# Goat River Watershed

# Telemetry Studies
# &
# Redd Surveys

## (2002 to 2003)

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# Abstract

The Goat River bull trout investigations coupled with the results of past water quality studies indicate that the Goat River supports a very important and highly sensitive population of large fluvial bull trout. Sixteen of twenty-eight bull trout were radio-tagged and tracked during 2002/03. The mean length and weight of radio-tagged (mature) bull trout was 617.5 mm and 2613 grams respectively. There was no significant difference in length or weights between female and male bull trout, or between Goat River and Macleod Creek spawners. Seven bull trout spawned in the upper Goat River, six in Macleod Creek; three remained downstream. The mean emigration rate was 0.48 km/day (SD = 0.69). The post-spawning Emigration rate was 25.9 km/day (SD = 19.88). The mean spawning residence was 20.1 days (SD = 1.69). The average distance to over-winter sites for tracked fish was 457.3 km; up to 505 km.

In 2003, redd counts for Macleod Creek and Goat River were 90 and 73 respectively; approximately 326 bull trout. Bull trout spawning distributions were found to be highly aggregated (k = 0.45) and associated with low gradient transitional zones, an abundance of large woody debris, cover and suitable spawning gravel. Evidence of visually suitable spawning habitat being vacant over the duration of the study suggests that groundwater plays a key role in spawning site selection.

Recommendations for the Goat River include protecting important bull trout spawning habitat and hydrological features through 'Wildlife Habitat Areas', and or 'Significant Fisheries Watershed' designations, monitoring water quality consistent with provincial standards, long-term monitoring of redds, and collecting micro satellite DNA and otolith micro-chemistry to determine and understand upper Fraser River bull trout stock structure and movement patterns.

# Acknowledgements

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# 1.0 Introduction

Throughout North America, bull trout (*Salvelinus confluentus*) populations are generally in decline and have become a species of concern. Bull trout are blue listed (vulnerable to extirpation or extinction) by the British Columbia Conservation Data Centre (CDC), are "Identified Wildlife" in the Forest Practices Code (IWMS Vol. 1), and are expected to be candidate species for wildlife habitat area (WHA) designations under the new "Forest and Range Practices Act". In the United States, many populations have become listed under the "Endangered Species Act". For instance, out of sixty-five populations surveyed in Oregon, twelve were categorized as extirpated, and thirty-one as having high or moderate risk of extirpation. In Washington State, fifteen of thirty-five populations are categorized as having a moderate or high risk of extirpation (1992 publications as cited by Thurow and Schill 1996).

Bull trout life-history patterns include large adfluvial (lake-run), fluvial (river-run) and small stream resident forms, each obligated to rear in cold headwater streams for at least the early juvenile portion of their lives (Rieman and McIntyre, 1993). Cold headwater streams required for spawning and early rearing limits bull trout distribution; their persistence in streams where temperatures exceed 15ºC is uncommon (Selong, et al., 2001, Rieman and McIntyre, 1993, Donald and Alger 1993).

Relative to other salmonids, adult and juvenile bull trout densities are often very low (Baxter and McPhail 1996, Bonar et al. 1997) and they can be extremely sensitive to angler exploitation, habitat degradation, and compete poorly with introduced species (Baxter and McPhail 1996). Within British Columbia, angler exploitation as a result of uncontrolled access, thermal and physical habitat loss and habitat fragmentation are the primary concerns. Population declines are largely attributed to the effects of resource management or development within watersheds (Ratliff and Howell 1992; Rieman and McIntyre 1993; Henjum et al. 1994).

Within the Robson Valley the Goat River watershed supports high quality woodland caribou (*Rangifer tarandus caribou*), grizzly bear (*Ursus arctos*), chinook salmon (*Oncorhynchus tshawytscha*) and bull trout values. Three years of water quality data indicates that the Goat River has exceptional water quality and cold water temperatures ideally suited to bull trout (Rex and Lheidli T'enneh, 2002). Anecdotal evidence of large adult bull trout and pending forest development activities in the watershed established the Goat River as a high priority for investigation. However, prior to 2002, with the exception of chinook salmon stock assessments (Fisheries and Ocean Canada) there had been no formal assessment of other fisheries values in the Goat River watershed. An ongoing study established in 2002 seeks to understand the importance of the Goat River bull trout population relative to other local populations.

<u>The primary objectives of the Goat River bull trout study are:</u>

- To identify and evaluate the significance of bull trout spawning and rearing habitat.
- To protect important bull trout spawning habitat and to collect baseline information that will allow for the evaluation of impacts that might occur as a result of proposed forest harvesting activities.

<u>Long-term objectives are:</u>

- To determine the level of spawning site fidelity, stock structure, abundance trends, and the significance of long migratory forms of bull trout, all of which will serve to provide management recommendations to stakeholders and to better understand Upper Fraser bull trout stock structure.

## 2.0 Study Area

The Goat River, located 144 km southeast of Prince George in the Robson Valley Forest District (53º- 31'- 54" N, 120º- 33'- 54" W), is a 6th order, 346 $km^2$ watershed (Figure 1). Biogeoclimatic zones in the watershed range from ICH wk3 (Interior Cedar Hemlock, wet cool) in the lower reaches, ESSFwk1 (Engelmann Spruce Sub-alpine Fir, wet-cool) through the majority of the drainage, with ESSF wc3 (wet-cold) and AT (Alpine Tundra) in the upper elevations.

Geological mapping (Ferguson, 2003) indicates that the river bottoms consist of "Cenozoic – Quaternary" alluvial deposits, with "Neoproterozoic" middle carbonate members from the Isaac formation dissecting small portions of the Upper Goat River and Macleod Creek. The North Star, West Macleod Creek and East Macleod Creek faults cross the upper Goat River and middle Macleod Creek areas.

With the exception of the Milk River sub-basin, the Goat River remains pristine with no road access or resource extraction beyond the Milk River confluence; a maintained "gold rush" heritage trail follows the Goat River into Bowron Lake Provincial Park. Exceptionally low turbidity and suspended sediment levels above the Milk confluence are a function of the pristine nature and lack of glacial melt-water input (Rex and Lheidli T'enneh, 2002). Access along the lower watershed is via a forestry road along the eastern side of the watershed into the Milk River watershed, with a new spur road ending just beyond the Milk River confluence of the Goat River. Forest harvesting activities, including road construction, are currently being proposed for the upper portions of the Goat River watershed.

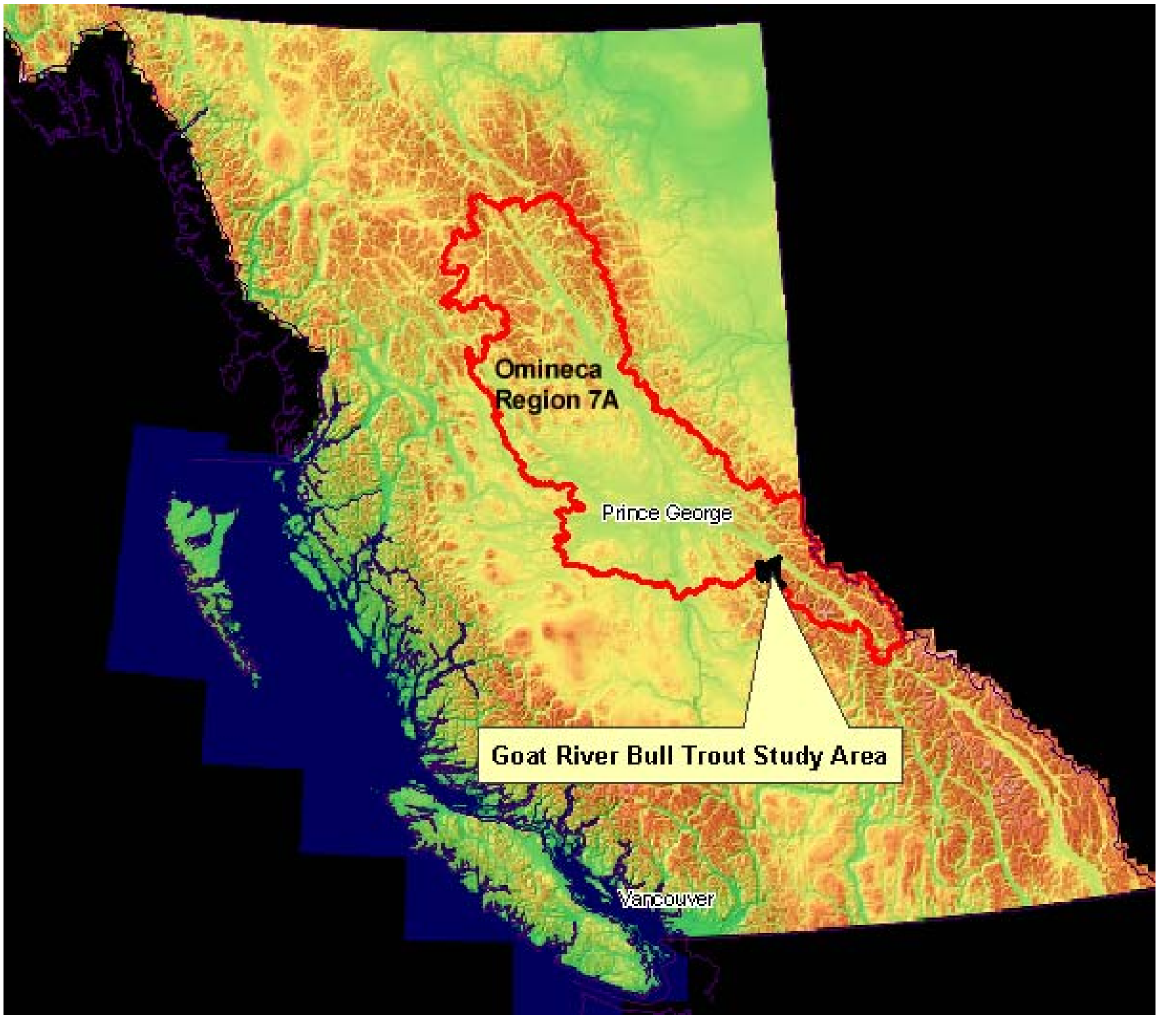


**Figure 1.** Overview of the Goat River study area in relation to British Columbia and the Omineca Region.

# 3.0 Methods

## *3.1Capture*

During July 2002, the Goat River was angled to scout probable holding pools and to assess the size and abundance of bull trout. Catch per unit effort (CPUE), spawning run-timing, and fish mass suitable for surgical implantation of Lotek ™ coded transmitters were evaluated to determine telemetry project feasibility.

Subsequent capture of bull trout for radio tagging occurred during August 8, 9 and 23 2002. During the first capture period (August 8-9, 2002), all bull trout were acquired by angling large pools located above the Milk River confluence, up to the Northstar Creek confluence (Figure 2). Except for fish sampled from a site at 22-km, access was by helicopter. The second sample period occurred on August 23, 2002 at a large pool above the Milk River confluence. Bull trout captured for surgical implantation of transmitters were held in black duffle bags with perforated plastic ends that allowed flow of water through the bag. Holding bags were anchored in the river at suitable locations until bull trout were ready to be processed. Each capture site was geo-referenced with a Garmin Etrex™ global positioning (GPS) unit and the data were plotted using ESRI® ArcMap™ 8.3 software.

All bull trout captured were sampled for fork-length (mm) and weight (grams), visually assessed for spawning characteristics (kype development, bright spawning colouration), and tagged with uniquely numbered Floy ™ (t-bar anchor) tags. Fin-ray age structures and tissue samples were taken from six bull trout during 2002. Eleven additional bull trout were sampled in August 2004 for length, weight and aging structures. Three female bull trout of the eleven were lethally sampled to collect otoliths for age validation, and to determine fecundity. The otoliths along with water samples collected from the Goat River, Macleod Creek, Northstar and the Milk River will also serve to assess the utility of using otolith micro-chemistry and water chemistry to identify stock structure, and the spatial and temporal movement patterns of bull trout.

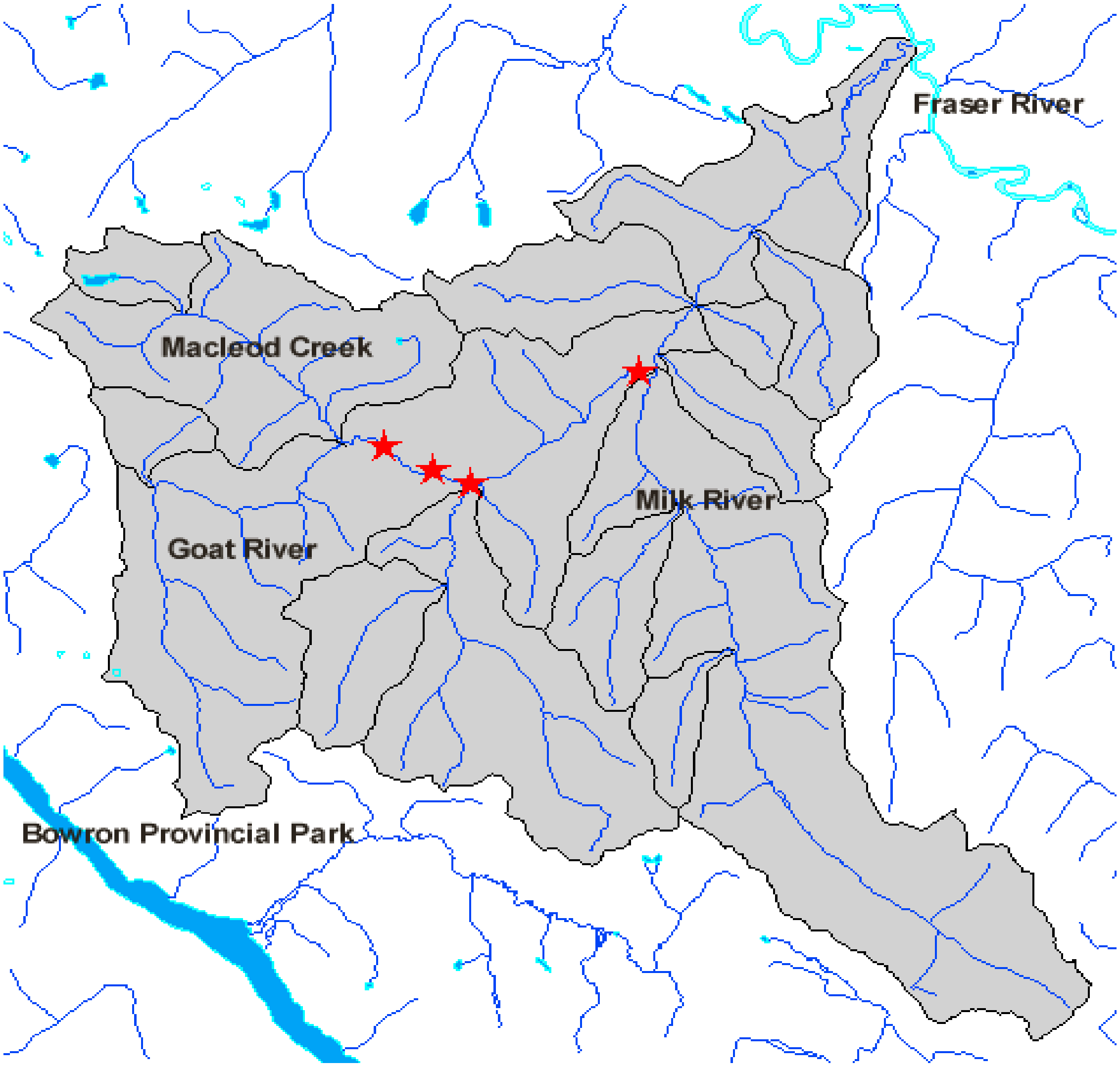


**Figure 2**. Locations where radio-tagged bull trout were captured during August 2002.

## *3.2 Radio-Telemetry*

All bull trout selected for surgery with a tag-body mass ratio of less than 2% (Winter 1996) were anaesthetized in 131-L plastic totes using a 10% clove oil-ethanol stock solution mixed with river water at a concentration of 40mg/L (Anderson et al 1997). Anaesthetization of bull trout was visually monitored; fish were considered ready for surgery after fish had reached total loss of equilibrium or loss of reflex reactivity (Schreck and Moyle 1990). Surgery times from anaesthesia to the end of surgery typically lasted 8-10 minutes.

Lotek™ MCFT-3EM ($n = 11$), or MCTF-3A ($n = 5$) coded microprocessor telemetry transmitters (149 kHz) with a 5-second pulse were used (Table 1); passive integrated transponder (PIT) tags were inserted into adductor muscle of the left operculum as a secondary identifier.

**Table 1.** Lotek radio transmitter specifications.

| Model | Dimensions (mm) | Air Weight (grams) | Water Weight (grams) | Life Expectancy at 5s (days) |
|---|---|---|---|---|
| MCFT-3EM | 11 x 43 | 8.9 | 4.3 | 399 |
| MCFT- 3A | 16 x 46 | 16.0 | 6.7 | *761 |

*(1139 days @ 50% duty cycle)

Surgical instruments and tags were sterilized with a distilled water/Chemisol™ solution. Radio tags were inserted through a 2-3 cm long ventral and medial incision, anterior to the pelvic girdle. The transmitter antenna was passed internally through the left abdominal wall, posterior and slightly dorsal to the pelvic girdle by the insertion of a hollow 14 gauge, 3.8 cm hypodermic needle. The antenna cable was passed through the needle and the needle was subsequently withdrawn. Incisions were closed using four “instrument tie-square knots” with Prolene ™ 2-0 (3.0 metric) polypropylene swage sutures. Exit and incision wounds were treated with betadine. Each fish was then held in slow moving current until the fish began ventilation on its own and could maintain an upright position, after which it was allowed to recover in a quiet, slack-water area over clean substrate. Each fish was found to swim in a vigorous fashion after recovery.

Schweizer 300C and Bell 206 (Jet Ranger) helicopters were used for tracking. Lotek ™ SRX-400 telemetry receivers were used in conjunction with a standard two-element yagi ‘H’ antenna. The receiver antenna was initially orientated horizontally on the leading edge of the landing skid, and was later re-orientated to a forward and vertical position to increase signal strength and accuracy. Tracking locations were geo-referenced and plotted using previously developed river kilometre designations.

Tracking flights started August 16, 2002 and were completed on a weekly basis through the expected immigration period in August. Flights were increased to two-times per week during the period in which the bull trout were on spawning grounds (expected residence period). During emigration, bull trout were tracked out of the Goat River watershed on a twice-weekly basis up to September 22, 2002 and then on a monthly basis through the winter until bull trout movement ceased, and the project could no longer be funded. The following spring, white sturgeon (*Acipenser transmontanus*) telemetry flights from a separate project were utilized to locate over-wintering bull trout in the Nechako River and the Fraser River downstream of Prince George. Nechako River white sturgeon base receiver stations were programmed to log bull trout movement data at the Stuart River confluence and the lower Nechako River.

During the spawning period, where radio-tagged bull trout were indicating signs of residence, sites were ground inspected for obvious signs of reproductive activity, such as the presence of adult bull trout on or near redd sites exhibiting spawning behaviours (e.g. digging, pairing of brightly coloured mature fish, and bouts of aggression between large male fish) or cleared patches of substrate, or the presence of adults in nearby pools or runs or other cover. UTM co-ordinates and general habitat data were recorded for each obvious redd site.

## 3.3 Redd Counts

During 2002, ground-based redd (gravel nest) surveys were completed in areas where telemetry results indicated a period of residence. Redd numbers and locations were visually assessed, geo-referenced and mapped with GIS software. These data were collected to determine if redd counts in the Goat River provided sufficient detection qualities to develop and track long term spatial distribution and abundance trends and to confirm spawning locations from telemetry data. Using redd detection as a presence-absence method, an exploratory flight was also made into the headwaters of Northstar Creek to determine if a set of falls located in the first reach acted as a barrier to bull trout migration. During 2002, small bull trout were visually observed in the headwaters, but no indication of spawning activity was observed.

During September 16-17, 2003, ground-based redd surveys were completed in Macleod Creek, the Upper Goat River residual (above Macleod confluence), and a short section of the upper Northstar drainage (Figure 4). Each stream was surveyed by two fisheries staff experienced in identifying bull trout redds. Visual observations were made by walking the margin or middle of the stream wearing polarized glasses and recording each redd encountered. Redd observations were recorded as "potential" (clean patches of gravel that were not clearly associated with digging, or redds that may have been washed out) or "absolute" (clear indication of digging with intact morphological characteristics of redds), with habitat relationships for each noted. Each redd was geo-referenced and mapped with GIS software.

Redd locations were recorded as being influenced by (within 1 metre) large woody debris (LWD), along stream banks, at open and exposed tail outs, general location within the context of the pool, and whether side channel habitat was being used for spawning. These site data will be evaluated to determine if "Resource Selection Functions" can serve to increase the ability to predict suitable habitat for spawning site selection. These data will also enable resource managers to identify and monitor key habitat variables at spawning sites, and identify key structural elements important to spawning and rearing habitat.

To evaluate relative abundance and the level of redd dispersion through each sub-basin, the data were analyzed using one-hundred metre river segments derived from

"Terrain Resource Information Management" (TRIM) maps. Bull trout have been shown to key in to very specific spawning areas (Baxter and Hauer 2000), therefore redd distribution were not assumed to be randomly distributed through the watershed, or through visually suitable habitat. To test this assumption equation (1) was first used to get an estimate of "k" (measure of dispersion; as k approaches infinity, negative binomial distribution approaches a Poisson distribution and a k of 200 or more indicates a random distribution) to characterize redd distribution (Krebs 1999). Estimation of the exponent 'k' was then evaluated by solving for equation (2) iteratively. By evaluation of observed versus expected values, 'U- Statistic Goodness-of-Fit Test' was used to determine if the data fitted a negative binomial distribution, equation (3). The standard error of U was determined using equation (4). If the standard error of k was less than two standard errors of U, then the redd distribution data is considered a sufficient fit to a negative binomial distribution. Evaluation of how the data is distributed will serve to determine what level of sampling intensity and scale is required to monitor long-term redd abundance.

(1) Approximate $\hat{k} = \dfrac{\bar{x}^2}{s^2 - \bar{x}}$

(2) $$(N)Log_e\left(1 + \frac{\bar{x}}{\hat{k}}\right) = \sum_{i=1}^{\infty}\left(\frac{A_x}{\hat{k} + x}\right)$$

where: $N$ = *Total number of river segments counted.*

$\bar{X}$ = *Observed mean*

$\hat{k}$ = *Estimated negative-binomial exponent*

$$A_x = \sum_{j=x+1}^{\infty}(f_j) = f_{x+1} + f_{x+2} + f_{x+3} + ......$$

*i= A counter (0,1,2,3….)*

*$f_x$= Observed number of quadrats containing x individuals*

*j= A counter (1,2,3,4……)*

(3) U = observed – expected variance

$$= s^2 - \left( \bar{x} + \frac{\bar{x}^2}{k} \right)$$

(4) S. E. $\left(\hat{U}\right) = \sqrt{\frac{1}{n}\left\{2\bar{x}\left(\bar{x}+a\right)\left(b\right)\left[\frac{\left(b^2\right)\left(\log_e b\right)-a\left(1+2a\right)}{\left(b\right)\left(\log_e b\right)-a}\right]+c\right\}}$

### 3.4 Additional Activities

Following the spawning period, temperature data loggers (32 kByte, Optic Stowaway temp-Onset Corp) were placed at selected redd sites to assess stream and inter-gravel water temperatures. Each logger was placed in an aluminium cylinder and attached to stable trees with 9.5 mm galvanized chain or 6.4 mm aircraft cable. At each site, one temperature logger was buried in the gravel adjacent to the mounded portion of a redd containing the eggs and one logger was left unburied on the stream bottom. Each data logger was retrieved and downloaded during 2003 redd surveys.

Finally, to assess the distribution and frequency of bull trout habitat types and to monitor changes within these habitats, a video-graphic aerial survey was completed in early October 2002. With the exception of the Milk River, the entire Goat watershed was flown by helicopter at approximately 300-500 meters elevation while a video and spatial record of the stream network was recorded with an externally mounted digital video recorder. The geographic position of the helicopter was monitored using the helicopter's GPS system so that habitat features can be later mapped and analysed. This video record will serve as a monitoring tool for future recreational and industrial activities within each sub-basin.

# 4.0 Results

## *4.1 Bull Trout Capture*

A total of twenty-eight bull trout were caught between July 11 and August 23, 2002, of which sixteen adult bull trout were radio-tagged and twelve sub-adults were Floy™ tagged and released (Figure 2, Table 2). All radio tagged bull trout were caught during August 8, 9 and 23rd (Photoplates 3-4, Appendix I). Fourteen of sixteen fish in the Goat River were located at least once following radio tagging. Based on movements of the fish that we were able to track, survival was 100 percent through the spawning period; all fish moved from capture sites.

**Table 2.** Summary of bull trout catch results for 2002 telemetry surveys.

| Date | General Location | Type | Effort (hrs) | BT Captured | Radio Tagged | CPUE | Mean Fork Length (mm) |
|---|---|---|---|---|---|---|---|
| Jul-11 | 5km/15km | Angling | 0.77 | 3 | 0 | 3.9 | 413 |
| Jul-18 | Milk Confluence | Angling | 1.33 | 4 | 0 | 3.0 | 393 |
| Aug-08 | Mid-Goat | Angling | 1.67 | 11 | 10 | 6.6 | 607 |
| Aug-09 | u/s Milk Confluence | Angling | 0.92 | 4 | 4 | 4.3 | 660 |
| Aug-23 | u/s Milk Confluence | Angling | 2.5 | 6 | 2 | 2.4 | 401 |
| | | | **7.19** | **28** | **16** | **4.0** | **519** |

The mean 'Catch Per-Unit Effort' for angling during 2002 was 4.0 (2.4-6.6) bull trout per hour. The mean tag-body mass ratio for radio tagged fish was 0.35% (0.157-0.615). The average length and weight of mature radio-tagged fluvial bull trout (n=16) was 617.5 mm (505 mm -780 mm) and 2613 grams (1300 g-5100 g) respectively; the average length of all bull trout sampled during 2002 was 519 mm (n = 28). The mean length of radio-tagged females and males was 577 mm (S. D. 60.47) and 649 mm (S.D. 82.11) respectively; there were no significant difference in lengths of male or female radio-tagged, or Goat and Macleod basin bull trout spawners (Table 3). To illustrate general growth characteristics, the mass-length regression results with a length frequency inset are illustrated in Figure 3.

Fin-ray aging structures from six fish resulted in a 505 and 520 mm bull trout that were 9 and 10 years old respectively, while sub-adult or resident bull trout between 305 and 410 mm were between 4 and 6 years old; ages from fin-rays will be validated with a few otoliths from samples collected in 2004. Visual assessment of sex resulted in 9 female, 15 male, and 4 undetermined sexes. There is likely a bias towards capturing mature males due to aggressive behaviour. The average Fulton's condition factor (K) for all fish captured was 1.06 (Appendix V).

**Table 3.** Summary of results for length and weight comparisons of male vs. female spawning bull trout and for Goat vs. Macleod spawning bull trout (α, 0.05).

| ***t-test Two-Sample Assuming Equal Variances*** | | | ***Mean Values*** | | | | | |
|---|---|---|---|---|---|---|---|---|
| ***Statistic*** | ***p-value*** | ***Significance*** | ***Male*** | ***SD*** | ***n*** | ***Female*** | ***SD*** | ***n*** |
| FL(mm) | 0.07362 | N | 648.9 | 82.11 | 9 | 577.14 | 60.47 | 7 |
| Mass (g) | 0.144503 | N | 2973.3 | 1190.13 | 9 | 2150 | 847.68 | 7 |
| | | | ***Goat*** | | | ***Macleod*** | | |
| Goat vs. Macleod FL (mm) | 0.890442 | N | 630 | 84.26 | 8 | 635.83 | 64.84 | 6 |
| Goat vs. Macleod Mass (g) | 0.938415 | N | 2813.8 | 1222.26 | 8 | 2766.67 | 915.96 | 6 |

## *4.2 Radio Telemetry*

Seven of the sixteen radio-tagged bull trout were tracked to spawning sites in the upper Goat River, six were tracked to spawning sites in the mid to upper reaches of Macleod Creek, one bull trout remained near the confluence of Northstar Creek during the peak spawning period, and two moved downstream after tagging (Table 4, Appendix II).

Immigration into the Goat River from the Fraser River during 2002 appeared to begin in mid to late July, continuing into the third week of August; small groups of bull trout were found throughout the watershed during early August. During 2002, bull trout appeared to arrive at spawning locations near the end of August to the first week of September.

Acquired telemetry locations allowed confirmation of spawning activities through ground investigations. During 2002, spawning activity (residence) began during the first week of September and continued over a three week period. The average residence time was 20.1 days (SD = 1.69)

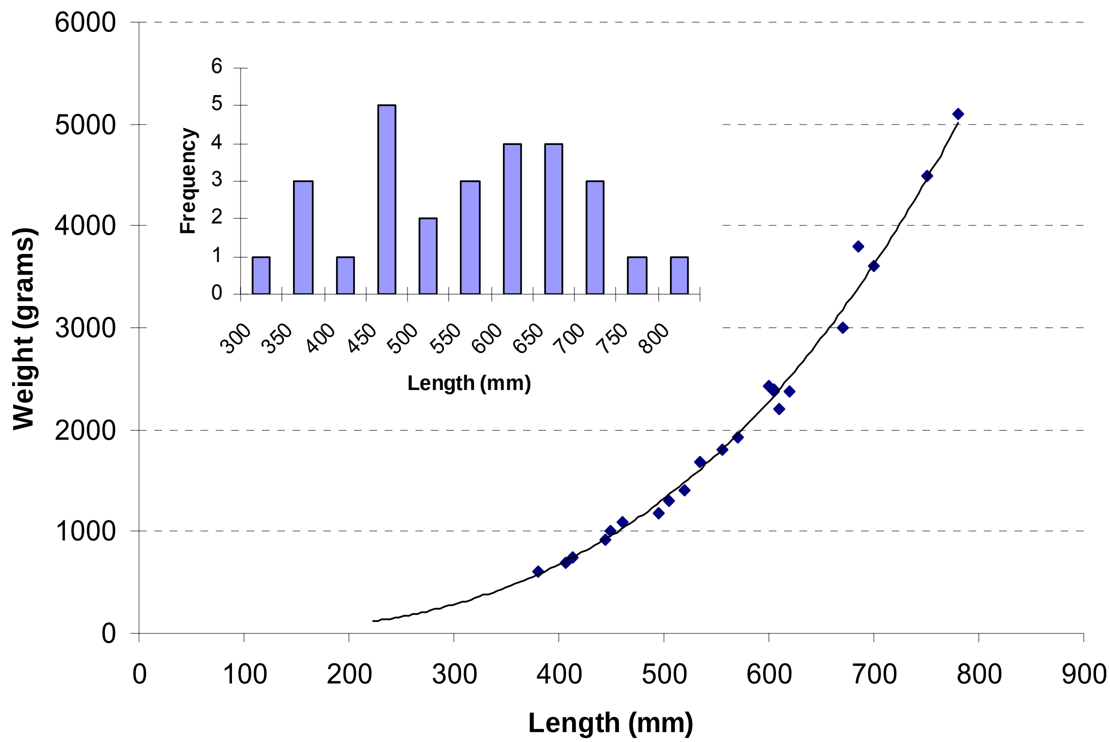


**Figure 3.** Length- weight regression of Goat River bull trout captured during 2002 (n= 23). The log-log regression equation is: *Log Mass(grams) = 3.0004 log length(mm) – 4.9997* ($r^2$ = 0.9932). Inset graph illustrates the length frequency distribution (n= 28).

Emigration out of the Goat River watershed during 2002 began around September 22, 2002; all but two radio-tagged and a few untagged bull trout had left the Goat River and were located in the Fraser River as far downstream as Longworth.

After the September 22, 2002 flight many of the radio-tagged bull trout were lost. Four bull trout were later located in the Nechako River near Vanderhoof and three were located in the Fraser River downstream of Prince George, near Quesnel. One bull trout (620-11) over-wintered in the Nechako and then migrated downstream of Prince George into the Fraser River. A summary of telemetry acquisitions for each bull trout tagged is found in Table 4. Three bull trout were repeat spawners in 2003, while the fate of the seven remaining bull trout remains unknown (Table 4).

**Table 4.** A general summary of fixation frequency, spawning and wintering areas, and last known fate.

| Frequency -code | Tag Site (km) | Times Located | Spawning stream | Wintering Stream | Comments |
|---|---|---|---|---|---|
| 620-10 | 33.4 | 15 | Upper Goat | Nechako | Spawned in 2003 |
| 620-11 | 29.0 | 13 | Macleod | Nechako | Moved into L. Fraser |
| 620-14 | 18.8 | 13 | Macleod | L. Fraser[1] | Last located June 19/03 |
| 620-13 | 20.1 | 9 | Macleod | Unknown | Last located Sept 20/02 |
| 620-19 | 20.1 | 6 | Unknown | U. Fraser[2] | Last located March 20/03 |
| 620-20 | 29.0 | 7 | Upper Goat | unknown | Last located Sept 22/02 |
| 620-22 | 29.0 | 7 | Upper Goat | unknown | Last located Sept 22/02 |
| 540-58 | 33.4 | 3 | Macleod | unknown | Last located Sept 22/02 |
| 580-16 | 20.2 | 8 | Goat | unknown | Last located Sept 22/02 |
| 560-20 | 20.1 | 3 | Unknown | U. Fraser[2] | Last located Dec 19/02 |
| 580-18 | 33.5 | 9 | Upper Goat | unknown | Spawned in 2003 |
| 540-60 | 33.4 | 1 | Upper Goat | unknown | Last located Aug 26/02 |
| 540-59 | 33.4 | 2 | Macleod | unknown | Last located Sept 22/02 |
| 480-54 | 33.4 | 3 | Macleod | Nechako | Last located May 29/03 |
| 580-22 | 33.4 | 9 | Upper Goat | L. Fraser[1] | Spawned in 2003 |
| 480-53 | 33.4 | 5 | Upper Goat | Nechako | Last located May 26/03 |

[1]. L. Fraser is the portion of the Fraser River between Prince George and Quesnel. [2]. U. Fraser is Prince George to Tete-Juane.

Migration up the Goat River to the spawning areas was quite variable and relatively slow paced (weeks) prior to the spawning period. The average rate of Immigration of bull trout (n = 11 bull trout, 26 location fixes) to spawning grounds was 0.48km/day (SD = 0.687). A comparison of movement rates amongst fish indicated no significant difference (p= 0.16). In contrast emigration rates to the Fraser River following spawning were rapid with most fish vacating the Goat River within a few days after spawning. The average downstream migration rates out of the Goat River to overwintering areas were 25.9 km/day (SD= 19.88). Accurate downstream migration rates could not be made due to an infrequent tracking schedule after the spawning period was over. As a result of rapid downstream migration and budget limitations, eight of the sixteen bull trout have not been relocated despite attempts to relocate all fish. Tracking flights were completed throughout all major tributaries in the upper Fraser, and Williams Lake biologists have assisted by scanning for Goat River bull trout frequencies as far downstream as the Chilcotin River. Of the bull trout located, two fish were located just upstream of Quesnel, four moved into the Nechako, and two remained in the Fraser River near Penny. The two fish near the community of Penny are assumed to have died due to no distinct movements after several flights. The average distance to over-winter sites for tracked fish was 457.3 km; up to 505 km.

### 4.3 Redd Counts

During September 19 and 22, 2002, redd counts were only completed at areas where radio-tagged bull trout were previously located. Those counts resulted in 28 and 11 redds being counted in the Goat River and Macleod Creek, over a total distance of 1.6 and 1.0 kilometres respectively. Segments of high gradient areas on the Goat River were not surveyed as a function of bull trout not being located in such habitat during 2002 telemetry flights.

During 2003, formal redd counts were completed through the entire Macleod Creek basin to the Goat River confluence, and from headwaters of the upper Goat River to the confluence of Macleod Creek (Figure 5). The total number of redds counted in 2003 was 163 for both basins. Macleod Creek redd counts resulted in a total of 90 absolute and 12 potential redds over a survey distance of 9.2 kilometres (67.2 % of the TRIM stream network). The Goat River count was 73 absolute and 14 potential redds over a survey distance of 7.95 kilometres (31.8% of TRIM stream network). Portions of the Goat River that were not surveyed were areas of high gradient and marginal bedrock type habitat. Limited spawning may occur at short gradient breaks where small patches of gravel suitable for spawning have accumulated but a survey of the entire stream length in Macleod Creek suggests otherwise; high gradient, low spawning habitat quality areas were not being used by spawning bull trout.

For 2003, the average number of redds per 100 metre river segment of the surveyed portions of Macleod and Goat were 0.968 and 0.918 respectively. To eliminate the effects of high gradient, non-spawning reaches of river on the analysis of redd distribution, high gradient river segments were removed from the analysis. Analysis of redd distribution was completed for river segments that were capable of supporting spawning activities. The distribution of redds in both the Macleod and Goat River basins were highly aggregated ($k = 0.446$ and 0.425 respectively) with the majority of suitable spawning habitat river segments (52% and 62.5%) having no evidence of spawning activity in 2003 (Figure 5 and 6). The observed values of U for redd distributions in Macleod and Goat River (-2.56 and -0.462) which are much less than twice the standard error of 2.67 and 0.628, indicating that a negative binomial distribution is an adequate fit of the redd distribution data (Table 5). Given the preponderance of zeros in the data, the data will require further evaluation; a zero inflated Poisson or a zero inflated negative binomial distribution may more accurately describe the distribution of the data and subsequently affect the sample size selection for future monitoring.

The presence of bull trout in the upper reaches of Northstar Creek was visually confirmed in September 2002. We were unable to determine if bull trout observed in upper

Northstar Creek were sub-adults or small adult residents; no absolute redds were observed during 2002 investigations of upper Northstar Creek. During 2003, the same reach was ground surveyed for redds and bull trout occurrence. One large redd was recorded, providing evidence that fluvial bull trout are able to ascend Northstar Creek to spawn when flows over the falls are ideal.

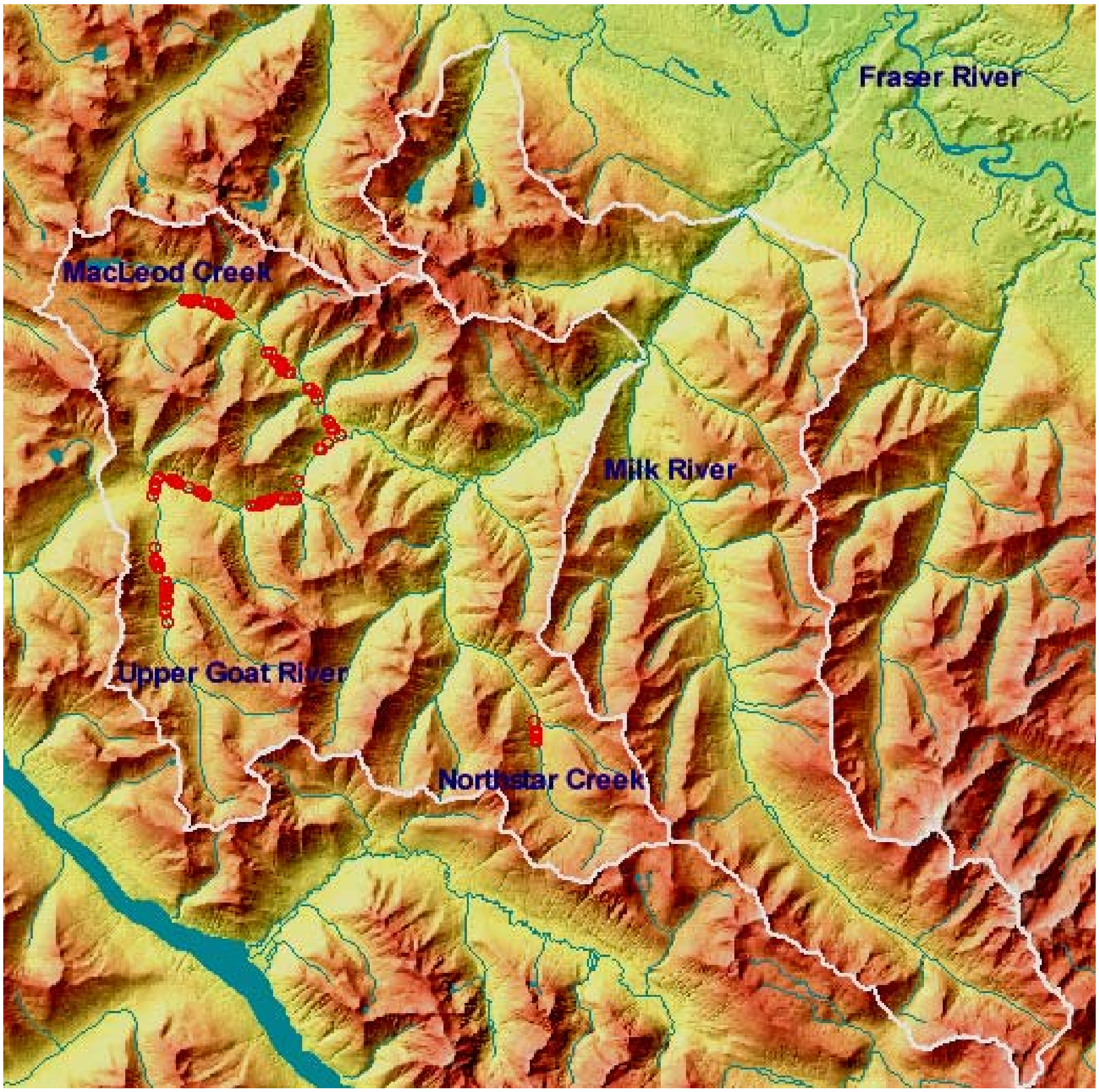


**Figure 4.** Distribution of bull trout redds counted in the Goat River watershed during 2003. Northstar Creek was not formally assessed due to downstream barrier.

**Table 5.** Redd distribution results and distribution statistics from 2003.

| Basin | Redd Count | Mean Count /100 metre | Variance | *k | U stat | S. E. $(\hat{U})$= |
|---|---|---|---|---|---|---|
| Macleod Creek | 90 | 1.76 | 6.18 | 0.446 | -2.56 | 2.67 |
| Goat River | 73 | 0.90 | 2.34 | 0.425 | -0.462 | 0.628 |

** Estimate of k from maximum-likelihood equation (2). U statistic calculated using equation (3), standard error of U calculated using equation (4)*

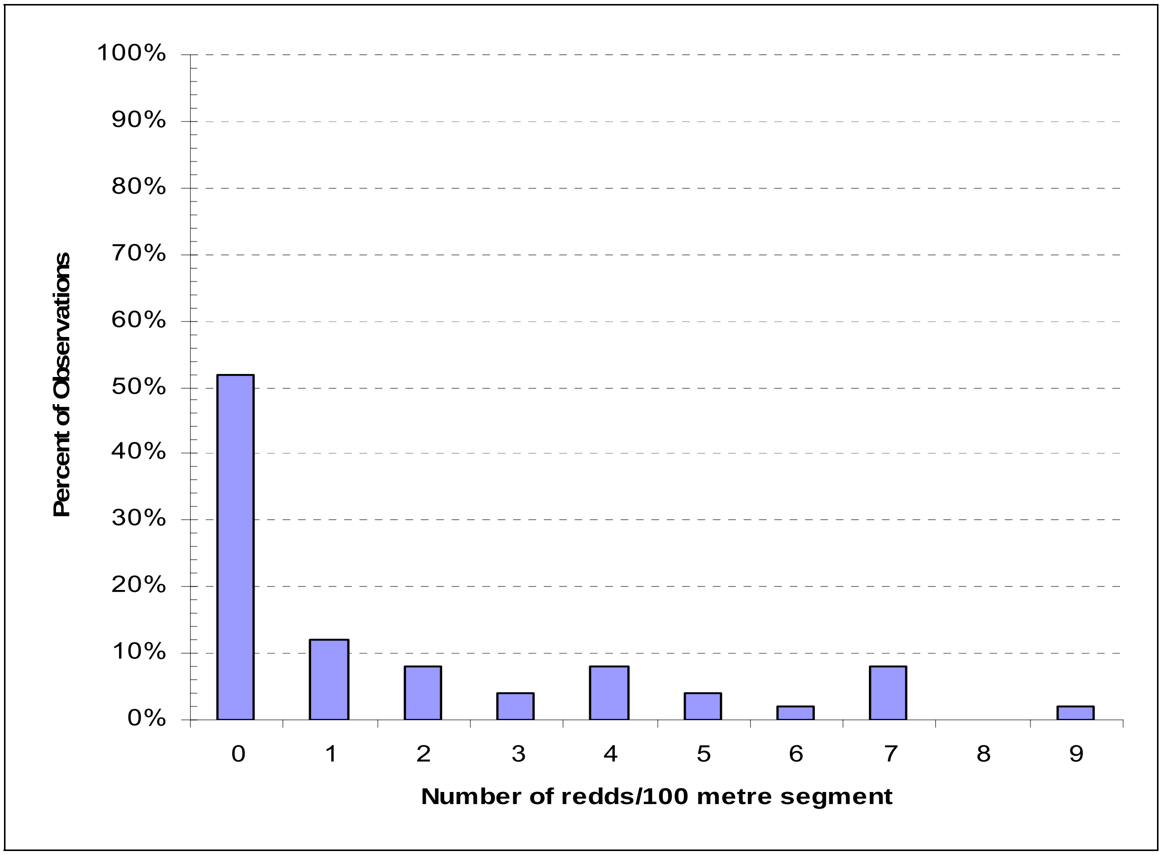


**Figure 5.** Frequency distribution of redds counted in the surveyed portion of suitable bull trout spawning habitat in Macleod Creek during September 2003.

Observations of the habitat that bull trout were spawning at resulted in nearly all fish spawning in areas with abundance of instream (LWD) or overhead cover, and where side-channel habitat or rearing habitat was within close proximity. In the Macleod Creek drainage, 62 redd sites (90 redds) were recorded as having confirmed spawning activity; the number of redds per river segment ranged from one to nine (Figure 5). Spawning habitat use in Macleod Creek resulted in 89 % (n= 41) of redd sites being located along the stream banks and associated with LWD. Conversely, redd sites that were recorded as being in more open habitat, only 11% (n= 5) were associated with LWD. For spawning sites not associated with LWD, 92 % (n= 12) were located in open areas. Macleod Creek is for the most part, a single thread channel, but where multiple channels were noted redd observations were compared; 97% (n= 59) of redd sites occurred within the main channel.

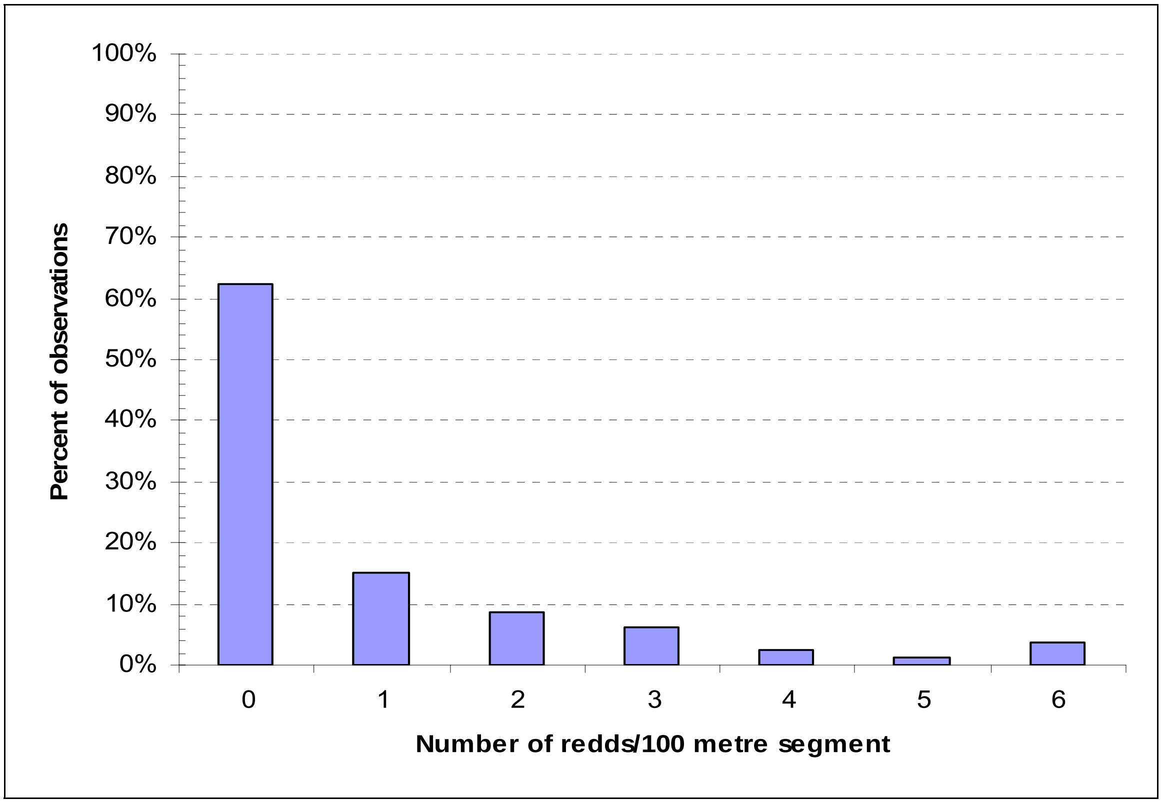


**Figure 6.** Frequency distribution of redds counted in the surveyed portion of suitable bull trout spawning habitat in the upper Goat River during September 2003.

The Goat River has a larger component of bull trout spawning in sub-alpine reaches and along wider channels of the middle reaches, and subsequently LWD appears to play a lesser or different role in redd site selection. At the sub-alpine reaches there are stretches of spawning habitat where riparian trees are small and do not contribute to stream side cover or local hydraulics. At the wider, middle and lower reaches of the Goat River, LWD distribution appears more clumped (small log jams), with less of the effective channel being affected by LWD. More bull trout were spawning in open tail outs or in areas along the banks where wood was not playing a direct role in cover or hydraulics. A total of 51 redd locations were noted during the 2003 redd surveys; the number of redds per river segment ranged from one to six (Figure 6). Goat River redd surveys resulted 51 % (n= 26) of redds being associated with LWD and 49 % (n=25) not being associated with LWD. Of redds associated with LWD, 92% were located against stream banks. For non-LWD associations, only 24% of redds observed were along the stream bank, 76% of redds detected were in relatively open areas. Results from 2003 redd data indicate that 97% (n= 59) of redd sites were located in the main river channel, which is a function of limited side channel habitat suitable for spawning.

Spawning sites were also characterized by meandering, low gradient, low hydraulic energy sites where accumulations of medium sized gravel suitable for spawning occurred. Gravel accumulations appear to be a function of LWD accumulations, in the form of small log jams (Appendix I, Photoplate 6-7). Video records of the stream network have yet to edited and analyzed but will provide an important tool for monitoring potential redd locations, LWD, pool and riffle frequencies and long-term habitat changes.

## 5.0 Discussion

Reconnaissance fish surveys and flights (MWLAP data on file) into the majority of Upper Fraser tributaries by Williamson and Zimmerman (2000), Zimmerman (pers. comm), suggests that high quality bull trout habitat exists at a very limited scale due to a variety of factors such as habitat degradation, high frequency of natural disturbances, natural and man-made barriers, reduced productive capacity through glacial melt-water input, and confined, high-gradient watersheds that have a very limited amount bounded alluvial valley segments. Bounded alluvial valley segments (BAV) are river sections defined by geomorphic nick points that result in the storage of alluvial deposits (gravel suitable for spawning) and hyporheic groundwater exchange (thermal stability at spawning sites). Groundwater and BAV's have been determined to be very important site selection elements for spawning bull trout (Baxter et al. 1999, Baxter et al. 2000, Ripley 2002). Corresponding with the rarity of quality bull trout spawning habitat and specific spawning site selection, bull trout generally occur in low densities (Baxter and McPhail 1996, Bonar et al. 1997), increasing the risk of extirpation due to habitat degradation or over-exploitation.

The results of the 2002 radio-telemetry study and spawning redd investigations, coupled with three years of water quality analyses (Rex at al. 2002), clearly supports the notion that the Goat River bull trout population and the associated spawning habitat is exceptional compared to other Upper Fraser watersheds. As a result of the 2002 radio-telemetry study, Goat River bull trout were found to have a larger average mass and were longer and had more pronounced migratory tendencies than previously studied bull trout in the Upper Fraser (Williamson and Zimmerman, 2000; Williamson and Pillipow, 2001). Preliminary results from a pilot otolith micro-chemistry project completed in 2004 suggest that Goat River bull trout reside in their natal stream or the Goat River mainstem for three years before migrating into the Fraser River (Clarke, personal communication). Further work will explore the utility of otolith microchemistry to determine stock structure, spawning periodicity, growth parameters, and identification of key forage and spawning habitats.

Emerging meta-population theory suggests that large bodied, migratory forms of bull trout (such as Goat River fish) that are not restricted by demographic barriers may be important as genetic dispersal mechanisms in patchy environments, and that long migrant forms may serve to reduce extinction risks in watersheds where anthropogenic risks or frequent natural disturbances are apparent (Rieman and McIntyre 1993; Dunham and Rieman 1999; Rieman and Dunham 2000; Dunham and Rieman 2002; Nelson at al. 2002; Rich et al. 2003). Nelson et al. (2002), indicates that large body form bull trout are often the first to decline, either through habitat fragmentation, alteration and destruction, over-exploitation, or a combination thereof. Dunham and Rieman (1999) suggest that the protection of larger, less isolated, and less road disturbed watersheds should be protected to serve as refugia or colonization sources.

Baxter et al. (2000) found that bull trout redd distribution and abundance are affected by areas of groundwater exchange through the stream substrate. Baxter et al. (2000) notes that at a watershed scale, bull trout redds were associated with "bounded alluvial valley" (BAV) segments and at transitional bed forms at a local scale. Large woody debris supports development of transitional bedforms and high intra-gravel water exchange.

Highly aggregated redd distributions within each sub-basin (Table 5), noted during the 2003 redd surveys are most likely associated with hyporheic groundwater exchange as a function of avalanche chutes, basin geomorphology (BAV's), and or underlying geological features such as the West Macleod Creek and North Star faults. The resulting aggregation of bull trout redds in the Goat River as described by the negative binomial factor 'k' further supports ground water site selection theory and is also evidence that bull trout, like other salmonids, demonstrate strong spawning site fidelity. As part of the 2003 redd counts, telemetry flights were completed over Macleod and Upper Goat spawning sites. Three radio-tagged fish were located in the exact same spawning sites as the previous year, emphasizing the need to ensure that bull trout spawning habitat and associated hydrological features are monitored and maintained. Long term monitoring of redds to gain and understanding of abundance patterns and spatial distribution must take in consideration of the aggregation patterns when developing a sample design. The affect of a highly aggregated negative binomial redd distribution such as that found in the Goat River increases the river segment sample size requirements and the level of precision that is achievable. For example if the desired level of error for counts is ± 25% and the mean ≈ 1.34 and k ≈ 0.446, the required number of segments will be 191 (Krebs, 1999). The high sample size requirements illustrate that a level of precision below ± 25% may be unachievable or cost and labour prohibitive, emphasizing the need for management options that are more conservative and reduces risks to habitat; further investigations into alternative statistical or modelling approaches should also be considered.

Along with suspected groundwater influences, all high use spawning sites in the Goat River occurred at low gradient bed-form transitional areas that were generally characterized as having higher sinuosity, accumulations of small to medium gravel with low silt, and an abundance of LWD. Hyporheic exchange requirements for spawning bull trout is supported by the fact that areas of recent avulsions in Macleod Creek had no spawning activity, despite all the structural elements being in place. The lower section of the upper Goat River also has all the structural elements that were recorded at high density redd sites, but has redd densities that are low relative to other sites.

Effective population size (the rate of genetic drift) is an important conservation concept that must be considered to ensure population viability. Rieman and Allendorf (2001) suggest that fish managers should seek to conserve a collection of interconnected populations that will meet a minimum of 1,000 spawning adults per year. Baxter et al. 1999, Hauer et al. 1999, Baxter et al. 2000, Ripley 2003, and Suttle et al. 2004 demonstrate that bull trout presence and abundance are negatively correlated to habitat degradation, increased road densities, percent harvest and amount of fine sediment deposited in the channel as a function of anthropogenic activities. Therefore, to protect bull trout populations such as those in the Goat River, it is not only important to ensure that protective measures are taken at the watershed scale, but that genetically interconnected populations (distinct population segments, DPS's) that make up evolutionarily significant units (ESU's) are identified at a landscape level and that bull trout are managed at the appropriate scale. For a population to be classified as an "evolutionarily significant unit", a population must be reproductively isolated and or must contribute significantly to the ecological/genetic diversity of the species. Distinct population segments are defined as the geographic range of a particular population.

Watershed and water quality assessments completed by Aquatic Resources Ltd (2000), Integrated Wood Services Ltd (2001), and Rex et al (2002) highlight the importance of ensuring fisheries significance is taken into account with the sensitivity of the watershed to landscape disturbances. Rex at al (2002) demonstrated that the background turbidity and suspended sediments values measured for Macleod and the upper Goat River were exceptionally low. The mean background NTU for Macleod Creek, with the exception of June, was below 1 "Nephelometric Turbidity Units" (NTU), and "Total Suspended Sediment" (TSS) were typically below the detection limits.

As a function of steep valley walls and numerous avalanche chutes, landslides are a regular occurrence in the Goat River watershed (Rex, 2002). Although our focus was on bull trout spawning activities, during the course of this study, we have noticed several new land slides. Rex (2002) noted a major landslide occurring in the Northstar sub-basin during 2000 and on the Goat River mainstem in October 2002. The Ministry of Water, Land and Air Protection biologists have noted an additional slide in the Northstar during 2004, and signs of slides in both the Macleod and Upper Goat drainages. Inspections of the slopes near the terminal end of the existing road above the Milk River confluence revealed numerous groundwater seeps, increasing the risk of slope instability and point source sediment pollution. Recent natural avulsions in the Macleod indicate that the high levels of fine sediment entrapped in the gravel matrix result in a complete absence of bull trout spawning; these sites will continue to be monitored during redd counts to determine how long of a period the absence of use remains and determine if our observations are consistent. If spawning bull trout continue to avoid recent avulsions, it follows that there is an expectation that altered hydrologic regimes will increase the rate of avulsions and the risk to bull trout viability in the Goat River. The Milk River watershed serves as an analog for watershed sensitivity and has clear evidence of what the risks might be to the Goat River if poor road placement, improper drainage, and a lack of post logging maintenance occur. In the Milk River drainage, several land slides are presently active and appear to be related to improper road placement or drainage management from past forest harvesting activities. The slides in the Milk River demonstrate that post-harvest risks to water quality and bull trout habitat values are high and that a greater emphasis on watershed scale planning, coupled with habitat protection measures is required. Watershed restoration activities that attempt to correct past impacts has been demonstrated to be cost prohibitive and in many cases not effective. There is a much greater benefit to all stakeholders if protective measures are part of the resource planning process.

As a function of the moderate to high landslide activity and evidence of site avoidance by bull trout at avulsion sites, the risks to bull trout spawning habitat and ultimately the persistence of a healthy population would appear to be heightened without protection of ecologically sensitive areas and un-controlled resource development.

## 6.0 Conclusion

There are several recommendations that have emerged as a result of studies completed in the Goat River to date.

1. It has been clearly acknowledged that the Goat River bull trout population is exceptional within the context of the Upper Fraser River, and that protective measures are warranted through existing tools such as "Wildlife Habitat Areas" (WHA's), "Significant Fisheries Watershed" designations, or a combination of measures that involves and serves all stakeholders interests without impacting the productive capacity of bull trout in the Goat River. Presently, the Ministry of Water, Land and Air Protection has initiated the process for a WHA with local stakeholders. Within the context of watershed or area designations, harvest plans will need to account for access issues, road placement and densities, and rotational patterns that limit or eliminate negative hydrological impacts in the watershed.

2. It is important to continue to develop an understanding of Upper Fraser bull trout population dynamics and more specifically the Goat River bull trout population. Continued monitoring of the Goat River bull trout is recommended along with watershed scale protective measures. As a result of the exceptional water clarity and high redd sight-ability found the in Goat River watershed, redd counts are proposed as a bull trout abundance monitoring tool. Redd counts along with habitat use data will also help to understand the spatial and temporal distribution of redds, the resource selection functions associated with spawning site selection, and ultimately the long term effects of resource extraction in the watershed and how spawning site selection might be affected. The use of redd counts for detecting

population trends is recognized as being the best method despite short term monitoring limitations and the affects of aggregated distributions on sample size requirements (Rieman and Myers 1997; Maxell, 1999; Krebs, 1999; Dunham and Rieman 2001). For redd counts to provide enough statistical power to detect population changes at a time scale appropriate for managers to respond, they must be aware of some of the redd count limitations, and set the levels of significance at a level that is more realistic. Myers (1999) suggests monitoring with one-tailed testing at $\alpha = 0.2$ to detect 10, 20 and 50% declines in 6, 4, and 2 years respectively. Given the statistical limitations associated with detecting trends in redd abundance, it is clear that a conservative or precautionary approach is required to ensure that spawning bull populations remain viable.

3. Groundwater mapping through site level assessments or remote sensing should be completed to ensure a comprehensive inventory of critical habitat has been completed and correlates with spawning site selection.

4. For aquatic life (fresh, marine and estuarine) the maximum induced turbidity (NTU or % of background) is:

- 8 NTU in 24 hrs when background is less than or equal to 8 NTU.
- A mean of 2 NTU in 30 days when background is less than or equal to 8 NTU.
- 8 NTU when background values are between 8-80 NTU and 10% when background levels are greater than or equal to 80 NTU.

The maximum induced suspended sediment (mg/L or % of background) is:

- 25 mg/L in 24 hours when the background level is less than or equal to 25 mg/L.
- A mean of 5 mg/L in 30 days when background is less than or equal to 25 mg/L.
- 25 mg/L when background levels are between 25-250 mg/L, and 10% when background suspended sediment is greater than or equal to 250 mg/L.

Suspended sediment and turbidity values in the Goat River are, on average, well below the minimal provincial criteria, it is recommended instrument precision be evaluated to determine if a 10% change can be detected with an appropriate level of confidence and that water quality criteria reflect the detection limit. The severity of ill-effects on various life stages of salmonids (Newcombe 1996) should be considered as a tool for determining acceptable sediment dose criteria in the Goat River watershed.

5. Further investigations into other Upper Fraser watersheds are recommended to determine if similar bull trout populations or stocks exist and to determine if DPS (distinct population segments)/ ESU's (evolutionarily significant units) exist, and to find similar redd site characteristics to the Goat River for the development of spawning index sites. Identifying other fluvial bull trout spawning watersheds will serve to develop a landscape management model that accounts for stock distinction; thus protecting groups of bull trout that may be functioning as a core meta-population that preserves genetic integrity of smaller populations. Landscape approaches to managing Upper Fraser bull trout should serve to understand how access, resource extraction and large scale climate change may affect distribution and life-history patterns of bull trout.

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# APPENDIX

# I

# PHOTO PLATES


Photoplate 1: Example of bull trout caught during reconnaissance sampling on July 19, 2002.

Photoplate 2: Sub-adult or resident bull trout sampled on July 19, 2002.


Photoplate 3: Radio-tagged bull trout (August 8, 2002).

Photoplate 4: Male bull trout tagged on August 08, 2002.

Photoplate 5: Juvenile bull trout observed during redd counts on September 17, 2002.

Photoplate 6: High density bull trout spawning area on the Upper Goat River during September 17, 2002.

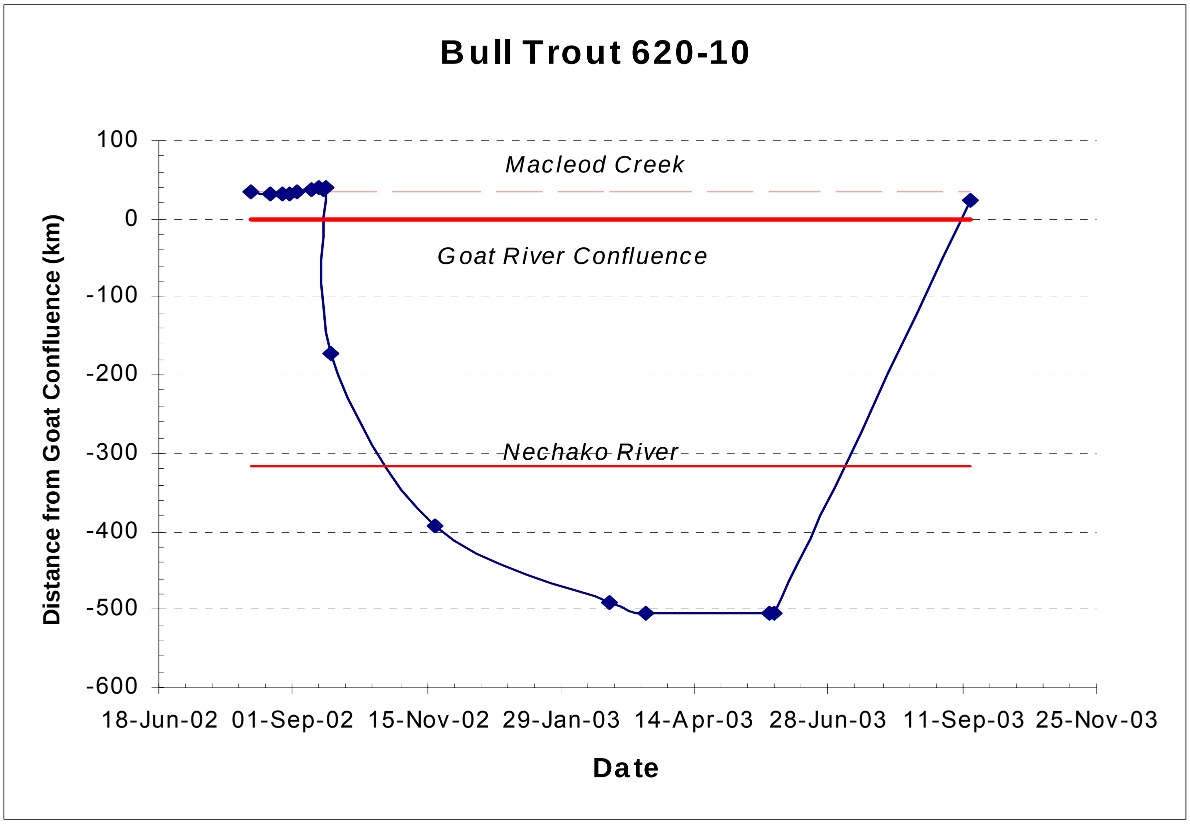
Photoplate 7: An example of ground water influence coupled with large woody debris serves to create ideal site conditions for spawning bull trout.

Photoplate 8: Large bull trout caught staging below the Goat River/ Macleod Creek area during August 2004.

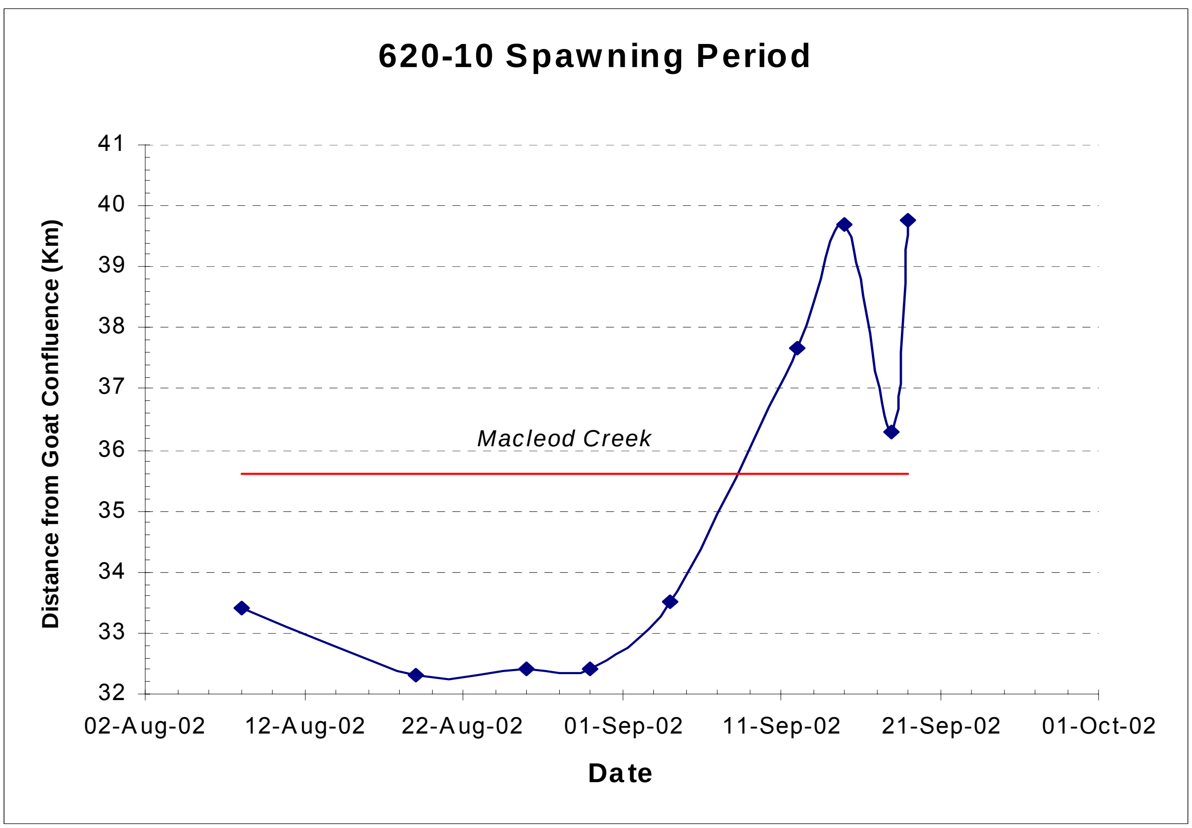
# APPENDIX

# II

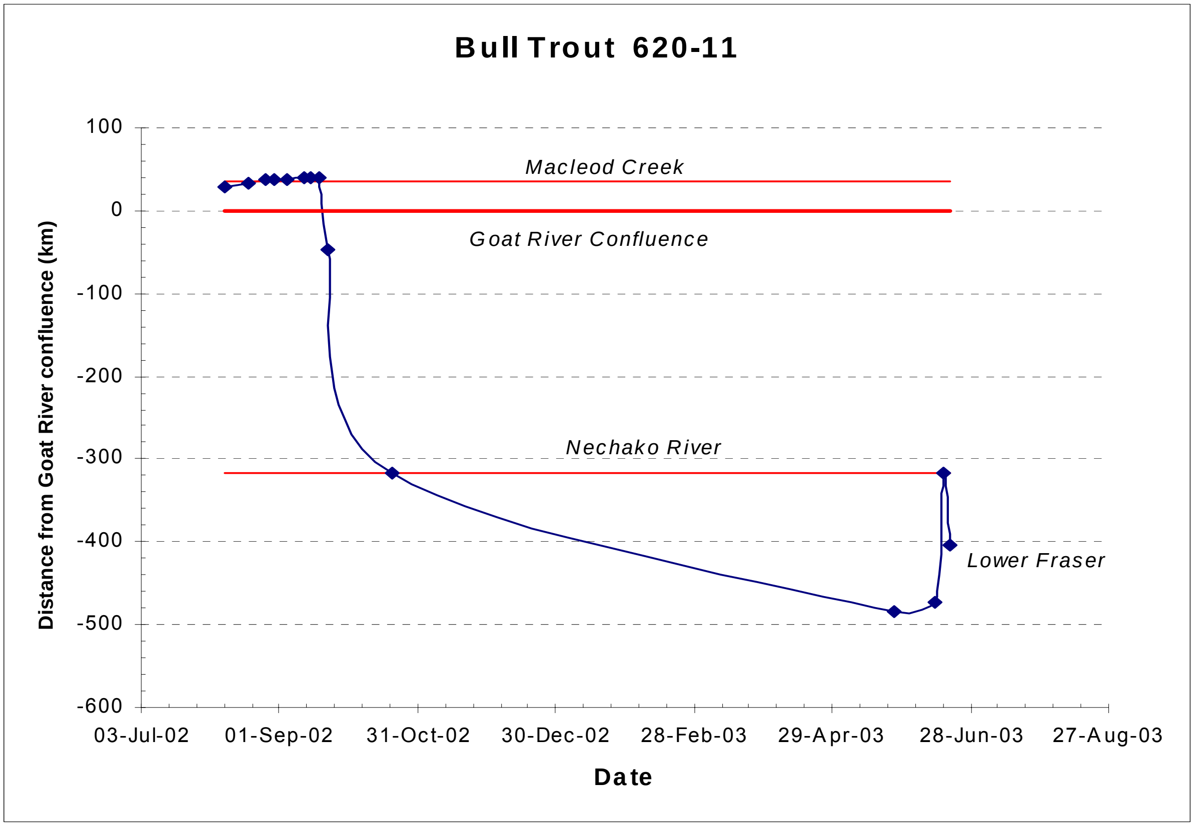
# TELEMETRY GRAPHS

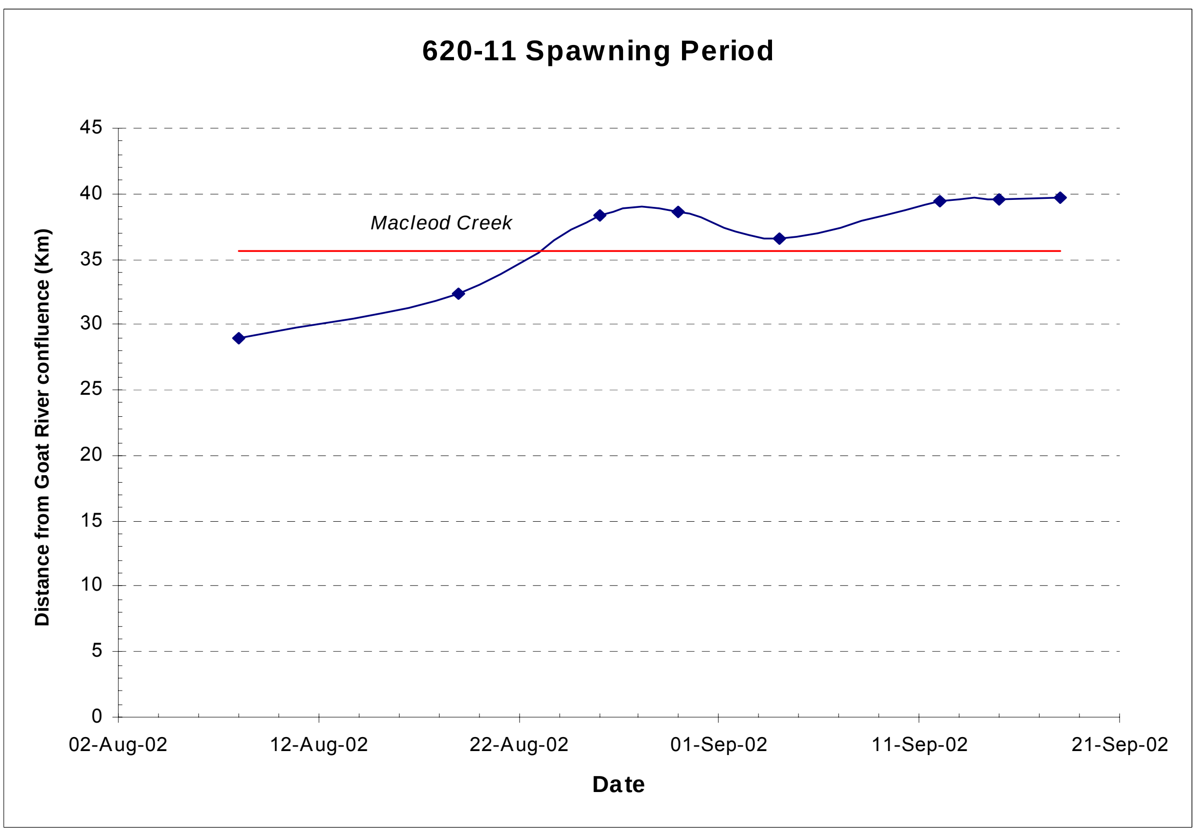


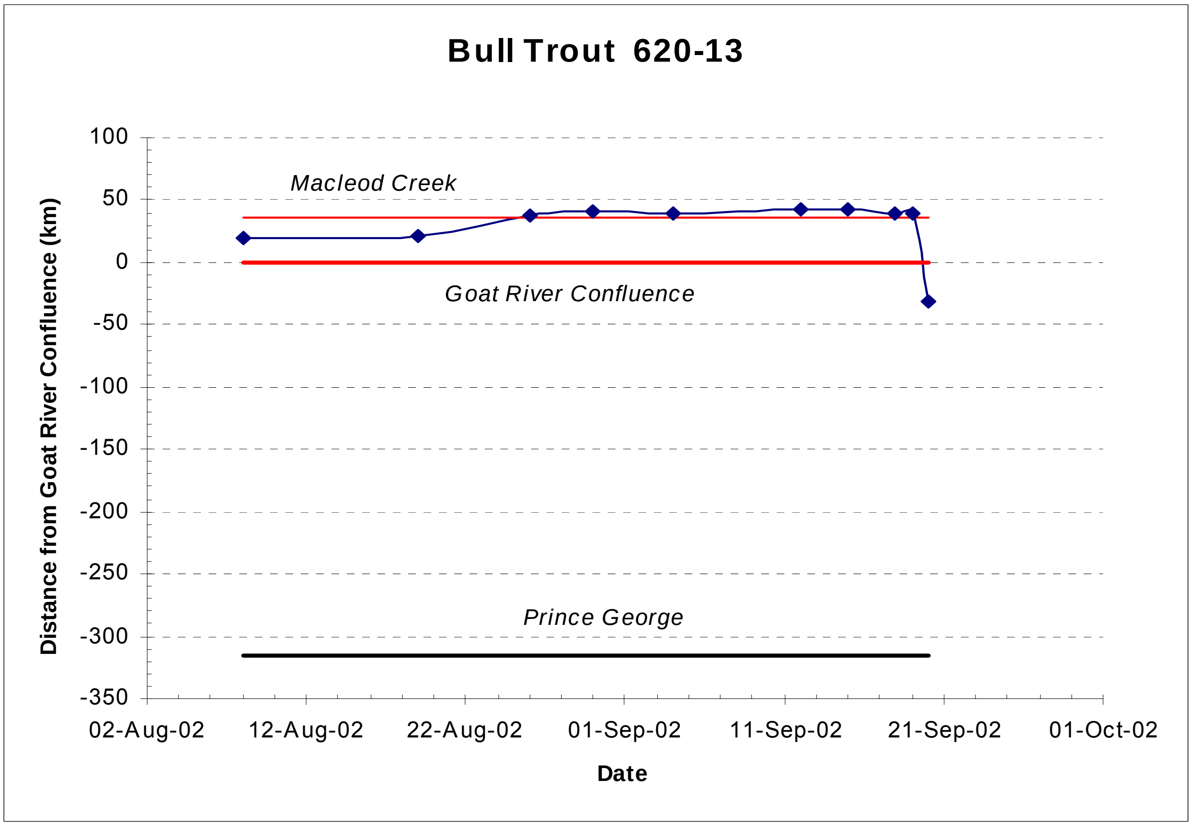
Bull Trout 620-10
Macleod Creek
Goat River Confluence
Nechako River
Distance from Goat Confluence (km)
100
0
-100
-200
-300
-400
-500
-600
18-Jun-02
01-Sep-02
15-Nov-02
29-Jan-03
14-Apr-03
28-Jun-03
11-Sep-03
25-Nov-03
Date

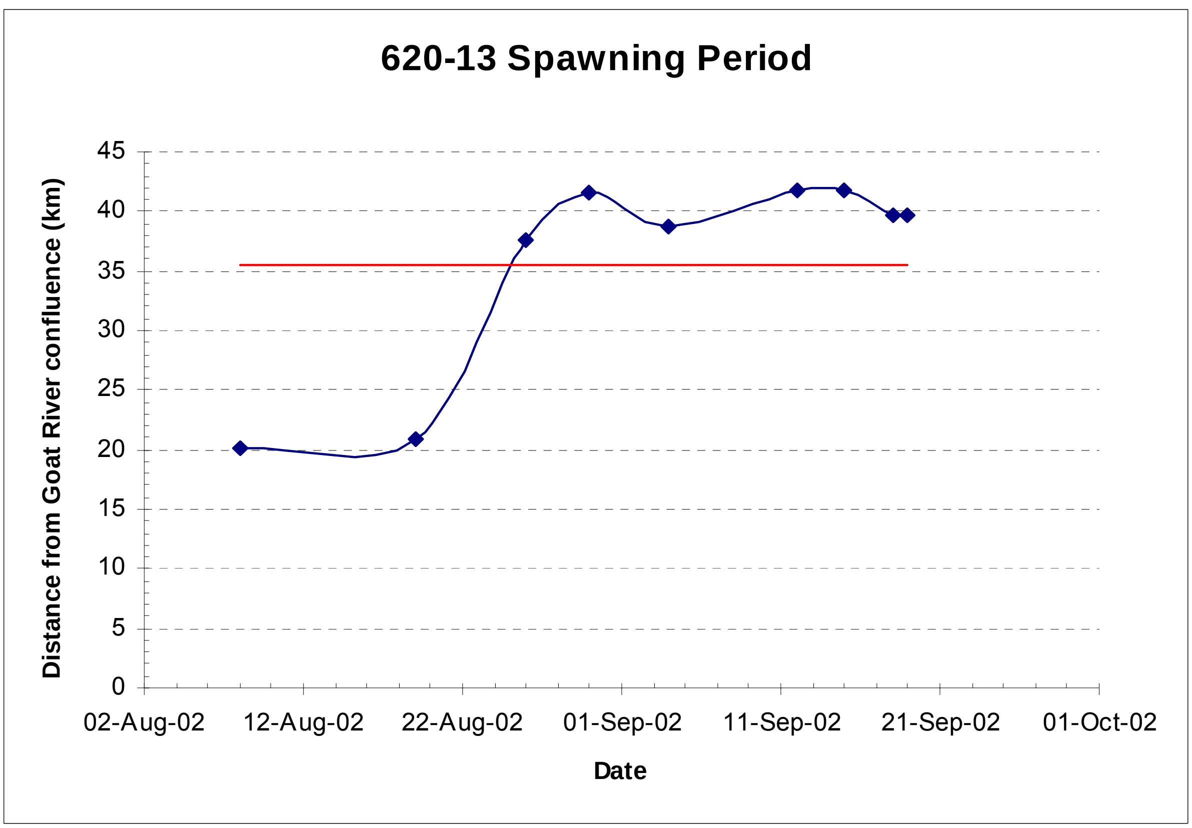
620-10 Spawning Period
Macleod Creek
Distance from Goat Confluence (Km)
41
40
39
38
37
36
35
34
33
32
02-Aug-02
12-Aug-02
22-Aug-02
01-Sep-02
11-Sep-02
21-Sep-02
01-Oct-02
Date


Bull Trout 620-11
100
0
-100
-200
-300
-400
-500
-600
Macleod Creek
Goat River Confluence
Nechako River
Lower Fraser
Distance from Goat River confluence (km)
03-Jul-02
01-Sep-02
31-Oct-02
30-Dec-02
28-Feb-03
29-Apr-03
28-Jun-03
27-Aug-03
Date

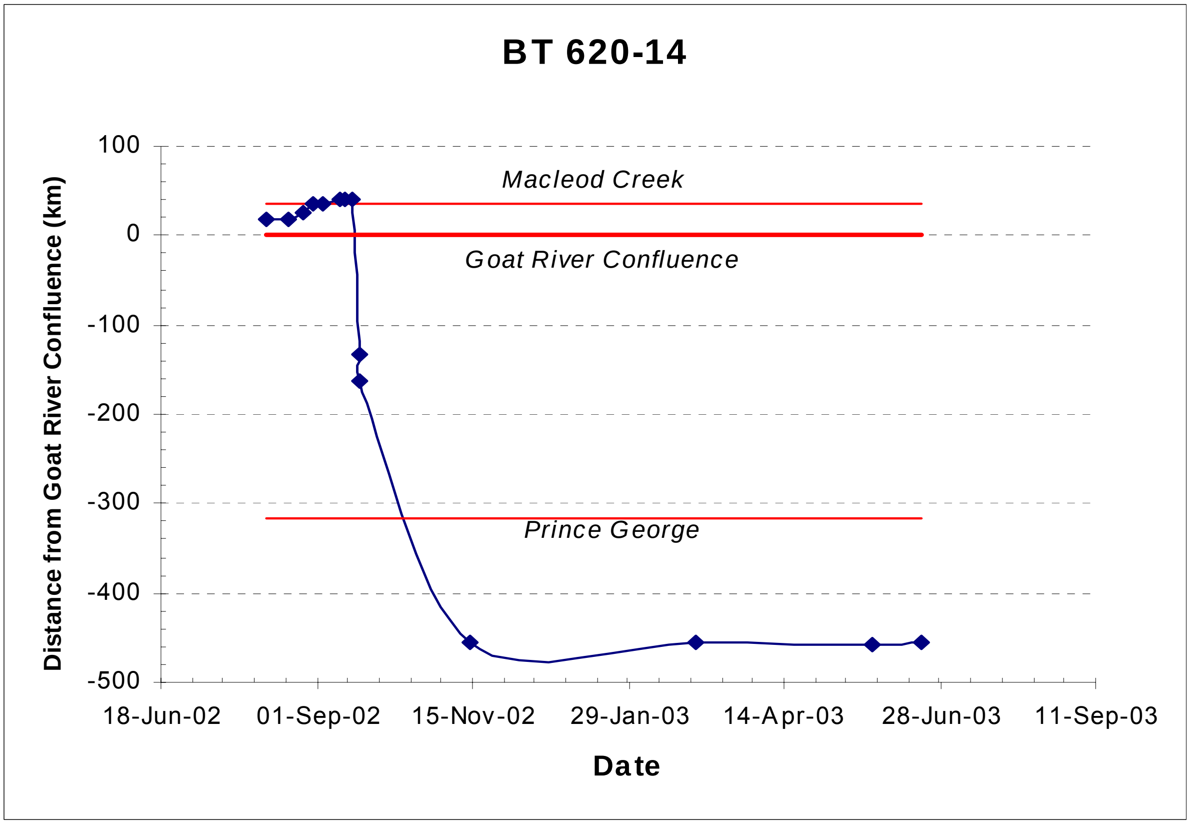

620-11 Spawning Period
45
40
35
30
25
20
15
10
5
0
Macleod Creek
Distance from Goat River confluence (Km)
02-Aug-02
12-Aug-02
22-Aug-02
01-Sep-02
11-Sep-02
21-Sep-02
Date

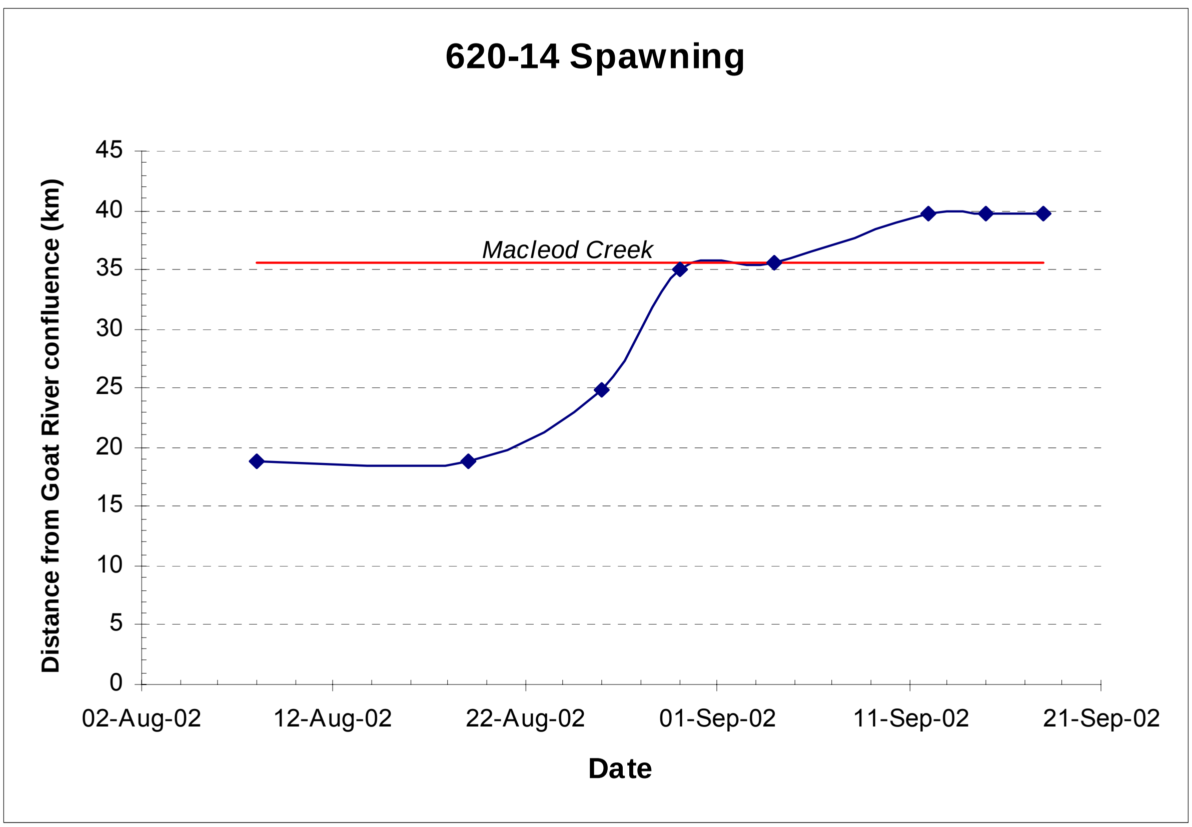


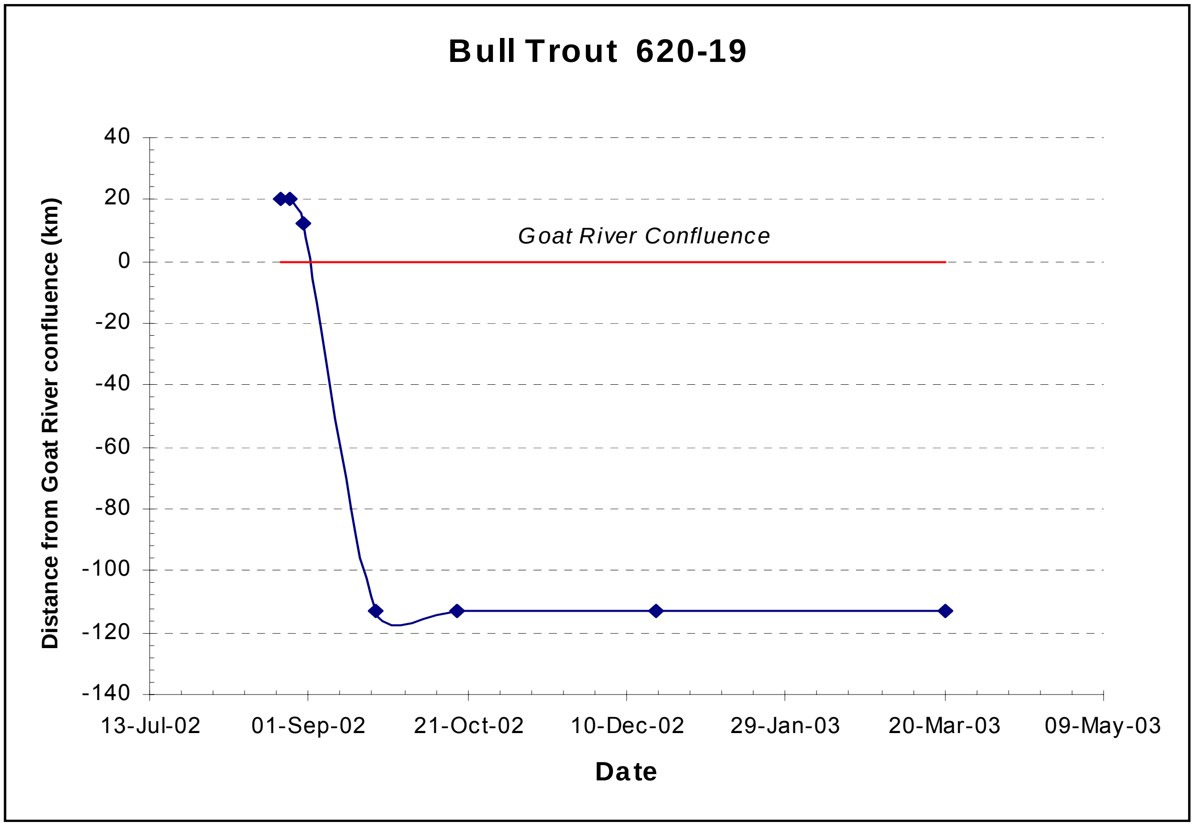
Bull Trout 620-13
Macleod Creek
Goat River Confluence
Prince George
Distance from Goat River Confluence (km)
100
50
0
-50
-100
-150
-200
-250
-300
-350
02-Aug-02
12-Aug-02
22-Aug-02
01-Sep-02
11-Sep-02
21-Sep-02
01-Oct-02
Date

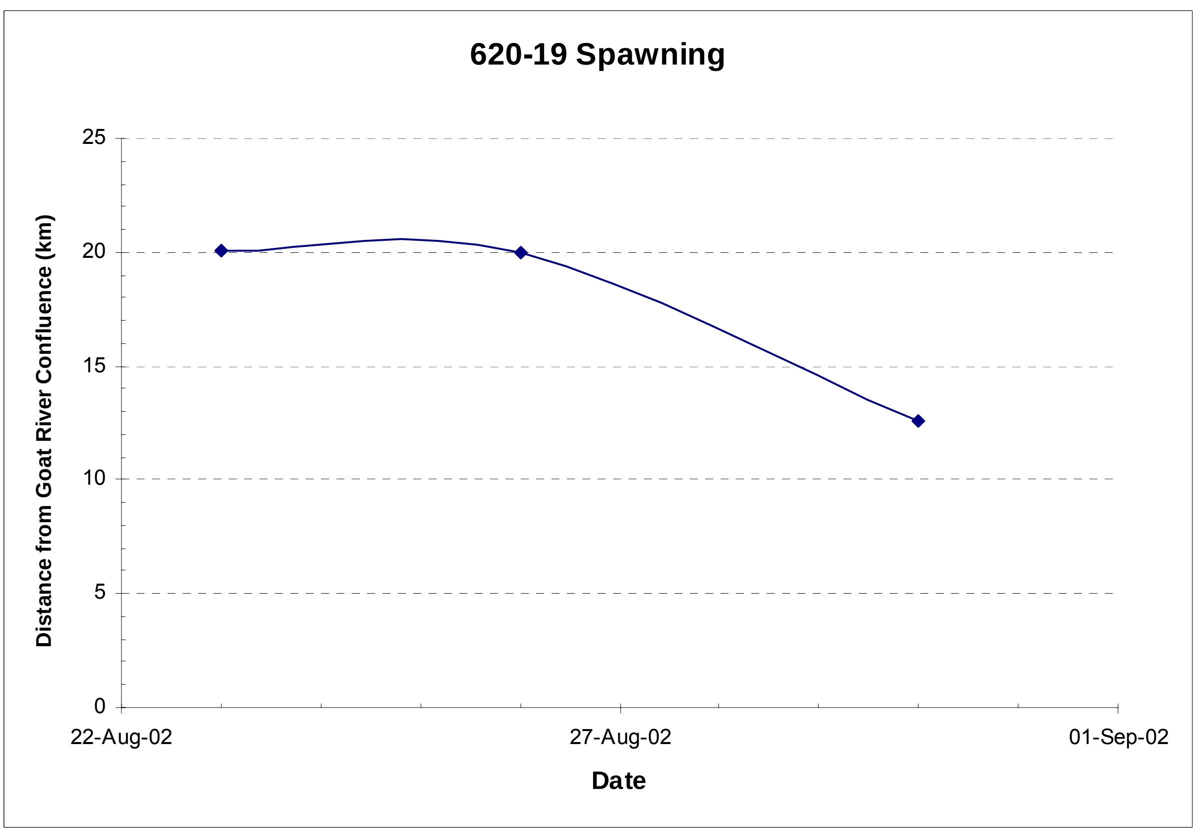
620-13 Spawning Period
Distance from Goat River confluence (km)
45
40
35
30
25
20
15
10
5
0
02-Aug-02
12-Aug-02
22-Aug-02
01-Sep-02
11-Sep-02
21-Sep-02
01-Oct-02
Date


BT 620-14
Macleod Creek
Goat River Confluence
Prince George
Distance from Goat River Confluence (km)
100
0
-100
-200
-300
-400
-500
18-Jun-02
01-Sep-02
15-Nov-02
29-Jan-03
14-Apr-03
28-Jun-03
11-Sep-03
Date

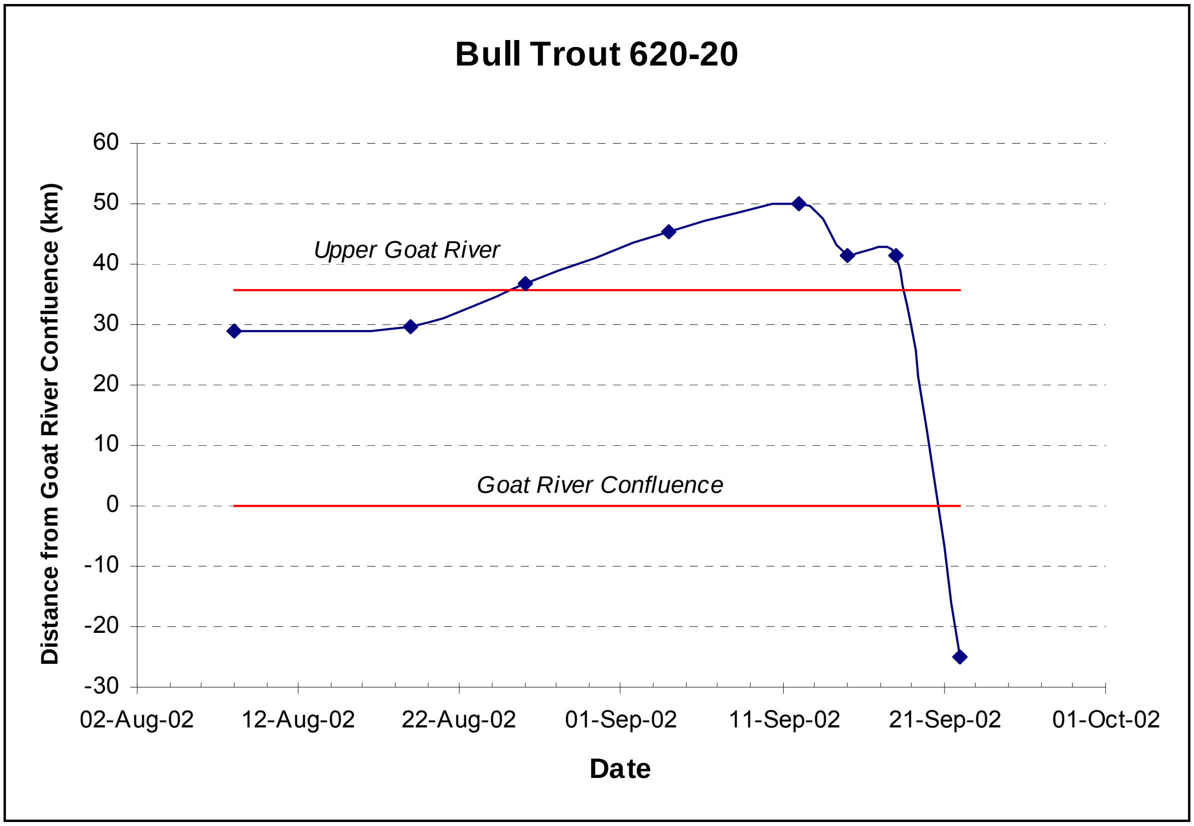

620-14 Spawning
Macleod Creek
Distance from Goat River confluence (km)
45
40
35
30
25
20
15
10
5
0
02-Aug-02
12-Aug-02
22-Aug-02
01-Sep-02
11-Sep-02
21-Sep-02
Date

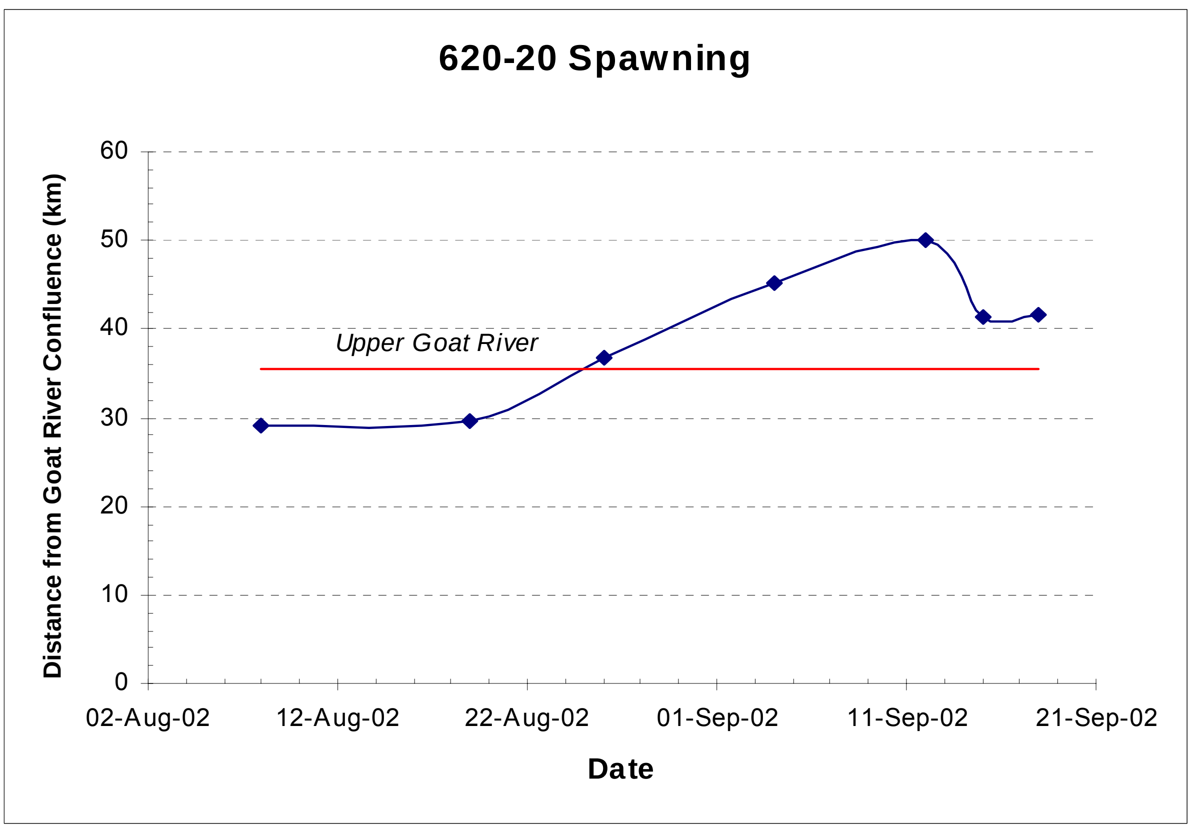


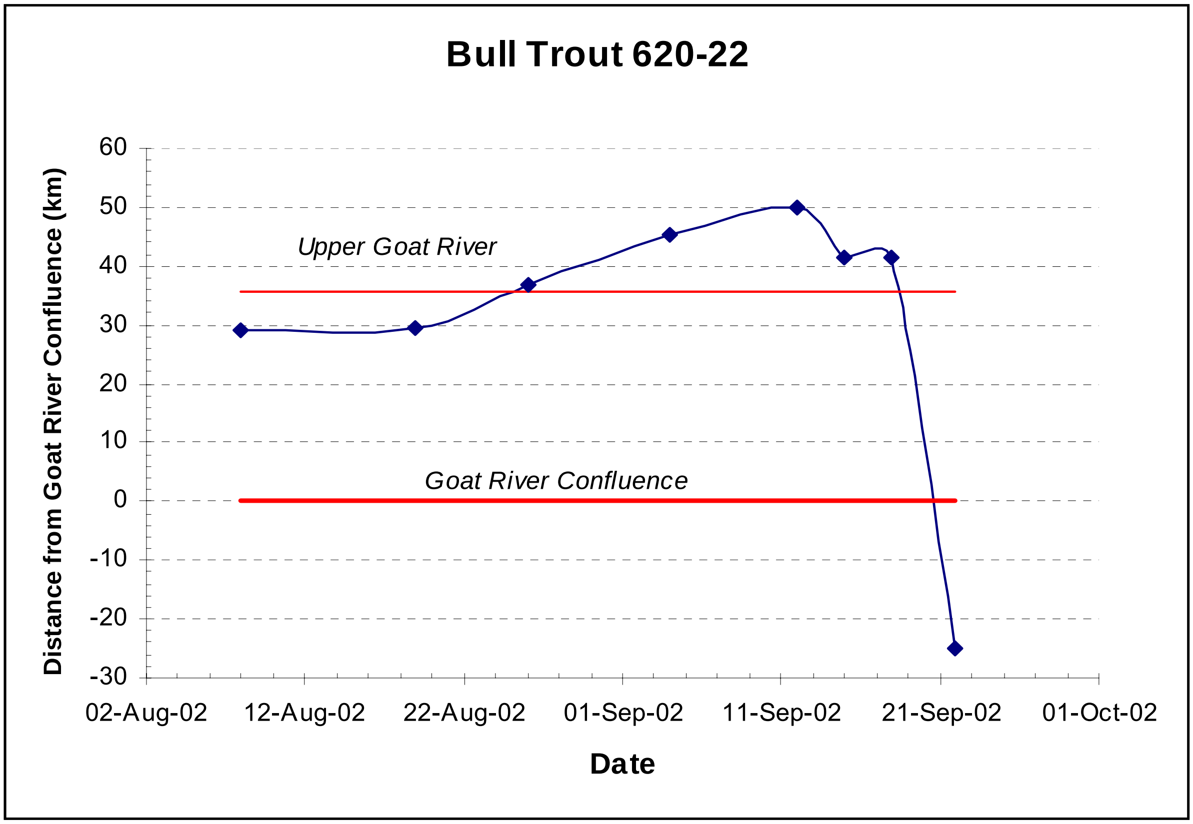
Bull Trout 620-19
Goat River Confluence
Distance from Goat River confluence (km)
40
20
0
-20
-40
-60
-80
-100
-120
-140
13-Jul-02
01-Sep-02
21-Oct-02
10-Dec-02
29-Jan-03
20-Mar-03
09-May-03
Date

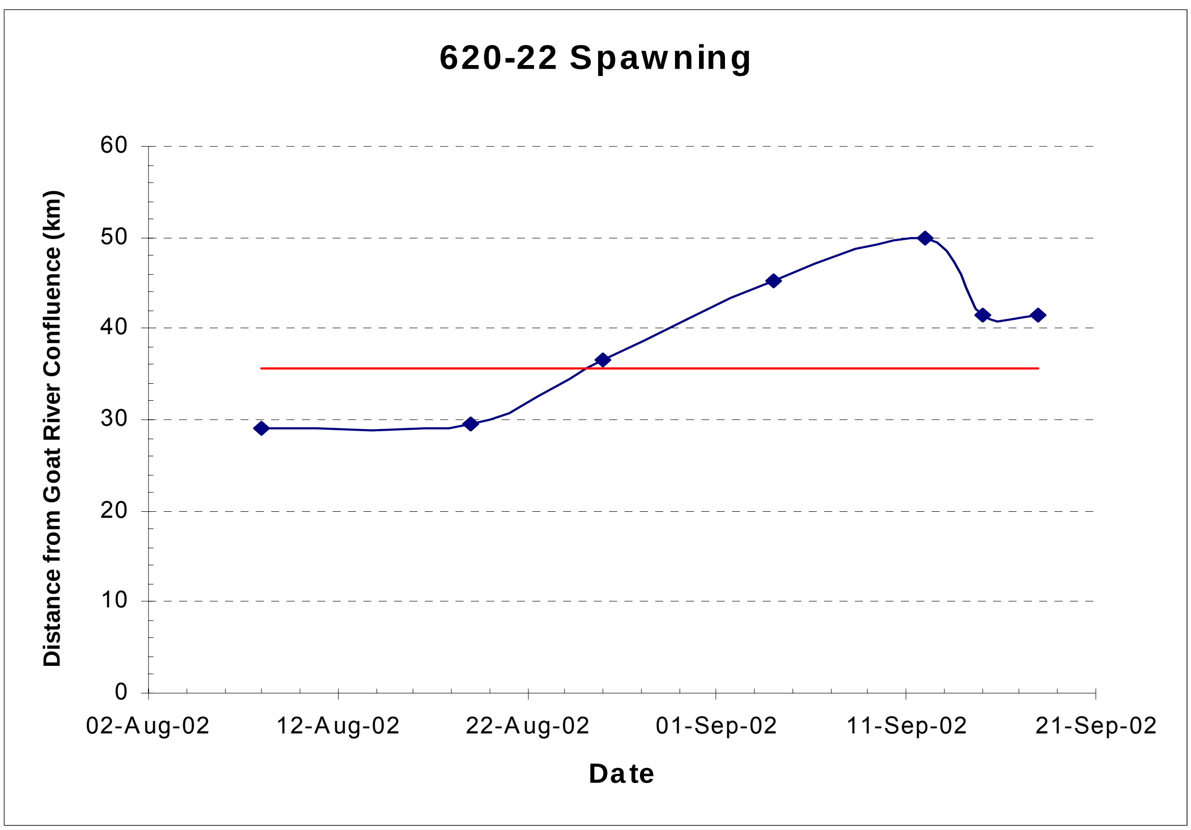
620-19 Spawning
Distance from Goat River Confluence (km)
25
20
15
10
5
0
22-Aug-02
27-Aug-02
01-Sep-02
Date


Bull Trout 620-20
Distance from Goat River Confluence (km)
60
50
40
30
20
10
0
-10
-20
-30
Upper Goat River
Goat River Confluence
02-Aug-02
12-Aug-02
22-Aug-02
01-Sep-02
11-Sep-02
21-Sep-02
01-Oct-02
Date

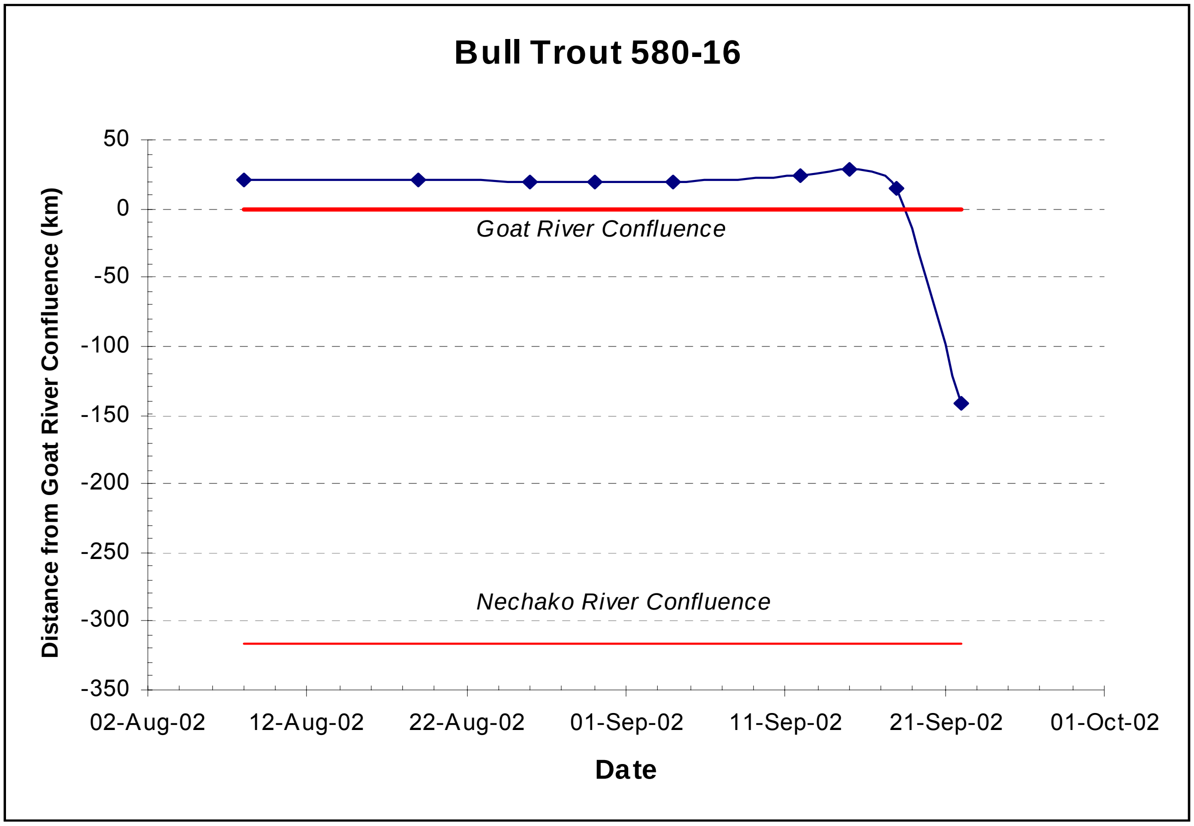

620-20 Spawning
Distance from Goat River Confluence (km)
60
50
40
30
20
10
0
Upper Goat River
02-Aug-02
12-Aug-02
22-Aug-02
01-Sep-02
11-Sep-02
21-Sep-02
Date

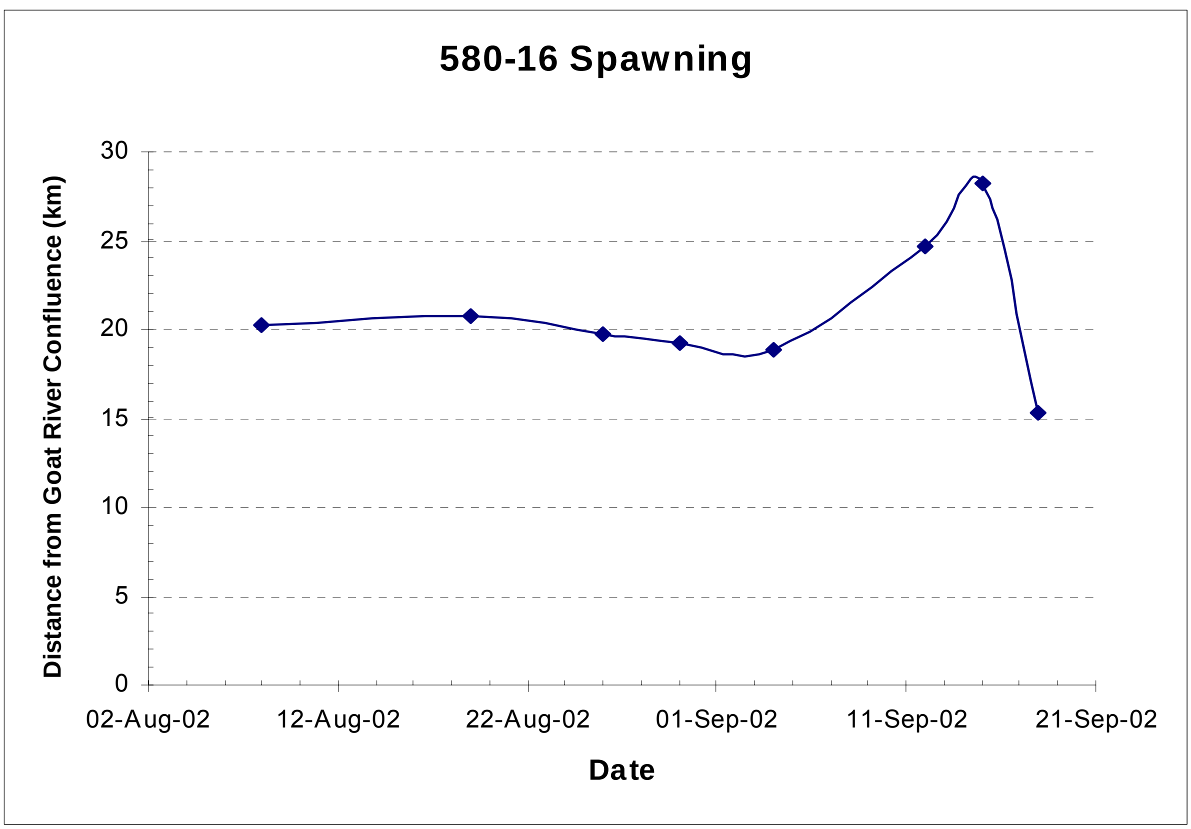


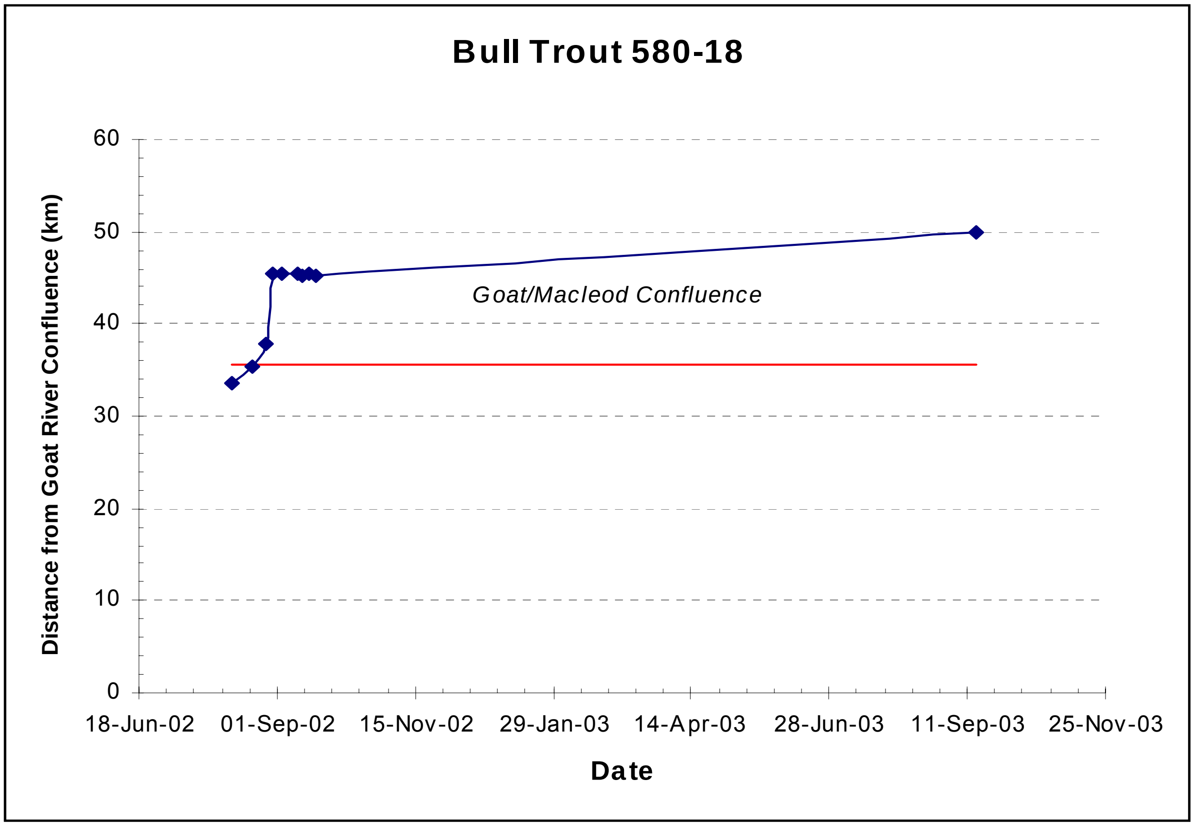
Bull Trout 620-22
Upper Goat River
Goat River Confluence
Distance from Goat River Confluence (km)
60
50
40
30
20
10
0
-10
-20
-30
02-Aug-02
12-Aug-02
22-Aug-02
01-Sep-02
11-Sep-02
21-Sep-02
01-Oct-02
Date

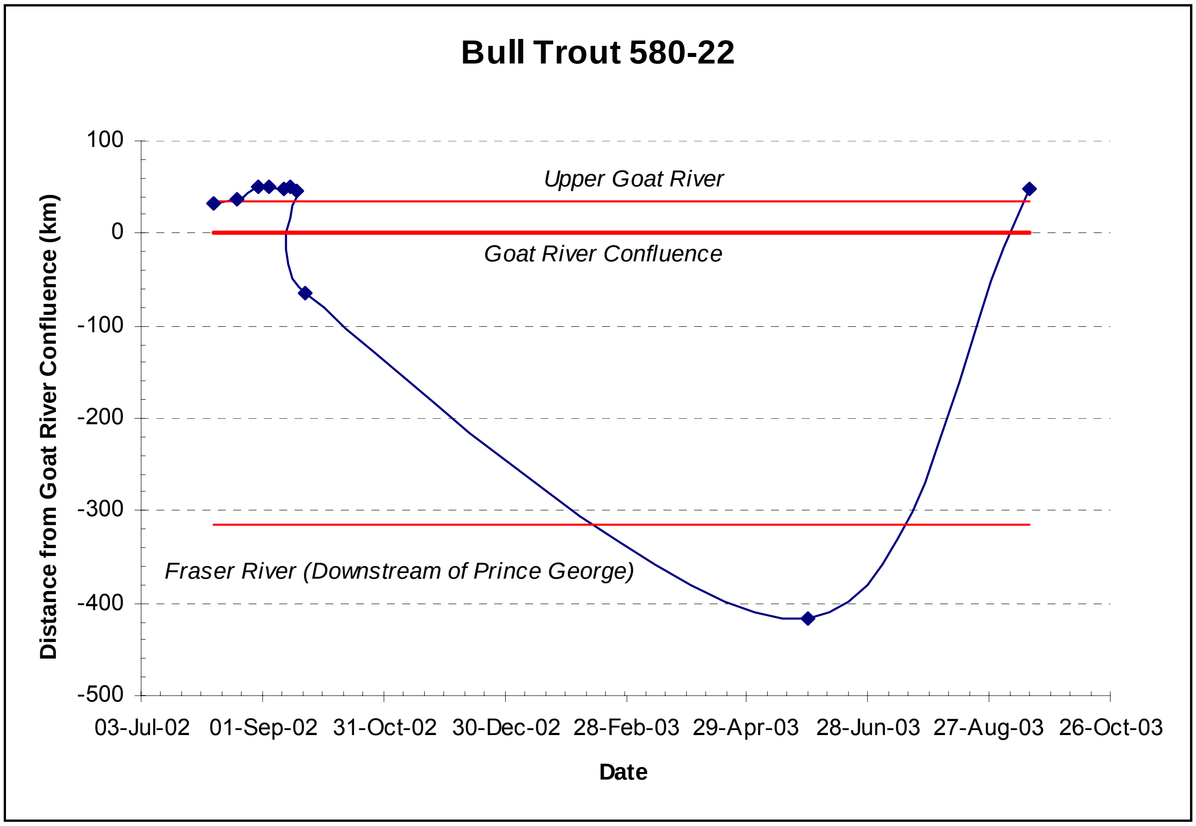



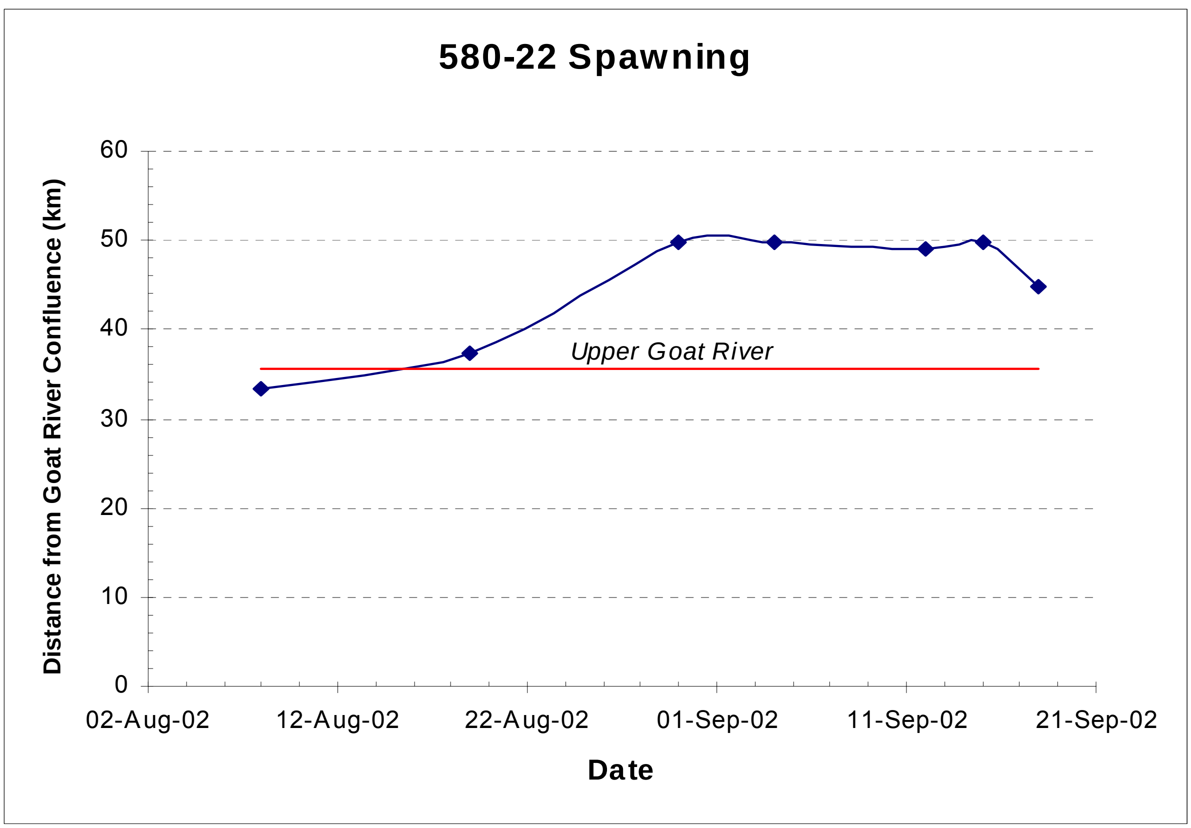
620-22 Spawning
Distance from Goat River Confluence (km)
60
50
40
30
20
10
0
02-Aug-02
12-Aug-02
22-Aug-02
01-Sep-02
11-Sep-02
21-Sep-02
Date

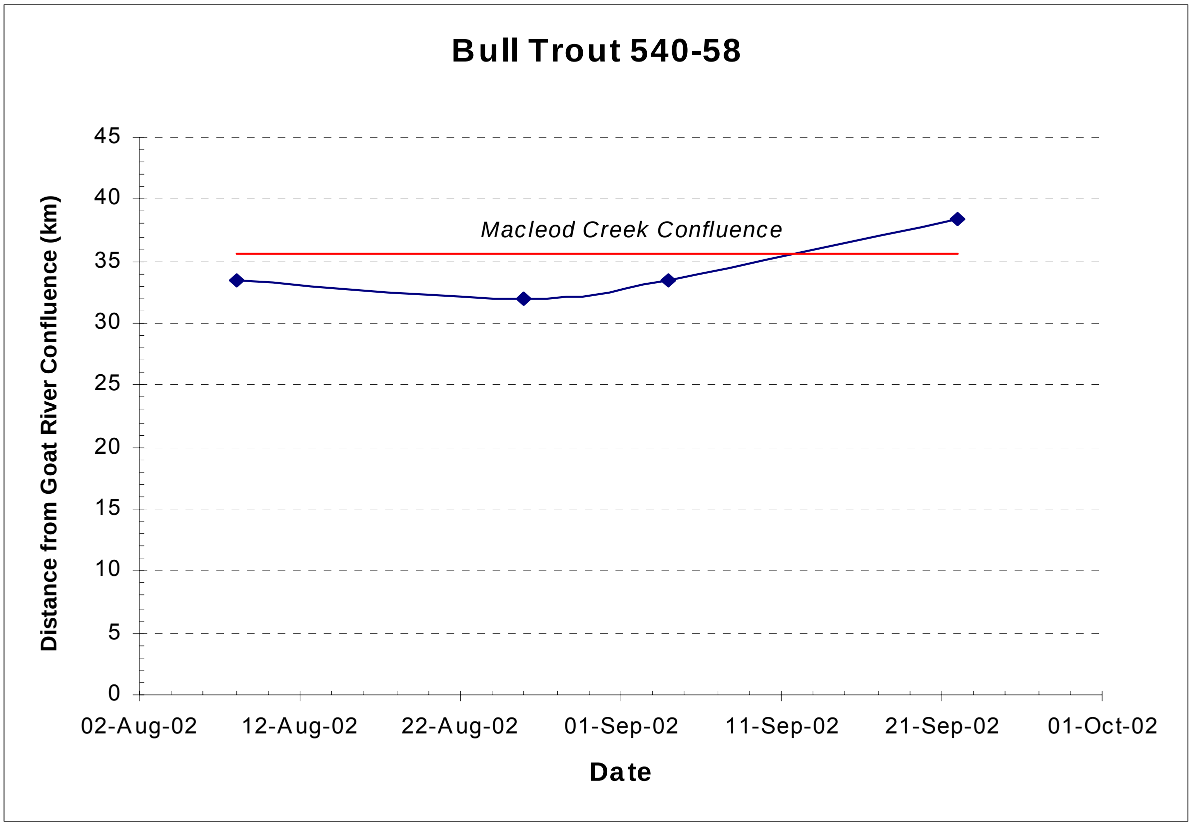

Bull Trout 580-16
50
0
-50
-100
-150
-200
-250
-300
-350
Distance from Goat River Confluence (km)
Goat River Confluence
Nechako River Confluence
02-Aug-02
12-Aug-02
22-Aug-02
01-Sep-02
11-Sep-02
21-Sep-02
01-Oct-02
Date

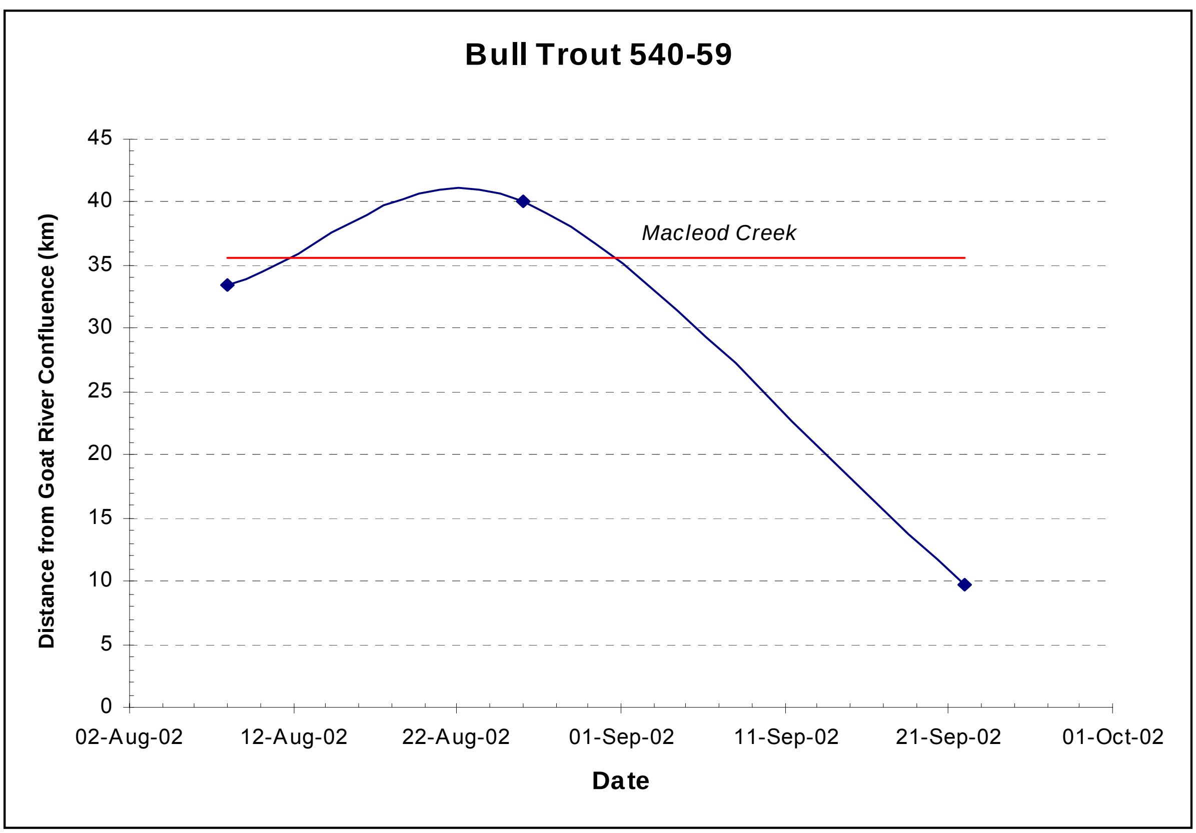

580-16 Spawning
30
25
20
15
10
5
0
Distance from Goat River Confluence (km)
02-Aug-02
12-Aug-02
22-Aug-02
01-Sep-02
11-Sep-02
21-Sep-02
Date

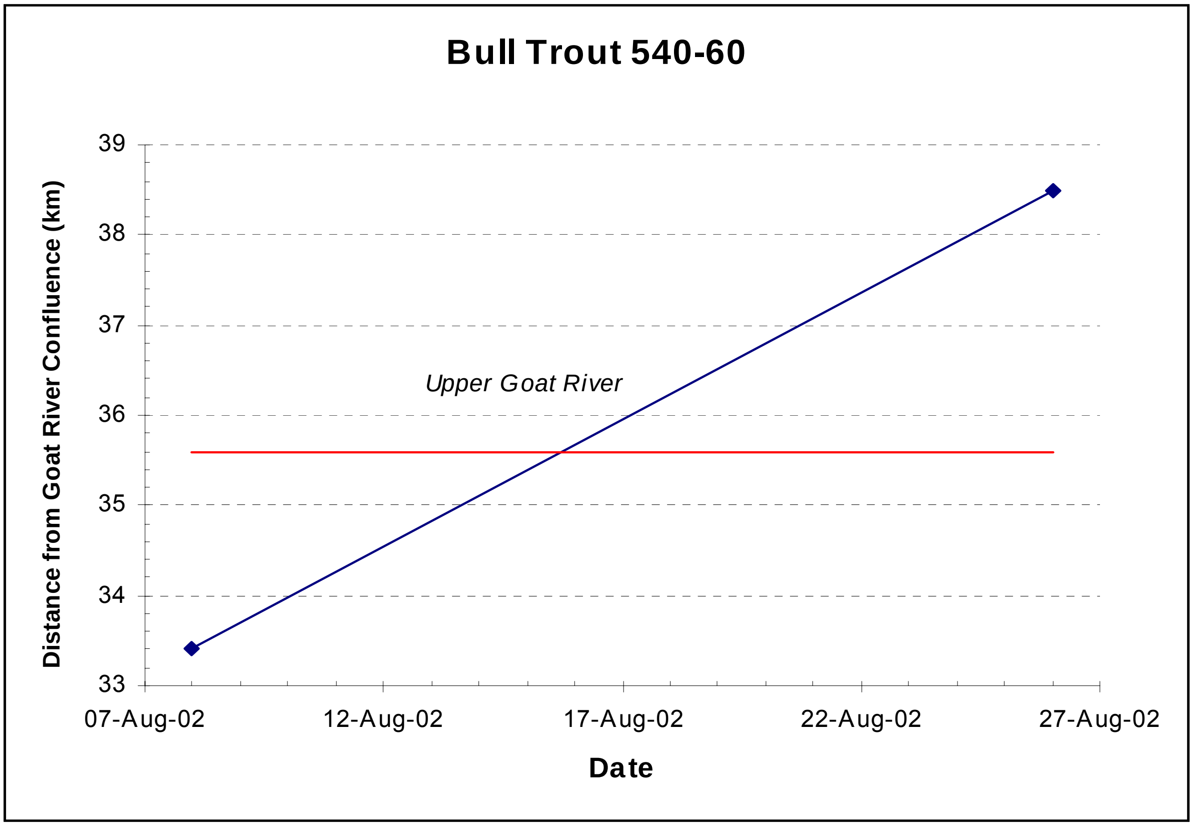

Bull Trout 580-18
Distance from Goat River Confluence (km)
60
50
40
30
20
10
0
Goat/Macleod Confluence
18-Jun-02
01-Sep-02
15-Nov-02
29-Jan-03
14-Apr-03
28-Jun-03
11-Sep-03
25-Nov-03
Date


Bull Trout 580-22
Upper Goat River
Goat River Confluence
Fraser River (Downstream of Prince George)
Distance from Goat River Confluence (km)
100
0
-100
-200
-300
-400
-500
03-Jul-02
01-Sep-02
31-Oct-02
30-Dec-02
28-Feb-03
29-Apr-03
28-Jun-03
27-Aug-03
26-Oct-03
Date

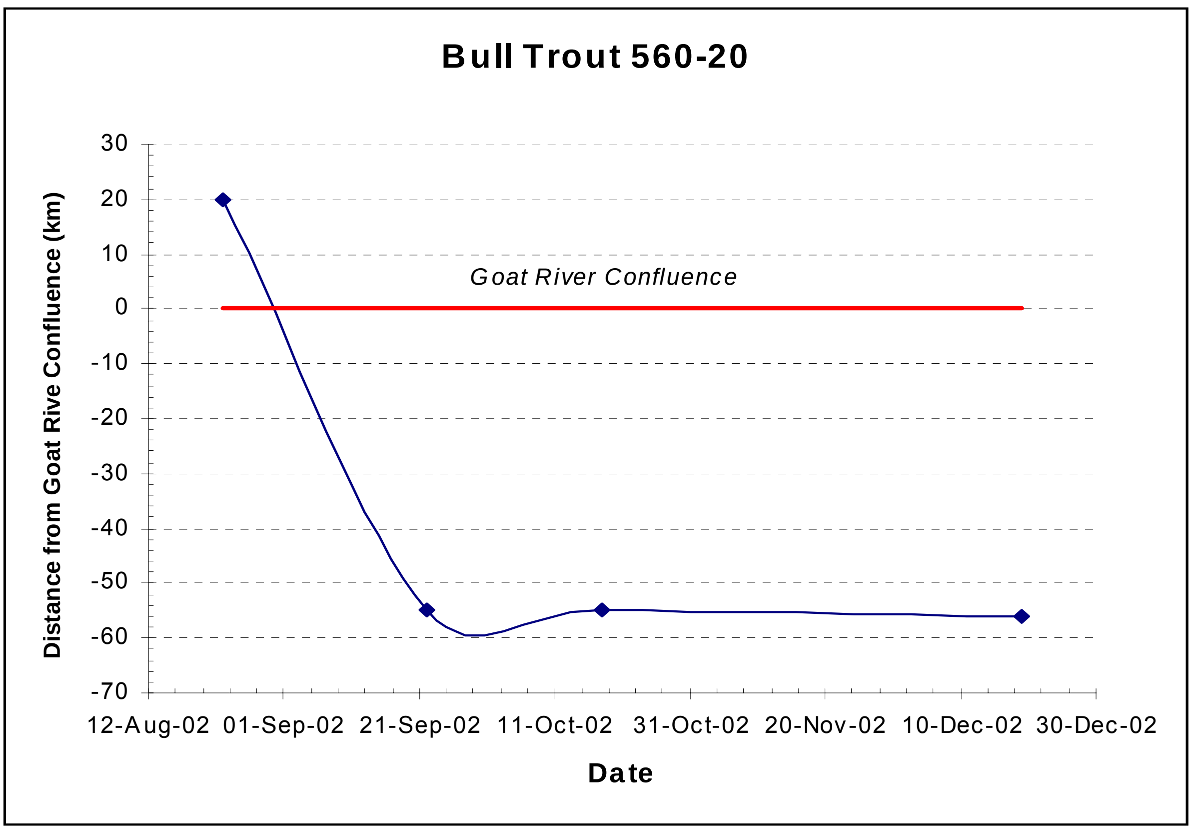

580-22 Spawning
Upper Goat River
Distance from Goat River Confluence (km)
60
50
40
30
20
10
0
02-Aug-02
12-Aug-02
22-Aug-02
01-Sep-02
11-Sep-02
21-Sep-02
Date


Bull Trout 540-58
Macleod Creek Confluence
Distance from Goat River Confluence (km)
45
40
35
30
25
20
15
10
5
0
02-Aug-02
12-Aug-02
22-Aug-02
01-Sep-02
11-Sep-02
21-Sep-02
01-Oct-02
Date

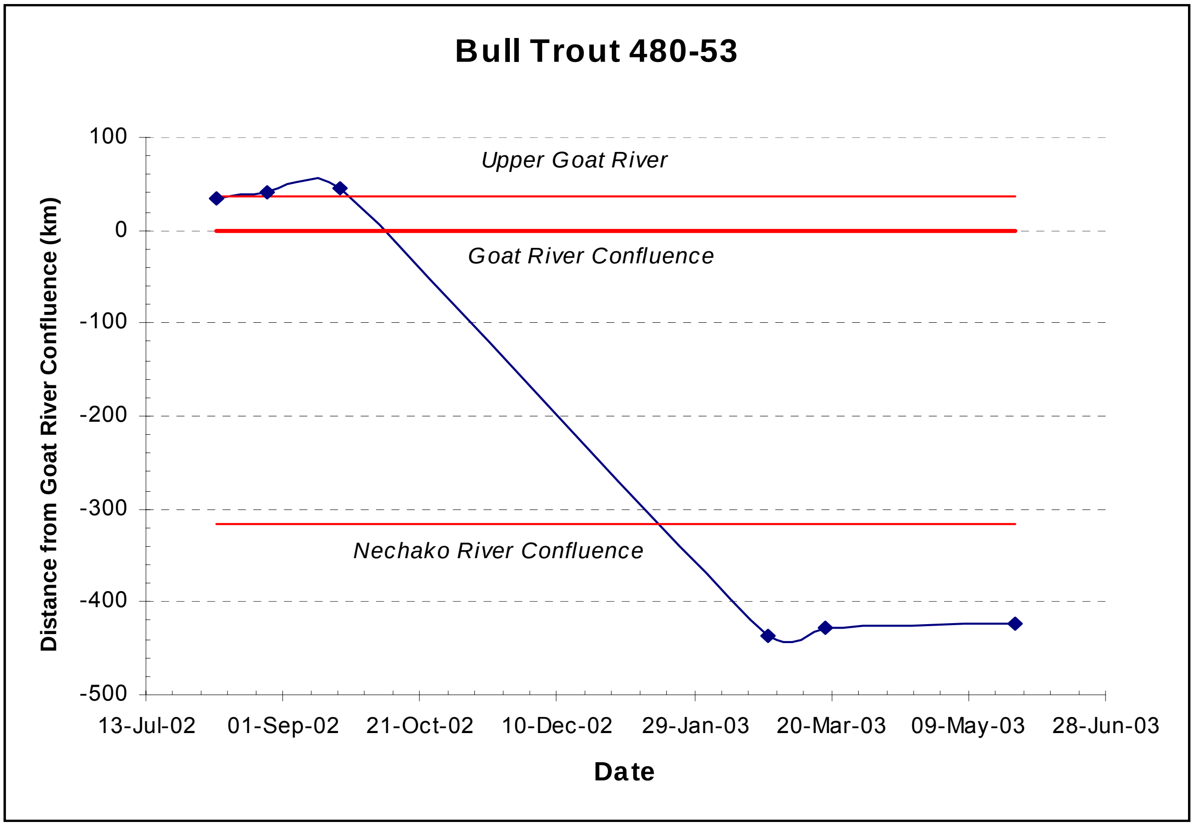

Bull Trout 540-59
Macleod Creek
Distance from Goat River Confluence (km)
45
40
35
30
25
20
15
10
5
0
02-Aug-02
12-Aug-02
22-Aug-02
01-Sep-02
11-Sep-02
21-Sep-02
01-Oct-02
Date

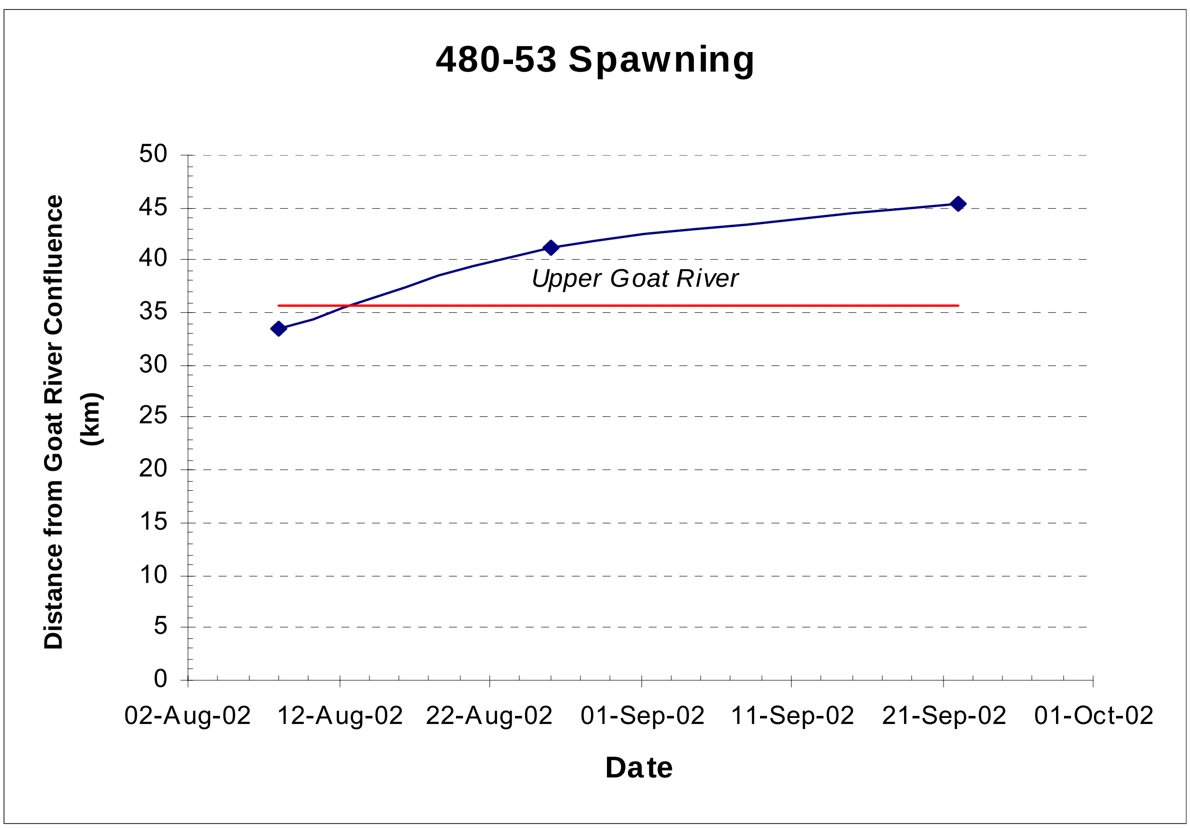


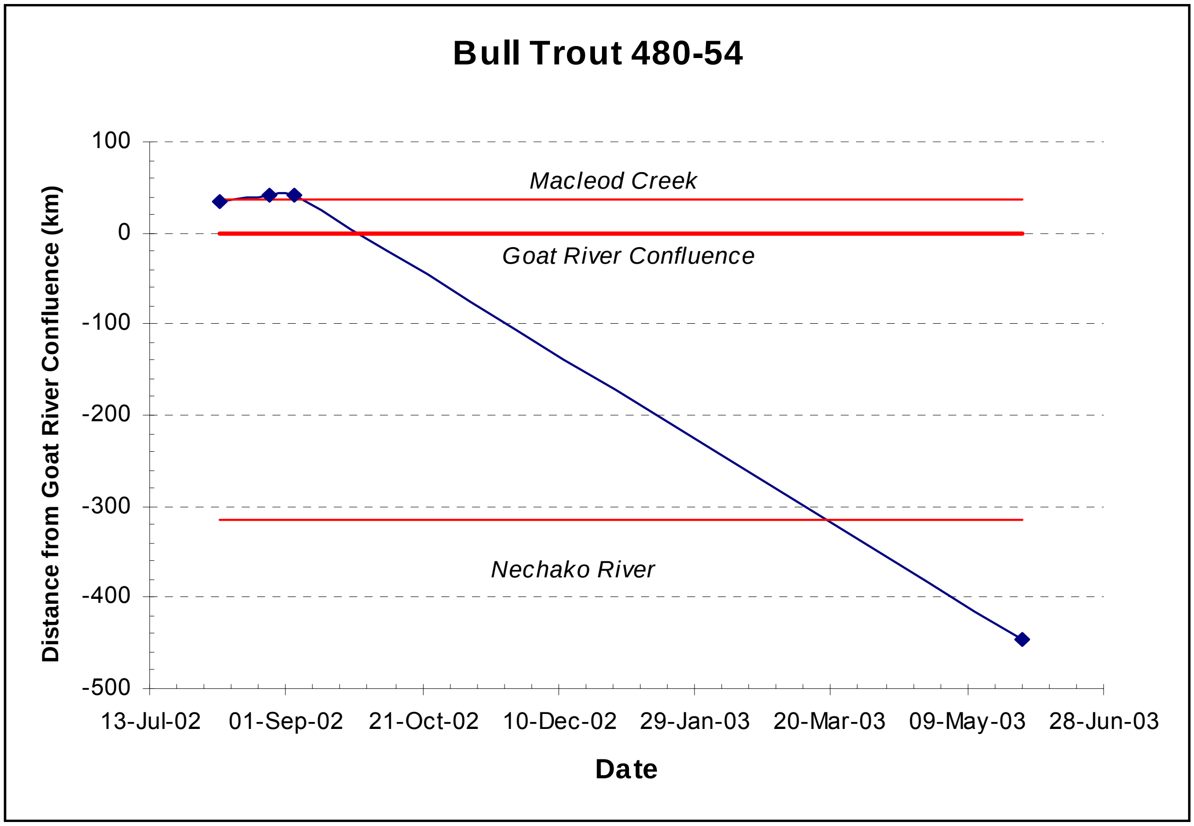
Bull Trout 540-60
Upper Goat River
Distance from Goat River Confluence (km)
39
38
37
36
35
34
33
07-Aug-02
12-Aug-02
17-Aug-02
22-Aug-02
27-Aug-02
Date

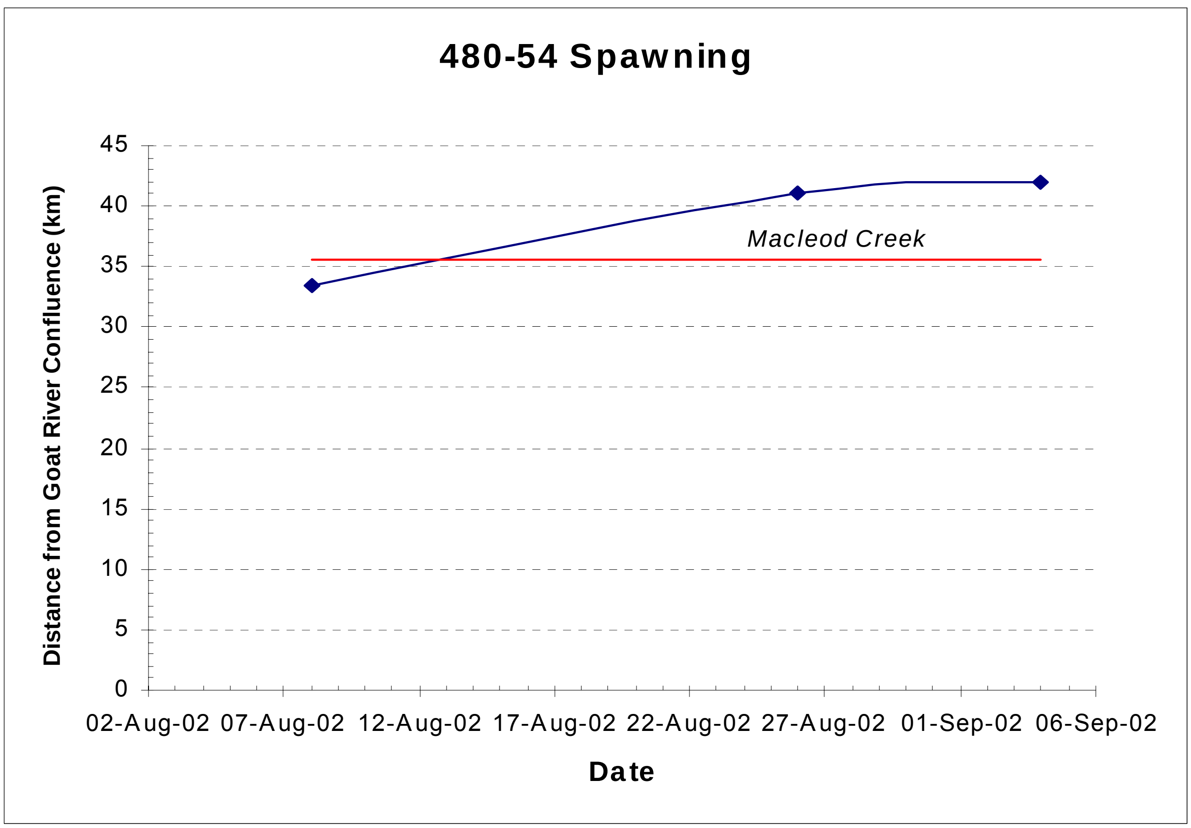



Bull Trout 560-20
Goat River Confluence
Distance from Goat Rive Confluence (km)
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
12-Aug-02
01-Sep-02
21-Sep-02
11-Oct-02
31-Oct-02
20-Nov-02
10-Dec-02
30-Dec-02
Date


Bull Trout 480-53
Upper Goat River
Goat River Confluence
Nechako River Confluence
Distance from Goat River Confluence (km)
100
0
-100
-200
-300
-400
-500
13-Jul-02
01-Sep-02
21-Oct-02
10-Dec-02
29-Jan-03
20-Mar-03
09-May-03
28-Jun-03
Date


480-53 Spawning
Upper Goat River
Distance from Goat River Confluence (km)
50
45
40
35
30
25
20
15
10
5
0
02-Aug-02
12-Aug-02
22-Aug-02
01-Sep-02
11-Sep-02
21-Sep-02
01-Oct-02
Date

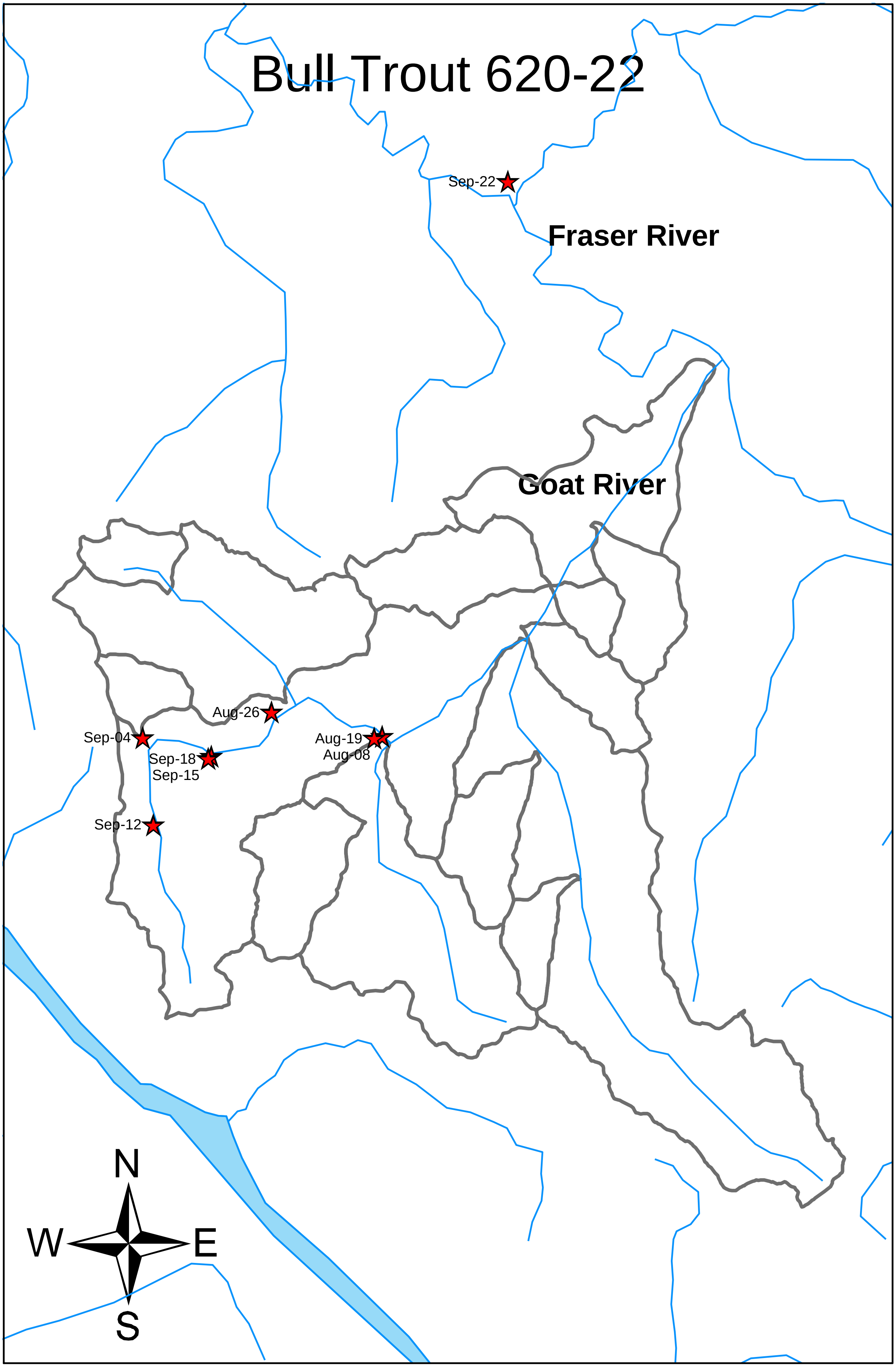

Bull Trout 480-54
Distance from Goat River Confluence (km)
100
0
-100
-200
-300
-400
-500
Macleod Creek
Goat River Confluence
Nechako River
13-Jul-02
01-Sep-02
21-Oct-02
10-Dec-02
29-Jan-03
20-Mar-03
09-May-03
28-Jun-03
Date


480-54 Spawning
Distance from Goat River Confluence (km)
45
40
35
30
25
20
15
10
5
0
Macleod Creek
02-Aug-02
07-Aug-02
12-Aug-02
17-Aug-02
22-Aug-02
27-Aug-02
01-Sep-02
06-Sep-02
Date

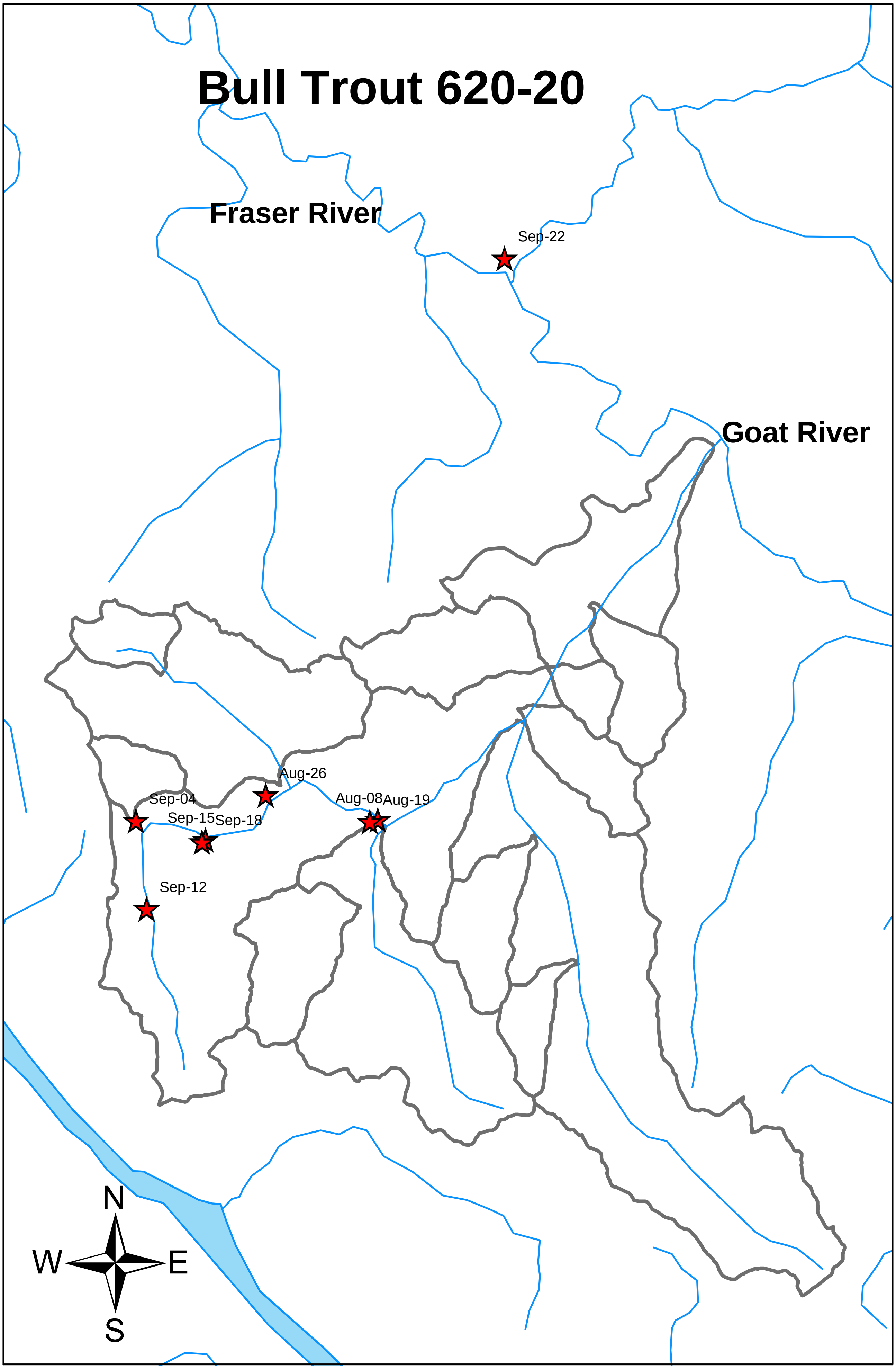
# APPENDIX

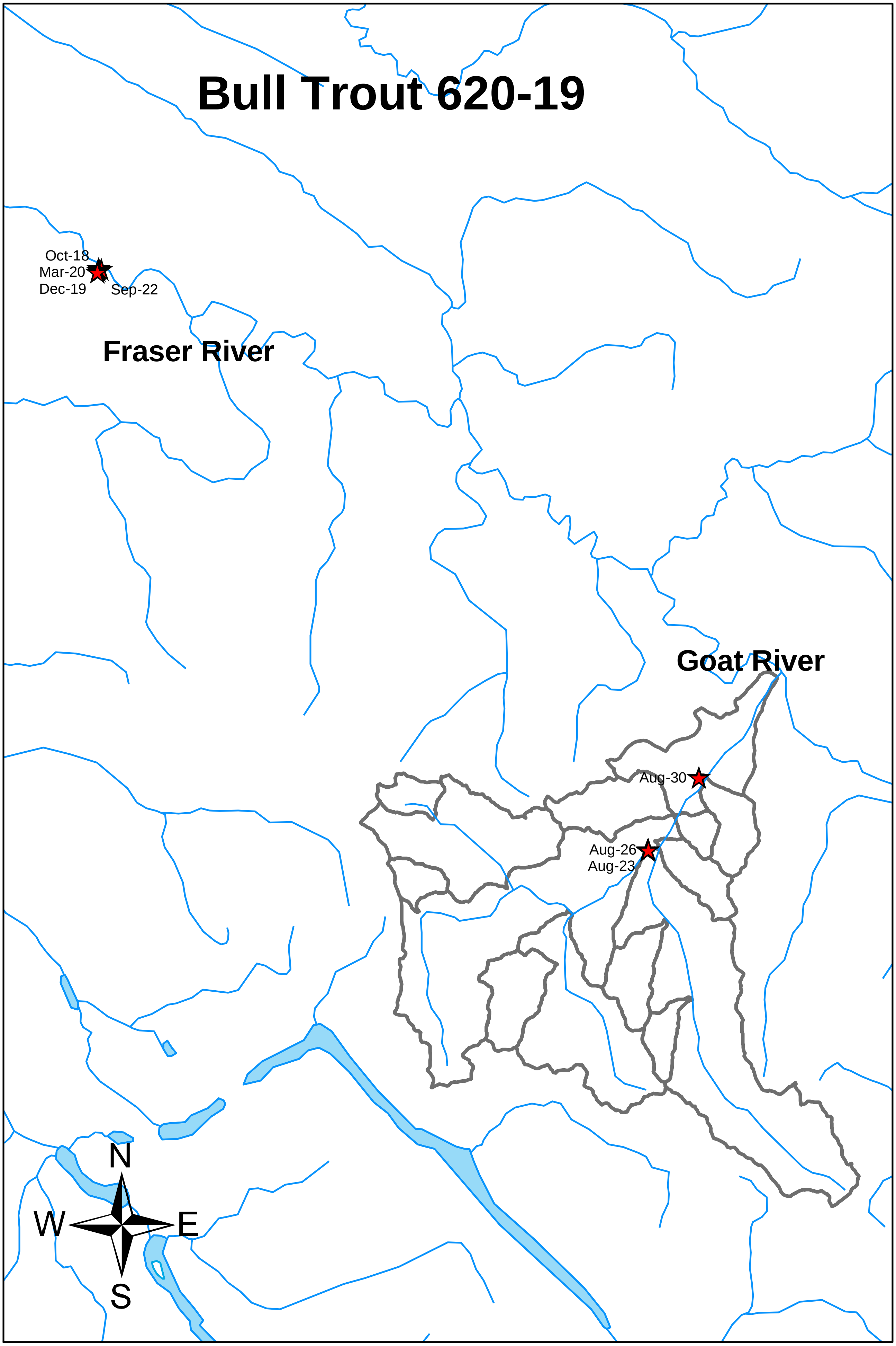
# III

# INDIVIDUAL BULL TROUT MOVEMENT MAPS



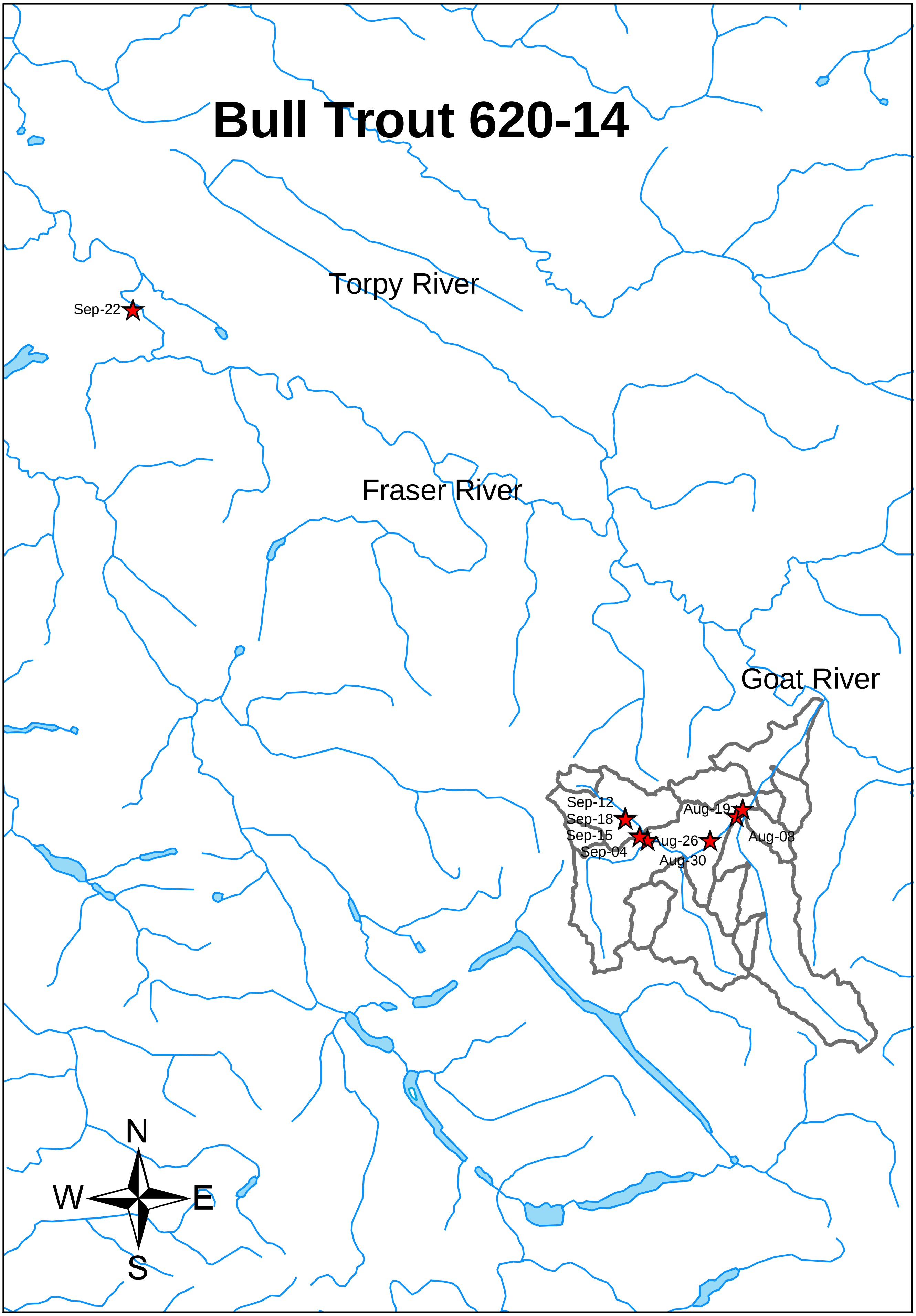
Bull Trout 620-22
Sep-22
Fraser River
Goat River
Aug-26
Sep-04
Aug-19
Aug-08
Sep-18
Sep-15
Sep-12
N
W
E
S

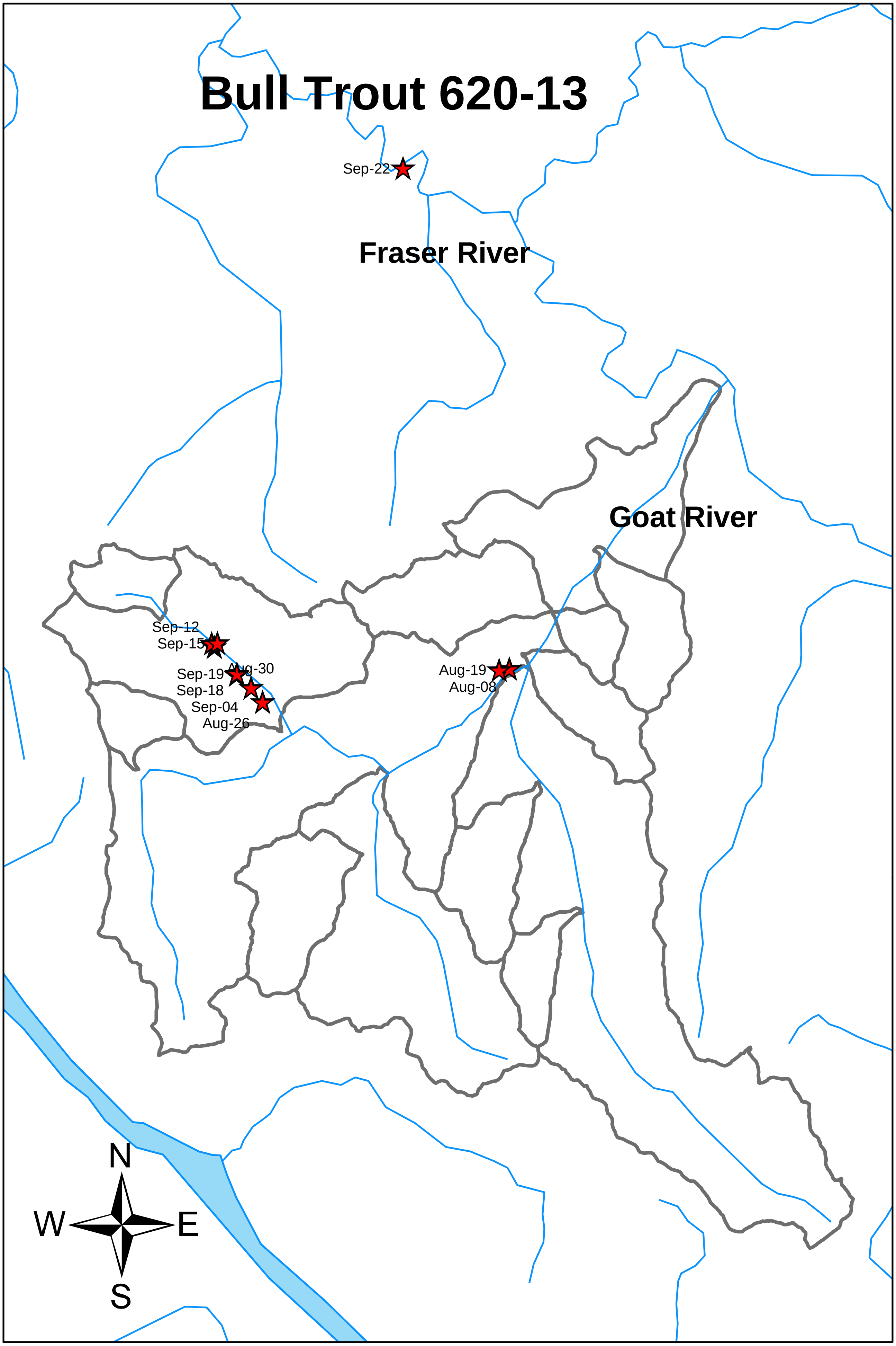

Bull Trout 620-20
Fraser River
Goat River
Sep-22
Aug-26
Sep-04
Sep-15
Sep-18
Aug-08
Aug-19
Sep-12
N
W
E
S



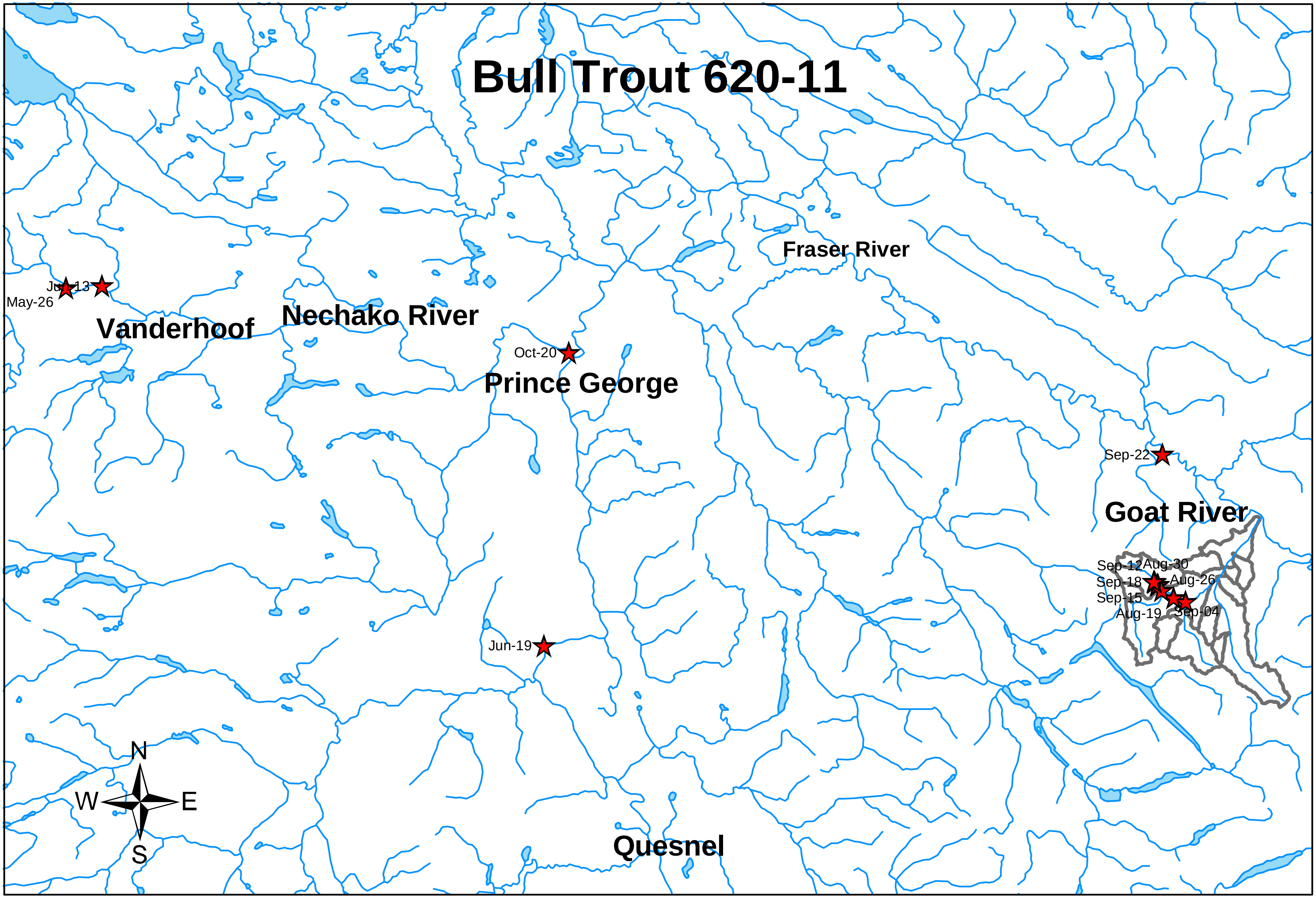
Bull Trout 620-19
Oct-18
Mar-20
Dec-19
Sep-22
Fraser River
Goat River
Aug-30
Aug-26
Aug-23
N
W
E
S

# Bull Trout 620-14

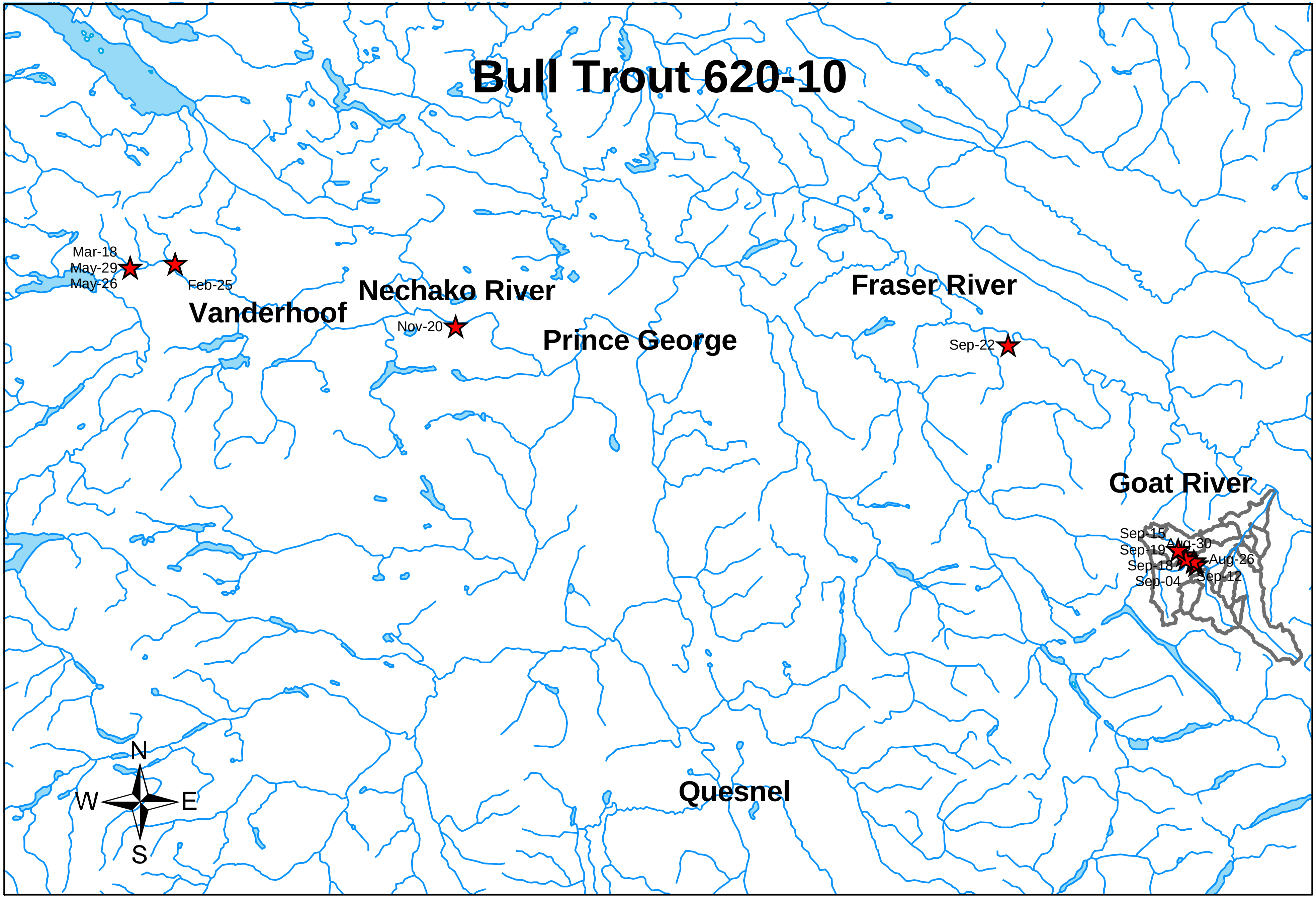




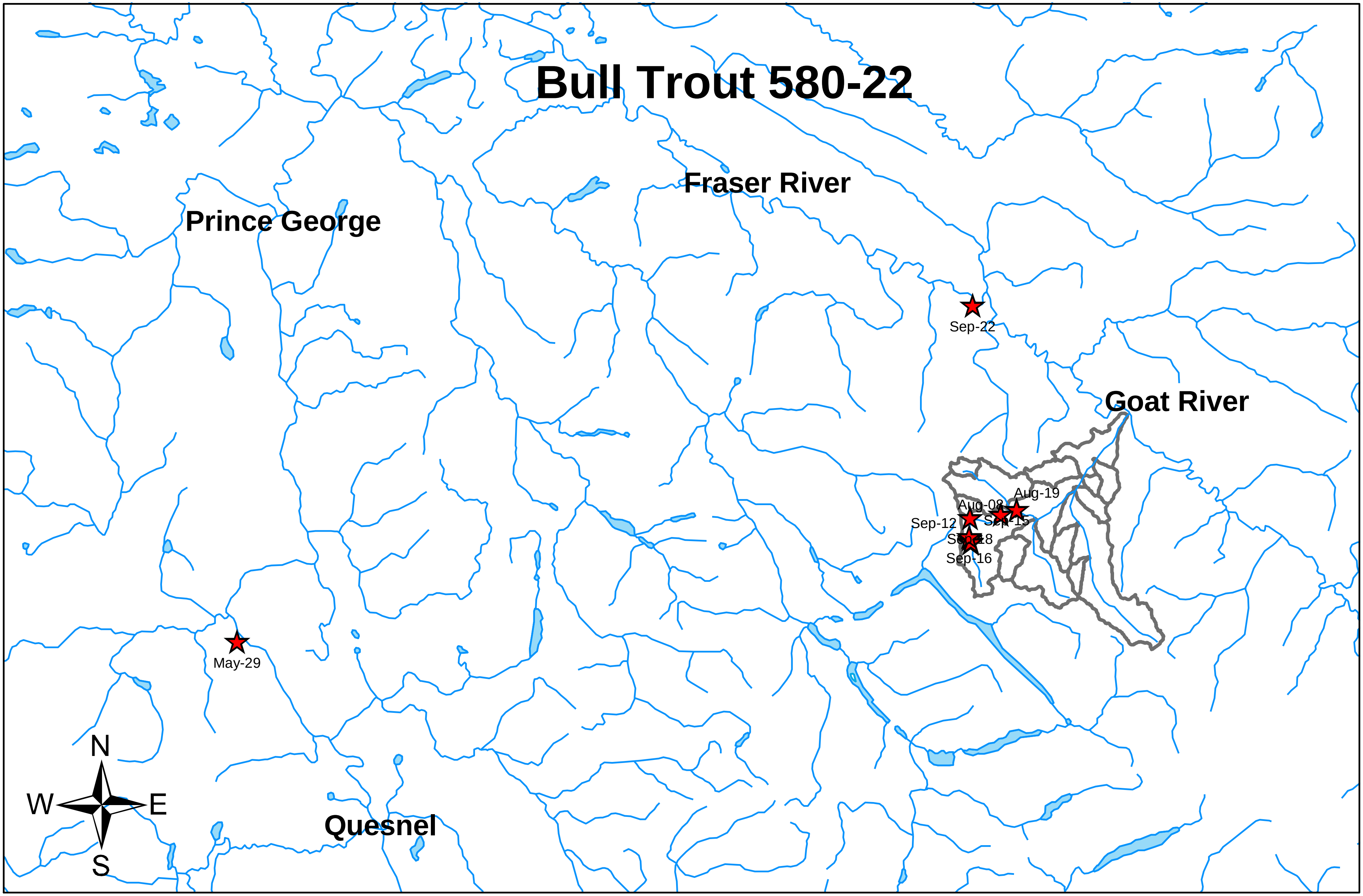
Bull Trout 620-13
Sep-22
Fraser River
Goat River
Sep-12
Sep-15
Sep-19
Aug-30
Sep-18
Sep-04
Aug-26
Aug-19
Aug-08
N
W
E
S

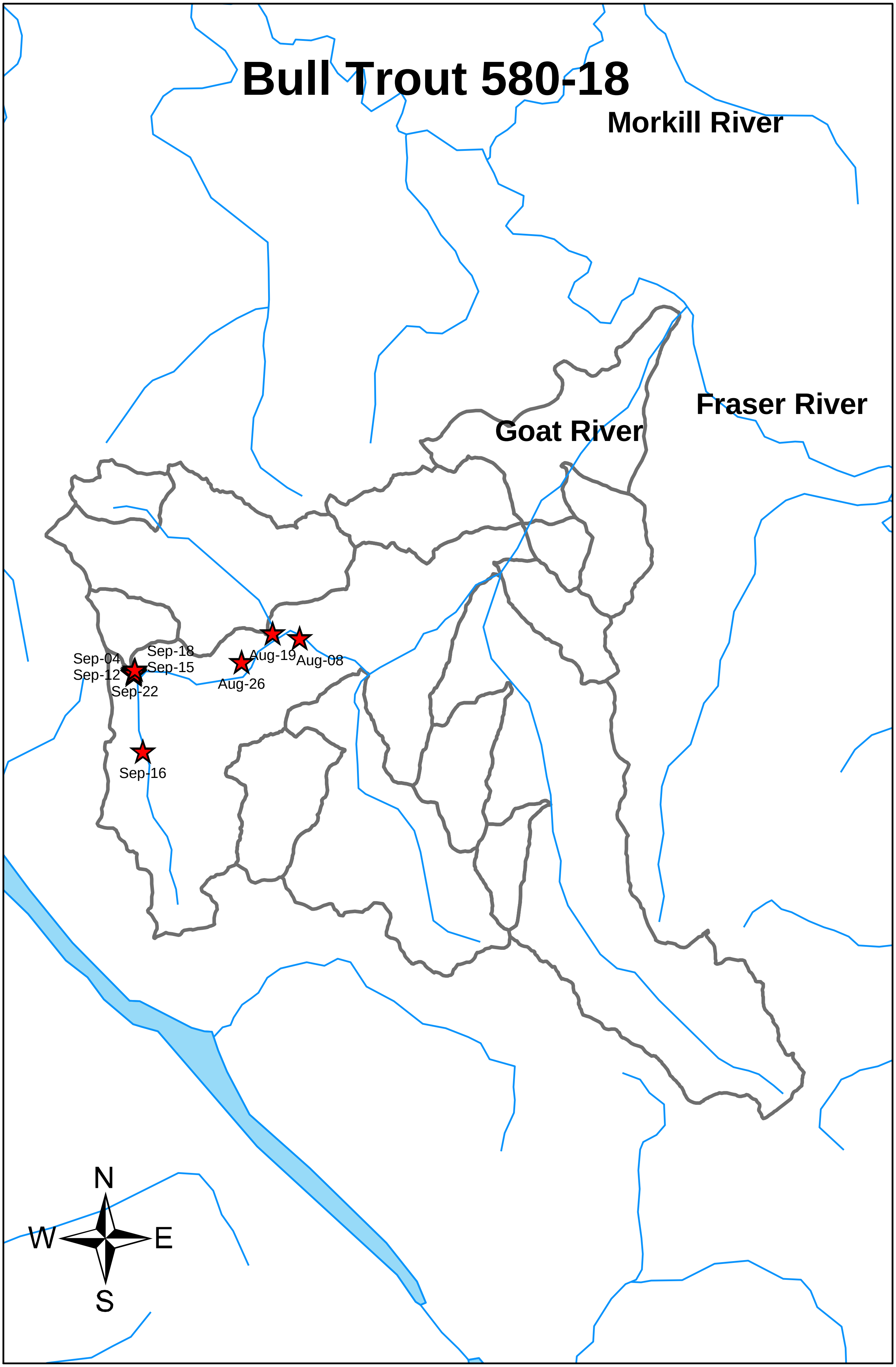


Bull Trout 620-11
Fraser River
Jun-13
May-26
Vanderhoof
Nechako River
Oct-20
Prince George
Sep-22
Goat River
Sep-12
Aug-30
Sep-18
Aug-26
Sep-15
Aug-19
Sep-04
Jun-19
Quesnel
N
W
E
S

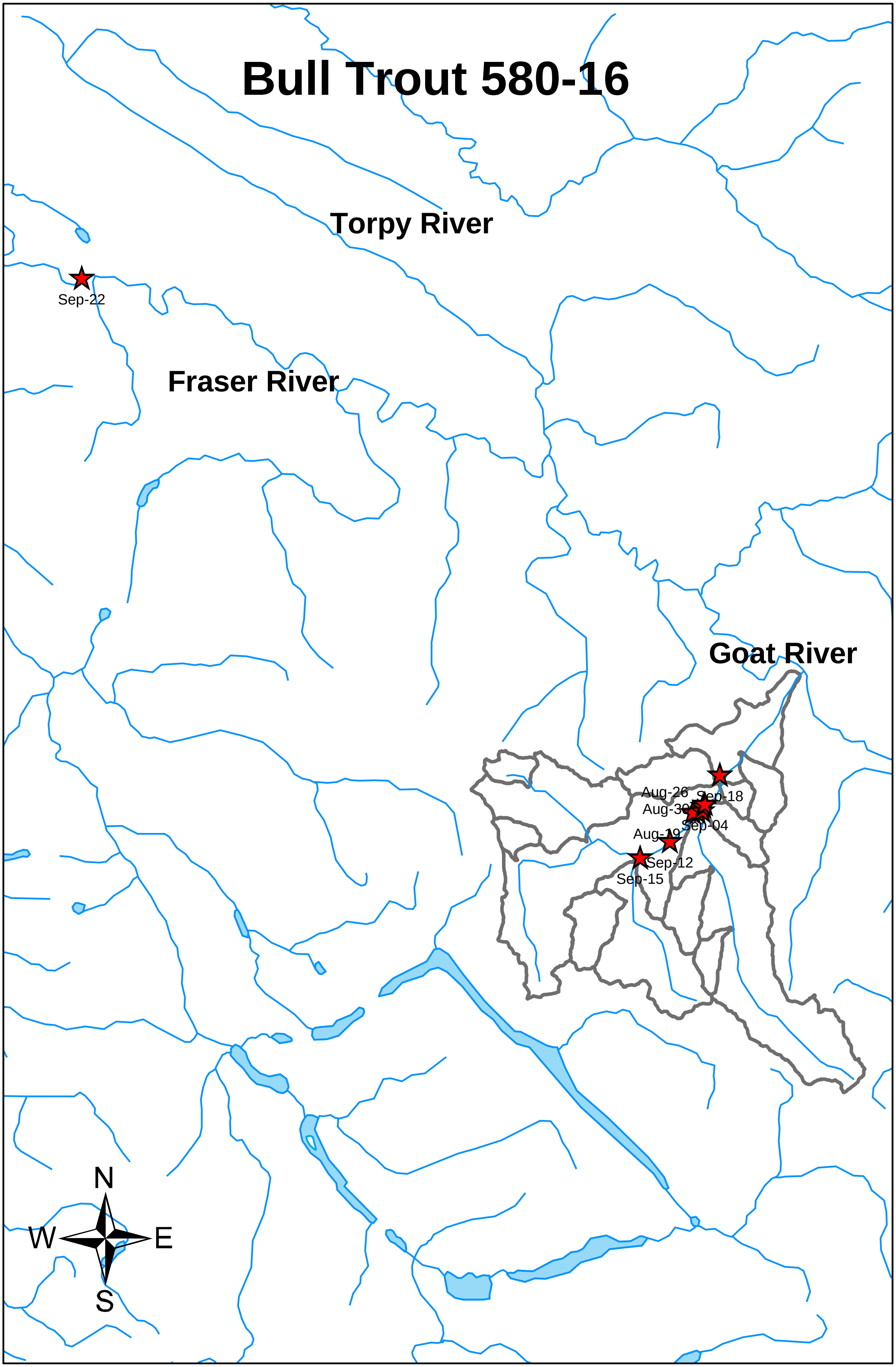


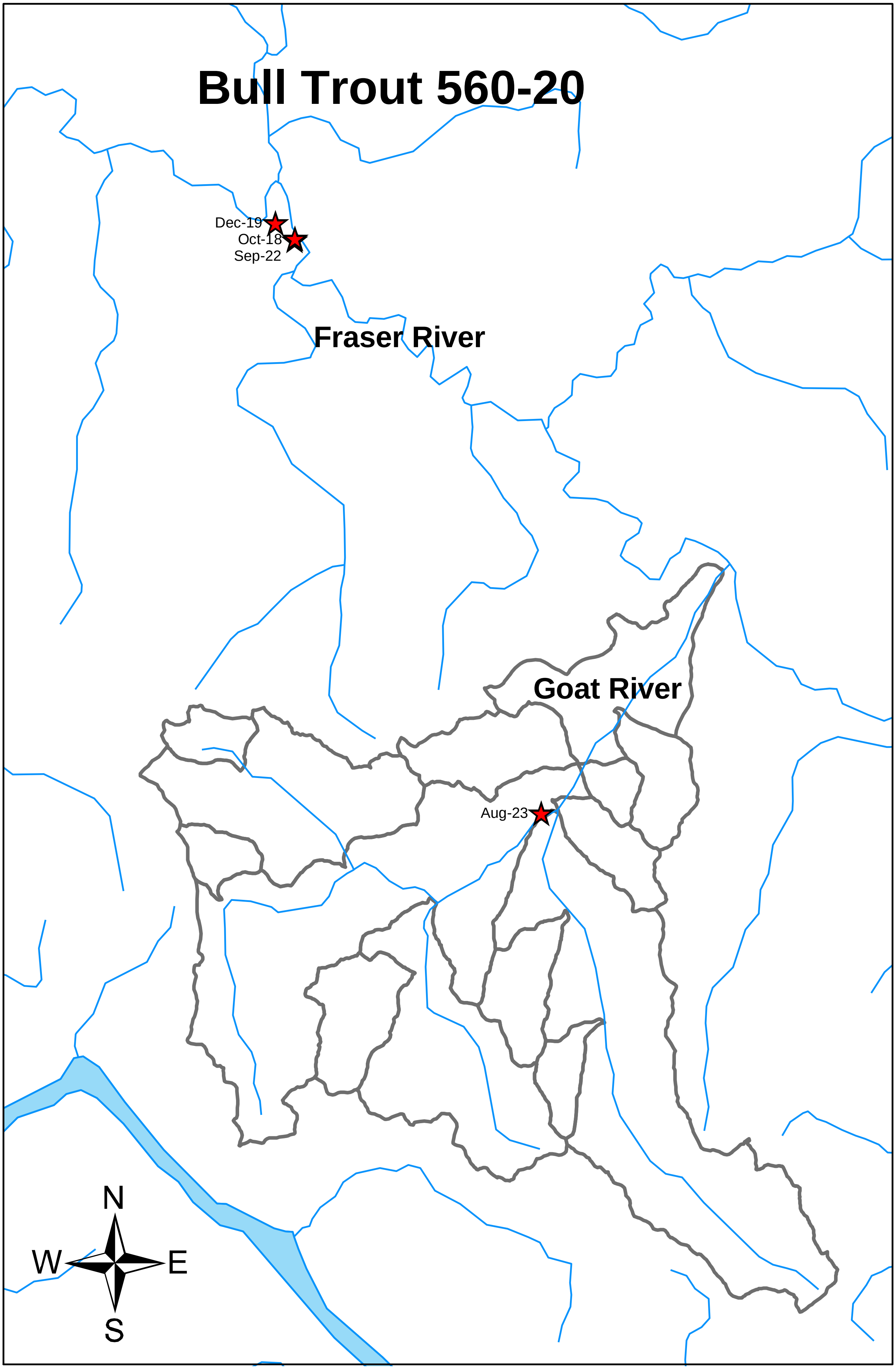
Bull Trout 620-10
Mar-18
May-29
May-26
Feb-25
Vanderhoof
Nechako River
Nov-20
Prince George
Fraser River
Sep-22
Goat River
Sep-15
Sep-19
Aug-30
Sep-18
Aug-26
Sep-04
Sep-12
Quesnel
N
W
E
S

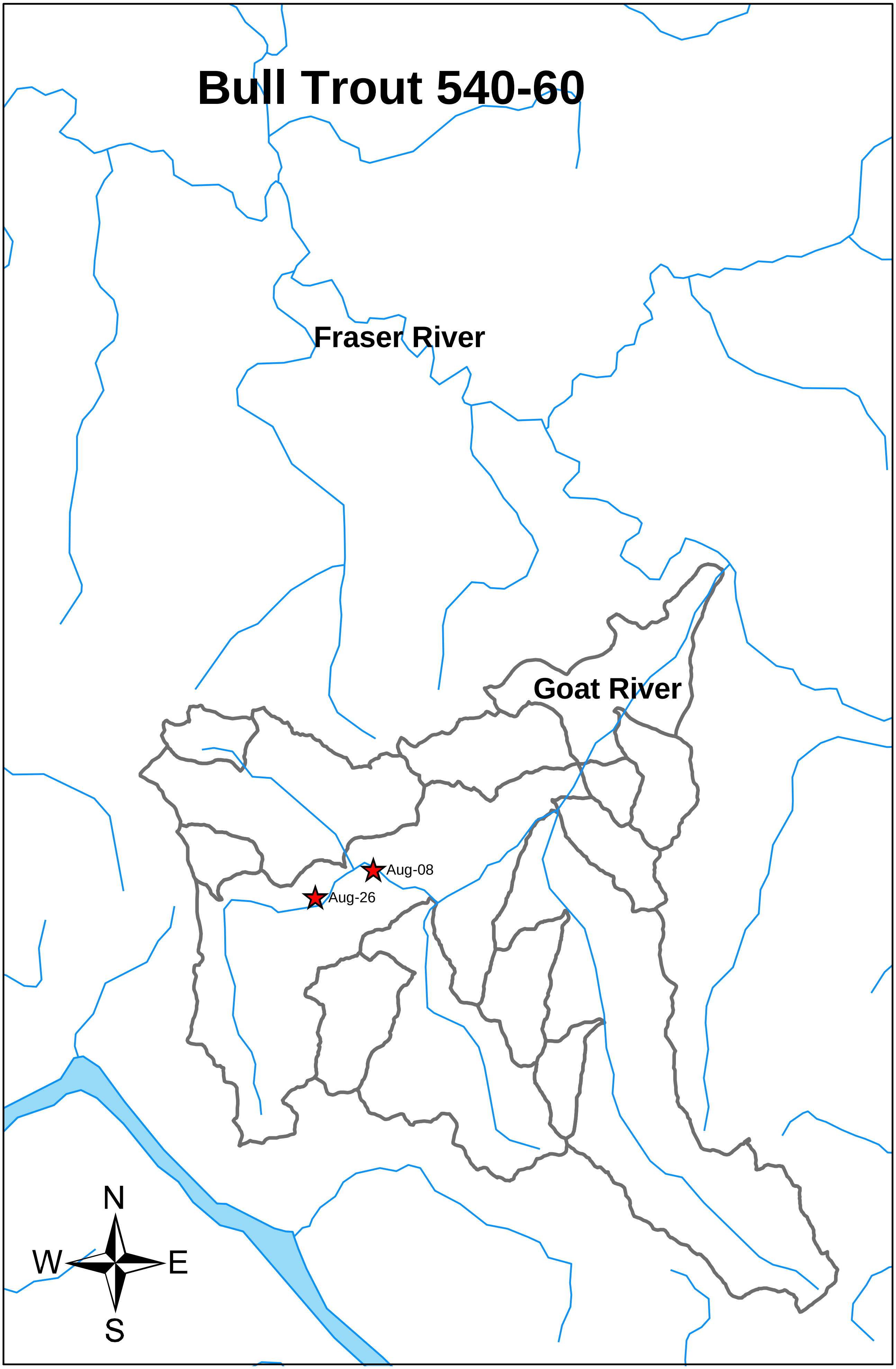

Bull Trout 580-22
Fraser River
Prince George
Goat River
Quesnel
Sep-22
May-29
Aug-19
Aug-08
Sep-12
Sep-15
Sep-16
N
W
E
S


Bull Trout 580-18
Morkill River
Fraser River
Goat River
Sep-04
Sep-12
Sep-18
Sep-15
Sep-22
Aug-19
Aug-08
Aug-26
Sep-16
N
W
E
S

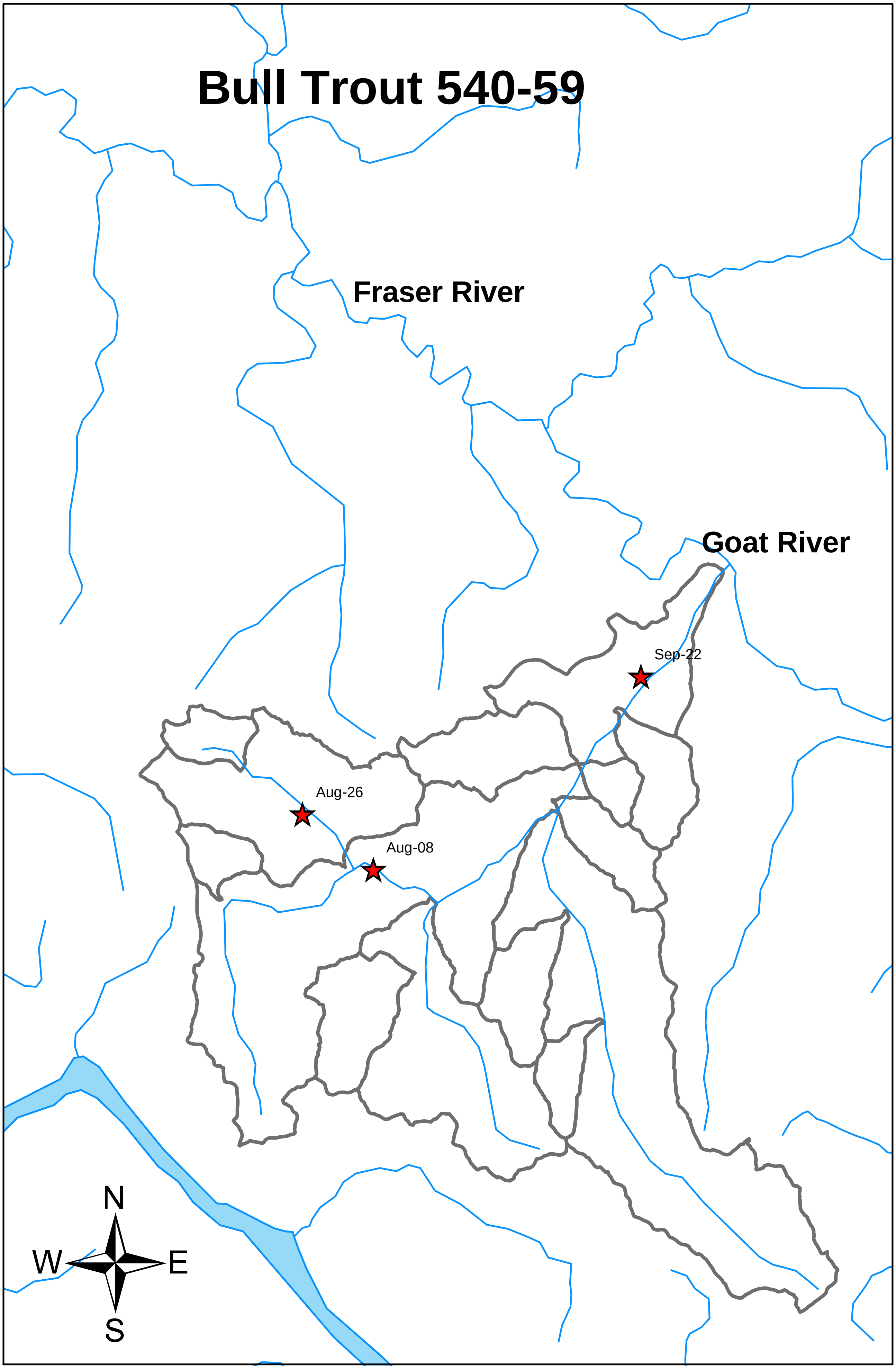
# Bull Trout 580-16



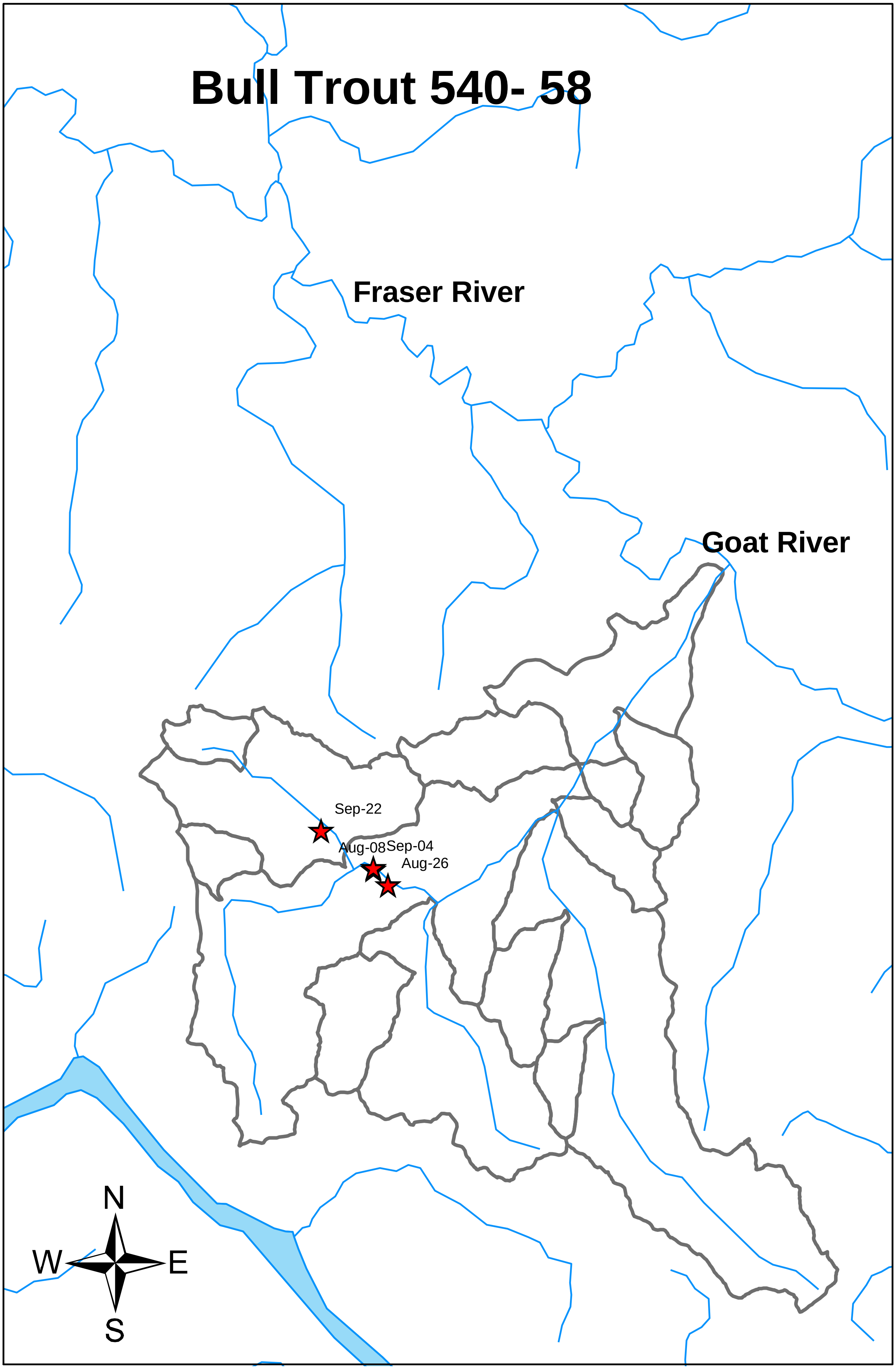

Bull Trout 560-20
Dec-19
Oct-18
Sep-22
Fraser River
Goat River
Aug-23
N
W
E
S

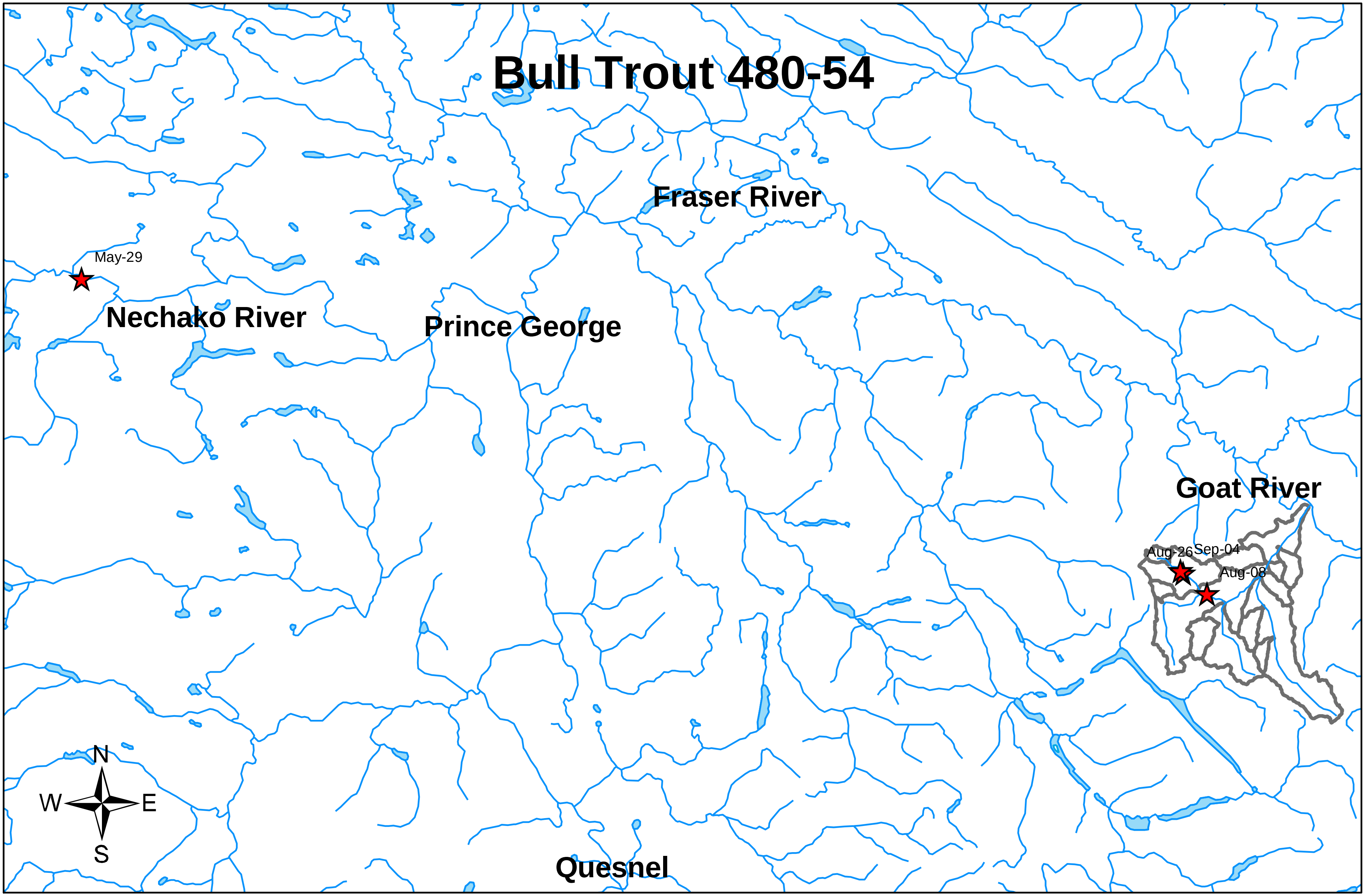


Bull Trout 540-60
Fraser River
Goat River
Aug-08
Aug-26
N
W
E
S

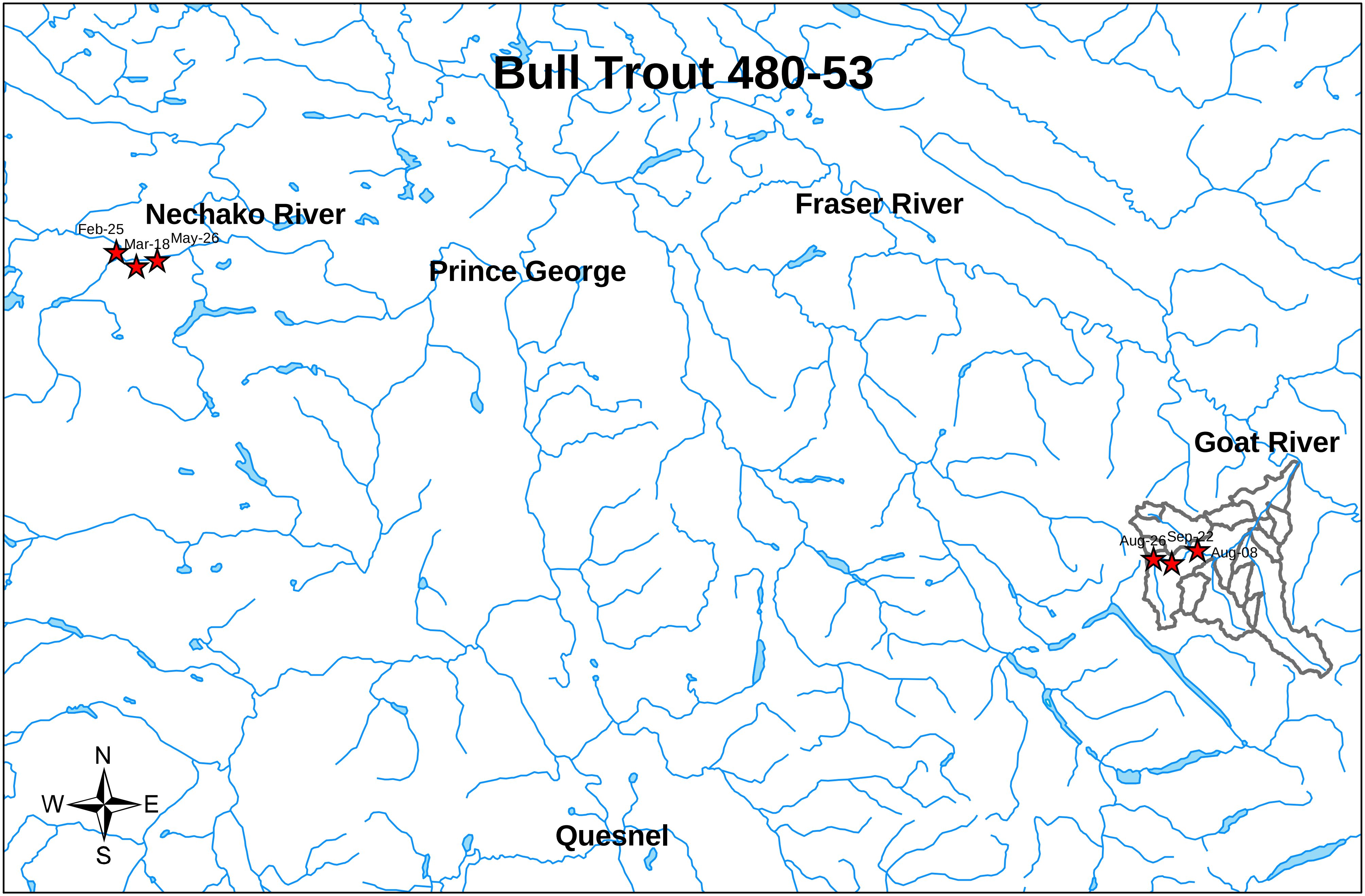

Bull Trout 540-59
Fraser River
Goat River
Sep-22
Aug-26
Aug-08
N
W
E
S

# Bull Trout 540- 58





Bull Trout 480-54
Fraser River
May-29
Nechako River
Prince George
Goat River
Aug-26
Sep-04
Aug-08
N
W
E
S
Quesnel



Bull Trout 480-53
Nechako River
Feb-25
Mar-18
May-26
Prince George
Fraser River
Goat River
Aug-26
Sep-22
Aug-08
Quesnel
N
W
E
S

# APPENDIX

# IV

# REDD COUNT ANALYSES

**Macleod** To determine if distribution fits a negative binomial distribution by estimating parameter k and caculating stat to ensure it fits
Calculates SE of U stat, and Confidence Intervals

| Number of redds per river section X | log(x+k/2) | log (x+k/2) | sinh-1(x) | sinh-1SQRT(x+0.375/k-0.75) | X^2 | X^3 | Number of River Segments (=quadrats), fx | Proportion of stems, Px | Xfx | X^2fx | X^3fx |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | -0.651695 | -1.057992 | 0 | #NUM! | 0 | 0 | 26 | 0.509804 | 0 | 0 | 0 |
| 1 | 0.087426 | 0.036429 | 0.881374 | #NUM! | 1 | 1 | 7 | 0.137255 | 7 | 7 | 7 |
| 2 | 0.346939 | 0.319626 | 1.443635 | #NUM! | 4 | 8 | 4 | 0.078431 | 8 | 16 | 32 |
| 3 | 0.50826 | 0.489607 | 1.818446 | #NUM! | 9 | 27 | 2 | 0.039216 | 6 | 18 | 54 |
| 4 | 0.625621 | 0.611458 | 2.094713 | #NUM! | 16 | 64 | 4 | 0.078431 | 16 | 64 | 256 |
| 5 | 0.71792 | 0.706504 | 2.312438 | #NUM! | 25 | 125 | 2 | 0.039216 | 10 | 50 | 250 |
| 6 | 0.794 | 0.784439 | 2.49178 | #NUM! | 36 | 216 | 1 | 0.019608 | 6 | 36 | 216 |
| 7 | 0.858718 | 0.850493 | 2.644121 | #NUM! | 49 | 343 | 4 | 0.078431 | 28 | 196 | 1372 |
| 8 | 0.91503 | 0.907814 | 2.776472 | #NUM! | 64 | 512 | 0 | 0 | 0 | 0 | 0 |
| 9 | 0.964872 | 0.958444 | 2.893444 | #NUM! | 81 | 729 | 1 | 0.019608 | 9 | 81 | 729 |
| 45 | 0.516709 | **0.460682** | | #NUM! | 285 | | 51 | 1.00 | 90 | 468 | 2916 |

| | |
|---|---|
| Mean | 1.76 |
| S^2 | 6.183529 |

| | original | k est (method 2) |
|---|---|---|
| **1. approximate k** | **0.705** | **0.175** |
| Method 2 estimate of k | 0.674 | 0.420963 |

***Maximum likelihood method of determining k confidence limits***

| | | | | |
|---|---|---|---|---|
| Mean of column C=y= | **0.516709** | CI (y) = | **0.83** | for values of k 2 to 5 |
| Mean, column E =y= | **#NUM!** | CI (y) = | **0.13** | for values of k >5 |
| Trigamma (k) = | **45.700862** | | | |
| **k change for equality equation** | | students t 0.05(2)(n-1) = 2 | | 2.01 |
| **0.446** | | | | |

***Confidence Intervals for method 2 of determining exponent k***

| | | | | |
|---|---|---|---|---|
| Trigamma (k) = | 211652.35 | CI (y) = | 56.2 | k 2-5 |
| | | CI (y) = | 9.07 | k > 5 |

**2. Determination of the Ax sums:**

| | |
|---|---|
| A0 | 25 |
| A1 | 18 |
| A2 | 14 |
| A3 | 12 |
| A4 | 8 |
| A5 | 6 |
| A6 | 5 |
| A7 | 1 |
| A8 | 1 |
| A9 | 0 |

**3a. Calculate the two sides of the equality equation**
To get a more accurate estimate of k, the values bolded below must come close together; are changed by altering approximate k bolded above (1).
(N)loge(1+mean/kest)= sum (Ax/kest+x)

**81.638158** 0.000814

**81.6373438**

U- statistic Goodness of Fit Test

U = observed variance- expected variance = S^2 -(mean+mean^2/k)

| | | |
|---|---|---|
| **U =** | **-2.5636582** | **Observed value** |
| U = | **-13.3765299** | |

a = mean/kest
b = 1+a
c = ba^4/b(logeb)-a)^2 x (b^(1+mean/a)-(mean+b)

| | | *Method 2* | | max-like | *Method 2* | | |
|---|---|---|---|---|---|---|---|
| a = | 3.95673965 | 10.08403 | ba^4 = | 1214.915 | 114613.29 | 1/n | 0.0196 |
| b = | 4.95673965 | 11.08403 | b(logeb)-a)^2 = | 15.82251 | 274.85236 | | 100.09 |
| c = | 261.085207 | 1683.425 | | 3.400257 | 4.036995 | | 70.833 |

Standard error of U:

| | | | |
|---|---|---|---|
| **SE(U) =** | **2.66888551** | | |
| S.E. (U) = | 2.66888551 | | |
| S.E. (U) = | **8.83181399** | **2 S. E. =** | **17.66363** |

$\frac{39.32921 \quad 35.26832}{3.977752}$

Confidence Intervals:

**Goat R** To determine if distribution fits a negative binomial distribution by estimating parameter k and caculating stat to ensure it fits
Calculates SE of U stat, and Confidence Intervals

| Number of redds per river section X | log(x+k/2) | sinh-1(x) | sinh-1SQRT(x+0.375/k-0.75) | X^2 | X^3 | Number of 100 metre river segments (=quadrats), **fx** | Proportion of stems, Px | % Px | Xfx | X^2fx | X^3fx |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | -0.672641 | 0 | #NUM! | 0 | 0 | 50 | 0.625 | 62.5 | 0 | 0 | 0 |
| 1 | 0 | 0.881374 | #NUM! | 1 | 1 | 12 | 0.15 | 15 | 12 | 12 | 12 |
| 2 | 0.30103 | 1.443635 | #NUM! | 4 | 8 | 7 | 0.0875 | 8.75 | 14 | 28 | 56 |
| 3 | 0.477121 | 1.818446 | #NUM! | 9 | 27 | 5 | 0.0625 | 6.25 | 15 | 45 | 135 |
| 4 | 0.60206 | 2.094713 | #NUM! | 16 | 64 | 2 | 0.025 | 2.5 | 8 | 32 | 128 |
| 5 | 0.69897 | 2.312438 | #NUM! | 25 | 125 | 1 | 0.0125 | 1.25 | 5 | 25 | 125 |
| 6 | 0.778151 | 2.49178 | #NUM! | 36 | 216 | 3 | 0.0375 | 3.75 | 18 | 108 | 648 |
| 21 | | | | 91 | | 80 | 1.00 | | 72 | 250 | 1104 |

| | |
|---|---|
| **Mean** | **0.90** |
| **S^2** | **2.344304** |
| | original |
| **1. approximate k** | **0.560824** |
| **Method 2 for estimati** | 0.470004 / 0.536904 |
| | **0.469998** |

**M.L CI for k>5**

| | | | | |
|---|---|---|---|---|
| Mean of column C=y= | | 0.312099 | CI (y) = | 0.811065 |
| Mean, column E =y= | | #NUM! | CI (y) = | 0.104402 |
| Trigamma (k) = | 69.0664338 | | | |

students t 0.05(2)(n-1) = 2.01

2.01

| | |
|---|---|
| **0.425** | **k change for equality equation** |
| **0.397** | **change k for method 2** |

transforme back transformed

| | | |
|---|---|---|
| method 2 | CI (y) = | 1.094299 |
| **125.7269** | CI (y) = | 0.140861 |

**2. Determination of the Ax sums:**

| | |
|---|---|
| A0 | 30 |
| A1 | 18 |
| A2 | 11 |
| A3 | 6 |
| A4 | 4 |
| A5 | 3 |
| A6 | 0 |
| A7 | 0 |
| A8 | 0 |
| A9 | 0 |

**3a. Calculate the two sides of the equality equation**
To get a more accurate estimate of k, the values bolded below must come close together; are changed by altering approximate k bolded above (1).
(N)loge(1+mean/kest)= sum (Ax/kest+x)

**90.96629**

0.001614

**90.96467**

**U- statistic Goodness of Fit Test**
U = observed variance- expected variance = S^2 -(mean+mean^2/k)

| | | |
|---|---|---|
| **U =** | **-0.461579** | **U for ML test (method 2)** |
| **U =** | **-0.595998** | |

a = mean/kest
b = 1+a
c = ba^4/b(logeb)-a)^2 x (b^(1+mean/a)-(mean+b)

| | maximum | Method 2 |
|---|---|---|
| a = | 2.117647 | 2.267003 |
| b = | 3.117647 | 3.267003 |
| c = | 31.91631 | 31.91631 |

| | M.L metho | **Method 2** |
|---|---|---|
| ba^4 = | 62.69621 | 86.28941 |
| b(logeb)-a)^2 = | 2.037364 | 2.562283 |
| | 1.037146 | 1.06017 |

Standard error of U:

| | | | |
|---|---|---|---|
| **SE(U) =** | **0.627575** | | |
| S.E. (U) = | 0.627575 | | |
| S.E. (U) = | **0.641932** | 2 S.E. (U) = | **1.283864** |

| | |
|---|---|
| 1/n | 0.0125 |
| | 16.93433 |
| | 31.63349 |
| 11.05209 | 11.08651 |
| 1.427363 | |

Confidence Intervals:

# APPENDIX

# V

# BULL TROUT CAPTURE DATA (2002-04)

**GOAT RIVER BULL TROUT DATA:**

| | | | | | | | | | | | | | Location Caught | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Date Captured | Year | Length (mm) | Weight (grams) | Fate | Age | Age Type | LOG L | LOG W | K | Sex | Maturity | Zone | Easting | Northing | River KM | Floy # | PIT | Tag Ratio | Freq | Code | Surgeon |
| 1 | Jul-11 | 2002 | 381 | 600 | R | | | 2.58 | 2.78 | 1.08 | M | | 10 | 640192 | 5918990 | 36.8 | 2001 | NA | 1.33 | NA | N A | |
| 2 | Jul-11 | 2002 | 445 | 920 | R | | | 2.65 | 2.96 | 1.04 | M | | 10 | 645787 | 5917696 | 28.17 | 2002 | NA | 0.87 | NA | N A | |
| 3 | Jul-11 | 2002 | 413 | 750 | R | | | 2.62 | 2.88 | 1.06 | M | | 10 | 645787 | 5917696 | 28.17 | 2003 | NA | 1.07 | NA | N A | |
| 4 | Jul-18 | 2002 | 223 | | R | | | 2.35 | | 0.00 | Juv | IMM | 10 | 652021 | 5922188 | 18.97 | NA | NA | | NA | N A | |
| 5 | Jul-18 | 2002 | 495 | 1180 | R | | | 2.69 | 3.07 | 0.97 | M | | 10 | 652245 | 5922571 | 18.5 | 2004 | NA | 0.68 | NA | N A | |
| 6 | Jul-18 | 2002 | 449 | 1000 | R | | | 2.65 | 3.00 | 1.10 | M | | 10 | 652245 | 5922571 | 18.5 | 2005 | NA | 0.80 | NA | N A | |
| 7 | Jul-18 | 2002 | 406 | 700 | R | | | 2.61 | 2.85 | 1.05 | ? | | 10 | 652245 | 5922571 | 18.5 | 2007 | NA | 1.14 | NA | N A | |
| 1 | Aug-08 | 2002 | 535 | 1680 | R | | | 2.73 | 3.23 | 1.10 | M | M | 10 | 645435 | 5917664 | 28.78 | 2010 | 423816655A | 0.48 | **0.620** | **22** | R. Pillipow |
| 2 | Aug-08 | 2002 | 670 | 3000 | R | | | 2.83 | 3.48 | 1.00 | M | M | 10 | 645435 | 5917664 | 28.78 | 2011 | 42383F461A | 0.27 | **0.620** | **11** | R. Pillipow |
| 3 | Aug-08 | 2002 | 460 | 1100 | R | | | 2.66 | 3.04 | 1.13 | M | M | 10 | 645435 | 5917664 | 28.78 | 2009 | NA | 0.73 | **NA** | **N A** | |
| 4 | Aug-08 | 2002 | 780 | 5100 | R | | | 2.89 | 3.71 | 1.07 | M | M | 10 | 642493 | 5919240 | 33.36 | 2012 | 42381D4B15 | 0.16 | **0.580** | **18** | C. Williamson |
| 5 | Aug-08 | 2002 | 700 | 3600 | R | | | 2.85 | 3.56 | 1.05 | M | M | 10 | 642493 | 5919240 | 33.36 | 2014 | 423A0D4E37 | 0.22 | **0.580** | **22** | C. Williamson |
| 6 | Aug-08 | 2002 | 620 | 2380 | R | | | 2.79 | 3.38 | 1.00 | M | M | 10 | 642493 | 5919240 | 33.36 | 2015 | 42382B1F18 | 0.34 | **0.540** | **59** | C. Williamson |
| 7 | Aug-08 | 2002 | 610 | 2200 | R | | | 2.79 | 3.34 | 0.97 | M | M | 10 | 642493 | 5919240 | 33.36 | 2016 | 42381D7A4B | 0.36 | **0.480** | **53** | C. Williamson |
| 8 | Aug-08 | 2002 | 570 | 1920 | R | | | 2.76 | 3.28 | 1.04 | M | M | 10 | 642493 | 5919240 | 33.36 | 2017 | 423A183A5D | 0.42 | **0.540** | **60** | C. Williamson |
| 9 | Aug-08 | 2002 | 570 | 1920 | R | | | 2.76 | 3.28 | 1.04 | F | M | 10 | 642493 | 5919240 | 33.36 | 2018 | 423A03097F | 0.42 | **0.540** | **58** | C. Williamson |
| 10 | Aug-08 | 2002 | 555 | 1810 | R | | | 2.74 | 3.26 | 1.06 | F | M | 10 | 642493 | 5919240 | 33.36 | 2019 | 423A043B49 | 0.44 | **0.620** | **10** | C. Williamson |
| 11 | Aug-08 | 2002 | 605 | 2380 | R | | | 2.78 | 3.38 | 1.07 | M | M | 10 | 644200 | 5918238 | 30.63 | 2020 | 42381E3110 | 0.34 | **0.480** | **54** | R. Pillipow |
| 12 | Aug-09 | 2002 | 750 | 4500 | R | | | 2.88 | 3.65 | 1.07 | M | M | 10 | 651557 | 5921845 | 19.8 | 2021 | 4238163F2F | 0.18 | **0.620** | **13** | R. Pillipow |
| 13 | Aug-09 | 2002 | 685 | 3800 | R | | | 2.84 | 3.58 | 1.18 | F | M | 10 | 651557 | 5921845 | 19.8 | 2022 | 4239706634 | 0.21 | **0.580** | **16** | R. Pillipow |
| 14 | Aug-09 | 2002 | 600 | 2420 | R | | | 2.78 | 3.38 | 1.12 | F | M | 10 | 651557 | 5921845 | 19.8 | 2023 | 4238210A6F | 0.33 | **0.620** | **14** | R. Pillipow |
| 15 | Aug-09 | 2002 | 605 | 2400 | R | | | 2.78 | 3.38 | 1.08 | F | M | 10 | 651557 | 5921845 | 19.8 | 2024 | 423A090430 | 0.33 | **0.620** | **20** | R. Pillipow |
| 16 | Aug-23 | 2002 | 520 | 1400 | R | | FR | 2.72 | 3.15 | 1.00 | F | M | 10 | 651557 | 5921845 | 19.8 | 2050 | 4239720233 | 0.57 | **0.560** | **20** | R. Pillipow |
| 17 | Aug-23 | 2002 | 505 | 1300 | R | | FR | 2.70 | 3.11 | 1.01 | F | M | 10 | 651557 | 5921845 | 19.8 | 2049 | 42382E1E23 | 0.62 | **0.620** | **19** | R. Pillipow |
| 18 | Aug-23 | 2002 | 320 | | R | 6 | FR | 2.51 | | | ? | | 10 | 652333 | 5922625 | 18.4 | 2048 | NA | NA | NA | | |
| 19 | Aug-23 | 2002 | 410 | | R | 5 | FR | 2.61 | | | F | | 10 | 652333 | 5922625 | 18.4 | 2047 | NA | NA | NA | | |
| 20 | Aug-23 | 2002 | 345 | | R | 5 | FR | 2.54 | | | F | | 10 | 652333 | 5922625 | 18.4 | 2046 | NA | NA | NA | | |
| 21 | Aug-23 | 2002 | 305 | | R | 4 | FR | 2.48 | | | ? | | 10 | 652333 | 5922625 | 18.4 | 2045 | NA | NA | NA | | |
| 22 | Aug-11 | 2004 | 601 | 2150 | K | | OT | 2.78 | | 0.99 | F | M | 10 | 641012 | 5919481 | 35.6 | NA | NA | NA | NA | | |
| 23 | Aug-11 | 2004 | 470 | 1080 | K | | OT | 2.67 | | 1.04 | M | M | 10 | 641012 | 5919481 | 35.6 | NA | NA | NA | NA | | |
| 24 | Aug-11 | 2004 | 698 | 3500 | R | | FR | 2.84 | | 1.03 | F | M | 10 | 641145 | 5919528 | 35.5 | 2084 | NA | NA | NA | | |
| 25 | Aug-11 | 2004 | 705 | 3300 | R | | FR | 2.85 | | 0.94 | M | M | 10 | 641145 | 5919528 | 35.5 | 2083 | NA | NA | NA | | |
| 26 | Aug-11 | 2004 | 558 | 1800 | R | | FR | 2.75 | | 1.04 | F | M | 10 | 641145 | 5919528 | 35.5 | 2082 | NA | NA | NA | | |
| 27 | Aug-11 | 2004 | 820 | 6000 | R | | FR | 2.91 | | 1.09 | M | M | 10 | 641145 | 5919528 | 35.5 | 2081 | NA | NA | NA | | |
| 28 | Aug-11 | 2004 | 842 | 5400 | R | | FR | 2.93 | | 0.90 | M | M | 10 | 641145 | 5919528 | 35.5 | 2080 | NA | NA | NA | | |
| 29 | Aug-11 | 2004 | 725 | 3700 | R | | FR | 2.86 | | 0.97 | M | M | 10 | 641145 | 5919528 | 35.5 | 2078 | NA | NA | NA | | |
| 30 | Aug-11 | 2004 | 520 | 1250 | R | | FR | 2.72 | | 0.89 | U | M | 10 | 641145 | 5919528 | 35.5 | 2076 | NA | NA | NA | | |
| 31 | Aug-11 | 2004 | 480 | 940 | K | | OT | 2.68 | | 0.85 | F | M | 10 | 641145 | 5919528 | 35.5 | NA | NA | NA | NA | | |
| 32 | Aug-11 | 2004 | 438 | 920 | R | | FR | 2.64 | | 1.09 | F | M | 10 | 641145 | 5919528 | 35.5 | 2576 | NA | NA | NA | | |

# APPENDIX

# VI

# DIGITAL DATA