U.S. Fish and Wildlife Service

Abundance Estimates of Juvenile Sockeye Salmon Emigrants from Meadow Creek, Alaska, 2013

Alaska Fisheries Data Series Number 2015-4

Anchorage Fish and Wildlife Field Office
Anchorage, Alaska
July 2015

The Alaska Region Fisheries Program of the U.S. Fish and Wildlife Service conducts fisheries monitoring and population assessment studies throughout many areas of Alaska. Dedicated professional staff located in Anchorage, Juneau, Fairbanks, Kenai, and Anchorage Fish and Wildlife Offices and the Anchorage Conservation Genetics Laboratory serve as the core of the Program's fisheries management study efforts. Administrative and technical support is provided by staff in the Anchorage Regional Office. Our program works closely with the Alaska Department of Fish and Game and other partners to conserve and restore Alaska's fish populations and aquatic habitats. Additional information about the Fisheries Program and work conducted by our field offices can be obtained at:

http://alaska.fws.gov/fisheries/index.htm

The Alaska Region Fisheries Program reports its study findings through two regional publication series. The **Alaska Fisheries Data Series** was established to provide timely dissemination of data to local managers and for inclusion in agency databases. The **Alaska Fisheries Technical Reports** publishes scientific findings from single and multi-year studies that have undergone more extensive peer review and statistical testing. Additionally, some study results are published in a variety of professional fisheries journals.

Alaska Fisheries Data Series Number 2015-4, July 2015
U.S. Fish and Wildlife Service

Abundance Estimates of Juvenile Sockeye Salmon Emigrants from Meadow Creek, Alaska, 2013

Kevin M. Foley

Abstract

Sockeye Salmon *Oncorhynchus nerka* require a diversity of habitats for completion of their freshwater life stages. Maintaining connectivity to sensitive areas is vital for the long-term stewardship of the species within the Matanuska-Susitna basin. At present, approximately 75 culvert road crossings occur within the waterways of the Meadow Creek drainage, with 80% assessed as impediments to juvenile salmonid migration. Restoration activities to improve fish passage have been ongoing for the past 15 years; however, current fish passage engineering is designed with juvenile Coho Salmon *O kisutch* as the target species. The goal of this project was to evaluate the importance of the Meadow Creek drainage as a rearing and overwintering location for juvenile Sockeye Salmon. A total of 8,184 juvenile Sockeye Salmon were captured in a fyke net with fry comprising 89% of the total Sockeye Salmon catch. Two distinct size classes among juvenile Sockeye Salmon were observed; 29–54 mm and 69–124 mm, suggesting the presence of two Sockeye Salmon cohorts within the Meadow Creek drainage. We found little evidence to suggest that Meadow Creek and its tributaries support significant numbers of summer stream rearing forms of Sockeye Salmon or smolt production. Fish passage designs for restoration activities in the Meadow Creek drainage need not further consider Sockeye Salmon, as present fish passage design criteria are adequate, and changes to include Sockeye Salmon are not warranted at this time.

Introduction

Pacific salmon *Oncorhynchus* spp. require a diversity of habitat types for completion of their various life stages. For salmon species with prolonged freshwater life history stages, such as Sockeye Salmon *O nerka,* habitat requirements for spawning are different than those needed for freshwater rearing including overwintering (Groot and Margolis 1991; Quinn 2005). Riverine born Sockeye Salmon can rear in rivers or migrate to sea during their first year indicating they can exploit a wider range of environmental conditions and habitats than Sockeye Salmon born in lake systems (Wood et al. 1987; Heifetz et al. 1989; Murphy et al. 1989; Eiler et al. 1992). Presence of both riverine and lake form Sockeye Salmon within a watershed suggests migrations could occur in both upstream and downstream directions with exchange between riverine and lake environments. Given the movement potential of these stocks, migrating juvenile Sockeye Salmon are vulnerable and susceptible to anthropogenic migratory barriers (e.g., road culverts), that disrupt connectivity between critical habitats.

In 2009 and 2010, the U.S. Fish and Wildlife Service (USFWS) used radiotelemetry to follow the movements, identify spawning locations, and estimate spawning distribution of adult Sockeye Salmon in the Big Lake watershed. Results from this work revealed Sockeye Salmon spawned in nearly equal proportions within Big Lake, and riverine environments within the watershed including Meadow Creek, the major surface-water inflow to Big Lake (USFWS, unpublished data). Utilization of riverine habitats for rearing by juvenile Sockeye Salmon is known to occur within main stem, tributary mouths, and upland slough areas (Wood et al. 1987; Murphy et al. 1989; Eiler et al. 1992). In 2011, seven juvenile Sockeye Salmon were captured as by-catch while sampling for juvenile Coho Salmon *O. kisutch* (Gerken and Sethi 2013). Given these fish were captured within the Meadow Creek portion of the drainage and in the main stem or near smaller lakes in August and September, suggests an alternate life history strategy to lake rearing individuals. At question for Sockeye Salmon are movement of juvenile fish within the Big Lake drainage, differential movements by cohort, and time of emigration. This study seeks to address questions related to movement of juvenile Sockeye Salmon from Meadow Creek to Big Lake.

Management Implications

Sockeye Salmon from the Big Lake drainage are an important target species for salmon commercial fisheries within the Central and Northern District of Upper Cook Inlet. Sockeye Salmon from this drainage also support the only personal use salmon fishery in northern Cook Inlet, Alaska (Dunker 2013). Currently, management is largely focused on harvest control and area managers rely on run enumeration and population modeling to manage fisheries. However, understanding early life history requirements and key rearing habitat areas are critical components to maintain and manage habitat necessary for sustained production. Understanding how Sockeye Salmon utilize these habitats and how they respond to anthropogenic disturbances is vital for the long-term stewardship of productive and diverse salmonid populations within the Matanuska-Susitna basin (hereafter Mat-Su).

Restoration and conservation efforts are presently underway within the Mat-Su. In particular, the Big Lake drainage is the current focus of culvert replacement efforts to increase the stream length and area available to juvenile salmon. However, it is difficult to prioritize these restoration activities without a better understanding of the life histories and habitat requirements for Sockeye Salmon. Prioritization for replacement of culverts thought to pose barriers to juvenile salmon migration is based largely on the length of habitat upstream of the culvert that would then be available to colonizing species of salmon after restoration or replacement. At present, area managers have given little consideration towards location of, access to or use of, these potential rearing and nursery areas by juvenile Sockeye Salmon.

Increased human development and urbanization around the cities of Anchorage and Wasilla have impacted stream biotic integrity. Given the variety and importance of management concerns in the region, work on movements and habitat use of juvenile Sockeye Salmon is both important and timely. Prior work on juvenile Sockeye Salmon within the Big Lake drainage has focused primarily on stock enhancement (Chlupach and Kyle 1990), seaward smolt enumeration to better manage sustainable yield (Litchfield and Willette 2002) and presence or absence sampling for inclusion of waters important for salmonid rearing and spawning into the Anadromous Waters Catalog (Johnson and Weiss 2007). This work initiates greater understanding of early life history and habitat use by juvenile Sockeye Salmon occurring in the Big Lake drainage.

Research Questions

This report documents a one-year study to estimate the number of Sockeye Salmon moving from Meadow Creek into Big Lake, Alaska. Of interest for culvert restoration is whether Meadow Creek or its tributaries provide rearing habitat to support juvenile Sockeye Salmon. Hypothesis:

H_{01}: Juvenile Sockeye Salmon do not use Meadow Creek or its tributaries as freshwater rearing habitat and emigrate to Big Lake as age-0 fish.
H_{A1}: Juvenile Sockeye Salmon use Meadow Creek or its tributaries as freshwater rearing habitat and a measurable proportion of these fish emigrate to Big Lake as age-1+ fish.

The overarching goal of this study was to estimate the abundance, age composition, and mean size of juvenile Sockeye Salmon emigrating from Meadow Creek, Alaska, from May 12 through June 20, 2013. The following objectives will help address our research question:

1. Estimate the abundance of emigrating juvenile Sockeye Salmon from Meadow Creek.
2. Estimate the mean length and weight of juvenile Sockeye Salmon emigrants from Meadow Creek, such that weight estimates are within 25% of the true value with 95% confidence (Seber 1982).
3. Estimate the age composition of emigrating juvenile Sockeye Salmon within d = 0.05 (effect size) of the true proportion with 95% confidence (Seber 1982; Carlson 1998).

Study Area

Located in Southcentral Alaska, the Meadow Creek watershed lies within the glaciated Mat-Su valley of upper Cook Inlet (Figure 1). The headwaters are located approximately 48 km north northwest of Anchorage near the city of Wasilla; the most rapidly growing and developed region of the Mat-Su Borough (U.S. Census Bureau 2010). Meadow Creek is the longest watercourse of the Big Lake watershed flowing approximately 10.3 km beginning from its upstream terminus at the confluence of Little Meadow and Lucille creeks to its mouth at the northeastern corner of Big Lake (Figure 2). Meadow Creek is a low-gradient peatland and groundwater dominant system fed by many small lakes and tributaries with strong influences from groundwater contributions and wetland-floodplain interactions (Jokela et al. 1991; Hogan 1995). Stream-channel patterns consist primarily of meandering channels with most reaches flowing through riparian wetlands, including palustrine emergent, shrub/scrub, and forested wetlands (Curran and Rice 2009). Adjacent riparian plant growth forms consist of shrub herb, deciduous forest, or mixed conifer/ deciduous forest (Viereck et. al. 1992). Within Meadow Creek, the most dominant cover type is instream vegetation, followed by overhanging vegetation. Gravel suitable for salmon spawning is present within the upper reaches of Meadow Creek, an area representing approximately 40% of the entire stream length, whereas lower stream reaches consist primarily of peat, silt and sand substrates (Curran and Rice 2002). Meadow Creek and its tributaries (e.g., Little Meadow Creek, Lucille Creek) was identified in a 2009-2010 USFWS radiotelemetry study as supporting approximately half of all returning adult Sockeye Salmon spawning sites (USFWS, unpublished data).

Methods

Fyke Operation

To collect fish, a modified double framed fyke net (hereafter fyke net) was installed near the crossing of Beaver Lake Road and Meadow Creek, approximately 6.3 river kilometers (rkm) upstream of the Meadow Creek effluent into Big Lake (Figures 1 and 2). Two wings, a central trap opening, and a fish holding live-box comprised the fyke net. Individual overlapping panels (1.8 m x 1.2 m and 1.2 m x 1.2 m) fabricated from 6061 T6 aluminum structural angles (5 cm x 5 cm x 0.3 cm) and black, 0.3 cm polyethylene standard duty mesh formed the two wings. The central trap was constructed from 0.3 cm, 15 kg netting with a 0.9 m x 0.9 m opening with approximately 76.2 cm between the first frame and the second. Two 0.9 m x 0.9 m internal trapping panels (winkers) between the front frames beveled towards the center and a vertical cap 15.2 cm wide x 15.2 cm tall left between the two winkers permit fish to enter, and not leave, the trap (Figure 3a). Netting material behind the second frame tapered over 0.9 m to a 40.6 cm diameter cone and clamped to a 1.2 m length x 1.2 m wide x 0.9 m high, 5052 marine grade aluminum fish holding live-box. The sides of the live-box were 0.3 cm perforated plate to facilitate water flow through (Figure 3b). Pending creek stage height, the entirety of the stream channel wetted-width was blocked off funneling fish into the trap and live-box. At higher water levels, it was not possible to block the entire channel. The fyke net was installed once the creek was free of ice and remaining ice posed no risk of damage to the wings and continued fishing until the migration of juvenile Sockeye Salmon subsided.

All fish captured in the fyke net were held in the live-box until they were counted. Live-box trap checks (“sets”) occurred every two to three hours in a 24-hour period and at greater frequencies during periods of peak movement and fish capture. A single sampling day corresponds to a 24-hour period beginning at 0000 hours and ending at 2359 hours. All captured fish were transferred from the live-box with a dip-net and transferred to an instream holding box for identification, sampling, and in the case of Coho Salmon smolt, mark identification (Appendix A). Identification of individual salmonid species was made by visual inspection of external physical characteristics (Pollard et al. 1997). All data, including mortality counts, were recorded on paper for each set. All components of the fyke net were cleaned every two to three hours or as needed to prevent net failure and blow-out. A pocket thermometer submerged at the fyke net live-box was used to measure water temperature at each set. Water discharge was recorded daily by the Alaska Department of Fish and Game (ADF&G) using a SonTech ADV or Teledyne StreamPro Acoustic Doppler at the same location (T.A. Cappiello, ADF&G, personal communication).

Whenever possible, daily subsamples of juvenile Sockeye Salmon were collected from the fyke net live-box for age, wet weight, and fork length (FL) to nearest mm measurements. A buffered stock solution of MS-222, 40 mg/L (Schoettger and Julin 1967) was used to anaesthetize all Sockeye Salmon undergoing length and weight measurements. Scales were collected for age verification from all sockeye smolt captured. Verification of length-cohort for smolting fish was established at >69 mm (Meehan 1962; McDonald 1984; Baer 2010). Scale samples were collected in the field using the procedure described by Jerald (1983) and placed upon a glass slide. Scale samples were examined with a microscope and aged using the standards and guidelines of Mosher (1968). Samples were aged by two independent observers and discrepancies between observations were resolved by a third party. Fish ages were reported using the European methods described by Jerald (1983).

Sampling Efficiency

Previously tagged Coho Salmon smolting through the study site (Gerken and Sethi 2013) provided the opportunity to estimate sampling efficiency of the fyke net. Two automated Passive Integrated Transponder (PIT) tag fixed-antenna arrays, one located 100 m upstream of the fyke net (hereafter Hatchery site) and the second downstream, at the outflow of Big Lake, (hereafter Bridge site) served as a baseline for the known number of individuals for determining fyke net sampling efficiency (Figure 1). Sampling efficiency was measured during periods when the fyke net extended across the entire stream channel wetted-width, hereafter referred to as “full stream closure”. All Coho Salmon smolt captured within the fyke net live-box were visually inspected for physical marks (i.e., clipped adipose fin indicating presence of a PIT tag) prior to release into Meadow Creek. A hand held antenna affixed to a PIT tag reader (Biomark; Model FS2001-ISO) confirmed visual observations of physical markings and PIT tag presence.

Electrofisher Sampling
Low catch rates of Sockeye Salmon fry at the fyke net may be indicative of a prolonged residency or as delayed downstream movements from Meadow Creek into Big Lake. Therefore, wadeable stream reaches within close proximity to known salmon spawning enclaves (Figure 2) were sampled using a backpack electrofisher (Smith-Root; Model LR-24) to detect for juvenile Sockeye Salmon presence-absence. Moving upstream, one electrofisher operator and a dip netter sampled for juvenile Sockeye Salmon within the stream reach by exposing all areas of cover to electricity (Reynolds 1996; Dunham et al. 2009). Particular attention was given to sampling within areas of the stream margins, low water velocities and off-channel habitat areas. Voltage, pulse, and frequency were adjusted to optimize catch, beginning with a 30-Hz DC pulse at 12% Duty Cycle (4 ms) and 220-280 V (Reynolds 1996; Dunham et al. 2009). The time of applied electricity (s) within each stream reach was recorded as a unit of effort.

Data Analyses

Enumeration of Catch
The number of Sockeye Salmon emigrating from Meadow Creek was estimated as the sum of all set abundance estimates, determined as;

$$\hat{N}^{total} = \sum_{j=1}^{J} \hat{N}_j^{set}, \qquad (1)$$

where J is the number of sets over the study period and $\hat{N}_j$, is the total Sockeye Salmon fry per set. The estimate of $\hat{N}^{total}$ is made up of direct count sets, therefore the variance of a set is zero as it represents a direct count.

We determined the mean weight of Sockeye Salmon fry, $\hat{\bar{x}}$ from samples collected over the course of the study period. To calculate the sample size necessary to estimate the mean weight of juvenile Sockeye Salmon with desired precision, we modeled 100,000 normally distributed random sockeye weights. Observations of juvenile Sockeye Salmon weights were based on information collected in neighboring systems close to the study area (Nemeth et. al., 2010; Baer 2011). Assuming a mixed age cohort, we expect the emigrant Sockeye Salmon weights to have a mean weight of 2.31 g and standard deviation of weights of 1.41 g.

To be 95% confident the sample mean is within a distance of +/- D of the true mean Sockeye Salmon fry weight, the sample size of n^* individual sockeye fry weights is determined as;

$$n^* = \frac{(z_{.025})^2\sigma^2}{D^2} = \frac{1.96^2\sigma^2}{D^2} \approx 3{,}054 \qquad (2)$$

where, D = 0.05 margin of error, and σ = 1.41.

Age Verification
Sockeye Salmon demonstrate a significant diversity in life history strategy including multiple year residencies within the freshwater environment (Groot and Margolis 1991; Quinn 2005; Powers et. al. 2007). Expected results are that Meadow Creek is used as a rearing area by multiple juvenile Sockeye Salmon cohorts and that a proportion of Sockeye Salmon migrate into Big Lake as older aged-class individuals. As such, captured fish will reside in two forms; smolt (>69 mm; Meehan 1962; McDonald 1984, Baer 2011) and age-0 fish (30–69 mm; McDonald 1984) would both be captured in the fyke net. To distinguish cohorts, fish FL were used to determine age class and differentiate between age-0 and age-1+ juvenile Sockeye Salmon. Scale samples from voucher smolt specimens (>69 mm) will be compared to model results.

Sampling Efficiency
Hatchery site sampling efficiency was measured during periods of full stream closure and was determined as;

$$\frac{\sum_{i=1}^{22} n_i^{hatchery\ detections}}{\sum_{i=1}^{22} N_i^{bridge\ detections}} \tag{3}$$

where; $\sum_{i=1}^{22} n_i^{hatchery\ detections}$ is the total PIT tagged fish detected at the Hatchery site and $\sum_{i=1}^{22} N_i^{bridge\ detections}$ is the total PIT tagged fish detected at the Bridge site.

Fyke net sampling efficiency was measured during periods of full stream closure and was determined as;

$$\frac{\sum_{i=1}^{22} n_i^{fyke\ net\ detections}}{\sum_{i=1}^{22} N_i^{bridge\ detections}} \tag{4}$$

where; $\sum_{i=1}^{22} n_i^{fyke\ net\ detections}$ is the total PIT tagged fish detected at the fyke net and $\sum_{i=1}^{22} N_i^{bridge\ detections}$ is the total PIT tagged fish detected at the Bridge site.

In determining fyke net sampling efficiency in this manner, we assume; (1) the marked population is defined as the total number of PIT tagged fish detected by the Bridge site. Each PIT tagged fish has an equal probability of detection at both the Hatchery site and fyke net and; (2) the marked population has a near instantaneous travel time from the Hatchery site and fyke net to the Bridge site and; (3) the marked population is closed and no other PIT tagged fish enter the population from areas other than upstream of the Bridge site.

Results

Sockeye Salmon
The fyke net was fished from May 12 through June 20, 2013. Partial stream closure (~20% wetted width) by the wings occurred from May 12 through May 29 as high water levels prevented full stream closure (100% wetted-width) until May 30. The fyke net was not fished during two periods, May 18–19, and May 25–28, when high water persisted, at which time a sliding door panel in the live-box was removed allowing downstream passage to all fish captured within the fyke net live-box.

Juvenile Sockeye Salmon fry and smolt were captured as they moved downstream through the fyke net. A total of 8,184 juvenile Sockeye Salmon were captured in the fyke net with fry comprising 89% of the total Sockeye Salmon catch (Table 1). Daily catches of Sockeye Salmon occurred for each day during the study period with the single largest daily catch, n = 1,900, occurring on May 13 (Figure 4). The highest catches within a day occurred at night and during early morning set checks occurring at approximately 0200 hours and 0800 hours (Figure 5a).

A total of 907 Sockeye Salmon were sampled for FL and weight measurements from May 21 to June 20 (Table 2). Of these, one fish was removed from analyses after the data revealed an erroneous weight measurement. Sockeye Salmon ranged in length from 29 mm to 124 mm FL (mean = 40 mm; SD = 15.2; Table 2). Among juvenile Sockeye Salmon FL measurements, two distinct size classes were observed; fish 29–54 mm and 69–124 mm (Figure 6). Sockeye Salmon weights ranged from 0.1–17 g (mean = 0.9 g; SD = 2.2; Table 2). Length-frequency analyses of Sockeye Salmon suggest the presence of age-0 and age-1+ fish occurring within the Meadow Creek drainage (Table 5; Figure 7. During the study period, no Sockeye Salmon were captured between 55–68 mm and 80–90 mm (Figure 6).

The mean weight of Sockeye Salmon determined from 906 samples was 0.87 g (Table 2). Our target goal of 3,054 Sockeye Salmon weights was not accomplished. Within measured fish 29–55 mm, an increasing trend within the daily mean FL over time was observed (Table 3; Figure 6). Contrast to measured fish 69–124 mm where a decreasing trend within the daily mean FL over time was observed (Table 3; Figure 6).

There were 42 scale samples collected from among juvenile Sockeye Salmon smolt (>69 mm). Among three independent observers, seven scale samples did not receive similar age classification (Appendix B). Of these, only one aged scale sample differed between observer two and observer three, whereas observer one reported six aged scale samples different than reported by observers two and three. Between the shortest and longest measured fish (69 and 124 mm FL) with scale samples collected, all observers reported the fish age at 1 year.

Catch per unit effort (number of fish per seconds of applied electricity) for backpack electrofisher sampling was 5.16×10^{-05}; a single Sockeye Salmon fry was captured during 19,389 s of electricity in 6,163 m of stream (Figure 2).

Sampling Efficiency
Approximately 573 PIT tagged Coho Salmon were detected at the Bridge site May 29 through June 20. Of these, 431 were detected at the Hatchery site and 56 in the fyke net. Fyke net sampling efficiency of PIT tagged Coho Salmon was approximately 10% compared to 75% at the Hatchery antenna array (Table 6).

Non-target species
Other species captured include; Coho Salmon *O. kisutch*, Sculpin *Cottidae*, Rainbow Trout *O. mykiss*, Longnose Sucker *Catostomus catostomus*, and Round Whitefish *Prosopium cylindraceum* (Table 1). A total 8,103 Coho Salmon were captured in the fyke net (Table 1). Coho Salmon smolts comprised 94% of the total Coho Salmon catch. The single largest daily catch occurred June 6 (Figure 8). Catches of Coho Salmon were highest between 1600 and 2200 hours (Figure 5a).

Stickleback *Gasterosteridae* and Lamprey *Petromyzontidae* were the two most abundant species captured in the fyke net (Table 1). Peak daily catches for Stickleback, Lamprey, and Sculpin species occurred on June 15, June 14, and June 12, respectively. Peak catches of Rainbow Trout *O. mykiss* occurred on June 13 and daily catches of Rainbow Trout were always less than 31 (Table 4; Figure 8).

Water Discharge
Mean instream flow measurements for May 2013 were approximately three times greater than the four year mean corresponding to 2009–2012, measured as approximately 114 and 29 cubic feet/sec (cfs), respectively (Thomas Cappiello, ADF&G, unpublished data). The single highest daily cfs recorded for May over the 4-year period was 66 cfs occurring May 1, 2012. During 2013, all but a single day during May exceeded 66 cfs. The range of instream flow recorded for May 2013 was approximately 65–125 cfs.

Discussion

This effort was the first attempt to estimate abundance and run-timing of juvenile Sockeye Salmon in the Meadow Creek watershed of Southcentral Alaska; previous efforts by ADF&G enumerated sockeye smolts emigrating from Big Lake (Chlupach and Kyle 1990; Litchfield and Willette 2002; Robert DeCino, ADF&G, personal communication). Late season ice break-up occurred approximately April 27 (Thomas Cappiello, ADF&G, personal communication) and high water flow prevented installation of the fyke net prior to May 12 with full stream closure occurring May 30. The largest single-day capture of Sockeye Salmon fry was observed with the initial deployment of the fyke on May 13 with the second largest catch occurring May 24. This suggests the outmigration of Sockeye Salmon fry from Meadow Creek was already in progress prior to installation of the fyke net and that the majority of the downstream movement had already occurred. Higher than average flow conditions occurring in early May 2013 on Meadow Creek may have restricted/delayed downstream migration of Sockeye Salmon fry into Big Lake. As such, we lack the ability to predict reliable abundance estimates with these data. The lack of 55–68 mm FL Sockeye Salmon within our samples is consistent with size thresholds represented in the literature for age-0 and age-1+ Sockeye Salmon (Meehan 1962; McDonald 1984, Baer 2011).

During all sample days and among the daily fyke net set checks, the largest numbers of Sockeye Salmon fry were collected at 0200 hours and 0800 hours, with approximately 2,100 and 1,600 fry, respectively (Figure 5A). This suggests that Sockeye Salmon fry movements were greatest between 0000 and 0200 hours and between 0600 and 0800 hours, respectively. Similar movement patterns by Sockeye Salmon fry during periods of low-light intensity are well supported within the literature (Groot 1965; Quinn 2005).

The most Sockeye Salmon smolt captured at the Meadow Creek fyke net was approximately 20 fish on June 6 (Figure 4). The number is low compared to approximately 89,000 Sockeye Salmon smolts captured on May 31 at the ADF&G fyke net operated in Fish Creek (Figure 1; Bob DeCino, ADF&G, personal communication). The large discrepancy in numbers captured at the Meadow Creek fyke net and the downstream ADF&G fyke net, leads us to believe that there are lag times associated with seaward migration patterns in the drainage. We captured only nine Sockeye Salmon smolt at the Meadow Creek fyke net prior to the May 31 peak at the ADF&G fyke net. For comparison, to determine effectiveness of our fyke operation, we examined catch rates of Coho Salmon smolt between the two sites. The Meadow Creek fyke net sampled approximately 10% of the Coho Salmon smolt available at the ADF&G fyke. Because Sockeye Salmon smolt numbers at the ADF&G fyke are an order of magnitude more abundant than Coho Salmon smolt (Bob DeCino, ADF&G personal communication) we believe that if Sockeye Salmon smolt were available during the Meadow Creek fyke net operation we would have captured a larger proportion of individuals.

Because our capture proportion was low (<0.001%), it is possible Sockeye smolt emigrated early, during the two weeks of open water before the fyke net was deployed in Meadow Creek. However, we believe there is little support for this idea. Given travel times of salmon smolt migrating from points upstream of the Meadow Creek fyke net to the ADF&G fyke net (Joshua Ashline, USFWS, personal communication) we would have expected a significant emigration of Sockeye Salmon smolt during late April and early May prior to May 15. However, this did not occur. No Sockeye Salmon smolts were captured at the ADF&G fyke net until May 25. Despite the relatively low contribution of Meadow Creek and its tributaries to the production of Sockeye Salmon smolt within the Big Lake drainage, these areas in aggregate may be important as refugia in the event of a stochastic disturbance in Big Lake. These fish represent an important life history variant of the larger population, and may be most reflective of the dynamics of the larger population of Sockeye Salmon in the region (Isaak et al 2003). However, Meadow Creek supports nearly half of the adult spawning Sockeye Salmon and therefore most of the Sockeye Salmon production within the Big Lake drainage (USFWS, unpublished data).

Sampling efficiency of the fyke net during full stream closure was approximately 10%, which is lower than anticipated (Table 6). One source of sampling efficiency bias is likely observer error and failure to recognize clipped adipose fins of marked juvenile Coho Salmon. Sampling efficiency increased with the use of a PIT tag reader (Biomark; Model FS2001-ISO) to check for tagged fish prior to visual observations of physical markings. This suggests personnel operating the fyke net were not identifying marked fish prior to their release downstream.

As a result of low catch rates of Sockeye Salmon fry at the Meadow Creek fyke net, it was theorized that age-0 individuals exhibited prolonged residency within Meadow Creek or its tributaries. That is, as an expression of summer stream rearing form, or as delayed downstream movements into Big Lake. To assess questions of a prolonged residency, we sampled wadeable stream reaches within Meadow Creek known to provide adult Sockeye Salmon spawning habitat (Figure 2). The low CPUE ($5.16x10^{-05}$) suggests that most Meadow Creek Sockeye Salmon are lake rearing, which lends further support to our assumption that outmigration of Sockeye Salmon fry from Meadow Creek into Big Lake had already occurred. However, we assert that unless formal presence/nondetection studies for Sockeye Salmon fry are conducted, it is possible that a stream rearing life history form of Sockeye Salmon occurs within Meadow Creek and its tributaries (MacKenzie et al. 2006).

The capture of a few older age class juvenile Sockeye Salmon emigrating from the Meadow Creek drainage suggests that some alternate rearing and overwintering habitat areas within the Meadow Creek drainage are utilized. In part, this study was intended to develop and test methods for capture of Sockeye Salmon fry in the Meadow Creek drainage. Our sampling methods were effective at capturing not only Sockeye Salmon fry, but also Coho Salmon smolt (Table 1). However, environmental conditions (i.e., late break-up and high spring flows) prevented reliable abundance estimates of juvenile Sockeye Salmon originating in the Meadow Creek drainage. In a broader management context, it is unknown whether or not a difference exists between Coho and Sockeye Salmon movement given the relative contribution of these alternate rearing areas to the production of Sockeye Salmon within the Big Lake drainage. Based on our findings, we conclude that the relative contribution of these rearing areas, and the existing salmon movement and potential culvert barrier issues around the watershed, are similar between species.

Results of this study can inform and provide direction for current and ongoing research and management within the region. Presently, ADF&G operates a smolt fyke net on Fish Creek within the lower Big Lake drainage (Litchfield and Willette 2002). Additional collaboration through partnerships may help explain the relative contribution of Meadow Creek Sockeye Salmon fry to the total Sockeye Salmon smolt production within the Big Lake watershed. Furthermore, results of this study may be integrated with findings from other USFWS studies in the region to explore questions of mortality and predation rates on Sockeye Salmon by Northern Pike *Esox lucius*.

Arguably the greatest anthropogenic threat to Alaska salmon fisheries is climate warming. As summer thermal maximums increase and summer baseline flows decrease, the potential loss of spawning and rearing habitat to riverine form Sockeye is of great concern. Furthermore, warmer water temperatures may result in an increase of productivity in nursery lakes with significant bottom-up trophic level implications for lake rearing forms. Establishing baseline data of these populations for long-term monitoring and management is vital in conserving Alaska's Sockeye Salmon diversity.

Recommendations

Despite the difficulties and problems with high flows and low sampling efficiency, there is little evidence to suggest that Meadow Creek and its tributaries support substantial numbers of summer stream rearing forms of Sockeye Salmon or smolt production. Therefore, based on our findings, Sockeye Salmon passage for Meadow Creek and its tributaries need not be further considered because most migration occurs downstream through only two culvert pipes (South Beaver Lake Rd and West Parks Highway). At present, both of these culverts meet current ADF&G fish passage criteria (Eisman and O'Doherty 2014).

Specific recommendations directed towards future fyke net studies conducted in Meadow Creek include a central fyke net with larger dimensions. This first year study used a custom fabricated net with a 0.9 m x 0.9 m central opening. A 1.2 m x 1.2 m (or larger) central net opening may be more suitable under high flow conditions to adequately pass drifting organic materials into the live-box. Given the difficulties of fyke net operations under high water conditions in Meadow Creek, alternative capture methods for juvenile Sockeye Salmon should be considered. Inclined plane traps, or rotary screw traps may be used exclusively, or in conjunction with a fyke net. However, assessing sampling efficiencies of these gear types must be incorporated for reliable population assessments. Additionally, it is recommended that studies be undertaken to account for detection probabilities of Sockeye Salmon within Meadow Creek using repeated survey of sites to best address questions about the presence/nondetection of Sockeye Salmon rearing within the riverine environment.

Acknowledgements

I would like to thank the Mat-Su Basin Salmon Habitat Partnership, for providing funding under the National Fish Habitat Action Plan, to make this study possible. This study was conducted by the USFWS, Anchorage Fish and Wildlife Field office. Bob DeCino and Mark Willette with the

Alaska Department of Fish and Game provided project guidance. Nathan Weber of Cook Inlet Aquaculture Association provided equipment support. Acknowledgement and appreciation to the field crew and volunteers who helped with this project: Casey Balthrop, Jennifer Gregory, Sarah Laske, Danielle McClain, Greg Muller, Matt Olsen, Steve Schwartz, and Casey Smith. Special appreciation to the many landowners who provided access to our field sites throughout the duration of the study.

References

Baer, R. T. 2011. Afognak Lake Sockeye Salmon stock monitoring, 2010. Alaska Department of Fish and Game, Fishery Data Series No. 11-27, Anchorage.

Carlson, S. R., L. G. Jr. Coggins, and C. O. Swanton. 1998. Simple stratified design for mark-recapture estimation of salmon smolt abundance. Alaska Fisheries Research Bulletin 5:88–102.

Chlupach, R. S. and G. B. Kyle. 1990. Enhancement of Big Lake Sockeye Salmon Oncorhynchus nerka: summary of fisheries production. Alaska Department of Fish and Game, FRED Division Technical Report No. 106, Juneau.

Dunker, K. J. 2013. Upper Cook Inlet personal use salmon fisheries, 2010-2012. Alaska Department of Fish Game, Fishery Data Series No. 13-59, Anchorage.

Eiler, J. H., B. D. Nelson, and R. F. Bradshaw. 1992. Riverine spawning by Sockeye Salmon in the Taku River, Alaska and British Columbia. Transactions of the American Fisheries Society 121:701–708.

Eisenman, M., and G. O'Doherty. 2014. Culvert inventory and assessment manual for fish passage in the State of Alaska: A guideto the procedures and techniques used to inventory and assess stream crossings 2009-2014. Alaska Department of Fish and Game, Special Publication No. 14-08, Anchorage.

Gerken, J. and S. Sethi. 2013. Juvenile Coho Salmon migration and habitat use in Meadow Creek, Southcentral Alaska, 2011. U.S. Fish and Wildlife, Alaska Fisheries Data Series 2013-1. Anchorage, Alaska.

Groot, C. 1965. On the orientation of young Sockeye Salmon (Oncorhynchus nerka) during their seaward migration out of lakes, 1965. Behaviour Supplement 14:I-198.

Groot, C. and L. Margolis. 1991. Pacific salmon life histories. University of British Columbia Press, Vancouver.

Heifetz, J. S., S. W. Johnson, K. V. Koski, and M. L. Murphy. 1989. Migration timing, size, and salinity tolerance of sea-type Sockeye Salmon (*Oncorhynchus nerka*) in an Alaska estuary. Canadian Journal of Fisheries and Aquatic Sciences 46:633–637.

Hogan, E. V. 1995. Overview of environmental and hydrologeologic conditions near Big Lake Alaska. U.S. Geological Survey Open-File Report 95-403 59 p.

Isaak, D. J., R. F. Thurow, B. E. Rieman, and J. B. Dunham. 2003. Temporal variation in asynchrony among Chinook Salmon (*Oncorhynchus tshawytscha*) redd counts from a wilderness area in central Idaho. Canadian Journal of Fisheries and Aquatic Sciences. 60:840–848.

Jerald, A. 1983. Age determination. Pages 301–324 *in* L. A. Nielsen and D. L. Johnson, editors. Fisheries Techniques. American Fisheries Society, Bethesda, Maryland.

Johnson, J., and E. Weiss. 2007. Catalog of waters important for spawning, rearing, or migration of anadromous fishes- Southcentral Region, Effective June1, 2007. Alaska Department of Fish and Game, Special Publication No. 07-05, Anchorage, Alaska.

Jokela, J. B., J.A. Munter, and J. G. Evans. 1991. Ground-water resources of the Palmer-Big Lake area, Alaska: A conceptual model. Alaska Department of Natural Resources Division of Geological and Geophysical Survey Report of Investigations 90-4, 38 p., 3 sheets, scale 1:25,000.

Litchfield, V. P., and T. M. Willette. 2002. Fish Creek Sockeye Salmon – Technical review. Alaska Department of Fish and Game, Regional Information Report No. 2A01-30, Anchorage, Alaska.

MacKenzie, D. I., J. D. Nichols, J. A. Royle, K. H. Pollock, L. L. Bailey, and J. E. Hines. 2006. Occupancy estimation and modeling: inferring patterns and dynamics of species occurrence. Elsevier, Amsterdam.

McDonald, J. and J. M. Hume. 1984. Babine Lake Sockeye Salmon (*Oncorhynchus nerka*) enhancement program: testing some major assumptions. Canadian Journal of Fisheries and Aquatic Sciences 41:70–92.

Meehan, W. R. and D. B. Siniff. 1962. A study of the downstream migrations of anadromous fishes in the Taku River, Alaska. Transactions of the American Fisheries Society 91:399–407.

Mosher, K. H. 1968. Photographic atlas of Sockeye Salmon scales. Fishery Bulletin 67:243–280.

Murphy, M. L, J. Heifetz, J. F. Thedinga, S. W. Johnson, and K. V. Koski. 1989. Habitat utilization by juvenile Pacific salmon (*Oncorhynchus*) in the glacial Taku River, southeast Alaska. Canadian Journal of Fisheries and Aquatic Sciences 46:1677–1685.

Nemeth, M. J., A. M. Baker, B. C. Williams, S. W. Raborn, J. T. Priest, and S. T. Crawford. 2010. Movement and abundance of freshwater fish in the Chuit River, Alaska, May through July 2009. Annual report prepared by LGL Alaska Research Associates, Inc., Anchorage, Alaska for PacRim Coal, L.P.

Pollard, W. R., G. F. Hartman, C. Groot, and P. Edgell. 1997. Field identification of coastal juvenile salmonids. Harbour Publishing. Madeira Park, British Columbia, Canada.

Powers, S. P., M. A. Bishop, S. Moffitt, and G. H. Reeves. 2007. Variability in freshwater, estuarine, and marine residence of Sockeye Salmon *Oncorhynchus nerka* within the Copper and Bering River Deltas, Alaska. *In* American Fisheries Society Symposium 54:87–99.

Quinn, T. P. 2005. The behavior and ecology of Pacific salmon and trout. University of Washington Press, Seattle.

Seber, G. A. 1982. The estimation of animal abundance and related parameters. 2nd edition. MacMillan, New York, N.Y.

Schoettger, R. A., and A. M. Julin. 1967. Efficacy of MS-222 as an anesthetic on four salmonids. United States Bureau of Sports Fisheries and Wildlife Investigations in Fish Control No 13, Washington, D. C.

United States Census Bureau. Demographic trends. Census.gov. 11 Apr 2011. Web. 14 Aug 2013.

Viereck, L. A., C. T. Dyrness, A. R. Batten, and K. J. Wenzlick. 1992. The Alaska vegetation classification. Gen. Tech. Rep. PNW-GTR-286. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 278 p.

Wood, C. C., B. E. Riddell, and D. T. Rutherford. 1987. Alternative juvenile life histories of Sockeye Salmon (*Oncorhynchus nerka*) and their contribution to production in the Stikine River, northern British Columbia. Canadian Special Publication of Fisheries and Aquatic Sciences 96: 12–24.

Table 1. Total catch of juvenile Sockeye Salmon by life stage and total catch of all other fish species captured in fyke net on Meadow Creek, Alaska, 2013.

Species	Total capture
Total Sockeye Salmon (*Oncorhynchus nerka*)	8,118
--Sockeye Salmon fry	7,255
--Sockeye Salmon smolt	66
Total Coho Salmon (*O. kisutch*)	8,103
--Coho Salmon fry	479
--Coho Salmon smolt	7,624
Rainbow Trout (*O. mykiss*)	320
Lamprey (Unidentified species)	26,102
Stickleback (Unidentified species)	37,109
Sculpin (unidentified species)	6,742
Longnose Sucker (*Catostomus catostomus*)	7
Round Whitefish (*Prosopium cylindraceum*)	1

Table 2. Matrix of summary statistics for *n* = 906 fork length and weight measurements of juvenile Sockeye Salmon, Meadow Creek, Alaska, 2013 (SD = Standard deviation; CL= confidence limit.)

Parameter	Mean	Range	SD	Variance	Lower 95% CL	Upper 95% CL
Fork length (mm)	40	29–124	15.2	231	39	41
Weight (g)	0.9	0.1–17	2.2	4.9	0.7	1.0

Table 3. Matrix of summary statistics for *n* = 906 fork length measurements of juvenile Sockeye Salmon, Meadow Creek, Alaska.

	Mean (mm)		Range (mm)		Standard Dev		Variance		*n*	
Date	<55	>68	<55	>68	<55	>68	<55	>68	<55	>68
5/21/2013	31		31–32		1		0.30		5	
5/22/2013	32		30–33		1		0.42		53	
5/23/2013	31	123	29–35	123	1		1.39		71	1
5/24/2013	32	75	30–34	71–78	1	5	0.98	24.5	68	2
*	*	*	*	*	*	*	*	*	*	*
5/30/2013	32		30–34		1		1.42		25	
5/31/2013	32	105	30–37	97–120	1	10	2.13	109	39	4
6/1/2013		108		101–114		7		44.9	0	4
6/2/2013		102		96–112		6.		36.3	0	6
*	*	*	*	*	*	*	*	*	*	*
6/4/2013		108		95–117		9		75.3		7
*	*	*	*	*	*	*	*	*	*	*
6/6/2013	36	110	32–44	94–124	3	10	9.47	107	13	6
*	*	*	*	*	*	*	*	*	*	*
6/8/2013		113		113					0	1
6/9/2013		69		69					0	1
6/10/2013	36		33–45		2		4.98		42	-
6/11/2013	36	89	31–44	79–98	3	13	8.81	181	88	2
6/12/2013	38	97	34–44	75–113	3	15	6.73	212	49	7
6/13/2013	38	72	34–44	72	3		7.17		43	1
6/14/2013	39		31–44		3		7.82		65	
6/15/2013	41	114	32–47	114	3		10.3		55	1
6/16/2013	41		34–51		4		15.2		41	
6/17/2013	39		32–51		4		14.8		64	
6/18/2013	42		32–54		5		22.7		44	
6/19/2013	42		33–51		4		14.9		38	
6/20/2013	41	91	34–51	75–106	4	16	16.3	240	57	3

"*" denotes a break in time series corresponding to zero collection of length weight data.
"†" denotes days the fyke net operated under partial stream closure.

Table 4. Total catches by day for all species excluding Longnose Sucker and Round Whitefish, captured in Meadow Creek, Alaska, 2013.

Date	Sockeye Salmon	Coho Salmon	Sculpin spp.	Rainbow Trout	Lamprey spp.	Stickleback spp.
5/12/2013†	101	0	0	0	0	1
5/13/2013†	1899	0	0	1	12	2
5/14/2013†	130	0	0	1	3	1
5/15/2013†	240	0	0	0	10	1
5/16/2013†	142	1	0	0	9	5
5/17/2013†	244	0	3	0	18	5
5/18/2013†	254	3	39	1	19	5
*	*	*	*	*	*	*
5/21/2013†	273	0	1	0	0	19
5/22/2013†	583	5	2	1	30	56
5/23/2013†	602	0	1	0	13	26
5/24/2013†	913	3	0	0	3	46
5/25/2013†	639	1	1	0	5	39
*	*	*	*	*	*	*
5/28/2013†	10	0	1	0	0	27
5/29/2013†	108	0	3	1	21	35
5/30/2013†	66	147	0	2	4	18
5/31/2013	180	65	1	1	59	354
6/1/2013	104	162	5	11	187	24
6/2/2013	95	203	13	7	52	126
6/3/2013	41	394	24	5	62	127
6/4/2013	28	484	13	21	24	315
6/5/2013	23	91	46	16	161	177
6/6/2013	46	1454	41	27	393	1139
6/7/2013	16	123	33	8	251	936
6/8/2013	160	332	124	23	1092	1906
6/9/2013	81	303	261	9	1435	2106
6/10/2013	160	258	464	19	1885	2200
6/11/2013	178	477	829	15	2012	2002
6/12/2013	98	422	1476	12	1211	1923
6/13/2013	160	433	332	30	2195	2230
6/14/2013	96	568	0	23	2930	3249
6/15/2013	83	608	333	23	2695	3538
6/16/2013	110	410	723	22	2121	2978
6/17/2013	78	444	610	10	2240	2736
6/18/2013	85	346	323	12	2120	2963
6/19/2013	82	228	512	9	1840	3217
6/20/2013	76	138	528	10	990	2577

"*" denotes non-operational periods of the fyke net.
"†" denotes days the fyke operated under partial stream closure.

Table 5. Fork length frequency of *n* = 906 juvenile Sockeye Salmon captured in Meadow Creek, Alaska, 2013.

Formatted: Line spacing: single

Size class (mm)	Frequency
1–19	0
20–29	45
30–39	626
40–49	180
50–59	9
60–69	1
70–79	7
80–89	0
90–99	11
100–109	12
110–119	13
120–130	2
131+	0

Table 6. Fyke net sampling efficiency determinants for the period May 29 through June 20, 2013, Meadow Creek, Alaska. Bridge and Hatchery sites are automated antenna array detection sites. Bridge site detections used as a baseline measure of marked population.

	Bridge	Hatchery	Fyke net
Total PIT tagged fish detected	573	431	56
Efficiency		0.752	0.097

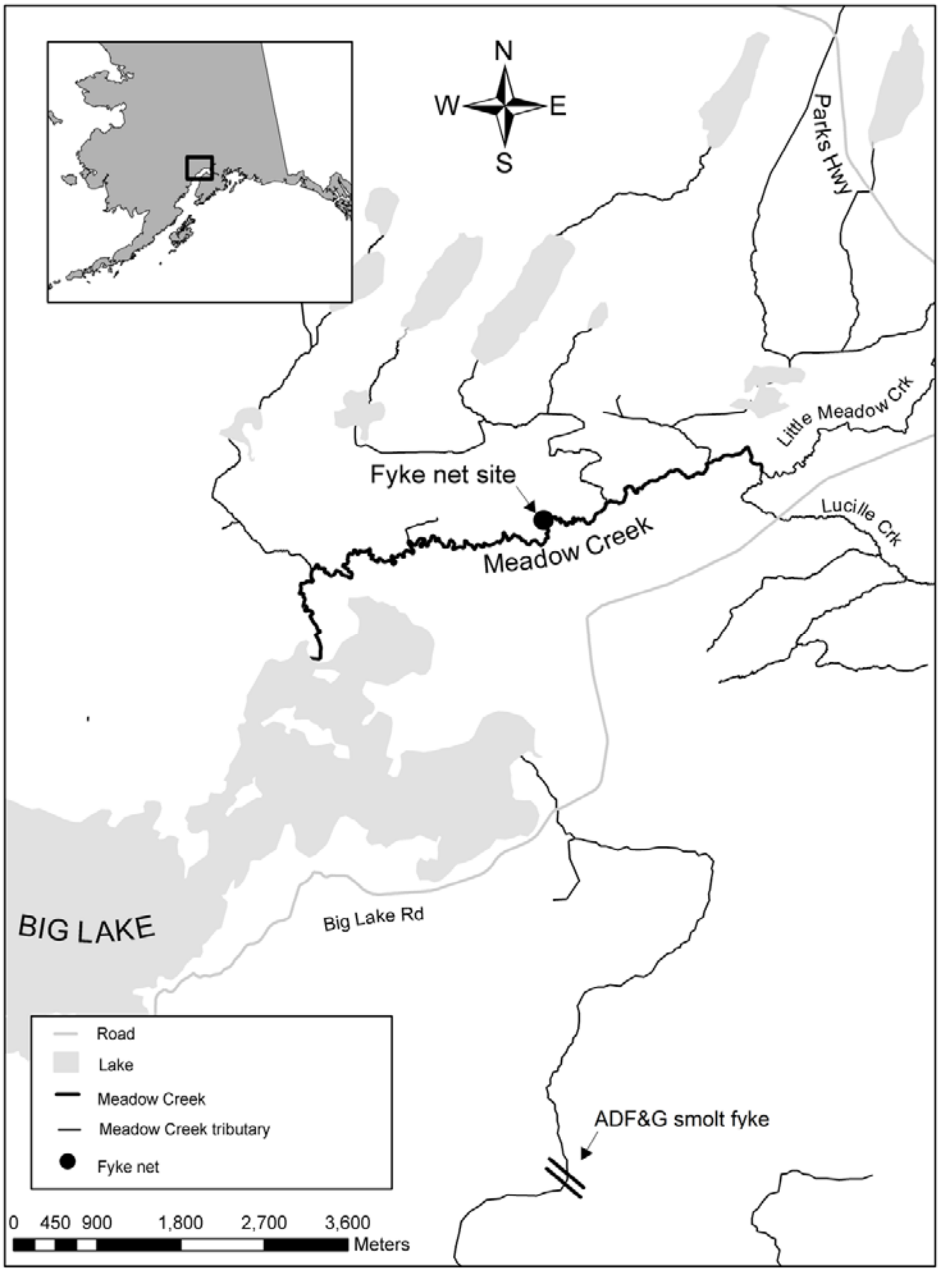

Figure 1. Meadow Creek fyke net deployment site and surrounding water bodies within Meadow Creek, Alaska 2013.

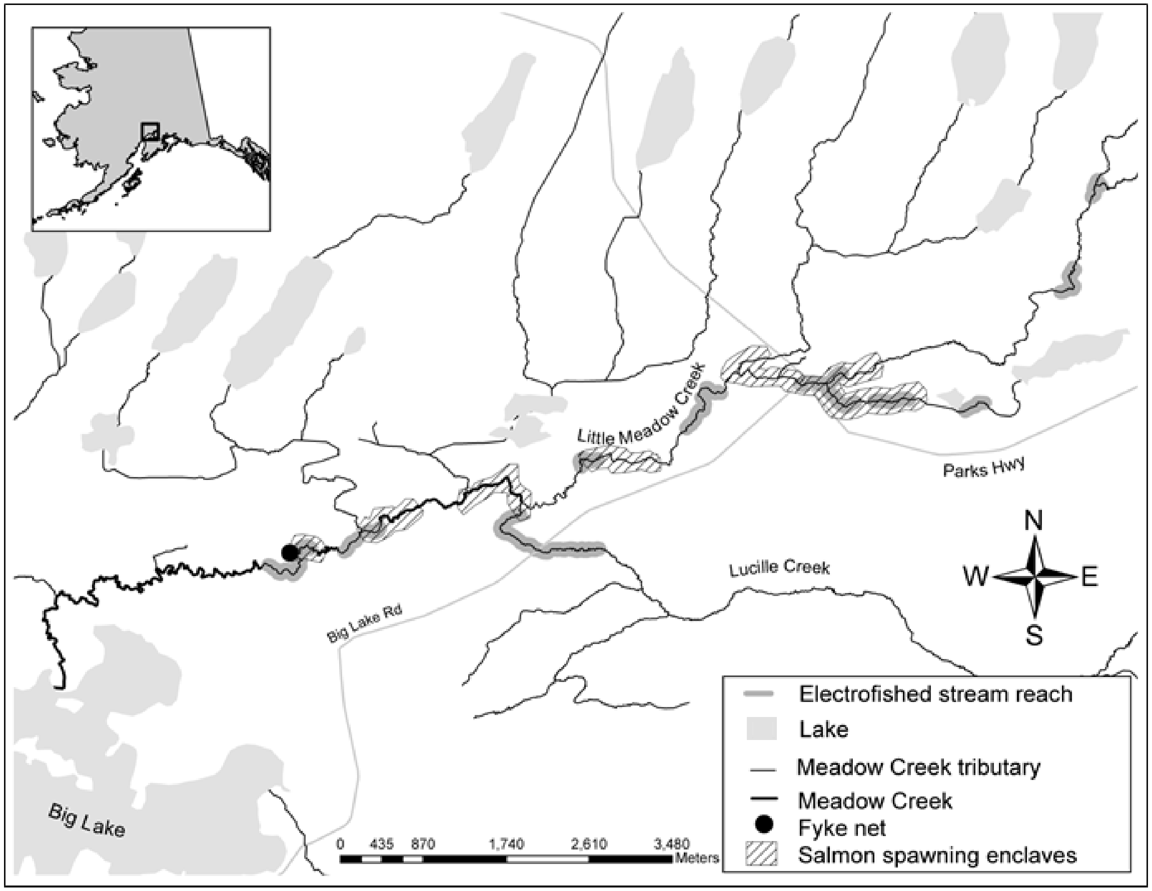

Figure 2. Stream reaches sampled in relation to spawning salmon enclaves occurring within Meadow Creek, Alaska, 2013. Spawning enclaves were identified in 2009-2010.

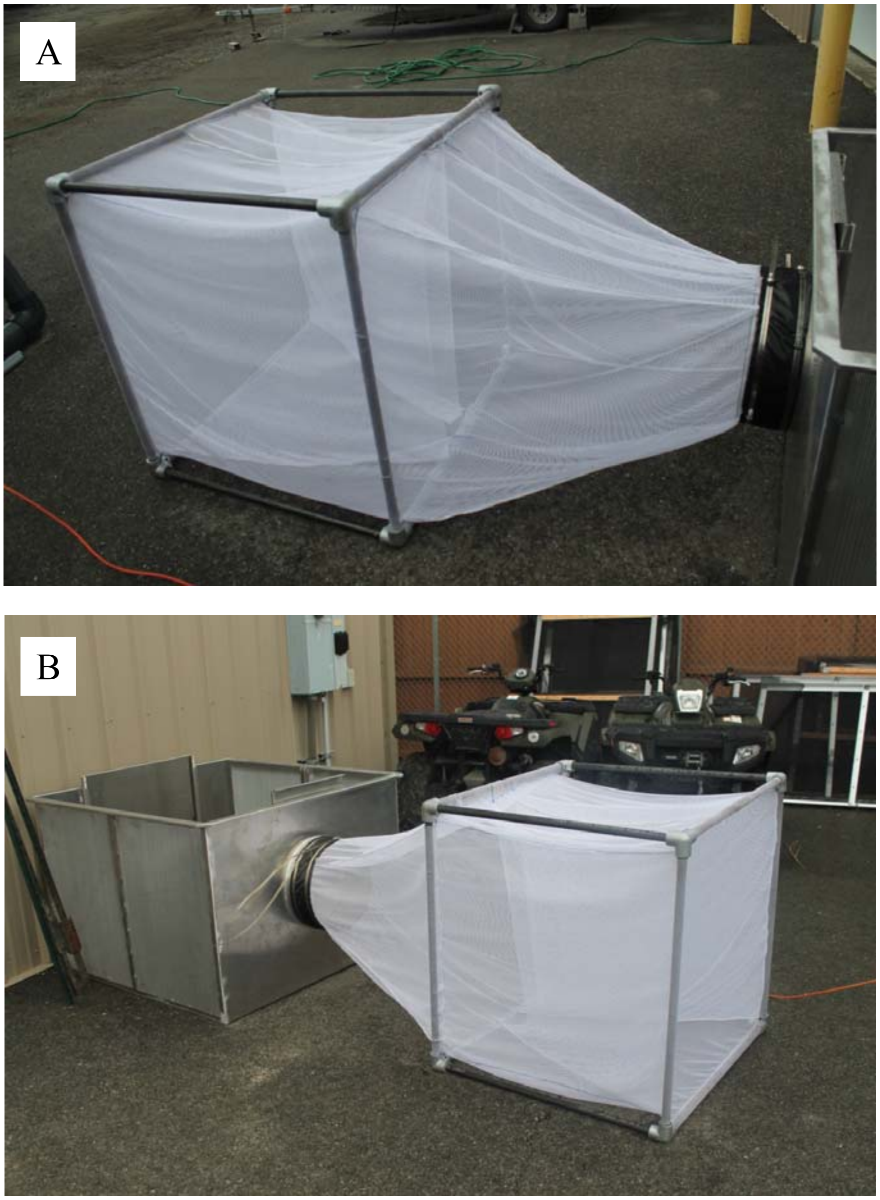

Figure 3. Modified double frame fyke net showing; (A) internal winkers and tapered cone affixed to trap live-box and; (B) live-box with perforated plate sides and removable back panel.

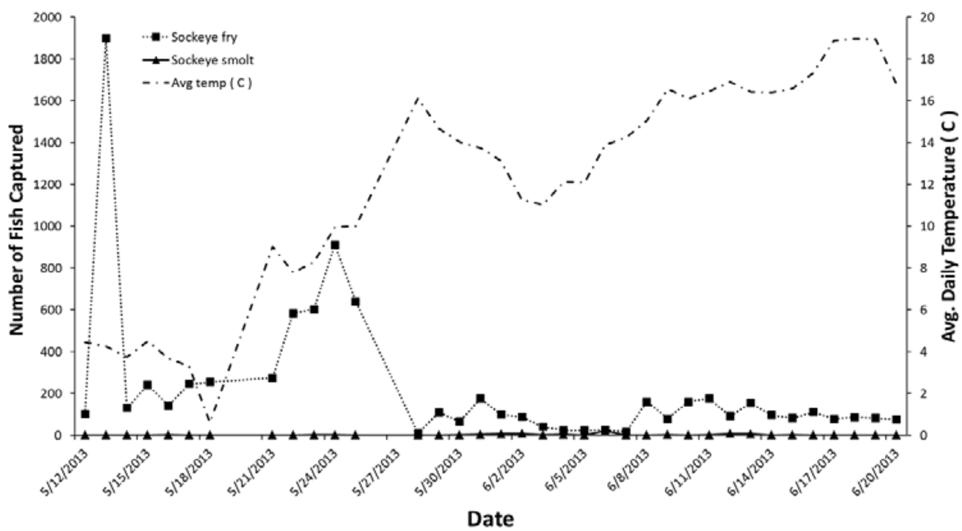

Figure 4. Daily enumeration of fyke net captured juvenile Sockeye Salmon plotted with daily average water temperature, Meadow Creek, Alaska, 2013.

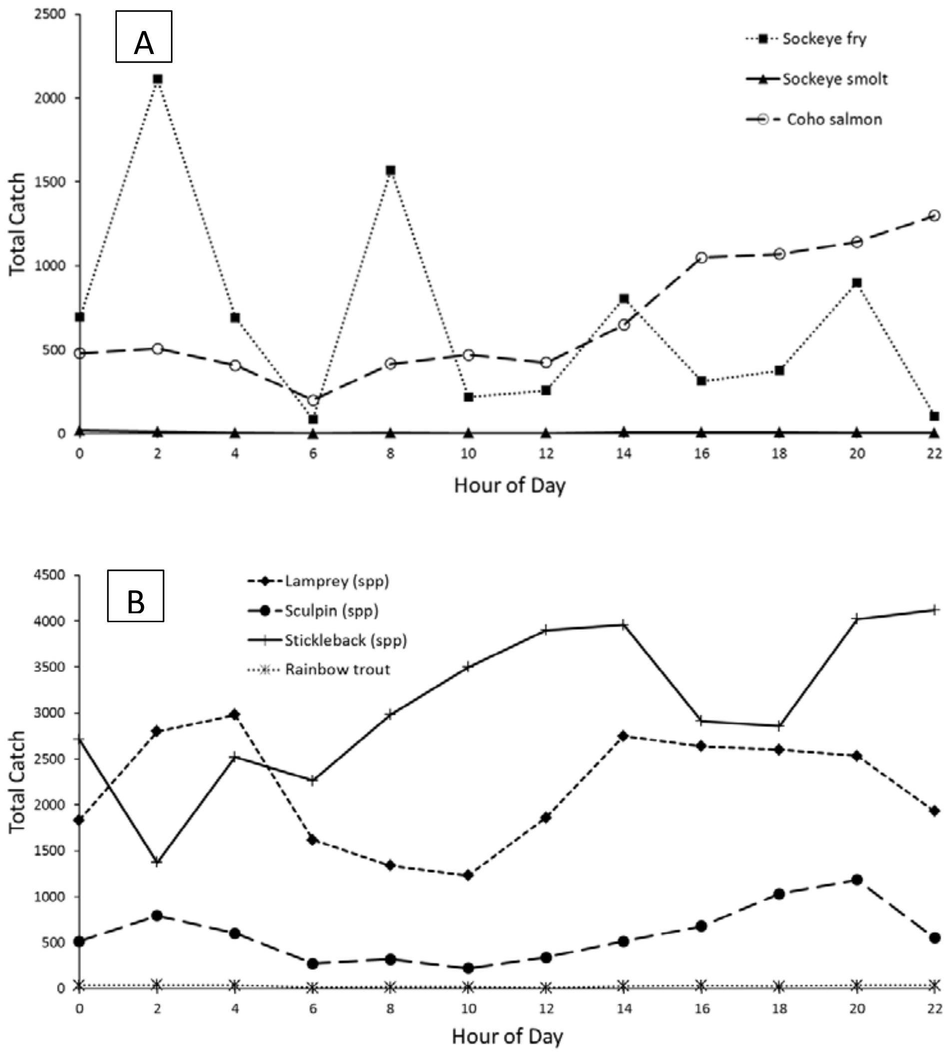

Figure 5. Total catch of juvenile Sockeye and Coho Salmon (A) and all other non-target species captured (excluding Longnose Sucker and Round Whitefish) adjusted by two-hour set check, Meadow Creek, Alaska, 2013.

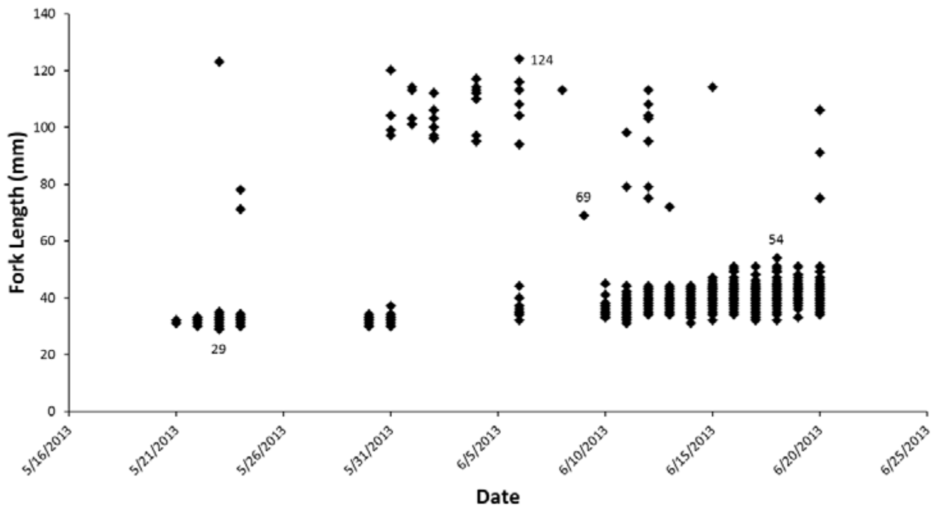

Figure 6. Fork length (FL) measurements of juvenile Sockeye Salmon (*n* = 906) Meadow Creek, Alaska, 2013. No FL measurements were recorded May 21 through May 30.

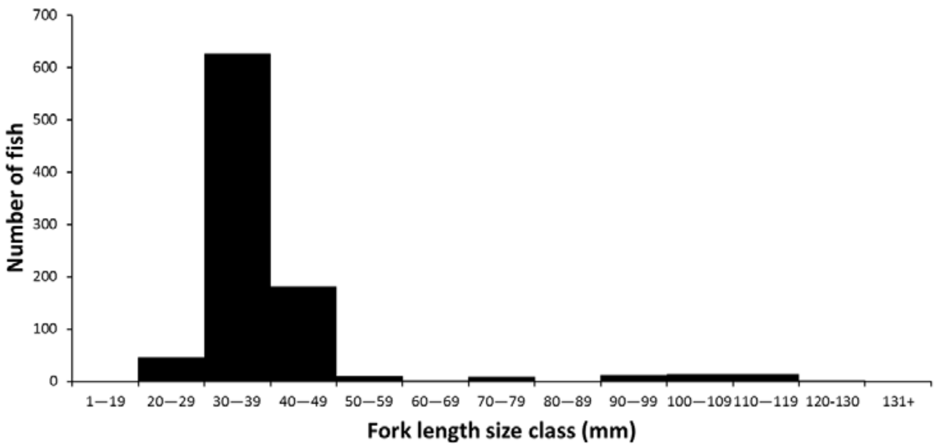

Figure 7. Histogram of *n* = 906 Sockeye Salmon fork length of fish captured in Meadow Creek, Alaska, 2013.

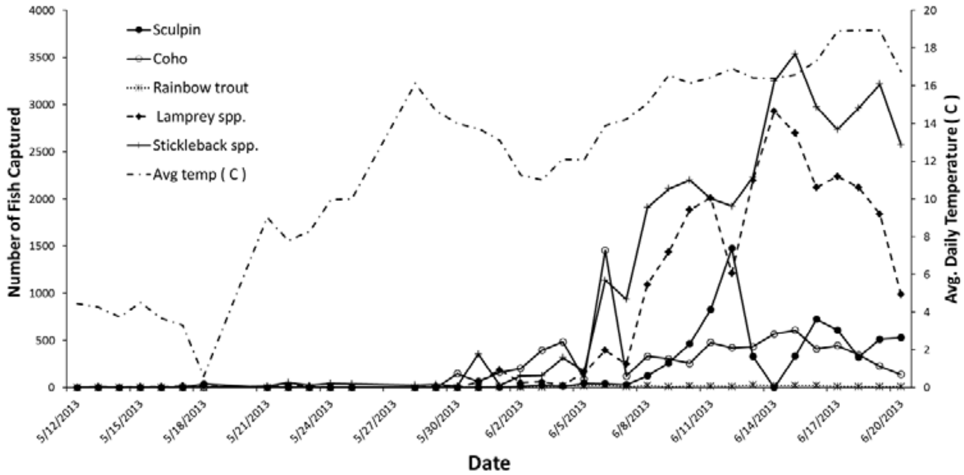

Figure 8. Total non-target species captured in Meadow Creek, Alaska, 2013. Longnose Sucker and Round Whitefish were excluded due to rare occurrence throughout the study period.

APPENDIX A.

Appendix A. USFWS technicians Matt Olsen and Jennifer Gregory remove captured fish from the fyke net live-box, Meadow Creek, Alaska, 2013.

APPENDIX B.

Appendix B. Comparison of age as predicted by scale samples (*N* = 41) and fork length (mm) by three independent observers. Values of 0, 1, and 2 represent age-0, age-1, and age-2+, respectively.

Sample number	Fork length	Observer 1 age	Observer 2 age	Observer 3 age
1	69	1	1	1
2	72	1	1	1
3	75	0	1	1
4	78	1	1	1
5	79	1	1	1
6	79	0	1	1
7	94	1	1	1
8	95	1	1	1
9	95	1	1	2
10	96	1	1	1
11	97	1	1	1
12	97	0	1	1
13	97	1	1	1
14	98	1	1	1
15	98	1	1	1
16	99	1	1	1
17	100	1	1	1
18	101	0	1	1
19	103	1	1	1
20	103	1	1	1
21	104	1	1	1
22	104	1	1	1
23	104	1	1	1
24	106	0	1	1
25	108	1	1	1
26	108	1	1	1
27	110	1	1	1
28	112	1	1	1
29	112	1	1	1
30	113	1	1	1
31	113	1	1	1
32	113	1	1	1
33	113	1	1	1
34	113	1	1	1

Appendix B (continued) Comparison of age as predicted by scale samples (*N* = 41) and fork length (mm) by three independent observers. Values of 0 and 1 represent age-0 and age-1, respectively.

Sample number	Fork length	Observer 1 age	Observer 2 age	Observer 3 age
35	113	1	1	1
36	114	1	1	1
37	116	0	1	1
38	117	1	1	1
39	120	1	1	1
40	123	1	1	1
41	124	1	1	1