (n=53) showed evidence of at least one spawning event, compared to 8% for the full sample (n=239). In addition, where freshwater (FW) age estimates were available for code 6 scales (n=32), they were included in the analysis (total FW ages n=271). Statistical analyses showed no difference between nose-fork lengths of the total sample, included or excluded code 6 fish, so the included FW ages were assumed to be accurate enough for monitoring purposes (i.e.: no significant differences in length structure as a proxy for age structure).

3.4 Steelhead Tagging

Steelhead intercepted in Alaskan commercial fisheries, Canadian commercial fisheries, First Nation fisheries and the Tyee Test Fishery may be tagged or marked prior to release. Steelhead enumerated at the weir were checked for the presence of these tags and marks. This information allows fisheries managers to assess migration rates, interception in domestic and international fisheries and survival following capture in these fisheries.

3.5 Steelhead Gillnet Scars

The presence of gillnet scars was noted for all Steelhead that migrated through the weir to the extent possible. The plexiglass viewing box allowed this information to be collected and avoided the need to handle fish. In some cases, not all fish with net scars may have been recorded due to turbid water conditions or limited observation time during high rates of migration.

3.6 Water Temperature and Level Measurement

Onset Hobo Pro v2® temperature loggers were placed in the river and in the air near the weir site to record hourly water and air temperatures. The water temperature loggers were placed at the upstream and downstream sides of the trap box respectively (about 2.5 meters apart) and have been secured in consistent locations annually since the current weir technicians (Moose Valley Outfitters) began operating the weir. Hourly data from the two water temperature loggers was averaged. For backup purposes, stream water and air temperatures were recorded each day using a minimum-maximum thermometer.

Water level measurements were recorded from a metric staff gauge located immediately upstream of the weir (Figure 8). Levels were recorded by weir staff twice a day, typically in the morning (~0900H) and evening (~2000H). Weir staff also recorded air temperature and weather conditions daily. For comparison purposes, the two daily water level measurements were averaged to determine the mean daily water level. Mean daily water temperature and level were compared against daily Steelhead migration to measure potential links between these variables.

As previously noted, the Sustut weir was repositioned in 2015, to a new location approximately 100 m upstream of the previous location. The staff gauge used for measuring water level was also moved and was fixed upstream of the new weir site (Figure 8). Moving the staff gauge, and the associated change in stream bathymetry, has implications for this project, which are provided in the discussion and recommendations sections of this report.

3.7 Male and Female Steelhead Run Timing

Run timing of male and female Steelhead was examined by plotting the cumulative percent of male and female Steelhead over the duration of weir operation.

4.0 Results

4.1 Steelhead Enumeration

Between August 1 and September 30, 1532 Steelhead migrated past the Sustut enumeration weir. This value is nearly twice the long term average (*n*=772; Table 1) and represents the highest recorded Steelhead count since monitoring began (Figure 10).

The first Steelhead migrated past the weir on August 8 and by September 1, 50% of the Steelhead enumerated had passed the weir (Table 1). This represents the second earliest date at which 50% of the migration has passed the weir. Since 1994, the date on which the first Steelhead arrived has ranged between July 28 (2004) and August 18 (1999). Information collected prior to 1994 was not included due to the variation in weir design and location.

The cumulative proportional distribution of Steelhead over time (Figure 11) indicates that approximately 67%, (*n*=1029) of Steelhead counted crossed the weir in five days, on

August 28 (*n*=208), August 31 (*n*=200), September 1 (*n*=345), September 2 (*n*=126) and September 26 (*n*=150). Steelhead were counted on 50 days of this 63 day project.

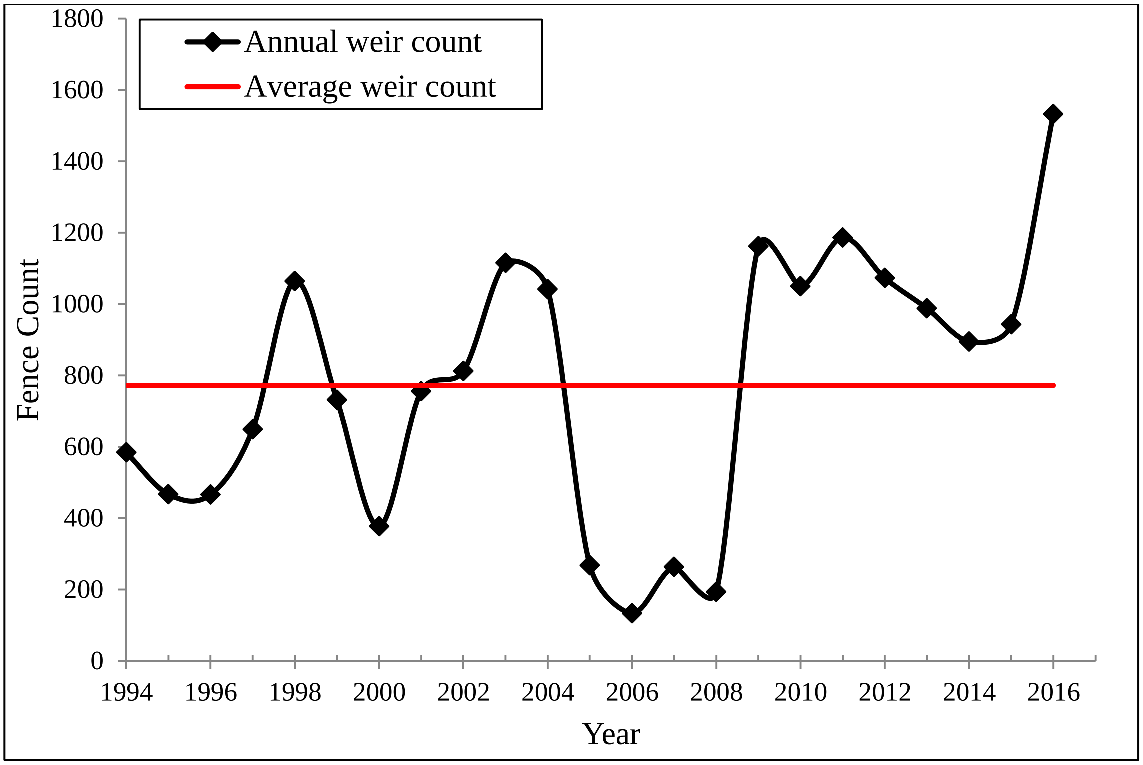

Figure 10. Annual total count of Steelhead migrating past the Sustut enumeration weir

Table 1. Sustut enumeration weir migration timing and environmental data

Year	Arrival Date of First Steelhead	Date of 50% Migration	Total Steelhead Enumerated	Rank	Mean water temperature (°C)	Mean water level (m)
1994	08-Aug	29-Aug	584	16	-	-
1995	08-Aug	08-Sep	467	17	-	-
1996	17-Aug	07-Sep	466	18	-	-
1997	09-Aug	13-Sep	649	15	-	-
1998	03-Aug	07-Sep	1064	6	-	0.27
1999	18-Aug	17-Sep	731	14	-	0.28
2000	08-Aug	07-Sep	377	19	-	0.30
2001	15-Aug	16-Sep	756	13	-	-
2002	09-Aug	02-Sep	812	12	-	0.23
2003	03-Aug	02-Sep	1115	4	-	0.31
2004	28-Jul	03-Sep	1042	8	-	0.34
2005	31-Jul	03-Sep	268	20	8.81	0.32
2006	09-Aug	04-Sep	133	23	8.71	0.21
2007	09-Aug	09-Sep	263	21	8.81	0.16
2008	08-Aug	07-Sep	193	22	9.11	0.23
2009	06-Aug	03-Sep	1162	3	9.61	0.20
2010	03-Aug	06-Sep	1050	7	8.91	0.12

2011	13-Aug	08-Sep	1186	2	8.65	0.27
2012	11-Aug	05-Sep	1073	5	9.29	0.15
2013	03-Aug	06-Sep	988	9	10.10	0.10
2014	03-Aug	20-Sep	895	11	9.31	0.11
2015	06-Aug	10-Sep	943	10	8.38	0.30
2016	**08-Aug**	**01-Sep**	**1532**	**1**	**9.47**	**0.25**
Minimum	28-Jul	29-Aug	133	-	8.38	0.10
Maximum	18-Aug	17-Sep	1532	-	10.10	0.34
Average	-	-	772	-	9.10	0.23

Notes:
1 - Total weir count does not include fish counted in the downstream pool following weir removal.
2 – Staff gauge used to measure water level was replaced in 2007 or 2008. It was moved again in 2015 approximately 100 m upstream of its former position to accommodate a similar re-location of the weir.

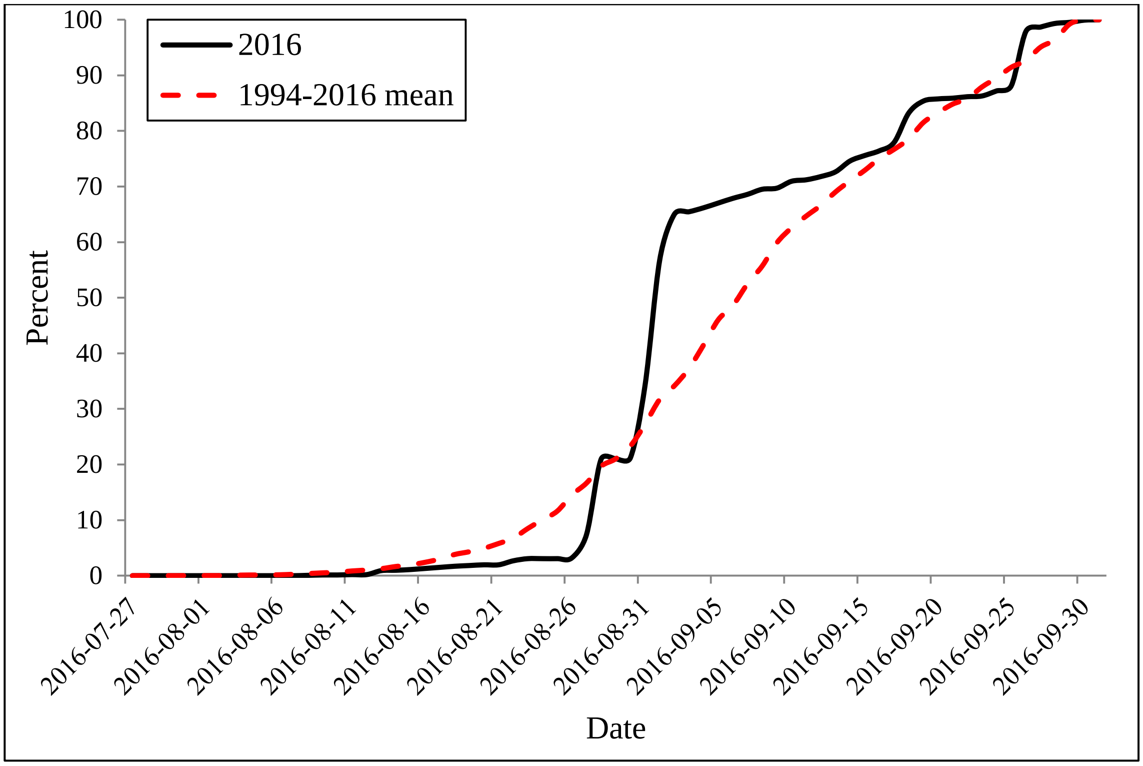

Figure 11. Daily cumulative percentage of Steelhead migrating past the Sustut enumeration weir

4.2 Management Framework

Steelhead counts through the weir have been at or above the Routine Management Zone for the last eight years. This is a significant increase compared to the preceding four years when the upper Sustut Steelhead population was within the Conservation Concern Zone and Extreme Conservation Concern Zone (Figure 12). The 1532 Steelhead that migrated through the weir represents 148% of the estimated adult production potential for the upper Sustut River (*n*=1036).

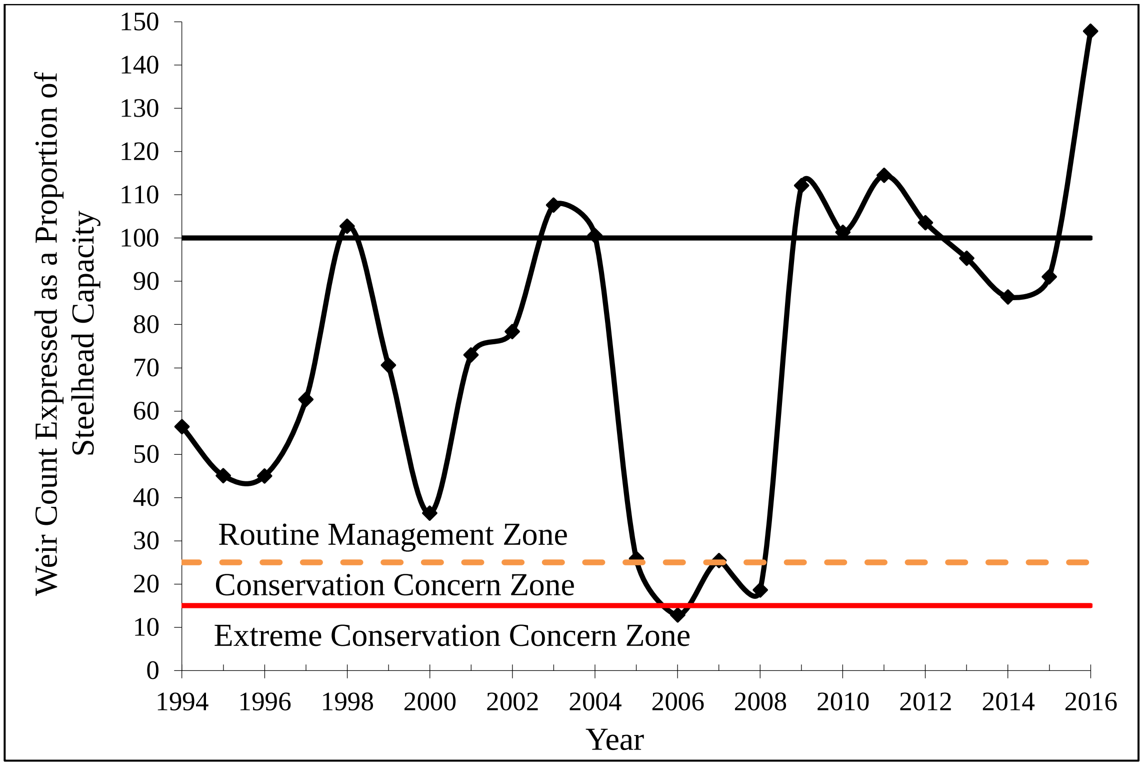

Figure 12. Annual total count of Steelhead shown as a proportion of estimated adult Steelhead capacity

4.3 Steelhead Biological Information

4.3.1 Scale analysis and age determination

The number of freshwater annuli (Figure 13) identified on all readable scale samples ranged from three to five. The predominant freshwater age was four and represented 78% (*n*=211) of the scales sampled with this information (*n*=271). Freshwater age three and five represented 5% and 17% of the sample respectively. The number of marine annuli (prior to the first spawning event, Figure 14) ranged from one to four. The predominant marine age (prior to first spawning event) was two (*n*=205) and represented 75% of scales sampled with this information (*n*=292). This is consistent with the modal ocean age of Steelhead returning to rivers throughout the province (McPhail, 2007). Maiden Steelhead (those that have not previously spawned) represented 89% (*n*=263) of the sample and 10% (*n*=29) of the scales showed evidence at least of one previous spawning event. Including all life history phases (i.e. freshwater and marine components, Figure 15), Steelhead were found to be in their 5th year of life to their 11th year of life.

Fish age was determined by adding freshwater and marine residency periods and spawning checks. For example, a Steelhead reported as 3.2S1 was deemed to have lived for approximately three years in freshwater, followed by two years in the ocean, it returned to spawn once, then returned to the ocean and was sampled during its second spawning migration. This adds to seven years plus the current year, and is reported as an individual in its 8th year of life. Age information from all fish sampled in 2016 is presented in Appendix Table 3.

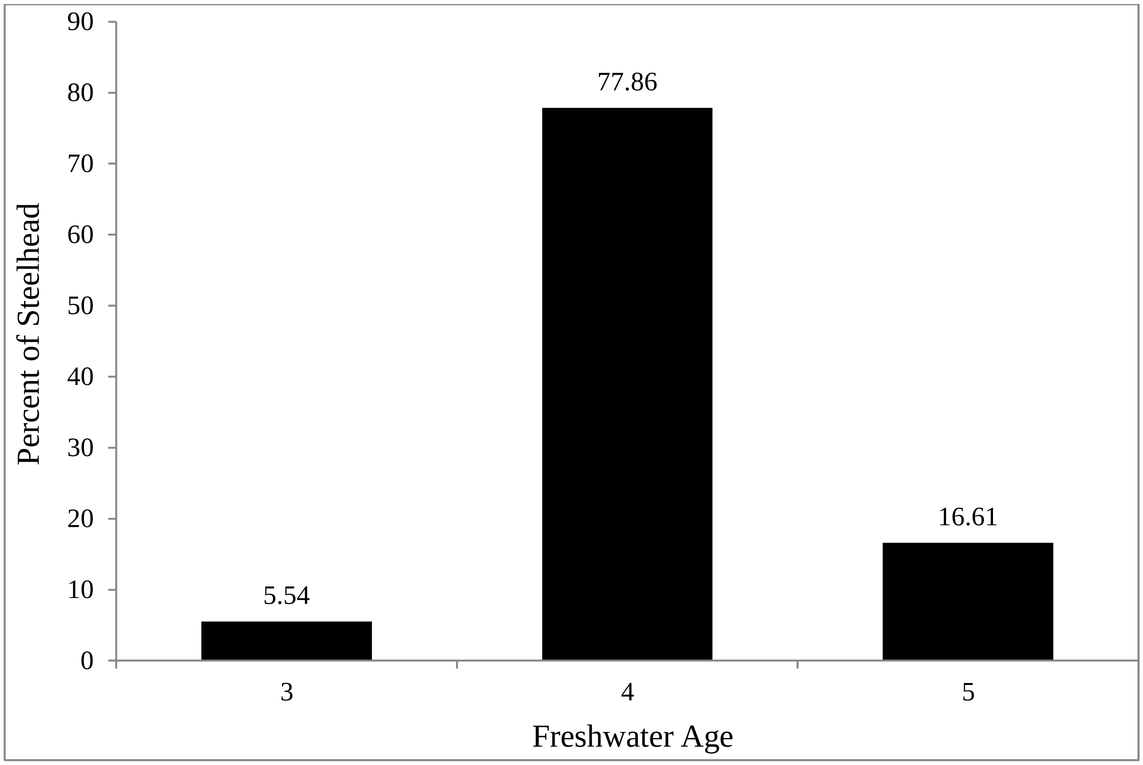

Figure 13. Freshwater ages of Steelhead sampled at the Sustut enumeration weir

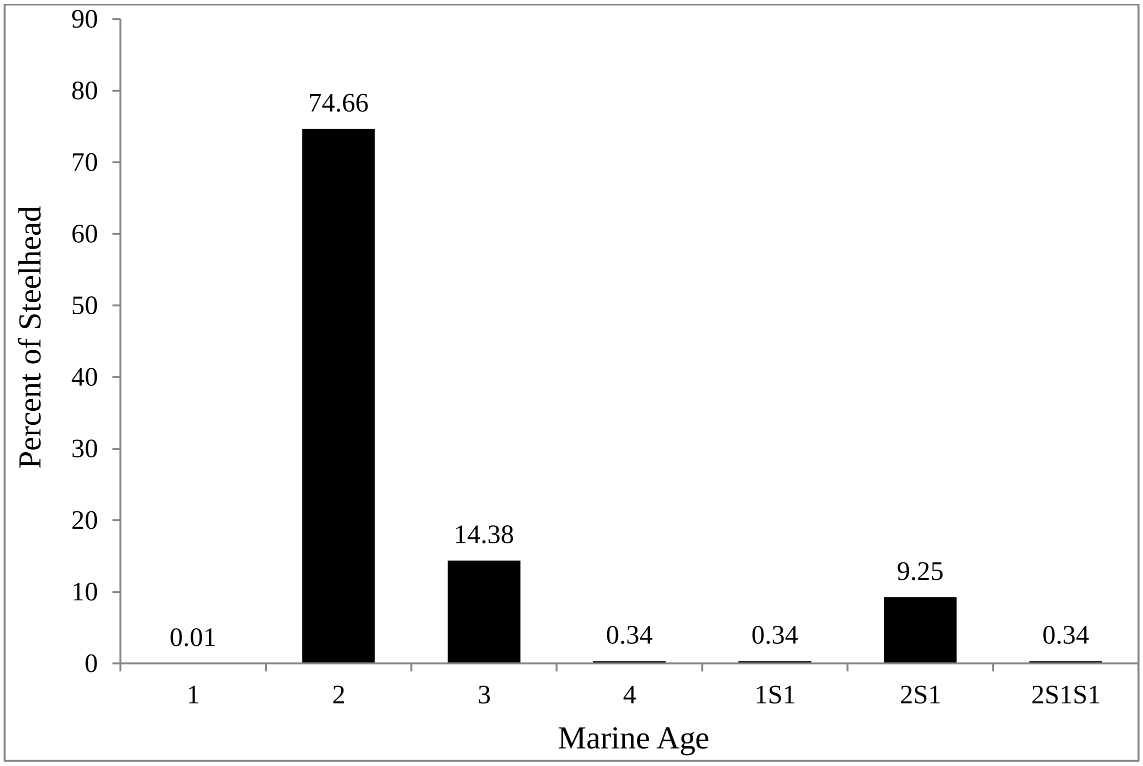

Figure 14. Marine ages of Steelhead sampled at the Sustut enumeration weir

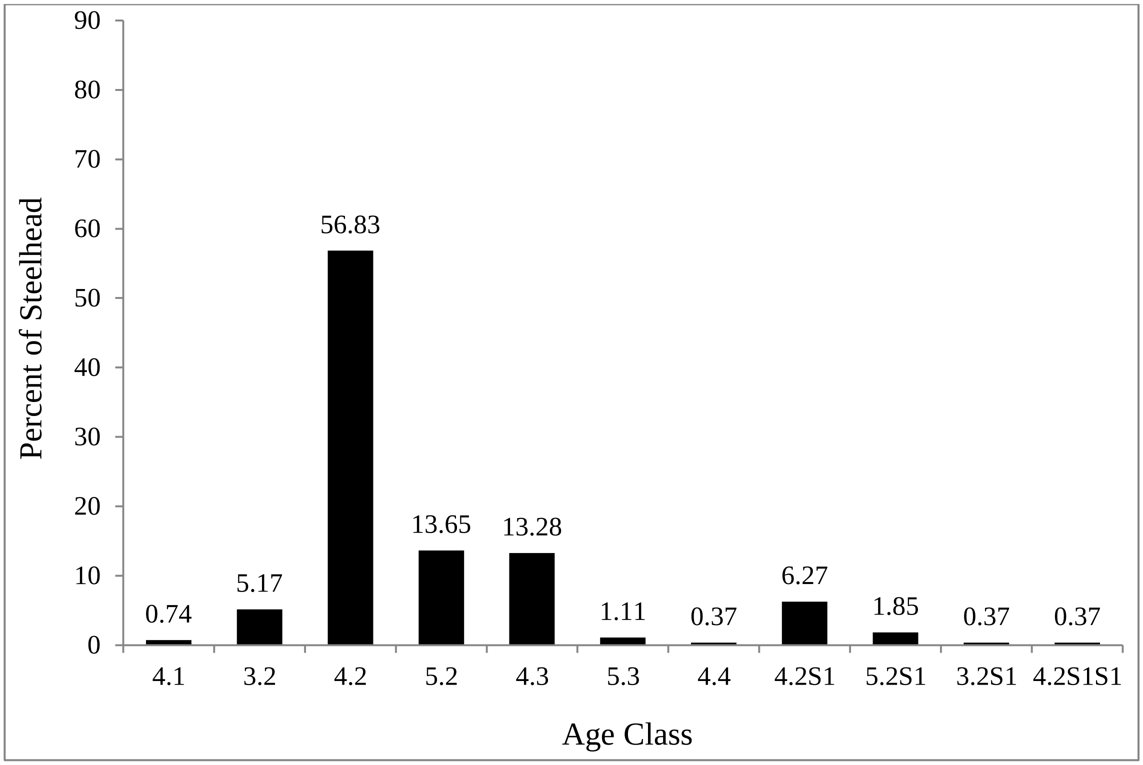

Figure 15. Age classes of Steelhead sampled at the Sustut enumeration weir

4.3.2 Length measurement and size distribution

A total of 110 male and 192 female Steelhead were measured for nose-fork length. Male lengths ranged from 590 to 930 mm and female lengths ranged from 645 to 870 mm. The percent of the total number of Steelhead measured at the weir was plotted in 20 mm increments of nose-fork length for each sex (Figure 16).

To compare the lengths of male and female Steelhead, a two sample t-test for unequal variances was used. This statistical analysis found that the mean score for female steelhead (M=732 SD 42.9, *n*=192) was significantly smaller than for males (M=778, SD=66.24, *n*=110), meaning that male fish in 2016 were, on average, larger than female fish; t(162) = 6.56, $p<0.05$.

4.3.3 Sex ratio

Of the 1532 Steelhead that migrated past the weir, 1019 (67%) were female and 513 (33%) were male resulting in a female to male ratio of 1.99:1. This is the third highest female to male ratio recorded for this project, with the lowest recorded at 1.23:1 in 1995 (Table 2).

4.3.4 Mortalities

There were no Steelhead mortalities observed at the weir during this project in 2016.

4.4 Steelhead Tagging

There were no Steelhead observed with tags at the weir in 2016.

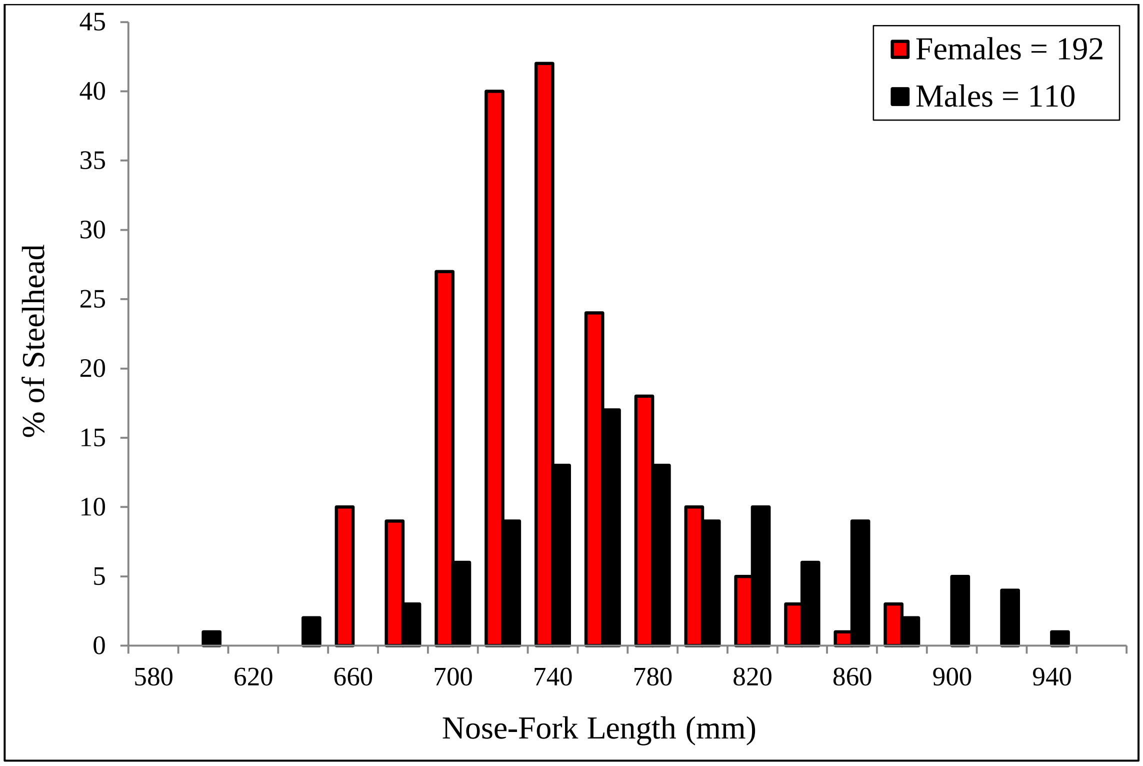

Figure 16. Percentage of male and female Steelhead by 20 mm categories of nose-fork length.

4.5 Steelhead Gillnet Scars

Weir observers recorded the presence of gillnet scars on Steelhead to the extent possible. Gillnet scars were present on 3.4% (*n*=52) of all Steelhead that passed through the weir in 2016 (Table 2). There were no significant differences in nose-fork length (n=30) or sex ratio (n=52) between gillnet scarred and un-scarred Steelhead. Steelhead with gillnet scars arrived at the weir between August 28 and September 29, with the majority of scarred fish arriving before September 10. Thirty seven of the Steelhead observed with net scars were female and 15 were male (2.5:1).

Table 2. Sustut enumeration weir Steelhead data

Year	Average Length (mm)		Fence Count	Repeat Spawners (%)	Mortalities (%)	Gillnet Scarred (%)			Sex Ratio (F:M)
	M	F				M	F	Total	
1994	824	737	584					2.0	1.55:1
1995	826	746	467	1.2	4.0			6.0	1.23:1
1996	829	739	466	1.3	2.8			14.0	1.58:1
1997	814	733	649	0.6	1.5	9.2	17.8	15.4	1.43:1
1998	827	749	1064		0.8	13.4	13.8	13.7	1.73:1
1999	848	756	731	2.5	0.3	6.1	9.9	8.5	1.64:1
2000	827	741	377	0.4	0.5	10.6	16.2	14.1	1.64:1

2001	864	771	756	2.5	1.9	10.1	14.5	12.8	1.63:1
2002			812	1.9	0.5	3.6	8.4	6.3	1.27:1
2003	780	730	1115	1.2	0.3	8.3	14.2	11.8	1.39:1
2004	818	745	1042		0.3	6.0	8.8	7.7	1.48:1
2005	859	741	268	19.0	0	3.3	5.5	4.8	2.01:1
2006			133		0	0.5	1.6	2.3	1.50:1
2007			263		0	2.7	4.6	3.8	1.39:1
2008			193		0	4.5	2.4	3.1	1.92:1
2009			1162		0.3	0.7	1.5	1.2	1.66:1
2010	793	746	1050	1.0	0	0.9	2.6	1.9	1.48:1
2011	824	756	1186	10.3	0.3	3.7	8.0	6.4	1.73:1
2012	801	728	1073	5.3	0.7	2.7	2.4	2.5	1.65:1
2013	816	752	988	9.2	0.6	0.5	0.5	1	1.96:1
2014	773	724	895	6.4	0	6.3	4.8	5.4	1.69:1
2015	804	743	943	8.2	0	0.2	1.3	1.5	2.13:1
2016	**778**	**732**	**1532**	**9.9**	**0**	**2.9**	**3.6**	**3.4**	**1.99:1**
Minimum	773	724	133	0.4	0	0.2	0.5	1.0	1.23
Maximum	864	771	1532	19.0	4.000	13.4	17.8	15.4	2.13
Mean	817	743	772	5.0	0.7	4.8	7.1	6.5	1.64

Note – Steelhead length, age and genetic information was not collected from 2006 to 2009 to eliminate handling stress while Steelhead abundance was in the Conservation Concern Zone.

4.6 Water Temperature

Water temperature was recorded hourly by a data logger from August 1 to September 30, 2016. The lowest temperature was recorded on September 16 (0900H) at 2.8°C and the highest temperature was recorded on August 3 (1700H) at 16.3°C (Figure 17). Since 2005, the average water temperature at the weir has ranged between 8.4°C and 10.1°C, averaging 9.1°C (Table 1).

4.7 Water Level

From August 1 to September 30, 2016, water levels ranged between 0.13 m (August 20) and 0.56 m (September 27; Figure 18). Water level measurements recorded for this project after 2015 cannot be compared to historical values as the staff gauge was relocated in 2015. It was fixed within a narrower and lower gradient section of river than the former position.

4.8 Male and Female Steelhead Run Timing

The first male Steelhead passed through the weir on August 8 and the first female arrived on August 9. The date when 50% of female and male Steelhead had migrated past the weir was September 1 (Figure 19).

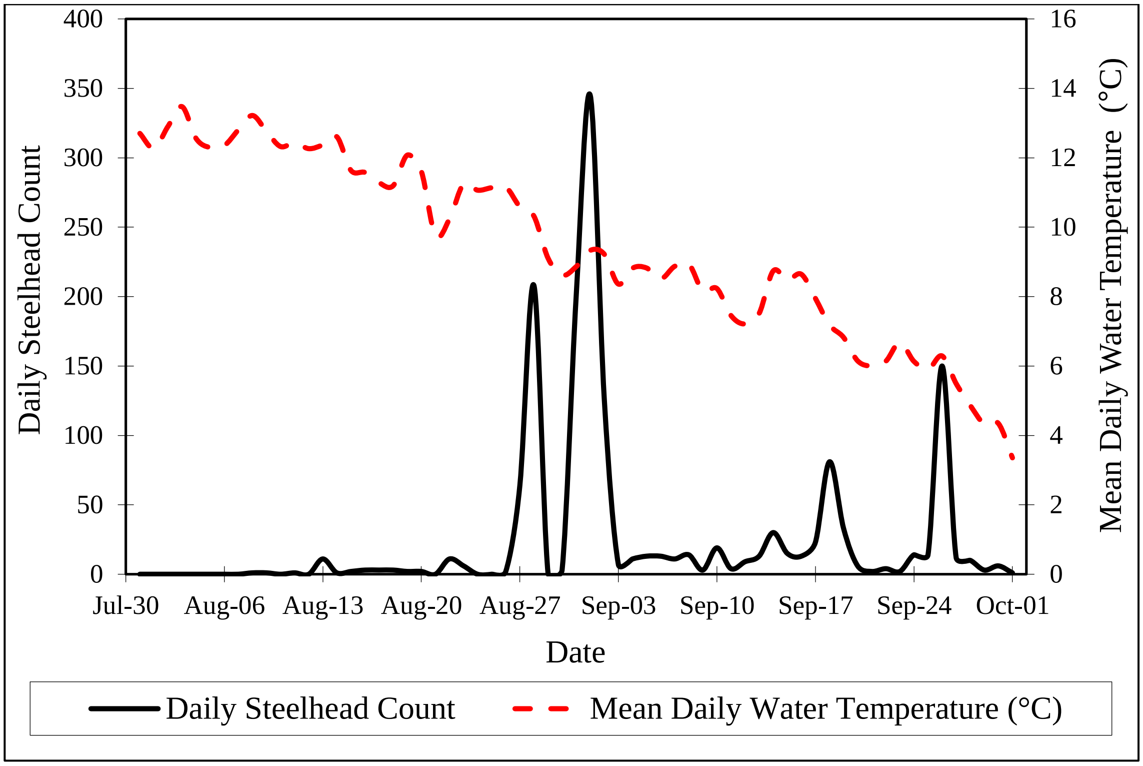

Figure 17. Mean daily water temperature and the number of Steelhead migrating past the Sustut enumeration weir

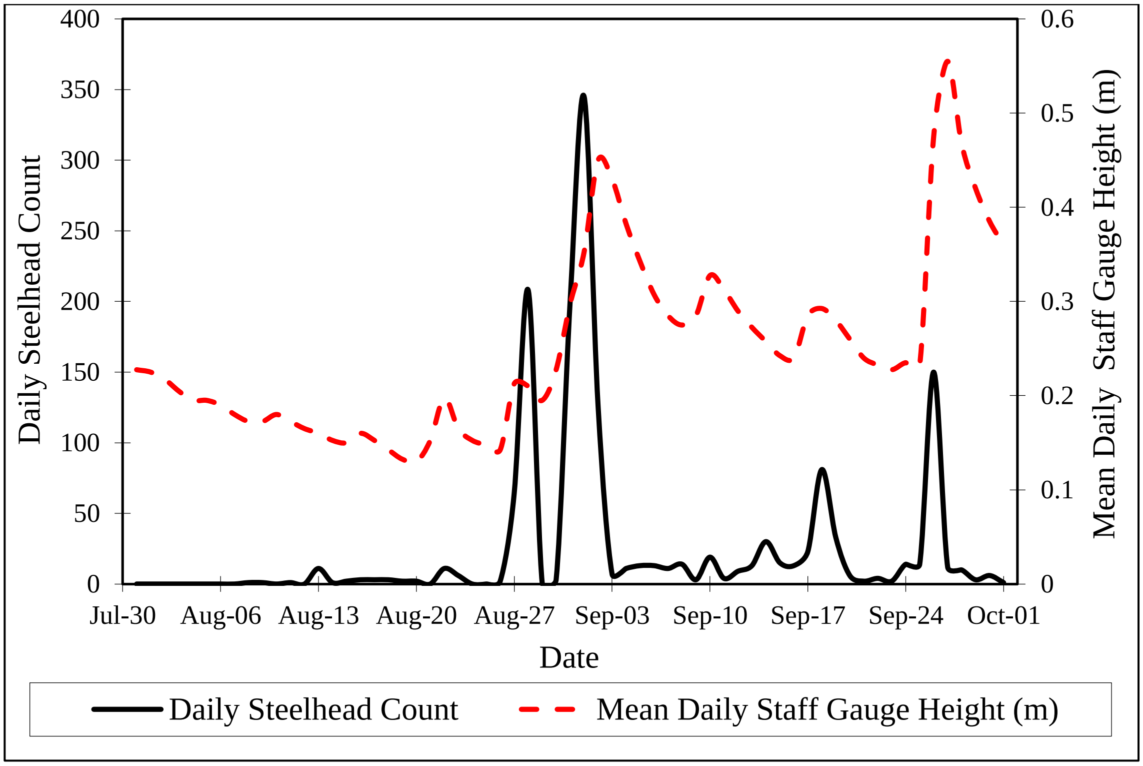

Figure 18. Mean daily staff gauge height and the number of Steelhead migrating past the Sustut enumeration weir

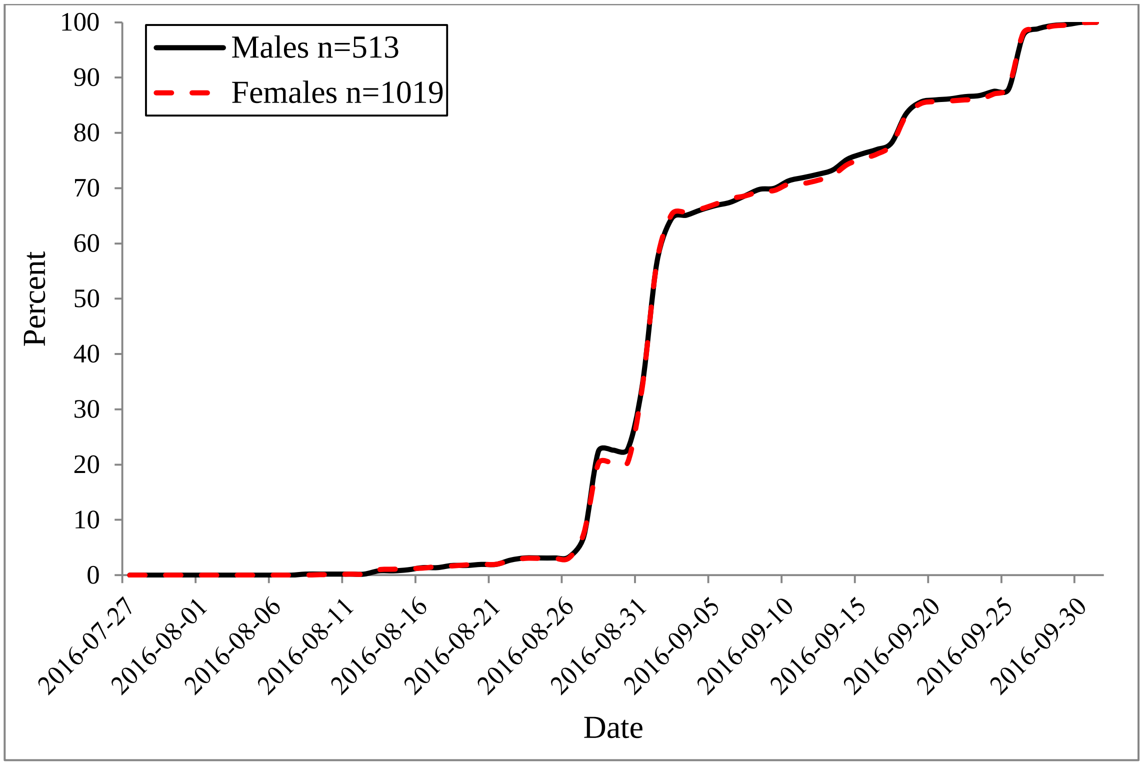

Figure 19. Daily cumulative percent of male and female Steelhead migrating past the Sustut enumeration weir

5.0 Discussion

The objectives for this project were to enumerate the upper Sustut River summer-run Steelhead population, examine Steelhead biological information, the effect of water level and temperature on Steelhead migration, the number and distribution of gillnet scarred Steelhead and the relative run timing of male and female Steelhead. The following section addresses these objectives by discussing the 2016 results and making linkages to historical findings part of this ongoing monitoring project.

5.1 Enumeration of Upper Sustut River Summer-Run Steelhead

In 2016, the Sustut River enumeration weir Steelhead count from August 1 to September 30 was 1532. This value is the highest since enumeration methods were standardized in 1994. During the last 23 years, weir counts have ranged from 133 (2006) to 1532 (2016). The 2016 population index value was approximately 99% above the long term average (*n*=772).

Since 1994, increases in Steelhead abundance have been followed by declines. Low returns during the 2005 to 2008 period fell within the conservation concern and extreme conservation concern zones (Figure 12). Potential impacts from climate change (Tydemers & Ward, 2001), shifts in freshwater and/or marine survival (Smith & Ward, 2000), interception in commercial salmon fisheries and losses from overwintering mortality (estimated at 11%; Beere, 1999) may lead to future fluctuations in Steelhead abundance. For these reasons, it is crucial that mangers take a precautionary approach to achieve the long term sustainability of this unique and vulnerable Steelhead stock.

5.2 Management Framework

According to a habitat based productivity model developed for the Skeena drainage (Tautz *et al* 1992) the 1532 Steelhead that migrated past the weir in 2016 was 48% higher than the estimated adult production at capacity for the system (1036 Steelhead).

In the context of interpreting annual weir count data relative to adult production potential thresholds, a factor to consider is the proportional difference between escapement measured in August and September and total adult returns to the upper Sustut River. In some years, large numbers of Steelhead have been observed moving through the weir site near the end of the project. For example, in 2014, 44% (*n*=394) of all Steelhead counted crossed the weir in the second to last day of this project. Further, in 2010 and 2012, 24% and 17% of all Steelhead counted crossed the weir in the last 10 days of September, which raises questions regarding the number of Steelhead that enter the upper Sustut after the weir is removed on October 1. A factor which may influence this significantly is discharge. Steelhead movements in the upper Sustut River appear to be closely linked with discharge (Figure 18). In years when discharge remains low throughout the months of August and September, a significant proportion of upper Sustut River Steelhead may not move through the weir before removal. Comparisons made between annual weir counts and adult production capacity estimates (Tautz *et al* 1992; Figure 12) rely on the assumption that weir counts represent total escapement through the weir. Based on the examples above, additional work is required assess the proportion of Steelhead entering the upper Sustut after weir removal. This may be achieved by extending weir operations into October in years when environmental conditions allow this to occur, or when low flows have been observed throughout August and September and it is observed that Steelhead are congregating in areas below the weir. Minimally, an approximate count of steelhead holding immediately below the weir should be conducted prior to weir removal.

The record number of Steelhead observed crossing the weir in 2016 presents a unique opportunity to conduct field based investigations into carrying capacity, fry density and smolt production in order to develop direct comparisons to model estimates from Tautz *et al* (1992). Such research would provide a high contrast picture of carrying capacity estimates due to the high abundances of offspring that would be expected after such a large return of adult Steelhead. Field based investigations of this nature may also shed light on management concerns surrounding the high sex ratio observed in this population, as described in the following section.

5.3 Sex Ratio

While the sex ratio observed at the Sustut enumeration weir has been female biased since 1994, it is higher than sex ratios reported for other major Steelhead bearing tributaries in the Skeena watershed (Parken & Morten, 1996).

The female biased sex ratio observed on the upper Sustut River is of management concern. Moore *et al* (2014) highlighted the importance of life history diversity in buffering environmental variability: as repeat spawning rates increase, probability of extinction decreases. The lack of males in the upper Sustut population, particularly large bodied males, indicates a selective removal of certain life history strategies from the population. The loss of those Steelhead over time is a direct loss of life history variability which negatively impacts population sustainability and the ability of the population to withstand environmental change. In addition, one of the inherent assumptions of the carrying capacity estimate referenced throughout (Tautz *et al*, 1992) is a balanced sex ratio (Tautz pers. comm.). Further investigation into this situation is encouraged, given that the existing carrying capacity estimate is reliant on an assumption that has been violated in every year of data collection thus far.

Upper Skeena River Steelhead, for which the upper Sustut River stock is an indicator, are unique globally. They exhibit exceptional size (the largest specimens in the world), early run timing, long distance and high elevation migrations. The unique genetic heritage associated with these traits is best protected through the maintenance of as many life history strategies as possible (Moore *et al* 2014), with particular attention paid to the protection of large bodied individuals, which are known to be more successful during reproduction (Seamons *et al* 2005). The female biased sex ratio may be linked to natural and/or anthropogenic selective pressures.

5.3.1 Natural selective pressures

Smolt sex ratios in Ohms *et al* (2014) were not found to be biased to either sex. Natural mortality (e.g.: outmigrant predation, ocean survival rates) for juvenile and maiden Steelhead should affect males and females similarly. As a result, we would expect that maiden Steelhead would return from ocean migrations in an approximate sex ratio of 1:1. This has been shown to be the case with few exceptions in other long-term monitoring programs (e.g.: Seamons *et al* 2005). For non-maiden Steelhead, iteroparity has been shown to be negatively correlated with body size (Matala *et al* 2016, Narum *et al* 2008) and being male (Beere 1999). Thus we can conclude that there may be an existing natural selection pressure against large male steelhead in this population.

5.3.2 Anthropogenic selective pressures

Anthropogenic selection pressures such as exposure to gillnet fisheries appear to affect male and female steelhead differently. It appears that when upper Sustut River Steelhead encounter gillnets, male Steelhead are killed at a higher rate than females due to their larger average size and differing morphology. This impact is compounded for emigrating male Steelhead kelts or those on repeat spawning immigrations, as they usually retain some secondary sexual characteristics (e.g.: enlarged kype) which increases their already elevated risk of becoming entangled in gillnets. This selective pressure, compounded with the existing naturally higher mortality for large male steelhead, artificially inflates the female to male sex ratio and creates a management concern.

5.3.3 Potential buffers to an artificially biased sex ratio

It has been documented that stream-resident populations can buffer effective population size (Martinez *et al*, 2000). Abundance of rainbow trout has been consistently low throughout the duration of the upper Sustut enumeration weir project (annual mean RB count *n*=4.5, range 1-12). Given this observation, there is little evidence to suggest that a large stream-resident spawning component exists which could mitigate such a significant female bias in the anadromous sex ratio. However, if an additional undocumented resident rainbow spawning component exists, it is unknown if resident rainbow populations could mitigate the loss of unique, large bodied Steelhead phenotypes.

5.4 Distribution of Gillnet Scarred Fish throughout the Run

Gillnet scars were identified on 3.4% (*n*=52) of Steelhead migrating past the Sustut weir in 2015. This value is below the long term average of 6.6% (Table 2). In 2016 there was no apparent trend in arrival time for scarred vs non-scarred Steelhead.

In 2016, Fisheries and Oceans Canada permitted ten commercial gillnet openings and four demonstration gillnet/seine fisheries in Area 4 (Skeena approach waters).

Three of the commercial openings (June 17 and 24 – 25) targeted Chinook (minimum mesh size 203mm or 8"). Due to their earlier timing, Chinook gillnet fisheries in the Skeena approach tend to encounter higher rates of post-spawn emigrating Steelhead kelts (especially large males) than immigrating summer run Steelhead. Gillnet encounters of emigrating successful Steelhead spawners is a management concern as outlined in section 5.3.

Seven of the commercial openings (July 8, 13, 22 – 23, August 5 – 6 and 9) targeted Sockeye (maximum mesh size 137mm or 5.4"). There is a predictable and observable decline in the daily Tyee test fishery Steelhead index numbers following these gillnet openings. The mortality of Steelhead in these fisheries results in a loss of life history diversity in the upper Sustut River Steelhead stock, which threatens stock sustainability.

There were four demonstration fishery notices issued by DFO that authorized four days of fishing for the Tsimshian Area 4 Sockeye Fishery Demonstration Fishery (North Coast Skeena First Nations Stewardship Society). DFO fishery notices for this demonstration fishery indicated that four days of fishing occurred on July 26 from 1000H to 2200H, July 27 from 0600H to 2200H and August 12 and 20 from 0500H to 2200H in management sub-areas 4-12 and 4-15. However, there were actually ten days fished by this fishery (Angela Addison, pers. comm.). Between two and seven vessels prosecuted this fishery for ten days on July 26-27, August 12-14 and 20-24, using 4.9" mesh gill nets

Upper Sustut River Steelhead may also encounter a number of gillnets fished by various First Nations subsistence harvesters throughout the Skeena River watershed.

5.5 Effect of Water Level and Temperature on Steelhead Migration

The mean water level at the upper Sustut enumeration weir was 0.25 m. Twenty-five percent (*n*=389) of Steelhead entered the trap box when water levels were below this level and 75% (*n*=1143) entered when water levels were above. This is consistent with previous observations which found the majority of Steelhead migrated past the weir during above average water levels. Steelhead migration did appear to be linked to water levels on several occasions in 2016. Substantial numbers (>100 fish) of Steelhead made upstream movements on August 28, 31, September 1, 2 and 26, associated with periods of high stream flow (Figure 18).

The average water level in the upper Sustut River (as measured at the weir site) has been generally decreasing inter-annually since 1998. A substantial increase was measured in 2015, and similarly in 2016 (Figure 20), however, this is attributed to the staff gauge being moved to a new location (100 m upstream) in 2015. Given this change, it is not possible to know how water levels at the new weir location compare to previous years.

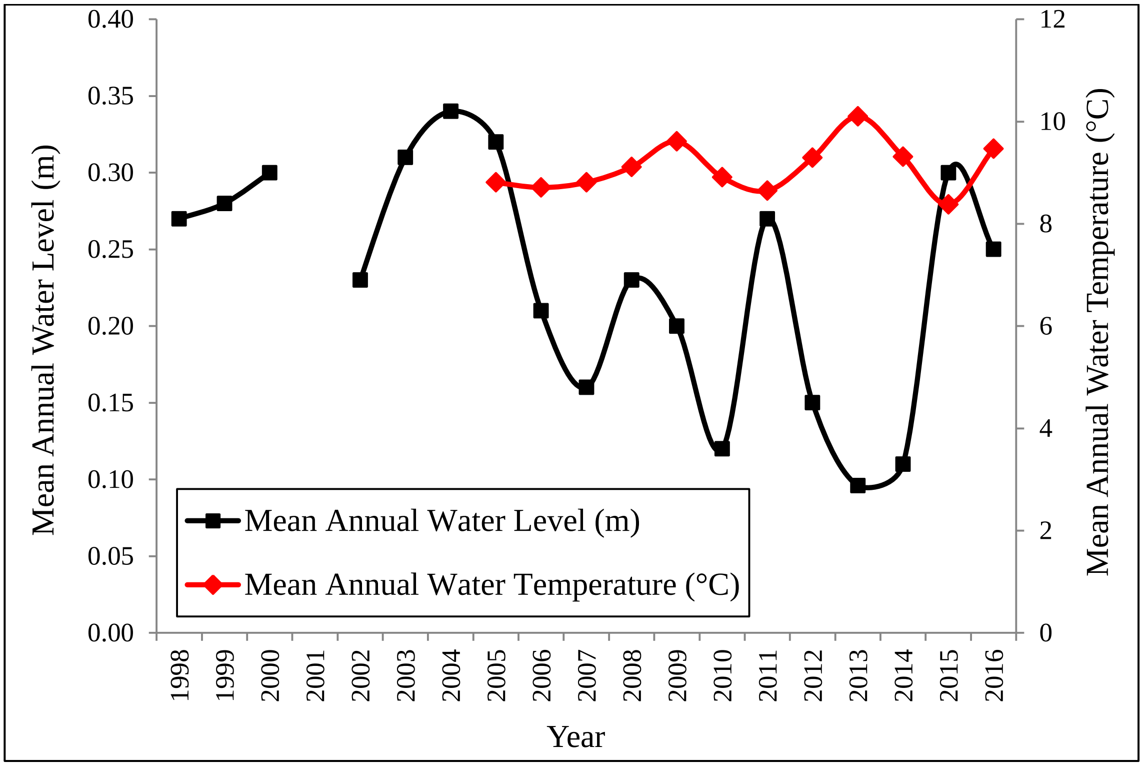

Figure 20. Mean annual water level and temperature at the Sustut enumeration weir in August and September

Given the risks that decreasing water level present to the upper Sustut Steelhead population (migration restriction, impoundment, stress/mortality from increased water temperatures, increased vulnerability to predators and in-river fisheries) and considering climate related variability, monitoring water levels in a consistent manner within the upper Sustut River (preferably close to the weir site) is warranted. This is recommended as monitoring water level elsewhere in the Sustut watershed, or the broader Skeena watershed upstream of the Babine River, is not possible given the lack of hydrometric stations in this drainage area.

The average water temperature during the project in 2015 was 9.47°C, which is well below the upper lethal limit of 27°C for rainbow trout (McPhail, 2007). Research has proven, however, that increases in stream temperature can negatively impact Steelhead populations (Sloat & Osterback, 2013). As such, continued monitoring of stream temperature during this project is warranted. In addition to monitoring temperature during weir operation, it would be advantageous to monitor maximum stream temperature within juvenile rearing habitat. This is a sensitive life history stage and shallow water environments have an elevated probability of experiencing temperature fluctuations.

5.6 The Importance of Continued Monitoring

The upper Sustut River enumeration weir is one of two long term indexes used to estimate summer run Steelhead abundance in the Skeena River watershed. It is also the only index available to monitor the abundance of upper Skeena River Steelhead stocks. This long term data set allows fisheries managers to compare variables among and between years including annual abundance, effect of water level and temperature on migration, the number and distribution of gillnet scarred Steelhead throughout the run, the relative run timing of male and female Steelhead, sex ratios and age composition. The ability to detect changes in these parameters and establish linkages to natural and anthropogenic impacts is vital to protecting the ecological, social and economic benefits Skeena Steelhead provide now and into the future.

6.0 Recommendations

1. Enumeration of the upper Sustut River Steelhead population should continue to be conducted annually. The long term monitoring data from this project provides fisheries managers with valuable information on abundance trends for all early run Skeena Steelhead populations and feedback on the impact of various fisheries on these stocks.
2. The manner in which environmental variables are monitored as part of this project should be evaluated. Confirming the location, timing and method where water temperature and flow and air temperature (and possibly other parameters) are measured with a hydrologist/climatologist would ensure that data is sampled using the best method possible. This improves the ability of this project to serve as an indicator for climate change monitoring in conjunction with weir operations. Monitoring water temperature during summer months is recommended to evaluate maximum stream temperatures and potential impacts to juvenile Steelhead. It is recommended that the feasibility of year-round environmental monitoring should be investigated.
3. In conjunction with increasing efforts to monitor environmental data with an eye toward climate change, the 2016 run and 2017 brood year provides an excellent opportunity to conduct field based investigations into the adult production estimates produced by Tautz *et al* (1992) and Lessard (2005). It is recommended that assessments of juvenile habitat occupancy, survival and recruitment be conducted.
4. It is recommended that the current minimum Target Reference Point (TRP) of 25% carrying capacity be evaluated to determine if it will conserve the upper Sustut Steelhead population above the Limit Reference Point and yield a precautionary approach to Steelhead management.
5. Agreement must be reached between BC and Canada regarding management actions to be taken when the upper Sustut Steelhead stock falls below the TRP. This plan should be reflected through the Steelhead objectives section of the North Coast Integrated Fisheries Management Planning process. Management actions described in Johnston *et al* (2002) should be put forward to federal agencies for consultation. Previous weir counts at or below the TRP did not result in the development of any plans or agreements that would mitigate commercial fishery impacts on this population.
6. Efforts to visually count Steelhead below the weir should continue. This should be undertaken when the weir is removed.
7. It is recommended to undertake a review of results at the Sustut weir every five years. Doing so would provide useful insight into changing environmental factors (water supply, ocean and climatic conditions) and anthropogenic impacts (in river

and ocean fisheries, resource development etc.) as they relate to conserving the upper Sustut Steelhead population.

8. The objectives of this report should be broadened to include Steelhead length and age investigation. Presenting an analysis of these parameters annually would increase the ability to monitor changes over time as they relate management of the upper Sustut Steelhead population. Also, all efforts should be made to ensure that sex and length information is recorded for all fish that are scale sampled and all fish exhibiting gillnet scars. This will allow analysis between these factors to be conducted.

7.0 Acknowledgments

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Ron, Wanda, Clayton, Leaf, Brome and Hawk Steffey repaired, installed, maintained and removed the Sustut weir. Their dedication to the project is above and beyond what is asked. Fish and fisheries managers benefit from their hard work and thoughtfulness.

Mark Beere coordinated funding, materials, logistics and sample analysis for this study and provided valuable comments for the final draft of this report. Furthermore, this annual report has been built upon the efforts of previous authors who include Paddy Hirshfield, Dean Peard, Ron Diewert, Regina and Ron Saimoto, Cory Williamson, Chuck Parken and Krista Morten.

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9.0 Appendices

Appendix Table 1. Daily and cumulative totals for all fish species enumerated at the Sustut enumeration weir in 2016.

Date	Chinook		Sockeye		Steelhead		Coho		Bull Trout		Whitefish		Rainbow Trout	
	Daily	Cum	Daily	Cum	Daily	Cum	Daily	Cum	Daily	Cum	Daily	Cum	Daily	Cum
31-Jul-16	11	11	0	0	0	0	0	0	0	0	0	0	0	0
01-Aug-16	49	60	1	1	0	0	0	0	0	0	2	2	0	0
02-Aug-16	15	75	0	1	0	0	0	0	1	1	8	10	0	0
03-Aug-16	35	110	0	1	0	0	0	0	0	1	0	10	0	0
04-Aug-16	26	136	0	1	0	0	0	0	1	2	3	13	0	0
05-Aug-16	11	147	0	1	0	0	0	0	0	2	1	14	0	0
06-Aug-16	31	178	0	1	0	0	1	1	0	2	0	14	0	0
07-Aug-16	24	202	1	2	0	0	0	1	0	2	0	14	0	0
08-Aug-16	16	218	0	2	1	1	0	1	0	2	0	14	0	0
09-Aug-16	24	242	6	8	1	2	1	2	0	2	4	18	0	0
10-Aug-16	27	269	0	8	0	2	1	3	0	2	2	20	0	0
11-Aug-16	2	271	66	74	1	3	8	11	1	3	2	22	0	0
12-Aug-16	7	278	0	74	0	3	0	11	0	3	0	22	0	0
13-Aug-16	15	293	150	224	11	14	9	20	1	4	0	22	1	1
14-Aug-16	7	300	36	260	1	15	6	26	0	4	1	23	0	1
15-Aug-16	5	305	5	265	2	17	0	26	1	5	0	23	0	1
16-Aug-16	10	315	42	307	3	20	10	36	2	7	1	24	0	1
17-Aug-16	4	319	8	315	3	23	5	41	0	7	0	24	0	1
18-Aug-16	8	327	23	338	3	26	2	43	0	7	3	27	0	1
19-Aug-16	0	327	9	347	2	28	2	45	0	7	1	28	0	1
20-Aug-16	0	327	8	355	2	30	1	46	0	7	0	28	1	2
21-Aug-16	2	329	2	357	0	30	1	47	0	7	0	28	0	2
22-Aug-16	3	332	137	494	11	41	26	73	0	7	0	28	0	2
23-Aug-16	2	334	18	512	6	47	4	77	0	7	1	29	0	2
24-Aug-16	0	334	1	513	0	47	0	77	0	7	0	29	0	2
25-Aug-16	0	334	2	515	0	47	0	77	0	7	0	29	0	2
26-Aug-16	0	334	20	535	2	49	3	80	0	7	2	31	0	2
27-Aug-16	0	334	242	777	64	113	28	108	0	7	4	35	1	3
28-Aug-16	0	334	158	935	208	321	58	166	0	7	2	37	0	3
29-Aug-16	0	334	0	935	1	322	0	166	0	7	1	38	0	3
30-Aug-16	1	335	12	947	3	325	0	166	0	7	0	38	0	3
31-Aug-16	0	335	80	1027	200	525	40	206	0	7	8	46	0	3
01-Sep-16	0	335	98	1125	345	870	79	285	0	7	1	47	0	3
02-Sep-16	0	335	47	1172	126	996	35	320	1	8	1	48	0	3
03-Sep-16	0	335	7	1179	7	1003	3	323	3	11	1	49	0	3
04-Sep-16	0	335	20	1199	11	1014	3	326	1	12	1	50	0	3

05-Sep-16	0	335	13	1212	13	1027	12	338	0	12	0	50	0	3
06-Sep-16	0	335	5	1217	13	1040	7	345	0	12	0	50	0	3
07-Sep-16	0	335	9	1226	11	1051	5	350	1	13	0	50	0	3
08-Sep-16	0	335	10	1236	14	1065	9	359	0	13	1	51	1	4
09-Sep-16	0	335	0	1236	3	1068	3	362	0	13	0	51	0	4
10-Sep-16	0	335	12	1248	19	1087	17	379	0	13	0	51	0	4
11-Sep-16	0	335	0	1248	4	1091	3	382	2	15	0	51	0	4
12-Sep-16	1	336	1	1249	9	1100	4	386	0	15	1	52	0	4
13-Sep-16	0	336	0	1249	13	1113	3	389	0	15	0	52	0	4
14-Sep-16	0	336	1	1250	30	1143	8	397	1	16	2	54	0	4
15-Sep-16	0	336	1	1251	15	1158	0	397	0	16	0	54	0	4
16-Sep-16	0	336	2	1253	13	1171	3	400	0	16	1	55	0	4
17-Sep-16	0	336	4	1257	23	1194	3	403	0	16	2	57	0	4
18-Sep-16	0	336	0	1257	81	1275	21	424	0	16	0	57	3	7
19-Sep-16	0	336	2	1259	33	1308	7	431	0	16	1	58	1	8
20-Sep-16	0	336	1	1260	6	1314	4	435	0	16	0	58	0	8
21-Sep-16	0	336	0	1260	2	1316	2	437	1	17	1	59	0	8
22-Sep-16	0	336	0	1260	4	1320	2	439	0	17	6	65	0	8
23-Sep-16	0	336	0	1260	2	1322	0	439	0	17	0	65	0	8
24-Sep-16	0	336	0	1260	14	1336	17	456	1	18	2	67	0	8
25-Sep-16	0	336	0	1260	14	1350	0	456	0	18	0	67	0	8
26-Sep-16	0	336	1	1261	150	1500	31	487	1	19	2	69	0	8
27-Sep-16	0	336	0	1261	12	1512	4	491	1	20	0	69	0	8
28-Sep-16	0	336	1	1262	10	1522	3	494	0	20	0	69	1	9
29-Sep-16	0	336	1	1263	3	1525	0	494	0	20	0	69	0	9
30-Sep-16	0	336	0	1263	7	1532	2	496	0	20	0	69	0	9

Appendix Table 2. Scale condition code definitions.

Condition Code	Definition
1	Good condition
2	Poor condition or questionable age
3	Freshwater age unreadable (eg. U.2)
4	Unreadable (eg. U.U)
5	Starting to regenerate (freshwater age may be under-estimated)
5a	Starting to regenerate, wide focus (freshwater age not under-estimated)
6	Regenerated (eg. R.2)
7	Missing
8	Resorption (eg. last marine annulus on edge of scale)
9	First freshwater annulus very vague, but must be present due to high circuli count and spacing relative to other freshwater annuli

Appendix Table 3. Steelhead scale ages from the Sustut enumeration weir in 2016.

Date	Time	Sex	Nose-Fork Length (cm)	Scale Book ID	Scale ID	Scale #	Condition Code	Age
2016-08-15	8:00	F	74	86118	1-41	1	**1**	5.2
2016-08-16	8:30	M	72	86118	2-42	2	**1**	4.2
2016-08-16	8:30	M	80.5	86118	3-43	3	**5a**	4.2
2016-08-19	8:00	F	73.5	86118	4-44	4	**1**	3.2
2016-08-19	8:00	F	82	86118	5-45	5	**1**	4.2
2016-08-20	8:00	M	78	86118	6-46	6	**6**	R.2
2016-08-23	8:00	F	71.5	86118	10-50	10	**1**	4.2
2016-08-23	8:00	M	73.5	86118	7-47	7	**9**	4.2
2016-08-23	8:00	F	70	86118	8-48	8	**9**	5.2
2016-08-23	8:00	F	80	86118	9-49	9	**1**	4.3
2016-08-27	8:00	F	73	86119	1-41	1	**1**	5.2
2016-08-27	8:00	M	79	86119	2-42	2	**5**	4.3
2016-08-28	8:00	F	75.5	86119	3-43	3	**1**	4.2S1
2016-08-28	8:00	F	79	86119	4-44	4	**1**	4.3
2016-08-28	8:00	F	76.5	86119	5-45	5	**1**	5.2
2016-08-28	8:00	F	79	86119	6-46	6	**1**	4.3
2016-08-28	8:00	F	80	86119	7-47	7	**1**	4.3
2016-08-28	8:00	F	67.5	86119	8-48	8	**5a**	4.2
2016-08-29	8:00	M	72.5	86119	9-49	9	**5a**	4.2
2016-08-30	8:00	M	73.5	86119	10-50	10	**1**	5.2
2016-08-30	19:00	F	72	86120	1-41	1	**6**	R.2
2016-08-31	8:00	M	76	86120	10-50	10	**1**	4.2
2016-08-31	8:00	F	74.5	86120	2-42	2	**1**	4.2
2016-08-31	8:00	M	85	86120	3-43	3	**1**	4.3
2016-08-31	8:00	F	71.5	86120	4-44	4	**1**	4.2
2016-08-31	8:00	F	84.5	86120	5-45	5	**6**	R.2S1
2016-08-31	8:00	F	73	86120	6-46	6	**9**	4.2
2016-08-31	8:00	M	76	86120	7-47	7	**1**	4.2
2016-08-31	8:00	F	71	86120	8-48	8	**1**	4.2
2016-08-31	8:00	F	74	86120	9-49	9	**1**	4.2
2016-08-31	19:00	M	88	87071	1-41	1	**5a**	4.3
2016-08-31	19:00	F	82	87071	2-42	2	**1**	4.3
2016-08-31	19:00	F	70	87071	3-43	3	**1**	4.2
2016-08-31	19:00	M	90	87071	4-44	4	**1**	4.3
2016-08-31	19:00	F	73.5	87071	5-45	5	**1**	5.2
2016-08-31	19:00	F	74.5	87071	6-46	6	**9**	4.2
2016-08-31	19:00	F	67.5	87071	7-47	7	**1**	5.2
2016-08-31	19:00	F	66	87071	8-48	8	**6**	R.2
2016-09-01	8:00	F	68.5	87072	10-50	10	**6**	R.2

2016-09-01	8:00	M	68.5	87072	1-41	1	**1**	4.2
2016-09-01	8:00	F	74	87072	2-42	2	**6**	R.2S1
2016-09-01	8:00	F	70	87072	3-43	3	**6**	R.2
2016-09-01	8:00	F	72	87072	4-44	4	**1**	4.2
2016-09-01	8:00	F	76.5	87072	5-45	5	**9**	4.3
2016-09-01	8:00	M	70	87072	6-46	6	**5a**	4.2
2016-09-01	8:00	F	78	87072	7-47	7	**5a**	4.2S1
2016-09-01	8:00	F	77	87072	8-48	8	**9**	4.3
2016-09-01	8:00	F	66	87072	9-49	9	**5a**	4.2
2016-09-01	8:00	F	68	87073	10-50	10	**9**	5.2
2016-09-01	8:00	M	78	87073	1-41	1	**9**	4.2S1
2016-09-01	8:00	M	74	87073	2-42	2	**1**	4.2
2016-09-01	8:00	M	72	87073	3-43	3	**6**	R.2
2016-09-01	8:00	M	69	87073	4-44	4	**1**	4.2
2016-09-01	8:00	F	87	87073	5-45	5	**5a**	4.2S1
2016-09-01	8:00	F	70.5	87073	6-46	6	**9**	5.2
2016-09-01	8:00	F	74	87073	7-47	7	**1**	5.2S1
2016-09-01	8:00	F	74.5	87073	8-48	8	**6**	R.2
2016-09-01	8:00	F	73	87073	9-49	9	**6**	R.2
2016-09-01	19:00	M	74	87071	10-50	10	**1**	4.2
2016-09-01	19:00	M	72	87071	9-49	9	**1**	5.2
2016-09-02	8:30	F	82.5	87074	10-50	10	**1**	5.2S1
2016-09-02	8:30	M	72	87074	1-41	1	**1**	4.2
2016-09-02	8:30	M	63	87074	2-42	2	**1**	4.1
2016-09-02	8:30	F	70	87074	3-43	3	**6**	R.2
2016-09-02	8:30	M	76	87074	4-44	4	**9**	4.2
2016-09-02	8:30	F	73	87074	5-45	5	**9**	4.2S1
2016-09-02	8:30	M	81.5	87074	6-46	6	**9**	4.2
2016-09-02	8:30	F	70	87074	7-47	7	**9**	4.2
2016-09-02	8:30	M	83	87074	8-48	8	**9**	4.3
2016-09-02	8:30	F	68.5	87074	9-49	9	**5a**	4.2
2016-09-02	8:30	F	71	87075	1-41	1	**1**	4.2
2016-09-02	8:30	F	73	87075	2-42	2	**5a**	5.2
2016-09-02	8:30	M	76	87075	3-43	3	**1**	4.2
2016-09-02	19:00	F	71.5	87075	4-44	4	**1**	4.2
2016-09-03	8:30	F	82	87075	5-45	5	**1**	4.3
2016-09-03	8:30	F	75.5	87075	6-46	6	**1**	4.2
2016-09-03	8:30	M	79	87075	7-47	7	**1**	4.2
2016-09-03	16:00	F	71	87075	8-48	8	**1**	4.2
2016-09-03	17:00	M	70	87075	9-49	9	**1**	4.2
2016-09-03	19:00	M	71.5	87075	10-50	10	**1**	4.2
2016-09-04	8:00	F	68.5	87076	1-41	1	**6**	R.2
2016-09-04	8:00	F	75.5	87076	2-42	2	**6**	R.2

2016-09-04	8:00	F	80.5	87076	3-43	3	**1**	4.3
2016-09-04	8:00	M	78	87076	4-44	4	**9**	4.3
2016-09-04	8:00	M	70	87076	5-45	5	**6**	R.2
2016-09-04	13:00	M	89.5	87076	6-46	6	**2**	4.2S1
2016-09-04	19:00	M	73.5	87076	7-47	7	**1**	4.2
2016-09-04	19:00	F	73.5	87076	8-48	8	**1**	4.2
2016-09-05	8:00	F	70	87076	10-50	10	**2**	4.2
2016-09-05	8:00	F	69	87076	9-49	9	**1**	4.2
2016-09-05	8:00	F	68.5	87077	1-41	1	**5**	4.2
2016-09-05	13:00	F	73	87077	2-42	2	**1**	4.2
2016-09-05	13:00	M	77.5	87077	3-43	3	**1**	4.2
2016-09-05	13:00	F	68.5	87077	4-44	4	**9**	4.2
2016-09-05	15:00	M	71.5	87077	5-45	5	**1**	4.2
2016-09-05	15:00	F	75	87077	6-46	6	**6**	R.3
2016-09-05	15:00	F	87	87077	7-47	7	**1**	4.2S1
2016-09-05	15:00	F	76.5	87077	8-48	8	**1**	4.2S1
2016-09-05	15:00	M	75	87077	9-49	9	**1**	4.3
2016-09-05	16:00	M	76	87077	10-50	10	**6**	R.2
2016-09-05	19:00	F	75.5	87078	1-41	1	**9**	4.2
2016-09-06	8:30	M	84	87078	2-42	2	**5**	4.4
2016-09-06	8:30	M	77	87078	3-43	3	**9**	5.2
2016-09-06	8:30	F	73	87078	4-44	4	**6**	R.2
2016-09-06	8:30	F	83.5	87078	5-45	5	**5**	4.2S1S1
2016-09-06	8:30	F	72.5	87078	6-46	6	**1**	4.2
2016-09-06	8:30	F	79.5	87078	7-47	7	**1**	5.3
2016-09-06	8:30	M	66.5	87078	8-48	8	**6**	R.2
2016-09-06	8:30	F	74	87078	9-49	9	**9**	5.2
2016-09-06	15:00	F	72	87078	10-50	10	**6**	R.2
2016-09-06	16:00	F	73.5	87079	1-41	1	**1**	4.2
2016-09-06	16:00	F	76	87079	2-42	2	**1**	5.2S1
2016-09-06	16:00	F	69	87079	3-43	3	**1**	4.2
2016-09-06	16:00	F	66	87079	4-44	4	**1**	4.2
2016-09-07	8:30	F	78	87079	5-45	5	**5**	4.2S1
2016-09-07	8:30	M	76.5	87079	6-46	6	**1**	4.2
2016-09-07	8:30	M	76.5	87079	7-47	7	**2**	4.2
2016-09-07	8:30	F	75	87079	8-48	8	**5**	4.2
2016-09-07	13:00	F	73	87079	10-50	10	**6**	R.3
2016-09-07	13:00	M	82.5	87079	9-49	9	**6**	R.2
2016-09-07	15:00	F	70.5	87080	1-41	1	**1**	5.2
2016-09-07	15:00	F	79	87080	2-42	2	**2**	5.2S1
2016-09-07	16:00	M	75.5	87080	3-43	3	**1**	5.2
2016-09-07	18:00	M	89	87080	4-44	4	**1**	4.3
2016-09-07	19:00	M	73.5	87080	5-45	5	**6**	R.2S1

2016-09-08	8:00	M	81	87080	6-46	6	**5**	4.2
2016-09-08	15:00	F	66	87080	7-47	7	**1**	3.2
2016-09-08	15:00	M	84.5	87080	8-48	8	**1**	4.3
2016-09-08	16:00	F	71.5	87080	10-50	10	**1**	4.2
2016-09-08	16:00	F	73.5	87080	9-49	9	**1**	4.2S1
2016-09-08	16:00	F	70.5	87081	1-41	1	**1**	4.2
2016-09-08	16:00	M	84.5	87081	2-42	2	**1**	5.3
2016-09-08	16:00	F	66	87081	3-43	3	**9**	4.2
2016-09-08	17:00	F	73.5	87081	4-44	4	**6**	R.2
2016-09-08	17:00	M	74.5	87081	5-45	5	**2**	4.2
2016-09-08	18:00	M	91	87081	6-46	6	**1**	4.3
2016-09-09	8:00	F	74.5	87081	7-47	7	**1**	4.2
2016-09-09	19:00	F	75.5	87081	8-48	8	**5**	4.2
2016-09-09	19:00	M	79.5	87081	9-49	9	**1**	4.2
2016-09-10	8:00	F	71	87081	10-50	10	**1**	4.2
2016-09-10	8:00	M	86	87082	1-41	1	**6**	R.3
2016-09-10	8:00	F	79	87082	2-42	2	**6**	R.2S1
2016-09-10	8:00	F	69	87082	3-43	3	**6**	R.2
2016-09-10	12:00	F	64.5	87082	4-44	4	**1**	4.2
2016-09-10	14:00	M	73	87082	5-45	5	**6**	R.2
2016-09-10	14:00	F	73	87082	6-46	6	**1**	4.2
2016-09-10	16:00	F	71	87082	10-50	10	**1**	4.2
2016-09-10	16:00	F	76.5	87082	7-47	7	**5**	4.2
2016-09-10	16:00	F	75.5	87082	8-48	8	**5a**	4.3
2016-09-10	16:00	M	81	87082	9-49	9	**1**	3.2
2016-09-10	19:00	M	76.5	87083	1-41	1	**1**	4.2
2016-09-10	19:00	M	74	87083	2-42	2	**1**	4.2
2016-09-10	19:00	F	82.5	87083	3-43	3	**5a**	4.2S1
2016-09-10	19:00	M	84.5	87083	4-44	4	**1**	4.3
2016-09-10	19:00	F	76	87083	5-45	5	**9**	4.3
2016-09-10	19:00	M	85	87083	6-46	6	**5a**	4.3
2016-09-10	19:00	F	74.5	87083	7-47	7	**1**	3.2
2016-09-11	8:00	M	75	87083	8-48	8	**5**	4.2
2016-09-11	15:00	M	59	87083	9-49	9	**1**	4.1
2016-09-11	18:00	F	72	87083	10-50	10	**1**	4.2
2016-09-11	18:00	M	78	87084	1-41	1	**6**	R.2
2016-09-12	8:00	M	75	87084	2-42	2	**1**	4.2
2016-09-12	8:00	M	81.5	87084	3-43	3	**6**	R.2
2016-09-12	17:00	F	72	87084	4-44	4	**1**	4.2S1
2016-09-12	17:00	F	75	87084	5-45	5	**1**	4.2
2016-09-12	17:00	F	72.5	87084	6-46	6	**1**	4.2
2016-09-12	17:00	F	69	87084	7-47	7	**1**	5.2
2016-09-12	19:00	M	67	87084	10-50	10	**5**	4.2

2016-09-12	19:00	F	73	87084	8-48	8	**9**	4.2
2016-09-12	19:00	F	73.5	87084	9-49	9	**1**	4.2
2016-09-13	8:30	F	70	87085	1-41	1	**1**	4.2
2016-09-13	8:30	M	80	87085	2-42	2	**1**	4.3
2016-09-13	8:30	F	79.5	87085	3-43	3	**1**	4.2
2016-09-13	8:30	M	73	87085	4-44	4	**9**	4.2
2016-09-13	8:30	F	72.5	87085	5-45	5	**1**	5.2
2016-09-13	14:00	F	77	87085	6-46	6	**5**	4.3
2016-09-13	17:00	F	79.5	87085	7-47	7	**1**	4.2S1
2016-09-13	17:00	M	72.5	87085	8-48	8	**6**	R.2
2016-09-13	19:00	F	69.5	87085	10-50	10	**5**	4.2
2016-09-13	19:00	F	66	87085	9-49	9	**1**	5.2
2016-09-13	19:00	F	69	87086	1-41	1	**9**	4.2
2016-09-13	19:00	M	75	87086	2-42	2	**9**	5.2
2016-09-13	19:00	F	73	87086	3-43	3	**1**	4.2
2016-09-14	8:00	F	76	87086	4-44	4	**6**	R.2
2016-09-14	13:00	M	76	87086	10-50	10	**1**	3.2
2016-09-14	13:00	M	74	87086	5-45	5	**9**	4.2
2016-09-14	13:00	F	66	87086	6-46	6	**1**	4.2
2016-09-14	13:00	M	79	87086	7-47	7	**1**	4.2
2016-09-14	13:00	F	68	87086	8-48	8	**1**	5.2
2016-09-14	13:00	F	71.5	87086	9-49	9	**1**	3.2
2016-09-14	13:00	M	91	87087	1-41	1	**1**	4.3
2016-09-14	13:00	F	77.5	87087	2-42	2	**1**	4.2
2016-09-14	13:00	M	85	87087	3-43	3	**1**	4.3
2016-09-14	13:00	F	74.5	87087	4-44	4	**5**	4.2
2016-09-14	13:00	F	70.5	87087	5-45	5	**1**	4.2
2016-09-14	13:00	F	76	87087	6-46	6	**1**	5.2
2016-09-14	13:00	F	73.5	87087	7-47	7	**5**	4.2
2016-09-14	15:00	F	69.5	87087	10-50	10	**5**	4.2
2016-09-14	15:00	F	73	87087	8-48	8	**6**	R.2
2016-09-14	15:00	F	69	87087	9-49	9	**1**	5.2
2016-09-14	15:00	F	67	87088	1-41	1	**5**	4.2
2016-09-14	15:00	M	82	87088	2-42	2	**1**	4.3
2016-09-14	15:00	M	77.5	87088	3-43	3	**1**	4.2
2016-09-14	16:00	F	71	87088	4-44	4	**9**	4.2
2016-09-14	16:00	F	78	87088	5-45	5	**5**	4.2
2016-09-14	17:00	M	76	87088	6-46	6	**1**	3.2
2016-09-14	17:00	F	74	87088	7-47	7	**1**	3.2
2016-09-14	17:00	M	72.5	87088	8-48	8	**9**	4.2
2016-09-14	19:00	F	69	87088	10-50	10	**5**	4.2
2016-09-14	19:00	M	91	87088	9-49	9	**6**	R.3
2016-09-14	19:00	F	72.5	87089	1-41	1	**6**	R.2

2016-09-14	19:00	F	76.5	87089	2-42	2	**2**	4.2
2016-09-14	19:00	F	71	87089	3-43	3	**9**	5.2
2016-09-15	8:00	F	73.5	87089	4-44	4	**1**	5.2
2016-09-15	8:00	M	85	87089	5-45	5	**5a**	4.3
2016-09-15	8:00	F	78	87089	6-46	6	**1**	4.2
2016-09-15	8:00	M	83	87089	7-47	7	**1**	5.2
2016-09-15	12:00	F	69	87089	8-48	8	**9**	4.2
2016-09-15	12:00	F	69	87089	9-49	9	**5**	4.2
2016-09-15	14:00	M	79	87089	10-50	10	**1**	3.2
2016-09-15	19:00	F	77	87090	1-41	1	**6**	R.2S1
2016-09-15	19:00	F	71.5	87090	2-42	2	**5a**	4.2
2016-09-15	19:00	F	72	87090	3-43	3	**1**	4.2
2016-09-15	19:00	M	80	87090	4-44	4	**1**	4.2
2016-09-15	19:00	F	69	87090	5-45	5	**6**	R.2
2016-09-15	19:00	M	71	87090	6-46	6	**1**	4.2
2016-09-15	19:00	F	77	87090	7-47	7	**1**	4.2
2016-09-16	8:00	F	74	87090	10-50	10	**9**	4.2
2016-09-16	8:00	M	84	87090	8-48	8	**1**	4.2S1
2016-09-16	8:00	M	89	87090	9-49	9	**5a**	4.3
2016-09-16	14:00	F	72.5	87091	1-41	1	**6**	R.1S1
2016-09-16	14:00	F	75.5	87091	2-42	2	**9**	4.2
2016-09-16	14:00	F	74.5	87091	3-43	3	**5**	4.2
2016-09-16	14:00	F	70	87091	4-44	4	**6**	R.2
2016-09-16	18:00	M	64	87091	10-50	10	**5**	3.2
2016-09-16	18:00	F	78	87091	5-45	5	**5**	4.2
2016-09-16	18:00	F	75	87091	6-46	6	**1**	4.2
2016-09-16	18:00	M	80.5	87091	7-47	7	**1**	4.2
2016-09-16	18:00	F	72	87091	8-48	8	**1**	4.2
2016-09-16	18:00	F	72	87091	9-49	9	**5a**	4.2
2016-09-17	13:00	F	70	87092	10-50	10	**1**	5.2
2016-09-17	13:00	F	73	87092	1-41	1	**6**	R.2
2016-09-17	13:00	F	71	87092	2-42	2	**1**	4.2
2016-09-17	13:00	M	68	87092	3-43	3	**2**	4.2
2016-09-17	13:00	F	73	87092	4-44	4	**9**	4.2
2016-09-17	13:00	F	73	87092	5-45	5	**6**	R.2
2016-09-17	13:00	F	81.5	87092	6-46	6	**5**	4.2S1
2016-09-17	13:00	F	66	87092	7-47	7	**9**	4.2
2016-09-17	13:00	F	87	87092	8-48	8	**6**	R.2S1
2016-09-17	13:00	M	78	87092	9-49	9	**1**	4.2
2016-09-18	8:00	F	71	87093	1-41	1	**1**	4.2
2016-09-19	8:30	M	75.5	87093	2-42	2	**1**	4.2
2016-09-19	8:30	M	82	87093	3-43	3	**9**	4.2
2016-09-19	8:30	F	67.5	87093	4-44	4	**1**	4.2

2016-09-19	8:30	M	81.5	87093	5-45	5	**6**	R.2
2016-09-19	8:30	F	71	87093	6-46	6	**6**	R.3
2016-09-19	8:30	M	70.5	87093	7-47	7	**1**	4.2
2016-09-20	19:00	F	71	87093	8-48	8	**6**	R.2
2016-09-21	18:00	F	73.5	87093	10-50	10	**9**	5.2
2016-09-21	18:00	M	75	87093	9-49	9	**2**	4.2
2016-09-22	16:00	F	72.5	87094	1-41	1	**6**	R.2
2016-09-22	17:00	F	70.5	87094	2-42	2	**1**	5.2
2016-09-22	19:00	M	88.5	87094	3-43	3	**1**	4.3
2016-09-23	19:00	F	71.5	87094	4-44	4	**9**	4.2
2016-09-24	8:30	F	73	87094	5-45	5	**9**	5.2
2016-09-25	8:30	F	77.5	87094	6-46	6	**5a**	5.2
2016-09-26	13:00	F	71	87094	10-50	10	**1**	4.2
2016-09-26	13:00	F	70	87094	7-47	7	**5**	5.2
2016-09-26	13:00	M	85	87094	8-48	8	**5a**	4.2S1
2016-09-26	13:00	M	80	87094	9-49	9	**9**	4.2
2016-09-27	11:00	M	77	87095	10-50	10	**1**	5.2
2016-09-27	11:00	M	78.5	87095	1-41	1	**6**	R.2S1
2016-09-27	11:00	M	76	87095	2-42	2	**9**	5.2
2016-09-27	11:00	M	71	87095	3-43	3	**1**	3.2
2016-09-27	11:00	M	77.5	87095	4-44	4	**1**	4.2
2016-09-27	11:00	F	68	87095	5-45	5	**1**	4.2
2016-09-27	11:00	F	78	87095	6-46	6	**1**	5.2
2016-09-27	11:00	F	75.5	87095	7-47	7	**6**	R.2S1
2016-09-27	11:00	M	93	87095	8-48	8	**6**	R.3
2016-09-27	11:00	F	68	87095	9-49	9	**1**	4.2
2016-09-27	15:00	F	65.5	87096	1-41	1	**6**	R.2
2016-09-27	15:00	F	68	87096	2-42	2	**1**	4.2
2016-09-28	8:30	F	79.5	87096	3-43	3	**5a**	4.2S1
2016-09-28	8:30	F	76	87096	4-44	4	**1**	5.2
2016-09-28	8:30	F	73	87096	5-45	5	**6**	R.2
2016-09-28	8:30	F	73	87096	6-46	6	**9**	4.2
2016-09-28	14:00	M	70	87096	7-47	7	**9**	4.2
2016-09-28	14:00	F	71.5	87096	8-48	8	**1**	3.2
2016-09-28	14:00	F	71.5	87096	9-49	9	**5**	4.2
2016-09-28	16:00	M	76	87096	10-50	10	**1**	4.2
2016-09-28	19:00	F	71	87097	1-41	1	**5a**	4.2
2016-09-28	19:00	M	87	87097	2-42	2	**2**	4.3
2016-09-29	19:00	M	90.5	87097	3-43	3	**6**	R.3
2016-09-29	19:00	F	71	87097	4-44	4	**1**	4.2
2016-09-29	19:00	F	72	87097	5-45	5	**6**	R.2
2016-09-30	9:30	F	72	87097	6-46	6	**6**	R.2
2016-09-30	9:30	F	76.5	87097	7-47	7	**2**	5.2

2016-09-30	9:30	F	71	87097	8-48	8	**5**	4.2
2016-09-30	9:30	M	83.5	87097	9-49	9	**1**	4.3
2016-09-30	14:00	M	82	87097	10-50	10	**1**	4.3
2016-09-30	14:00	F	71.5	87098	1-41	1	**1**	3.2
2016-10-01	12:00	F	73	87098	2-42	2	**5a**	4.2

Appendix Table 4. Environmental data recorded at the Sustut enumeration weir.

Date	Mean Daily Water Temperature (°C)	Mean Daily Staff Gauge Height (m)	Date	Mean Daily Water Temperature (°C)	Mean Daily Staff Gauge Height (m)
2016-08-01	12.27	0.225	2016-09-01	9.33	0.3525
2016-08-02	12.90	0.2175	2016-09-02	9.22	0.45
2016-08-03	13.47	0.205	2016-09-03	8.36	0.43
2016-08-04	12.55	0.195	2016-09-04	8.82	0.3825
2016-08-05	12.29	0.195	2016-09-05	8.83	0.3425
2016-08-06	12.35	0.19	2016-09-06	8.51	0.3075
2016-08-07	12.81	0.18	2016-09-07	8.87	0.285
2016-08-08	13.22	0.1725	2016-09-08	8.94	0.275
2016-08-09	12.76	0.1725	2016-09-09	8.16	0.285
2016-08-10	12.32	0.18	2016-09-10	8.23	0.3275
2016-08-11	12.44	0.1725	2016-09-11	7.46	0.3125
2016-08-12	12.26	0.165	2016-09-12	7.21	0.29
2016-08-13	12.37	0.16	2016-09-13	7.51	0.2725
2016-08-14	12.60	0.1525	2016-09-14	8.74	0.2575
2016-08-15	11.64	0.15	2016-09-15	8.48	0.2425
2016-08-16	11.58	0.16	2016-09-16	8.64	0.24
2016-08-17	11.28	0.1525	2016-09-17	7.95	0.285
2016-08-18	11.20	0.1425	2016-09-18	7.19	0.2925
2016-08-19	12.08	0.1325	2016-09-19	6.82	0.28
2016-08-20	11.61	0.13	2016-09-20	6.15	0.26
2016-08-21	9.76	0.1525	2016-09-21	6.00	0.24
2016-08-22	10.24	0.1975	2016-09-22	6.14	0.2325
2016-08-23	11.25	0.165	2016-09-23	6.68	0.2275
2016-08-24	11.07	0.1525	2016-09-24	6.13	0.235
2016-08-25	11.14	0.1475	2016-09-25	5.90	0.2325
2016-08-26	11.16	0.1425	2016-09-26	6.29	0.475
2016-08-27	10.59	0.2125	2016-09-27	5.49	0.555
2016-08-28	10.32	0.21	2016-09-28	4.87	0.4675
2016-08-29	9.11	0.195	2016-09-29	4.33	0.42
2016-08-30	8.61	0.2275	2016-09-30	4.34	0.385
2016-08-31	8.86	0.2975			