Lubbock River Arctic Grayling Count: 2018 Fisheries Monitoring Program

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Government of Yukon, Fish and Wildlife Branch in collaboration with Carcross/Tagish First Nation

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Executive summary

In 2018, the Government of Yukon conducted a weir count to determine the numbers of spawning Arctic grayling in the upper Lubbock River. Two weirs, at the upstream and downstream ends of the upper Lubbock River Arctic grayling spawning area, were operated between April 22 and July 2. During this period, we observed 1,082 grayling entering the spawning area. Of these, 915 were large enough to be included in our census. Among the largest grayling, we recorded 755 mature grayling (≥ 230 mm) that had migrated upstream to the spawning area, and only 6 that had traveled downstream from Little Atlin Lake. In addition to the adults, our traps also caught 257 juvenile grayling (< 230 mm in size) moving upstream and 14 juveniles moving downstream from Little Atlin Lake. The majority of grayling came upstream from Atlin Lake (N = 866), with very few coming from Little Atlin (N = 14). In addition to the grayling, we counted 96 northern pike, 63 round whitefish, 780 longnose suckers and one lake trout passing through the traps. The number of counted grayling in 2018 were considerably lower compared to estimates from previous snorkel surveys conducted in 2014 and 2017. We speculate that the presence of a low head beaver dam, located just below the spawning area, impeded grayling from reaching the spawning beds.

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Introduction

Arctic grayling (*Thymallus arcticus*) are ubiquitous throughout the Yukon Territory, Canada, and are considered an important subsistence species for Indigenous communities. They are also an important sport fish for resident anglers (Scott and Crossman, 1973; Northcote, 1995; DFO, 2019). Despite this importance, few territorial studies have documented their life history characteristics, described their temporal spawning patterns, or quantified their spawning densities. As such, their spring habitat use and spawning requirements are not well understood, making it difficult for the territorial government to establish management actions or recommend mitigations in the case of industrial developments (Environment Yukon, 2010).

Arctic grayling have a wide distribution, occurring in most freshwater drainages of sub-arctic Asia and western North America. In Canada, they are found from the shores of Hudson Bay to the borders of Alaska and in the northern portions of the western provinces of Manitoba, Saskatchewan, Alberta and British Columbia (Scott and Crossman, 1973). In some areas of their range, population assessments indicate a decline in grayling abundance, which may be the beginning of a range contraction from their southerly latitudinal maximums (Alberta Environment et al., 2015). These declines have been attributed to climate change, habitat fragmentation, industrial development, and overharvest (McAllister and Harington, 1969; Kaya, 1992; Vincent, 1962; Alberta Environment et al., 2015). Such declines increase the importance of understanding grayling behaviour in areas where populations remain resilient and habitats intact. Understanding their spawning behaviors is particularly important, as grayling are most vulnerable during this stage due to their specific habitat requirements for both adults and young-of-the-year (Lopez et al., 2005).

To spawn, Arctic grayling require clear, slow-moving, well-oxygenated waters with temperatures around 4°C (Larocque et al., 2014). They prefer spawning on gravel substrates near vegetated stream banks. The vegetation provides cover for the emerging fry, which begin to hatch two to four weeks after spawning. Arctic grayling are particularly vulnerable during this emergent stage, as they can easily be killed by high water, turbulence, sedimentation or stranding (McLeay et al., 1987; Stewart et al., 2007; Alberta Environment and Parks and Alberta Conservation Association, 2015).

Grayling are spring spawners, generally spawning from mid-April to early June (Stewart et al., 2007). However, spawning periods vary with latitude, starting later in the spring as one moves north. Grayling will migrate large distances during spring spawning, homing to their natal drainages. Consequently, higher-order streams contain populations that are genetically distinguishable from their neighbors (McPhail and Lindsey, 1970; Prystupa et al., 2021).

In 2017, to overcome challenges in assessing grayling populations in large, turbid streams, the Yukon government initiated a field investigation to determine the efficacy of using grayling genetics to assess population abundance (Prystupa et al., 2021). As part of this genetic study, weirs were constructed on the Lubbock River to directly census its grayling population as a reference to determine accuracy of genetics-derived population abundance estimates. Additionally, it was hoped that the weir numbers would help validate a previously employed assessment technique; snorkel surveys. Historically, Yukon has used snorkel surveys to assess the abundance of spawning Arctic grayling in the Lubbock River (Jessup and Millar, 2012). Originally, this technique was calibrated using a mark-recapture methodology, but it has never been validated for accuracy or precision based on direct counts.

The weirs were also established because it is well known that other species, such as northern pike (*Esox lucius*), round whitefish (*Prosopium cylindraceum*) and longnose suckers (*Catostomus catostomus*), use the Lubbock River during spring. By tabulating the arrivals and departures of these species, we hoped to gain insights into how they interact with the spawning Arctic grayling.

Herein, we report the results of a weir survey conducted on a population of spawning Arctic grayling in the Lubbock River. We compare these results with those from three separate snorkel surveys conducted concurrently during the spawning event. Additionally, we report on the temporal spawning requirements and patterns of Arctic grayling, as well as observations on three other species that use the Lubbock River during the same time: northern pike, round whitefish and longnose suckers.

Study area

The Lubbock River is part of the Yukon River drainage, located in south-central Yukon, near the British Columbia border. Flowing south from Little Atlin to Atlin Lake, it is approximately 18 km in length, averages only 10 m in width, and seldom exceeds 2 m in depth. It contains stream features such as riffles, runs, pools, eddies and debris jams. The substrate is primarily gravel with silt, clay and organic detritus (Figure 1).

In addition to the presence of Arctic grayling, the stream is also frequented by longnose suckers, lake whitefish (*Coregonus clupeaformis*), round whitefish, northern pike, slimy sculpin (*Cottus cognatus*), burbot (*Lota lota*) and the occasional lake trout (*Salvelinus namaycush*).

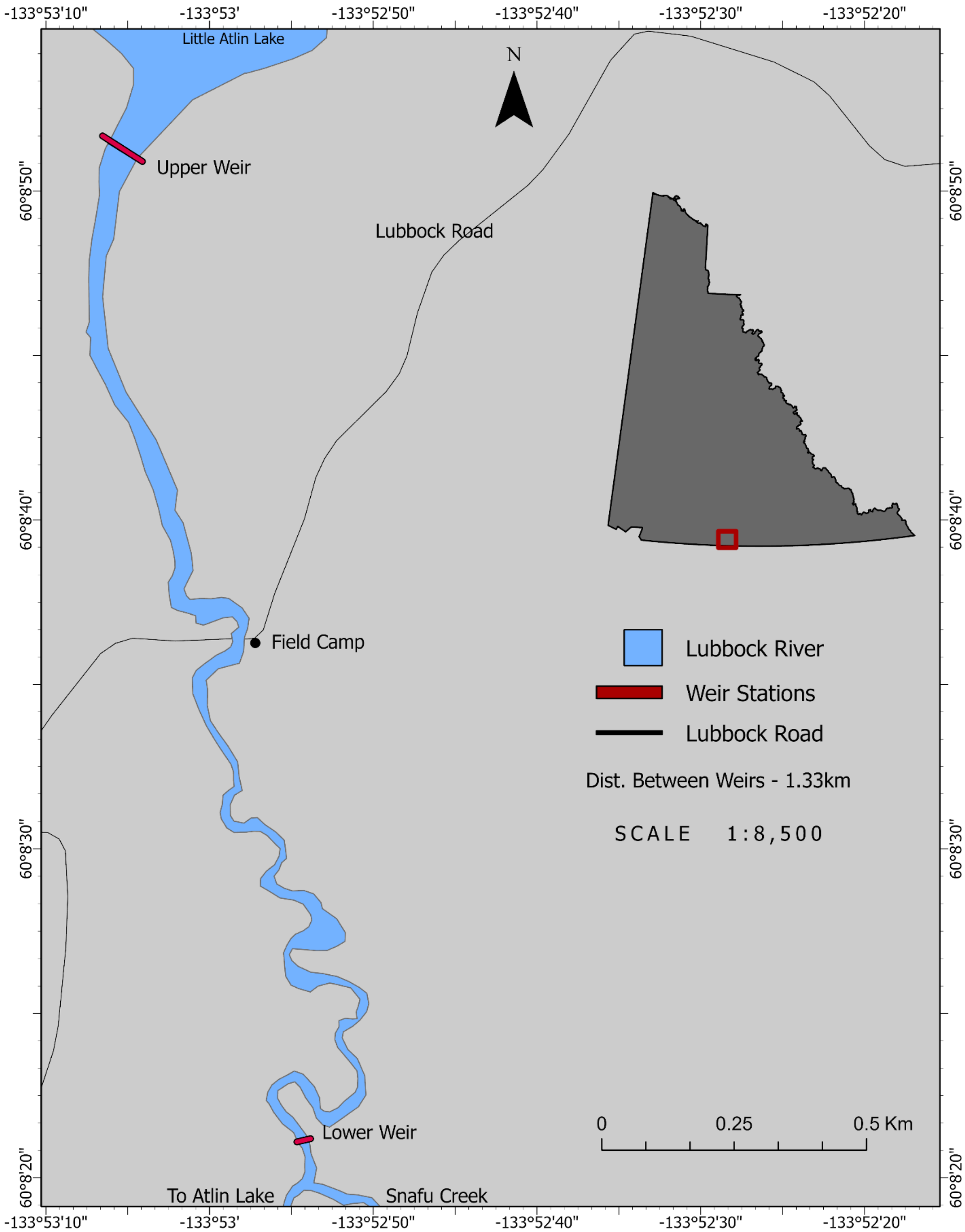

Figure 1. Map indicating the approximate location of the Lubbock River and weir placements. Inset of the Yukon shows the approximate location of the Lubbock study area (red box).

Methodology

Weir enumerations

To enumerate spawning grayling arriving downstream from Atlin Lake and upstream, from Little Atlin Lake, we established two weirs in the Lubbock River. The weirs were constructed using aluminum conduit pickets, each 2 cm in diameter and 152 cm in length. The pickets were evenly spaced 3.5 cm apart, center to center, creating a gap of approximately 1.6 cm between each picket. The picket fences were set at an angle, pointing downstream, and we braced the bottoms with sandbags. These sandbags served a dual purpose: keeping the fences in place and preventing inadvertent fish passage underneath the weir.

The first weir was placed at the outlet of Little Atlin Lake, where it exits into the Lubbock River, while the second was set approximately 1 km downriver from the outlet to capture fish migrating upstream (Figure 2). The weirs partitioned the majority of Lubbock's primary spawning habitat. Installed in each of the two weirs were two aluminum-framed, vexar-lined box traps, one pointing upstream and the other downstream, for a total of four traps. This setup allowed us to enumerate fish as they entered and exited the spawning area. Additionally, each trap was equipped with a HOBO temperature logger that recorded water temperatures every 15 minutes.

Two people constantly staffed the weirs during the spawning period. Initially, we checked the traps every two hours to ensure they did not become over-crowded with migrating grayling. Later, we reduced the checks to three times per day (early morning, late afternoon and late evening). If fish were present, individuals were sampled for species, sex, weight, fork length and for their age and genetics (via scales and adipose fin clips). In addition to this sampling, a subset of grayling were floy-tagged (FF_94) to determine their average residency time. We also tallied the total number of fish entering and exiting the weirs daily, by trap.

We assumed that all fish ≈140 mm in length could not pass through the gaps in our weir's pickets and were therefore included as part of our migration totals. Fish smaller than this size were believed to be able to pass freely through and were excluded to avoid double-counting. However, we sampled all fish found in the traps, regardless of size, for body measurements, age and genetics.

Figure 2. The general weir construction used for assessing the Lubbock River spawning population. Images show the downstream weir (A) and the upstream (Little Atlin Lake outlet) weir (B). Both weirs were in place for the duration of the spawning period (April 27 and July 2).

Analysis

To determine if there were any underlying patterns in spawning arrivals, we first graphed the daily frequencies of grayling arrivals and departures through the weirs. Next, to test whether arriving grayling were smaller as the days progressed, we ran two tests. First, we performed a one-way ANOVA to determine whether any visually observed pulses had significant differences in their size compositions. Then, using simple linear regression, we tested whether the sequence of run timing (April 27 to July 2) significantly predicted mean daily fish length over the course of the spawning run. These tests included all fish sampled from our arrival traps, regardless of whether they were immature.

Furthermore, recognizing that other species were present during the grayling-spawning run, we sought to determine if there was an association between grayling and the presence of these species. To test for this, we computed Spearman Rank Order correlation coefficients to assess the relationships between daily arrivals of the various species. All statistical tests were performed using IBM SPSS Analytics.

Snorkel surveys

During the period when the weir was present, we employed a snorkel survey methodology first described by Jessup and Millar (2012) to tally the number of grayling within the area enclosed by the weirs. The Government of the Yukon has traditionally used this methodology to quantify the number of adult grayling during the Lubbock River spawning event. However, when the technique was initially developed, it was validated using a mark-recapture survey and, as a result, has never been validated by comparing snorkel results with actual census totals.

We conducted snorkel surveys on three separate occasions during the spawning period (May 22, May 29, and June 30). Starting from the upper weir, two snorkelers, swimming in tandem, moved downstream toward the lower weir. Each surveyor was responsible for recording all observed adult grayling in either the left or right portion of the stream, bisecting the stream. Handheld tally counters were used to record observations.

Expansion factor

To account for missed grayling due to changing water visibility, we expanded our snorkel estimates by applying a sightability index created by Jessup and Millar (2012), which had been calibrated for Lubbock's water clarity (Thurow 1994; Yukon Fish and Wildlife internal data):

$$Y = 0.29036X - 0.1622$$

Where:
Y = Sightability
X = Visibility in meters

$$N = n / \text{Sightability}$$

Where:
N = Total population size
n = Number of fish observed

Furthermore, to determine whether snorkel surveys could accurately capture the overall run timing—its beginning, peak, and end—we also plotted population estimates from two previous snorkel surveys conducted in 2014 and 2017. We compared these plots with our daily weir counts (arrivals minus departures).

Results

We completed the weir construction on April 20 and began monitoring on April 21. We monitored the weirs daily for approximately two months (67 days) and then disassembled them on July 2. During this period, we found 1,082 grayling in our entry traps. Of these, 915 were large enough to be included in our census. To be included, we selected only those grayling obstructed by our weir pickets. We did not include all sampled grayling because some were small juveniles (< 140 mm) that likely could pass unhindered through the pickets. This meant we could potentially count them more than once. We also discovered that 42 grayling, during their spawning residency, had entered, exited and re-entered the weir traps. We identified these fish by the absence of a previously sampled adipose fin or a tail clip. As such, we adjusted our tabulation to ensure these individuals were only counted and measured once. In addition, an additional eight smaller fish escaped during our measuring attempts and were not sampled. This brought our total census number to 866 individuals, and the sample number to 1,032.

Among the largest grayling, we recorded 755 mature grayling (≥ 230 mm) that had migrated upstream to the spawning area, and 6 that had traveled downstream from Little Atlin Lake. In addition to the adults, our traps also caught 257 juvenile grayling (< 230 mm in size) moving upstream and 14 juveniles moving downstream from Little Atlin Lake. Among the juveniles, 166 were very small (≤ 140 mm). The majority of grayling came upstream (N = 866), with very few coming from Little Atlin Lake (N = 14).

During our monitoring period, the water temperature rose from 4°C to 16°C. On April 29, the first grayling arrived when the water temperature was 4°C. By measuring the sizes of grayling as they arrived and counting the daily frequencies, we observed that arriving grayling became significantly smaller as the days progressed (Figure 3A) and that there were three distinct pulses when grayling arrivals increased. The first pulse occurred between May 4 and May 13 (9 days), peaking on May 8. The second was a weaker influx, occurring between May 15 and May 23, lasting 8 days. Finally, the third occurred between June 18 and June 30 (12 days) and peaked on June 24. Among the pulses, the mean length of grayling significantly differed ($F = 373.95$, $P \leq 0.001$). A Scheffé's test for multiple comparisons found that the mean length among each of the three groups significantly differed ($P \leq 0.001$), with each group being significantly smaller than the previous one. Between May 4 and May 13, the largest and likely oldest grayling first arrived (N = 505, mean length = 346 mm, ± 2.2 mm). The second pulse, which consisted of smaller adults and sub-adults, followed (N = 177, mean length = 315 mm, ± 5.5 mm). The last pulse was largely composed of juveniles (N = 225, mean length = 155 mm, ± 6.4 mm) (Figure 3B).

We floy-tagged a subset of 62 larger, newly arrived grayling to calculate residency time among the spawning adults. In accordance with the tagged grayling's arrivals and departures, the mean residency on the spawning beds for adult grayling was approximately 32 days ± 4.61 (N = 31).

Adult grayling departures from the spawning beds began on May 24, when water temperatures reached 10°C. However, the largest numbers departed on June 17, when water temperatures reached 16°C. In total, we tallied 339 adults exiting the lower weir, and 228 adults passing through the upper weir into Little Atlin Lake. The remaining, unaccounted for grayling were presumed to have either stayed between the two weirs until they were dismantled or were lost to predation or angling.

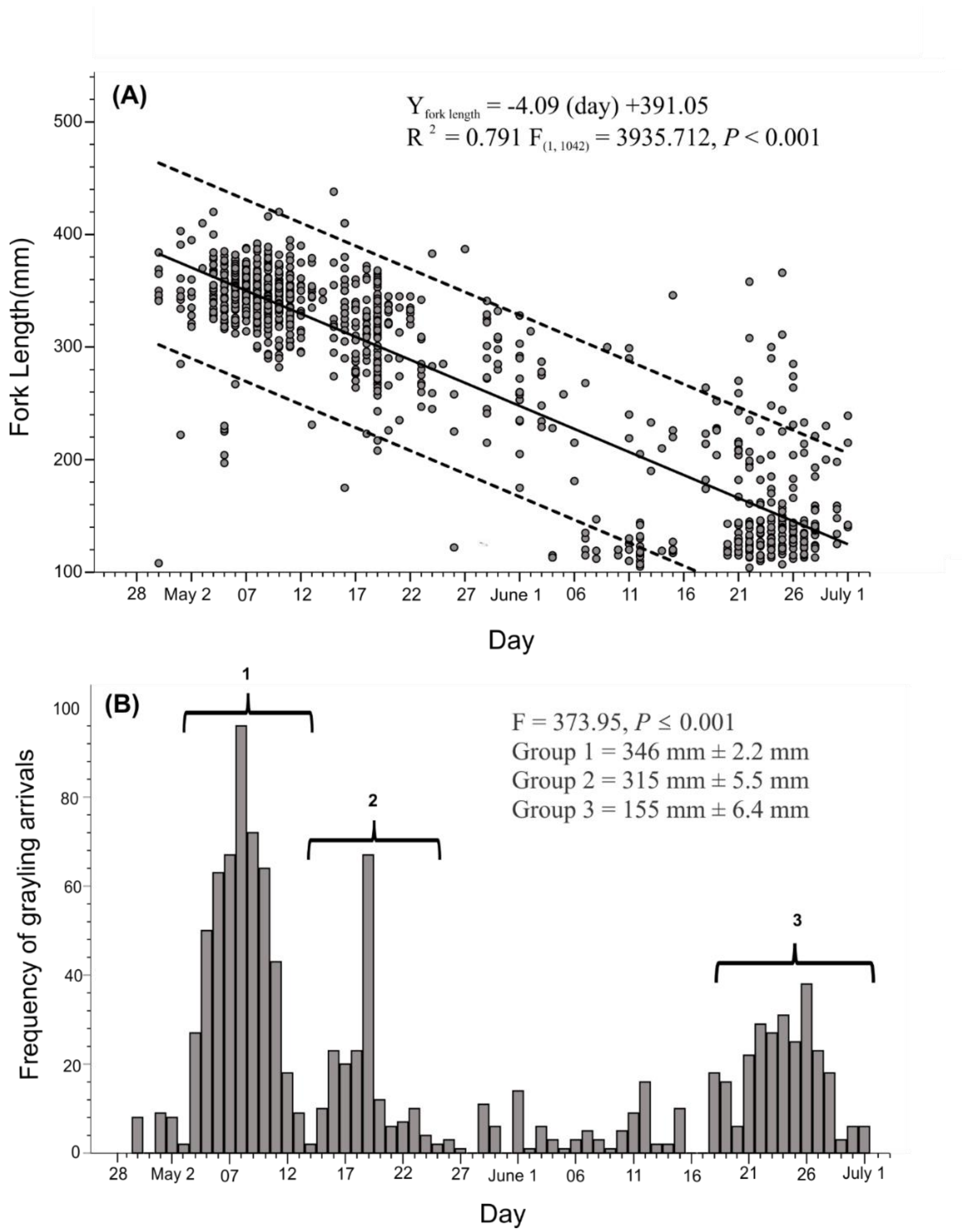

Figure 3. Graph depicting the linear relationship between Arctic grayling fork length and their arrival day in the Lubbock River, dashed lines represent the 95% confidence limits. The regression results are also reported (A). Graph displaying the frequency of arrivals, brackets indicate observed arrival pulses. Mean group sizes and ANOVA results comparing among pulses for fish lengths are also reported; Coefficient of Determination (r^2), F-Statistic (F) and Significance (p) reported.

Other species:

We also had 96 northern pike enter our weir, and the frequency of their arrivals positively correlated with grayling arrivals. The pike and grayling moderately correlated, with the peaks of their arrivals occurring during the same time ($r([63]) = 0.428$, $p < 0.001$). When we examined the travel direction for the arriving pike, the majority came downstream from Little Atlin Lake (N = 78), with only a few swimming upstream from Atlin Lake (N = 18) (Figure 4A). Accompanying the grayling, we also counted 63 round whitefish. Their peak arrivals coincided with the grayling's peak, and the ebb and flow of their arrivals positively correlated with those of the grayling ($r ([63]) = 0.602$, $p < 0.001$). All round whitefish arrivals swam upstream from Atlin Lake (Figure 4B).

In addition to the grayling, 780 longnose suckers passed through our entry traps. A few suckers began arriving on May 19 and started to depart just three days later, on May 22. However, the largest numbers arrived in mid-June. When compared to the peak grayling arrivals, suckers arrived later and were not in synchrony with the grayling run, arriving just after the second peak in the grayling run. Their arrivals did not correlate with those of the grayling ($r([63]) = -0.001$, $p < 0.991$) (Figure 4C), nor did they correlate with the northern pike's ($r([63]) = -0.175$, $p < 0.723$) or round whitefish's arrivals ($r([63]) = -0.040$, $p < 0.753$). When we compared the species for frequency of daily departures, there were no significant correlations.

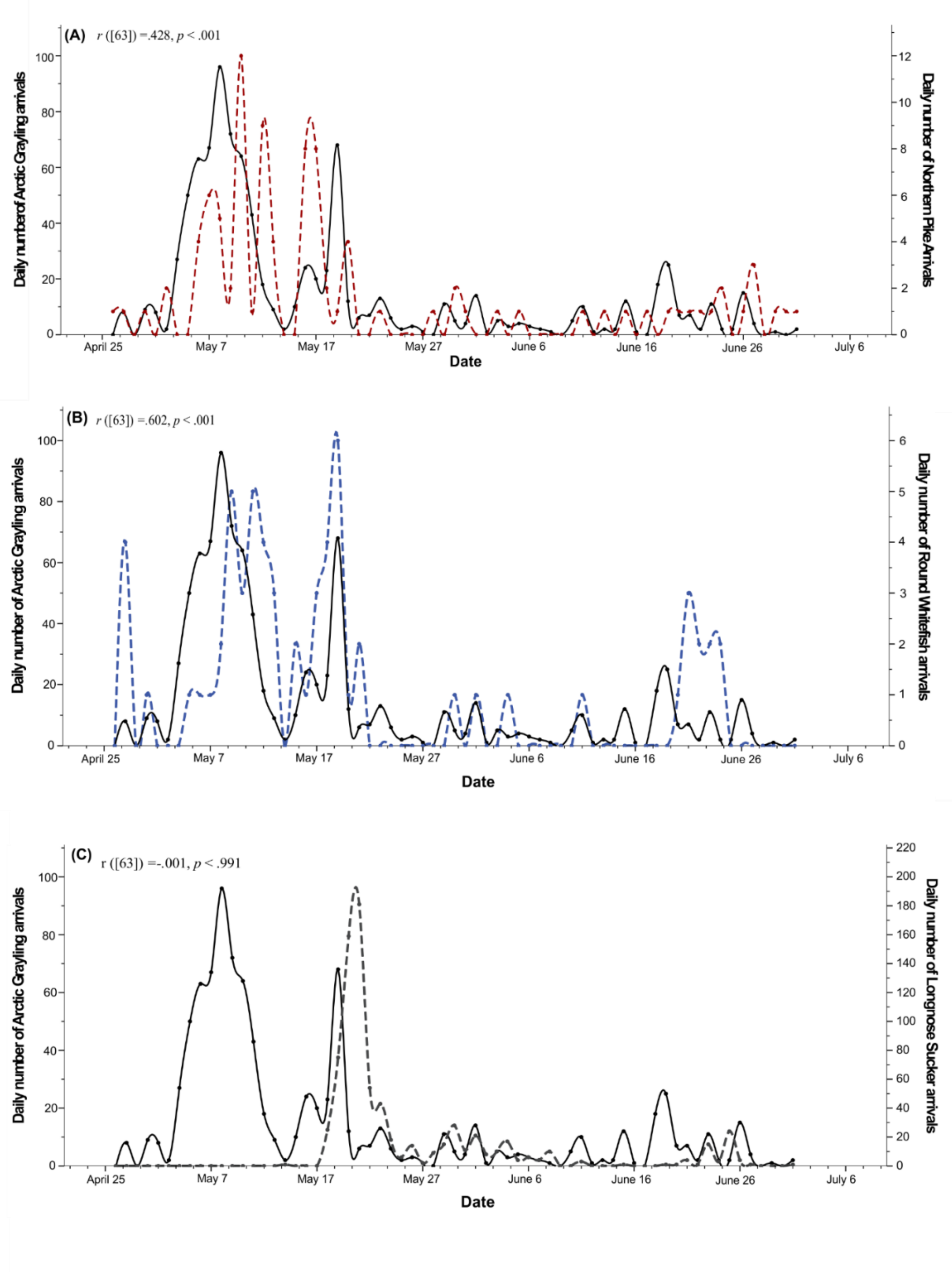

Figure 4. Shows the relationship between daily numbers of grayling arrivals compared with the numbers of daily arrivals for northern pike (A), round whitefish (B) and longnose suckers (C). Also displayed are the results of the Spearman Rank Order correlation coefficients for each comparison; correlation coefficient (r), significance level (p).

Comparison of methodologies for Arctic grayling population estimates

When we compared our weir counts (arrivals minus departures) to the expanded snorkel survey estimates, we found that the snorkel survey counts were consistently lower than our weir counts (Table 1). On average, the snorkel surveys underestimated the weir counts by 26 percent. When we compared the pattern of run timing — including its beginning, peak, and end — the weir counts (arrivals minus departures) seemed somewhat consistent with the patterns observed during two previously completed snorkel surveys (2014 and 2017). We found that the timing of arrivals and the period when the runs peaked were consistent across years (Figure 5). However, the end dates of the runs differed: while 2014 and 2018 were relatively the same, the 2017 run began departing approximately 24 days earlier, with peak numbers lasting only a few days.

Table 1. Compares the three 2018 snorkel estimates to weir-based counts from the same date. The number of snorkel estimates refers to the numbers of passes (counts) that occurred and were averaged to form the mean snorkel estimate and its associated 95% confidence interval. Fence Count indicates the numbers of fish that passed through the entry traps, minus those that departed through the exit traps. The percent difference represents the difference between the two estimates.

DATE	NUMBER OF SNORKEL ESTIMATES	SNORKEL MEAN ESTIMATE WITH EXPANSION (95% CI +/-)	FENCE COUNT (ENTRIES – DEPARTURES)	PERCENT DIFFERENCE
05/22/2018	2	475 ± 80.4	680	30%
05/29/2018	3	562 ± 166	651	14%
06/30/2018	2	279 ± 2.94	414	33%

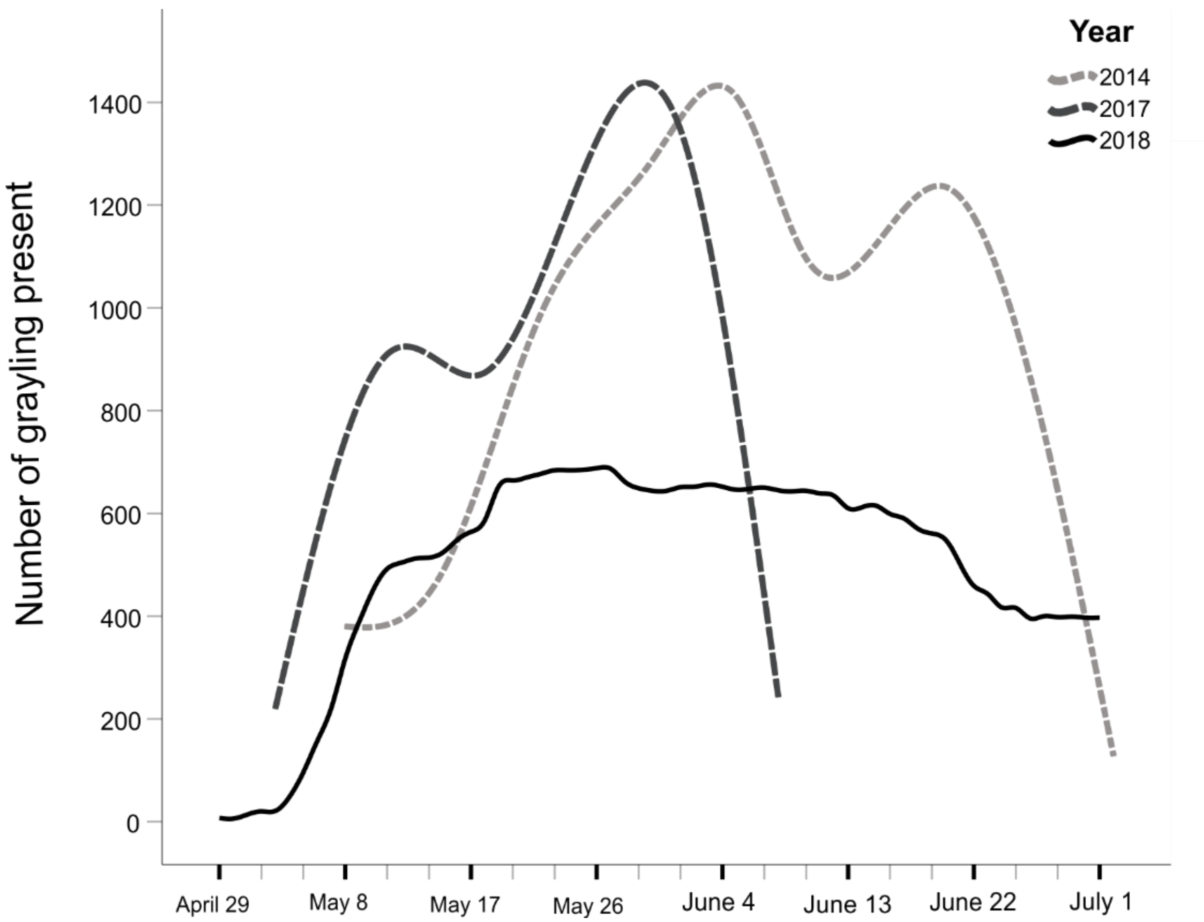

Figure 5. Comparison of the snorkel survey counts from 2014 (grey hatched) and 2017 (black hatched) to the daily arrivals, minus departures, from the 2018 weir counts (solid black).

Discussion

Results from our weir counts indicate that the Arctic grayling spawning run in the Lubbock River is an upstream migration, predominantly originating from Atlin Lake, with relatively few fish migrating downstream from Little Atlin Lake. While some of the grayling arriving from downstream may have been Lubbock residents, we believe it to be unlikely and that the majority migrated from Atlin Lake. The optimal temperature range for Arctic grayling ranges between 5° C and 12°C, while they experience stress when temperatures approach 17°C and, actively avoiding temperatures exceeding 20°C (Larocque et al., 2014). Recorded water temperatures during our study period reached 16°C, exceeding their optimal. These temperatures occurred in mid-June, suggesting that the Lubbock will become unsuitable for adult grayling as the summer progresses.

The run began in late April, when the water temperature averaged 4°C, and finished by late June, when the water temperature reached 17°C. The run exhibited a size-based structure, with the largest grayling arriving first, followed by smaller adults and sub-adults. Interestingly, near the end of the run, juvenile fish (≤ 140mm) arrived at the spawning beds. These juvenile fish were not present at the start of the spawning run but arrived in large numbers during its latter days, when the adults were still present.

The residency time for the spawning grayling was much longer than previously thought, with fish staying on the spawning beds for an average of 32 days ± 4.61. In accordance with our results, we found variations in two of the estimates between the snorkel survey run size approximations and the actual run counts through the weir, which calls into question the validity of using snorkel surveys for estimating the Lubbock River run. However, in keeping with our 2014 and 2017 comparisons, the timing pattern of the run could still be determined using snorkel surveys, which served to identify the run's initiation, peak, and end. It should be noted that in 2017, the run ended earlier than in 2014 and 2018. Temperature may have played a role in the grayling's early departure in 2017. Recorded water temperatures had reached 14°C by June 8th in 2017, while in both 2014 and 2018, temperatures did not reach 14°C until 10 days later.

Between April 29 and June 26, the largest grayling arrived, and in total, 915 adult grayling were counted. When the run began, the water temperature was 4°C. Tack (1972) reported that the preferred spawning conditions for Arctic grayling begin at 4°C and continue until temperatures reach 16°C (Stewart et al. 2007). In accordance with our findings, this temperature relationship also holds true for the Yukon. We tallied 567 departing grayling, with 339 exiting towards Atlin Lake and 228 departing upstream towards Little Atlin Lake. Scattered departures began on May 7, ten days after the first arrivals. However, the largest departures began on June 16, when the mean water temperature was 12°C. The greatest departures occurred when the mean water temperature reached 16°C. Interestingly, we observed that at 16°C, the remaining grayling began to school, which we believe signaled an imminent departure. However, after several days of clouds and rain, mean water temperatures dropped to 14°C, and the schooling behaviour dissipated, with individual grayling reestablishing their spatial territories. Movements by grayling to avoid high water temperatures have been reported (Schallock 1966). Further, Wojick (1955) observed that when lake surface water temperatures reached 17°C, grayling began to school and moved to cooler waters (e.g., a stream outlet at 12°C).

We found a structure in grayling arrivals, with the largest arriving first, followed by smaller adults, sub-adults and juveniles. It has been documented that male grayling arrive on the spawning beds first, followed by females (Barton and Schill 2005). This may account for the run's modal size distributions. There is sexual dimorphism in grayling, with males being larger than females (Englmaier et al. 2022). During our monitoring, we classified all sampled grayling as either male or female based on their morphometric differences. Refining the belief that males arrive first, our classifications revealed that both males and females arrived simultaneously. However, early male arrivals were twice as numerous as females. Later, as the spawning event progressed, the ratio became closer to one-to-one.

To account for the late-arriving juveniles, and in accordance with Tack (1972), we believe this may be a mechanism for the young to imprint on the spawning beds. Tack reported that one- and two-year-old grayling were present on the spawning beds, but their arrivals lagged the adults. He hypothesized that their presence may have been due to imprinting, which occurs both on the spawning beds and feeding grounds. In our study, juveniles did not appear in our spawning traps until later in the spawning run, much after the first adult arrivals. Additionally, there were no reports of juveniles during our first and second trial snorkeling events. However, we identified schools of young grayling during our third trial.

Other species

During the spawning event, we also recorded many round whitefish and northern pike entering and departing through our weirs. In total, we tallied 63 round whitefish and 96 northern pike entering the area. It is likely that both species were there to feed. In the case of the round whitefish, it is possible they were feeding on newly hatched invertebrates or on the grayling's eggs and resulting fry (Guin 1982, Harper 1961). Additionally, all the observed round whitefish traveled upstream from Atlin Lake, interspersed among the grayling arrivals. Given the strong correlation between the round whitefish arrivals and those of the grayling (Figure 3), and the fact that the upstream distance from Atlin to the Lubbock spawning shoal is approximately 17 km, it is unlikely that the presence of round whitefish was a random occurrence. We are uncertain what caused the round whitefish to migrate with the grayling; however, it has been reported that they follow other species onto their spawning beds. For example, in New Hampshire, the round whitefish are sometimes called the "shad waiters," referring to their habit of waiting for American shad (*Alosa sapidissima*) to spawn so they can feed on their eggs (Harper 1961). Stewart et al. (2007) reported that round whitefish have been observed hovering above spawning longnose suckers, presumably waiting to feed on their newly laid eggs.

Given the correlation between grayling and northern pike arrivals, we also believe that northern pike were opportunistically feeding on the abundant grayling. Pike are opportunistic predators, and salmonids, such as Arctic grayling, are a preferred food source (Sepulveda et al., 2013; Stewart et al. 2007). While northern pike are spring spawners, we attribute the influx of northern pike to post-spawning activity for several reasons. In our monitoring of the two weirs, we traversed the banks of the Lubbock several times daily and did not observe any spawning pike in the shallow, clear waters. Nor did our survey technicians report witnessing spawning pike during our three snorkeling events. However, in several instances, we recorded specific individuals making multiple trips, back and forth, from Little Atlin Lake. As such, we infer that these movements were likely foraging behaviors. There are few records of northern pike performing feeding migrations, but Ovidio (2005) reported a post-spawning downstream migration of pike. Although the authors speculated this migration could have been for feeding, they did not have enough data to draw definitive conclusions. Other species have been shown to have feeding migrations. For example, Koed et al. (2000) reported similar upstream and downstream movements in adult pikeperch (Stizostedion lucioperca), and suggested these movements were part of a feeding migration. What is particularly interesting in our case is that the vast majority of northern pike arrived from Little Atlin Lake, moving downstream to the grayling's spawning bed. Given that these pike were unlikely to have a direct scent cue, we are uncertain what environmental or physiological factors triggered this foraging migration.

In addition to northern pike and Arctic grayling, we also counted 780 mature longnose suckers spawning in the Lubbock. The arrival time of these fish minimized direct competition for spawning habitat, as it occurred slightly after the major pulse of Arctic grayling. Arguably, the spawning longnose suckers likely provided an additional food source (eggs) for the round whitefish (Stewart et al. 2007).

Weir vs. snorkel population estimates:

We found that the three snorkel estimates consistently underestimated the weir counts by 30%, 14% and 33%, respectively, with only one weir count falling within the 95% confidence interval of the snorkel estimate. It must be noted that our estimates did not account for grayling that may have been harvested or predated during the survey period. That said, two persons were present during the entire period the grayling were resident on the spawning beds, and we believe the angling pressure was not substantial. Therefore, while mortalities account for a portion of the snorkel underestimates, it does not account for all discrepancies.

In the past, we chose to use snorkeling surveys because they are an inexpensive and non-lethal method for quantifying fish populations (Weaver et al. 2014). However, many environmental and behavioral factors can affect population estimates using this technique. For example, we used an expansion factor to adjust for uncounted fish, but this factor was based on water clarity, which can worsen with each snorkel run. Additionally, the stream banks of the Lubbock have undercuts and many fallen trees, which serve as excellent hiding spots and obstructions to line of sight.

The 2014 and 2017 snorkel survey results reflected the timing of the run's start, peak and end, and generally agreed with our weir results (Figure 4). However, in accordance with our 2014 and 2017 snorkel survey tallies, we noticed that the reported numbers of grayling present peaked at much higher numbers when compared to the 2018 weir results. This suggests that the 2018 grayling run may have been impeded or underwent a major population reduction (Figure 4). We believe there are two potential explanations for the 2018 low returns. First, the presence of a low-head beaver dam just below the spawning beds may have served as a partial obstruction to grayling passage. Second, the presence of our weir may have also deterred fish passage, as we observed grayling below the weir.

Supporting this assertion, the population estimate derived from close-kin mark-recapture using genetic analysis placed the population at approximately 1,800 individuals. (95% CI ≈ 1,200-2,400) (Prystupa et al. 2021). This estimate more closely aligned with the maximum snorkel counts from 2014 and 2017, which yielded expanded population estimates of approximately 1,400 for both years (figure 5).

Our findings indicate that Yukon Arctic grayling share similar temperature requirements to populations elsewhere in North America. The Lubbock spawning event began when water temperatures reached 4°C and appeared to end when they approached 17°C. Grayling activities surrounding the spawning event lasted for approximately one month, with grayling staying resident for 32 days ± 4.61. Our daily counts of other species accompanying the grayling during spawning revealed that grayling are an important keystone species. Both round whitefish and northern pike were presumed to use the spawning grayling or their eggs as food sources. Our finding that northern pike appeared to perform a downstream foraging migration is one of the first on record. The incongruity between snorkel survey results and fence counts would likely have been reduced if we had accounted for angler harvest. Nevertheless, contrary to expectations, our work points to a consistent bias, with snorkel surveys underestimating the actual number of spawners present. This discrepancy is likely associated with trying to observe and count grayling while floating downstream in swift water, with many deadfalls and bank undercuts obstructing the surveyors' views.

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