# NASS RIVER
# STEELHEAD HABITAT CAPABILITY
# PRODUCTION MODEL
# AND PRELIMINARY ESCAPEMENT GOALS

**for**

**Ministry of Water, Land and Air Protection**
**PO Box 5000,**
**3726 Alfred Avenue,**
**Smithers, BC V0J 2N0**

**February 2005**

**Skeena Fisheries Report # SK 142**

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**by**

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## EXECUTIVE SUMMARY

This report describes a habitat-based steelhead production model for the Nass watershed and presents the results for 63 sub-basin watersheds of 3rd order size or greater (1:20,000 mapping). The primary objective was to develop a habitat-based method for estimating smolt production capacity and spawning potential of Nass River tributary streams based on watershed features, physical habitat data, and biological production parameters. The model predicts the amount of suitable habitat available to support juvenile (fry) steelhead for rearing and converts these habitat estimates into production estimates for smolts and minimum escapement levels required to fully seed the available habitat. The watersheds studied include 26 winter steelhead populations systems, 34 summer population systems, and two sympatric systems.

The model was run for accessible area of 4th order or larger streams (4th order model) as well as for 3rd order or larger streams (3rd order model). Six different models were used to estimate the number of smolts at stream carrying capacity (based on the amount of useable length or area for fry). Three of the models used carrying capacity estimates of smolt production for the Keogh River, on northern Vancouver Island; and three used carrying capacity estimates of smolt production for the Cranberry River, a Nass summer run steelhead tributary.

Including just 4th order or larger tributaries, smolt production estimates for all confirmed steelhead habitat in the winter population systems ranged from 17,774 to 55,266 for the six different models. Smolt production estimates for all confirmed habitats for the sympatric populations ranged from 2,759 to 9,891. Smolt production estimates for all confirmed habitats for the summer populations ranged from 86,417 to 248,272.

Using the Model 6 smolt production estimate (Adjusted Areas Model), and only including tributaries for which steelhead are known to be present, the required number of winter run spawners to fully seed fry habitat in the lower Nass River tributaries was estimated to be 1,204. For the sympatric populations, the required number of spawners was estimated to be 310. The estimated required number of spawners for the summer populations with confirmed steelhead presence was 12,386 which is within the range of recent mark-recapture estimates of this aggregate of summer stocks for the period 1997-2001.

The model was particularly sensitive to alkalinity, mean smolt age, and egg-to-fry survival estimates.

# INTRODUCTION

The need to establish escapement goals is fundamental to wild stock conservation and sustainability of steelhead (*Oncorhyncus mykiss*) fisheries in British Columbia. The Nisga'a Final Agreement includes a commitment to define the Nisga'a entitlement for Nass summer-run steelhead. Some of the critical information required to negotiate this entitlement has been collected during the last ten years through Nisga'a catch monitoring and escapement estimation programs as well as provincial assessment programs. However, there remains considerable uncertainty regarding the escapement goal for Nass steelhead. The inherent difficulties in obtaining direct estimates of juvenile steelhead production, catch estimates and escapements on a stock-specific basis preclude the use of a stock recruit approach to estimating carrying capacity and escapement goals. The alternative approach entails quantifying the amount of steelhead rearing habitat available and using estimates of biological parameters to determine carrying capacity (Tautz et al. 1992). This report describes a habitat-based steelhead capability production model for the Nass watershed and presents the results for 63 sub-basin watersheds. The model also predicts the required number of spawners to fully seed the available habitat.

The primary objective of this project was to develop a habitat-based method for estimating smolt production capacity of Nass River tributary streams based on watershed features, physical habitat data, and biological production parameters. The model predicts the amount of suitable habitat available to support juvenile (fry) steelhead for rearing and converts these habitat estimates into production estimates for smolts and minimum escapement levels required for the maximum smolt yield. The results of habitat-based models are highly sensitive to the relationships and parameters used to estimate maximum smolt yields from habitat and back-calculate spawner requirements from smolt yield. However, these models provide a means to quantify the production potential for a wide range of stream systems, identifying areas with high production potential and focusing field data collection activities.

Results are presented for 63 tributaries to the Nass River, including the upper Nass mainstem above Damdochax. Only major tributaries of stream order 3 or greater were included. Although steelhead presence is not confirmed for many of the smaller Nass River tributaries, few were excluded from the model. Rather, the model allows for inclusion of those systems that are later confirmed to be steelhead-bearing streams.

# STUDY AREA

The Nass River originates in the Skeena Mountains of northwestern British Columbia and flows southwest for approximately 400 km into Portland Inlet (Figure 1). The Nass River drainage is roughly 25,000 km$^2$ with a mean annual discharge (MAD) of over 779 m$^3$s$^{-1}$ at the Shumal Water Survey of Canada (WSC) gauge near Gitwinksihlkw. There are numerous salmonid-bearing tributaries to the main Nass River.

The Nass watershed encompasses two ecoprovinces (Coastal Mountains and Sub-Boreal Interior) and contains six biogeoclimatic zones: Alpine Tundra, Sub-Boreal Spruce, Engelmann

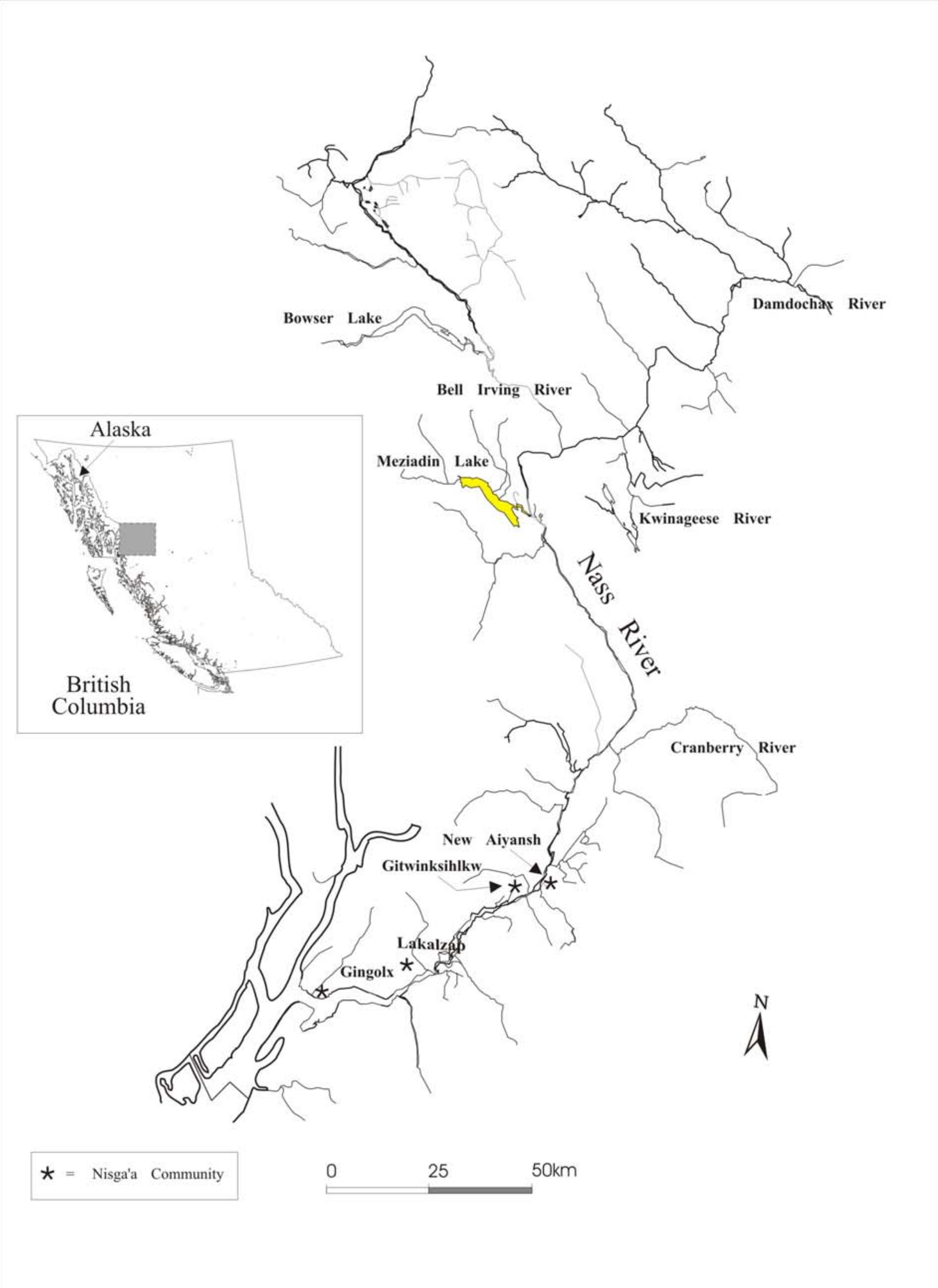

Figure 1. Map of Nass River and major tributaries.

Spruce-Subalpine Fir, Interior Cedar-Hemlock, Mountain Hemlock, and Coastal Western Hemlock (Pojar et al. 1987).

There are both winter and summer run stocks of steelhead in the Nass River drainage. Summer run stocks utilize tributaries to the Nass River upstream of the canyon at Gitwinksihlkw. Winter run stocks utilize tributaries to the Nass River downstream of the canyon at Grease Harbour (approximately 20 km upstream of Gitwinksihlkw). The Tseax River and Seaskinnish Creek have overlapping runs of both winter and summer steelhead and they are referred to as sympatric steelhead populations in the remainder of this document. All steelhead in the Nass watershed are of wild origin and no hatchery propogation or production occurs there.

## EMPIRICAL DATA

### Stream Order

Stream orders were determined using a method developed by Horton (1945) and later modified by Strahler (1957) and were determined from the BC Terrain Resource Information Management (TRIM) digital mapping (1:20000 scale).

### Stream Gradient

Stream gradients were determined from 1:20000 TRIM. To facilitate later sensitivity analyses, the gradient output from the GIS analysis was stratified into 2% gradient bins, from 0% to 12%. We set the maximum gradient useable by steelhead juveniles at 8%.

### Mean Annual Discharge

Limited data exists for system-specific estimates of MAD in the Nass River drainage (Parken 1997a). There are only four WSC stations with records. These are for the Nass River itself at Shumal Creek, the Bell-Irving River below Bowser, Surprise Creek, and Craven Creek. Therefore, to estimate tributary-specific MAD, we determined biogeoclimatic zone classifications for all Nass River tributaries, Skeena River tributaries, and one station in Portland Canal (Lime Creek) with WSC records for MAD (Table 1). Estimates from two reference stations were derived for each Nass tributary and in all cases the larger of the two estimates was used in the model (Appendix A). Mean Annual Discharge from the Shumal station was used to estimate MAD for all Upper Nass tributaries above Shumal.

The formula used to calculate MAD for ungauged watersheds within each biogeoclimatic zone from MAD for gauged watersheds in the same biogeoclimatic zone was:

$$MAD_u = WAREA_u \bullet \frac{MAD_g}{WAREA_g} \qquad (1)$$

where the subscript *u* denotes ungauged watersheds and the subscript *g* denotes gauged watersheds.

Table 1. Water Survey of Canada Stations used in the Nass steelhead model.

| Station name | Watershed | Station Number | Latitude | Longitude | Drainage Area ($km^2$) | MAD (m3/s) | Years monitored (n) | Biogeo-climatic Zones |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| Nass River at Shumal | Nass River | 08DB001 | 56 15 50N | 129 05 10W | 18500 | 781.0 | 1930-1995 (42) | ICH/MC |
| Bell-Irving at Bowser | Bell-Irving | 08DA010 | 56 16 45N | 129 08 40W | 5160 | 288.7 | 1989-1995 (6) | ICHvc/ESSF |
| Surprise | Meziadin River | 08DA005 | 56 06 35N | 129 28 33W | 221 | 15.01 | 1968-1995 (27) | ICHvc/ESSF |
| Lime | Lime Creek | 08DB010 | 55 27 15N | 129 28 48W | 39.4 | 1.81 | 1977-1995 (15) | CWHws |
| Patsey | Patsey Creek | 08DB012 | 55 25 08N | 129 24 57W | 4.68 | 0.225 | 1988-1995 (8) | MH |
| Kispiox | Kispiox R. | 08EB004 | 55 28 00N | 127 44 31W | 1870 | 45.03 | 1967-1955 (29) | ICHmc/ESSF |
| Kitsum kalum | Kitsum kalum R. | 08EG006 | 54 34 55N | 126 39 37W | 2180 | 123.25 | 1931-1949 (4) | CWHws |
| Zymagotitz | Zymagotitz | 08EG011 | 54 31 07N | 128 43 40W | 376 | 23.72 | 1961-1994 (34) | CWHws |
| Exchamsiks | Exchamsiks | 08EG012 | 54 21 47N | 129 18 41W | 370 | 43.27 | 1965-1995 (31) | CWHvm |
| Chatham S. | Union Creek | 08DB002 | 54 38 45N | 130 15 45W | 60.3 | 7.2 | 1930 (1) | CWHvh |

## Mean Smolt Age

Parken (1997b) summarized mean smolt ages for Nass River steelhead populations up to December, 1997. Additional scale samples were collected in 1998. Mean smolt age (MSA) used in the production model were calculated using all data (Table 2).

Table 2. The mean and standard deviation (SD) in smolt age for steelhead from the Bell-Irving, Cranberry, Ishkheenickh, Kincolith, Kwinageese, Meziadin, Tseax and upper Nass rivers, Damdochax and Chambers creeks, Nass River fishwheels, Nisga'a fishery catch monitoring program and all winter steelhead pooled.

| **Population** | **Smolt age** | | |
|---|---|---|---|
| | **Mean (yr.)** | **SD (yr.)** | **Sample size** |
| Summer populations | | | |
| Bell-Irving | 3.35 | 0.61 | 115 |
| Cranberry | 3.48 | 0.57 | 368 |
| Damdochax | 3.55 | 0.57 | 113 |
| Kwinageese | 3.47 | 0.58 | 143 |
| Meziadin | 3.43 | 0.67 | 61 |
| Upper Nass River | 3.52 | 0.59 | 25 |
| Pooled summer steelhead | | | |
| Fishwheels (1996-98)[1] | 3.41 | 0.59 | 1,121 |
| Sympatric populations | | | |
| Tseax[1,] | 3.25 | 0.44 | 28 |
| Winter populations | | | |
| Chambers | 3.18 | 0.38 | 40 |
| Ishkheenickh | 3.32 | 0.47 | 44 |
| Kincolith[1] | 3.46 | 0.61 | 52 |
| Pooled winter steelhead | | | |
| Catch monitoring[1] | 3.38 | 0.50 | 26 |
| All winter steelhead pooled[1] | 3.34 | 0.51 | 162 |

[1] Includes data collected by the Nisga'a Fisheries Program.

Smolt ages interpreted from adult steelhead scales were suspected to underestimate the actual smolt age because some steelhead were suspected to be under-aged (Tautz et al. 1992; Parken 1998). The scales were suspected to be under-aged because the first-year annulus may be indistinguishable on fish that form few circuli before the end of the first growing season and thus the first observed annulus represents the second winter (Jensen and Johnsen 1982; Hooton et al. 1987). These fish were identified by high circuli counts to the first observed annulus. Similar to circuli counts, scale formation was dependent on fish size (Clutter and Whitesel 1956; Jensen and Johnsen 1982; Lentsch and Griffith 1987) and for fish that do not grow large enough to form scales during the first-year, the first observed annulus represented age-2 and not age-1 (Jensen and Johnsen 1982; Hooton et al. 1987). Investigations in 1998 found the lack of scale formation on small (<45 mm) age-0 steelhead, but the analyses are incomplete at this time (Parken 1998).

The percentage of fish with an indistinguishable first-year annulus was estimated first by predicting the maximum number of circuli a steelhead would form in its first year (C1). Second, adult steelhead scales were examined and the circuli were counted to the first observed annulus. Next, the percentage of adult steelhead that exceeded the maximum expected circuli count was determined (Jensen and Johnsen 1982; Lentsch and Griffith 1987; Parken 1998). The percentage of adult steelhead that exceeded the C1 criteria was the percentage of steelhead under-aged by one year. Thus, if 17% of the adult steelhead exceeded the C1 criteria, then 0.17 years were added to the MSA. This method of adjusting smolt ages does not account for steelhead that do not form scales during the first year.

Relationships were developed between the number of circuli from the scale focus to scale margin and fork length of age-0 steelhead from the Bell-Irving, Cranberry, Kwinageese and Tseax rivers and all samples pooled (Figure 2). The number of circuli was predicted for a 70 mm steelhead (C1), which was the maximum size assumed for a Nass River age-0 steelhead near the end of the growing season (Parken 1998). Age-0 steelhead larger than 70 mm, were collected from the Bell-Irving River, Kwinageese River and Damdochax Creek and they were assumed to be missing the first-year annulus (Triton 1994a, b; Saimoto and Saimoto 1998; Parken 1998).

The predicted maximum number of circuli formed during the first year ranged from eight in the Bell-Irving and Tseax rivers to 11 in the Kwinageese River (Figure 2). Lidstone (1999) suspected that Nass River steelhead scales with 10 or more circuli to the first observed annulus may be lacking the first-year annulus, based on the reading of juvenile and adult steelhead scales in 1997 and 1998. The number of circuli to the first observed annulus was determined for adult steelhead from the Bell-Irving, Cranberry, Kincolith, Kwinageese, Meziadin, Tseax and upper Nass rivers, Damdochax Creek, Nass River fishwheels, Nisga'a catch monitoring program and all winter steelhead pooled (Table 3). For adult steelhead aged in 1997 and 1998, zero (upper Nass River) to 50% (Tseax River) of adult steelhead had circuli counts to the first observed annulus that exceeded the predicted maximum (C1; Table 3).

Mean smolt age was also estimated from the growing season length with a model developed by Tautz et al. (1992) for Skeena River summer steelhead (Table 4). The length of the growing season was the number of days that the mean daily water temperature exceeded 7 $^{o}$C (Table 4).

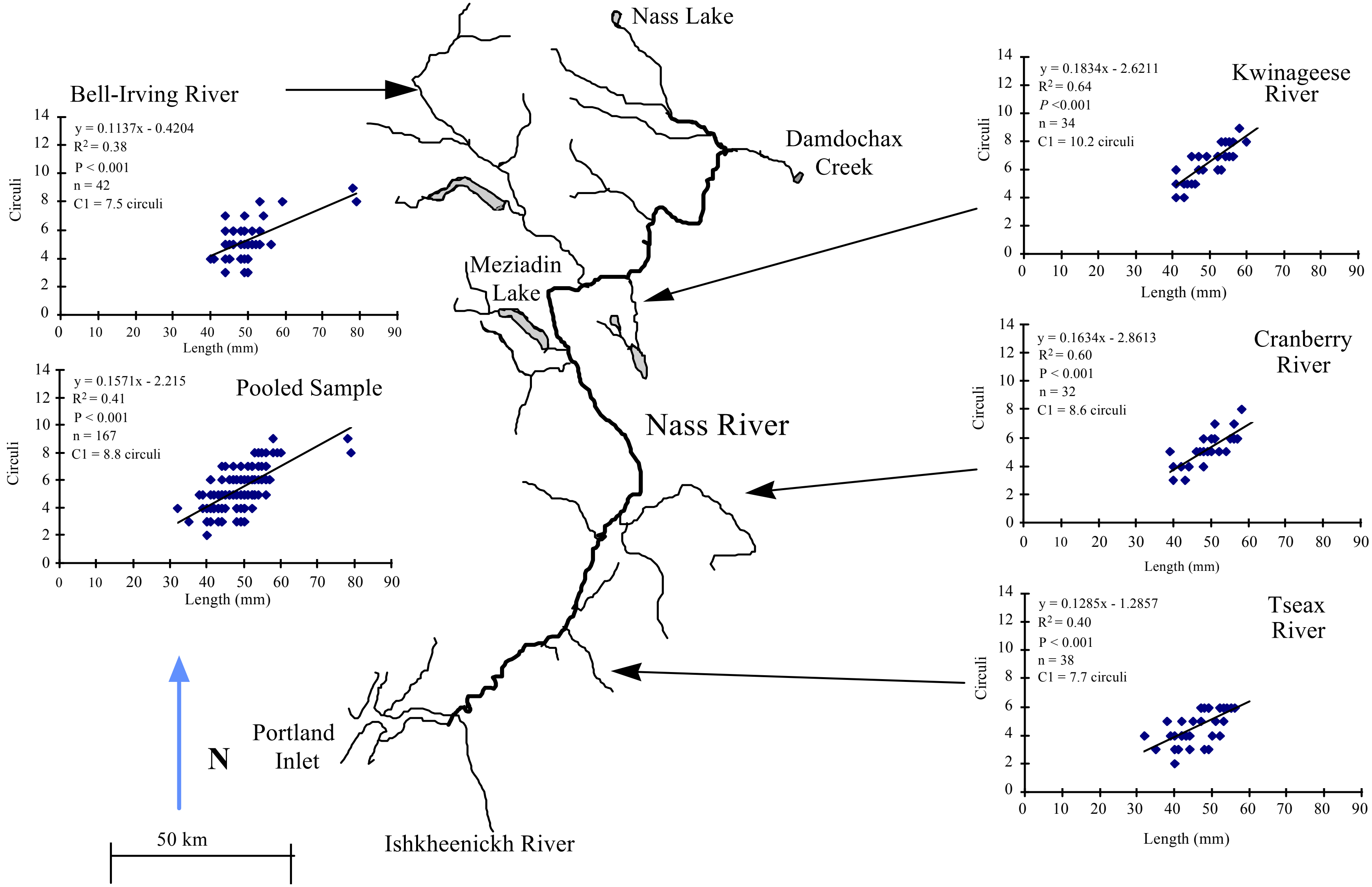

Figure 2. The relationship between circuli counts from the scale focus to the scale margin and fork length of age-0 steelhead from the Bell-Irving, Kwinageese, Cranberry, and Tseax rivers and all samples pooled.

Table 3. The mean, range and sample size (n) of circuli counted from the scale focus to the first annulus for adult steelhead from the Bell-Irving, Cranberry, Kincolith, Kwinageese, Meziadin, Tseax and upper Nass rivers, Damdochax Creek, Nass River fishwheels, Nisga'a catch monitoring program and all winter steelhead pooled.

| | | **Adult steelhead** | | | | **Adjusted MSA (years)** |
|---|---|---|---|---|---|---|
| | | **Number of circuli** | | | **Percentage exceeding C1** | |
| **Population** | **C1** | **Mean** | **Range** | **n** | | |
| Summer populations | | | | | | |
| Bell-Irving | 7.5 | 6.4 | 3-12 | 115 | 17% | 3.52 |
| Cranberry | 8.6 | 8.0 | 3-12 | 230 | 17% | 3.65 |
| Damdochax | 8.8[1] | 6.8 | 2-10 | 61 | 5% | 3.60 |
| Kwinageese | 10.2 | 8.4 | 4-13 | 84 | 2% | 3.49 |
| Meziadin | 8.8[1] | 7.4 | 5-12 | 45 | 11% | 3.54 |
| Upper Nass River | 8.8[1] | 6.8 | 4-9 | 24 | 0% | 3.52 |
| Pooled summer steelhead | | | | | | |
| Fishwheels (1997) | 8.8[1] | 7.2 | 2-13 | 796 | 11% | 3.52 |
| Sympatric populations | | | | | | |
| Tseax | 7.7 | 7.9 | 5-9 | 20 | 50% | 3.75 |
| Winter populations | | | | | | |
| Kincolith | 8.8[1] | 7.0 | 4-11 | 26 | 12% | 3.58 |
| Pooled winter steelhead | | | | | | |
| Catch Monitoring | 8.8[1] | 7.6 | 5-11 | 16 | 13% | 3.51 |
| All winter steelhead pooled | 8.8[1] | 7.2 | 4-11 | 42 | 12% | 3.46 |

[1] C1 estimated from the pooled sample in Figure 2.

Table 4. The beginning date, end date, and growing season length in 1998 and the estimated mean smolt age (MSA).

| **Waterbody** | **Beginning date** | **End date** | **Growing season length (days)[4]** | **Estimated MSA (years)** |
|---|---|---|---|---|
| Summer populations | | | | |
| Bell-Irving River | June 2 | September 27 | 113 | 4.04 |
| Bowser River | before May 23 | August 26 | 96 | 4.49[1] |
| Cranberry River | May 16 | October 6 | 143 | 3.35 |
| Kwinageese River | May 16 | October 20 | 158 | 3.05 |
| Kiteen River | May 27 | October 3 | 130 | 3.64 |
| Meziadin River | NA | after October 24 | NA | NA |
| Oweegee Creek | May 2 | October 7 | 159 | 3.04 |
| Ksedin Creek | May 18 | September 27 | 133 | 3.57[1] |
| Snowbank Creek | June 17 | September 6 | 81 | 4.93 |
| Tchitin River | May 29 | September 27 | 122 | 3.82 |
| Teigen Creek | June 26 | October 2[2] | 101 | 4.35[2] |
| Sympatric populations | | | | |
| Seaskinnish Creek | April 15 | October 21 | 190 | 2.50 |
| Tseax River | May 15 | November 7[2] | 183 | 2.61[2] |
| Winter Populations | | | | |
| Chambers Creek | May 15 | October 10 | 153 | 3.15 |
| Ishkheenickh River | May 26 | October 9 | 143 | 3.35 |
| Zolzap Creek[3] | Mean of 1994 and 1995 data | | 171 | 2.82 |

[1] The entire growing season was not measured in 1998 and the growing season estimate may differ by a few days.

[2] The end date for the growing season was estimated from data collected in 1997.

[3] Data from Nass (1997a, b).

[4] Some days between the beginning and end dates had mean daily water temperatures below 7 $^{O}$C and were excluded from the growing season length estimates.

## Female Length

Mean female length data for Nass River steelhead populations is summarized in Table 5. Data were available for five distinct summer run populations, one sympatric population, and three winter populations. The pooled mean for each of these population groups was used for those systems not having female length estimates.

Table 5. The mean and standard deviation (SD) in female length for steelhead in the Bell-Irving, Cranberry, Ishkheenickh, Kincolith, Kwinageese, Meziadin Tseax and upper Nass rivers, Damdochax Creek, Nass River fishwheels, Nisga'a fishery catch monitoring program and all winter steelhead pooled.

| Population | Female length | | |
|---|---|---|---|
| | Mean (cm) | SD (cm) | Sample size |
| Summer populations | | | |
| Bell-Irving | 68.3 | 7.2 | 60 |
| Cranberry | 69.9 | 7.7 | 273 |
| Damdochax | 74.3 | 6.2 | 72 |
| Kwinageese | 71.7 | 7.7 | 85 |
| Meziadin | 71.2 | 9.6 | 45 |
| Upper Nass River | 70.4 | 7.7 | 20 |
| Pooled summer steelhead | | | |
| Fishwheels (1996-98) | 67.8 | 8.3 | 704 |
| Sympatric populations | | | |
| Tseax[1] | 75.6 | 8.9 | 7 |
| Winter populations | | | |
| Chambers | 82.1 | 7.2 | 27 |
| Ishkheenickh | 79.6 | 6.2 | 42 |
| Kincolith[1] | 74.3 | 7.0 | 30 |
| Pooled winter steelhead | | | |
| Catch monitoring[1] | 68.8 | 9.3 | 19 |
| All winter steelhead pooled | 77.1 | 8.4 | 118 |

[1] Includes data collected by the Nisga'a Fisheries Program.

## Alkalinity

Measures of alkalinity for Nass River tributaries were obtained from a variety of sources including; Saimoto and Saimoto 1998, Parken 1997a, Triton Environmental Consultants Ltd. 1994b, and Triton Environmental Consultants Ltd. 1994a (Table 6). Additional total alkalinity samples were collected by Nisga'a Fisheries during the summer low flow period in 2000 and 2001 and incorporated into the model.

Total alkalinity measured from water samples was the most reliable estimate and was used in the model when the data existed. For systems where there was no alkalinity data, total alkalinity was estimated from water conductivity measured during the 1998 summer low flow period (Parken 1997a and NTC 1998a-g) using (Ptolemy 1992):

$$ALK = 0.421 \bullet COND - 2.31 \tag{2}$$

($r^2 = 0.86$).

Table 6. The total alkalinity estimated from water samples collected during summer low flow period, stream conductivity measured during summer low flow period, and water yield.

| | **Total alkalinity (mg/l) estimated from:** | | |
|---|---|---|---|
| **Population** | **Water sample** | **Conductivity** | **Water yield[g]** |
| Summer populations | | | |
| Bell-Irving | 64.0[a] | 55.4[b] | 17.4 |
| Bowser | 44.0[a] | 26.5 | 17.4 |
| Cranberry (main) | 83.0 | 65.2[b] | 22.5 |
| Cranberry (Kiteen) | 62.5[b] | 60.3[b] | 22.5 |
| Damdochax | 43.3[e] | | 17.4 |
| Hodder | 62.0[a] | | 17.4 |
| Konigus | 53.0 | | 17.4 |
| Kwinageese | 23.1[d] | 14.2 | 17.4 |
| Kwinatahl | 24.3 | 28.4[b] | 18.1 |
| Meziadin | 35.0 | 26.3 | 17.4 |
| Muskaboo | 42.8 | | 17.4 |
| Panorama | 54.4 | | 17.4 |
| Paw | 23.6[b] | | 17.4 |
| Taylor | 33.3 | | 17.4 |
| Tchitin | 46.7 | | 17.4 |
| Teigen | 57.0[a] | 52.4 | 17.4 |
| Treaty Creek | 54.0 | | 17.4 |
| Upper Nass River | 51.7 | | 17.4 |
| White | 32.8[b] | 30.2[b] | 17.4 |
| Sympatric populations | | | |
| Seaskinnish | 104.0 | 34.7 | 18.1 |
| Tseax | 34.0 | 26.3 | 18.1 |
| Winter populations | | | |
| Ansedegan | 38.0[c] | 48.2[f] | 18.1 |
| Burton | 25.0[c] | 7.4[f] | 12.8 |
| Chambers | 20.0[c] | | 21.8 |
| Chemainuk | | 39.8[f] | 12.8 |
| Diskangieq | 24.0[c] | | 18.1 |
| Ginlulak | 31.0[c] | | 18.1 |
| Gish | | 52.4[f] | 18.1 |
| Greenville | 13.0[c] | | 18.1 |
| Iknouk | 28.0[c] | 6.1[f] | 18.1 |
| Keazoah | 38.0[c] | 6.1[f] | 18.1 |
| Kincolith | 39.8 | 6.1[f] | 21.0 |
| Ksedin | 21.0[b] | 22.8[f] | 18.1 |
| Ksemamaith | 38.0[c] | 39.8[f] | 18.1 |
| Kwinyarh | 21.0[c] | 31.4[f] | 18.1 |
| Monkley | 35.0[c] | 11.2[f] | 12.8 |
| Zolzap | 27.0[c] | | 18.1 |

[a] Saimoto and Saimoto 1998.
[b] Parken, C.K. 1999h.
[c] Nisga'a Fisheries Program. 2000. (Unpublished data).
[d] Triton Environmental Consultants Ltd. 1994b.
[e] Triton Environmental Consultants Ltd. 1994a.
[f] NTC 1998a-g.
[g] Alkalinity calculations were generated from water yield as a function of mean annual discharge.

Where neither alkalinity nor conductivity was available, alkalinity was predicted from water yield (WY; $m^3 s^{-1} km^{-2}$) (Ptolemy 1992) using:

$$ALK = 10^{1.69 - 0.54 \bullet \mathrm{Log}_{10}(100 \bullet WY)} \tag{3}$$

($r^2 = 0.56$).

## MODEL DESCRIPTION

### Juvenile Steelhead Distributions

The model defines the distribution of steelhead fry in the Nass River watershed based on stream order and mean annual discharge (MAD). The model uses stream order and MAD as criteria to classify streams that are steelhead bearing (Appendix B).

Sebastian et al. (1991) reported juvenile steelhead use to be high in stream orders of 3, 4, and 5 (1:50000 map base) for high-yield British Columbia streams. For the Nass model, we assumed that only those tributary watersheds of stream order 4 or greater (1:20000 TRIM map base) could support steelhead rearing (4th order model). If all 3rd order streams or larger are included, the Nass model includes stream courses that would have been excluded from the model had a 1:50000 map base been used. However, with the use of a toggle, the model can also be run for 3rd order or larger streams.

Tautz et al. (1992) suggested that steelhead distribution in the Skeena drainage is limited to those tributary systems with MAD of greater than 1.0 to 1.5 $m^3/s$. This was based on considerable empirical data for steelhead distributions within the Skeena drainage. However, other authors have noted steelhead presence in small 3rd order streams with discharges less than 0.5 $m^3/s$ (Sheppard and Johnson 1985, Bustard and Narver 1975, Hume and Parkinson 1987).

In the Nass, considerably less is known about the distribution of steelhead except in the major tributary systems such as the Cranberry, Ishkheenickhh, Tseax, Damdochax, and Kwinageese. The smaller tributary watersheds have received very little attention and there is virtually no data relating MAD to steelhead presence. Accordingly, for the Nass model, we used a conservative estimate of MAD equal to 0.5 $m^3/s$ as the lower limit of distribution so as not to exclude potential steelhead bearing streams. Field verification of steelhead presence in some Nass streams is still required. Tributaries currently included in the model may be excluded based on observations of stream turbidity and water temperature.

### Accessible Length

The length of stream within a tributary accessible to steelhead is restricted by; barriers to migration, gradient, flows (see above for discussion of MAD), water quality (dissolved oxygen, turbidity, temperature), as well as evolutionary distribution or recolonization factors.

Waterfalls, debris jams, and excessive water velocities may impede fish access into otherwise suitable habitat. However, assessing whether or not a natural obstruction (e.g. falls, cascade, chute) is a barrier is not easy. Falls that are insurmountable at one time of the year may be passed at other times under different flows (Bjornn and Reiser 1991). Powers and Orsborn (1985) reported that the ability of salmonids to pass over barriers is dependent on the swimming velocity of the fish, the horizontal and vertical distances to be jumped, and the angle to the top of the barrier. The pool depth to height ratio is also important (Stuart 1962). Reiser and Peacock (1985) determined a maximum jumping height for steelhead of 3.4 m, under optimal conditions.

For the Nass steelhead model, we used a conservative height estimate of 2.0 m for an obstruction to be considered a barrier. We also considered that a point along the stream course where gradient exceeded 100% ($45^{o}$) for longer than 50 m would also be a barrier to steelhead migration.

We used the limited information on barriers within the Nass drainage to restrict steelhead use in systems where such information existed. The sources of information on barriers included FISS (1991a and b), Aquatic Biophysical Maps (1977), unpublished information from WLAP, and data gathered through Watershed Restoration Program studies (NTC 1994-98) and Fish Inventory Projects (NTC 1998a-h). Appendix C lists the known barriers for the Nass River drainage.

In terms of gradient, steelhead have been reported to occur in habitats ranging in gradient from less than 1 to 6% (Hume and Parkinson 1987, Roper et al. 1994, Bisson et al. 1988, Bustard and Narver 1975). For this model, accessibility was defined as all stream segments of 8% gradient or less, contiguous from the stream mouth up to a known barrier of greater than 2 m in height or a gradient of 100% over 50 m. The 8% gradient value for accessible area to steelhead juveniles was supported with data for the upper Kincolith River (NTC 1998a). In this reconnaissance level inventory, 80% (n=10) of juvenile steelhead captured during fish surveys were found in reaches with gradients less than 8%.

Water quality and it's relation to steelhead use is not part of this model and may account for inappropriate inclusion of some tributaries in the model. However, until such data exists, the model maintains the flexibility to include or exclude such systems.

The total accessible stream length within each Nass tributary was calculated from digital TRIM files (1:20000 scale) using ARCINFO and stratified according to gradient and stream order (Appendix D). The model was designed to allow for the summation of accessible length for stream orders greater than 3 and to determine the proportional contribution of 3rd order or larger streams.

Additional knowledge of the expected distribution of steelhead within drainages was used to determine which stream orders to include in the model for specific tributaries. For example, only 5th order or larger stream sections were included for the Cranberry River. This decision was based on the fact that very little rearing habitat exists for steelhead fry in the tributaries to the Cranberry River.

## Stream Width

This model component uses MAD to predict average late-summer stream width. Tautz et al. (1992) compiled widths for 119 reaches from 47 different streams in British Columbia to develop the following relationship between MAD and stream width:

$$WIDTH = 5.42 \bullet MAD^{0.523} \tag{4}$$

The adjusted $r^2$ value for this relationship was 0.93 with a coefficient of variation (CV) of 12.1. Average widths for small streams were determined by averaging point width measurements within a reach unit (unpublished data from WLAP, NTC 1994-98). For large streams, average widths were determined from large-scale aerial photos (i.e. 1:2000 to 10000) either by averaging several point width measurements or by digitizing stream area and dividing by thalweg length.

Because we only calculated MAD for the mouth of each tributary watershed, the predicted width only applies to the mainstem of the watershed, at some point below all major sources of inflows to the mainstem. Therefore, for watersheds of stream order 5 or greater, the model overestimates the stream width of the lower order tributary streams within the watershed.

To account for this, we examined the relationship between actual widths of different stream orders and found that stream width decreased by approximately 50% for each decrease in stream order. That is, within a watershed, the stream width for a 4th order stream was approximately half that for a 5th order stream and the stream width for a 5th order stream was approximately half that for a 6th order stream (Appendix E). This was calculated as:

$$WIDTH_{i-1} = 0.5 \bullet WIDTH_i \tag{5}$$

where the subscript *i* denotes the stream order.

## Useable Area

This component of the model predicts the universe of suitable fry habitat based on the estimated fraction of stream width that is hydraulically suitable for steelhead fry rearing and stream or reach length. Hydraulically suitable fry habitat was expressed as a percentage of stream width and determined from depth-velocity probability-of-use curves (Bovee 1982) developed for the Coquihalla River (Ptolemy 1989). An analysis of 628 stream reaches in the province of British Columbia revealed the following relationship between percent useable width (%UW), $MAD_{adj}$ and low flow stage (LFS):

$$\%UW = 10^{(2.390.275 \bullet \log_{10}(MAD_{adj}+1)0.4 \bullet \log_{10}(LFS+1))}\ 1 \tag{6}$$

The adjusted $r^2$ for this relationship was 0.59 with a CV of 11.9. Low flow stage is determined as a percentage of MAD. Critical Period Monthly Mean Flows (CPPM) (also referred to as LFS) for the Skeena ranged from 8% to 109% (Tautz et al. 1992). Lower Skeena tributaries such as Zymoetz and Kleanza had reported CPPM values of 82% and 59%, respectively. Ptolemy (R. Ptolemy, WLAP, pers. comm.) suggests that the CPPM (September) for the Nass River drainage is 110% of MAD. This value was used in the model to determine useable width for all tributaries.

Theoretical useable width (USW) for each stream order within each tributary was then calculated (Appendix F):

$$USW_o = \%UW_o \bullet Width_o \tag{7}$$

where the subscript *o* denotes stream order.

Finally, useable stream area (*USA*) (Appendix F) could be calculated using:

$$USA = \sum[USW_o \bullet LENGTH_o] \tag{8}$$

where $LENGTH_o$ is the accessible stream length by stream order.

## Smolt Yield

Six different models were used to estimate the number of smolts at stream carrying capacity (based on the amount of useable length or area for fry).

### Model 1: Keogh Smolts per kilometre of stream

Tautz et al. (1992) reported carrying capacity estimates of smolt production as 300 per kilometre for the Keogh River, based on 7500 smolts for 25 km of rearing habitat and a 14% smolt to adult survival. We applied this estimate to the accessible stream length for Nass River tributaries.

### Model 2: Keogh Smolts per square metre of stream

Tautz et al. (1992) reported carrying capacity estimates of smolt production as 0.058 smolts per square metre of useable area in the Keogh River. We applied this estimate to the accessible useable stream area for Nass River tributaries.

Model 3: Cranberry Smolts per kilometre of stream

Keogh River estimates of smolt numbers at carrying capacity would be expected to overestimate densities for larger river systems and where smolt age is greater such as in northern rivers. We therefore, determined smolt output per kilometre using data from Sebastian (1987); although it is unknown if the populations were at carrying capacity when the measurements were made. However, the mid 1980s was a period of high steelhead production across much of its range on the Pacific coast. The Sebastian (1987) estimate was 200 smolts per kilometre. We applied this estimate to the accessible stream length.

Model 4: Cranberry Smolts per square metre of stream

We used a smolt output of 0.033 smolts per square metre using data from Sebastian (1987) and applied this estimate to the accessible useable stream area for Nass River tributaries.

Model 5: Keogh River smolts per kilometre with nutrient and smolt size adjustment

One way to adjust for system specific differences in juvenile steelhead rearing conditions between the Keogh River and Nass River tributary watersheds is to account for stream productivity (nutrients) and the length of the rearing period to smoltification (mean smolt age) (Tautz et al. 1992). This was done for the Nass River Steelhead Production Model. First, alkalinity was used to determine the standing crop (SC) of steelhead in kg/ha at the end of summer for the Keogh River and the respective Nass tributary watersheds (Tautz et al. 1992):

$$SC = 36.3 \bullet ALK^{0.5} \tag{9}$$

($r^2$=0.30, p=0.01)

This then enabled calculation of the first adjustment factor:

$$ADJUST1 = \frac{SCROP_{Nasstrib}}{SCROP_{Keogh}} \tag{10}$$

Adjustment factor 2 is a function of MSA and was determined for the Keogh and Nass tributaries using:

$$SPACE = 1.24 \bullet (MSA) - 1.31 \tag{11}$$

where SPACE is the total space required to produce a smolt (Tautz et al. 1992).

The second adjustment factor was calculated using:

$$ADJUST2 = \frac{SPACE_{Keogh}}{SPACE_{Nasstrib}} \tag{12}$$

Lastly, the total number of smolts per kilometre of accessible stream for each tributary using the Keogh density of 300 smolts per kilometre was adjusted by:

$$SMOLTS = SMOLTS_{Model1} \bullet ADJUST1 \bullet ADJUST2 \tag{13}$$

Appendix G contains the results of the above calculations to derive the nutrient adjustment factors.

Model 6: Keogh River smolts per kilometre with nutrient and smolt size adjustment

Model 6 followed the same steps as Model 5, but the adjustments were applied against the Keogh smolts per square metre (Model 2).

## Escapement Required

The required number of spawners to fully seed the available habitat was determined for each tributary using the following equations from Tautz et al. (1992):

Fry to Smolt Survival

The number of fry required to produce the maximum smolt production was determined using the following (Symons 1979, Tautz et al. 1992):

$$FRYSURV = e^{-0.7174 \bullet MSA} \tag{14}$$

Egg to Fry Survival

The number of eggs required was then derived using an estimate for egg to fry survival of 10%. This survival rate can be expected to vary considerably among years which means that the required number of eggs to fully seed the available fry habitat will also vary from year to year.

Female Fecundity

To determine the required number of spawners to produce sufficient eggs requires information on fecundity. The number of eggs per female of Nass steelhead was estimated using data for Nass River steelhead and the following relation developed by Atagi (1999):

$$EGGS = e^{1.8054 \bullet Ln(LENGTH) - 3.278} \tag{15}$$

Adult lengths of female steelhead were available for three winter populations, one sympatric population, and six summer populations (Table 5). For those systems without female length data, pooled means of the winter, sympatric or summer populations were applied.

Required Escapement

Finally, assuming a 1:1 sex ratio, the required number of spawners to fully seed the accessible rearing habitat was calculated as:

$$SPAWNERS = 2 \bullet SMOLTS \bullet FRYSURV^{-1} \bullet EGGSURV^{-1} \bullet EGGS^{-1} \tag{16}$$

## RESULTS

Results are presented here for 63 tributary systems to the Nass River and include 26 winter populations, two sympatric populations and 34 summer populations. The model was run for accessible area of 4th order or greater.

### Smolt Capacity

As per Sebastian et al. (1991) and Tautz et al. (1992), we recommend inclusion of only 4th order or larger streams in determining smolt production capacity for the Nass drainage. Smolt production would likely be overestimated by 20% using the 3rd order model (using Model 6) for winter populations, by 10% for sympatric populations, and by nearly 0% (0.5%) for summer populations. Very few 3rd order streams were considered suitable steelhead habitat for Nass steelhead populations.

Using the 4th order model, smolt production estimates for all confirmed habitat in the winter population systems ranged from 17,774 for Model 4 to 55,266 for Model 1 (Appendix H, Table 7). Smolt production estimates for the sympatric populations ranged from 2,759 for Model 4 to 9,891 for Model 5. Smolt production estimates for the summer populations ranged from 86,417 for Model 4 to 248,272 for Model 5.

We recommend Model 6 as the most appropriate model to use for determining steelhead productive capacity in the Nass and establishing escapement goals. This is the same model used by Tautz et al. (1992) to determine steelhead capacity in the Skeena drainage. Model 6 suggests a smolt production at capacity of 31,221 for the confirmed winter populations, 6,235 for the sympatric populations, and 192,014 for the summer populations (Table 7).

Table 7. Estimates of smolt productive capacity using 6 different models.

| | Keogh Length Model 1 | Keogh Area Model 2 | Cranberry Length Model 3 | Cranberry Area Model 4 | Adjusted Keogh Length Model 5 | Adjusted Keogh Area Model 6 |
|---|---|---|---|---|---|---|
| Winter populations | | | | | | |
| All Systems | 69,093 | 37,987 | 46,062 | 21,613 | 68,880 | 38,139 |
| Confirmed[1] | 55,266 | 31,238 | 36,844 | 17,774 | 54,851 | 31,221 |
| Sympatric populations | | | | | | |
| All Systems | 7,644 | 4,849 | 5,096 | 2,759 | 9,891 | 6,235 |
| Confirmed[2] | 7,644 | 4,849 | 5,096 | 2,759 | 9,891 | 6,235 |
| Summer populations | | | | | | |
| All Systems | 296,772 | 211,050 | 197,848 | 120,080 | 352,737 | 255,942 |
| Confirmed[3] | 198,474 | 151,885 | 132,316 | 86,417 | 248,272 | 192,014 |

[1] Confirmed winter populations were Kincolith, Iknouk, Keazoah, Chambers, Ishkheenickh, Ksedin, Ksemamaith, Kwinyarh, and Zolzap.

[2] Confirmed sympatric populations were Tseax River and Seaskinnish Creek.

[3] Confirmed summer populations were Tchitin, Kinskuch, Brown Bear, Meziadin, Cranberry (main), Cranberry (Kiteen), Bell-Irving (above Teigen, Teigen-Bowser, below Bowser), Bowser, Taft, Treaty, Teigen, Hodder, Kwinageese, Damdochax and upper Nass (above Damdochax).

## Required Escapement

Table 8 (see also Appendix I) contains estimates of the required number of spawners to fully seed the available habitat. Using Model 6, and only including tributaries for which steelhead are known to be present, the required number of winter run spawners to fully seed habitat in the lower Nass River tributaries is estimated to be 1,200 (Table 8). The Ishkheenickhh, Kincolith, Iknouk and Kwiniak (Ksedin) rivers account for 93% of the potential number of spawners (Figure 3).

For the sympatric populations, the required number of spawners was estimated to be 310, with the Tseax River accounting for 63% of this and the Seaskinnish the remaining 37% (Table 8).

Using Model 6, the estimated required number of spawners for the summer populations with confirmed steelhead presence was 12,400 (Table 8). Cranberry, Kiteen, Bell-Irving, Damdochax, Kwinageese, and Upper Nass accounted for 97% of the total aggregate spawners (Figure 4).

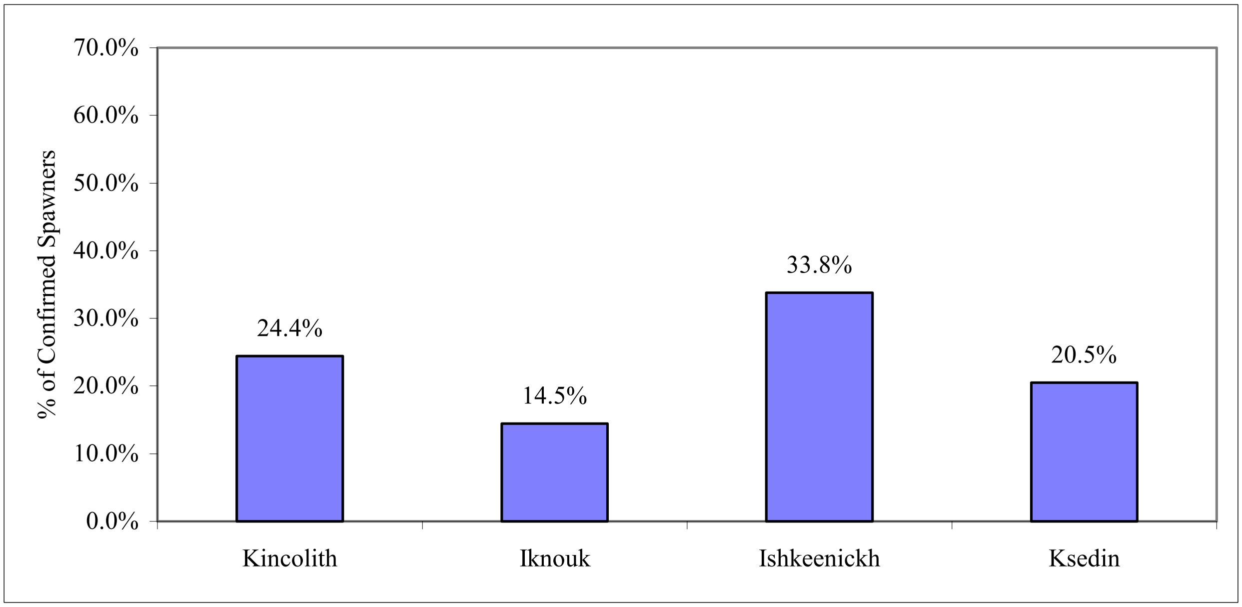

Figure 3. Distribution of winter run steelhead among the major tributary producers in the Lower Nass.

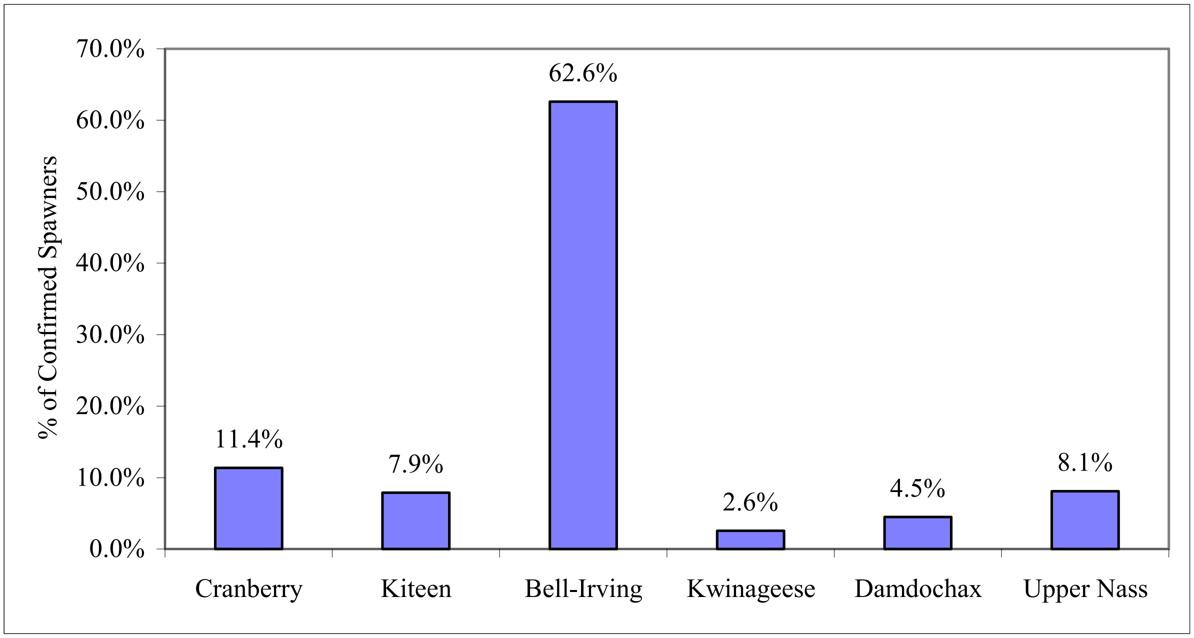

Figure 4. Distribution of summer run steelhead among the major tributary producers in the Upper Nass.

Table 8. Estimates of required number of spawners to fully seed available habitat.

| | Keogh Length Model 1 | Keogh Area Model 2 | Cranberry Length Model 3 | Cranberry Area Model 4 | Adjusted Keogh Length Model 5 | Adjusted Keogh Area Model 6 |
|---|---|---|---|---|---|---|
| Winter populations | | | | | | |
| All Systems | 2,629 | 1,452 | 1,753 | 826 | 2,647 | 1,473 |
| Confirmed[1] | 2,091 | 1,189 | 1,394 | 677 | 2,101 | 1,204 |
| Sympatric populations | | | | | | |
| All Systems | 380 | 241 | 253 | 137 | 491 | 310 |
| Confirmed[2] | 380 | 241 | 253 | 137 | 491 | 310 |
| Summer populations | | | | | | |
| All Systems | 17,789 | 13,019 | 11,859 | 7,407 | 20,995 | 15,662 |
| Confirmed[3] | 12,751 | 9,987 | 8,501 | 5,682 | 15,642 | 12,386 |

[1] Confirmed winter populations were Kincolith, Iknouk, Keazoah, Chambers, Ishkheenickh, Ksedin, Ksemamaith, Kwinyarh, and Zolzap.

[2] Confirmed sympatric populations were Tseax River and Seaskinnish Creek.

[3] Confirmed summer populations were Tchitin, Kinskuch, Brown Bear, Meziadin, Cranberry (main), Cranberry (Kiteen), Bell-Irving (above Teigen, Teigen-Bowser, below Bowser), Bowser, Taft, Treaty, Teigen, Hodder, Kwinageese, Damdochax and upper Nass (above Damdochax).

## Sensitivity Analyses

The following section describes some of the sensitivities of the model to various parameters. We used the required number of summer population spawners as the sensitivity output for this analysis.

### *Steelhead Streams*

Table 8 shows the difference in the total number of required spawners when all potential systems are included versus only those with confirmed steelhead presence. The inclusion of unconfirmed systems made little difference to the total estimate for winter populations (difference of 250 fish) because the majority of steelhead inhabit the four major systems. In the case of summer populations, inclusion of all systems increased the estimate of the required number of spawners by 2,500 fish. White River, Taylor River, and Muskaboo River accounted for the vast majority of the potential “extra production” (2280 spawners). Future work should focus on confirming or refuting steelhead use in these three systems.

### *Useable Area*

Four main components are relevant to the determination of useable area within each tributary. The first is the accessible length of stream. For many of the lower Nass tributaries, the locations of confirmed barriers to anadromous migration are known. These barriers define the upper limit of steelhead access to the system. However, for many of the upper Nass tributaries, the upstream limit of steelhead use is not well understood; particularly the use of major tributaries to systems such as Cranberry, Kiteen, and Bell-Irving; as well as the Upper Nass. Given the uncertainty of use within these watersheds, (and other Upper Nass systems), we limited the distribution within these major systems to primarily mainstem habitat. The inclusion of 4th and 5th order tributary lengths for these systems would increase the available habitat above what is presented here.

The second component relevant to the determination of useable area is the prediction of stream width from MAD using equation 4. Figure 5 shows the relationship between predicted and actual stream widths for summer run tributaries in the Nass. The relationship appears to work well for predicting stream width.

The third component in the determination of uesable area is the calculation of stream width for sub-watersheds within drainages. Equation 4 predicts the stream width near the mouth of the "parent" stream. If the parent stream is a 5th order stream, then the 4th order tributaries flowing into it will have smaller stream widths. We used a 50% reduction in stream width for each reduction in stream order (equation 5). If 60% were used as the stream width reduction factor then the estimate of required spawners for the summer populations (confirmed systems) increased from 12,386 to 12,839 (a 4% increase). Similarly, if 40% were used, then the estimate of spawners decreased to 11,866 (a 4% reduction). Figure 6a illustrates how the required number of spawners varies as the stream width reduction factor is varied.

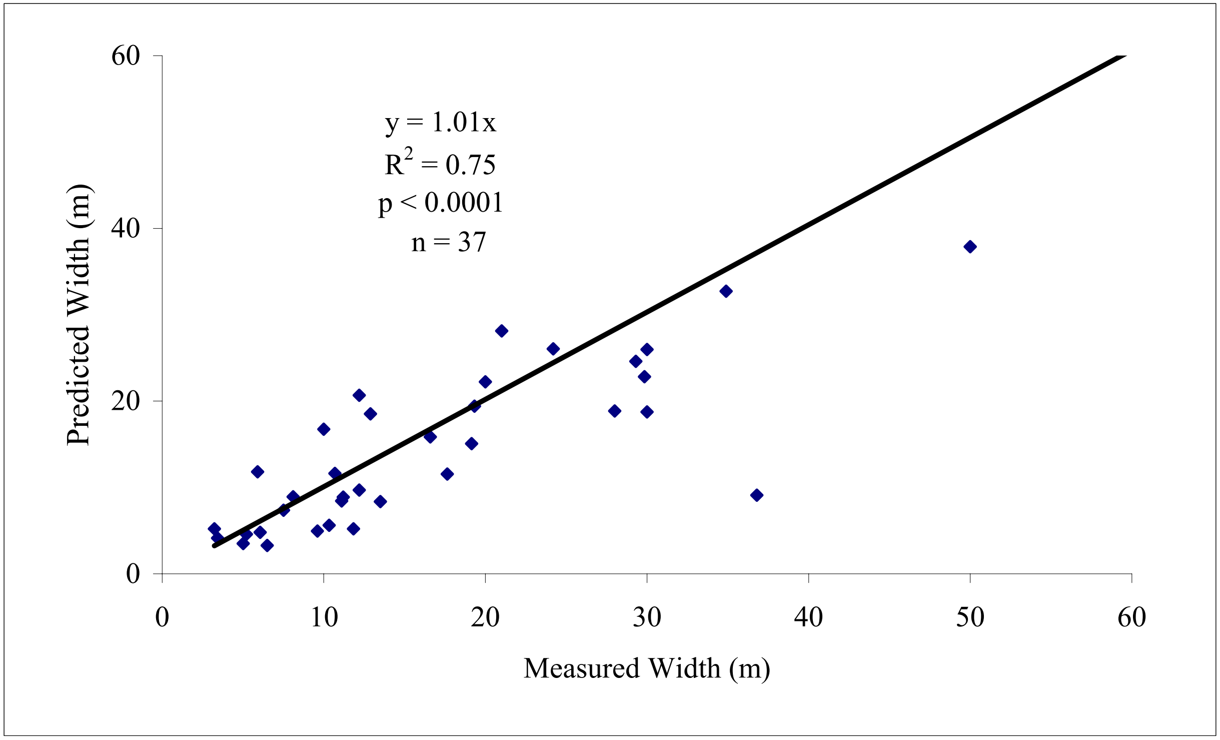

Figure 5. Relationship between measured stream width and predicted stream width for Nass River steelhead systems.

Finally, MAD and LFS are used in equations 4 and 6 to derive the percent useable width for each stream order. MAD is estimated from Water Survey of Canada data for select watersheds within the Nass and lower Skeena watersheds and the potential bias asociated with the estimated MAD values for each tributary will affect the estimate of useable area and resulting estimate of smolt productivity.

We examined two approaches to estimating MAD for Nass drainages supporting summer populations. The first used the WSC station at Shumal to prorate MAD for all drainages upstream of Shumal (Shumal method). The second (Zone method) used WSC stations at Bell-Irving, Meziadin, and Kispiox to prorate MAD for the non-gauged watersheds. The difference in the required number of summer run spawners was slight (12,386 for the Shumal method and 13,572 for the Zone method). We also examined directional bias in MAD for all watersheds using the Shumal method (Figure 6b). The final estimate of spawners was relatively robust to errors in the estimate of MAD.

In general, the model was fairly tolerant of errors in the width reduction factor and MAD. The required number of summer run spawners ranged from 10,000 to 14,000 over a wide range of potential error in these parameters.

Similarly, biases in LFS will also affect the estimate. Figure 6c shows the response of the required number of summer run spawners to changes in the estimate of LFS. The model results were more sensitive to errors in LFS (estimates ranging from 10,000 to 16,000 spawners).

*Mean Smolt Age*

The model was run with different mean smolt age estimates to account for under-aging biases. The model predicted the number of required spawners from mean smolt age estimates that were adjusted to account for under-aging bias resulting from an indistinguishable first-year annulus. The mean smolt age from steelhead scales was not adjusted for winter steelhead populations where circuli counts to the first annulus did not exist (Chambers Creek and Ishkheenickh River). The model also predicted the number of required spawners from mean smolt age estimates based on the growing season length. The mean smolt age was estimated from adult steelhead scales for populations where the growing season length was unknown. For some populations, the mean smolt age estimated from the growing season length was less than the mean smolt age from adult steelhead scales (e.g. sympatric populations; Tables 2, 4). Thus, the number of required spawners was also predicted from the method that produced the oldest mean smolt age estimate. The variability among the different estimates was small, ranging from 10,420 to 12,386 summer run spawners (Figure 6d).

*Fecundity*

The number of required spawners to fully seed the available rearing habitat was calculated with the length-fecundity relationship developed from Nass River summer steelhead (Atagi 1999). We compared the final estimate of the required number of spawners to fully seed the available habitat using this fecundity relation with that of (Tautz et al. 1992) for Skeena summer run steelhead. Using the Skeena fecundity estimate decreased the estimate of the required number of spawners by 4% for the summer populations (from 12,386 to 11,884).

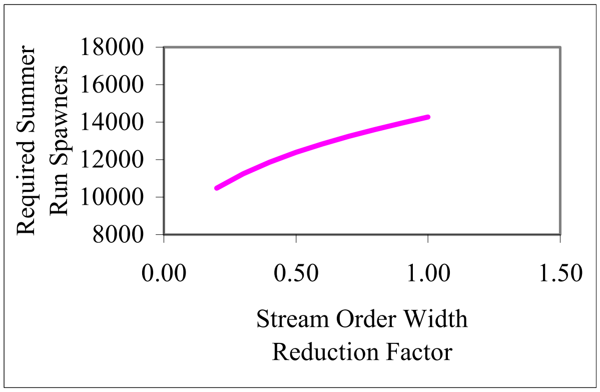

Figure 6a. Change in the required number of summer run spawners with change in the reduction factor used to determine stream width in tributaries (equation 5). A factor of 1 indicates no reduction in width.

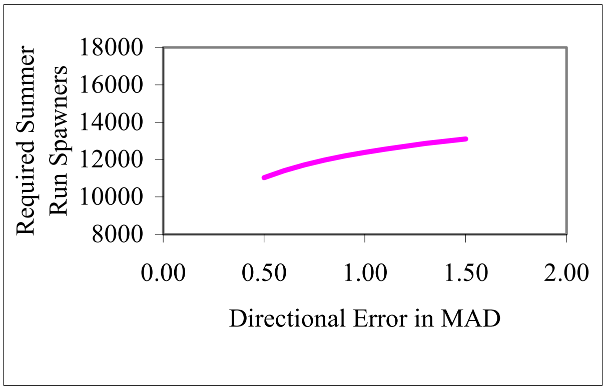

Figure 6b. Change in the required number of summer run spawners with directional error in Mean Annual Discharge (MAD). A factor of 1 indicates no error in MAD.

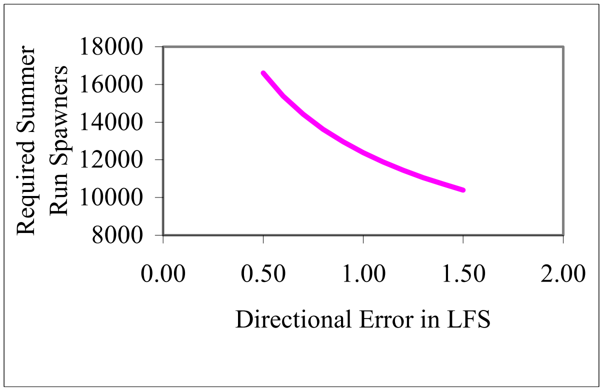

Figure 6c. Change in the required number of summer run spawners with directional error in low flow stage (LFS). A factor of 1 indicates no error in LFS.

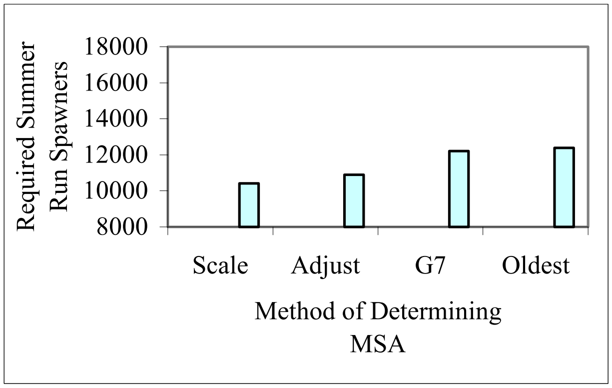

Figure 6d. Change in the required number of summer run spawners with different calculation of mean smolt age (MSA).

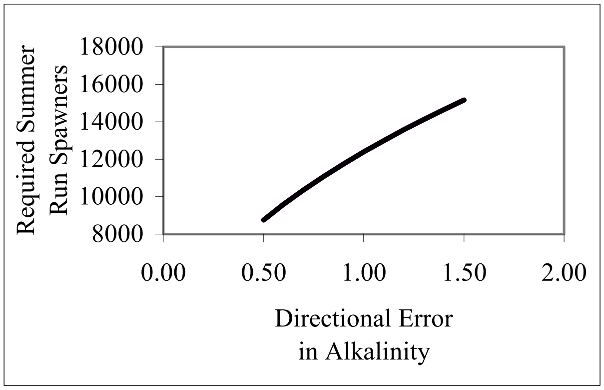

Figure 6e. Change in the required number of summer run spawners with directional bias in alkalinity.

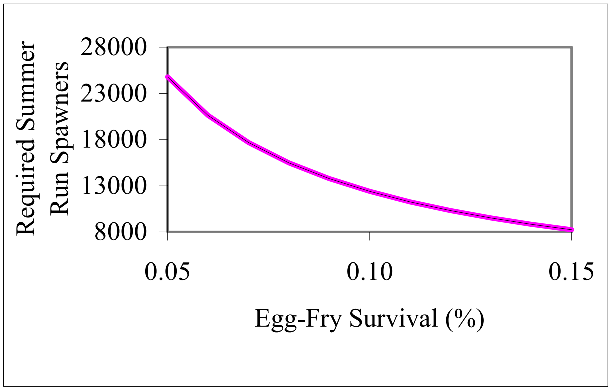

Figure 6f. Change in the required number of summer run spawners with egg to fry survival (percent).

*Productivity Measures and Adjustments*

A key variable used in the derivation of Model 6 is alkalinity, which is used to adjust Keogh River smolt densities. We examined directional bias in alkalinity for summer run populations (Figure 6e). The model was quite sensitive to error in alkalinity with estimates ranging from 8,758 to 15,169 summer run spawners for directional errors in alkalinity of 50% to 150%.

*Survivals*

The model was most sensitive to egg-to-fry survival (Figure 6f). Estimates of the required number of summer run spawners increased two-fold from 12,386 to 24,771 with a corresponding decrease in egg-to-fry survival from 10% to 5%.

## Preliminary Escapement Goals

Three methods have been proposed, developed or implemented for determining escapement goals for British Columbia steelhead. All three methods require determining the freshwater rearing capability and for simplicity they will be called the (1) stock-recruitment method, (2) simple management rule, and (3) fully seeded rearing habitat method.

The stock-recruitment method was implemented for Skeena River summer steelhead (Tautz et al. 1992; Hooton 1999). Tautz et al. (1992) estimated the freshwater habitat capability for Skeena River summer steelhead and used estimates of ocean survival to estimate the adult summer steelhead production at capacity ($P_{Replacement}$). Tautz et al. (1992) also calculated stock-specific productivity estimates (Beverton-Holt's A value) based on stock-specific life history characteristics (mean fecundity) and survival estimates (egg-fry, fry-smolt, and smolt-adult survivals). This information was then used to calculate the number of spawners at maximum sustainable yield (MSY; $P_{MSY}$):

$$P_{MSY} = P_{Replacement} \times \left[ \frac{\left( A - 1 + \sqrt{1 - A} \right)}{A} \right]$$

In order to apply the stock-recruitment method to Nass River steelhead, stock-specific productivity was calculated for each population. Beverton-Holt's A values were calculated for favourable conditions of ocean survival (15.4%; Johnston et al. 2002) and for unfavourable conditions of ocean survival (10.4%; Parken 1997b). Stock-specific productivity was calculated with empirical data collected to December 1998 following the methods described by Tautz et al. (1992) and Parken (1997b). Mean smolt ages were from the method that produced the oldest mean smolt age estimate and fecundity was estimated with the Nass summer run relationship. Stock-specific productivity (Beverton-Holt A value) was sensitive to smolt-to-adult survival estimates (Table 9).

The asymptotic adult steelhead production at capacity was calculated with Model 6 for systems with confirmed steelhead presence and for all systems (Table 10). The asymptotic maximum adult production was calculated from the asymptotic maximum smolt production and smolt-to-adult survival for favourable and unfavourable conditions (Table 10).

Table 9. The stock-specific productivity (Beverton-Holt's A value) for major steelhead systems in the Nass River.

| **Population** | **Beverton-Holt's A value**<br>**Smolt- adult Survival = 15.4%** | **Smolt – adult survival = 10.4%** |
|---|---|---|
| Summer populations | | |
| Bell-Irving | 0.77 | 0.50 |
| Cranberry | 0.88 | 0.74 |
| Kiteen | 0.88 | 0.74 |
| Damdochax | 0.91 | 0.80 |
| Kwinageese | 0.91 | 0.81 |
| Meziadin | 0.90 | 0.79 |
| Sympatric populations | | |
| Tseax[1] | 0.90 | 0.77 |
| Seaskinnish | 0.90 | 0.77 |
| Winter populations | | |
| Iknouk | 0.94 | 0.86 |
| Ishkheenickh | 0.95 | 0.89 |
| Kincolith[1] | 0.91 | 0.81 |
| Ksedin | 0.93 | 0.84 |

Table 10. Asymptotic maximum smolt and adult production estimates for Nass River steelhead.

| | Asymptotic maximum smolt production[4] | Asymptotic maximum adult production[4] | |
|---|---|---|---|
| | (Model 6) | 15.4% Smolt – Adult Survival | 10.4% Smolt – Adult Survival |
| Winter populations | | | |
| All Systems | 38,139 | 5,873 | 3,966 |
| Confirmed[1] | 31,221 | 4,808 | 3,247 |
| Sympatric populations | | | |
| All Systems | 6,235 | 960 | 648 |
| Confirmed[2] | 6,235 | 960 | 648 |
| Summer populations | | | |
| All Systems | 255,942 | 39,415 | 26,618 |
| Confirmed[3] | 192,014 | 29,570 | 19,969 |

[1] Confirmed winter populations were Kincolith, Iknouk, Keazoah, Chambers, Ishkheenickh, Ksedin, Ksemamaith, Kwinyarh, and Zolzap.

[2] Confirmed sympatric populations were Tseax River and Seaskinnish Creek.

[3] Confirmed summer populations were Tchitin, Kinskuch, Brown Bear, Meziadin, Cranberry (main), Cranberry (Kiteen), Bell-Irving (above Teigen, Teigen-Bowser, below Bowser), Bowser, Taft, Treaty, Teigen, Hodder, Kwinageese, Damdochax and upper Nass (above Damdochax).

The number of spawners at replacement was required in order to estimate the number of spawners at MSY. The number of spawners at replacement ($P_{Replacement}$) was related to the asymptotic maximum adult production ($R_{max}$) by:

$$P_{Replacement} = R_{max} \times A$$

where $A$ was Beverton-Holt's A value.

The second method to develop escapement goals was based on the simple management rule for steelhead conservation, proposed by Johnston et al. (2002). The method requires an estimate of the freshwater habitat capability and ocean survival conditions to calculate the asymptotic maximum adult steelhead production. Johnston et al. (2002) found that a spawner abundance of about 35% of asymptotic maximum recruitment will perform well in terms of maximizing harvestable surplus steelhead and minimizing risk of overharvest for unproductive populations. They recommend that populations exceeding the threshold would be in the zone for "routine fisheries management", whereas populations below the threshold would be associated with a significant degree of conservation concern or extreme conservation concern (Johnston et al. (2002).

The third method for establishing escapement goals was based on the number of required spawners to fully seed the freshwater habitat (Model 6). The fully seeded rearing habitat method does not rely on an estimate of ocean survival.

The required number of spawners (escapement goal) for Nass River steelhead for these three methods is presented in Table 11. Estimates for both favourable and unfavourable smolt to adult survival are presented.

The three methods provide different spawner requirements, which can be evaluated as a percentage of the maximum asymptotic adult production (Table 12). Johnston et al. (2002) proposed the spawner abundances should be near or exceed 35% of the adult production capacity for "routine fisheries management". The stock-recruitment method did not achieve spawner requirements in the zone for "routine fisheries management" for summer, winter or sympatric populations. As defined, the simple management rule achieved spawner requirements in the zone for "routine fisheries management" for summer, winter and sympatric populations.

In comparison, the fully seeded rearing habitat method achieved spawner requirements that were near to or in the zone for "routine fisheries management" for all populations.

Table 11. The number of required spawners using MSY, the Simple Management Rule of 35%, and the Model 6 habitat model.

| | Required spawners at MSY ($P_{MSY}$) | | Required spawners for Simple Management Rule (35%) | | Required spawners to fully seed rearing habitat |
|---|---|---|---|---|---|
| | 15.4% Smolt-Adult | 10.4% Smolt-Adult | 15.4% Smolt-Adult | 10.4% Smolt-Adult | |
| Winter Populations | | | | | |
| All Systems | 1,099 | 919 | 2,056 | 1,388 | 1,473 |
| Confirmed[1] | 898 | 750 | 1,683 | 1,136 | 1,204 |
| Sympatric Populations | | | | | |
| All Systems | 210 | 162 | 336 | 227 | 310 |
| Confirmed[2] | 210 | 162 | 336 | 227 | 310 |
| Summer Populations | | | | | |
| All Systems | 9,110 | 5,959 | 13,795 | 9,316 | 15,662 |
| Confirmed[3] | 6,924 | 4,298 | 10,350 | 6,989 | 12,386 |

[1] Confirmed winter populations were Kincolith, Iknouk, Keazoah, Chambers, Ishkheenickh, Ksedin, Ksemamaith, Kwinyarh, and Zolzap.

[2] Confirmed sympatric populations were Tseax River and Seaskinnish Creek.

[3] Confirmed summer populations were Tchitin, Kinskuch, Brown Bear, Meziadin, Cranberry (main), Cranberry (Kiteen), Bell-Irving (above Teigen, Teigen-Bowser, below Bowser), Bowser, Taft, Treaty, Teigen, Hodder, Kwinageese, Damdochax and upper Nass (above Damdochax).

Table 12. Steelhead spawner requirements, as a percentage of the maximum asymptotic adult production for the stock recruitment method, simple management rule, and the fully-seeded rearing habitat method (confirmed systems only).

| | Required spawners at MSY ($P_{MSY}$) | | Required spawners for Simple Management Rule (35%) | | Required spawners to fully seed rearing habitat | |
|---|---|---|---|---|---|---|
| | 15.4% Smolt-Adult | 10.4% Smolt-Adult | 15.4% Smolt-Adult | 10.4% Smolt-Adult | 15.4% Smolt-Adult | 10.4% Smolt-Adult |
| Winter Populations | | | | | | |
| Confirmed[1] | 19% | 23% | 35% | 35% | 25% | 37% |
| Sympatric Populations | | | | | | |
| Confirmed[2] | 22% | 25% | 35% | 35% | 22% | 48% |
| Summer Populations | | | | | | |
| Confirmed[3] | 23% | 22% | 35% | 35% | 42% | 62% |

## DISCUSSION

The Nass steelhead habitat capability model is a useful tool for improving understanding of Nass River steelhead. The model predicts the capacity of Nass River tributary habitat to produce steelhead smolts. This predictive ability is dependent on the empirical data and relationships used in the model. The model estimates 1,204 winter run spawners, 310 sympatric spawners, and 12,386 summer run spawners to fully seed the available fry habitat in confirmed steelhead producing systems. These estimates of spawner requirements were near to or in the zone for "routine fisheries management".

These interim spawner requirements do not account for uncertainty such as in sex ratios, disproportionate returns to tributary systems or variation in stock strength as discussed by Tautz et al. (1992) for Skeena River steelhead. Accordingly, the Nass estimates presented here should be used with caution and may best be considered minimums. Tautz et al. (1992) recommended an expansion factor of 1.52 for model-derived estimates of Skeena steelhead spawner requirements. It is not known if a similar expansion should be applied to Nass River steelhead. However, current harvest rates on Nass River steelhead are presumed to be quite low. Should harvest rates increase substantially, then the interim minimum spawner requirements for Nass steelhead should be reviewed.

Independent Petersen mark-recapture estimates of summer run escapement to the Nass River have been produced for 1997 to 2001. Estimates have ranged from 9,320 in 1999 to 12,802 in 1997. These estimates are close to the number of required spawners determined by the model, suggesting that the available habitat is near to fully seeded, with a spawner-to-spawner replacement of near 1:1. This is consistent with expectations for recruitment of steelhead given the extremely low marine survival rates observed in recent years. As ocean conditions improve, we should observe an increase in smolt-to-adult survival and higher adult production of Nass steelhead.

### Physical Parameters of Model

The sensitivity analyses we performed suggest that of all physical parameters evaluated, the model is most sensitive to errors in alkalinity (Figure 6). The model requires alkalinity measures for each steelhead producing tributary. For the Nass model, these data were available for all major steelhead producing tributaries, with the exception of Ishkleenick. Alkalinity measures should be repeated for all major systems to examine interannual variability.

Low Flow Stage was the next most sensitive physical parameter in the model. Low Flow Stage (LFS) is assumed to be the mean monthly discharge (as a percent of MAD) for the late summer period when juvenile steelhead still occupy tributary fry/parr habitat. For the Nass River, this is assumed to be in September. Mean September discharge for WSC stations at Shumal, Surprise, Bowser, Craven and Lime, as a percentage of MAD, was 110% (range from 98% to 132%). These stations represent good geographic coverage of the Nass watershed and so variability among tributaries is likely to be relatively small (less than 20%). Additional WSC stations installed by Nisga'a Fisheries at Cranberry, Meziadin, Kwinageese, Zolzap, and

Diskangieq will eventually allow further refinement of this parameter. For now, however, potential errors in LFS are assumed to be relatively small.

### Life-History Parameters of Model

Parken (1997b) provides a detailed dicussion of the life history components of the Nass model. Parken found that smolt-adult survival and egg-fry survival were the two most sensitive parameters. Only egg-fry survival influences the estimate of the required number of spawners to fully seed the available fry habitat. A wide range of egg-to-fry survival estimates exist in the literature and egg-to-fry survival is influenced by habitat quality (e.g. cover) and environmental factors (e.g. floods and droughts). As it is unlikely that estimates of egg-to-fry survival will ever be available for Nass steelhead, users of the model must recognize this as a critical parameter in the model.

Mean smolt age was the next most sensitive life history parameter. We used the conservative oldest values for mean smolt age in the model.

## RECOMMENDATIONS

We recommend that the required number of spawners for confirmed Nass River steelhead systems, as predicted by the habitat model 6, be adopted as the minimum escapement goal for maximum production of Nass steelhead. Additional recommendations are:

1. Capacity estimates should be conservatively based on fourth order or larger streams until steelhead distributions can be further defined.
2. As a priority, steelhead presence and distribution should be confirmed or refuted for White River, Taylor River and Muskaboo River.
3. Data on Mean Annual Discharge from additional water gauging stations that have been installed by Nisga'a Fisheries at Meziadin, Kwinageese, Cranberry, Zolzap, and Diskangieq should be added to the model when available.
4. Low Flow Stage should be re-evaluated when data are available from the new survey stations.
5. Additional and repeated measures of alkalinity should be obtained for the major steelhead producing systems (Iknouk, Ishkheenickh, Kincolith, Ksedin, Tseax, Seaskinnish, Bell-Irving, Meziadin, Cranberry, Kiteen, Kwinageese, and Damdochax).
6. Capacity estimates should be conservatively based on the oldest mean smolt age calculations.
7. Mean smolt age should be determined for the 12 major stocks so that the model relies less on the pooled mean.
8. Escapement estimates of summer run steelhead should be derived every 3rd year using the fishwheels and mark-recapture.
9. Management of Nass River steelhead would benefit with the establishment of a summer run indicator stock where biological life history data (smolts out, adults back) could be obtained on an annual basis.
10. Field verification of steelhead presence in streams with MAD greater than $0.5 m^3 s^{-1}$.

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# APPENDIX A

## CALCULATION OF MEAN ANNUAL DISCHARGE FOR NASS RIVER SUB-WATERSHEDS

Appendix A. Estimates of mean annual discharge (MAD) for Nass River tributaries derived from Nass and Skeena Water Survey of Canada reference stations. Reference station data from Parkin 1997.

| Nass Watershed | Reference Station | Reference Stn. Biogeoclimatic Zone | Reference Stn. Area (km$^2$) | Reference Stn. MAD (m$^3$/s) | Nass Wshd Biogeoclimatic Zone | Nass Wshd Area (km$^2$) | Nass Wshd MAD (m$^3$/s) |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| Kincolith | Lime Creek | CWHws | 39.4 | 1.8 | CWHws | 225.9 | 10.4 |
| Kincolith | Patsey Creek | MH | 4.7 | 0.2 | CWHws | 225.9 | 10.9 |
| Iknouk | Kitsumkalum | CWHws | 2180.0 | 123.3 | CWHws | 112.4 | 6.4 |
| Iknouk | Zymagotitz | CWHws | 376.0 | 23.7 | CWHws | 112.4 | 7.1 |
| Keazoah | Kitsumkalum | CWHws | 2180.0 | 123.3 | CWHws | 11.5 | 0.7 |
| Keazoah | Zymagotitz | CWHws | 376.0 | 23.7 | CWHws | 11.5 | 0.7 |
| Anliyen (Greenville) | Kitsumkalum | CWHws | 2180.0 | 123.3 | CWHws | 40.7 | 2.3 |
| Anliyen (Greenville) | Zymagotitz | CWHws | 376.0 | 23.7 | CWHws | 40.7 | 2.6 |
| Diskangieq | Kitsumkalum | CWHws | 2180.0 | 123.3 | CWHws | 36.4 | 2.1 |
| Diskangieq | Zymagotitz | CWHws | 376.0 | 23.7 | CWHws | 36.4 | 2.3 |
| Anudol | Kitsumkalum | CWHws | 2180.0 | 123.3 | CWHws | 123.7 | 7.0 |
| Anudol | Zymagotitz | CWHws | 376.0 | 23.7 | CWHws | 123.7 | 7.8 |
| Inieth | Kitsumkalum | CWHws | 2180.0 | 123.3 | CWHws | 9.5 | 0.5 |
| Inieth | Zymagotitz | CWHws | 376.0 | 23.7 | CWHws | 9.5 | 0.6 |
| Cugiladap | Kitsumkalum | CWHws | 2180.0 | 123.3 | CWHws | 6.2 | 0.3 |
| Cugiladap | Zymagotitz | CWHws | 376.0 | 23.7 | CWHws | 6.2 | 0.4 |
| Wegiladap | Kitsumkalum | CWHws | 2180.0 | 123.3 | CWHws | 17.0 | 1.0 |
| Wegiladap | Zymagotitz | CWHws | 376.0 | 23.7 | CWHws | 17.0 | 1.1 |
| Wilyayaanooth | Kitsumkalum | CWHws | 2180.0 | 123.3 | CWHws | 12.7 | 0.7 |
| Wilyayaanooth | Zymagotitz | CWHws | 376.0 | 23.7 | CWHws | 12.7 | 0.8 |
| Giswatz | Kitsumkalum | CWHws | 2180.0 | 123.3 | CWHws/ICHmc | 13.3 | 0.8 |
| Giswatz | Zymagotitz | CWHws | 376.0 | 23.7 | CWHws/ICHmc | 13.3 | 0.8 |
| Gingietl | Kitsumkalum | CWHws | 2180.0 | 123.3 | CWHws/ICHmc | 14.7 | 0.8 |
| Gingietl | Zymagotitz | CWHws | 376.0 | 23.7 | CWHws/ICHmc | 14.7 | 0.9 |
| Gish | Kitsumkalum | CWHws | 2180.0 | 123.3 | CWHws/ICHmc | 14.7 | 0.8 |
| Gish | Zymagotitz | CWHws | 376.0 | 23.7 | CWHws/ICHmc | 14.7 | 0.9 |
| Chemainuk | Exchamsiks | CWHvm | 370.0 | 43.3 | CWHvm | 58.1 | 6.8 |
| Chemainuk | Chatham Sd | CWHvh | 60.3 | 7.2 | CWHvm | 58.1 | 6.9 |
| Burton | Exchamsiks | CWHvm | 370.0 | 43.3 | CWHvm | 96.0 | 11.2 |

Appendix A (cont).

| Nass Watershed | Reference Station | Reference Stn. Biogeoclimatic Zone | Reference Stn. Area (km$^2$) | Reference Stn. MAD (m$^3$/s) | Nass Wshd Biogeoclimatic Zone | Nass Wshd Area (km$^2$) | Nass Wshd MAD (m$^3$/s) |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| Burton | Chatham Sd | CWHvh | 60.3 | 7.2 | CWHvm | 96.0 | 11.5 |
| Monkley | Exchamsiks | CWHvm | 370.0 | 43.3 | CWHvm | 35.7 | 4.2 |
| Monkley | Chatham Sd | CWHvh | 60.3 | 7.2 | CWHvm | 35.7 | 4.3 |
| Chambers | Exchamsiks | CWHvm | 370.0 | 43.3 | CWHvm | 89.9 | 10.5 |
| Chambers | Chatham Sd | CWHvh | 60.3 | 7.2 | CWHvm | 89.9 | 10.7 |
| Welda | Exchamsiks | CWHvm | 370.0 | 43.3 | CWHvm | 31.3 | 3.7 |
| Welda | Chatham Sd | CWHvh | 60.3 | 7.2 | CWHvm | 31.3 | 3.7 |
| Quilgauw | Kitsumkalum | CWHws | 2180.0 | 123.3 | CWHws | 37.0 | 2.1 |
| Quilgauw | Zymagotitz | CWHws | 376.0 | 23.7 | CWHws | 37.0 | 2.3 |
| Ishkheenickhh | Kitsumkalum | CWHws | 2180.0 | 123.3 | CWHws | 579.4 | 32.8 |
| Ishkheenickhh | Zymagotitz | CWHws | 376.0 | 23.7 | CWHws | 579.4 | 36.6 |
| Ginlulak | Kitsumkalum | CWHws | 2180.0 | 123.3 | CWHws | 43.0 | 2.4 |
| Ginlulak | Zymagotitz | CWHws | 376.0 | 23.7 | CWHws | 43.0 | 2.7 |
| Kwiniak (Ksedin) | Kitsumkalum | CWHws | 2180.0 | 123.3 | CWHws | 248.1 | 14.0 |
| Kwiniak (Ksedin) | Zymagotitz | CWHws | 376.0 | 23.7 | CWHws | 248.1 | 15.7 |
| Ksemamaith | Kitsumkalum | CWHws | 2180.0 | 123.3 | CWHws | 68.4 | 3.9 |
| Ksemamaith | Zymagotitz | CWHws | 376.0 | 23.7 | CWHws | 68.4 | 4.3 |
| Ansedegan | Kitsumkalum | CWHws | 2180.0 | 123.3 | CWHws | 28.5 | 1.6 |
| Ansedegan | Zymagotitz | CWHws | 376.0 | 23.7 | CWHws | 28.5 | 1.8 |
| Kwinyarh | Kitsumkalum | CWHws | 2180.0 | 123.3 | CWHws | 15.6 | 0.9 |
| Kwinyarh | Zymagotitz | CWHws | 376.0 | 23.7 | CWHws | 15.6 | 1.0 |
| Zolzap | Kitsumkalum | CWHws | 2180.0 | 123.3 | CWHws | 32.0 | 1.8 |
| Zolzap | Zymagotitz | CWHws | 376.0 | 23.7 | CWHws | 32.0 | 2.0 |
| Tseax | Shumal | ICH / MC | 18500.0 | 781.0 | CWHws/ICHmc | 608.3 | 25.7 |
| Tseax | Zymagotitz | CWHws | 376.0 | 23.7 | CWHws/ICHmc | 608.3 | 38.4 |
| Seaskinnish | Shumal | ICH / MC | 18500.0 | 781.0 | CWHws/ICHmc | 204.6 | 8.6 |
| Seaskinnish | Zymagotitz | CWHws | 376.0 | 23.7 | CWHws/ICHmc | 204.6 | 12.9 |
| Gitwinksihlkw | Shumal | ICH / MC | 18500.0 | 781.0 | CWHws/ICHmc | 7.0 | 0.3 |
| Gitwinksihlkw | Zymagotitz | CWHws | 376.0 | 23.7 | CWHws/ICHmc | 7.0 | 0.4 |
| Shumal | Shumal | ICH / MC | 18500.0 | 781.0 | CWHws/ICHmc | 99.6 | 4.2 |

Appendix A (cont).

| Nass Watershed | Reference Station | Reference Stn. Biogeoclimatic Zone | Reference Stn. Area (km$^2$) | Reference Stn. MAD (m$^3$/s) | Nass Wshd Biogeoclimatic Zone | Nass Wshd Area (km$^2$) | Nass Wshd MAD (m$^3$/s) |
|---|---|---|---|---|---|---|---|
| Shumal | Zymagotitz | CWHws | 376.0 | 23.7 | CWHws/ICHmc | 99.6 | 6.3 |
| Kwinamuck | Shumal | ICH / MC | 18500.0 | 781.0 | CWHws/ICHmc | 61.5 | 2.6 |
| Kwinamuck | Zymagotitz | CWHws | 376.0 | 23.7 | CWHws/ICHmc | 61.5 | 3.9 |
| Kwinatahl | Shumal | ICH / MC | 18500.0 | 781.0 | CWHws/ICHmc | 306.1 | 12.9 |
| Kwinatahl | Zymagotitz | CWHws | 376.0 | 23.7 | CWHws/ICHmc | 306.1 | 19.3 |
| Kshadin | Shumal | ICH / MC | 18500.0 | 781.0 | CWHws/ICHmc | 105.1 | 4.4 |
| Kshadin | Zymagotitz | CWHws | 376.0 | 23.7 | CWHws/ICHmc | 105.1 | 6.6 |
| Tchitin | Bowser | ICHvc/ESSF | 5160.0 | 288.7 | ICHmc/ESSFwv | 248.2 | 13.9 |
| Tchitin | Surprise | ICHvc/ESSF | 221.0 | 15.0 | ICHmc/ESSFwv | 248.2 | 16.9 |
| Kinskutch | Bowser | ICHvc/ESSF | 5160.0 | 288.7 | ICHmc/ESSFwv | 476.9 | 26.7 |
| Kinskutch | Surprise | ICHvc/ESSF | 221.0 | 15.0 | ICHmc/ESSFwv | 476.9 | 32.4 |
| Paw | Bowser | ICHvc/ESSF | 5160.0 | 288.7 | ICHmc/ESSFwv | 176.7 | 9.9 |
| Paw | Surprise | ICHvc/ESSF | 221.0 | 15.0 | ICHmc/ESSFwv | 176.7 | 12.0 |
| Brown Bear | Bowser | ICHvc/ESSF | 5160.0 | 288.7 | ICHmc | 227.7 | 12.7 |
| Brown Bear | Surprise | ICHvc/ESSF | 221.0 | 15.0 | ICHmc | 227.7 | 15.5 |
| Van Dyke | Bowser | ICHvc/ESSF | 5160.0 | 288.7 | ICHmc | 34.0 | 1.9 |
| Van Dyke | Surprise | ICHvc/ESSF | 221.0 | 15.0 | ICHmc | 34.0 | 2.3 |
| White | Bowser | ICHvc/ESSF | 5160.0 | 288.7 | ICHmc | 954.0 | 53.4 |
| White | Surprise | ICHvc/ESSF | 221.0 | 15.0 | ICHmc | 954.0 | 64.8 |
| Meziadin | Bowser | ICHvc/ESSF | 5160.0 | 288.7 | ICHmc | 719.3 | 40.2 |
| Meziadin | Surprise | ICHvc/ESSF | 221.0 | 15.0 | ICHmc | 719.3 | 48.9 |
| Cranberry Main | Kispiox | ICHmc | 1870.0 | 45.0 | ICHmc/ESSFwv | 974.8 | 23.5 |
| Cranberry Main | Shumal | ICH / MC | 18500.0 | 781.0 | ICHmc/ESSFwv | 974.8 | 41.2 |
| Cranberry – Kiteen | Kispiox | ICHmc | 1870.0 | 45.0 | CWHws/ICHmc | 885.3 | 21.3 |
| Cranberry – Kiteen | Shumal | ICH / MC | 18500.0 | 781.0 | CWHws/ICHmc | 885.3 | 37.4 |
| Bell-Irving (below Bowser) | Bowser | ICHvc/ESSF | 5160.0 | 288.7 | ICHvc/ESSFwv | 4954.0 | 277.2 |
| Bell-Irving (below Bowser) | Surprise | ICHvc/ESSF | 221.0 | 15.0 | ICHvc/ESSFwv | 4954.0 | 336.5 |
| Bell-Irving (below Teigen) | Bowser | ICHvc/ESSF | 5160.0 | 288.7 | ICHvc/ESSFwv | 4498.0 | 251.7 |
| Bell-Irving (below Teigen) | Surprise | ICHvc/ESSF | 221.0 | 15.0 | ICHvc/ESSFwv | 4498.0 | 305.5 |
| Bell-Irving (above Teigen) | Bowser | ICHvc/ESSF | 5160.0 | 288.7 | ICHvc/ESSFwv | 1295.8 | 72.5 |
| Bell-Irving (above Teigen) | Surprise | ICHvc/ESSF | 221.0 | 15.0 | ICHvc/ESSFwv | 1295.8 | 88.0 |

| Appendix A (cont). | | | | | | | |
|---|---|---|---|---|---|---|---|
| Nass Watershed | Reference Station | Reference Stn. Biogeoclimatic Zone | Reference Stn. Area (km$^2$) | Reference Stn. MAD (m$^3$/s) | Nass Wshd Biogeoclimatic Zone | Nass Wshd Area (km$^2$) | Nass Wshd MAD (m$^3$/s) |
| | | | | | | | |
| Bowser | Bowser | ICHvc/ESSF | 5160.0 | 288.7 | ICHvc/ESSFwv | 1262.0 | 70.6 |
| Bowser | Surprise | ICHvc/ESSF | 221.0 | 15.0 | ICHvc/ESSFwv | 1262.0 | 85.7 |
| Taft | Bowser | ICHvc/ESSF | 5160.0 | 288.7 | ICHvc/ESSFwv | 474.0 | 26.5 |
| Taft | Surprise | ICHvc/ESSF | 221.0 | 15.0 | ICHvc/ESSFwv | 474.0 | 32.2 |
| Treaty | Bowser | ICHvc/ESSF | 5160.0 | 288.7 | ICHvc/ESSFwv | 427.1 | 23.9 |
| Treaty | Surprise | ICHvc/ESSF | 221.0 | 15.0 | ICHvc/ESSFwv | 427.1 | 29.0 |
| Teigen | Bowser | ICHvc/ESSF | 5160.0 | 288.7 | ICHvc/ESSFwv | 351.7 | 19.7 |
| Teigen | Surprise | ICHvc/ESSF | 221.0 | 15.0 | ICHvc/ESSFwv | 351.7 | 23.9 |
| Hodder | Bowser | ICHvc/ESSF | 5160.0 | 288.7 | ICHvc/ESSFwv | 72.3 | 4.0 |
| Hodder | Surprise | ICHvc/ESSF | 221.0 | 15.0 | ICHvc/ESSFwv | 72.3 | 4.9 |
| Kwinageese | Bowser | ICHvc/ESSF | 5160.0 | 288.7 | ESSFwv | 552.3 | 30.9 |
| Kwinageese | Surprise | ICHvc/ESSF | 221.0 | 15.0 | ESSFwv | 552.3 | 37.5 |
| Saladamis | Bowser | ICHvc/ESSF | 5160.0 | 288.7 | ICHmc/ESSFwv | 75.0 | 4.2 |
| Saladamis | Surprise | ICHvc/ESSF | 221.0 | 15.0 | ICHmc/ESSFwv | 75.0 | 5.1 |
| Sanyam | Bowser | ICHvc/ESSF | 5160.0 | 288.7 | ICHmc/ESSFwv | 96.6 | 5.4 |
| Sanyam | Surprise | ICHvc/ESSF | 221.0 | 15.0 | ICHmc/ESSFwv | 96.6 | 6.6 |
| Sanskisoot | Bowser | ICHvc/ESSF | 5160.0 | 288.7 | ICHmc/ESSFwv | 103.3 | 5.8 |
| Sanskisoot | Surprise | ICHvc/ESSF | 221.0 | 15.0 | ICHmc/ESSFwv | 103.3 | 7.0 |
| Taylor | Bowser | ICHvc/ESSF | 5160.0 | 288.7 | ICHmc/ESSFwv | 753.2 | 42.1 |
| Taylor | Surprise | ICHvc/ESSF | 221.0 | 15.0 | ICHmc/ESSFwv | 753.2 | 51.2 |
| Sallysout | Bowser | ICHvc/ESSF | 5160.0 | 288.7 | ICHmc/ESSFwv | 333.2 | 18.6 |
| Sallysout | Surprise | ICHvc/ESSF | 221.0 | 15.0 | ICHmc/ESSFwv | 333.2 | 22.6 |
| Vile | Bowser | ICHvc/ESSF | 5160.0 | 288.7 | ICHmc/ESSFwv | 188.0 | 10.5 |
| Vile | Surprise | ICHvc/ESSF | 221.0 | 15.0 | ICHmc/ESSFwv | 188.0 | 12.8 |
| Kotsinka | Bowser | ICHvc/ESSF | 5160.0 | 288.7 | ICHmc/ESSFwv | 312.4 | 17.5 |
| Kotsinka | Surprise | ICHvc/ESSF | 221.0 | 15.0 | ICHmc/ESSFwv | 312.4 | 21.2 |
| Damdochax | Bowser | ICHvc/ESSF | 5160.0 | 288.7 | ICHmc/ESSFwv | 737.4 | 41.3 |
| Damdochax | Surprise | ICHvc/ESSF | 221.0 | 15.0 | ICHmc/ESSFwv | 737.4 | 50.1 |
| Muskaboo | Bowser | ICHvc/ESSF | 5160.0 | 288.7 | ICHmc/ESSFwv | 614.9 | 34.4 |
| Muskaboo | Surprise | ICHvc/ESSF | 221.0 | 15.0 | ICHmc/ESSFwv | 614.9 | 41.8 |
| Panorama | Bowser | ICHvc/ESSF | 5160.0 | 288.7 | ICHmc/ESSFwv | 90.6 | 5.1 |

| Appendix A (cont). | | | | | | | |
|---|---|---|---|---|---|---|---|
| Nass Watershed | Reference Station | Reference Stn. Biogeoclimatic Zone | Reference Stn. Area (km$^2$) | Reference Stn. MAD (m$^3$/s) | Nass Wshd Biogeoclimatic Zone | Nass Wshd Area (km$^2$) | Nass Wshd MAD (m$^3$/s) |
| | | | | | | | |
| Panorama | Surprise | ICHvc/ESSF | 221.0 | 15.0 | ICHmc/ESSFwv | 90.6 | 6.2 |
| Konigus | Bowser | ICHvc/ESSF | 5160.0 | 288.7 | ICHmc/ESSFwv | 471.7 | 26.4 |
| Konigus | Surprise | ICHvc/ESSF | 221.0 | 15.0 | ICHmc/ESSFwv | 471.7 | 32.0 |
| Upper Nass | Bowser | ICHvc/ESSF | 5160.0 | 288.7 | ICHmc/ESSFwv | 735.6 | 41.2 |
| Upper Nass | Surprise | ICHvc/ESSF | 221.0 | 15.0 | ICHmc/ESSFwv | 735.6 | 50.0 |

# APPENDIX B

# KNOWN AND PREDICTED (SUSPECTED) STEELHEAD PRODUCING TRIBUTARIES IN THE NASS WATERSHED

Appendix B. Stream order and accessible length for Nass River tributaries, as well as prediction of use by steelhead juveniles.

| | Watershed | Watershed Code | Area (km$^2$) | MAD[1] (m$^3$/s) | Stream Order[2] | Steelhead Use Predicted from MAD[4] | Steelhead/ Rainbow present (confirmed)[5] |
|---|---|---|---|---|---|---|---|
| Winter Populations | | | | | | | |
| | | | | | | | |
| 1 | Kincolith | 70-0100 | 225.9 | 10.9 | 4 | Y | Y |
| 2 | Iknouk | 70-0600 | 112.4 | 7.1 | 4 | Y | Y |
| 3 | Keaszoah | | 11.5 | 0.7 | 3 | Y | Y |
| 4 | Anliyen (Greenville) | | 40.7 | 2.6 | 4 | Y | U |
| 5 | Diskangieq | | 36.4 | 2.3 | 4 | Y | U |
| 6 | Anudol | | 123.7 | 7.8 | 5 | Y | N |
| 7 | Inieth | | 9.5 | 0.6 | 3 | Y | N |
| 8 | Cugiladap | | 6.2 | 0.4 | 3 | N | N |
| 9 | Wegiladap | | 17.0 | 1.1 | 4 | Y | N |
| 10 | Wilyayaanooth | | 12.7 | 0.8 | 3 | Y | RB |
| 11 | Giswatz | | 13.3 | 0.8 | 3 | Y | N |
| 12 | Gingietl | | 14.7 | 0.9 | 3 | Y | RB |
| 13 | Gish | | 14.7 | 0.9 | 3 | Y | RB |
| 14 | Chemainuk | | 58.1 | 6.9 | 4 | Y | N |
| 15 | Burton | | 96.0 | 11.5 | 5 | Y | RB |
| 16 | Monkley | | 35.7 | 4.3 | 4 | Y | RB |
| 17 | Chambers | 70-0200 | 89.9 | 10.7 | 4 | Y | Y |
| 18 | Welda | | 31.3 | 3.7 | 3 | Y | U |
| 19 | Quilgauw | | 37.0 | 2.3 | 4 | Y | U |
| 20 | Ishkheenickhh | 71-0000 | 579.4 | 36.6 | 7 | Y | Y |
| 21 | Ginlulak | 70-1200 | 43.3 | 2.7 | 4 | Y | N |
| 22 | Kwiniak (Ksedin) | 70-1400 | 248.1 | 15.7 | 5 | Y | Y |
| 23 | Ksemamaith | 70-1500 | 68.4 | 4.3 | 4 | Y | Y |
| 24 | Ansedegan | 70-1800 | 28.5 | 1.8 | 4 | Y | U |
| 25 | Kwinyarh | 70-2000 | 15.6 | 1.0 | 3 | Y | Y |
| 26 | Zolzap | 70-2300 | 32.0 | 2.0 | 5 | Y | Y |
| | | | | | | | |
| Sympatric Populations | | | | | | | |
| | | | | | | | |
| 27 | Tseax | 70-2700 | 608.3 | 38.4 | 6 | Y | Y |
| 28 | Seaskinnish | 70-2900 | 204.6 | 12.9 | 5 | Y | Y |
| 29 | Gitwinksihlkw Ck | | 7.0 | 0.4 | 3 | N | N |
| | | | | | | | |

| Appendix B (cont) | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Watershed | Watershed Code | Area (km$^2$) | MAD [1] (m$^3$/s) | Stream Order [2] | Steelhead Use Predicted from MAD [4] | Steelhead/ Rainbow present (confirmed) [5] |
| Summer Populations | | | | | | | |
| | | | | | | | |
| 30 | Shumal | 70-2600 | 99.6 | 6.3 | 4 | Y | U |
| 31 | Kwinamuck | | 61.5 | 3.9 | 4 | Y | N |
| 32 | Kwinatahl | | 306.1 | 19.3 | 6 | Y | RB |
| 33 | Kshadin | | 105.1 | 6.6 | 5 | Y | U |
| 34 | Tchitin | 70-3500 | 248.2 | 16.9 | 6 | Y | Y |
| 35 | Kinskuch | 72-0000 | 476.9 | 32.4 | 5 | Y | Y |
| 36 | Paw | 70-4000 | 176.7 | 12.0 | 6 | Y | U |
| 37 | Brown Bear | 70-3900 | 227.7 | 15.5 | 4 | Y | Y |
| 38 | Van Dyke Ck | | 34.1 | 2.3 | 4 | Y | U |
| 39 | White | 74-0000 | 954.0 | 64.8 | 6 | Y | N |
| 40 | Meziadin | | 719.3 | 48.9 | 6 | Y | Y |
| 41 | Cranberry Main | 73-0000 | 974.8 | 41.2 | 7 | Y | Y |
| 42 | Cranberry-Kiteen | | 885.5 | 37.4 | 7 | Y | Y |
| 43 | Bell-Irving below Bowser | 76-0000 | 4954.0 | 336.5 | 7 | Y | Y |
| 44 | Bell-Irving (Bowser to Teigen) | | 4498.0 | 305.5 | 7 | Y | Y |
| 45 | Bell-Irving (above Teigen) | | 1295.8 | 88.0 | 7 | Y | Y |
| 46 | Bowser | | 1262.0 | 85.7 | 7 | Y | Y |
| 47 | Taft | | 474.0 | 32.2 | 6 | Y | Y |
| 48 | Treaty | | 427.1 | 29.0 | 6 | Y | Y |
| 49 | Teigen | | 351.7 | 23.9 | 6 | Y | Y |
| 50 | Hodder | | 72.3 | 4.9 | 5 | Y | Y |
| 51 | Kwinageese | 70-4500 | 552.3 | 37.5 | 6 | Y | Y |
| 52 | Saladamis | 70-4600 | 75.0 | 5.1 | 5 | Y | U |
| 53 | Sanyam | 70-4700 | 96.6 | 6.6 | 5 | Y | U |
| 54 | Sanskisoot | 70-4800 | 103.3 | 7.0 | 5 | Y | U |
| 55 | Taylor | 77-0000 | 753.2 | 51.2 | 7 | Y | N |
| 56 | Sallysout | | 333.2 | 22.6 | 6 | Y | U |
| 57 | Vile | 70-5200 | 188.0 | 12.8 | 5 | Y | U |
| 58 | Kotsinka | 70-5300 | 312.4 | 21.2 | 5 | Y | U |
| 59 | Damdochax | 78-0000 | 737.4 | 50.1 | 7 | Y | Y |
| 60 | Muskaboo | 79-0000 | 614.9 | 41.8 | 6 | Y | N |
| 61 | Panorama | 70-5600 | 90.6 | 6.2 | 5 | Y | N |
| 62 | Konigus | | 471.7 | 32.0 | 6 | Y | N |
| 63 | Upper Nass | | 735.6 | 50.0 | 6 | Y | Y |
| | | | | | | | |

# APPENDIX C

# LISTING OF KNOWN BARRIERS TO STEELHEAD WITHIN THE NASS DRAINAGE

Appendix C. Listing of known barriers to steelhead within the Nass drainage.

| Watershed | Longitude | Latitude | Height (metres) | Distance (metres) from Stream Mouth |
|---|---|---|---|---|
| Ansedegan | -129.3544 | 55.12854 | 7 | 2008 |
| | -129.355 | 55.12936 | 4 | 1909 |
| | -129.3547 | 55.12891 | 3 | 1963 |
| | -129.3544 | 55.12854 | 6 | 2008 |
| Anudol | -129.5231 | 55.17048 | 5 | 16123 |
| | -129.5223 | 55.16903 | 2 | 15952 |
| | -129.5192 | 55.16482 | 3 | 15432 |
| | -129.5174 | 55.161 | 4 | 14944 |
| | -129.5194 | 55.15826 | 2 | 14576 |
| | -129.5053 | 55.09959 | 2 | 6412 |
| | -129.527 | 55.12362 | 6 | 10089 |
| | -129.5269 | 55.12321 | 3 | 10030 |
| | -129.5202 | 55.12225 | 3 | 9471 |
| Burton | -129.8626 | 54.95412 | 8 | 418 |
| Chambers | -130.0313 | 54.89061 | 8 | 6001 |
| Chemainuk | -129.1398 | 55.28621 | 1 | 9769 |
| | -129.1593 | 55.28764 | 4 | 11354 |
| | -129.1593 | 55.28765 | 3 | 11354 |
| | -129.1398 | 55.2862 | 3 | 9769 |
| Diskangieq | -129.5938 | 55.10128 | 4 | 11203 |
| | -129.5703 | 55.09481 | 3 | 9376 |
| | -129.5712 | 55.09485 | 4 | 9435 |
| | -129.5703 | 55.09481 | 4 | 9376 |
| Ginlulak | -129.4197 | 55.04218 | 8 | 5664 |
| Greenville | -129.6411 | 55.05008 | 5 | 8415 |
| | -129.6404 | 55.03215 | 2 | 6109 |
| | -129.6292 | 55.02614 | 3 | 4807 |
| | -129.6281 | 55.0247 | 2 | 4630 |
| | -129.6411 | 55.05008 | 3 | 8415 |
| | -129.639 | 55.04855 | 8 | 8184 |
| | -129.6333 | 55.0271 | 3 | 5122 |
| | -129.634 | 55.0271 | 2 | 5164 |
| Ishkheenickhh | -129.5636 | 54.899170 2 | 5 | 13863 |
| | -129.5986 | 54.78937 | 2 | 29816 |

| Appendix C (cont.) | | | | |
|---|---|---|---|---|
| Watershed | Longitude | Latitude | Height (metres) | Distance (metres) from Stream Mouth |
| Kincolith | -129.5841 | 55.20763 | 8 | 41292 |
| | -129.5844 | 55.2093 | 6 | 41315 |
| | -129.5875 | 55.20735 | 8 | 40967 |
| | -129.6543 | 55.18825 | 7 | 35657 |
| | -129.6574 | 55.18666 | 5 | 35425 |
| | -129.6886 | 55.175900 1 | 5 | 33602 |
| | -129.6857 | 55.17207 | 3 | 34123 |
| | -129.6851 | 55.17157 | 2 | 34196 |
| | -129.7312 | 55.18048 | 7 | 29757 |
| | -129.7425 | 55.168500 1 | 3 | 27809 |
| | -129.744 | 55.150970 1 | 3 | 25604 |
| | -129.7569 | 55.126640 1 | 5 | 22724 |
| | -129.7643 | 55.127400 1 | 5 | 22132 |
| | -129.7799 | 55.11672 | 4 | 20300 |
| | -129.7818 | 55.11596 | 3 | 20208 |
| | -129.5815 | 55.20805 | 4 | 41447 |
| Ksemamaith | -129.3525 | 55.09492 | 2 | 4957 |
| | -129.3497 | 55.0945 | 2 | 5135 |
| | -129.3496 | 55.09432 | 3 | 5167 |
| | -129.3874 | 55.0935 | 4 | 2086 |
| | -129.3797 | 55.09232 | 2 | 2764 |
| | -129.3769 | 55.09142 | 2 | 2968 |
| Kwiniak | -129.3684 | 55.03439 | 2 | 8152 |
| Kwinyarh | -129.3203 | 55.14156 | 4 | 1717 |
| Shumal | -129.2725 | 55.2646 | 3 | 12859 |
| | -129.2725 | 55.2646 | 5 | 12859 |
| | -129.2743 | 55.26208 | 6 | 12946 |
| | -129.322 | 55.26113 | 3 | 16292 |
| | -129.3242 | 55.26063 | 4 | 16430 |
| Tseax | -129.0323 | 55.1769 | 3 | 9602 |
| | -129.0374 | 55.17947 | 3 | 9112 |
| | -129.0188 | 55.16783 | 5 | 11477 |
| | -128.9792 | 55.13797 | 3 | 15992 |
| | -128.9826 | 55.13786 | 3 | 15773 |

| Appendix C (cont.) | | | | |
|---|---|---|---|---|
| Watershed | Longitude | Latitude | Height (metres) | Distance (metres) from Stream Mouth |
| Welda | -129.8735 | 54.941910 1 | 5 | 990 |
| Gingietl | -129.2912 | 55.193210 1 | 5 | 1272 |
| | -129.2912 | 55.19321 | 8 | 1272 |
| Wilyayaanooth | -129.3783 | 55.16856 | 7 | 902 |
| Cranberry | -128.6003 | 55.5965 | 8 | 25239 |
| | -128.4569 | 55.61805 | 3 | 43832 |
| Kiteen | -128.6496 | 55.23669 | 2 | 44875 |
| Kshadin | -129.0055 | 55.42896 | 2 | 153 |
| | -129.0105 | 55.43233 | 4 | 675 |
| | -129.0147 | 55.4312 | 2 | 983 |
| | -129.0146 | 55.43116 | 2 | 983 |
| | -129.0165 | 55.43246 | 4 | 1384 |
| | -129.0191 | 55.43563 | 4 | 2014 |
| | -129.0184 | 55.43216 | 2 | 1391 |
| | -129.0472 | 55.4402 | 4 | 3884 |
| | -129.0531 | 55.4434 | 6 | 4450 |
| | -129.0554 | 55.44421 | 2 | 4628 |
| | -129.0623 | 55.44654 | 6 | 5174 |
| | -129.0636 | 55.44736 | 2 | 5298 |
| | -129.0636 | 55.44734 | 2 | 5296 |
| Kwinatahl | -129.0928 | 55.3894 | 2 | 8615 |
| | -129.141 | 55.41749 | 2 | 13628 |
| | -129.147 | 55.41988 | 6 | 14167 |
| | -129.1483 | 55.421290 1 | 5 | 14352 |
| Seaskinnish | -129.0257 | 55.2858 | 2 | 4811 |
| | -128.9917 | 55.30999 | 2 | 9026 |
| | -128.9946 | 55.30807 | 8 | 8742 |
| | | | | |

# APPENDIX D

## ACCESSIBLE LENGTH OF STREAM LESS THAN 8% GRADIENT AND FOR THIRD AND FOURTH ORDER OR GREATER WATERSHEDS WITHIN THE NASS WATERSHED

## Appendix D. Accessible stream length by gradient class and stream order for Nass River tributaries.

| | | | | | Accessible Length (m) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Stream Order:: | 3 | 3 | 4 | 4 | 5 | 5 | 6 | 6 | 7 | 7 |
| Gradient (%):: | 0-4 | 4-8 | 0-4 | 4-8 | 0-4 | 4-8 | 0-4 | 4-8 | 0-4 | 4-8 |
| | | | | | | | | | | |
| Winter Populations | | | | | | | | | | |
| | | | | | | | | | | |
| Kincolith | 1400 | 1560 | 27330 | 480 | 0 | 0 | 0 | 0 | 0 | 0 |
| Iknouk | 780 | 650 | 23000 | 1370 | 0 | 0 | 0 | 0 | 0 | 0 |
| Keaszoah | 650 | 120 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Anliyen (Greenville) | 4400 | 1030 | 2480 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Diskangieq | 0 | 0 | 8160 | 800 | 0 | 0 | 0 | 0 | 0 | 0 |
| Anudol | 0 | 0 | 0 | 0 | 6380 | 30 | 0 | 0 | 0 | 0 |
| Inieth | 480 | 280 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cugiladap | 980 | 240 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Wegiladap | 0 | 0 | 770 | 420 | 0 | 0 | 0 | 0 | 0 | 0 |
| Wilyayaanooth | 570 | 200 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Giswatz | 980 | 240 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Gingietl | 610 | 490 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Gish | 5070 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Chemainuk | 4400 | 1000 | 9360 | 290 | 0 | 0 | 0 | 0 | 0 | 0 |
| Burton | 0 | 0 | 0 | 0 | 220 | 60 | 0 | 0 | 0 | 0 |
| Monkley | 1820 | 760 | 3110 | 1900 | 0 | 0 | 0 | 0 | 0 | 0 |
| Chambers | 2950 | 1090 | 5970 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Welda | 4930 | 3090 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Quilgauw | 2640 | 410 | 6980 | 50 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ishkheenickhh | 15430 | 6800 | 19010 | 7610 | 19320 | 3690 | 10410 | 0 | 24290 | 120 |
| Ginlulak | 2260 | 970 | 3580 | 10 | 0 | 0 | 0 | 0 | 0 | 0 |
| Kwiniak (Ksedin) | 7570 | 6000 | 16620 | 3130 | 12420 | 0 | 0 | 0 | 0 | 0 |
| Ksemamaith | 600 | 1440 | 2000 | 1000 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ansedegan | 1310 | 310 | 1410 | 80 | 0 | 0 | 0 | 0 | 0 | 0 |
| Kwinyarh | 1020 | 500 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Zolzap | 2900 | 310 | 1500 | 530 | 4420 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | | | | |
| Total | 63750 | 27590 | 131280 | 17670 | 42760 | 3780 | 10410 | 0 | 24290 | 120 |
| | | | | | | | | | | |
| Sympatric Populations | | | | | | | | | | |
| | | | | | | | | | | |
| Tseax | 3450 | 3550 | 0 | 0 | 15890 | 750 | 130 | 0 | 0 | 0 |
| Seaskinnish | 0 | 0 | 40 | 0 | 8350 | 320 | 0 | 0 | 0 | 0 |
| Gitwinksihlkw Ck | 780 | 290 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | | | | |
| Total | 4230 | 3840 | 40 | 0 | 24240 | 1070 | 130 | 0 | 0 | 0 |

Appendix D. (cont).

| | | | | Accessible Length (m) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Stream Order:: | 3 | 3 | 4 | 4 | 5 | 5 | 6 | 6 | 7 | 7 |
| Gradient (%):: | 0-4 | 4-8 | 0-4 | 4-8 | 0-4 | 4-8 | 0-4 | 4-8 | 0-4 | 4-8 |
| | | | | | | | | | | |
| Summer Populations | | | | | | | | | | |
| | | | | | | | | | | |
| Shumal | 130 | 270 | 14430 | 1530 | 0 | 0 | 0 | 0 | 0 | 0 |
| Kwinamuck | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Kwinatahl | 0 | 0 | 0 | 0 | 0 | 0 | 8380 | 230 | 0 | 0 |
| Kshadin | 0 | 0 | 0 | 0 | 20 | 50 | 0 | 0 | 0 | 0 |
| Tchitin | 1160 | 840 | 0 | 0 | 0 | 0 | 16820 | 170 | 0 | 0 |
| Kinskuch | 20 | 0 | 0 | 0 | 1500 | 0 | 0 | 0 | 0 | 0 |
| Paw | 16410 | 4690 | 13330 | 1540 | 22130 | 3530 | 2180 | 380 | 0 | 0 |
| Brown Bear | 0 | 0 | 300 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Van Dyke Ck | 0 | 0 | 400 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| White | 0 | 0 | 0 | 0 | 29140 | 1140 | 21240 | 0 | 0 | 0 |
| Meziadin | 0 | 0 | 0 | 0 | 0 | 0 | 8120 | 0 | 0 | 0 |
| Cranberry Main | 0 | 0 | 0 | 0 | 0 | 0 | 75600 | 0 | 3600 | 0 |
| Cranberry-Kiteen | 0 | 0 | 0 | 0 | 0 | 0 | 5660 | 200 | 43460 | 0 |
| Bell-Irving below Bowser | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 35680 | 0 |
| Bell-Irving (Bowser to Teigen) | 0 | 0 | 0 | 0 | 0 | 0 | 9140 | 800 | 63200 | 0 |
| Bell-Irving (above Teigen) | 0 | 0 | 0 | 0 | 0 | 0 | 35710 | 0 | 25050 | 0 |
| Bowser | 0 | 0 | 0 | 0 | 2420 | 560 | 29280 | 0 | 4640 | 0 |
| Taft | 0 | 0 | 0 | 0 | 0 | 0 | 23870 | 0 | 0 | 0 |
| Treaty | 0 | 0 | 0 | 0 | 8720 | 790 | 20180 | 0 | 0 | 0 |
| Teigen | 0 | 0 | 0 | 0 | 24380 | 2150 | 19490 | 0 | 0 | 0 |
| Hodder | 0 | 0 | 0 | 0 | 13280 | 3960 | 0 | 0 | 0 | 0 |
| Kwinageese | 0 | 0 | 0 | 0 | 22140 | 4750 | 11950 | 170 | 0 | 0 |
| Saladamis | 0 | 0 | 0 | 0 | 8620 | 2820 | 0 | 0 | 0 | 0 |
| Sanyam | 0 | 0 | 0 | 0 | 260 | 80 | 0 | 0 | 0 | 0 |
| Sanskisoot | 0 | 0 | 0 | 0 | 8740 | 2740 | 0 | 0 | 0 | 0 |
| Taylor | 0 | 0 | 0 | 0 | 21900 | 5930 | 36300 | 0 | 11570 | 0 |
| Sallysout | 0 | 0 | 0 | 0 | 0 | 0 | 1370 | 300 | 0 | 0 |
| Vile | 0 | 0 | 0 | 0 | 19240 | 360 | 0 | 0 | 0 | 0 |
| Kotsinka | 0 | 0 | 0 | 0 | 10390 | 110 | 0 | 0 | 0 | 0 |
| Damdochax | 0 | 0 | 0 | 0 | 25840 | 860 | 18380 | 0 | 12160 | 0 |
| Muskaboo | 0 | 0 | 0 | 0 | 15030 | 550 | 44950 | 0 | 0 | 0 |
| Panorama | 0 | 0 | 0 | 0 | 10040 | 6020 | 0 | 0 | 0 | 0 |
| Konigus | 0 | 0 | 0 | 0 | 0 | 0 | 690 | 0 | 0 | 0 |
| Upper Nass | 0 | 0 | 0 | 0 | 27290 | 8420 | 33900 | 0 | 0 | 0 |
| | | | | | | | | | | |
| Total | 17720 | 5800 | 28460 | 3070 | 271080 | 44820 | 423210 | 2250 | 199360 | 0 |
| | | | | | | | | | | |

# APPENDIX E

# PREDICTED WIDTH, BY STREAM ORDER FOR NASS WATERSHEDS

## Appendix E. Predicted width, by stream order, for Nass watersheds.

| | Watershed | Actual W Width (m) | Pred. Width (Main Order) | Pred. Width (Main Order-1) | MAD (Main Order-1) | Pred. Width (Main Order-2) | MAD (Main Order-2) | Pred. Width (Main Order-3) | MAD (Main Order-3) | Pred. Width (Main Order-4) | MAD (Main Order-4) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | |
| Winter Populations | | | | | | | | | | | |
| | | | | | | | | | | | |
| 1 | Kincolith | 28.0 | 18.9 | 9.4 | 2.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 2 | Iknouk | 19.1 | 15.1 | 7.5 | 1.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 3 | Keazoah | 5.2 | 4.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 4 | Anliyen (Greenville) | 11.2 | 8.9 | 4.4 | 0.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 5 | Diskangieq | 13.5 | 8.4 | 4.2 | 0.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 | Anudol | 16.6 | 15.9 | 7.9 | 2.1 | 4.0 | 0.6 | 0.0 | 0.0 | 0.0 | 0.0 |
| 7 | Inieth | 3.4 | 4.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 8 | Cugiladap | 6.5 | 3.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 9 | Wegiladap | 10.3 | 5.6 | 2.8 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 10 | Wilyayaanooth | 6.1 | 4.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 11 | Giswatz | 9.6 | 5.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 12 | Gingietl | 11.8 | 5.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 13 | Gish | 3.2 | 5.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 14 | Chemainuk | | 14.9 | 7.5 | 1.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 15 | Burton | 19.3 | 19.4 | 9.7 | 3.0 | 4.9 | 0.8 | 0.0 | 0.0 | 0.0 | 0.0 |
| 16 | Monkley | 17.7 | 11.6 | 5.8 | 1.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 17 | Chambers | 30.0 | 18.8 | 9.4 | 2.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 18 | Welda | | 10.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 19 | Quilgauw | 11.1 | 8.4 | 4.2 | 0.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 20 | Ishkheenickhh | | 35.6 | 17.8 | 9.7 | 8.9 | 2.6 | 4.4 | 0.7 | 2.2 | 0.2 |
| 21 | Ginlulak | 36.8 | 9.1 | 4.6 | 0.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 22 | Kwiniak (Ksedin) | 29.8 | 22.8 | 11.4 | 4.2 | 5.7 | 1.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| 23 | Ksemamaith | 10.7 | 11.6 | 5.8 | 1.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 24 | Ansedegan | 7.5 | 7.4 | 3.7 | 0.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 25 | Kwinyarh | | 5.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 26 | Zolzap | | 7.8 | 3.9 | 0.5 | 2.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | | | | | | | | | | |
| Sympatric Populations | | | | | | | | | | | |
| | | | | | | | | | | | |
| 27 | Tseax | | 36.5 | 18.3 | 10.2 | 9.1 | 2.7 | 4.6 | 0.7 | 0.0 | 0.0 |
| 28 | Seaskinnish | 10.0 | 16.7 | 8.4 | 2.3 | 4.2 | 0.6 | 0.0 | 0.0 | 0.0 | 0.0 |
| 29 | Gitwinksihlkw Ck | 5.0 | 3.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | | | | | | | | | | |
| Summer Populations | | | | | | | | | | | |
| | | | | | | | | | | | |
| 30 | Shumal | | 11.5 | 5.7 | 1.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 31 | Kwinamuck | 8.1 | 8.9 | 4.5 | 0.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

Appendix E (cont).

| | Watershed | Actual W Width (m) | Pred. Width (Main Order) | Pred. Width (Main Order-1) | MAD (Main Order-1) | Pred. Width (Main Order-2) | MAD (Main Order-2) | Pred. Width (Main Order-3) | MAD (Main Order-3) | Pred. Width (Main Order-4) | MAD (Main Order-4) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 32 | Kwinatahl | 12.2 | 20.7 | 10.3 | 3.4 | 5.2 | 0.9 | 2.6 | 0.2 | 0.0 | 0.0 |
| 33 | Kshadin | 5.9 | 11.8 | 5.9 | 1.2 | 3.0 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 |
| 34 | Tchitin | 12.9 | 18.5 | 9.3 | 2.8 | 4.6 | 0.7 | 2.3 | 0.2 | 0.0 | 0.0 |
| 35 | Kinskuch | 24.2 | 26.1 | 13.0 | 5.3 | 6.5 | 1.4 | 0.0 | 0.0 | 0.0 | 0.0 |
| 36 | Paw | | 15.5 | 7.8 | 2.0 | 3.9 | 0.5 | 1.9 | 0.1 | 0.0 | 0.0 |
| 37 | Brown Bear | | 17.7 | 8.9 | 2.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 38 | Van Dyke Ck | | 6.6 | 3.3 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 39 | White | | 37.4 | 18.7 | 10.7 | 9.4 | 2.8 | 4.7 | 0.8 | 0.0 | 0.0 |
| 40 | Meziadin | | 32.3 | 16.2 | 8.1 | 8.1 | 2.1 | 4.0 | 0.6 | 0.0 | 0.0 |
| 41 | Cranberry Main | 50.0 | 37.9 | 18.9 | 10.9 | 9.5 | 2.9 | 4.7 | 0.8 | 2.4 | 0.2 |
| 42 | Cranberry-Kiteen | | 36.0 | 18.0 | 9.9 | 9.0 | 2.6 | 4.5 | 0.7 | 2.3 | 0.2 |
| 43 | Bell-Irving below Bowser | 70.0 | 88.6 | 44.3 | 55.3 | 22.2 | 14.7 | 11.1 | 3.9 | 5.5 | 1.0 |
| 44 | Bell-Irving (Bowser to Teigen) | 50.3 | 84.3 | 42.1 | 50.2 | 21.1 | 13.4 | 10.5 | 3.6 | 5.3 | 0.9 |
| 45 | Bell-Irving (above Teigen) | | 44.0 | 22.0 | 14.5 | 11.0 | 3.9 | 5.5 | 1.0 | 2.7 | 0.3 |
| 46 | Bowser | | 43.3 | 21.7 | 14.1 | 10.8 | 3.8 | 5.4 | 1.0 | 2.7 | 0.3 |
| 47 | Taft | 30.0 | 26.0 | 13.0 | 5.3 | 6.5 | 1.4 | 3.2 | 0.4 | 0.0 | 0.0 |
| 48 | Treaty | 29.3 | 24.6 | 12.3 | 4.8 | 6.1 | 1.3 | 3.1 | 0.3 | 0.0 | 0.0 |
| 49 | Teigen | 20.0 | 22.2 | 11.1 | 3.9 | 5.6 | 1.0 | 2.8 | 0.3 | 0.0 | 0.0 |
| 50 | Hodder | 12.2 | 9.7 | 4.9 | 0.8 | 2.4 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| 51 | Kwinageese | 21.0 | 28.1 | 14.1 | 6.2 | 7.0 | 1.6 | 3.5 | 0.4 | 0.0 | 0.0 |
| 52 | Saladamis | | 9.9 | 5.0 | 0.8 | 2.5 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| 53 | Sanyam | | 11.3 | 5.7 | 1.1 | 2.8 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 |
| 54 | Sanskisoot | | 11.7 | 5.9 | 1.2 | 2.9 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 |
| 55 | Taylor | | 33.1 | 16.5 | 8.4 | 8.3 | 2.2 | 4.1 | 0.6 | 2.1 | 0.2 |
| 56 | Sallysout | | 21.6 | 10.8 | 3.7 | 5.4 | 1.0 | 2.7 | 0.3 | 0.0 | 0.0 |
| 57 | Vile | | 16.0 | 8.0 | 2.1 | 4.0 | 0.6 | 0.0 | 0.0 | 0.0 | 0.0 |
| 58 | Kotsinka | | 20.9 | 10.4 | 3.5 | 5.2 | 0.9 | 0.0 | 0.0 | 0.0 | 0.0 |
| 59 | Damdochax | 34.9 | 32.7 | 16.4 | 8.3 | 8.2 | 2.2 | 4.1 | 0.6 | 2.0 | 0.2 |
| 60 | Muskaboo | | 29.8 | 14.9 | 6.9 | 7.4 | 1.8 | 3.7 | 0.5 | 0.0 | 0.0 |
| 61 | Panorama | | 10.9 | 5.5 | 1.0 | 2.7 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 |
| 62 | Konigus | | 25.9 | 13.0 | 5.3 | 6.5 | 1.4 | 3.2 | 0.4 | 0.0 | 0.0 |
| 63 | Upper Nass | | 32.7 | 16.3 | 8.2 | 8.2 | 2.2 | 4.1 | 0.6 | 0.0 | 0.0 |

# APPENDIX F

# THEORETICAL USEABLE WIDTH AND USEABLE AREA FOR NASS WATERSHEDS

Appendix F. Theoretical useable width and useable area for Nass watersheds.

| | Watershed | Low Flow Stage | Theor. % Us. Width (m) | | | | | Theoretical Useable Width (m) | | | | | Theoretical Useable Area (m$^2$) | Theoretical Useable Area (m$^2$) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | %MAD | Main Order | Main Ord-1 | Main Ord-2 | Main Ord-3 | Main Ord-4 | 3rd ord | 4th ord | 5th Ord | 6th Ord | 7th Ord | >3rd order | >4th order | | |
| Winter Populations | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| 1 | Kincolith | 110 | 18% | 25% | 0% | 0% | 0% | 2.3 | 3.4 | 0.0 | 0.0 | 0.0 | 100835 | 93938 | | |
| 2 | Iknouk | 110 | 20% | 27% | 0% | 0% | 0% | 2.0 | 3.0 | 0.0 | 0.0 | 0.0 | 76472 | 73570 | | |
| 3 | Keazoah | 110 | 31% | 0% | 0% | 0% | 0% | 1.4 | 0.0 | 0.0 | 0.0 | 0.0 | 1099 | 0 | | |
| 4 | Anliyen (Greenville) | 110 | 25% | 31% | 0% | 0% | 0% | 1.4 | 2.2 | 0.0 | 0.0 | 0.0 | 13124 | 5570 | | |
| 5 | Diskangieq | 110 | 26% | 32% | 0% | 0% | 0% | 1.3 | 2.2 | 0.0 | 0.0 | 0.0 | 19417 | 19417 | | |
| 6 | Anudol | 110 | 20% | 26% | 32% | 0% | 0% | 1.3 | 2.1 | 3.1 | 0.0 | 0.0 | 19857 | 19857 | | |
| 7 | Inieth | 110 | 32% | 0% | 0% | 0% | 0% | 1.3 | 0.0 | 0.0 | 0.0 | 0.0 | 1002 | 0 | | |
| 8 | Cugiladap | 110 | 33% | 0% | 0% | 0% | 0% | 1.1 | 0.0 | 0.0 | 0.0 | 0.0 | 1337 | 0 | | |
| 9 | Wegiladap | 110 | 30% | 34% | 0% | 0% | 0% | 1.0 | 1.7 | 0.0 | 0.0 | 0.0 | 1976 | 1976 | | |
| 10 | Wilyayaanooth | 110 | 31% | 0% | 0% | 0% | 0% | 1.5 | 0.0 | 0.0 | 0.0 | 0.0 | 1142 | 0 | | |
| 11 | Giswatz | 110 | 31% | 0% | 0% | 0% | 0% | 1.5 | 0.0 | 0.0 | 0.0 | 0.0 | 1846 | 0 | | |
| 12 | Gingietl | 110 | 30% | 0% | 0% | 0% | 0% | 1.6 | 0.0 | 0.0 | 0.0 | 0.0 | 1728 | 0 | | |
| 13 | Gish | 110 | 30% | 0% | 0% | 0% | 0% | 1.6 | 0.0 | 0.0 | 0.0 | 0.0 | 8125 | 0 | | |
| 14 | Chemainuk | 110 | 20% | 27% | 0% | 0% | 0% | 2.0 | 3.0 | 0.0 | 0.0 | 0.0 | 39851 | 28969 | | |
| 15 | Burton | 110 | 18% | 24% | 31% | 0% | 0% | 1.5 | 2.4 | 3.4 | 0.0 | 0.0 | 959 | 959 | | |
| 16 | Monkley | 110 | 23% | 29% | 0% | 0% | 0% | 1.7 | 2.6 | 0.0 | 0.0 | 0.0 | 17485 | 13114 | | |
| 17 | Chambers | 110 | 18% | 25% | 0% | 0% | 0% | 2.3 | 3.4 | 0.0 | 0.0 | 0.0 | 29486 | 20107 | | |
| 18 | Welda | 110 | 23% | 0% | 0% | 0% | 0% | 2.5 | 0.0 | 0.0 | 0.0 | 0.0 | 20203 | 0 | | |
| 19 | Quilgauw | 110 | 26% | 32% | 0% | 0% | 0% | 1.3 | 2.2 | 0.0 | 0.0 | 0.0 | 19385 | 15307 | | |
| 20 | Ishkheenickhh | 110 | 13% | 18% | 25% | 31% | 35% | 0.8 | 1.4 | 2.2 | 3.3 | 4.5 | 251107 | 233979 | | |
| 21 | Ginlulak | 110 | 25% | 31% | 0% | 0% | 0% | 1.4 | 2.3 | 0.0 | 0.0 | 0.0 | 12796 | 8202 | | |
| 22 | Kwiniak (Ksedin) | 110 | 16% | 23% | 29% | 0% | 0% | 1.7 | 2.6 | 3.7 | 0.0 | 0.0 | 120170 | 97380 | | |
| 23 | Ksemamaith | 110 | 23% | 29% | 0% | 0% | 0% | 1.7 | 2.6 | 0.0 | 0.0 | 0.0 | 11356 | 7883 | | |
| 24 | Ansedegan | 110 | 27% | | | | | 33% | | | | | 0% | 0% | 0% | 1.2 |
| 25 | Kwinyarh | 110 | 30% | 0% | 0% | 0% | 0% | 1.6 | 0.0 | 0.0 | 0.0 | 0.0 | 2444 | 0 | | |
| 26 | Zolzap | 110 | 27% | 32% | 35% | 0% | 0% | 0.7 | 1.3 | 2.1 | 0.0 | 0.0 | 13930 | 11734 | | |
| | | | | | | | | | | | | | | | | |
| | Total | | | | | | | | | | | | 792049 | 654940 | | |

Appendix F (cont).

| | Watershed | Low Flow Stage | Theor. % Us. Width (m) | | | | | Theoretical Useable Width (m) | | | | | Theoretical Useable Area ($m^2$) | Theoretical Useable Area ($m^2$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | %MAD | Main Order | Main Ord-1 | Main Ord-2 | Main Ord-3 | Main Ord-4 | 3rd ord | 4th ord | 5th Ord | 6th Ord | 7th Ord | >3rd order | >4th order |
| | | | | | | | | | | | | | | |
| Sympatric Populations | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| 27 | Tseax | 110 | 13% | 18% | 25% | 31% | 0% | 1.4 | 2.3 | 3.3 | 4.6 | 0.0 | 65884 | 55934 |
| 28 | Seaskinnish | 110 | 19% | 26% | 32% | 0% | 0% | 1.3 | 2.2 | 3.2 | 0.0 | 0.0 | 27678 | 27678 |
| 29 | Gitwinksihlkw Ck | 110 | 33% | 0% | 0% | 0% | 0% | 1.2 | 0.0 | 0.0 | 0.0 | 0.0 | 1238 | 0 |
| | | | | | | | | | | | | | | |
| | Total | | | | | | | | | | | | 94800 | 83612 |
| | | | | | | | | | | | | | | |
| Summer Populations | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| 30 | Shumal | 110 | 23% | 29% | 0% | 0% | 0% | 1.7 | 2.6 | 0.0 | 0.0 | 0.0 | 42303 | 41629 |
| 31 | Kwinamuck | 110 | 25% | 31% | 0% | 0% | 0% | 1.4 | 2.3 | 0.0 | 0.0 | 0.0 | 0 | 0 |
| 32 | Kwinatahl | 110 | 17% | 24% | 30% | 34% | 0% | 0.9 | 1.6 | 2.5 | 3.5 | 0.0 | 30401 | 30401 |
| 33 | Kshadin | 110 | 22% | 29% | 34% | 0% | 0% | 1.0 | 1.7 | 2.6 | 0.0 | 0.0 | 185 | 185 |
| 34 | Tchitin | 110 | 18% | 25% | 31% | 35% | 0% | 0.8 | 1.4 | 2.3 | 3.3 | 0.0 | 58459 | 56861 |
| 35 | Kinskuch | 110 | 15% | 21% | 28% | 0% | 0% | 1.8 | 2.8 | 3.9 | 0.0 | 0.0 | 5949 | 5912 |
| 36 | Paw | 110 | 20% | 27% | 32% | 35% | 0% | 0.7 | 1.2 | 2.1 | 3.1 | 0.0 | 93686 | 79378 |
| 37 | Brown Bear | 110 | 18% | 25% | 0% | 0% | 0% | 2.2 | 3.3 | 0.0 | 0.0 | 0.0 | 982 | 982 |
| 38 | Van Dyke Ck | 110 | 28% | 33% | 0% | 0% | 0% | 1.1 | 1.8 | 0.0 | 0.0 | 0.0 | 740 | 740 |
| 39 | White | 110 | 12% | 18% | 25% | 31% | 0% | 1.4 | 2.3 | 3.4 | 4.6 | 0.0 | 200702 | 200702 |
| 40 | Meziadin | 110 | 13% | 19% | 26% | 32% | 0% | 1.3 | 2.1 | 3.1 | 4.4 | 0.0 | 35325 | 35325 |
| 41 | Cranberry Main | 110 | 12% | 18% | 25% | 31% | 34% | 0.8 | 1.5 | 2.3 | 3.4 | 4.7 | 272804 | 272804 |
| 42 | Cranberry-Kiteen | 110 | 13% | 18% | 25% | 31% | 35% | 0.8 | 1.4 | 2.3 | 3.3 | 4.6 | 217905 | 217905 |
| 43 | Bell-Irving below Bowser | 110 | 8% | 11% | 16% | 23% | 30% | 1.6 | 2.6 | 3.7 | 5.0 | 6.7 | 239516 | 239516 |
| 44 | Bell-Irving (Bowser to Teigen) | 110 | 8% | 12% | 17% | 24% | 30% | 1.6 | 2.5 | 3.6 | 4.9 | 6.6 | 464332 | 464332 |
| 45 | Bell-Irving (above Teigen) | 110 | 11% | 17% | 23% | 30% | 34% | 0.9 | 1.6 | 2.5 | 3.6 | 5.0 | 254965 | 254965 |

Appendix F (cont).

| | Watershed | Low Flow Stage | Theor. % Us. Width (m) | | | | | Theoretical Useable Width (m) | | | | | Theoretical Useable Area ($m^2$) | Theoretical Useable Area ($m^2$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | %MAD | Main Order | Main Ord-1 | Main Ord-2 | Main Ord-3 | Main Ord-4 | 3rd ord | 4th ord | 5th Ord | 6th Ord | 7th Ord | >3rd order | >4th order |
| | | | | | | | | | | | | | | |
| 46 | Bowser | 110 | 11% | 17% | 23% | 30% | 34% | 0.9 | 1.6 | 2.5 | 3.6 | 5.0 | 136404 | 136404 |
| 47 | Taft | 110 | 15% | 21% | 28% | 33% | 0% | 1.1 | 1.8 | 2.8 | 3.9 | 0.0 | 93940 | 93940 |
| 48 | Treaty | 110 | 16% | 22% | 29% | 33% | 0% | 1.0 | 1.8 | 2.7 | 3.8 | 0.0 | 103184 | 103184 |
| 49 | Teigen | 110 | 16% | 23% | 30% | 34% | 0% | 0.9 | 1.6 | 2.6 | 3.7 | 0.0 | 139203 | 139203 |
| 50 | Hodder | 110 | 24% | 31% | 34% | 0% | 0% | 0.8 | 1.5 | 2.4 | 0.0 | 0.0 | 40860 | 40860 |
| 51 | Kwinageese | 110 | 15% | 21% | 28% | 33% | 0% | 1.2 | 1.9 | 2.9 | 4.1 | 0.0 | 127795 | 127795 |
| 52 | Saladamis | 110 | 24% | 31% | 34% | 0% | 0% | 0.8 | 1.5 | 2.4 | 0.0 | 0.0 | 27420 | 27420 |
| 53 | Sanyam | 110 | 23% | 29% | 34% | 0% | 0% | 1.0 | 1.7 | 2.6 | 0.0 | 0.0 | 879 | 879 |
| 54 | Sanskisoot | 110 | 23% | 29% | 34% | 0% | 0% | 1.0 | 1.7 | 2.6 | 0.0 | 0.0 | 30262 | 30262 |
| 55 | Taylor | 110 | 13% | 19% | 26% | 32% | 35% | 0.7 | 1.3 | 2.2 | 3.2 | 4.4 | 225666 | 225666 |
| 56 | Sallysout | 110 | 17% | 23% | 30% | 34% | 0% | 0.9 | 1.6 | 2.5 | 3.6 | 0.0 | 6024 | 6024 |
| 57 | Vile | 110 | 19% | 26% | 32% | 0% | 0% | 1.3 | 2.1 | 3.1 | 0.0 | 0.0 | 60991 | 60991 |
| 58 | Kotsinka | 110 | 17% | 24% | 30% | 0% | 0% | 1.6 | 2.5 | 3.5 | 0.0 | 0.0 | 37265 | 37265 |
| 59 | Damdochax | 110 | 13% | 19% | 26% | 32% | 35% | 0.7 | 1.3 | 2.1 | 3.1 | 4.4 | 168110 | 168110 |
| 60 | Muskaboo | 110 | 14% | 20% | 27% | 32% | 0% | 1.2 | 2.0 | 3.0 | 4.2 | 0.0 | 235092 | 235092 |
| 61 | Panorama | 110 | 23% | 30% | 34% | 0% | 0% | 0.9 | 1.6 | 2.5 | 0.0 | 0.0 | 40742 | 40742 |
| 62 | Konigus | 110 | 15% | 22% | 28% | 33% | 0% | 1.1 | 1.8 | 2.8 | 3.9 | 0.0 | 2712 | 2712 |
| 63 | Upper Nass | 110 | 13% | 19% | 26% | 32% | 0% | 1.3 | 2.1 | 3.1 | 4.4 | 0.0 | 260604 | 260604 |
| | Total | | | | | | | | | | | | 3655407 | 3638790 |

# APPENDIX G

# TABLE OF PRODUCTIVITY ADJUSTMENT FACTORS FOR MODELS 5 AND 6 USING METHODS OF TAUTZ ET AL (1992)

Appendix G. Table of adjustment factors to account for productivity differences between Keogh River and Nass tribuitaries (as per Tautz et al. 1992).

| | Watershed | Area (km$^2$) | Stream Order | Water Yield (m$^3$/s/km$^2$) | Specific Conductance | Alkalinity (mg/l) | Alkalinity (mg/l) | Alkalinity (mg/l) | Alkalinity (mg/l) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |
| Winter Populations | | | | | | | | | |
| | | | | | | | | | |
| 1 | Kincolith | 225.9 | 4 | 0.048 | 20 | 39.8 | 21.0 | 6.1 | 39.8 |
| 2 | Iknouk | 112.4 | 4 | 0.063 | 20 | 28 | 18.1 | 6.1 | 28.0 |
| 3 | Keazoah | 11.5 | 3 | 0.063 | 20 | 38 | 18.1 | 6.1 | 38.0 |
| 4 | Anliyen (Greenville) | 40.7 | 4 | 0.063 | | 13 | 18.1 | | 13.0 |
| 5 | Diskangieq | 36.4 | 4 | 0.063 | | 24 | 18.1 | | 24.0 |
| 6 | Anudol | 123.7 | 5 | 0.063 | | | 18.1 | | 18.1 |
| 7 | Inieth | 9.5 | 3 | 0.063 | | | 18.1 | | 18.1 |
| 8 | Cugiladap | 6.2 | 3 | 0.063 | | | 18.1 | | 18.1 |
| 9 | Wegiladap | 17.0 | 4 | 0.063 | | | 18.1 | | 18.1 |
| 10 | Wilyayaanooth | 12.7 | 3 | 0.063 | | | 18.1 | | 18.1 |
| 11 | Giswatz | 13.3 | 3 | 0.063 | | | 18.1 | | 18.1 |
| 12 | Gingietl | 14.7 | 3 | 0.063 | | | 18.1 | | 18.1 |
| 13 | Gish | 14.7 | 3 | 0.063 | 130 | | 18.1 | 52.4 | 60.8 |
| 14 | Chemainuk | 58.1 | 4 | 0.119 | 100 | | 12.8 | 39.8 | 47.0 |
| 15 | Burton | 96.0 | 5 | 0.119 | 23 | 25 | 12.8 | 7.4 | 25.0 |
| 16 | Monkley | 35.7 | 4 | 0.119 | 32 | 35 | 12.8 | 11.2 | 35.0 |
| 17 | Chambers | 89.9 | 4 | 0.119 | | 20 | 12.8 | | 20.0 |
| 18 | Welda | 31.3 | 3 | 0.119 | | 22 | 12.8 | | 22.0 |
| 19 | Quilgauw | 37.0 | 4 | 0.063 | | | 18.1 | | 18.1 |
| 20 | Ishkheenickhh | 579.4 | 7 | 0.063 | | | 18.1 | | 18.1 |
| 21 | Ginlulak | 43.3 | 4 | 0.063 | | 31 | 18.1 | | 31.0 |
| 22 | Kwiniak (Ksedin) | 248.1 | 5 | 0.063 | 60 | 30 | 18.1 | 22.8 | 30.0 |
| 23 | Ksemamaith | 68.4 | 4 | 0.063 | 100 | 38 | 18.1 | 39.8 | 38.0 |
| 24 | Ansedegan | 28.5 | 4 | 0.063 | 120 | 38 | 18.1 | 48.2 | 38.0 |
| 25 | Kwinyarh | 15.6 | 3 | 0.063 | 80 | 21 | 18.1 | 31.4 | 21.0 |
| 26 | Zolzap | 32.0 | 5 | 0.063 | | 27 | 18.1 | | 27.0 |
| | | | | | | | | | |

Appendix G (cont).

| | Watershed | Area (km$^2$) | Stream Order | Water Yield (m$^3$/s/km$^2$) | Specific Conductance | Alkalinity (mg/l) | Alkalinity (mg/l) | Alkalinity (mg/l) | Alkalinity (mg/l) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |
| Sympatric Populations | | | | | | | | | |
| | | | | | | | | | |
| 27 | Tseax | 608.3 | 6 | 0.063 | 68 | 34.0 | 18.1 | 26.3 | 34.0 |
| 28 | Seaskinnish | 204.6 | 5 | 0.063 | 88 | 104.0 | 18.1 | 34.7 | 104.0 |
| 29 | Gitwinksihlkw Ck | 7.0 | 3 | 0.063 | | | 18.1 | | 18.1 |
| | | | | | | | | | |
| Summer Populations | | | | | | | | | |
| | | | | | | | | | |
| 30 | Shumal | 99.6 | 4 | 0.063 | | | 18.1 | | 18.1 |
| 31 | Kwinamuck | 61.5 | 4 | 0.063 | | | 18.1 | | 18.1 |
| 32 | Kwinatahl | 306.1 | 6 | 0.063 | 73 | 24.3 | 18.1 | 28.4 | 24.3 |
| 33 | Kshadin | 105.1 | 5 | 0.063 | | | 18.1 | | 18.1 |
| 34 | Tchitin | 248.2 | 6 | 0.068 | | 46.7 | 17.4 | | 46.7 |
| 35 | Kinskuch | 476.9 | 5 | 0.068 | | | 17.4 | | 17.4 |
| 36 | Paw | 176.7 | 6 | 0.068 | | 23.6 | 17.4 | | 23.6 |
| 37 | Brown Bear | 227.7 | 4 | 0.068 | | | 17.4 | | 17.4 |
| 38 | Van Dyke Ck | 34.1 | 4 | 0.068 | | | 17.4 | | 17.4 |
| 39 | White | 954.0 | 6 | 0.068 | 77 | 32.8 | 17.4 | 30.2 | 32.8 |
| 40 | Meziadin | 719.3 | 6 | 0.068 | 68 | 35.0 | 17.4 | 26.3 | 35.0 |
| 41 | Cranberry Main | 974.8 | 7 | 0.042 | 160 | 83.0 | 22.5 | 65.2 | 83.0 |
| 42 | Cranberry-Kiteen | 885.5 | 7 | 0.042 | 149 | 62.5 | 22.5 | 60.3 | 62.5 |
| 43 | Bell-Irving below Bowser | 4954.0 | 7 | 0.068 | | 64.0 | 17.4 | | 64.0 |
| 44 | Bell-Irving (Bowser to Teigen) | 4498.0 | 7 | 0.068 | 137 | 64.0 | 17.4 | 55.4 | 64.0 |
| 45 | Bell-Irving (above Teigen) | 1295.8 | 7 | 0.068 | | 64.0 | 17.4 | | 64.0 |
| 46 | Bowser | 1262.0 | 7 | 0.068 | 68 | 44.0 | 17.4 | 26.5 | 44.0 |
| 47 | Taft | 474.0 | 6 | 0.068 | | | 17.4 | | 17.4 |
| 48 | Treaty | 427.1 | 6 | 0.068 | | 54.0 | 17.4 | | 54.0 |
| 49 | Teigen | 351.7 | 6 | 0.068 | 130 | 57.0 | 17.4 | 52.4 | 57.0 |

| Appendix G (cont). | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Watershed | Area (km$^2$) | Stream Order | Water Yield (m$^3$/s/km$^2$) | Specific Conductance | Alkalinity (mg/l) | Alkalinity (mg/l) | Alkalinity (mg/l) | Alkalinity (mg/l) |
| | | | | | | | | | |
| 50 | Hodder | 72.3 | 5 | 0.068 | | 62.0 | 17.4 | | 62.0 |
| 51 | Kwinageese | 552.3 | 6 | 0.068 | 39 | 23.1 | 17.4 | 14.2 | 23.1 |
| 52 | Saladamis | 75.0 | 5 | 0.068 | | | 17.4 | | 17.4 |
| 53 | Sanyam | 96.6 | 5 | 0.068 | | | 17.4 | | 17.4 |
| 54 | Sanskisoot | 103.3 | 5 | 0.068 | | | 17.4 | | 17.4 |
| 55 | Taylor | 753.2 | 7 | 0.068 | | 33.3 | 17.4 | | 33.3 |
| 56 | Sallysout | 333.2 | 6 | 0.068 | | | 17.4 | | 17.4 |
| 57 | Vile | 188.0 | 5 | 0.068 | | | 17.4 | | 17.4 |
| 58 | Kotsinka | 312.4 | 5 | 0.068 | | | 17.4 | | 17.4 |
| 59 | Damdochax | 737.4 | 7 | 0.068 | | 43.3 | 17.4 | | 43.3 |
| 60 | Muskaboo | 614.9 | 6 | 0.068 | | 42.8 | 17.4 | | 42.8 |
| 61 | Panorama | 90.6 | 5 | 0.068 | | 54.4 | 17.4 | | 54.4 |
| 62 | Konigus | 471.7 | 6 | 0.068 | | 53.0 | 17.4 | | 53.0 |
| 63 | Upper Nass | 735.6 | 6 | 0.068 | | 51.7 | 17.4 | | 51.7 |
| | | | | | | | | | |
| | Total | | | | | | | | |

[1] Specific conductance as measured in the field

[2] Alkalinity as measured in the field (sources are WLAP and Nisga’a Fisheries)

[3] Alkalinity as predicted from water yield, equation 8

[4] Alkalinity as predicted from conductivity, equation 7

[5] Alkalinity value used to predict standing crop of late summer fry, actual data used when available

# APPENDIX H

# SMOLT PRODUCTIVITY ESTIMATES USING SIX DIFFERENT MODELS FOR NASS RIVER STEELHEAD

Appendix H. Comparison of 6 different model predictions of maximum smolt production for Nass River tributaries. (Model uses stream orders of 4 or larger depending on tributary).

| | Watershed | 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 Six Estimates | SE of Six Estimates |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |
| Winter Populations | | | | | | | | | |
| | | | | | | | | | |
| 1 | Kincolith | 8343 | 5448 | 5562 | 3100 | 9926 | 6482 | 6477 | 2395 |
| 2 | Iknouk | 7311 | 4267 | 4874 | 2428 | 7660 | 4471 | 5168 | 1985 |
| 3 | Keazoah | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | Anliyen (Greenville) | 744 | 323 | 496 | 184 | 531 | 231 | 418 | 212 |
| 5 | Diskangieq | 2688 | 1126 | 1792 | 641 | 2607 | 1092 | 1658 | 851 |
| 6 | Anudol | 1923 | 1152 | 1282 | 655 | 1621 | 971 | 1267 | 454 |
| 7 | Inieth | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | Cugiladap | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | Wegiladap | 357 | 115 | 238 | 65 | 301 | 97 | 195 | 120 |
| 10 | Wilyayaanooth | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | Giswatz | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | Gingietl | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 13 | Gish | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 14 | Chemainuk | 2895 | 1680 | 1930 | 956 | 3616 | 2098 | 2196 | 937 |
| 15 | Burton | 84 | 56 | 56 | 32 | 83 | 55 | 61 | 20 |
| 16 | Monkley | 1503 | 761 | 1002 | 433 | 1761 | 891 | 1058 | 490 |
| 17 | Chambers | 1791 | 1166 | 1194 | 664 | 1795 | 1169 | 1296 | 433 |
| 18 | Welda | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 19 | Quilgauw | 2109 | 888 | 1406 | 505 | 1777 | 748 | 1239 | 629 |
| 20 | Ishkheenickhh | 25335 | 13571 | 16890 | 7721 | 22374 | 11985 | 16313 | 6611 |
| 21 | Ginlulak | 1077 | 476 | 718 | 271 | 1187 | 524 | 709 | 359 |
| 22 | Kwiniak (Ksedin) | 9651 | 5648 | 6434 | 3214 | 10008 | 5857 | 6802 | 2594 |
| 23 | Ksemamaith | 900 | 457 | 600 | 260 | 1098 | 558 | 646 | 305 |
| 24 | Ansedegan | 447 | 173 | 298 | 98 | 546 | 211 | 295 | 171 |
| 25 | Kwinyarh | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 26 | Zolzap | 1935 | 681 | 1290 | 387 | 1991 | 700 | 1164 | 685 |
| | | | | | | | | | |
| | Total (all systems) | 69093 | 37987 | 46062 | 21613 | 68880 | 38139 | 46962 | 19249 |
| | Total (confirmed) | 55266 | 31238 | 36844 | 17774 | 54851 | 31221 | 37866 | 15007 |
| | | | | | | | | | |
| Sympatric Populations | | | | | | | | | |
| | | | | | | | | | |
| 27 | Tseax | 5031 | 3244 | 3354 | 1846 | 5183 | 3342 | 3667 | 1254 |
| 28 | Seaskinnish | 2613 | 1605 | 1742 | 913 | 4708 | 2892 | 2412 | 1333 |
| 29 | Gitwinksihlkw Ck | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | | | |
| | Total (all systems) | 7644 | 4849 | 5096 | 2759 | 9891 | 6235 | 6079 | 2587 |
| | Total (confirmed) | 7644 | 4849 | 5096 | 2759 | 9891 | 6235 | 6079 | 2587 |
| | | | | | | | | | |

Appendix H (cont).

| | Watershed | 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 Six Estimates | SE of Six Estimates |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |
| Summer Populations | | | | | | | | | |
| | | | | | | | | | |
| 30 | Shumal | 4788 | 2414 | 3192 | 1374 | 3937 | 1985 | 2948 | 1274 |
| 31 | Kwinamuck | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 32 | Kwinatahl | 2583 | 1763 | 1722 | 1003 | 2460 | 1679 | 1868 | 579 |
| 33 | Kshadin | 21 | 11 | 14 | 6 | 17 | 9 | 13 | 6 |
| 34 | Tchitin | 5097 | 3298 | 3398 | 1876 | 5998 | 3881 | 3925 | 1452 |
| 35 | Kinskuch | 450 | 343 | 300 | 195 | 363 | 276 | 321 | 86 |
| 36 | Paw | 12927 | 4604 | 8618 | 2619 | 12131 | 4320 | 7537 | 4346 |
| 37 | Brown Bear | 90 | 57 | 60 | 32 | 73 | 46 | 60 | 20 |
| 38 | Van Dyke Ck | 120 | 43 | 80 | 24 | 97 | 35 | 66 | 38 |
| 39 | White | 15456 | 11641 | 10304 | 6623 | 17099 | 12878 | 12334 | 3741 |
| 40 | Meziadin | 2436 | 2049 | 1624 | 1166 | 2761 | 2323 | 2060 | 582 |
| 41 | Cranberry Main | 23760 | 15823 | 15840 | 9003 | 39719 | 26450 | 21766 | 10785 |
| 42 | Cranberry-Kiteen | 14796 | 12638 | 9864 | 7191 | 21546 | 18404 | 14073 | 5334 |
| 43 | Bell-Irving below Bowser | 10704 | 13892 | 7136 | 7904 | 13659 | 17727 | 11837 | 4027 |
| 44 | Bell-Irving (Bowser to Teigen) | 21942 | 26931 | 14628 | 15323 | 27999 | 34365 | 23531 | 7721 |
| 45 | Bell-Irving (above Teigen) | 18228 | 14788 | 12152 | 8414 | 23259 | 18870 | 15952 | 5286 |
| 46 | Bowser | 11070 | 7911 | 7380 | 4501 | 10177 | 7273 | 8052 | 2337 |
| 47 | Taft | 7161 | 5449 | 4774 | 3100 | 4765 | 3626 | 4812 | 1433 |
| 48 | Treaty | 8907 | 5985 | 5938 | 3405 | 10440 | 7015 | 6948 | 2471 |
| 49 | Teigen | 13806 | 8074 | 9204 | 4594 | 15061 | 8808 | 9924 | 3874 |
| 50 | Hodder | 5172 | 2370 | 3448 | 1348 | 6496 | 2976 | 3635 | 1889 |
| 51 | Kwinageese | 16800 | 7412 | 11200 | 4217 | 15801 | 6971 | 10400 | 5093 |
| 52 | Saladamis | 3432 | 1590 | 2288 | 905 | 2766 | 1282 | 2044 | 958 |
| 53 | Sanyam | 102 | 51 | 68 | 29 | 82 | 41 | 62 | 27 |
| 54 | Sanskisoot | 3444 | 1755 | 2296 | 999 | 2776 | 1415 | 2114 | 906 |
| 55 | Taylor | 22710 | 13089 | 15140 | 7447 | 25315 | 14590 | 16382 | 6562 |
| 56 | Sallysout | 501 | 349 | 334 | 199 | 404 | 282 | 345 | 103 |
| 57 | Vile | 5880 | 3538 | 3920 | 2013 | 4739 | 2851 | 3823 | 1370 |
| 58 | Kotsinka | 3150 | 2161 | 2100 | 1230 | 2539 | 1742 | 2154 | 658 |
| 59 | Damdochax | 17172 | 9750 | 11448 | 5548 | 21149 | 12009 | 12846 | 5535 |
| 60 | Muskaboo | 18159 | 13635 | 12106 | 7758 | 22949 | 17232 | 15306 | 5296 |
| 61 | Panorama | 4818 | 2363 | 3212 | 1344 | 6865 | 3367 | 3661 | 1946 |
| 62 | Konigus | 207 | 157 | 138 | 90 | 291 | 221 | 184 | 71 |
| 63 | Upper Nass | 20883 | 15115 | 13922 | 8600 | 29006 | 20994 | 18087 | 7095 |
| | | | | | | | | | |
| | Total (all systems)<br>Total (confirmed) | 296772<br>198474 | 211050<br>151885 | 197848<br>132316 | 120080<br>86417 | 352737<br>248272 | 255942<br>192014 | 239072<br>168230 | 92902<br>65020 |

# APPENDIX I

# ESTIMATE OF THE REQUIRED NUMBER OF STEELHEAD SPAWNERS TO FULLY SEED AVAILABLE FRY HABITAT

Appendix I. Estimate of the required number of steelhead spawners to fully seed available fry habitat.

| | Watershed | Area ($km^2$) | Stream Order | Steelhead/ Rainbow present (confirmed) [5] | Smolts Produced | Fry Produced | Required Eggs | Female Length | Female fecundity | Required Spawners |
|---|---|---|---|---|---|---|---|---|---|---|
| Winter Populations | | | | | | | | | | |
| | | | | | | | | | | |
| 1 | Kincolith | 225.9 | 4 | Y | 6482 | 84547 | 845470 | 743 | 5752 | 294 |
| 2 | Iknouk | 112.4 | 4 | Y | 4471 | 53502 | 535015 | 771 | 6150 | 174 |
| 3 | Keazoah | 11.5 | 3 | Y | 0 | 0 | 0 | 771 | 6150 | 0 |
| 4 | Anliyen (Greenville) | 40.7 | 4 | U | 231 | 2760 | 27601 | 771 | 6150 | 9 |
| 5 | Diskangieq | 36.4 | 4 | U | 1092 | 13073 | 130732 | 771 | 6150 | 43 |
| 6 | Anudol | 123.7 | 5 | N | 971 | 11615 | 116153 | 771 | 6150 | 38 |
| 7 | Inieth | 9.5 | 3 | N | 0 | 0 | 0 | 771 | 6150 | 0 |
| 8 | Cugiladap | 6.2 | 3 | N | 0 | 0 | 0 | 771 | 6150 | 0 |
| 9 | Wegiladap | 17.0 | 4 | N | 97 | 1156 | 11558 | 771 | 6150 | 4 |
| 10 | Wilyayaanooth | 12.7 | 3 | RB | 0 | 0 | 0 | 771 | 6150 | 0 |
| 11 | Giswatz | 13.3 | 3 | N | 0 | 0 | 0 | 771 | 6150 | 0 |
| 12 | Gingietl | 14.7 | 3 | RB | 0 | 0 | 0 | 771 | 6150 | 0 |
| 13 | Gish | 14.7 | 3 | RB | 0 | 0 | 0 | 771 | 6150 | 0 |
| 14 | Chemainuk | 58.1 | 4 | N | 2098 | 25113 | 251133 | 771 | 6150 | 82 |
| 15 | Burton | 96.0 | 5 | RB | 55 | 659 | 6589 | 771 | 6150 | 2 |
| 16 | Monkley | 35.7 | 4 | RB | 891 | 10663 | 106628 | 771 | 6150 | 35 |
| 17 | Chambers | 89.9 | 4 | Y | 1169 | 11442 | 114418 | 821 | 6888 | 33 |
| 18 | Welda | 31.3 | 3 | U | 0 | 0 | 0 | 771 | 6150 | 0 |
| 19 | Quilgauw | 37.0 | 4 | U | 748 | 8954 | 89539 | 771 | 6150 | 29 |
| 20 | Ishkheenickh | 579.4 | 7 | Y | 11985 | 132543 | 1325428 | 796 | 6514 | 407 |
| 21 | Ginlulak | 43.3 | 4 | N | 524 | 6276 | 62764 | 771 | 6150 | 20 |
| 22 | Kwiniak (Ksedin) | 248.1 | 5 | Y | 5857 | 75850 | 758501 | 771 | 6150 | 247 |
| 23 | Ksemamaith | 68.4 | 4 | Y | 558 | 6679 | 66786 | 771 | 6150 | 22 |
| 24 | Ansedegan | 28.5 | 4 | U | 211 | 2522 | 25216 | 771 | 6150 | 8 |
| 25 | Kwinyarh | 15.6 | 3 | Y | 0 | 0 | 0 | 771 | 6150 | 0 |
| 26 | Zolzap | 32.0 | 5 | Y | 700 | 8379 | 83795 | 771 | 6150 | 27 |
| | | | | | | | | | | |
| | Total (all systems) | 2002 | | | 38139 | 455733 | 4557325 | | | 1473 |
| | Total (confirmed) | 1383 | | | 31221 | 372941 | 3729414 | | | 1204 |
| | Difference | 619 | | | 6918 | 82791 | 827912 | | | 269 |
| | | | | | | | | | | |
| Sympatric Populations | | | | | | | | | | |
| | | | | | | | | | | |
| 27 | Tseax | 608.3 | 6 | Y | 3342 | 49247 | 492470 | 756 | 5935 | 166 |
| 28 | Seaskinnish | 204.6 | 5 | Y | 2892 | 42621 | 426210 | 756 | 5935 | 144 |
| 29 | Gitwinksihlkw Ck | 7.0 | 3 | N | 0 | 0 | 0 | 756 | 5935 | 0 |
| | | | | | | | | | | |
| | Total (all systems) | 820 | | | 6235 | 91868 | 918680 | | | 310 |
| | Total (confirmed) | 813 | | | 6235 | 91868 | 918680 | | | 310 |
| | Difference | 7 | | | 0 | 0 | 0 | | | 0 |

| Appendix I (cont). | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Watershed | Area (km$^2$) | Stream Order | Steelhead/ Rainbow present (confirmed) [5] | Smolts Produced | Fry Produced | Required Eggs | Female Length | Female fecundity | Required Spawners |
| Summer Populations | | | | | | | | | | |
| | | | | | | | | | | |
| 30 | Shumal | 99.6 | 4 | U | 1985 | 24802 | 248018 | 678 | 4876 | 102 |
| 31 | Kwinamuck | 61.5 | 4 | N | 0 | 0 | 0 | 678 | 4876 | 0 |
| 32 | Kwinatahl | 306.1 | 6 | U | 1679 | 20978 | 209777 | 678 | 4876 | 86 |
| 33 | Kshadin | 105.1 | 5 | U | 9 | 110 | 1105 | 678 | 4876 | 0 |
| 34 | Tchitin | 248.2 | 6 | Y | 3881 | 60133 | 601327 | 678 | 4876 | 247 |
| 35 | Kinskuch | 476.9 | 5 | Y | 276 | 3453 | 34528 | 678 | 4876 | 14 |
| 36 | Paw | 176.7 | 6 | U | 4320 | 53979 | 539792 | 678 | 4876 | 221 |
| 37 | Brown Bear | 227.7 | 4 | Y | 46 | 573 | 5734 | 678 | 4876 | 2 |
| 38 | Van Dyke Ck | 34.1 | 4 | U | 35 | 432 | 4323 | 678 | 4876 | 2 |
| 39 | White | 954.0 | 6 | N | 12878 | 160901 | 1609014 | 678 | 4876 | 660 |
| 40 | Meziadin | 719.3 | 6 | Y | 2323 | 29438 | 294378 | 712 | 5326 | 111 |
| 41 | Cranberry Main | 974.8 | 7 | Y | 26450 | 362770 | 3627704 | 699 | 5152 | 1408 |
| 42 | Cranberry-Kiteen | 885.5 | 7 | Y | 18404 | 250618 | 2506176 | 699 | 5152 | 973 |
| 43 | Bell-Irving below Bowser | 4954.0 | 7 | Y | 17727 | 321616 | 3216159 | 683 | 4941 | 1302 |
| 44 | Bell-Irving (Bowser to Teigen) | 4498.0 | 7 | Y | 34365 | 623493 | 6234925 | 683 | 4941 | 2524 |
| 45 | Bell-Irving (above Teigen) | 1295.8 | 7 | Y | 18870 | 342360 | 3423603 | 683 | 4941 | 1386 |
| 46 | Bowser | 1262.0 | 7 | Y | 7273 | 182246 | 1822462 | 683 | 4941 | 738 |
| 47 | Taft | 474.0 | 6 | Y | 3626 | 65785 | 657852 | 683 | 4941 | 266 |
| 48 | Treaty | 427.1 | 6 | Y | 7015 | 127269 | 1272693 | 683 | 4941 | 515 |
| 49 | Teigen | 351.7 | 6 | Y | 8808 | 199596 | 1995959 | 683 | 4941 | 808 |
| 50 | Hodder | 72.3 | 5 | Y | 2976 | 54002 | 540018 | 683 | 4941 | 219 |
| 51 | Kwinageese | 552.3 | 6 | Y | 6971 | 85247 | 852471 | 717 | 5394 | 316 |
| 52 | Saladamis | 75.0 | 5 | U | 1282 | 16014 | 160141 | 678 | 4876 | 66 |
| 53 | Sanyam | 96.6 | 5 | U | 41 | 513 | 5133 | 678 | 4876 | 2 |
| 54 | Sanskisoot | 103.3 | 5 | U | 1415 | 17674 | 176739 | 678 | 4876 | 72 |
| 55 | Taylor | 753.2 | 7 | N | 14590 | 182289 | 1822888 | 678 | 4876 | 748 |
| 56 | Sallysout | 333.2 | 6 | U | 282 | 3518 | 35181 | 678 | 4876 | 14 |
| 57 | Vile | 188.0 | 5 | U | 2851 | 35621 | 356209 | 678 | 4876 | 146 |
| 58 | Kotsinka | 312.4 | 5 | U | 1742 | 21764 | 217640 | 678 | 4876 | 89 |
| 59 | Damdochax | 737.4 | 7 | Y | 12009 | 158900 | 1589001 | 743 | 5752 | 552 |
| 60 | Muskaboo | 614.9 | 6 | N | 17232 | 215294 | 2152940 | 678 | 4876 | 883 |
| 61 | Panorama | 90.6 | 5 | N | 3367 | 42064 | 420641 | 678 | 4876 | 173 |
| 62 | Konigus | 471.7 | 6 | N | 221 | 2764 | 27640 | 678 | 4876 | 11 |
| 63 | Upper Nass | 735.6 | 6 | Y | 20994 | 262300 | 2622999 | 704 | 5219 | 1005 |
| | | | | | | | | | | |
| | Total (all systems) | 23669 | | | 255942 | 3928517 | 39285170 | | | 15662 |
| | Total (confirmed) | 19598 | | | 192014 | 3129799 | 31297989 | | | 12386 |
| | Difference | 4070 | | | 63928 | 798718 | 7987181 | | | 3276 |

[1] Number of smolts at maximum production for specified model

[2] Number of fry required to fully seed habitat and produce maximum smolts, equation 14

[3] Number of eggs required to fully seed habitat given specified egg to fry survival

[4] Female length from either tributary specific data or average

[5] Female fecundity predicted from female length, equation 15

[6] Required number of spawners calculated using equation 16

[7] ST Confirmed: Tchitin, Kinskuch, Brown Bear, Meziadin, Cranberry-Main, Cranberry-Kiteen, Bell-Irving below Bowser, Bell-Irving (bowser-Teigen), Bell-Irving (above Teigen), Bowser, Taft, Treaty, Teigen, Hodder, Kwinageese, Damdochax, upper Nass