

**The reproductive biology of steelhead
(*Oncorhynchus mykiss*)
in the Deadman River, 1998**

**Prepared for:
Ministry of Environment, Lands and Parks
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Hunters, anglers, trappers and guides contribute to the Trust Fund enhancement projects through license surcharges. Tax deductible donations assist in the work of the Trust fund are welcomed.

Abstract

From April 20 to May 29, 1998, the Ministry of Environment, Lands and Parks, Fisheries Branch, operated the Deadman River fish fence with funding provided by the Habitat Conservation Fund. The purpose of the program was to enumerate and biologically sample steelhead and rainbow trout (*Oncorhynchus mykiss*) migrating upstream to spawn and to study their spawning distribution in the Deadman River using radio telemetry. During the period of operation, 105 female and 77 male steelhead migrated through the fence a total of 41 male and 12 female non-anadromous *O. mykiss* were also captured. All steelhead were marked with an operculum punch in order to conduct a mark-recapture experiment in the event the fish fence was pulled due to high water conditions. 28 steelhead were marked at the Deadman/Thompson confluence for a mark-recapture experiment downstream of the fence. The Adjusted Petersen Estimate mark-recapture determined an escapement estimate of steelhead in the Deadman river downstream of the fence to be 512. The escapement estimate upstream of the fish fence was 182. Spawner counts were also conducted in an attempt to determine timing of spawning steelhead and important spawning areas. 21 steelhead were radio tagged at the confluence of the Deadman and Thompson Rivers an additional seven steelhead were floy tagged. Angling was the method used for fish capture and tag placement. Radio telemetry results identified spawning areas which were distributed from approximately 12 km to 37 km upstream of the Deadman/Thompson confluence. Steelhead movements were tracked with mobile telemetry equipment from a pickup truck or on foot. Two fixed radio telemetry stations were set up along the Deadman River as well. The first station was set up at the 15.2 km mark on the Deadman River road near a man made weir, the second station was located at the fish fence itself located 19.2 km upstream of the confluence.

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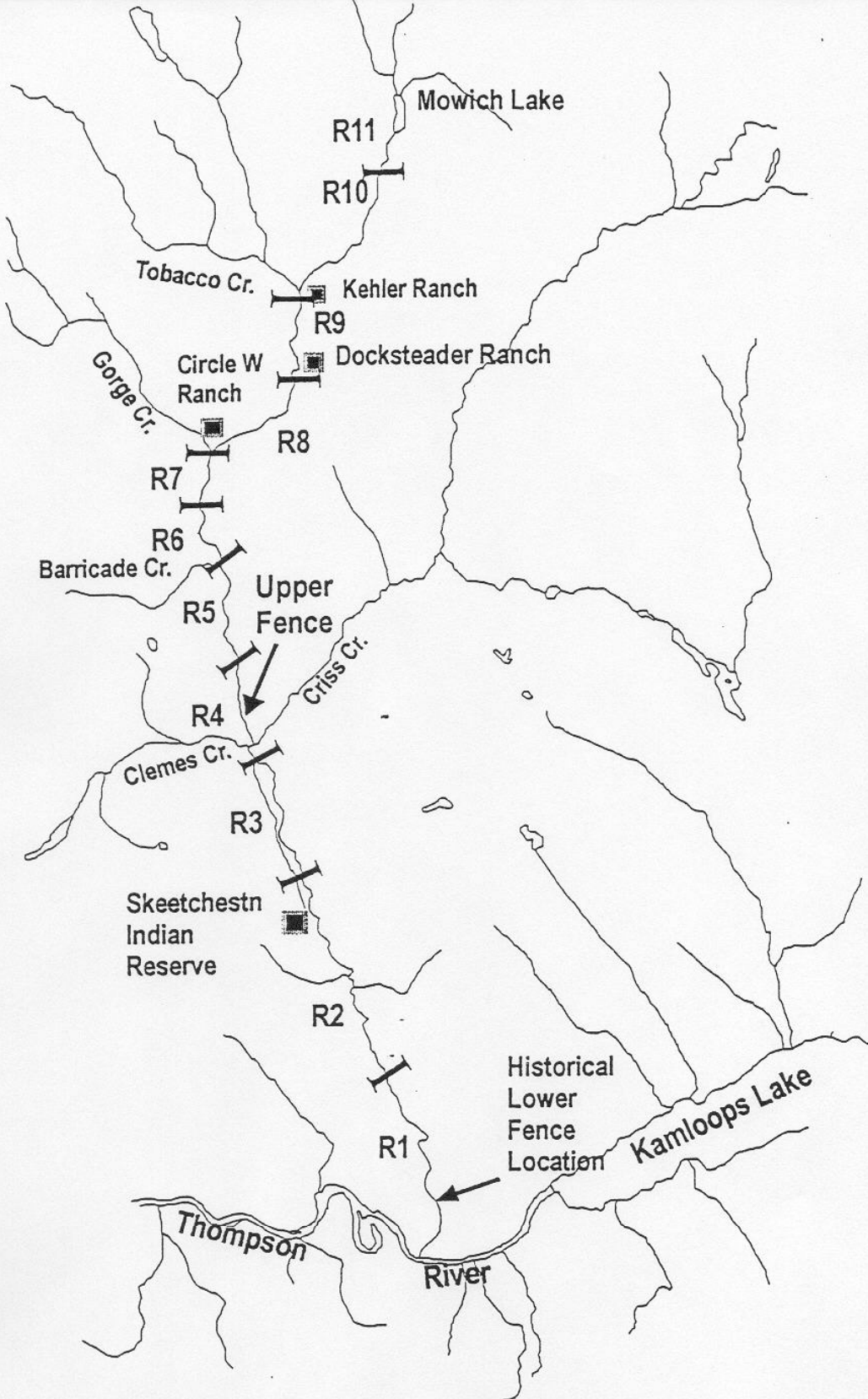
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3.0 The Deadman River and Tributaries.

4.0 Introduction

Since 1983 the Ministry of Environment, Lands and Parks Fisheries Branch has attempted to operate a fish fence operation on the Deadman River to enumerate steelhead. During the 1980's the Ministry of Environment, Lands and Parks (MOELP) Fisheries Biologists became increasingly concerned with the conservation of steelhead stocks. By 1987, steelhead mortality in the sport fishery was reduced drastically by imposing catch and release restrictions. MOELP also entered into negotiations with the Department of Fisheries and Oceans (DFO) and First Nations to address management strategies in non-selective commercial and aboriginal salmon fisheries and assist in the conservation of Thompson steelhead (Bison, 1997). Habitat loss is also recognized as a factor contributing to the decline and instability of the Deadman River steelhead stock.

In 1983, the BC Ministry of Environment, Fisheries Branch, began enumerating steelhead in the Deadman River. An adult fence trap was constructed above the Criss Creek confluence to enumerate and biologically sample steelhead. Due to low snowpack and moderate freshets over the previous three years, a second fence was constructed 300 meters from its confluence with the Thompson River in 1986. The upper and lower fish fences were both in operation until 1987. Throughout the years 1988, 1989 and 1990 only the lower fence was in operation on the Deadman River. The Upper Deadman River fish fence has been operated from 1991 to 1997. This fish fence is located approximately 15 km from the Thompson River above the Criss Creek confluence. (Figure 1.0)

In 1996, fish fence operation was ceased after only seven days of operation due to extremely high spring freshet conditions that resulted in the destruction of 2 of the 3 A frame fence panel support structures. The fish fence was rebuilt in the same location (15 km upstream from the Thompson River) on April 1st and 2nd, 1997. The Habitat Conservation Fund provided the funds needed to operate the fence trap.

The purpose of this report is to summarize results from fence operation, stream walking observations and mark-recapture analysis from the 1998 fence operation. A second objective was to track the daily movements of 20 radio tagged steelhead within the Deadman River.

The ongoing commitment by the Habitat Conservation Fund has provided the operating funds needed to monitor and study the Deadman River Steelhead population. The purpose of this report is to summarize results from fence operation, stream walking observations, mark-recapture analysis and radio telemetry results from the 1998 fence operation.

5.0 Study area

The Deadman River originates from the Kukwaus Plateau region of the Thompson Plateau. The Deadman River flows through numerous lakes including Vidette, Deadman, Skookum, Snohoosh and Mowich, eventually entering the Thompson River four kilometers down stream of Kamloops Lake. The Deadman River flows through the Skeetchestn Indian Reserve, south west of Savona, British Columbia. The eastern border consists of the Thompson Plateau while the Arrow Hills border the watershed to the west.

The Deadman River is approximately ninety kilometers in length and has two large tributaries; Criss Creek and Joe Ross Creek (Moore, 1985). Stream discharges have ranged from 58.5 cubic meters per second in 1990 to 0.00 cubic meters per second in 1919. The mean annual discharge for the Deadman River in 1997 was 1.15 cubic meters per second (Water Survey of Canada Station 08LF027 above Criss Creek).

Kamloops airport receives approximately 255 mm of precipitation annually. Snow occurs for approximately five to seven months each year, and comprises approximately 30% of total annual precipitation (Moore, 1985).

Fishes found within the Deadman River watershed consist of rainbow trout/steelhead (*Oncorhynchus mykiss*), chinook (*O. tshawytscha*), coho (*O. kisutch*), pink (*O. gorbuscha*), kokanee (*O. nerka*), pacific lamprey (*Lampetra tridentata*), longnose dace (*Rhinichthys cataractae*), large scale sucker (*Catostomus macrocheilus*), mountain whitefish (*Prosopium williamsoni*), cottids (*cottidae*), and northern squawfish (*Ptychocheilus oregonensis*) (Moore, 1985; McPhail, 1992; Galesloot, 1997).

There are six Biogeoclimatic zones that lie within the study area, the Bunchgrass Ponderosa Pine (*Pinus contorta*) zone, the Interior Douglas Fir (*Pseudotsuga menziesii*) zone, the Montane Spruce zone, and the Engelmann Spruce (*Picea engelmannii*) - Subalpine Fir (*Abies lasiocarpa*) zone.

6.0 Methods

Fish fence operations commenced on April 20 to May 29, 1998, when six steel grates were installed to prevent upstream migration of adult fish. A steel V-shaped lead panel was also installed in front of the

trap box. The installation of the lead panel and grates converted the fish fence into a one-way adult trap where fish were captured, enumerated and sampled for relevant biological data. A water intake control panel was used to maintain flows through the one way trap. Debris accumulation on the grates increased in conjunction with increasing stream flows, necessitating more frequent cleaning to maintain adequate flows through the fishway.

The trap was inspected five to ten times daily, depending upon the number of fish trapped. Upon first entering the trap, the lead panel was blocked to prevent the escape of fish from the trap. Fish were then captured using a 3 cm stretch mesh, cotton dip net.

Captured steelhead were enumerated and sampled for biological data which included, fork length, weight, scale samples, sex, spaghetti/floy tag number, presence/absence of an adipose fin clip, and presence/absence of a maxillary clip. Sexual identification was determined by using secondary sex characteristics such as body size, head shape, adipose fin size, tightness of scales and girth. General comments regarding overall condition such as presence of abrasions, wounds, scars, net marks, red spots, parasites and degree of coloration were also recorded. A small round hole was made in the left operculum of each steelhead with a stationary punch in order to provide a positive means of identifying recaptured fish. The estimated steelhead escapement for steelhead below the fish fence for 1998 was calculated using the Adjusted Petersen Estimate, mark-recapture formula; $N^* = (M+1) * (C+1) / R+1$ (Ricker, 1975).

Captured rainbow trout were enumerated and sampled for biological data similar to steelhead. The same criterion was used for sexual identification of non-anadromous trout except that suspected males were confirmed by milking and suspected females were confirmed by belly fullness, presence of an ovipositor and expulsion of eggs. Instead of an operculum punch, individual rainbow trout were tagged below the dorsal on the right side, using sequentially numbered and color coded Floy tags. Tagging provided a means of positively identifying recaptured fish and may provide information on the movement patterns of rainbow trout within the Thompson River system.

Spawner presence/absence, densities, activities and numbers along with the location of redds was determined through stream walks, which were carried out as many times as water clarity and flows would permit. Reconnaissance efforts were concentrated on Reach 9 of the Deadman River; this includes the Circle W ranch to upstream of the Dockstader ranch (Figure 1.0). Reach 9 is known to contain high densities of spawning steelhead along with Reach 4, located upstream and downstream of the fish fence respectively (Maricle, 1987). Reach 4 could not be surveyed for spawner activity due to water turbidity

and high flows (Figure 1.0).

Water temperatures were recorded every morning at (0700 hr) using a min/max thermometer, and also recorded hourly with a Stowaway temperature recorder above and below Criss Creek. Water levels were recorded using a meter stick. Discharge data was obtained from the Water Survey of Canada's Station No. 08LF027, located above Criss Creek in the Deadman River.

Twenty one radio transmitters were used to study the migratory patterns, spawning behavior and habitat used by spawning steelhead. The transmitters were manufactured by Lotek Engineering Inc. of Aurora, Ontario. They were the esophageal implant type with an external "whip" antenna. The transmitter was placed in the mouth and gently pushed into the stomach using a blunt probe. Seven steelhead were also fitted with floy tags to provide a larger sample size for mark-recapture analysis.

Migratory behavior was monitored daily by vehicle using a Lotek SRX 400 telemetry receiver, two fixed stations were also used to monitor fish movements. Areas that were inaccessible by vehicle were tracked on foot using a portable receiver and directional antenna.

The fix telemetry stations were located at a man made weir located approximately 15.2 km upriver of the Deadman Thompson confluence and at the fish fence site.

In order to calculate an accurate redd residency time for Deadman River steelhead, redd days were calculated by using stationary days of 3 days or more at or near the peak of migration. Radio tagged steelhead that showed irregular movement patterns were not included in order to get an average redd residency time.

7.0 Results

Operation of the fish fence occurred over a period of days, from (April 20 to May 29, 1998).

The number of steelhead captured at the fish fence in 1998 was 182, of which 105 were female (58%) and 77 were male (42%) (Figure 2.0).

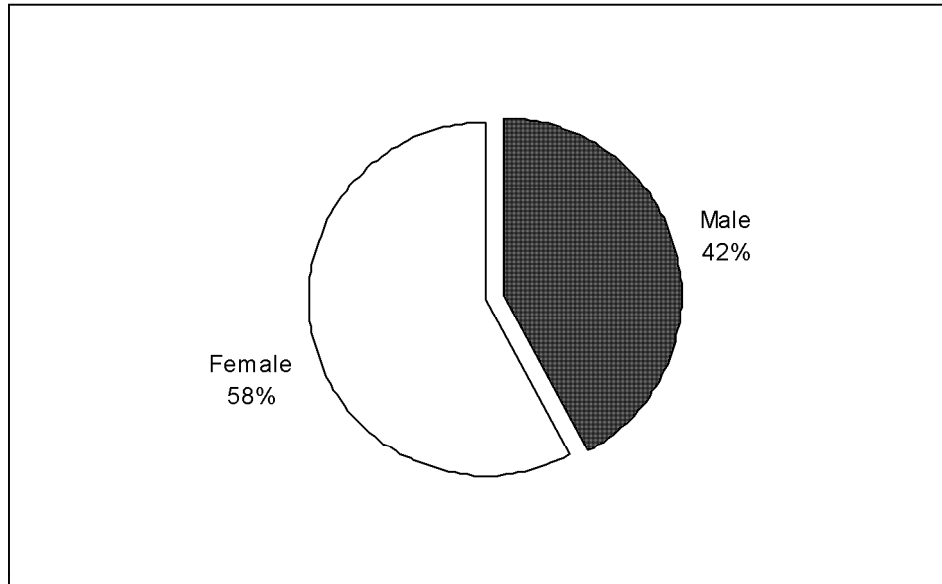


Figure 2.0. Sex ratio of steelhead captured in the Deadman River Fish Fence, 1998.

This results in a male to female sex ratio of 1:1.4. Male fork lengths ranged from 75 to 99.0 cm with an average of 86.9 cm, and weights ranged from 4.5 to 9.5 kg with a mean of 6.4 kg. Female fork lengths ranged from 73.0 to 91.0 cm with a mean of 81.2 cm, and weights ranged from 4.0 to 7.5 kg with an average of 5.7 kg (See Table 1.0 and 2.0 and Appendix II).

Emigrating steelhead or kelts began arriving at the fish fence on May 16/98. A total of 88 steelhead kelts were processed, of these 41 (47%) were mortalities on arrival. Of the 88 kelts captured at the fish fence 2 steelhead did not have operculum punches present, indicating that steelhead are able to bypass the fence site without being handled. The Petersen Mark-Recapture Estimate for above the fish fence for 1998 was not necessary because the fish fence was not removed at any time throughout the season.

Stream discharge data is not available until January 1998 and will be analyzed and added to this report at that time. See figure 6.0.

Stream water temperature steadily increased from April 26 on as did steelhead immigration. An increase in steelhead immigrants can be seen during the period of May 6-16 which also coincides with the highest recorded temperatures during fence operation.

Bison (1991), reported a possible correlation between water temperature and steelhead immigration on the Bonaparte River in 1991 (Bison, 1991). Renn (1996) also reported a positive correlation between water temperature and steelhead immigration on the Bonaparte River. Renn (1996) found that migration

occurred in two main pulses, with each pulse being preceded by a sharp rise in water temperature. Both Bison and Renn, found that migration did not occur at significant rates until water temperatures approached 8 degrees Celsius (Bison, 1990, Renn, 1996). See figure 4.0.

Sex ratios of Deadman River steelhead for 1998 were 1:1.4 with 42% males and 58% females. Sex ratios for Deadman River steelhead have remained inconsistent from 1984 to 1998, ranging from 1:0.9 in 1990 to 1:2.3 in 1984 (Figure 3.0).

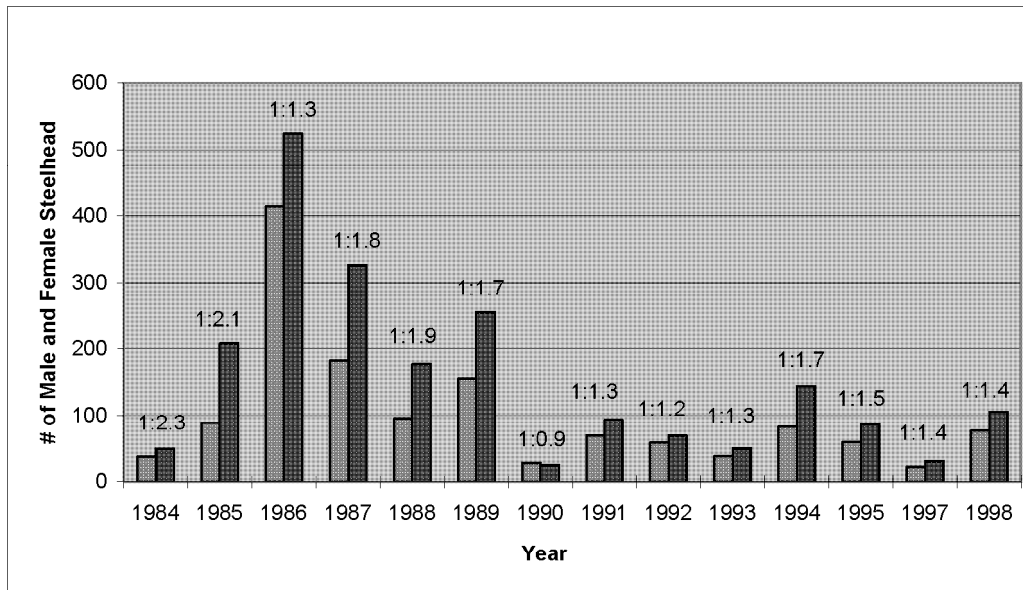


Figure 3.0 Anadromous *O. mykiss* male to female sex ratios and relative escapements for the Deadman River, 1984 to 1998.

Deadman River steelhead fork lengths for 1998 were 86.9 cm average for males and 81.2 cm average for females. These average fork lengths for males and females in 1998 were above the average for the years 1983 to 1997. The range for male fork lengths between 1983 and 1998 was 80.4 cm to 87.3 cm with an average male fork length of 84.1 cm. Female fork lengths ranged from 71.8 cm to 80.7 cm with an average of 78.6 cm (Table 1.0).

Table 1.0 Comparison of Deadman River steelhead fork lengths between 1983 and 1998.

Year	Male		Female	
	n	mean fork length (cm)	n	mean fork length (cm)
1983	17	87.0	17	74.8
1984	82	83.0	172	78.7
1985	37	81.6	49	78.1
1986	414	86.6	524	78.5
1987	182	85.0	327	78.0
1988	14	80.4	26	80.3
1989	17	82.8	29	78.0
1990	28	79.3	25	71.8
1991	69	84.9	93	80.2
1992	59	83.8	69	80.1
1993	38	84.7	48	80.6
1994	83	83.7	144	77.6
1995	61	84.3	86	79.7
1996	N/A	N/A	N/A	N/A
1997	22	87.3	31	80.7
1998	77	86.9	105	81.2
Average		84.1		78.6

Deadman River steelhead weights were not well recorded from 1983 to 1996. A total of 195 male steelhead were weighed during this period producing an average weight of 6.3 kg. The average weight for male steelhead in 1998 was consistent with the average at 6.4 kg. The average weight for female steelhead from 1983 to 1997 was 5.4 kg. A total of 377 female steelhead were weighed from 1983 to 1997. The average weight for 1998 was 5.7 kg (Table 2.0).

Table 2.0 Comparison of Deadman River steelhead weights from 1983 to 1998.

Year	Male		Female	
	n	mean weight (kg)	n	mean weight (kg)
1984	88	5.7	197	5.3
1985	26	6.4	37	5.7
1986	23	6.0	2	4.3
1987	38	6.4	53	6.6
1997	20	6.9	30	5.3
1998	77	6.4	105	5.7
Average		6.3		5.4

No data for 1983, 1988-1996.

Spawner counts were attempted in 1998 to determine spawner densities, sex ratios and number of redds but due to spring freshet conditions steelhead and redd counts were low. The majority of spawning activity was observed within the Dockstader property or Reach 9 (See appendix III).

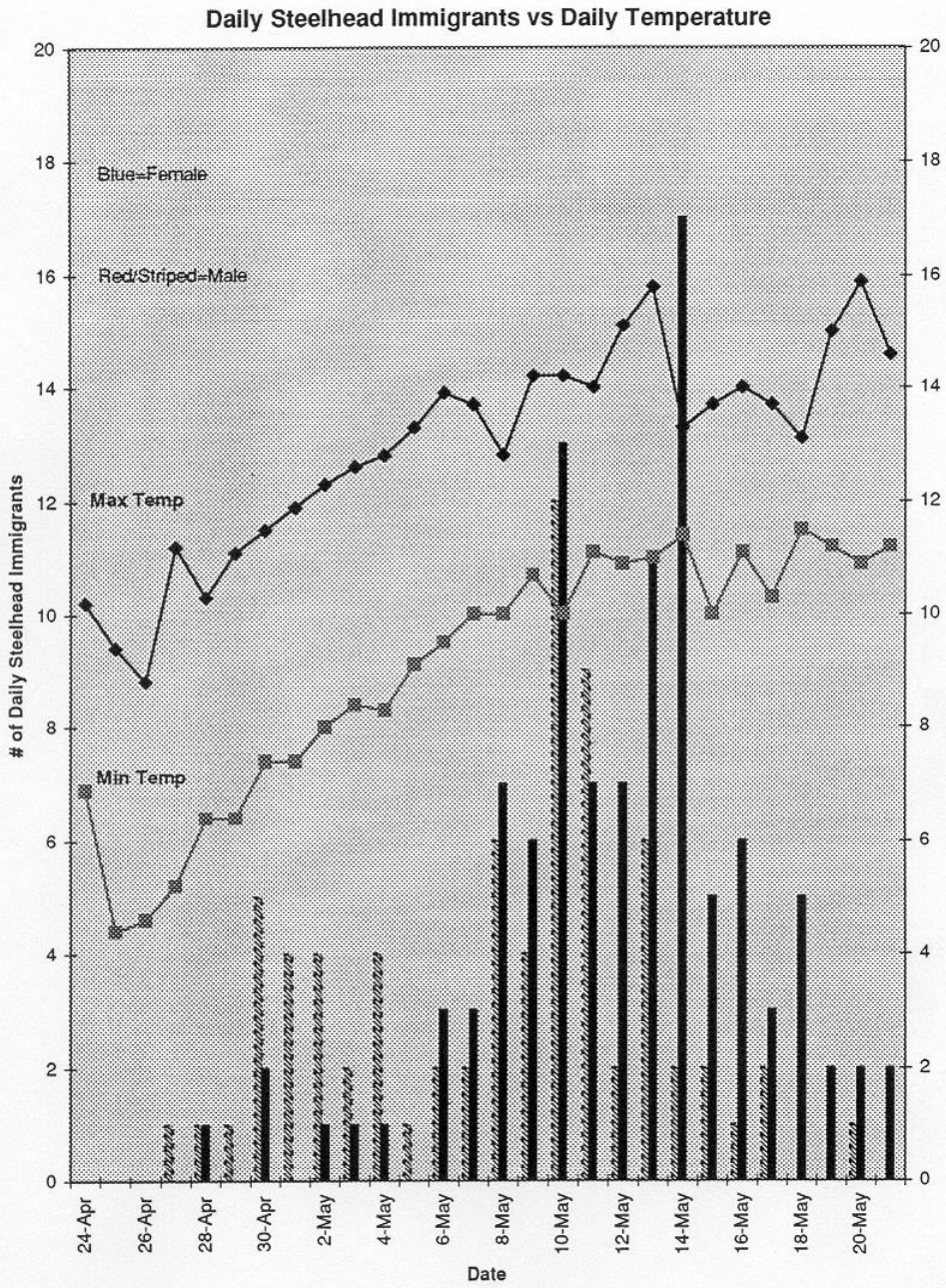


Figure 4.0 Steelhead Immigration in Relation to Stream Temperature

Daily Male and Female Steelhead Immigration

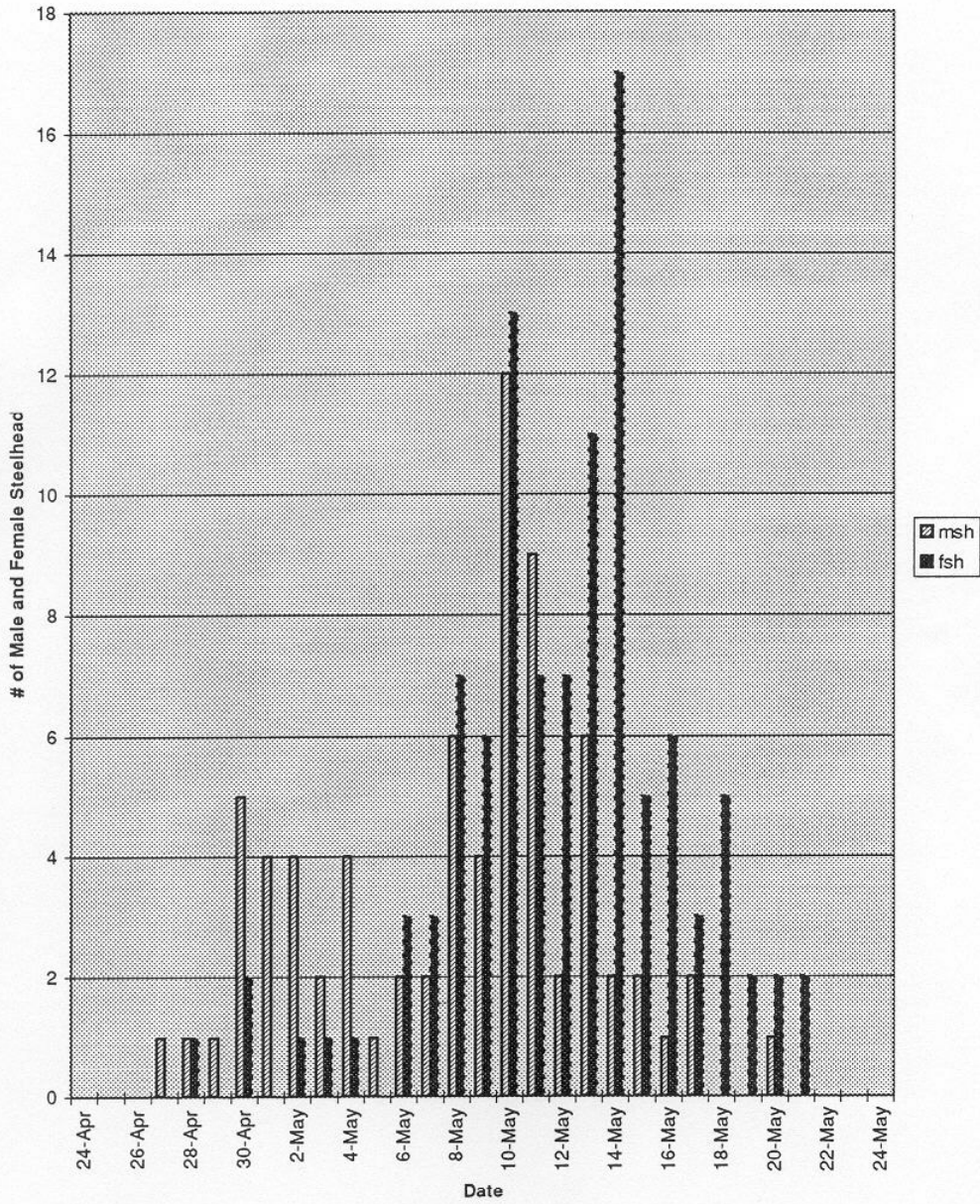


Figure 5.0 Daily Male and Female Steelhead Immigration

**Figure 6.0 Steelhead male and female immigration in relation to stream discharge.
Data not available until January 1998.**

Telemetry Results

A total of 21 radio transmitters and 7 spaghetti tags were distributed to steelhead by angling at the Deadman/Thompson River confluence from late March to late April, 1998. Of these 21 radio tags, 1 appeared to have been regurgitated and remained in the Thompson River just downstream of the CNR bridge below the Deadman/Thompson confluence. The other 20 radio tags were tracked on a daily basis to either emigration or death. Radio tagged steelhead were recorded spawning between approximately 12 km upriver of the Deadman/Thompson River confluence to approximately 37 km upriver (Table 3.0).

Seven radio tagged and 2 spaghetti tagged steelhead migrated through the fish fence located 19.2 km upstream of the confluence. These 9 steelhead indicate that there were approximately 512 steelhead below the fish fence based on Petersen's mark-recapture formulae.

Four radio tagged steelhead migrated as far as the fish fence itself but did not migrate through, 2 of these fish spawned immediately downstream of the fence, 1 spawned approximately 1 km downstream of the fence and the fourth fish spawned approximately 4 km downstream of the fence.

A permanent fixed radio telemetry station was erected at the weir site on the Deadman River, of the 20 steelhead that were radio tagged 18 migrated up to or past this fixed station. Of these 18 steelhead 5 dropped back downstream and spawned and another 2 steelhead spawned immediately upstream of the weir. Two steelhead did not migrate past the weir and spawned 4.7 and 2.8 km downstream of the weir structure.

Two steelhead were tracked into Criss Creek, one steelhead migrated 8.9 km upstream of the Criss Creek/Deadman River confluence, the other radio tagged steelhead spawned approximately 2.3 km upstream of the Criss Creek/Deadman River confluence. A natural barrier approximately 2.5 km up Criss Creek was thought to impede upstream migration. The steelhead that was tracked past this barrier is the first observation of steelhead migration past this point.

Emigration rates of post spawned steelhead were generally very rapid. Steelhead that were tracked on their downstream migration generally appeared to reach the Thompson River by the next day.

Two fixed telemetry stations set up on the Fraser River have recorded the downstream movements of 6 Deadman River radio tagged steelhead.

Table 3.0 Suspected Spawning locations and times for radio tagged, Deadman River steelhead

Radio Tag no.	Sex	Spawning Location (stream km)	Dates at Spawning location	Comments
20/74	f	11.9	May 11-17	Below Weir
20/76	f	14.5	May 7-18	Below Weir
20/77	m	1.8 (Criss Creek)	May 18-25	Criss Creek
20/78	f	32	May 6-10	Above Fence
20/79	m	37.5	May 17-23	Above Fence- Below Mowich Lk
20/80	m	28	May 16-21	Above Fence
20/85	f	16.9	May 11-15	Between Weir and Fence
20/87	f	10.5	May 13-19	Below Weir
20/88	m	12.7	May 13-24	Below Weir
20/89	f	9.7	May 14-19	Below Weir
20/90	f	25.3	May 14-20	Above Fence
20/91	m	14.8	May 13-20	Below Weir
20/92	f	19.2 (Fence)	May 15-19	Just Below Fence
20/93	m	12.7	May 13-21	Below Weir
20/94	m	29	May 11-?	Radio Tag is in Eagles Nest at Bob Georges
20/96	f	19.2 (Fence)	May 17-23	Just Below Fence
20/97	f	24.5	May 8-14	Above Fence
20/98	f	24.9	May 10-21	Above Fence
20/100	m	8.9 (Criss Creek)	May 15-19	Past obstruction in Criss Creek
20/101	f	14.4	May 13-19	Below Weir

Deadman River Residency Timing

The residency times for male steelhead ranged from 20 to 32 days with an average residency time of 24.6 days. Female steelhead residency times ranged from 11 to 32 days with an average stay of 21.3 days.

The redd residency times for male steelhead ranged from 5 to 9 days with an average redd residency time of 6.9 days. Female redd residency times ranged from 4 to 11 days with an average redd residency time of 6.5. Steelhead that either died or post spawn regurgitated their radio tag at the same location as their redd location were also not included due to an undetermined number of days on the redd (Appendix I).

In 1984, Moore and Olmstead, reported redd residency times in the Deadman River to be approximately 5 days. This redd residency timing was based on observing fish on redds rather than radio telemetry results.

8.0 Discussion

Sex Ratios

An average sex ratio of 1:1.4 male to female for Deadman River steelhead can partially be related to residualism where steelhead will favor maturation in fresh water over smolting (Figures 6.0, 7.0). Residualism has also been observed among steelhead from the Bonaparte River, near Cache Creek. Male to female steelhead sex ratios have increased to a mean of 1:2.3 males (Renn, 1996). In the Keogh River, near Port Hardy on Vancouver Island, sex ratios of steelhead from 1976-1986 were similar with 1324 males and 1839 females (1:1.4) (Ward, 1990). In the Sustut River, located at the upper end of the Skeena River, sex ratios of steelhead for 1993 were also similar with 65 males and 117 females (1:1.8) (Saimoto, 1993).

Renn (1996), explains that a reduction in population density will also have a tendency to increase the rate of residualism by reducing competition for available resources within the system. Less competition means higher growth and maturation rates. Renn, also explains that certain activities that enhance the productivity of a system such as pulp mill effluent, fertilizer from agricultural land and increased stream temperatures from development could increase residualism (Renn, 1996).

“Peven (1990), produced a model which compared the overall fecundity (fitness) of anadromous and non-anadromous life histories in *O. mykiss*, it was found that their overall fecundities were similar. The most important factor for increasing fecundity in non-anadromous trout was their size at maturity. In anadromous *O. mykiss*, the most important factor for increasing fitness was the survivorship of smolts to adults. Any environmental factor or human activity therefore (such as commercial interception and sport fishing), that reduces the survivorship of smolts to adults, would tend to provide selection pressure for an entirely fresh water life history” (Renn, 1996).

Redd Residency Timing

In 1984, Moore and Olmsted, found that steelhead within the Deadman River have an average redd residency time of approximately 5 days (Moore and Olmsted, 1985). This was based on visual observations of steelhead on redds. In 1998, redd residency times were calculated using daily radio telemetry results. Based on radio telemetry results the redd residency period for males was 6.9 days and 6.5 days for female steelhead, however the use of telemetry results would tend to over estimate redd residency because spawning events of short duration (less than three days) would not be accounted for. Visual observations of whether steelhead were actually on a flat or in holding water were not confirmed. At the very least, the telemetry results corroborate with the observations of Moore and Olmsted (1985).

Escapement Estimates

Over the past 15 years steelhead escapement estimates for the Deadman River have been based on the number of steelhead that migrate through the fence plus an additional 30% that spawn below the fish fence and Criss Creek. The 30% addition for downstream spawners is based on past stream walks when the spring flows in the Deadman River were a lower and more stable river (pers comm Maricle, 1998).

In 1985, a spawner distribution profile of the Deadman River, was built based on observed redds. The profile estimated a 20% spawner distribution below the fish fence and 80% spawner distribution above the fish fence (Moore and Olmsted, 1985).

In 1998, 182 steelhead migrated through the fence, the estimate should then be approximately $(182 + 30\%(182)) = 237$ steelhead. However in 1998, 27 steelhead were either radio tagged or spaghetti tagged at the confluence with the Thompson. Of these 27 marked fish 9 were recaptured at the fish fence, this results in an escapement estimate of 512 steelhead below the fish fence and 694 for the entire Deadman River using Petersen's mark-recapture equation.

In 1987, 423 steelhead migrated through the fish fence resulting in an escapement estimate of approximately 550 steelhead $(423 + 30\%)$. In 1987, Maricle, marked 28 steelhead with floy tags at the mouth of the Deadman River and recovered only seven of these steelhead at the fish fence. This results in an escapement estimate of 1537 steelhead below the fence, and an escapement estimate of 1960 steelhead instead of 550 for the entire river (Maricle, 1987). McGregor believes floy tag loss could account for the lower than expected recapture of marked steelhead in 1987 but the results seem to coincide with the 1998 mark recapture results (pers comm McGregor, 1998).

Does the fish fence impede upstream migration?

A total of 11 radio tagged steelhead either migrated through the fish fence or right up to the fence. Four of these steelhead migrated upstream until the fish fence itself and then appeared to be hampered by the fence from further upstream migration. Of the 7 steelhead that migrated through the fish fence 3 were males and 4 were females. All of the male steelhead that migrated up to the fence were able to find their way through while only half of the females that made it to the fish fence migrated through it. Even though a sample size of 11 steelhead is small, the radio tag data seems to suggest that more aggressive males migrate through the fence easier than female steelhead. Past stream walks on the Deadman River above and below the fish fence site produced an escapement estimate of about 70 % of the steelhead spawning above the fish fence site and approximately 30 % below the fish fence. If we believe these figures to be accurate then one explanation for the mark recapture results of 1987 and 1998, is that the

fish fence itself is hampering upstream migration of steelhead in the Deadman River and forcing steelhead to spawn below the fish fence.

Radio tagged steelhead were either delayed or prevented from upstream migration by the fish fence. The 3 male steelhead that migrated up to and then through the fish fence were delayed 3, 5, and 12 days. The 4 female steelhead that migrated through the fish fence were delayed anywhere from 2-5 days. Three female steelhead migrated up to the fish fence and held immediately downstream of the fish fence for 3, 5 and 7 days. The fish fence appears to be hampering the upstream migration of female steelhead than more aggressive male steelhead. Male steelhead appear to be able to hold longer at the fence site before migrating through. One male steelhead was held up for 12 days before it migrated through the fence while the longest a female steelhead was able to hold below the fence was 7 days.

If the fish fence is hampering female steelhead from upstream migration the male to female sex ratios for the above fence spawning population could be greatly affected.

Future mark recapture experiments are needed below the fence in order to estimate a more accurate escapement for the Deadman River and continued assessment or experimentation with the fence are required to determine whether the fence itself discourages steelhead from migrating to upstream areas..

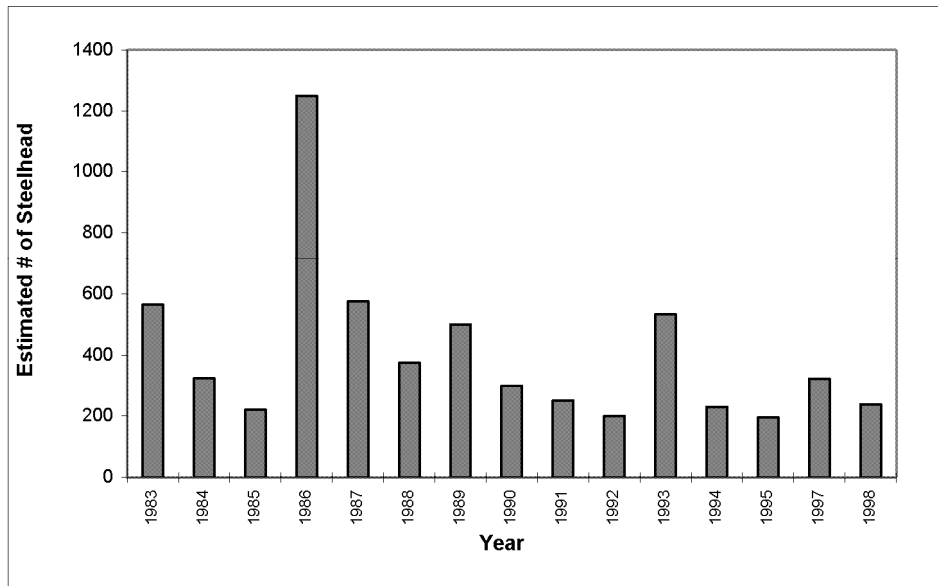


Figure 7.0 Estimated Steelhead Escapements for the Deadman River from 1983 to 1998.

9.0 Recommendations

- Mark-recapture experiments using radio tags and or spaghetti tags need to be conducted on the Deadman River below the fish fence to better understand the escapement estimate below the fish fence.
- The fish fence on the Deadman River needs to be redesigned to allow easier fish passage or alternatively replace the fence site with an alternative enumerating device such as a electronic fish counter
- If the fence cannot be replaced with an alternative counting method at this time then experimentation with the fence and radio tagged steelhead to determine whether the fence is altering steelhead behaviour should take place.

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