ABUNDANCE AND LIFE HISTORY CHARACTERISTICS OF ADULT CRANBERRY RIVER STEELHEAD, 1997

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Abstract

In 1997, the abundance of adult Cranberry River steelhead (*Oncorhynchus mykiss*) was estimated with mark-recapture sampling in 26 of the 30 river kilometers of the identified main overwintering habitat. From October 6 to 10, steelhead were marked with numbered Floy anchor tags and adipose fin clips which distinguished marked from unmarked steelhead in the recovery sample (November 3 to 7). Unbiased Petersen (Chapman's modification) and Bayesian mark-recapture estimators were used to calculate adult steelhead abundance in the areas sampled. Abundance was estimated for conditions that assumed no hook and release mortality in the tag application sample and for conditions that assumed hook and release mortality (9.1%) in the tag application sample. Sampling selectivity was investigated by examining the spatial, size, age, and sex biases in the tag application and recovery samples; however, none were detected.

The Bayesian steelhead abundance (mode) for the entire area sampled was 782 steelhead (95% confidence limits: 560-1,372 steelhead) and the Petersen abundance was 753 steelhead (95% confidence limits: 550-1,352 steelhead) when the application sample was adjusted for hook and release mortality. Petersen mark-recapture estimates were consistently lower than the Bayesian modes which indicated the size of the application and recovery samples may have been too small and the number of marked steelhead recovered may have been too low for accurate Petersen estimates. The Bayesian estimator is recommended under these conditions of small samples.

The Cranberry River abundance estimate assisted in evaluating the different carrying capacity predictions of the Nass River steelhead production model. We recommend that Model 6 of the Nass River steelhead production model should be used to predict steelhead carrying capacity and escapement requirements based on the results of this study.

In 1997, male steelhead (mean = 69.3 cm) were similar in size to female steelhead (mean = 67.2 cm; Mann-Whitney U = 5841, $P = 0.313$), however males (mean = 75.2 cm) were larger than females at ocean age 2+ (mean = 70.1 cm; t-test = -5.94, $P = 0.005$). The most common age group was 3.1+ for males and 3.2+ for females and the mean smolt age was 3.32 years. Repeat spawners were rare (2.3%) among the 171 steelhead with readable scales. Twelve of the 241 steelhead sampled (5.0%) in the Cranberry River had Floy tags that were applied at the Nass River fishwheels by the Nisga'a Tribal Council in 1997. For fishwheel tagged steelhead recaptured in the Cranberry River, the mean date for steelhead sampled at fishwheel 2 was August 21, whereas the mean date for steelhead sampled at fishwheels 3 and 4 was August 30. None of the steelhead sampled at fishwheel 1 were recaptured in the Cranberry River. Between the application and recovery samples, Floy tagged steelhead made small movements within reaches, but there was no evidence of movement between reaches 2 and 3. Of the 233 steelhead examined, 30 (13%) had head wounds, 15 (6%) had gillnet marks, and 44 (19%) had predator scars.

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1.0.0.0 Introduction

Little information exists on the abundance of summer or winter steelhead (*Oncorhynchus mykiss*) populations in the Nass River watershed. Previous investigations indirectly estimated adult steelhead abundance based on the relative distribution of radio tagged steelhead in 1993 (Alexander and Koski 1995; Koski and English 1996). Other investigations estimated juvenile steelhead abundance and smolt production and then used provincial biostandards of steelhead survival to estimate theoretical adult steelhead returns. Thus, theoretical adult steelhead abundance was indirectly estimated for the Damdochax (Triton 1994a), Kwinageese (Triton 1994b) and Cranberry (Sebastian 1987) rivers by measuring steelhead fry and parr densities. No investigations have directly measured the abundance of any adult steelhead population in the Nass River (Koski and English 1996).

The B.C. Fisheries Branch has developed a habitat capability model to predict smolt production and adult abundances for Nass River summer and winter steelhead populations (Bocking *et al*. 1998). However, the relative efficiency of the model's predictions could not be assessed due to the absence of direct adult steelhead abundance estimates. Therefore, the Cranberry River population was selected to directly estimate adult steelhead abundance to assist in evaluating the model's predictions because of good river access and previous studies had described the main overwintering areas (Lough 1983; Koski and English 1996).

The abundance of Cranberry River steelhead was estimated by Sebastian (1987) and Koski and English (1996). In 1986, Sebastian (1987) measured steelhead fry densities in four mainstem reaches (excluding the Kiteen River) and estimated the total fry population. Provincial biostandards of steelhead survival were then used to estimate adult steelhead abundance at 2,400 steelhead in the absence of harvest and 1,200 steelhead when commercial and native harvests were included (Sebastian 1987). For steelhead returning in the summer of 1993 to the Cranberry and Kiteen rivers, Koski and English (1996) estimated 1,000 adult steelhead passed Canyon City (Gitwinksihklw) that were destined for the Cranberry River. Koski and English (1996) estimated the Cranberry and Kiteen river steelhead escapement at 925 fish after accounting for in-river harvests. These telemetry estimates were based on six radio tagged steelhead moving into the Cranberry River (Koski and English 1996).

The objectives of the fall population mark-recapture abundance were:

1) to investigate sampling selectivity between application and recovery samples by examining spatial, size, age and sex related bias;
2) to investigate indicators of immigration and tag loss as sources of bias in abundance estimates, and if sampling areas could be grouped for analyses;
3) and to estimate the abundance of adult steelhead in part of the Cranberry River with mark-recapture sampling.

The objectives of the summary of life history characteristics were:

1) to examine the size distribution of male and female steelhead;
2) to examine the age composition of steelhead between years;
3) to examine the length at age of steelhead between years;
4) to examine the sex, tag number and size distribution of Fishwheel tagged steelhead and summarize the movements of recaptured steelhead, and;
5) to summarize observations of steelhead condition.

2.0.0.0 Study Area

The Cranberry River originates in the Hazelton Mountains of west central British Columbia and flows northwest for approximately 110 km to its confluence with the Nass River (Figure 1). Above its confluence with the Kiteen River, the Cranberry River drains approximately 955 km^2 and has an estimated mean annual discharge of 23.0 m^3/s and mean summer wetted width of 30 m (Sebastian 1987). The Cranberry River has eleven main tributaries: Kiteen River and Calvin, Borden, Ginmiltkun, Derrick, McKnight, Calmin, Aluk, Douse, Tsugwinselda and Weber creeks (Figure 2). The Cranberry River consists of four main reaches based on gradient, channel confinement and flow (Sebastian 1987; Figure 2; Table 1). Common fish species in the Cranberry River include sockeye salmon (*O. nerka*), chinook salmon (*O. tshawytscha*), coho salmon (*O. kisutch*), pink salmon (*O. gorbuscha*), steelhead trout, Rocky Mountain whitefish (*Prosopium williamsoni*), bull char (*Salvelinus confluentus*), Dolly Varden char (*S. malma*) and Pacific lamprey (*Lampetra tridentata*; Sebastian 1987; Bustard 1994; Parken 1997a). The Cranberry River watershed lies within the Coast Mountain ecoprovince and contains five biogeoclimatic zones: Alpine Tundra, Engelmann Spruce-Subalpine Fir, Interior Cedar-Hemlock, Mountain Hemlock, Coastal Western Hemlock (Pojar and Nuzsdorfer 1988).

For this study, the middle Cranberry River was chosen as the study area because it included the main overwintering areas for radio tagged steelhead described by Lough (1983) and Alexander and Koski (1995; Figure 2). In 1979, Lough (1983) radio tagged 13 and Floy tagged 36 steelhead from October 31 to November 28. Tagging was attempted throughout the river, however most steelhead were tagged between river kilometer 18 (rkm; measured from the Cranberry/Nass confluence) and rkm 25 and none were tagged upstream of rkm 26. Small upstream and downstream movements (<5 rkm) were documented, but the steelhead showed little or no movement from this part of the mainstem throughout the fall and winter (Lough 1983). Thus, steelhead appeared to move into the lower 30 rkm of the Cranberry River in the fall, but showed little inclination to move upstream of rkm 30 in any numbers until the spring-time spawning movements (Lough 1983). The overwintering locations were described for four radio tagged steelhead in Alexander and Koski (1995). Of these four steelhead, Koski and English (1996) reported that one overwintered in the Nass River at the Cranberry/Nass confluence, two overwintered in the lower Cranberry, and one overwintered in the middle Cranberry. Steelhead also overwinter in the Cranberry River downstream of the confluence with the Kiteen River (M.C. Beere, personal communication), however this area was excluded from the study area due to logistical and personnel limitations.

The middle Cranberry River was divided into seven sections based on access points and river length that could be effectively sampled by a two person crew during one day (Figure 2; Table 1). The Cranberry River was sampled from the confluence of the Kiteen and Cranberry rivers (rkm 3.5) to a point 2 km upstream of the northern Highway 37 bridge (rkm 30.5), except for a 1 rkm area (Figure 2). The area sampled included the heaviest overwintering area observed by Lough (1983; McKnight Creek (rkm 21-26)) and all of reach 2 and part of reach 3 (Figure 2). The canyon section near Ginmiltkun Creek (rkm 14.5) was the reach break between reaches 2 and 3 (Table 1; Sebastian 1987). The area sampled represents approximately 26 of the 110 rkm of river and about 26 of the 30 rkm of the main overwintering habitat, based on Lough's results (1983).

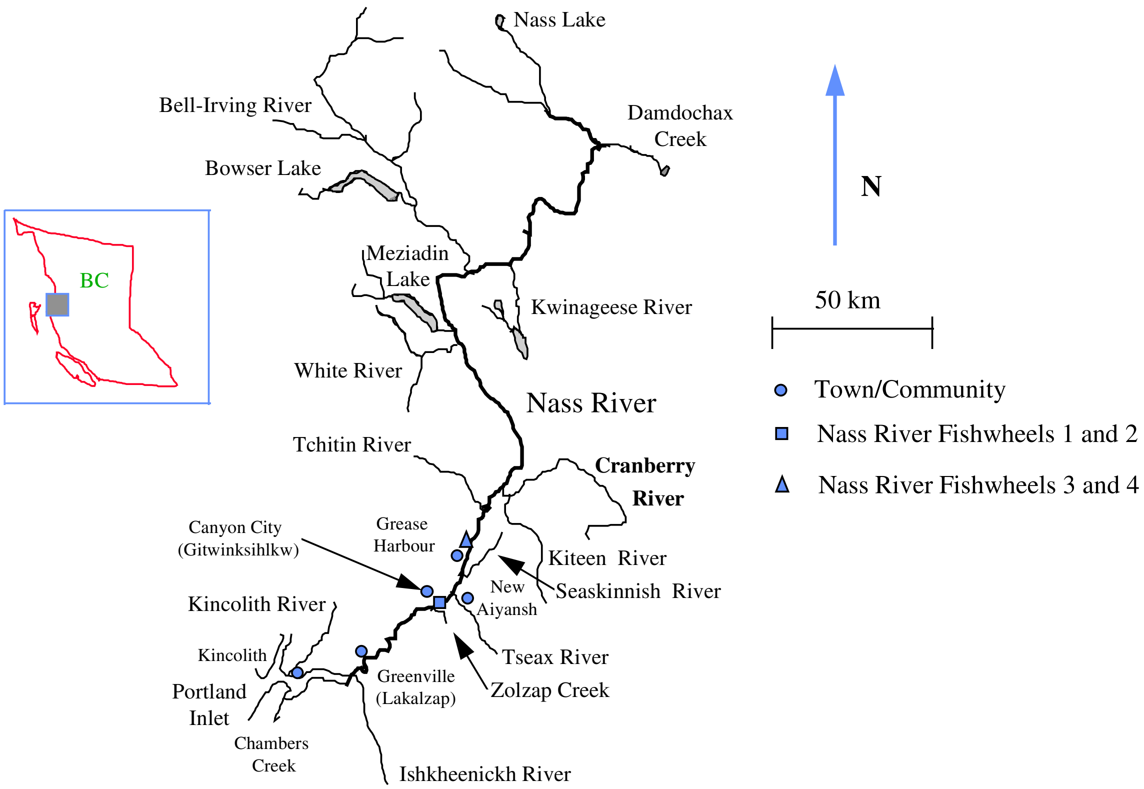

Figure 1. The Nass River watershed and major tributaries.

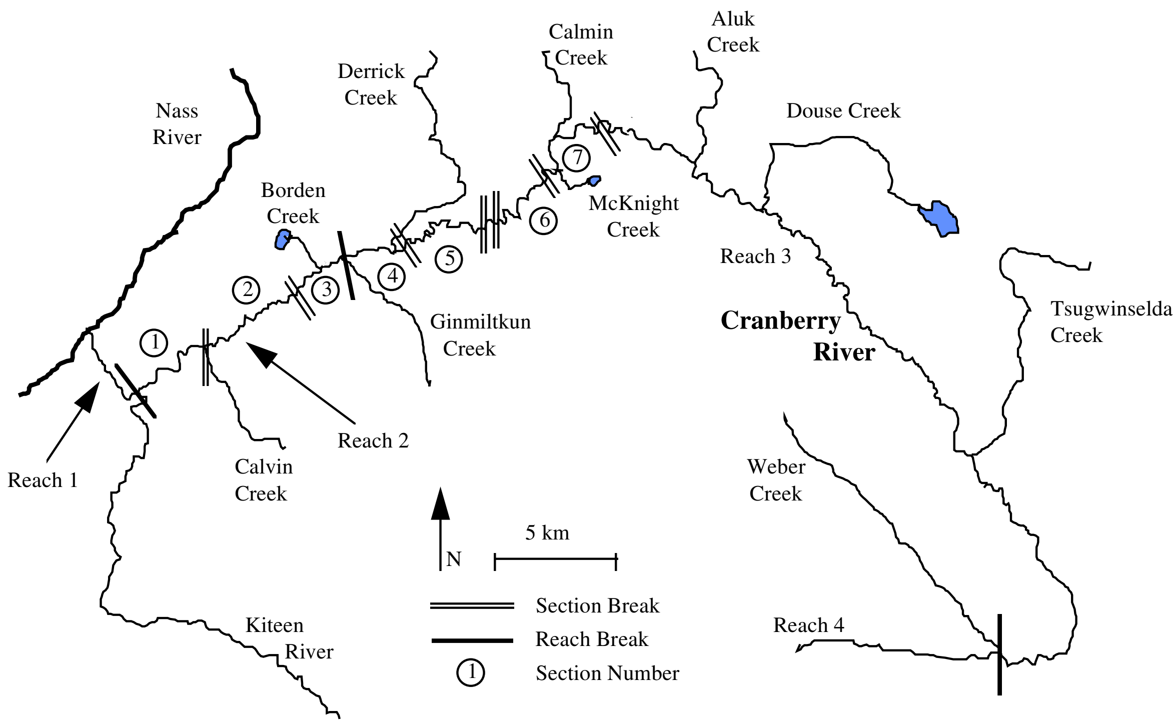

Figure 2. A detailed map of the study area with labeled reaches and sections used for analyses. The boundary descriptions and river kilometers were located in Table 1.

Table 1. The boundary descriptions and river kilometer (rkm) locations for reaches defined by Sebastian (1987) and section boundaries used for analyses.

Location	Boundary Description	River Kilometers (rkm)
Reach 1	Cranberry/Nass confluence to Kiteen/Cranberry confluence	0-3.5
Reach 2	Kiteen/Cranberry confluence to Canyon at Ginmiltkun Creek	3.5-14.75
Reach 3	Canyon at Ginmiltkun Creek to Weber/Cranberry confluence	14.75-76.0
Reach 4	Weber/Cranberry confluence to Headwaters	76.0-109
Section 1	Cranberry/Kiteen confluence to Calvin Creek	3.5-8.25
Section 2	Calvin Creek to Powerline	8.25-11.75
Section 3	Powerline to Canyon at Ginmiltkun Creek	11.75-14.75
Section 4	Canyon at Ginmiltkun Creek to rkm 19.25	14.75-19.25
Section 5	rkm 19.25 to Cranberry Junction	19.25-22.0
Section 6	rkm 23.0 to rkm 26.5	23.0-26.5
Section 7	rkm 26.5 to rkm 30.5	26.5-30.5

3.0.0.0 Methods

3.1.0.0 Steelhead Abundance Estimates

All fish were captured by angling in reaches 2 and 3 from October 6 to 10 and November 3 to 7, 1997. The two sampling periods refer to the tag application sample (October 6 to 10) and the recovery sample (November 3 to 10). All fish were identified to species using visual characteristics described in Scott and Crossman (1973) and McPhail and Carveth (1994). However, only steelhead were sampled in order to minimize the unnecessary handling of other fish species. The location, number captured or observed, tag colour and tag number were recorded for other fish species (Parken 1997a).

During the tag application sample, steelhead were tagged with a uniquely numbered orange Floy anchor tag below the dorsal fin. A small piece of adipose fin tissue was removed for genetic analysis and stock identification. The clipped adipose fin functioned as a secondary mark to allow the assessment of Floy anchor tag loss. Approximately five scales per fish were collected between the lateral line and dorsal fin for aging from each steelhead. The sex, fork length, location (section and reach) and the presence of gillnet marks, predator scars, or head wounds were recorded for all steelhead sampled. If steelhead were caught that were Floy tagged at the Nass River fishwheels, the tag number, sex, fork length and the presence of gillnet marks, predator scars, or head wounds were recorded. Adipose fin tissue and scale samples were collected from steelhead with fishwheel tags that were not sampled at the fishwheels, as evidenced by the condition of their adipose fin.

During the recovery sample, the tag number, sex and location (section and reach) were recorded for all recaptured steelhead. For adipose fin sampled steelhead without tags, the presence of a tag scar below the dorsal fin determined if the fish had lost its tag or if it was one of the steelhead that was recently adipose fin sampled, but not tagged (DNA sampled in September, 1997 by M.C. Beere). The sex, fork length, location (section and reach) and the presence of gillnet marks, predator scars, or head wounds were recorded for unmarked steelhead. Scale samples were collected from some of the unmarked steelhead for aging. All unmarked steelhead were tagged with a uniquely numbered orange Floy anchor tag that was applied below the dorsal fin. Tag numbers identified steelhead as being marked during the application or recovery sample. Also, the recovery sample was tagged with the anticipation that a multiple pass estimator (e.g. Schnabel, Schumacher-Eschmeyer etc.) would be employed.

The abundance of steelhead ($\hat{N}$) in part of the Cranberry River (rkm 3.5 to rkm 28) from October 6 to November 10 was estimated using unbiased Petersen mark-recapture estimators (Chapman's modification) and Bayesian maximum likelihood estimators. The population abundance was calculated for the area sampled within two strata (reach 2 and reach 3) and for the entire area sampled. From herein, reach 2 refers to sections 1, 2 and 3 and reach 3 refers to sections 4, 5, 6 and 7. Petersen and Bayesian estimators were summed for reaches 2 and 3 to provide alternative population abundance estimates for the entire area sampled.

The unbiased Petersen estimator ($\hat{N}$) was calculated for each reach and the entire area sampled with equation 1 (Seber 1982; Krebs 1989):

Equation 1
$$\hat{N} = \frac{(M+1)(C+1)}{R+1} - 1$$

where *M* was the number of steelhead marked during the application sample, *C* was the number of steelhead examined for marks during the recovery sample and *R* was the number of marked steelhead observed during the recovery sample. The variance of the unbiased Petersen estimator ($Var(\hat{N})$) was calculated with equation 2 (Starr and Schubert 1990; Farwell *et al*. 1992; Schubert 1993; Atagi 1995):

Equation 2
$$Var(\hat{N}) = \frac{(\hat{N})^2(C-R)}{(C+1)(R+2)}$$

Binomial confidence limits (95%) for $\hat{N}$ were calculated from the binomial confidence limits (95%) of the mark rate (*R*/*C*; equation 3) which were substituted into equation 4 (Krebs 1989):

Equation 3
$$\text{95\% Binomial Confidence Limits} = \frac{R}{\mathrm{C}} \pm \left\{1.96\left[\sqrt{\frac{(1-R/M)(R/C)(1-R/C)}{C-1}}\right] + \frac{1}{2C}\right\}$$

Equation 4
$$\text{95\% Binomial Confidence Limits on } \hat{N} = \frac{C}{R}M$$

The summed Petersen estimator for the area sampled ($\hat{N}_{area\_sampled}$) was calculated with equation 5 (Starr and Schubert 1990; Farwell *et al*. 1992; Schubert 1993; Atagi 1995):

Equation 5
$$\hat{N}_{area\_sampled} = \hat{N}_{reach\_2} + \hat{N}_{reach\_3}$$

Equation 6
$$Var(\hat{N}_{area\_sampled}) = Var(\hat{N}_{reach\_2}) + Var(\hat{N}_{reach\_3})$$

Equation 7
$$\text{95\% Confidence Limits} = \hat{N}_{area\_sampled} \pm 1.96\sqrt{Var(\hat{N}_{area\_sampled})}$$

and the variance for the area sampled ($Var(\hat{N}_{\mathrm{area\_sampled}})$) was used to calculate 95% confidence limits with the normal approximation method (Starr and Schubert 1990; Farwell *et al*. 1992; Schubert 1993; Atagi 1995).

The Bayesian estimator was calculated with a sequential Bayes algorithm described by Gazey and Staley (1986) with the assumption that the prior distribution was uniform. The mode of the posterior probability distribution was the population abundance estimate. The upper and lower 95% confidence limits were the 2.5 and 97.5% quantiles, respectively (Gazey and Staley 1986; Hilborn and Walters 1992).

The Bayesian maximum likelihood estimator yields larger abundance estimates than the unbiased Petersen mark-recapture estimator when the number of animals marked and the total number examined is low (Gazey and Staley 1986). This results from the unbiased Petersen mark-recapture estimator yielding abundance estimates with substantial negative bias and exceedingly large confidence limits when the number of animals marked and the total number examined is low (Robson and Regier 1964; Gazey and Staley 1986). However, both estimators yield similar abundance estimates for large samples ($M/\hat{N} > 0.5$), but when small samples were collected the Bayesian estimator was recommended ($M/\hat{N} < 0.5$; Gazey and Staley 1986). Gazey and Staley (1986) reported the following advantages of the Bayesian estimator over the unbiased Petersen mark-recapture estimator: the probability of observing the data at feasible population sizes is calculated exactly, the method works well for all cases regardless of sample size or sampling procedure, and inferences can be made directly, since the estimate completely describes the uncertainty of the population size given the data.

3.1.1.0 Sampling Selectivity

A number of assumptions were required for the unbiased Petersen and Bayesian estimators to be accurate. The main assumptions were (1) the population was closed and thus the population size did not change between the application and recovery samples; (2) the probability of capturing a marked steelhead at any given time was equal to the proportion of marked steelhead in the population at that time; (3) steelhead did not lose their marks between the application and recovery samples; and (4) all marked steelhead were identified in the recovery sample (Gazey and Staley 1986).

To investigate if marked steelhead were randomly distributed among unmarked steelhead (assumption 2), spatial, size, age and sex related biases were examined in the recovery sample (Starr and Schubert 1990; Begich 1992; Farwell *et al*. 1992; Schubert 1993; Pahlke and Bernard 1996; Begich 1997). To examine if all fish had the same probability of occurring in the recovery sample (assumption 2), spatial, size, age and sex related biases were examined in the application sample (Starr and Schubert 1990; Begich 1992; Farwell *et al*. 1992; Schubert 1993; Pahlke and Bernard 1996; Begich 1997).

Other characteristics observed on steelhead were not used for bias investigations. The incidence of fishwheel tags or gillnet marks could not be used for bias investigations due to small samples of steelhead with fishwheel tags or gillnet marks. Similarly, the incidence of predator scars or head wounds could not be used for bias investigations since these rates may increase with the amount of time steelhead reside in the Cranberry River. For example, some predators such as river otters were observed in the river and a steelhead may be more likely to have an encounter with one as the fish spends more time in the river. Similarly, head wounds may be related to surmounting impediments such as canyons and rock falls.

3.1.1.1 Location

Spatial bias in the application sample was investigated by comparing the mark incidence between reach 2 and reach 3 in the recovery sample with a chi-square test of homogeneity. Spatial recovery bias was investigated by stratifying the application sample by reach and comparing the mark incidence among recovered and non-recovered components with a chi-square test of homogeneity. The distribution of steelhead sampled within each section was compared between the application and recovery samples with a chi-square test of homogeneity.

3.1.1.2 Steelhead Size

Size related bias in the application sample was investigated by comparing the size distribution of marked and unmarked steelhead in the recovery sample with a Kolmogorov-Smirnov two-sample test. Size related recovery bias was investigated by stratifying the application sample by recovered and non-recovered components and comparing the size distributions of each with a Kolmogorov-Smirnov two-sample test. Size related application and recovery bias was investigated separately for males and females, since significant size differences between the sexes were reported for other steelhead populations (Hooton *et al*. 1987; Parken *et al*. 1997).

3.1.1.3 Steelhead Age

Age related bias in the application sample was investigated by comparing the ocean age composition of marked and unmarked steelhead in the recovery sample with the Yates continuity correction of the chi-square test of homogeneity and the freshwater age composition with *t*-tests (Zar 1984). Age related recovery bias was investigated by stratifying the application sample into recovered and non-recovered components and comparing the ocean age composition of each with a Yates continuity correction of the chi-square test of homogeneity and the freshwater age composition with a Student's *t*-test. For age related application and recovery bias analyses, ocean age 2+ and older steelhead (including repeat spawners) were grouped to meet the assumptions of the chi-square test for expected cell counts. All scales were aged by C. Lidstone at Birkenhead Scale Analyses, D'Arcy, B.C. (Lidstone 1997).

3.1.1.4 Steelhead Sex

Sex related bias in the application sample was investigated by comparing the sex ratio of marked and unmarked steelhead in the recovery sample with a chi-square test of homogeneity. Sex related recovery bias was investigated by stratifying the application sample into recovered and non-recovered components and comparing the sex composition of each with a chi-square test of homogeneity.

3.1.1.5 Immigration

Due to logistical and monetary constraints, the sampled area of the Cranberry River could not be physically closed (assumption 1). Therefore, steelhead abundance may have changed between samples due to emigration, immigration, native harvest, poaching, natural mortality or predation (Bison 1993). However, application and recovery samples were collected over a short period of time (approximately one month) to minimize changes in steelhead abundance.

Substantial immigration of unmarked steelhead between samples would inflate the unbiased Petersen and Bayesian estimators (Krebs 1989). Evidence of significant immigration was investigated by examining changes in the incidence of fishwheel tags and gillnet marks between the application and recovery samples. Floy anchor tags were applied to steelhead captured at the Nass River fishwheels by the Nisga'a Tribal Council from July 28 to September 3, 1997. Approximately 5 to 10 percent of steelhead migrating passed the fishwheels were tagged (M.R. Link, personal communication). Gillnet marks were evident on steelhead intercepted during the commercial or native gillnet fisheries that usually operate from June to mid September (Koski and English 1996). For steelhead migrating after the fishwheels or gillnet fisheries had ceased, few if any marks (tags or gillnet) would be expected. If a substantial number of these fish entered the study area between samples, the incidence of fishwheel tags and gillnet marks would be expected to decrease in the recovery sample. The incidence of fishwheel tags or gillnet marks was compared between the application and recovery samples with a chi-square test of homogeneity.

3.1.1.6 Tag Loss

Floy tag loss was examined by giving all steelhead in the application sample a secondary mark. A small piece of the adipose fin was removed for genetic analyses during the application sample and served as the secondary mark. In the recovery sample, steelhead that were adipose fin sampled, but did not have a tag were examined for the presence of a tag scar below the dorsal fin because some untagged adipose fin sampled steelhead were already present in the river. The presence of hooks or hook scars also assisted in distinguishing adipose fin sampled steelhead with tag loss.

3.1.1.7 Reaches 2 and 3

Steelhead sampled in reach 2 were compared to those in reach 3 to determine whether they were collected from the same population and whether the strata could be pooled. The sex ratio, size distribution, ocean age composition and mean smolt age of steelhead from reaches 2 and 3 were compared for the application and recovery samples. For analyses, ocean age 2+ and older steelhead were grouped to meet the assumptions of the chi-square test for expected cell counts (Zar 1984). The application and recovery samples were pooled to improve sample sizes for comparing the incidence of gillnet marks and incidence of fishwheel tags between steelhead from reaches 2 and 3.

For bias investigations regarding location, steelhead age, steelhead sex and immigration, a *post hoc* power analysis was performed to investigate if there was no effect (or bias) or whether the analysis had a low probability of detecting an effect if one was present (Peterman 1990). The statistical power of a test was the probability of detecting a sampling bias, provided differences existed between the application and recovery samples. A statistical test with power equal to 0.80 or 0.95 was considered to have high power (Cohen

1988; Peterman 1992). The effect size was reported to indicate the standardized degree of the difference between the application and recovery samples, and it was an indicator of the biological significance of the differences between the application and recovery samples (Cohen 1988; Thomas and Juanes 1996). The power of the effect size observed in the sample and the detectable effect size was estimated with G*Power (Erdfelder *et al*. 1996; Buchner *et al*. 1997). The detectable effect size was estimated when alpha and beta were set at 0.05 and 0.20, respectively and with the observed sample size and variance (Cohen 1988; Peterman 1990). The detectable effect size was the effect size required to indicate sampling bias between the application and recovery samples (reject the null hypothesis) with an 80 percent chance. A retrospective power analysis was not performed for steelhead size because G*Power was unable to calculate power for the Kolmogorov-Smirnov two-sample test.

3.1.2.0 Mark - Recapture Estimates

Steelhead abundance was estimated separately for the area sampled within reach 2, reach 3, for reach 2 and 3 summed and for the entire area sampled. Both Petersen and Bayesian estimators were calculated for each area for conditions with and without hook and release mortality for the application sample. It was possible that some steelhead in the application sample died from angling, since hooking and releasing adult salmonids influences survival (Wydoski 1977; Hooton 1987; Bendock and Alexandersdottir 1993). Thus, steelhead abundance estimates were also calculated with the number of fish marked in the application sample adjusted for hook and release mortality.

A hook and release mortality of 9.1 percent was used to adjust the number of marks applied in the application sample, since most steelhead were caught with roe and barbed hooks (Hooton 1987). The number of fish marked during the application sample has been adjusted in other studies where mortality associated with tagging and handling was suspected. For example, mark-recapture estimates of chum salmon in the Tanana River, Alaska used a 5.0 percent mortality to adjust the number of fish marked during the application sample (Cappiello and Bromaghin 1997).

Few estimates of hook and release mortality exist for adult anadromous salmon and steelhead during their freshwater upstream spawning migration and no estimates were found for summer steelhead. For Keogh River winter steelhead, the observed hooking mortality was 9.1 percent for the combination of barbed hooks and bait and 3 percent for barbless hooks and bait (Hooton 1987). Hooton (1987) also reported a 3.4 percent mortality rate for British Columbia steelhead collected as hatchery brood stock that were angled on baited, barbed hooks and held in a fish hatchery until sexual maturity. Mongillo (1984) reported 7 to 12 percent mortality for winter steelhead collected for hatchery brood stock from four separate sources in Washington and British Columbia. These steelhead were angled with roe and lures, and after Mongillo (1984) considered handling mortality, the hooking mortality associated with roe was estimated at less than 10 percent. Hooking mortality averaged 7.6 percent (range, 4.1 to 10.6%) for adult chinook salmon in the Kenai River, Alaska that were angled on bait and lures and assessed with radio telemetry (Bendock and Alexandersdottir 1993).

3.2.0.0 Life History Characteristics

3.2.1.0 Steelhead Length Distributions

Steelhead fork lengths were measured to the nearest centimeter. Fork lengths of male and female steelhead were compared using length-frequency histograms and compared with a non-parametric Mann-Whitney U test to avoid the assumptions of equal variances and normality (Zar 1984). The fork lengths of steelhead were compared to those sampled in other freshwater return years (data from Parken 1997b) with a Kruskal-Wallis test. Cranberry River steelhead (all summer run) were grouped by the year they returned to freshwater for their upstream spawning migration.

3.2.2.0 Steelhead Age Distributions

The ocean age compositions of male and female steelhead were compared with a chi-square test of homogeneity and the mean smolt age was compared with a Student's *t*-test. The ocean age composition was compared between freshwater return years (data from Parken 1997b) with a chi-square test of homogeneity. For analyses between years, ocean age 2+ and older steelhead were grouped to meet the assumptions of the chi-square test for expected cell counts (Zar 1984). The mean smolt age was compared between freshwater return years (data from Parken 1997b) with an ANOVA test where Tukey's HSD test was used for *post hoc* comparisons (Zar 1984). All scales were aged by C. Lidstone at Birkenhead Scale Analyses, D'Arcy, B.C.

3.2.3.0 Steelhead Length at Age

Parametric tests were used for comparisons of length at age because lengths were normally distributed and had similar variances within an age group. The mean fork lengths were compared between males and females for each ocean age group with a Student's *t*-test. Fork lengths were compared between age groups for males and females with an ANOVA test, and Tukey's HSD test was used for *post hoc* comparisons (Zar 1984). The fork lengths for ocean age groups were compared between years with an ANOVA test and Tukey's HSD test was used for *post hoc* comparisons (Zar 1984). The mean length of male and female steelhead within an ocean age group were compared between freshwater return years (data from Parken 1997b) with an ANOVA test and Tukey's HSD test was used for *post hoc* comparisons (Zar 1984).

3.2.4.0 Steelhead Recaptures

Sex, fork length, location (section and reach) and the presence of gillnet marks, predator scars, or head wounds were recorded for steelhead that had Floy anchor tags from the Nass River fishwheels. The colour and number of the fishwheel tags was recorded and compared to the Ministry of Environment, Lands and Parks Skeena Region TAGS database. The fork length of steelhead with fishwheel tags was compared to the fork lengths of those without fishwheel tags with a Mann-Whitney U test to investigate size selectivity of the Nass

River fishwheels. For steelhead with fishwheel tags, the mean tagging dates were summarized for fishwheels 1 and 2 and fishwheels 3 and 4. Fishwheel 1 was combined with fishwheel 2 and fishwheel 3 was combined with fishwheel 4 to improve sample sizes and due to the proximity of fishwheels 1 and 2 and fishwheels 3 and 4 (Figure 2; Link 1995; Link and Gurak 1997). Also, the locations were summarized for steelhead that were captured multiple times within the Cranberry River to infer individual steelhead movements.

3.2.5.0 Steelhead Condition

The incidence of head wounds, gillnet marks and predator scars were summarized. The incidence of head wounds and gillnet marks were compared between reaches 2 and 3 with chi-square tests of homogeneity. The fork lengths of male and female steelhead with gillnet marks were compared to male and female steelhead without gillnet marks with a Mann-Whitney U test. For the application and recovery samples, the incidence of predator scars was compared between reaches 2 and 3 with a chi-square test of homogeneity. Also, the incidence of predator scars was compared between the application and recovery samples with a chi-square test.

4.0.0.0 Results

4.1.0.0 Steelhead Abundance Estimates

4.1.1.0 Sampling Selectivity

4.1.1.1 Location

In the recovery sample the mark incidence was similar in reaches 2 and 3 (chi-square $\chi^2 = 0.085$, $P = 0.770$; Table 2). The detectable effect size (w = 0.27) was much larger than the observed effect size (w = 0.04), and thus power was low (power = 0.07). The similar mark incidence and very small effect size indicated there was no spatial bias in the application sample. When the application sample was stratified into reaches 2 and 3, the mark incidence was similar for recovered and unrecovered steelhead (chi-square $\chi^2 = 1.353$, $P = 0.245$; Table 2). The detectable effect size (w = 0.24) was larger than the observed effect size (w = 0.12), and thus power was low (power = 0.30). The similar mark incidence and small effect size indicated there was no spatial related recovery bias.

Table 2. The number of steelhead marked in the application sample, the number examined in the recovery sample, the number of marked fish recovered, the mark incidence in the recovery sample and the percentage of marked steelhead recovered.

Stratum	Number Marked	Number Examined	Number Recaptured	Mark Incidence (%)	Percentage Recovered (%)
Reach 2	76	70	12	17.1	15.8
Reach 3	65	40	6	15.0	9.2
Total	**141**	**110**	**18**	**16.4**	**12.8**

The distribution of steelhead sampled within each section differed between the application and recovery samples (chi-square $\chi^2 = 42.72$, $P < 0.005$; Figure 3). However, samples were too small to investigate spatial related bias in the application sample or spatial related recovery bias by each section.

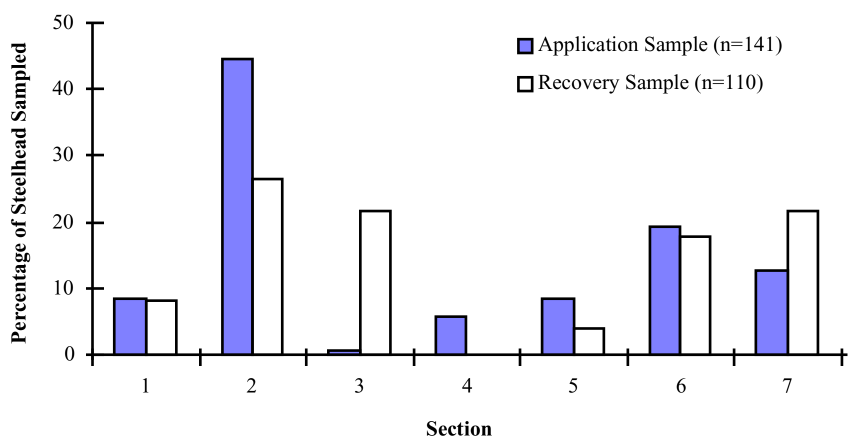

Figure 3. The spatial distribution of steelhead sampled during the application and recovery samples.

4.1.1.2 Steelhead Size

In the recovery sample the size distribution was similar for marked and unmarked female steelhead (Kolmogorov-Smirnov Z = 0.895, P = 0.400) and for marked and unmarked male steelhead (Kolmogorov-Smirnov Z = 0.915, P = 0.372). The similar size of marked and unmarked steelhead among males and females in the recovery sample indicated there was no size related bias in the application sample. In the application sample the size distribution was similar for recovered and unrecovered females (Kolmogorov-Smirnov Z = 0.739, P = 0.646) and for recovered and unrecovered males (Kolmogorov-Smirnov Z = 1.003, P = 0.267). The similar size of marked and unmarked steelhead among males and females in the application sample indicated there was no size related bias in the recovery sample.

4.1.1.3 Steelhead Age

In the recovery sample the ocean age distribution was similar between marked and unmarked steelhead (chi-square χ^2 = 0.813, P = 0.367; Table 3). The detectable effect size (w = 0.40) was slightly larger than the observed effect size (w = 0.38), and thus power was moderate (power = 0.74). The similar age distribution and moderate power of the analysis indicated there was no ocean age related bias in the application sample. In the application sample the ocean age distribution was similar for recovered and unrecovered steelhead (chi-square χ^2 = 0.157, P = 0.692). The detectable effect size (w = 0.24) was larger than the observed effect size (w = 0.14) and thus power was low (power = 0.37). The similar ocean age distribution and small effect size indicated there was no ocean age related recovery bias.

In the recovery sample the mean smolt age was similar between marked and unmarked steelhead (t-test = -0.961, P = 0.343). The detectable effect size (d = 0.99) was much larger than the observed effect size (d = 0.39), and thus power was low (power = 0.20). The similar mean smolt age and small effect size indicated there was no freshwater age related bias in the application sample. In the application sample the mean smolt age distribution was similar for recovered and unrecovered steelhead (t-test = -1.243, P = 0.217). The detectable effect size (d = 0.83) was much larger than the observed effect size (d = 0.36), and thus power was low (power = 0.23). The similar mean smolt ages and small effect size indicated there was no freshwater age related recovery bias.

Table 3. The ocean age composition of Cranberry River steelhead by percentage (%) and number (n) for the application and recovery samples.

Ocean Age[1]	**Application Sample**			**Recovery Sample**		
	Recovered (n)	**Not Recovered (n)**	**Total (n)**	**Marked (n)**	**Unmarked (n)**	**Total (n)**
1+	17.6% (3)	25.4% (31)	24.5% (34)	17.6% (3)	34.4% (11)	28.6% (14)
2+, 3+, 4+	82.4% (14)	74.6% (91)	75.5% (105)	82.4% (14)	65.6% (21)	71.4% (35)
Total (n)	**100% (17)**	**100% (122)**	**100% (139)**	**100% (17)**	**100% (32)**	**100% (49)**

1. Ocean age 3+ and 4+ include the repeat spawner categories 1S1+ and 2S1+, respectively.

4.1.1.4 Steelhead Sex

In the recovery sample the sex ratio was similar for marked and unmarked steelhead (chi-square χ^2 = 0.279, P = 0.598; Table 4). The detectable effect size (w = 0.27) was larger than the observed effect size (w = 0.07), and thus power was low (power = 0.10). The similar sex ratio and small effect size indicated there was no sex related bias in the application sample. In the application sample the sex ratio was similar for recovered and unrecovered steelhead (chi-square $\chi^2 = 0.074$, $P = 0.786$; Table 4). The detectable effect size (w = 0.24) was larger than the observed effect size (w =- 0.03), and thus power was low (power = 0.06). The similar sex ratio and small effect size indicated there was no sex related recovery bias.

Table 4. The sex composition of Cranberry River steelhead by percentage (%) and number (n) for the application and recovery samples.

	Application Sample			Recovery Sample		
	Recovered (n)	**Not Recovered (n)**	**Total (n)**	**Marked (n)**	**Unmarked (n)**	**Total (n)**
Male	38.9% (7)	42.3% (52)	41.8% (59)	38.9% (7)	45.6% (42)	44.5% (49)
Female	61.1% (11)	57.7% (71)	58.2% (82)	61.1% (11)	54.4% (50)	55.5% (61)
Total	**100% (18)**	**100% (123)**	**100% (141)**	**100% (18)**	**100% (92)**	**100% (110)**

4.1.1.5 Immigration

The incidence of fishwheel tags was similar for the application and recovery samples (chi-square $\chi^2 = 0.030$, $P = 0.862$; Table 5). The detectable effect size (w = 0.18) was much larger than the observed effect size (w = 0.01), and thus the power was low (power = 0.06). Furthermore, the incidence of steelhead with gillnet marks was similar for the application and recovery samples (chi-square $\chi^2 = 1.695$, $P = 0.193$; Table 6). The detectable effect size (w = 0.18) was larger than the observed effect size (w = 0.13), and thus the power was low (power = 0.51). The similarity in the incidence of fishwheel tags as well as gillnet marks between sampling periods and the small observed effect sizes for both analyses indicated an insignificant amount of steelhead immigration to the study area between sampling periods.

Table 5. The incidence of fishwheel tags observed on Cranberry River steelhead by percentage (%) and number (n) for the application and recovery samples.

	Application Sample (n)	**Recovery Sample (n)**	**Total (n)**
Fishwheel Tag	5.0% (7)	5.5% (6)	5.2% (13)
No Fishwheel Tag	95.0% (134)	94.5% (104)	94.8% (238)
Total	**100% (141)**	**100% (110)**	**100% (251)**

Table 6. The incidence of gillnet marks observed on Cranberry River steelhead for application and recovery samples.

	Application Sample (n)	**Recovery Sample (n)**	**Total (n)**
Gillnet Marks	4.3% (6)	8.2% (9)	6.0% (15)
No Gillnet Marks	95.7% (135)	91.8% (101)	94.0% (136)
Total	**100% (141)**	**100% (110)**	**100% (251)**

4.1.1.6 Tag Loss

One of the 18 steelhead (5.6%) recovered had lost the Floy anchor tag, but was identified by the missing piece of adipose fin and by the tagging scar below the dorsal fin. It was unnecessary to correct the estimate for tag loss since all steelhead in the application sample were marked with an adipose fin clip.

4.1.1.7 Reaches 2 and 3

The size distribution of female steelhead was similar for reaches 2 and 3 during the application (Kolmogorov-Smirnov Z = 0.765, $P = 0.602$) and during the recovery sample (Kolmogorov-Smirnov Z =0.870, $P = 0.436$). Similarly, the size distribution of male steelhead was similar for reaches 2 and 3 during the application (Kolmogorov-Smirnov Z = 0.737, $P = 0.649$) and recovery samples (Kolmogorov-Smirnov Z = 0.855, $P = 0.457$). The similar size distributions among males and females for reaches 2 and 3 indicated the samples were drawn from the same population.

The ocean age composition of steelhead was similar for reaches 2 and 3 during the application sample (chi-square $\chi^2 = 0.002$, $P = 0.968$) and during the recovery sample (chi-square $\chi^2 = 0.131$, $P = 0.717$). This was similar to the results for the size distributions. Also, the mean smolt age was similar for reaches 2 and 3 during the application (*t*-test = -0.139, $P = 0.690$) and recovery samples (*t*-test = 0.822, $P = 0.416$). The similar freshwater and ocean age compositions indicated the samples were drawn from the same population.

The sex ratio was similar for reaches 2 and 3 during the application sample (chi-square $\chi^2 = 0.567$, $P = 0.451$) and the recovery sample (chi-square $\chi^2 = 1.610$, $P = 0.204$; Table 7). The similar sex ratios observed in reaches 2 and 3 indicated the samples were drawn from the same population.

Table 7. The sex composition of Cranberry River steelhead in reaches 2 and 3 by percentage (%) and number (n) of the application and recovery samples.

	Application Sample			**Recovery Sample**		
	Reach 2 (n)	**Reach 3 (n)**	**Total (n)**	**Reach 2 (n)**	**Reach 3 (n)**	**Total (n)**
Male	44.7% (34)	38.5% (25)	41.8% (59)	40.0% (28)	52.5% (21)	44.5% (49)
Female	55.3% (42)	61.5% (40)	58.2% (82)	60.0% (42)	47.5% (19)	55.5% (61)
Total	**100% (76)**	**100% (65)**	**100% (141)**	**100% (70)**	**100% (40)**	**100% (110)**

Samples were insufficient for comparisons of the incidence of gillnet marks and fishwheel tags for the application and recovery samples. Therefore, the application and recovery samples were pooled to increase sample sizes, since no size, age, or sex related biases were observed in the application or recovery samples. The incidence of steelhead with gillnet marks was similar for reaches 2 and 3 (chi-square $\chi^2 = 0.022$, $P = 0.882$). Also, the incidence of steelhead with fishwheel tags was similar for reaches 2 and 3 (chi-square $\chi^2 = 0.813$, $P = 0.367$). The similar incidence of gillnet marks and fishwheel tags observed on steelhead from reaches 2 and 3 indicated samples were drawn from the same population.

4.1.2.0 Mark - Recapture Estimates

4.1.2.1 Unadjusted Estimates

From October 6 to 10, 76 steelhead in reach 2 and 65 steelhead in reach 3 were released with Floy anchor tags and adipose fin clips (total = 141; Table 8). From November 3 to 7, 71 steelhead in reach 2 and 39 in reach 3 were examined for marks of which 12 steelhead in reach 2 and 6 steelhead in reach 3 were marked.

For reach 2, the Petersen abundance estimate was 425 steelhead (95% confidence limits: lower = 296, upper = 934) and the Bayesian estimate (mode) was 450 (95% confidence limits: lower = 306, upper = 868; Table 8). For reach 3, the Petersen abundance estimate was 376 steelhead (95% confidence limits: lower = 236, upper = 2049) and the Bayesian estimate (mode) was 422 (95% confidence limits: lower = 252, upper = 940). The Bayesian estimates for reach 2 and reach 3 were 6 and 12 percent higher than the respective Petersen estimates. The large upper confidence limit for the reach 3 Petersen estimate may be over-inflated due to the low number of recaptures ($R < 7$; Krebs 1989).

Steelhead were grouped for reaches 2 and 3 for the application sample and for the recovery sample because the steelhead sampled in reaches 2 and 3 were similar in terms of the size distributions, ocean age composition, mean smolt age, sex ratio, incidence of gillnet marks and the incidence of fishwheel tags. For the total area sampled, the Petersen population estimate was 829 steelhead (95% confidence limits: lower = 605, upper = 1496) and the Bayesian estimate (mode) was 861 steelhead (95% confidence limits: lower = 615, upper = 1507; Table 8). The summed Petersen and Bayesian estimates were 802 and 872 steelhead, respectively. The Bayesian estimates for the total area sampled and the summed reach 2 and 3 estimates were 16 percent and 8 percent higher than the respective Petersen estimates. The confidence interval for the summed Petersen estimate (95% confidence limits: lower = 491, upper = 1113) was narrower than the interval for the total Petersen estimate (Table 8).

4.1.2.2 Adjusted Estimates

When the number of marked fish was adjusted for hook and release mortality (9.1%) the Petersen and Bayesian abundance estimates decreased and the confidence intervals became slightly narrower (Table 9). The adjusted Peterson and Bayesian estimates decreased by about nine percent for reach 2, reach 3, summed reach 2 and 3, and the total area from the unadjusted estimates.

For reach 2, the adjusted Bayesian estimate (408 steelhead) was five percent higher than the adjusted Petersen abundance estimate (387 steelhead; Table 9). For reach 3, the adjusted Bayesian estimate (383 steelhead) was 12 percent higher than the adjusted Petersen abundance estimate (342 steelhead). For the summed reaches 2 and 3, the adjusted Bayesian estimate (791 steelhead) was eight percent higher than the adjusted Petersen abundance estimate (729 steelhead). For the entire area sampled, the adjusted Bayesian estimate (782 steelhead) was four percent higher than the adjusted Petersen abundance estimate (753 steelhead).

Table 8. The Cranberry River steelhead mark-recapture estimates (Petersen and Bayesian) for reach 2, reach 3, summation estimate for both reaches, and a total estimate for the study area.

	Number of Fish Marked (M)	Number of Fish Examined (C)	Number of Marks Recovered (R)	Adjusted Tag Rate (C+1)/(R+1)	Petersen Estimate ($\hat{N}$)	Lower 95% Confidence Limit	Upper 95% Confidence Limit	Bayesian Estimate ($\hat{N}$) Mode	Lower 95% Confidence Limit	Upper 95% Confidence Limit
Reach 2	76	71	12	5.54	425	296	934	450	306	868
Reach 3[1]	65	39	6	5.71	376	236	2049	422	252	940
Summation Estimate					802	491	1113	872	NA	NA
Total	**141**	**110**	**18**	**5.84**	**829**	**605**	**1496**	**861**	**615**	**1507**

1. Abundance estimates for reach 3 should be interpreted cautiously since the number of marks recovered (R) was less than seven (Krebs 1989).

Table 9. The Cranberry River steelhead mark-recapture estimates (Petersen and Bayesian) for reach 2, reach 3, summation estimate for both reaches, and a total estimate for the study area when the number of fish marked was adjusted for hook and release mortality (9.1%; Hooton 1987).

	Number of Fish Marked (M)	Number of Fish Examined (C)	Number of Marks Recovered (R)	Adjusted Tag Rate (C+1)/(R+1)	Petersen Estimate ($\hat{N}$)	Lower 95% Confidence Limit	Upper 95% Confidence Limit	Bayesian Estimate ($\hat{N}$) Mode	Lower 95% Confidence Limit	Upper 95% Confidence Limit
Reach 2	69	71	12	5.54	387	270	840	408	279	813
Reach 3[1]	59	39	6	5.71	342	214	1826	383	231	922
Summation Estimate					729	446	1011	791	NA	NA
Total	**128**	**110**	**18**	**5.84**	**753**	**550**	**1352**	**782**	**560**	**1372**

1. Abundance estimates for reach 3 should be interpreted cautiously since the number of marks recovered (R) was less than seven (Krebs 1989).

4.2.0.0 Life History Characteristics

4.2.1.0 Steelhead Length Distributions

In 1997, 227 steelhead were identified for sex and measured in the Cranberry River. A total of 128 (56.4 percent) were female and 99 (43.6 percent) were male which resulted in a female to male sex ratio of 1.29:1. The mean fork length of female steelhead was 69.3 cm whereas the mean fork length of male steelhead was 67.2 cm. The length distribution of male and female steelhead, as grouped by 2 cm categories, illustrated that males and females were bimodally distributed (Figure 4). For the lower peak in the distribution, males and females appeared similar in length, however for the higher peak, males appeared larger than females. Statistically, the fork lengths of males and females were similar (Mann-Whitney U = 5841, P = 0.313; Table 10).

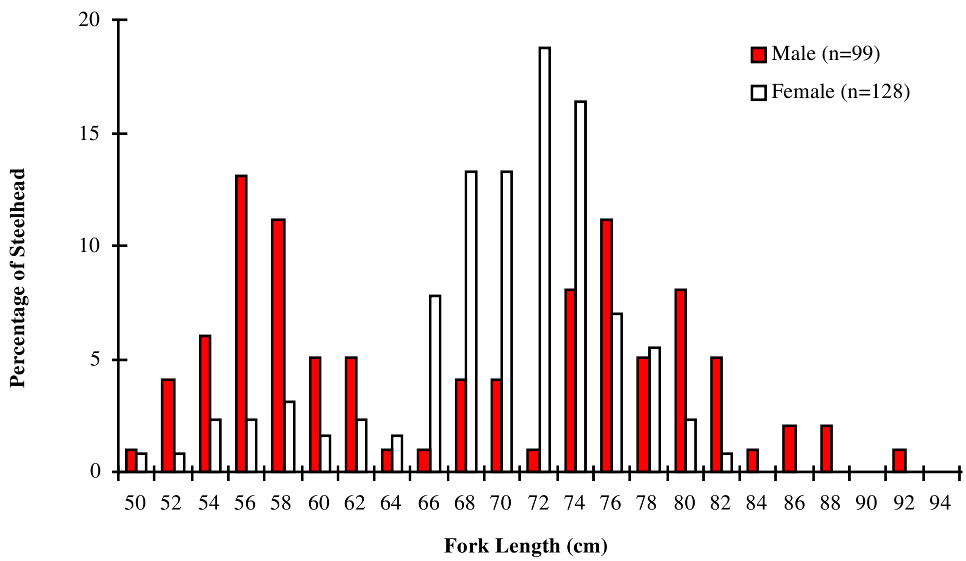

Figure 4. The percentage of male and female steelhead by categories of fork length (cm).

For the freshwater return years of 1977, 1979, 1996, and 1997, male and female steelhead were similar in size (Table 10). Males were similar in size for all years examined (Kruskal-Wallis = 3.247, P = 0.517) and females were also similar in size for all years examined (Kruskal-Wallis = 6.456, P = 0.168).

Table 10. A summary of the mean, standard error, standard deviation and range in fork lengths for male and female summer steelhead sampled in the Cranberry River for the freshwater return years of 1997, 1996, 1995, 1979, and 1977.

	Freshwater Return Year[1]					*Kruskal-Wallis*
	1997	**1996**	**1995**	**1979**	**1977**	***P* values**
Female						
Mean fork length (cm)	69.32	66.6	72.2	65.7	70.6	0.168
Standard error (cm)	0.56	2.83	1.30	2.12	2.17	
Standard deviation (cm)	6.29	9.38	4.31	9.50	10.83	
Size range (cm)	50-81	53-78	62-79	53-81	56-89	
Sample size	128	11	11	20	25	
Male						
Mean fork length (cm)	67.1	71.4	68.6	65.6	66.9	0.517
Standard error (cm)	1.11	2.07	3.53	1.68	1.88	
Standard deviation (cm)	11.02	8.54	11.18	8.38	9.42	
Size range (cm)	50-91	58-88	52-85	53-86	58-87	
Sample size	99	17	10	25	25	
Mann-Whitney U, *P* values	0.313	0.191	0.512	0.991	0.350	

1. Data for 1996, 1979 and 1977 from Parken (1997b).

4.2.2.0 Steelhead Age Distributions

The most common age group was 3.1+ for males and 3.2+ for females. Repeat spawners were rare (2.3%) among the 171 steelhead with readable ocean age. The ocean age composition differed between males and females (chi-square $\chi^2 = 31.89$, $P < 0.005$; Table 11), however the mean smolt age was similar between males and females (t-test = 0.005, P = 0.996). Among males, the ocean age composition differed between the freshwater return years of 1997, 1996, 1979 and 1977 (chi-square $\chi^2 = 5.84$, $P < 0.005$). Furthermore, the ocean age composition among females differed between the freshwater return years of 1997, 1979 and 1977 (chi-square $\chi^2 = 19.25$, $P < 0.005$). The freshwater return year of 1996 was excluded from the analysis for the ocean age composition of females due to few samples. The difference in ocean age composition may reflect variable recruitment between years or variable ocean survival. The mean smolt age differed between freshwater return years (ANOVA, F = 5.77, $P = 0.001$; Table 12). The mean smolt age in 1977 differed from 1996 (Tukey HSD = 0.42, $P = 0.024$), and 1997 (Tukey HSD = 0.41, $P < 0.005$), but was similar to 1979 (Tukey HSD = 0.26, $P = 0.168$). All other pairwise comparisons indicated the mean smolt ages were similar (Tukey HSD > -0.26, $P > 0.168$).

Table 11. A summary of the ocean age composition of male and female Cranberry River steelhead, fall 1997.

	Ocean Age			
Sex	**1+ n (percent)**	**2+ n (percent)**	**3+[1] n (percent)**	**All n (percent)**
Female	10 (10.1)	82 (82.8)	7 (7.1)	99 (57.9)
Male	35 (48.6)	34 (47.2)	3 (4.2)	72 (42.1)
All	**45 (26.3)**	**116 (67.8)**	**10 (5.8)**	**171 (100)**

1. Includes repeat spawners .1S1+ and .2S1+.

Table 12. A summary of the mean, standard error, standard deviation and range in smolt age for the freshwater return years of 1997, 1996, 1979 and 1977.

	Freshwater Return Year[1]				*ANOVA*
	1997	**1996**	**1979**	**1977**	***P* values**
Mean smolt age (yr.)	3.32	3.31	3.47	3.73	0.001
Standard error (yr.)	0.06	0.09	0.08	0.06	
Standard deviation (yr.)	0.70	0.47	0.55	0.45	
Age range (yr.)	2-6	3-4	3-5	3-4	
Sample size	136	26	43	48	

1. Data for 1996, 1979 and 1977 from Parken (1997b).

4.2.3.0 Steelhead Length at Age

In 1997, male and female steelhead were similar in size at ocean age 1+ (t-test = -2.00, $P = 0.052$), however males (mean = 75.2 cm) were larger than females at ocean age 2+ (mean = 70.1 cm; t-test = -5.94, $P = 0.005$; Table 13). Among males, length increased with ocean age (ANOVA F = 181.14, $P < 0.005$; Tukey HSD, $P < 0.037$). Similarly for females, length increased with ocean age (ANOVA F = 94.38, $P < 0.005$; Tukey HSD, $P < 0.005$). In comparison, adult male steelhead were similar in size between freshwater age 2, 3 and 4 (ANOVA F = 0.247, $P = 0.863$) and adult female steelhead were similar in size between freshwater age 2, 3 and 4 (ANOVA F = 2.37, $P = 0.060$). Adult size was independent of freshwater age for Cranberry River steelhead in 1997.

The mean fork lengths were compared between freshwater return years separately for males and females. Among females, ocean age 1+ steelhead were similar in length for the freshwater return years of 1977, 1979, 1996, and 1995 (ANOVA F = 2.03, $P = 0.132$; Table 14). The mean length of ocean age 1+ male steelhead differed between years (ANOVA, F = 8.84, $P < 0.0005$). Among males, ocean age 1+ steelhead in 1997 were smaller than those in 1977 (Tukey HSD = -4.45, $P < 0.0005$) and 1979 (Tukey HSD = -3.89, $P = 0.002$), but were similar to those in 1996 (Tukey HSD = -3.80, $P = 0.097$). All other pairwise comparisons indicated similar results (Tukey HSD $\geq$ 0.56, $P > 0.967$). The mean length of ocean age 2+ female steelhead differed between years (ANOVA F = 10.07, $P < 0.0005$). Among females, ocean age 2+ steelhead in 1997 were smaller than those in 1977 (Tukey HSD = -6.68, $P < 0.0005$), but were similar to those in 1979 (Tukey HSD = -2.33, $P = 0.409$) and 1996 (Tukey HSD = -2.50, $P = 0.448$). All other pairwise comparisons between years indicated similar results (Tukey HSD = -4.48, $P > 0.079$). Among males, ocean age 2+ steelhead were similar in length for the freshwater return years of 1977, 1979, 1996 and 1997 (ANOVA F = 0.66, $P = 0.978$).

Table 13. The size, standard error (SE), standard deviation (SD), range and sample size of Cranberry River steelhead (1997) at freshwater and ocean age.

Freshwater Age	Sex		Ocean Age 1+	2+	3+	All
2	Female	Length (cm)	NA	72.0	79.0	74.8
		SE (cm)	NA	0.58	1.00	1.77
		SD (cm)	NA	1.00	1.41	3.96
		Range (cm)	NA	71-73	78-80	71-80
		Sample size	NA	3	2	5
	Male	Length (cm)	55.0	73.3	NA	67.2
		SE (cm)	1.00	3.12	NA	4.33
		SD (cm)	1.41	6.24	NA	10.61
		Range (cm)	54-56	67-80	NA	54-80
		Sample size	2	4	NA	6
3	Female	Length (cm)	54.2	69.5	77.0	68.1
		SE (cm)	0.66	0.63	NA	0.90
		SD (cm)	1.48	4.09	NA	6.22
		Range (cm)	52-56	57-78	NA	82-78
		Sample size	5	42	1	48
	Male	Length (cm)	57.5	73.6	86.5	66.1
		SE (cm)	0.93	1.42	0.50	1.94
		SD (cm)	3.58	4.91	0.71	10.47
		Range (cm)	50-64	60-79	86-87	50-87
		Sample size	15	12	2	29
4	Female	Length (cm)	52.5	71.0	78.3	70.4
		SE (cm)	2.50	0.87	0.33	1.46
		SD (cm)	3.54	3.71	0.58	7.02
		Range (cm)	50-55	64-80	78-79	50-80
		Sample size	2	18	3	23
	Male	Length (cm)	56.8	77.1	NA	63.9
		SE (cm)	0.91	1.01	NA	2.33
		SD (cm)	3.27	2.67	NA	10.41
		Range (cm)	51-62	73-80	NA	51-80
		Sample size	13	7	NA	20
5	Female	Length (cm)	57.0	76.0	NA	66.5
		SE (cm)	NA	NA	NA	9.50
		SD (cm)	NA	NA	NA	13.44
		Range (cm)	NA	NA	NA	57-76
		Sample size	1	1	NA	2
	Male	Length (cm)	54.0	80.0	NA	67.0
		SE (cm)	NA	NA	NA	13.00
		SD (cm)	NA	NA	NA	18.38
		Range (cm)	NA	NA	NA	54-80
		Sample size	1	1	NA	2
6	Female	Length (cm)	NA	81.0	NA	81.0
		Sample size	NA	1	NA	1
All	Female	Length (cm)	54.3	70.1	78.1	69.3
		SE (cm)	0.70	0.46	0.40	0.56
(includes		SD (cm)	2.21	4.15	1.07	6.29
steelhead		Range (cm)	50-57	57-81	77-80	50-81
with		Sample size	10	82	7	128
regenerated	Male	Length (cm)	55.6	75.2	80.7	67.2
scales)		SE (cm)	0.58	0.76	5.84	1.11
		SD (cm)	3.42	4.46	10.12	11.02
		Range (cm)	50-64	60-83	69-87	50-91
		Sample size	35	34	3	99

Table 14. A summary of the mean, standard error and standard deviation range in fork length of ocean age 1+ and 2+ steelhead for the freshwater return years of 1997, 1996, 1979 and 1977.

Ocean Age			**Freshwater Return Year**				***ANOVA***
			1997	**1996**	**1979**	**1977**	***P* values**
1+	Female	Mean Length (cm)	54.3	56.0	58.6	57.9	0.132
		Standard error (cm)	0.70	1.58	2.21	0.83	
		Standard deviation (cm)	2.21	3.16	6.63	2.48	
		Range (cm)	50-57	53-60	53-74	56-61	
		Sample size	10	4	9	9	
	Male	Mean Length (cm)	56.6	60.4	60.5	61.1	0.005
		Standard error (cm)	0.58	1.50	0.87	0.82	
		Standard deviation (cm)	3.42	3.36	3.50	3.16	
		Range (cm)	50-64	58-66	53-66	58-66	
		Sample size	35	5	16	15	
2+	Female	Mean Length (cm)	70.1	72.6	72.4	76.9	0.005
		Standard error (cm)	0.46	1.90	1.20	1.38	
		Standard deviation (cm)	4.15	5.03	3.60	4.97	
		Range (cm)	57-81	67-78	66-79	71-89	
		Sample size	82	7	9	13	
	Male	Mean Length (cm)	75.2	76.0	74.9	75.5	0.978
		Standard error (cm)	0.76	1.65	2.40	2.85	
		Standard deviation (cm)	4.46	5.23	6.79	9.00	
		Range (cm)	60-83	69-88	69-86	63-87	
		Sample size	34	10	8	10	

4.2.4.0 Steelhead Recaptures

Twelve of the 241 steelhead sampled in the Cranberry River (5.0%; includes eight steelhead sampled by M.C. Beere prior to the application sample) had Floy tags that were applied at the Nass River fishwheels by the Nisga'a Tribal Council (Table 15). Also, one of the 18 marked steelhead (5.6%) captured in the recovery sample had a fishwheel tag. Steelhead with fishwheel tags represented a consistent proportion of the steelhead sampled in the Cranberry River because: the frequency of fishwheel tagged steelhead was similar between the application and recovery samples (Table 5); the frequency was similar between reach 2 and reach 3; and the frequency of fishwheel tagged steelhead among all steelhead was similar to the frequency of fishwheel tagged steelhead in the marked component of the recovery sample (Fisher's Exact, $P = 0.999$) and the observed effect size was very small (w = 0.01). Another fishwheel tag was reported by a recreational angler, however the number of steelhead without tags captured by the angler was not reported (Table 15).

Of the 13 steelhead with fishwheel tags, six were male and seven were female (Table 15). Twelve of the 13 steelhead were identified for sex upon recapture and for six of them there was a 50 percent error discrepancy in the sex recorded at recapture and initial tagging. For the fish identified in the Cranberry River, the sex ratio was similar between steelhead with fishwheel tags and those without fishwheel tags (chi-square $\chi^2 = 0.228$, $P = 0.633$).

Table 15. A summary of fishwheel tag recoveries in the Cranberry River, 1997 by location (FW=fishwheel, R=reach and S=section).

Tagging Information					Recapture Information			
Tag No.	**Location**	**Date**	**Sex**	**Length**	**Location**	**Date**	**Sex**	**Length**
n6305	FW2	Aug. 13	f	53.0	R=3, S=7	Oct. 6	m	51.0
n6144	FW3	Aug. 21	m	71.0	R=3, S=6	Oct. 7	f	69.0
n6218	FW2	Aug. 23	f	75.0	R=3, S=6	Oct. 7	f	67.0
n6234	FW2	Aug. 25	f	54.0	R=3, S=5	Oct. 8	m	55.0
n6449	FW3	Sept. 3	f	66.0	R=2, S=2	Oct. 9	f	66.0
n6354	FW2	Aug. 19	m	74.0	R=2, S=1	Oct. 10	f	74.0
n6357	FW2	Aug. 20	m	58.0	R=2, S=2	Oct. 10	m	55.0
n6516	FW4	Sept. 1	m	51.0	R=3, S=7	Nov. 3	m	NA
n6381	FW2	Aug. 21	m	53.0	R=3, S=6	Nov. 4	f	54.0
n6369	FW2	Aug. 21	m	55.0	R=3, S=6	Nov. 4	m	55.0
n6373	FW2	Aug. 21	m	56.0	R=2, S=2	Nov. 6	m	NA
n6242	FW2	Aug. 26	m	77.0	R=2, S=2	Nov. 6	f	81.0
n6413[1]	FW4	Aug. 31	f	67.0	R=3, S=6	Sept. 21	NA	NA

1. This steelhead was reported by a recreational angler.

The mean length of male and female steelhead with fishwheel tags was 53.8 cm and 68.5 cm, respectively. Steelhead with fishwheel tags (mean = 61.2 cm) were smaller than those without fishwheel tags (mean = 68.8 cm; Mann-Whitney U = 679.5, $P = 0.006$). The smaller size of steelhead with fishwheel tags indicated negative size bias (selectivity) at the Nass River fishwheels. For steelhead with fishwheel tags, fork lengths differed by an average of 2.1 cm (range, 0.0 to 8.0 cm) between measurements taken at the fishwheels and at the Cranberry River.

Of the 13 steelhead with fishwheel tags, two, two and nine steelhead were sampled at fishwheels 4, 3 and 2, respectively (Table 15). None of the steelhead sampled at fishwheel 1 were recaptured in the Cranberry River. For steelhead recaptured in the Cranberry River, the mean date for steelhead sampled at fishwheel 2 was August 21, whereas the mean date for steelhead sampled at fishwheels 3 and 4 was August 30.

Steelhead movements within the Cranberry River were available for 22 steelhead (Table 16). Four steelhead were recaptured during the application sample in sections adjacent to the tagging locations. Three of these steelhead were recaptured in areas downstream of the tagging location on the following day. One steelhead was recaptured upstream of the tagging location within two days, however this was an isolated record since sections were typically sampled in a down-stream manner.

Eighteen of the 22 steelhead with movement information were sampled during both the application and the recovery samples (Table 16). During the recovery sample, 10 steelhead were captured in the same section as the application sample, five were captured in the section upstream of the application sample and three were captured in the section downstream of the application sample. None of the recaptured steelhead had moved between reaches 2 and 3.

Table 16. A summary of steelhead captured and then recaptured within the Cranberry River, 1997 by location (FW=fishwheel, R=reach and S=section).

Tagging Information					Recapture Information			
Tag No.	**Location**	**Date**	**Sex**	**Length**	**Location**	**Date**	**Sex**	**Length**
10112	R=3, S=4	Oct. 8	f	73.0	R=3, S=5	Oct. 9	f	NA
10064	R=3, S=6	Oct. 7	f	71.0	R=3, S=5	Oct. 9	f	NA
10093	R=2, S=2	Oct. 9	m	58.0	R=2, S=1	Oct. 10	m	NA
10019	R=2, S=2	Oct. 9	m	77.0	R=2, S=1	Oct. 10	m	NA
10072	R=3, S=6	Oct. 7	m	74.0	R=3, S=6	Nov. 3	m	NA
10050	R=3, S=7	Oct. 6	NA	NA	R=3, S=7	Nov. 3	f	NA
10057	R=3, S=7	Oct. 6	f	55.0	R=3, S=7	Nov. 3	f	NA
10119	R=3, S=5	Oct. 9	f	71.0	R=3, S=7	Nov. 4	f	NA
10118	R=3, S=5	Oct. 9	f	73.0	R=3, S=6	Nov. 4	f	NA
10006	R=3, S=6	Oct. 7	f	60.0	R=3, S=6	Nov. 4	f	NA
n6449	FW3	Sept. 3	f	66.0	R=2, S=2	Oct. 9	f	66.0
n6449	FW3	Sept. 3	f	66.0	R=2, S=3	Nov. 5	f	NA
10217	R=2, S=2	Oct. 10	f	71.0	R=2, S=2	Nov. 6	f	NA
10100	R=2, S=2	Oct. 10	f	70.0	R=2, S=2	Nov. 6	f	NA
10014	R=2, S=2	Oct. 9	m	83.0	R=2, S=2	Nov. 6	m	NA
10016	R=2, S=2	Oct. 9	m	61.0	R=2, S=2	Nov. 6	m	NA
10203	R=2, S=1	Oct. 10	m	60.0	R=2, S=2	Nov. 7	m	NA
10013	R=2, S=3	Oct. 9	f	68.0	R=2, S=3	Nov. 7	f	NA
10099	R=2, S=3	Oct. 9	m	70.0	R=2, S=2	Nov. 7	m	NA
10086	R=2, S=3	Oct. 9	f	71.0	R=2, S=2	Nov. 7	f	NA
10123	R=2, S=3	Oct. 9	m	80.0	R=2, S=2	Nov. 7	m	NA
tag loss	R=2, S=1	Oct. 10	NA	NA	R=2, S=1	Nov. 7	f	73.0
10120	R=2, S=1	Oct. 9	f	66.0	R=2, S=2	Nov. 7	f	NA

4.2.5.0 Steelhead Condition

Thirty of the 233 steelhead (13%) examined had head wounds which appeared as a red open sore on the skin of the head (Figure 5). When the application and recovery samples were pooled, steelhead sampled in reach 2 had a higher incidence of head wounds than those sampled in reach 3 (chi-square $\chi^2 = 4.271$, $P = 0.039$; Table 17).

Table 17. The incidence of head wounds on Cranberry River steelhead in reaches 2 and 3 of the application and recovery samples by percentage (%) and number (n).

	Reach 2 (n)	**Reach 3 (n)**	**Total (n)**
Head Wound	16.4% (24)	7.6% (8)	12.7% (32)
No Head Wounds	83.6% (122)	92.4% (97)	87.3% (219)
Total	**100% (146)**	**100% (105)**	**100% (251)**

Figure 5. Photographs of head wounds observed on Cranberry River steelhead.

Fifteen of the 233 steelhead (6%) examined had gillnet marks. When the application and recovery samples were pooled, the incidence of gillnet marks was similar between reaches 2 and 3 (chi-square $\chi^2 = 0.022$, $P = 0.882$). Male steelhead with gillnet marks (mean = 60.8 cm) were of similar size to male steelhead without gillnet marks (mean = 67.5 cm; Mann-Whitney U = 148.5, $P = 0.166$). Female steelhead with gillnet marks (mean = 70.9 cm) were of similar size to female steelhead without gillnet marks (mean = 69.2 cm; Mann-Whitney U = 466.5, $P = 0.268$).

Forty-four of 233 steelhead (19%) examined had predator scars. During the application sample, the incidence of predator scars was similar between reaches 2 and 3 (chi-square $\chi^2 = 1.210$, $P = 0.271$). During the recovery sample, the incidence of predator scars was similar between reaches 2 and 3 (chi-square $\chi^2 = 2.510$, $P = 0.113$). The incidence of predator scars was similar between the recovery and application samples (chi-square $\chi^2 = 0.661$, $P = 0.416$).

5.0.0.0 Discussion

5.1.0.0 Steelhead Abundance Estimates

The mark-recapture abundance estimates were susceptible to bias from a number of sources such as non-representative tag application or recovery, an open population, and tag loss. The assumption that the population was closed was difficult to evaluate and thus, was assessed with indicators of immigration and rudimentary sampling in areas outside of the study area. Tag loss bias was eliminated by giving all fish in the application sample a small adipose fin clip as a secondary mark that could not be lost or regenerated between samples.

The true representativeness of the application and recovery samples could not be tested because the true population parameters were unknown. However, the application and recovery samples were examined for spatial, size, age and sex related biases as indicators of weakness in the study design. No biases were detected that were related to location, size, age, or sex in the recovery or application samples (Table 18). Although, these results should be interpreted cautiously because of the small number of marked steelhead that were recovered. Nearly 13 percent of steelhead in the application sample (unadjusted for hooking mortality) were recovered, however the number recovered was actually small (R = 18) which decreased the ability of the chi-square, Kolmogorov-Smirnov and Student's t tests to detect application and recovery biases as indicated by the *post hoc* power analysis.

Table 18. Summary of statistical test results for sampling selectivity bias investigations.

Bias Test	Application Sample	Recovery Sample
Location	No bias detected	No bias detected
Steelhead Size	No bias detected	No bias detected
Steelhead Age	No bias detected	No bias detected
Steelhead Sex	No bias detected	No bias detected

The observed effect sizes in the application and recovery bias investigations were generally in the small to medium range (Cohen 1988), and indicated the differences were biologically insignificant (Thomas and Juanes 1996). However, too few steelhead were sampled to conclusively determine whether the small observed differences were statistically different, as indicated by the *post hoc* power analysis. For bias investigations with small effect sizes, near 0.10, very large sample sizes of at least an order of magnitude higher would have been necessary to achieve 80 percent power, the level recommended by Cohen (1988) and Peterman (1990). Since all the observed effect sizes were less than the detectable effect sizes for alpha of 0.05 and beta of 0.20, the bias investigations should be interpreted cautiously, but the small observed effect sizes indicated the differences were biologically insignificant.

Population closure would be difficult to achieve aside from physically implementing barriers to immigration and emigration, which was not practical with this study. Also, the entire Cranberry River could not be sampled due to logistical and personnel limitations. In 1997, the spatial distribution of steelhead sampled differed between the recovery and application samples. No steelhead movements were observed between reaches 2 and 3, although small movements were observed within reaches. Similarly, evidence of Cranberry River steelhead behavior during the fall of 1979 indicated individual steelhead only made small movements within the stream (< 5 rkm), especially during late fall which was the time period of the 1997 assessments (Lough 1983). In 1979, the fish showed little or no movement from the main overwintering area of the mainstem (rkm 15 to 26) throughout the fall and winter (Lough 1983).

Few sampling attempts were conducted outside of the study area. Steelhead presence was confirmed in the Cranberry River below the area sampled and in the Kiteen River during the application sample. During the recovery sample, no steelhead were sampled in a 0.75 rkm section above the study area, although steelhead presence had been confirmed in this area during the fall of previous years. It was entirely possible that some level of immigration and emigration occurred between sampling periods. However, no significant immigration of steelhead without fishwheel tags or gillnet marks was detected, based on the incidence of fishwheel tags and gillnet marks between the application and recovery samples.

Tag loss in the Cranberry River was within the range reported for other steelhead enumeration programs. Approximately 5.6 percent of Cranberry River steelhead lost their Floy anchor tags during the month long period between samples. In Toboggan Creek, tag loss was measured among adult steelhead between the pre- and post-spawning periods, which usually spanned one to two months between tag application and recovery (unpublished data, O'Neill 1994, 1995 and 1996). In Toboggan Creek, tag loss was similar between 1994 (3.8%; unpublished data, O'Neill 1994) and 1995 (3.6%; unpublished data, O'Neill 1995), but was considerably higher in 1996 (18.8%; unpublished data, O'Neill 1996). Tag loss was also measured between the pre- and post-spawning periods in the Karluk River, Alaska (Begich 1992, 1997). Begich (1992) reported a lower tag loss (3%) for Karluk River steelhead in the spring of 1992 for samples collected from two to four months after tagging, but higher tag loss (11%) was observed for samples collected from one to three months after tagging in 1996 (Begich 1997). The variability in tag loss estimates indicated tag loss may also be influenced by factors other than the amount of time between application and recovery samples.

The Bayesian abundance estimates were higher than the Petersen estimates for all comparisons, which was consistent to the results of Gazey and Staley (1986) and Atagi (1995). The adjusted Bayesian estimates were 5, 12, 8 and 4 percent higher than the adjusted Petersen estimators for reach 2, reach 3, summed reach 2 and 3, and the total area sampled, respectively. Due to the small samples ($M+C \leq N$) and low numbers of recaptures, the Petersen abundance estimates were negatively biased (Robson and Regier 1964; Ricker 1975; Gazey and Staley 1986; Krebs 1989; Edwards *et al*. 1997). Under these conditions the Bayesian estimators and confidence limits were preferred over the Petersen estimators, since the Bayesian estimator works well for small samples (Gazey and Staley 1986; Atagi 1995).

The abundance of adult Cranberry River steelhead was estimated for a small fraction (24%) of the total length of the river, but was estimated for the majority (approximately 87%)

of the main overwintering habitat described by Lough (1983). Thus, the estimates for the entire area sampled were underestimates of the fall escapement for Cranberry River steelhead. The estimates for the area sampled should not be extrapolated to the remaining length of river due to the observed non-uniform distribution of steelhead (Figure 3). The escapement estimate for the area sampled was probably higher than the number of spawners since measurements were made before overwintering mortality and in-river native harvests during the winter and spring.

The estimated abundance of adult Cranberry River steelhead within the area sampled was similar to previous indirect estimates for the population. Approximately 560 to 1,372 steelhead were in the area from rkm 3.5 to rkm 30.5 (adjusted for hooking mortality; Bayesian mode = 782). Sebastian (1983) estimated the escapement for the Cranberry River population, that excluded Kiteen River steelhead, from field surveys of 1986 juvenile steelhead rearing densities and life history survival estimates. Sebastian's (1987) estimate of 1,200 steelhead was within the confidence limits of the area sampled in 1997. Similarly, Koski and English's (1996) estimate of steelhead bound for the Cranberry and Kiteen rivers with similar run timing as those radio tagged (925 steelhead) was also within the confidence limits of the area sampled in 1997. The different point estimates must be compared cautiously since the methods differed and estimates were conducted during different years and may reflect variable recruitment or ocean survival between years (Ward and Slaney 1988).

5.1.1.0 Comparisons of Carrying Capacity Predictions

The Nass River steelhead production model consisted of a number of alternative models to provide a range of carrying capacity estimates based on stream length and area of third order or greater watersheds (determined from 1:20,000 scale TRIM maps; Bocking *et al*. 1998; Table 19). Models 1 and 2 were based on the observed smolt production per kilometer and per square meter (respectively) of Keogh River winter steelhead at carrying capacity (Tautz *et al*. 1992). Models 3 and 4 were based on the estimated smolt production per kilometer and per square meter (respectively) of Cranberry River summer steelhead from observed fry densities in 1986 (Sebastian 1987). Models 5 and 6 were based on Keogh River winter steelhead smolt production at carrying capacity that was adjusted for juvenile rearing conditions in each tributary with the methods described by Tautz *et al*. (1992). Carrying capacity was influenced by rearing conditions such as the length of the rearing period to smoltification and stream productivity levels, which interact with fry-to-smolt survival rates and juvenile rearing densities, respectively (Slaney *et al*. 1986; Tautz *et al*. 1992; Bocking and English 1992; Parken 1997c).

Table 19. A comparison of adult steelhead production estimates for the Cranberry River, Kiteen River and Cranberry River watershed (total) for accessible habitat in stream order 3 and greater tributaries and stream order 4 and greater tributaries from the Nass River steelhead production model (with smolt-to-adult survival = 10.4%; data from Bocking *et al*. 1998).

Stream Order Criteria	**River**	**Model 1 (Keogh Length)**	**Model 2 (Keogh Area)**	**Model 3 (Cranberry Length)**	**Model 4 (Cranberry Area)**	**Model 5 (Keogh Length/ Adjust)**	**Model 6 (Keogh Area/ Adjust)**	**Mean of Model Estimates**
3rd Order	Cranberry	9,276	3,649	6,184	2,076	16,259	6,396	7,307
	Kiteen	6,627	2,739	4,418	1,558	4,497	1,858	3,606
	Total	15,903	6,388	10,602	3,634	20,756	8,254	10,913
4th Order	Cranberry	6,364	3,190	4,243	1,815	11,155	5,591	5,393
	Kiteen	4,483	2,416	2,989	1,374	3,042	1,639	2,657
	Total	10,847	5,606	7,232	3,189	14,197	7,230	8,050

The Nass River steelhead production model provided estimates with different stream order criteria for steelhead distribution (Table 19; Bocking *et al*. 1998). In comparison, the distribution of steelhead in the Skeena steelhead carrying capacity model was limited to third order or greater streams, as determined from 1:50,000 scale NTS maps (Tautz *et al*. 1992). The increased map scale and higher resolution of the Nass River steelhead production model may have detected more first order streams, and accordingly caused streams identified as third order from 1:50,000 maps to be classified as fourth order (positive bias). Thus, carrying capacity estimates were calculated separately for third and fourth order streams as criteria for steelhead distribution.

The different steelhead distribution criteria resulted in higher carrying capacity estimates when third order streams rather than when fourth order streams were the criteria (Table 19). For the Cranberry River, the inclusion of third order streams had a larger effect on carrying capacity estimates from length-based (models 1, 3 and 5) than area-based models (models 2, 4 and 6). The smaller effect on the area-based models may have resulted from the adjustments in stream width for changes in stream order.

Nass River steelhead carrying capacity estimates should conservatively be based on fourth order or greater streams as opposed to third order or greater streams. Although potential errors in stream order classification were not significant in the Skeena steelhead carrying capacity model (Bocking and English 1992), a positive bias in stream classification may over-estimate the steelhead distribution and thus over-estimate the total useable habitat. This effect would over-estimate steelhead carrying capacity. For this reason, the carrying capacity model estimates from fourth order or greater streams must be interpreted cautiously until empirical investigations in the Nass watershed can substantiate any potential biases.

Each carrying capacity model yielded alternative escapement requirements to fully seed the available steelhead rearing habitat (Table 20). The escapement requirements were directly influenced by the magnitude of the different models' predictions of carrying capacity. Thus, models with high carrying capacity estimates had high escapement requirements with respect to the other models, and models with low carrying capacity estimates had relatively low escapement requirements.

Table 20. A comparison of the number of adult steelhead spawners required to fully seed the rearing habitat for stream order greater than or equal to 3 or 4 for the Cranberry River, Kiteen River and Cranberry River watershed (total) from the Nass River steelhead production model (from Bocking *et al*. 1998).

Stream Order >	**River**	**Model 1 (Keogh Length)**	**Model 2 (Keogh Area)**	**Model 3 (Cranberry Length)**	**Model 4 (Cranberry Area)**	**Model 5 (Keogh Length/ Adjust)**	**Model 6 (Keogh Area/ Adjust)**	**Mean of Model Estimates**
Order 3	Cranberry	2,161	850	1,441	484	3,787	1,490	1,702
	Kiteen	1,379	570	919	324	936	387	753
	Total	3,540	1,420	2,360	808	4,723	1,877	2,455
Order 4	Cranberry	1,482	743	988	423	2,598	1,302	1,256
	Kiteen	933	503	622	286	633	341	553
	Total	2,415	1,246	1,610	709	3,231	1,643	1,809

Of the six models presented, the model 6 carrying capacity estimate may be the most appropriate for the Cranberry River because of the results of adult steelhead escapement estimates, the model's structure made adjustments for rearing conditions, and the model estimated an intermediate escapement requirement. Adult steelhead escapement estimates were less than the model 6 estimate (5,591 steelhead), since they were either influenced or made some assumptions regarding exploitation (Table 21). The model 6 estimate was intermediate of the other five model predictions (Table 19) and was higher than the theoretical habitat capability of the Cranberry River estimated by Sebastian (1987; Table 21). The structure of model 6 made adjustments to the maximum smolt production per square meter in the Keogh River to account for geographical disparity in rearing conditions between the Keogh and Nass watersheds. Although model 5 had similar adjustments for rearing conditions, the length-based estimate was too large: nearly twice the model 6 estimate. Also, the model 6 escapement requirement to fully seed the available steelhead rearing habitat was intermediate of the other estimates (Table 20). However, the estimate should be interpreted cautiously since the rearing period was estimated from adult steelhead scales, which may underestimate the rearing period (Hooton *et al*. 1987; Tautz *et al*. 1992; Parken 1997b).

In comparison, the other models had carrying capacity estimates that did not account for differences in rearing conditions (models 1 and 2) or were based on measurements in the Cranberry River when it was unknown if the population was at carrying capacity (models 3 and 4). The length-based models yielded high carrying capacity estimates (4,243 to 11,155 steelhead) with respect to the area-based models (1,815 to 5,591 steelhead; Table 18). The model 4 estimate (1,815 steelhead) was similar to previous abundance estimates (Table 21), however this model was based on observed Cranberry River fry densities at a time when it was unknown if the juvenile population was at carrying capacity. The similarity of model 4 to previous abundance estimates indicated the predicted total useable area adequately reflected the available habitat the Cranberry River. The model 2 estimate (3,190 steelhead) was similar to the theoretical habitat capability estimated by Sebastian (1987; 3,432 steelhead; Table 21). However, model 2 was based on smolt production for Keogh River winter steelhead, and thus the predictions may not represent the rearing conditions for Nass

River summer or winter steelhead because of geographical disparity and differences in life history.

Table 21. A summary of the adult steelhead abundance estimates and confidence limits [95%] for different components of the Cranberry River population.

Year of study and reference	Abundance estimate (adult steelhead)	Area	Estimate calculated from:	Exploitation assumptions
1986 Sebastian 1987	2,400 [1,494, 3,350]	Reaches 1 to 4 Cranberry River	Observed fry densities	No harvest (no commercial, native or sport)
1986 Sebastian 1987	1,200	Reaches 1 to 4 Cranberry River	Observed fry densities	Commercial and native harvest only
1986[1] Sebastian 1987	3,432	Reaches 1 to 4 Cranberry River	Theoretical habitat capability model	No Harvest (carrying capacity)
1993[2] Koski and English 1996	1,000	Cranberry and Kiteen rivers	Radio telemetry relative tag distribution	Commercial and native harvest prior to sampling at fishwheels
1993[2] Koski and English 1996	925	Cranberry and Kiteen rivers	Radio telemetry relative tag distribution	Commercial and native harvest prior and post sampling at fishwheels
1997 Current study	782 [560, 1372]	Reaches 2 and 3 (rkm 3.5-30.5) Cranberry River	Mark-recapture angling in Cranberry River	Commercial and native harvest prior to sampling

1. Smolt-to-adult survival of 10.4% was applied to the estimated production of 33,000 smolts.
2. Data collected and presented by Alexander and Koski (1995).

The Nass River steelhead production model (model 6) predicted at least 1,302 successfully spawning steelhead would be required to fully seed the habitat (Table 20; data from Bocking et al. 1998). The model's prediction was within the confidence limits (95%) of the escapement abundance estimate for the area sampled in 1997 (550 to 1,372 steelhead). The number of spawning steelhead was probably lower than the 1997 escapement abundance estimate, since measurements did not account for overwintering mortality or in-river native harvest. When the Kiteen River system was included, the model predicted at least 1,643 successfully spawning steelhead would be required to fully seed the accessible habitat of the entire Cranberry River watershed (Table 20). This prediction was much higher than the indirect escapement estimate for the entire Cranberry River watershed from the 1993 telemetry project (925 steelhead; Koski and English 1996). These results indicated current exploitation levels in some years may not allow enough adult steelhead to reach the Cranberry River watershed in order to fully seed the habitat, or alternatively current ocean survival rates may be too low to permit the current exploitation levels.

5.2.0.0 Life History Characteristics

The similar size of male and female Cranberry River steelhead in 1997 was consistent with the results reported for other Nass River steelhead (Parken 1997b). Males were larger than females among ocean age 1+ but the difference was not significant, however males were significantly larger than females for ocean age 2+. Larger males than females at a given ocean age were similar to the results reported for some Nass River steelhead populations

(Parken 1997b), Skeena River steelhead in the Tyee test fishery (Chudyk 1976), Kitsumkalum River (Lough and Whately 1984), Kispiox River (Whately 1977), Babine River (Narver 1969), as well as steelhead in Copper Creek (Chudyk and Walsh 1982; Queen Charlotte Islands (QCI)), Yakoun River (de Leeuw 1987; QCI), Vancouver Island (Hooton *et al*. 1987) and Keogh River (Ward and Slaney 1988). Size differences between males and females that were pooled among ocean ages may be less evident, since the proportion of the returning adult population in the different ocean age groups may vary between years and sexes (Whately 1977; Chudyk *et al*. 1977; Whately *et al*. 1978; Chudyk and Whately 1980; O'Neill and Whately 1984; Hooton *et al*. 1987; Ward and Slaney 1988).

The length of adult Cranberry River steelhead returning in 1997 increased with ocean age similar to the results for other summer steelhead populations. From the Nass watershed, summer steelhead sampled from the Cranberry, Kwinageese, Meziadin and Nass River fishwheels (1996) increased in length with increases in ocean age (Parken 1997b). From the Skeena River watershed, summer steelhead sampled in the Tyee test fishery (Chudyk 1976) and the Zymoetz River (Chudyk and Whately 1980) increased in length with ocean age.

Adult size was similar between freshwater ages of Cranberry River steelhead in 1997 which was similar to the results previously reported for this population (Parken 1997b). For other Nass River populations, similar results were reported for steelhead in Damdochax Creek, Meziadin River and the Nass River fishwheels (1996), but adult size increased with freshwater age for Kwinageese steelhead (Parken 1997b). In the Kalama River, Washington, Leider *et al*. (1986) reported similar adult lengths between freshwater ages for summer and winter steelhead. Chudyk (1976) reported Skeena River summer steelhead length increased with freshwater age. Conversely, Ward and Slaney (1988) reported the size of adult Keogh River steelhead decreased as freshwater age increased, but noted that adult length increased with freshwater age for ocean age 2+ steelhead and was similar between freshwater ages for ocean age 3+ steelhead.

In 1997, the frequency of repeat spawners among Cranberry River steelhead (2%) was lower than previous estimates for the population (5%; Parken 1997b). Also, the frequency of Cranberry River repeat spawners was lower than estimates for other Nass River steelhead populations in the Kwinageese River (5%), Meziadin River (6%) and Damdochax Creek (13%; Parken 1997b). The low percentage of repeat spawning summer steelhead in the Cranberry River was similar to the results reported for Skeena River steelhead populations in the Sustut River (1-6%; Saimoto 1995, Parken and Morten 1996), Kitsumkalum River (3%; Lough and Whately 1984), Bulkley River (3%; O'Neill and Whately 1984), Suskwa River (4%; Chudyk 1978), Morice River (7%; Whately *et al*. 1978) and Babine River (3.6%; Narver 1969; 8.5%; Whately and Chudyk 1979). However, the percentage of repeat spawners was reported to be substantially higher in the Kispiox River (18%; Whately 1977) and the Zymoetz River (29%; Chudyk and Whately 1980). Hooton *et al*. (1987) reported approximately seven percent of Vancouver Island summer steelhead were repeat spawners which was similar to the six percent reported for Kalama River summer steelhead (Leider *et al*. 1986). Comparisons of the frequency of repeat spawners between rivers should be made cautiously because the sampling occurred during different time periods and the results may partially reflect variable recruitment or ocean survival (Ward and Slaney 1988), or inter-annual variability between populations.

The recaptured steelhead with fishwheel tags migrated through the Nass River from mid August to early September. However, some steelhead may have been in the Nass River later than early September, since the fishwheel operations were terminated on September 3, 1997. These results were consistent with the radio telemetry results from 1993, when Cranberry River steelhead traveled up the Nass River from August to early October (Alexander and Koski 1995). Based on this limited information, Cranberry River steelhead may have later freshwater entries than some Skeena River summer steelhead populations.

In 1997, Cranberry River steelhead exhibited small instream movements between the application and recovery samples. These results were consistent with the observations from 1979, when small (< 5 rkm) upstream and downstream movements were documented (Lough 1983). In 1979, telemetry and Floy tag results indicated steelhead in the area from rkm 15 to rkm 26 made little or no movements throughout the fall or winter, but activity increased in April (Lough 1983).

Head wounds were common among Cranberry River steelhead (13%) in 1997 and were also reported to be common among Kwinageese River steelhead in 1981 (Schultze 1981). These wounds were observed on Cranberry River steelhead in other years (G. Wolfe, personal communication), although none were observed on the 29 steelhead sampled in 1996 (Tetreau 1996). Furthermore, head wounds were rare among Nass River steelhead collected for genetic samples and were rare among steelhead sampled at the fishwheels (M.R. Link, personal communication). Also, head wounds were rare among Skeena River summer steelhead (M.C. Beere, personal communication). The cause of these head wounds was unknown, however they could be associated with migrations through canyon areas or rock falls in the Cranberry River or possibly they may be influenced from disease infecting an open wound or scrape..

6.0.0.0 Recommendations

1. The Nass steelhead carrying capacity estimates should conservatively be based on fourth order (as determined by TRIM: 1:20,000) or greater streams as opposed to third order or greater streams, until the steelhead rearing productivity of third order streams can be evaluated.

2. The model 6 carrying capacity estimates appeared to be the most appropriate for the Cranberry River steelhead population. Thus, we recommend the model 6 estimates be used for other Nass River summer steelhead populations.

3. Detailed notes should be made when steelhead are hooked in a vital area (gills, eye, or tongue) or if they are bleeding. These notes may assist in estimating the number of steelhead that may experience hooking mortality.

4. A secondary non-lethal mark, such as the adipose fin clip, should continue to be used during the application sample in adult steelhead mark-recapture studies. In addition to assessing tag loss between sampling periods, the tissue can be used for stock identification and other genetic studies. Begich (1997) used a left ventral fin clip to assess tag loss in steelhead between samples.

5. The Cranberry River fall steelhead abundance should be measured with similar methods and study design (standardized sampling) periodically every five years, in the absence of a more comprehensive escapement index monitoring population in the Nass River watershed. This type of study at this interval length would be useful to measure long term changes in relative abundance, sex composition, age composition, size composition and genetic diversity of Cranberry River steelhead.

6. Another telemetry study is recommended to describe the relative overwintering distribution of steelhead, overwinter survival, spawning locations, proportion of steelhead spawning in the Kiteen River, spawning timing, spawning survival, and possibly to assess Native harvest. Radio tag application sampling should be distributed throughout the run beginning in late August or early September and continue to the end of October. The radio tag application should be temporally representative to sufficiently describe the overwintering distribution of the population. Also, radio tags should be applied in reach 1 (downstream of the Cranberry/Kiteen confluence) to include steelhead bound for the Kiteen and Cranberry rivers.

7. If this mark-recapture study is repeated, more sampling outside of the study area is recommended provided that resources are sufficient and telemetry data indicates overwintering in other areas.

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8.0.0.0 Literature Cited

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8.0 Appendix

Appendix A. A summary of steelhead tagging data in the Cranberry River, 1997.

Steelhead ages were reported with the number of winters spent in freshwater before the decimal point followed by the number of winters spent in the ocean. A + identifies a summer steelhead with some scale growth after its last winter in the ocean. In contrast, winter steelhead do not have a + because they entered freshwater near the end of the winter. An S identifies a previous spawning event and represents 1 ocean year and an R represents regenerated scales that could not be used to determine age. A steelhead age 3.2S1+ was a summer steelhead that spent 3 winters in freshwater before smolting and then spent 2 winters in the ocean before its first spawning run and then spent another winter in the ocean before making its second spawning migration. The steelhead was freshwater age 3 and ocean age 4. Steelhead ages that were not linked to length or sex data were summarized in a box beside the sampling date and related information.

Date	Length (cm)	Sex	Tag Colour	Tag Letter	Tag Number	DNA Number	Scale Number	Scale Age	Samplers	Comments
6-Oct.	71.0	f	orange		10001	1	1	4.2+	DA/RT	
6-Oct.	79.0	m	orange		10002	2	2	3.2+	DA/RT	
6-Oct.	57.0	m	orange		10003	3	3	4.1+	DA/RT	
6-Oct.	67.0	f	orange		10051	4	4	4.2+	DA/RT	
6-Oct.	73.0	m	orange		10052	5	5	3.2+	DA/RT	
6-Oct.	70.0	f	orange		10053	6	6	3.2+	DA/RT	
6-Oct.	69.0	f	orange		10054	7	7	3.2+	DA/RT	
6-Oct.	66.0	f	orange		10055	8	8	3.2+	DA/RT	fungus under jaw
6-Oct.	65.0	f	orange		10056	9	9	3.2+	DA/RT	
6-Oct.	55.0	f	orange		10057	10	10	4.1+	DA/RT	
6-Oct.	57.0	m	orange		10058	11	11	4.1+	DA/RT	scar
6-Oct.	67.0	f	orange		10059	12	12	R.2+	DA/RT	
6-Oct.	55.0	m	orange		10060	13	13	4.1+	DA/RT	
6-Oct.	51.0	m	orange	n	6305	NA	NA	R.1+	DA/RT	no DNA, no scales
6-Oct.	64.0	m	orange		no tag	14	14	3.1+	MB/CP	split caudal fin
6-Oct.	66.0	f	orange		10101	15	15	R.2+	MB/CP	
6-Oct.	76.0	f	orange		no tag	16	16	3.2+	MB/CP	
7-Oct.	74.0	f	orange		10102	17	17	3.2+	MB/CP	hook scar
7-Oct.	57.0	f	orange		10104	18	18	5.1+	MB/CP	
7-Oct.	50.0	f	orange		10105	19	19	4.1+	MB/CP	some blood
7-Oct.	69.0	m	orange		10106	20	20	2.2+	MB/CP	hook scar
7-Oct.	64.0	f	orange		10070	21	21	4.2+	DA/RT	scar
7-Oct.	73.0	m	orange		10071	22	22	4.2+	DA/RT	
7-Oct.	74.0	m	orange		10072	23	23	3.2+	DA/RT	clean
7-Oct.	56.0	f	orange		10073	24	24	3.1+	DA/RT	tail scar
7-Oct.	69.0	f	orange	n	6144	25	25	3.2+	DA/RT	scar
7-Oct.	74.0	f	orange		10074	26	26	3.2+	DA/RT	clean
7-Oct.	50.0	m	orange		10075	27	27	3.1+	DA/RT	
7-Oct.	79.0	f	orange		10061	28	28	4.3+	DA/RT	scars, net mark
7-Oct.	78.0	f	orange		10062	29	29	2.3+	DA/RT	GN mark, scar tail
7-Oct.	67.0	f	orange		10063	30	30	4.2+	DA/RT	tail scar
7-Oct.	71.0	f	orange		10064	31	31	3.2+	DA/RT	old scar
7-Oct.	78.0	f	orange		10065	32	32	4.3+	DA/RT	clean
7-Oct.	55.0	m	orange		10066	33	33	3.1+	DA/RT	
7-Oct.	69.0	f	orange		10067	34	34	3.2+	DA/RT	
7-Oct.	69.0	f	orange		10068	35	35	3.2+	DA/RT	

Date	Length (cm)	Sex	Tag Colour	Tag Letter	Tag Number	DNA Number	Scale Number	Scale Age	Samplers	Comments
7-Oct.	71.0	f	orange		10069	36	36	4.2+	DA/RT	clean
7-Oct.	67.0	f	orange	n	6218	37	37	4.2+	DA/RT	
7-Oct.	75.0	m	orange		10005	38	38	R.2+	DA/RT	old scar
7-Oct.	78.0	m	orange		10004	39	39	4.2+	DA/RT	
7-Oct.	60.0	f	orange		10006	40	40	R.2+	DA/RT	
7-Oct.	71.0	f	orange		10007	41	41	2.2+	DA/RT	net scar
7-Oct.	80.0	m	orange		10008	42	42	2.2+	DA/RT	
7-Oct.	79.0	m	orange		10009	43	43	4.2+	DA/RT	
7-Oct.	75.0	m	orange		10010	44	44	3.2+	DA/RT	
8-Oct.	67.0	f	orange		10107	45	45	3.2+	MB/CP	blood
8-Oct.	75.0	m	orange		10108	46	46	3.2+	MB/CP	hook scar
8-Oct.	74.0	f	orange		10109	47	47	R.2+	MB/CP	
8-Oct.	57.0	m	orange		10116	48	48	R.1+	MB/CP	face wound
8-Oct.	86.0	m	orange		10110	49	49	3.3+	MB/CP	large girth, photos
8-Oct.	69.0	f	orange		10111	50	50	3.2+	MB/CP	seal scar
8-Oct.	66.0	f	orange		10112	51	51	R.2+	MB/CP	
8-Oct.	80.0	f	orange		10083	52	52	2.3+	DA/RT	
8-Oct.	76.0	f	orange		10115	53	53	5.2+	MB/CP	bird scar
8-Oct.	75.0	m	orange		10011	54	54	3.2+	DA/RT	
8-Oct.	73.0	f	orange		10012	55	55	4.2+	DA/RT	old scars
8-Oct.	66.0	f	orange		10076	56	56	R.2+	DA/RT	old scar
8-Oct.	62.0	m	orange		10078	57	57	4.1+	DA/RT	
8-Oct.	71.0	f	orange		10080	58	58	3.2+	DA/RT	anal fin scar
8-Oct.	65.0	f	orange		10081	59	59	3.2+	DA/RT	
8-Oct.	51.0	m	orange		10082	60	60	R.1+	DA/RT	
8-Oct.	53.0	m	orange		10113	171	171	4.1+	MB/CP	already sampled by Beere
8-Oct.	55.0	m	orange	n	6234	168	168	3.1+	MB/CP	already DNA sampled
9-Oct.	66.0	f	orange	n	6449	61	61	3.2+	DA/RT	
9-Oct.	68.0	f	orange		10013	62	62	4.2+	DA/RT	
9-Oct.	83.0	m	orange		10014	63	63	R.2+	DA/RT	spotless
9-Oct.	73.0	f	orange		10015	64	64	R.2+	DA/RT	
9-Oct.	61.0	m	orange		10016	65	65	3.1+	DA/RT	
9-Oct.	75.0	m	orange		10017	66	66	3.2+	DA/RT	
9-Oct.	74.0	f	orange		10018	67	67	4.2+	DA/RT	clean
9-Oct.	77.0	m	orange		10019	68	68	U.2+	DA/RT	hook scar
9-Oct.	80.0	m	orange		10020	69	69	4.2+	DA/RT	
9-Oct.	78.0	f	orange		10021	70	70	3.2+	DA/RT	
9-Oct.	55.0	f	orange		10022	71	71	3.1+	DA/RT	head fungus, seal scar
9-Oct.	81.0	m	orange		10023	72	72	R.2+	DA/RT	
9-Oct.	56.0	m	orange		10024	73	73	3.1+	DA/RT	
9-Oct.	70.0	f	orange		10084	74	74	3.2+	DA/RT	caudal scar
9-Oct.	65.0	f	orange		10085	75	75	3.2+	DA/RT	clean
9-Oct.	71.0	f	orange		10086	76	76	4.2+	DA/RT	
9-Oct.	63.0	f	orange		10087	77	77	3.2+	DA/RT	clean
9-Oct.	75.0	m	orange		10088	78	78	R.2+	DA/RT	bright, head scar
9-Oct.	60.0	m	orange		10089	79	79	3.1+	DA/RT	
9-Oct.	77.0	m	orange		10090	80	80	U.2+	DA/RT	coloured
9-Oct.	53.0	f	orange		10091	81	81	R.1+	DA/RT	
9-Oct.	67.0	f	orange		10092	82	82	U.2+	DA/RT	head scar
9-Oct.	58.0	m	orange		10093	83	83	4.1+	DA/RT	tail damage

Date	Length (cm)	Sex	Tag Colour	Tag Letter	Tag Number	DNA Number	Scale Number	Scale Age	Samplers	Comments
9-Oct.	73.0	f	orange		10094	84	84	4.2+	DA/RT	nose damage, GN marks
9-Oct.	69.0	f	orange		10095	85	85	3.2+	DA/RT	
9-Oct.	74.0	f	orange		10096	86	86	3.2+	DA/RT	nasty head wound
9-Oct.	73.0	f	orange		10097	87	87	2.2+	DA/RT	
9-Oct.	77.0	f	orange		10098	88	88	R.1S1+	DA/RT	
9-Oct.	70.0	m	orange		10099	89	89	3.2+	DA/RT	
9-Oct.	69.0	m	orange		10117	90	90	R.1S1+	MB/CP	head scar, anal scar
9-Oct.	73.0	f	orange		10118	91	91	R.2+	MB/CP	
9-Oct.	71.0	f	orange		10119	92	92	3.2+	MB/CP	head scar
9-Oct.	71.0	f	orange		10121	93	93	4.2+	MB/CP	deep hook
9-Oct.	66.0	f	orange		10120	NA	NA		MB/CP	nose bleed, no DNA, no scales
10-Oct.	71.0	f	orange		10132	94	94	R.2+	MB/CP	some blood
10-Oct.	87.0	m	orange		10131	95	95	3.3+	MB/CP	hook in mouth, recaptured 2 times
10-Oct.	77.0	m	orange		10130	96	96	4.2+	MB/CP	head scar
10-Oct.	59.0	m	orange		10129	97	97	3.1+	MB/CP	
10-Oct.	54.0	m	orange		10128	98	98	2.1+	MB/CP	head scar
10-Oct.	70.0	f	orange		10127	99	99	3.2+	MB/CP	
10-Oct.	74.0	f	orange	n	6354	100	100	3.2+	MB/CP	tagged low on lateral surface, deep hook, cut leader
10-Oct.	72.0	f	orange		10126	101	101	3.2+	MB/CP	
10-Oct.	68.0	f	orange		10125	102	102	3.2+	MB/CP	
10-Oct.	72.0	f	orange		10124	103	103	3.2+	MB/CP	some blood
10-Oct.	80.0	m	orange		10123	104	104	5.2+	MB/CP	recaptured 2 times
10-Oct.	76.0	f	orange		10122	105	105	4.2+	MB/CP	
10-Oct.	70.0	f	orange		10204	106	106	R.2+	DA/RT	head scar
10-Oct.	60.0	m	orange		10203	107	107	4.1+	DA/RT	head scar
10-Oct.	68.0	f	orange		10205	108	108	3.2+	DA/RT	scar
10-Oct.	60.0	m	orange		10206	109	109	3.1+	DA/RT	net marks
10-Oct.	62.0	f	orange		10207	110	110	3.2+	DA/RT	
10-Oct.	67.0	f	orange		10208	111	111	U.2+	DA/RT	
10-Oct.	57.0	m	orange		10209	112	112	4.1+	DA/RT	
10-Oct.	72.0	f	orange		10210	113	113	2.2+	DA/RT	
10-Oct.	72.0	f	orange		10211	114	114	3.2+	DA/RT	bright
10-Oct.	54.0	m	orange		10212	115	115	3.1+	DA/RT	
10-Oct.	70.0	f	orange		10213	116	116	U.2+	DA/RT	deep hook
10-Oct.	57.0	f	orange		10214	117	117	R.1+	DA/RT	
10-Oct.	57.0	f	orange		10215	118	118	3.2+	DA/RT	nasty head wound
10-Oct.	79.0	m	orange		10216	119	119	4.2+	DA/RT	
10-Oct.	71.0	f	orange		10217	120	120	3.2+	DA/RT	scars
10-Oct.	61.0	m	orange		10202	121	121	3.1+	DA/RT	caudal scar
10-Oct.	73.0	f	orange		10201	122	122	4.2+	DA/RT	net marks
10-Oct.	70.0	m	orange		10100	123	123	R.2+	DA/RT	
10-Oct.	55.0	m	orange	n	6357	124	124	4.1+	DA/RT	nose damage
10-Oct.	74.0	m	orange		10025	125	125	3.2+	DA/RT	clean
10-Oct.	75.0	f	orange		10026	126	126	3.2+	DA/RT	nose and chin wounds, fresh
10-Oct.	80.0	f	orange		10027	127	127	4.2+	DA/RT	nose wound
10-Oct.	67.0	f	orange		10028	128	128	3.2+	DA/RT	clean

Date	Length (cm)	Sex	Tag Colour	Tag Letter	Tag Number	DNA Number	Scale Number	Scale Age	Samplers	Comments
10-Oct.	58.0	m	orange		10029	129	129	U.1+	DA/RT	head scar, dorsal and caudal fin damage
10-Oct.	71.0	f	orange		10030	130	130	4.2+	DA/RT	head wound and predator scar
10-Oct.	71.0	f	orange		10031	131	131	4.2+	DA/RT	predator scar
10-Oct.	58.0	m	orange		10032	132	132	3.1+	DA/RT	
10-Oct.	54.0	m	orange		10033	133	133	4.1+	DA/RT	
10-Oct.	54.0	m	orange		10034	134	134	n/s	DA/RT	tail split, healed adipose clip??
10-Oct.	62.0	m	orange		10035	135	135	4.1+	DA/RT	predator scar
10-Oct.	74.0	m	orange		10036	136	136	4.2+	DA/RT	
10-Oct.	77.0	m	orange		10037	137	137	2.2+	DA/RT	
3-Nov.	67.0	f	orange		10151	NA	138	3.2+	CP/JL	scales/cut hook off
3-Nov.	71.0	f	orange		10401	NA	139	3.2+	DA/RT	scales/clean
3-Nov.	55.0	m	orange		10402	NA	NA		DA/RT	clean
3-Nov.	56.0	m	orange		10403	NA	NA		DA/RT	clean
3-Nov.	68.0	f	orange		10251	NA	140	3.2+	DA/RT	head scar
3-Nov.	76.0	f	orange		10252	NA	NA		DA/RT	clean
3-Nov.	72.0	f	orange		10253	NA	NA		DA/RT	head scar
3-Nov.	74.0	f	orange		10254	NA	NA		DA/RT	good
3-Nov.	51.0	m	orange	n	6516	NA	NA	4.1+	DA/RT	not sampled for DNA, net marks
4-Nov.	76.0	m	orange		10152	NA	141	R.2+	CP/JL	hook scar
4-Nov.	74.0	f	orange		10301	NA	142	R.2+	CP/JL	
4-Nov.	67.0	f	orange		10255	NA	143	3.2+	DA/RT	GN marks
4-Nov.	73.0	m	orange		10256	NA	144	R.2+	DA/RT	dark
4-Nov.	69.0	f	orange		10257	NA	145	3.2+	DA/RT	head scar, wound, split dorsal
4-Nov.	74.0	m	orange		10258	NA	146	R.2+	DA/RT	
4-Nov.	52.0	f	orange		10259	NA	147	3.1+	DA/RT	good
4-Nov.	61.0	m	orange		10260	NA	148	3.1+	DA/RT	
4-Nov.	54.0	f	orange	n	6381	NA	149	3.1+	DA/RT	
4-Nov.	75.0	m	orange		10261	NA	NA		DA/RT	
4-Nov.	80.0	m	orange		10262	NA	NA		DA/RT	
4-Nov.	55.0	m	orange		10263	NA	NA		DA/RT	
4-Nov.	75.0	m	orange		10264	NA	NA		DA/RT	
4-Nov.	55.0	m	orange	n	6369	NA	NA	3.1+	DA/RT	
4-Nov.	54.0	m	orange		10404	NA	150	5.1+	DA/RT	
4-Nov.	74.0	m	orange		10405	NA	151	3.2+	DA/RT	clean
4-Nov.	56.0	m	orange		10406	NA	NA		DA/RT	
4-Nov.	65.0	f	orange		10407	NA	152	R.2+	DA/RT	predator scar
4-Nov.	71.0	m	orange		10408	NA	NA		DA/RT	GN marks, bright
4-Nov.	82.0	m	orange		10409	NA	NA		DA/RT	
4-Nov.	70.0	f	orange		10410	NA	153	4.2+	DA/RT	predator scar, chin scar
4-Nov.		f	orange		10411	NA	NA		DA/RT	no length, some blood
5-Nov.	76.0	m	orange		10412	NA	NA		DA/CP	clean
5-Nov.	67.0	m	orange		10413	NA	154	2.2+	DA/CP	split caudal fin
5-Nov.	57.0	m	orange		10153	NA	155	3.1+	DA/CP	
5-Nov.	56.0	m	orange		10265	NA	156	3.1+	RT/JL	good
5-Nov.	77.0	f	orange		10266	NA	157	3.2S1+	RT/JL	head wound
5-Nov.	79.0	m	orange		10302	NA	158	3.2+	RT/JL	dorsal injury

Date	Length (cm)	Sex	Tag Colour	Tag Letter	Tag Number	DNA Number	Scale Number	Scale Age	Samplers	Comments
6-Nov.	73.0	f	orange		10267	NA	NA		CP/RT	GN mark
6-Nov.	68.0	f	orange		10268	NA	NA		CP/RT	tail scar
6-Nov.	55.0	m	orange		10269	NA	NA		CP/RT	GN mark
6-Nov.	81.0	m	orange		10270	NA	NA		CP/RT	
6-Nov.	88.0	m	orange		10271	NA	NA		CP/RT	
6-Nov.	78.0	f	orange		10272	NA	NA		CP/RT	clean
6-Nov.	71.0	f	orange		10273	NA	NA		CP/RT	GN mark
6-Nov.	76.0	f	orange		10274	NA	NA		CP/RT	head wound
6-Nov.	71.0	f	orange		10275	NA	NA		CP/RT	
6-Nov.	56.0	m	orange	n	6373	NA	NA	2.1+	CP/RT	
6-Nov.	57.0	f	orange		10154	NA	NA		CP/RT	
6-Nov.	73.0	f	orange		10155	NA	159	R.2+	CP/RT	head wound, seal scar
6-Nov.	74.0	f	orange		10156	NA	160	R.2+	CP/RT	split caudal/predator scar
6-Nov.	82.0	m	orange		10157	NA	NA		CP/RT	
6-Nov.	82.0	m	orange		10158	NA	NA		CP/RT	predator scar near caudal
6-Nov.	76.0	f	orange		10159	NA	NA		CP/RT	
6-Nov.	62.0	f	orange		10160	NA	NA		CP/RT	deep hook, some blood
6-Nov.	54.0	f	orange		10161	NA	161	3.1+	CP/RT	GN marks
6-Nov.	85.0	m	orange		10162	NA	NA		CP/RT	dorsal fin scar
6-Nov.	81.0	f	orange	n	6242	NA	162	6.2+	CP/RT	not DNA sampled
6-Nov.	76.0	f	orange		10416	NA	163	3.2+	DA/JL	predator scar
6-Nov.	NA	m	orange		10304	NA	NA		DA/JL	
6-Nov.	91.0	m	orange		10305	NA	NA		DA/JL	
6-Nov.	73.0	f	orange		10414	NA	164	3.2+	DA/JL	predator scar, bright
6-Nov.	57.0	m	orange		10415	NA	165	4.1+	DA/JL	clean
6-Nov.	NA	f	orange		10306	NA	NA		DA/JL	
6-Nov.	NA	f	orange		10307	NA	NA		DA/JL	
6-Nov.	NA	m	orange		10308	NA	NA		DA/JL	
6-Nov.	NA	f	orange		10309	NA	NA		DA/JL	
7-Nov.	69.0	f	orange		10277	NA	NA		DA/CP/RT	good
7-Nov.	60.0	f	orange		10278	NA	NA		DA/CP/RT	good
7-Nov.	76.0	m	orange		10279	NA	NA		DA/CP/RT	tail damage, split dorsal
7-Nov.	68.0	f	orange		10280	NA	NA		DA/CP/RT	clean
7-Nov.	62.0	f	orange		10281	NA	NA		DA/CP/RT	clean
7-Nov.	66.0	m	orange		10282	NA	NA		DA/CP/RT	tail damage/missing maxilla
7-Nov.	71.0	f	orange		10283	NA	NA		DA/CP/RT	
7-Nov.	70.0	f	orange		10284	NA	NA		DA/CP/RT	GN marks
7-Nov.	67.0	m	orange		10285	NA	NA		DA/CP/RT	GN marks
7-Nov.	72.0	f	orange		10286	NA	NA		DA/CP/RT	
7-Nov.	58.0	m	orange		10287	NA	NA		DA/CP/RT	
7-Nov.	60.0	m	orange		10288	NA	NA		DA/CP/RT	otter scrape
7-Nov.	51.0	m	orange		10289	NA	NA		DA/CP/RT	nose damage
7-Nov.	73.0	f	orange		10290	NA	NA		DA/CP/RT	
7-Nov.	70.0	f	orange		10291	NA	NA		DA/CP/RT	head damage
7-Nov.	76.0	f	orange		10417	NA	NA		DA/CP/RT	
7-Nov.	57.0	m	orange		10418	NA	NA		DA/CP/RT	
7-Nov.	74.0	f	orange		10419	NA	NA		DA/CP/RT	
7-Nov.	70.0	f	orange		10420	NA	NA		DA/CP/RT	
7-Nov.	71.0	f	orange		10421	NA	NA		DA/CP/RT	

Date	Length (cm)	Sex	Tag Colour	Tag Letter	Tag Number	DNA Number	Scale Number	Scale Age	Samplers	Comments
7-Nov.	71.0	f	orange		10163	NA	NA		DA/CP/RT	head wound, photos
7-Nov.	67.0	f	orange		10164	NA	NA		DA/CP/RT	
7-Nov.	78.0	f	orange		10165	NA	166	4.2S1+	DA/CP/RT	already DNA sampled, healed adipose fin
7-Nov.	67.0	m	orange		10166	NA	NA			
7-Nov.	73.0	f	orange		10422	NA	NA		DA/CP	recap that had lost tag and was retagged
7-Nov.	73.0	f	orange		10423	NA	NA		DA/CP	predator scar/head wound, photos
7-Nov.	67.0	m	orange		10424	NA	167	3.2+	DA/CP	scales, bright

Appendix B. The mean daily water temperatures in the Cranberry River from October 6 to 10 and November 3 to 7, 1997.

Date	Mean Daily Water Temperature
October 6	5.80
October 7	5.88
October 8	5.31
October 9	4.70
October 10	4.46
November 3	NA
November 4	NA
November 5	NA
November 6	NA
November 7	NA

Appendix C. A summary of Kiteen River steelhead data.

Date	Length (cm)	Sex	Tag Colour	Tag Letter	Tag Number	DNA Number	Scale Number	Age	Samplers	Comments
10-Oct.	72	f	NA	NA	NA	1	1	3.2+	MB/CP	seal scar
10-Oct.	74	f	NA	NA	NA	2	2	3.2+	MB/CP	seal scar