Run Timing, Seasonal Distribution and Biological Characteristics of Dolly Varden in the Kanektok River, Togiak National Wildlife Refuge, 2002 - 2003

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Mark J. Lisac

Abstract

Dolly Varden *Salvelinus malma* are an important component to the ecosystem in southwest Alaska and are utilized heavily in the region's subsistence and sport fisheries. Togiak National Wildlife Refuge has initiated research to investigate the life history of and habitat use by Dolly Varden throughout the Refuge. This report summarizes the information collected from Dolly Varden in the Kanektok River during 2002 and 2003. A resistance board weir operated by the Alaska Department of Fish and Game at river km 67.6 was used to enumerate the Dolly Varden run. A total of 13,546 Dolly Varden were counted migrating upstream past the weir between 8 July and 3 August 2002. Dolly Varden were captured by weir live trap (n = 190) and beach seine (n = 1,290) to collect biological data, deploy radio tags, and to estimate the number of mature prespawning fish in the weir count between 20 July and 3 August. Based on the proportion of mature fish in three weekly time strata (64.6% to 43.1%), an estimated 3,161.5 (SE = 189.6) mature Dolly Varden passed upstream of the weir between 8 July and 3 August 2002. Sixty Dolly Varden were successfully radio-tagged and released between 10 and 28 July and relocated on sixteen tracking events between 1 August 2002 and 30 May 2003. Suspected spawning locations were identified for 47 (78.3%) radio-tagged Dolly Varden. Thirty-one (51.7%) fish survived spawning and selected overwintering locations in the mainstem Kanektok River. Emigration from freshwater to the ocean began after the tracking survey on 3 May 2003 and all live fish (21) had left the Kanektok River by 30 May 2003. The fates of the remaining fish were: 29 (48.3%) mortalities; 4 (6.7%) harvested in the subsistence fishery; and 6 (10%) unknown.

Introduction

Dolly Varden are important to the subsistence fishery harvest from the Kanektok River (Wolfe et al. 1984; Willard Church, Native Village of Kwinhagak Natural Resource Department, personal communication). Quantitative information concerning the subsistence harvest of Dolly Varden in the Kanektok River is sparse, but they are likely harvested in such quantities to match or exceed the harvest of salmon by weight (Wolfe et al. 1984). The Alaska Community Profile Database (ADCED 2003) reported an annual harvest of over 24,247 char by residents of Quinhagak.

The Alaska Department of Fish and Game (Department) reports that sport catch of char (Dolly Varden and Arctic char) in the entire Kanektok River drainage has averaged 22,150 fish from 1995 to 1999 (Dunaway and Sonnichsen 2001). Sport harvest of these fish is small ranging from 3-11% of the catch, and averaged 421 fish during the same period. Angler effort averaged 7,329 angler days annually during this five-year period.

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Both subsistence and sport fishers have expressed concerns regarding declines in abundance and size of char in other systems within the Togiak National Wildlife Refuge (Refuge) (USFWS 1990, 1991). Similar concerns for char populations throughout southwest Alaska prompted the Alaska Board of Fisheries in 1997 to reduce the daily bag limit from 10 to 3 char per day throughout the region.

In response to these concerns and to provide more information for developing management strategies, the Refuge initiated research to learn more about the life history of and habitat use by Dolly Varden throughout the Refuge. Previous information has been collected and reported for Dolly Varden in the Togiak River drainage (Lisac and Moran 1999; Lisac and Nelle 2000; Reynolds 2000; Lisac and Buchholtz 2001; Crane et al. 2003) and the Middle Fork of the Goodnews River (Lisac 2002, 2004). Radio telemetry, visual marking, genetic analysis, and otolith microchemistry have been used successfully to document aspects of the life history, and identify important spawning and overwintering habitat for anadromous Dolly Varden in these two drainages.

These studies, as well as local knowledge, suggest that anadromous Dolly Varden in the Kanektok River have the following life history traits: 1) fish return to the river from saltwater during late June to late August; 2) spawning occurs in freshwater during late fall; 3) overwintering occurs within the drainage (either rivers or lakes); and 4) fish return to saltwater during late April-May. Annual runs consist of mature fish returning home to spawn and other immature and nonspawning fish. The later group are generally more numerous and are likely comprised of fish from various river stocks (Lisac and Nelle 2000; Lisac 2004).

Since 2001 the Department has operated a weir to estimate salmon escapement in the Kanektok River (Estensen and Diesinger 2003). The weir is located at approximately river-kilometer (rkm) 67.6 upstream from Kuskokwim Bay and downstream of the major tributaries in the drainage. The weir is a floating resistance-board design which allows the project to be operated for a longer season and during periods of high water, and also provides an estimate of the daily and seasonal Dolly Varden passage. The weir was operated between 9 August through 3 October 2001 and approximately 2,500 Dolly Varden were counted.

The approximately 76 m weir used at the Kanektok River site is comprised of three major parts: the resistance board panel section, the fixed picket section and the substrate rail (Tobin 1994; Stewart 2002). The resistance board panel sections are constructed of 25 mm x 6.1 m PVC schedule 40 pickets laid out on stringers at approximately 16 pickets per 1.2 m panel. The space, or gap, between the pickets is approximately 43 mm. The larger gap design allows the weir to stay operational during periods of moderately high water flow while still preventing most salmon passage upstream.

Although the weir provides an estimate of Dolly Varden upstream migration, fish below a certain size likely pass through the picket space undetected. The size of the fish and the proportion of the run that these fish contribute are unknown. This coupled with the fact that Dolly Varden runs in much of Alaska are composed of stocks of mixed origin and maturity makes monitoring this species problematic (DeCicco 1985; Whalen 1992; Larson 1997; Lisac and Nelle 2000).

Other studies have dealt with the problem of providing a meaningful estimate of Dolly Varden abundance in a variety of ways (Whalen 1992; Larson 1997). Whalen (1992) concluded that monitoring spawner abundance of Dolly Varden would provide a more useful number that could

be compared between years and contribute to long-term monitoring. The key element is to estimate the number of spawning, mature fish returning annually to the system. This has been accomplished by apportioning the total estimated Dolly Varden daily counts by maturity index and size.

The early component of the Dolly Varden run is generally comprised of a higher proportion of mature, prespawning fish (Whalen 1992; Larson 1997; Lisac and Moran 1999; Lisac and Nelle 2000). The proportion of prespawner as well as the size of fish size has been documented to decline as the run progresses. Based on previous studies (Lisac and Moran 1999; Lisac 2002; Estensen and Diesinger 2003) the most important time in which to estimate Dolly Varden spawner abundance is early July to mid-August.

The objectives of this study were to: 1) describe the migratory behavior and seasonal distribution of radio-tagged Dolly Varden in the Kanektok River watershed in order to identify spawning and freshwater overwintering areas, 2) determine the feasibility of using the Kanektok weir for annually enumerating the stock status of Dolly Varden, estimating the number of prespawning Dolly Varden, and determining run timing and maturity schedule, and 3) describe length frequency distribution of Dolly Varden passing the Kanektok River weir by sex, maturity and time strata.

Study Area

The Kanektok River drainage lies along the northern boundary of the 4.7 million acre Togiak National Wildlife Refuge in southwest Alaska (Figure 1). The river originates in the Ahklun Mountains in the northeast corner of the Refuge and drains approximately 2,261 km^2 (Walsh et al. 2005). The Kanektok River flows from Kagati and Pegati Lakes, elevation 320 m, westerly for 146 km to Kuskokwim Bay. Numerous tributaries feed the lakes. Two named tributaries, Atmugiak and Akamunak Creeks, feed Kagati Lake. River discharge was calculated to be 14.1 cms in July 1983 below the outlet of Kagati Lake. The river width was 70.1 m at the site. The upper portion of the river is a single channel as it flows through mountain valleys. The river emerges from the mountains and flows across a broad alluvial plain composed primarily of gravel substrate where the river becomes braided with multiple side channels. The upper 116 km of the Kanektok River are within the Refuge Wilderness Area, while the lower 30 km of river are bordered by Quinhagak Village corporation lands. The Village of Quinhagak is located near the mouth of the Kanektok River at Kuskokwim Bay.

Four major tributaries flow from the south and join the Kanektok River in the uppermost 72 km of the river below Kagati Lake. They are (from lower to uppermost): Takshilik, Nukluk, Klak, and Kanuktik creeks. Several smaller named tributaries flow from the north: Quickumguila, Olumagwilute, Sam, Nakailingak, Amakatatee and Paiyun creeks. Only Kanuktik and Klak Creeks have headwater lakes of any significant size (MacDonald 1996).

Methods

Biological Characteristics

Dolly Varden were captured by using the weir to funnel fish into a live trap attached to the upstream side of the weir and by beach seining upstream of the weir. Seine sites were selected

based on the first areas encounter with Dolly Varden concentrations while motoring upstream of the weir. Capture efforts began on 8 July and continued until 3 August 2002.

Species confirmation was determined by using external characteristics previously reported by Lisac and Moran (1999). All fish captured were measured for fork length to the nearest millimeter. Fish implanted with transmitters were also weighed to the nearest 0.25 kg. All Dolly Varden not radio tagged which were greater than 250 mm fork length were marked with an individually numbered T-bar anchor tag.

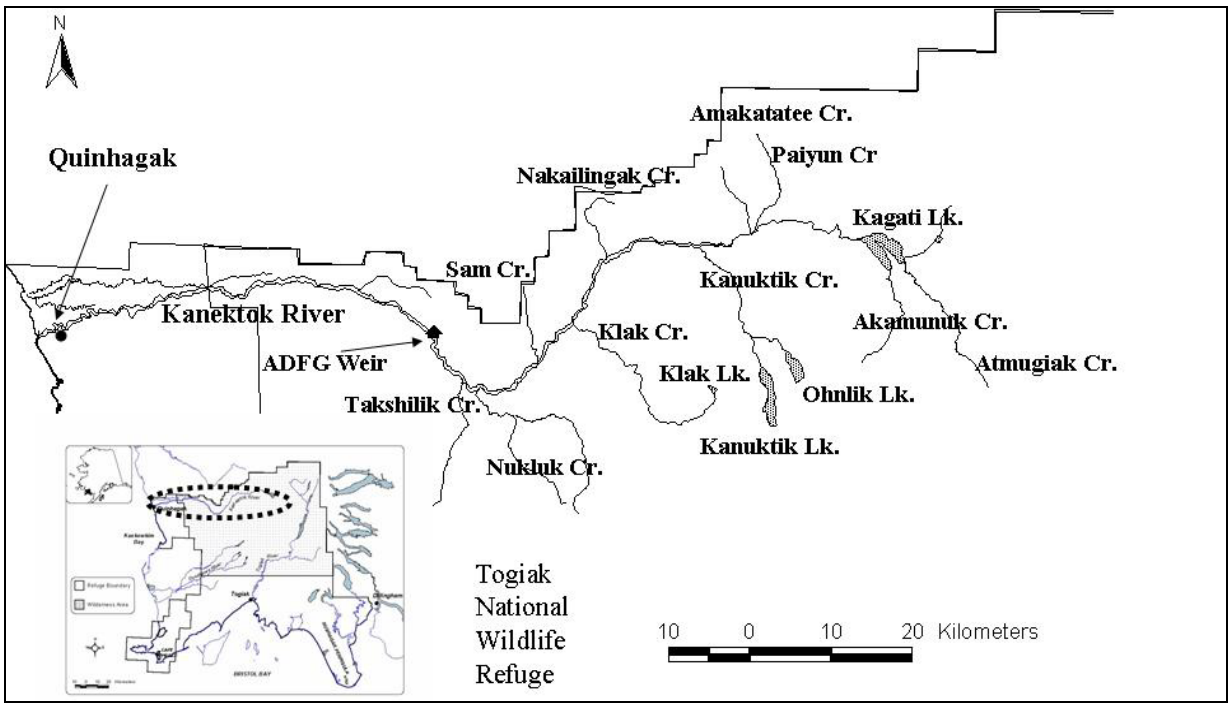

Figure 1. Kanektok River drainage, Togiak National Wildlife Refuge.

A maturity index was used to determine maturity class by sex (Table 1). Photographic keys were used to train all field personnel to identify sex and maturity of fish using external characteristics. The primary external characteristics used were the coloration of the body, head, jaw and fins. Fish were characterized as being either 1) silver or showing no color; 2) showing signs of color change (darkening opercle, head and jaws, reddening of fins with white leading edge); or 3) full spawning colors. Head shape, kype formation, a swollen ovipositor or abdomen were used as sex determinant characteristics. Dolly Varden were periodically photographed and sacrificed to confirm maturity index and sex based on gonad development.

A 1-cm^2 portion of bony-rayed fin tissue was collected from each sacrificed or radio tagged Dolly Varden as a genetic sample. Tissues were stored in vials containing alcohol and archived. Sagittal otoliths were also collected from all sample mortalities and archived.

Mean fork lengths and length frequency distributions (10 mm increment) were determined by sex and maturity index for each gear type. Cumulative length frequency distributions (1.0 mm increments) are compared between maturity index (prespawners vs. others), by gear type, and

between each of the three time intervals using a Kolmogorov-Smirnov (K-S) two sample test ($p = 0.05$) (Hintze 2002).

Abundance and Run Timing

Dolly Varden migrating upstream in the Kanektok River are counted at a weir operated by the Department. Estensen and Diesinger (2003) provide a detailed description of how this weir is configured and operated. The early portion of the run was targeted for this study because other studies have shown that proportion of prespawning Dolly Varden decreases throughout the run (Whalen 1992; Larson 1997; Lisac and Nelle 2000; Lisac 2004).

The number of Dolly Varden prespawners passing through the weir was estimated by applying the proportion of prespawners observed in three 5-day sample periods to the total Dolly Varden weir count for the time strata (Larson 1997), by:

$$N_s = \sum P_i * N_i$$

where:

N_s = estimated number of prespawners for the sample period,

P_i = proportion of prespawners in the weekly sample i, and

N_i = the sum of weir counts for week i.

The variance was estimated as: $V(N_s) = \sum N_i^{2} * V(P_i)$

where: $V(P_i) = (N_i – n_i / N_i) (P_i (1 - P_i) / (n_i - 1))$

n_i = number of prespawners in sample i

Seasonal Distribution

Radio tags (60) were implanted in prespawning fish presumed to be enroute to their natal waters to spawn. To obtain representative segments of the run both temporarily and spatially, tag application was equally distributed over a ten-day period.

Only prespawning Dolly Varden greater than 400 mm and with a minimum weight of 1000 g (such that the radio tag was less than or equal to 2% of fish weight (Winter 1983) were targeted for radio tagging. Because natural mortality is higher for spawning males (Blackett 1968; Kruger 1981; Armstrong 1984; Larson 1997), a greater proportion of females were targeted for radio tagging to increase the longevity of telemetry data.

Upon capture, fish were held in a net pen upstream of the weir and anesthetized as described by Anderson et al. (1997). A radio transmitter was surgically implanted into the intra-peritoneal cavity of each fish once stage 3-4 anesthesia was attained (Summerfelt and Smith 1990). Surgical procedures were similar to those used by Hart and Summerfelt (1975) except a grooved-director technique (Palmer 1996; Lisac and Moran 1999) was used to route the external antenna under the pelvic girdle and through the body wall anterior to the vent. Three to four stitches and liquid suture adhesive were use to seal the incision. After surgery, the fish were moved directly

into the river at a location with gently moving water such that the fish were able to remain upright. All radio tagged fish were measured and photographed.

Table 1. Criteria for determining maturity index in Dolly Varden sampled in the Kanektok River, 2002.

Maturity	Definition	Female criteria	Male criteria	Color code
Unknown	Unable to determine maturity.			1
Immature	Fish not having reached the capability to spawn.	Ovary, but egg diameter too small to measure < 0.90 mm.	Lacked any noticeable testes development.	1
Nonspawner	Any fish capable of spawning, but not in the year of capture.	Egg diameter 1.2 mm to 1.6 mm.	Testes cylindrical and 1.0 mm.	1
Potential spawner	Gonad development between nonspawner and prespawner criteria. May spawn in year of capture.	Egg diameter between 1.6 mm and 2.0 mm.	Testes are somewhat flattened and 3 or 4 mm wide.	1 or 2
Prespawner	Fish capable of spawning in year of capture.	- Egg diameter >= 2.0 mm (during June) - Egg diameter > 2.3 mm (during July) - Egg diameter > 3.0 mm (by August).	Testes enlarged and of milky-white appearance. Testes from 10-30 mm wide.	2 or 3
Spawning or spawned out	Fish determined to have spawned.	Completely mature female, eggs easily stripped.	Completely mature male, freely running milt.	3

We used radio transmitters with individual frequencies between 162 and 163 MHz transmitting at 55 pulses-per-minute (ppm). The transmitters were equipped with a mortality switch, which would cause the pulse rate to increase to approximately 100 ppm after 12 hours of no motion. The transmitters weighed 15 grams in air and trailed a plastic-coated wire antenna approximately 30 cm long. To increase the transmission life, the duty cycle was set at 12 hours per day (0900 to 2100 hrs). The warranted transmitter battery life was 400 days.

The movements of radio-tagged fish were monitored using a programmable scanning receiver (ATS 1998). Aerial tracking was scheduled to begin as soon as possible after radio transmitters were implanted. From late July to November, when Dolly Varden are suspected to move to their spawning destinations, tracking was scheduled to occur approximately 3 times per month. During the winter months, December to February, aerial tracking was scheduled approximately once each month. During March through May, the survey frequency was increased to 2 - 3 times per month as it was suspected that Dolly Varden begin emigrating to sea during the spring thaw and early summer.

Aerial tracking followed established procedures (USFWS 1981; Mech 1983) and was conducted from a fixed-wing aircraft with an “H” antenna attached to the wing strut on each side of the aircraft. The aircraft flew at 90-300 m above ground level. Search areas included the mainstem river, headwater lakes, and most tributaries. GPS was used to determine the location of the fish

when peak volume of the transmitter was heard by the observer. Signal status was recorded as either live or mortality mode. Fish were considered dead if they were reported harvested, the transmitter was recovered from the river, or if the transmitter was operating in mortality mode during two or more tracking flights. In the later case, the fish's tracking history was reviewed to determine when the mortality was likely to have occurred. Only the first mortality signal and prior location data were used in this analysis.

These data were analyzed to describe seasonal distribution, and suspected spawning and overwintering locations of radio-tagged Dolly Varden. Locations were plotted on digitized maps of the Kanektok River drainage using Arcview™ GIS software. To facilitate the analysis and discussion of location data the main Kanektok River was divided into study sections A through F (Figure 2). The boundaries of these sections were established at the Refuge boundary, the weir location, and at the confluence with major tributaries.

Suspected spawning areas were identified based on the furthest upstream location a radio-tagged fish was found during surveys occurring throughout August, September and October - the time when spawning is likely to occur. The time of spawning of each individual fish was interpolated from its location history. Overwintering areas were described based on the location of radio-tagged fish during the months of December through March. Radio-tagged fish were assumed to have emigrated from freshwater into the sea when they could no longer be located in the river, and had exhibited downstream migration during previous tracking flights. The earliest possible date for individual fish to have emigrated to the sea was assumed to be the day after they were last located in the river.

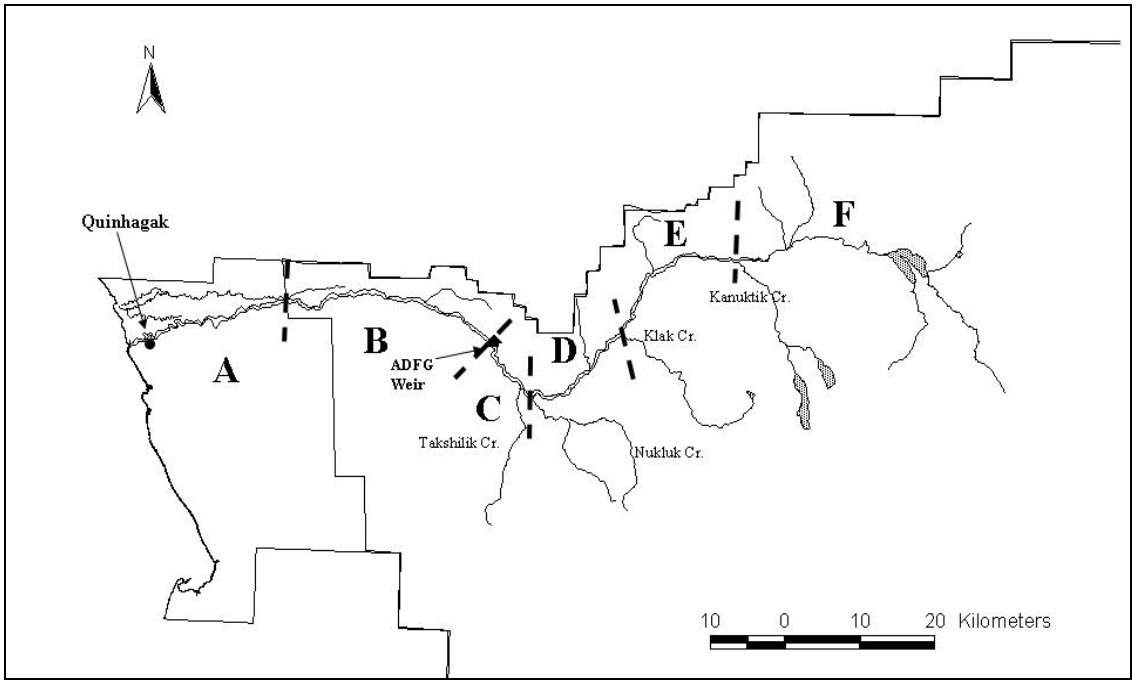

Figure 2. Kanektok River study sections and prominent tributaries, 2002 - 2003.

Results

Abundance and Run Timing

The Department began operating the weir on 1 July and continued until 20 September 2002. Dolly Varden were first observed on 2 July when 18 fish were counted (Appendix 1). The total number of Dolly Varden counted through the weir during 2002 was 15,198 (Estensen and Diesigner 2003). The greatest daily number of Dolly Varden counted at the weir (*n*=2,245; 14.8%) occurred on 18 July. During an eleven-day period between 14 and 24 July, 71.7% (*n*=10,895) of the Dolly Varden run was counted through the weir.

Dolly Varden capture efforts occurred between 8 July and 3 August 2002. A total of 13,546 (89.1 % of the run) Dolly Varden were counted at the weir during our field operations (Figure 3). Daily passage during this time period ranged from 21 (8 July) to 2,245 (18 July) Dolly Varden.

The weir live trap was monitored for most of the 27 days with varying levels of effort and success. During the beginning of field operations, the live trap was monitored more intensely when the emphasis was on capturing fish for radio tag implants. The first Dolly Varden was captured in the live box on 10 July. Dolly Varden were captured and sampled from the live trap during 18 days between 10 to 31 July. Capture success ranged from 0 to 27 Dolly Varden captured per day. A total of 190 Dolly Varden (1.4% of the weir count) were captured using this method. The weir sample was comprised of 50.5% (*n*=96) males, 48.4% (*n*=92) females, and 2 fish of unknown sex (Table 2). Prespawners accounted for 79.5% of all Dolly Varden captured in the weir live trap.

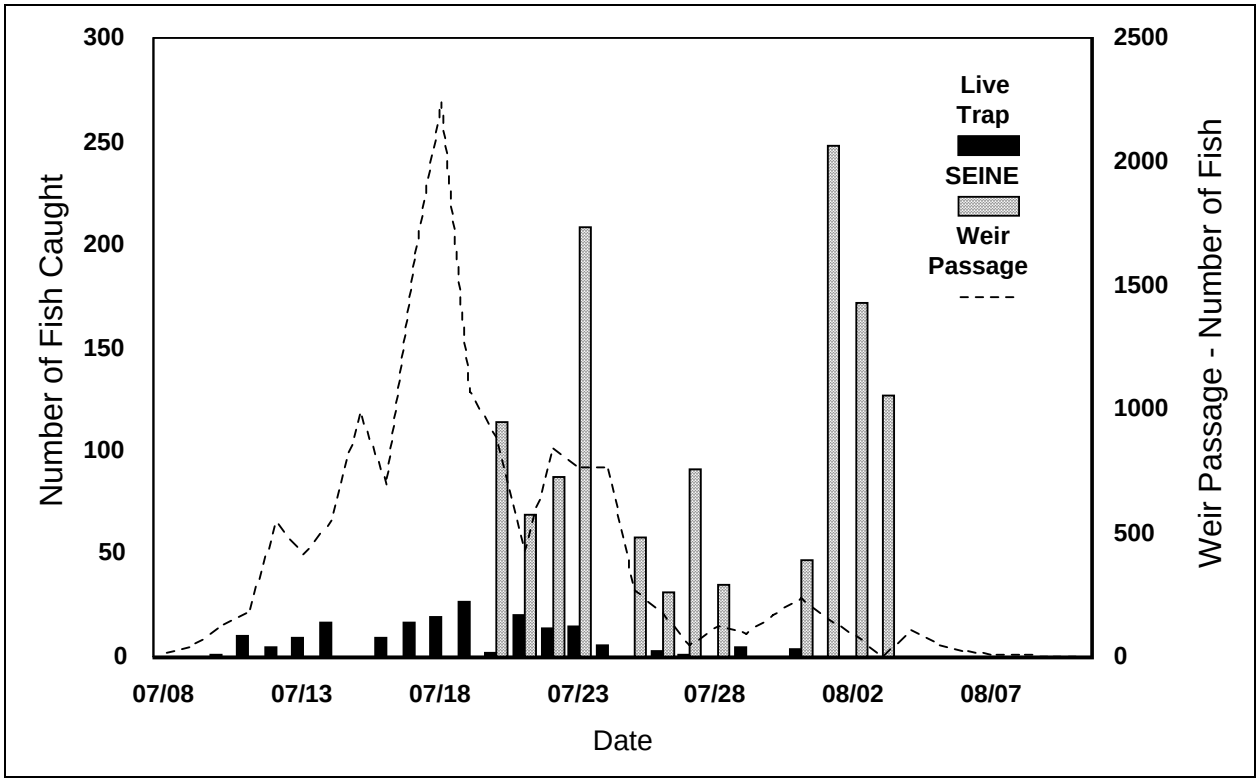

Figure 3. Daily number of Dolly Varden passing the weir, and captured by weir live trap and seine, Kanektok River, 2002.

Of the 190 Dolly Varden sampled by weir live trap, 187 were measured for fork length (Table 3, Figures 4 and 5). These fish ranged in fork length from 399 to 640 mm, and averaged 513.4 mm (SD = 44.24). Prespawners (n = 149) ranged from 416 to 640 mm in fork length. Mean length of prespawners was 523.5 mm (SD = 42.0). Mean fork length for nonspawners was 474.6 mm (SD = 22.79). Cumulative length frequency distributions of between prespawners and nonspawners captured at the weir were significantly different (Dmax = 0.5876; $p < 0.001$).

Beach seining began on 20 July and was conducted for 12 of 15 days until 3 August 2002 (Figure 3 and Appendix 1). Thirty-nine seine hauls occurred at 5 sites located approximately 5 to 10 km upstream of the weir (Appendix 2). Seine capture success was greater than that accomplished by using the weir live trap, ranging from 35 to 248 Dolly Varden captured per day (Appendix 1). Approximately 25% of the 5,097 Dolly Varden counted through the weir during this time period were captured by beach seine. The seine sample was comprised of 27.4% (n=354) males, 64.3% (n=830) females, and 8.2% (n=106) fish of unknown sex (Table 2). Prespawners accounted for 55.0% of all Dolly Varden captured by seine.

Table 2. Proportions of Dolly Varden by sex and maturity index, captured by weir live trap (n = 190) and seine (n = 1,290) from the Kanektok River, 2002.

Captured at Weir				
Sex	Maturity Index			
	All	Prespawners	Nonspawners	Unknown
Unknown	1.1	0.5		0.5
Males	50.5	41.6	5.3	3.7
Females	48.4	37.4	4.2	6.8
Total	100.0	79.5	9.5	11.1

Captured by Seine				
Sex	Maturity Index			
	All	Prespawners	Nonspawners	Unknown
Unknown	8.2	0.1	3.3	4.8
Males	27.4	19.0	6.3	2.2
Females	64.3	35.9	14.7	13.8
Total	100.0	55.0	24.3	20.8

Of the 1,290 Dolly Varden sampled by seine, 1,288 were measured for fork length (Table 4, Figures 4 and 5). Seine-caught fish ranged in fork length from 313 to 658 mm, and averaged 427.7 mm (SD = 54.95). Prespawners ranged in fork length from 320 to 638 mm and averaged 458.9 mm (SD = 45.65). Mean fork length of nonspawners was 375.9 mm (SD = 38.61). Cumulative length frequency distributions of prespawners and nonspawners captured by seine were significantly different (Dmax = 0.6250; $p < 0.001$).

Cumulative length frequency distributions of the samples collected by the two gear types were significantly different (Dmax = 0.6596; $p < 0.0001$) (Figure 4). Dolly Varden greater than 470 mm accounted for 20% of the fish captured by seine and 85% of the fish captured in the weir live trap. The weir sample contained no fish less than 399 mm.

Mean and cumulative distributions of fork length for each of the three weekly time strata indicate a declining trend in size over time (Table 5, 6 and Figure 6). Mean fork length declined from

450.4 (SD = 48.20) to 403.6 mm (SD = 50.02). Cumulative fork length distributions are significantly different ($p > 0.05$) between each time strata.

Although no fish less than 399 mm were captured in the weir live trap sample, the daily weir count does contain fish of all sizes (ie. not all small fish pass through the weir uncounted). The seine sample size was larger and contained a larger length frequency distribution range and is considered to be more representative of the size and maturity composition of the weir count. The proportion of mature fish observed in the seine sample was used to provide an estimate of the number of mature prespawning Dolly Varden in the total weir count during three weekly time strata (Table 7). An estimated 3,161 (SE = 189.6) prespawning Dolly Varden passed upstream of the weir between 20 July and 3 August.

Table 3. Mean fork lengths (mm) of Dolly Varden by sex and maturity index captured by the weir live trap from the Kanektok River, 2002.

		Maturity Index			
		All	Prespawners	Nonspawners	Unknown
Sex					
Unknown	*n*	2	1		1
	mean	470.5	435		506
	SD	35.50			
Males	*n*	95	78	10	7
	mean	530.3	541.9	477.1	477.0
	SD	44.90	40.00	27.40	9.24
	min	435	437	435	468
	max	637	637	533	493
Females	*n*	90	70	7	13
	mean	496.5	504.4	471.0	467.6
	SD	35.81	33.45	12.94	35.30
	min	399	416	454	399
	max	640	640	490	535
All	*n*	187	149	17	21
	mean	513.4	523.5	474.6	470.9
	SD	44.24	42.00	22.79	29.33
	min	399	416	435	399
	max	640	640	533	535

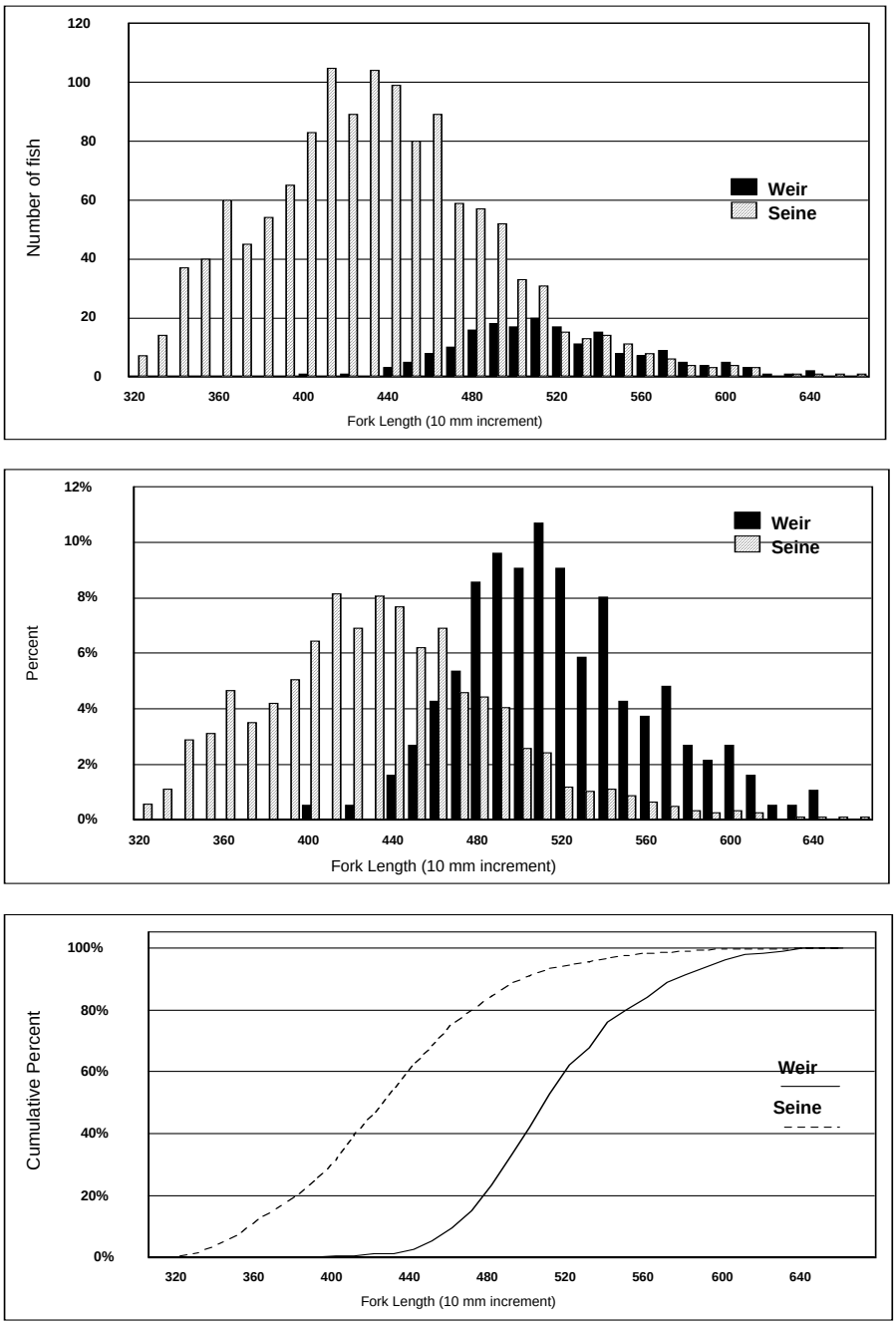

Figure 4. Number, percent and cumulative percent fork length frequency distributions for all Dolly Varden captured by beach seine (*n* = 1,288) and weir live trap (*n*=187) in the Kanektok River, 2002.

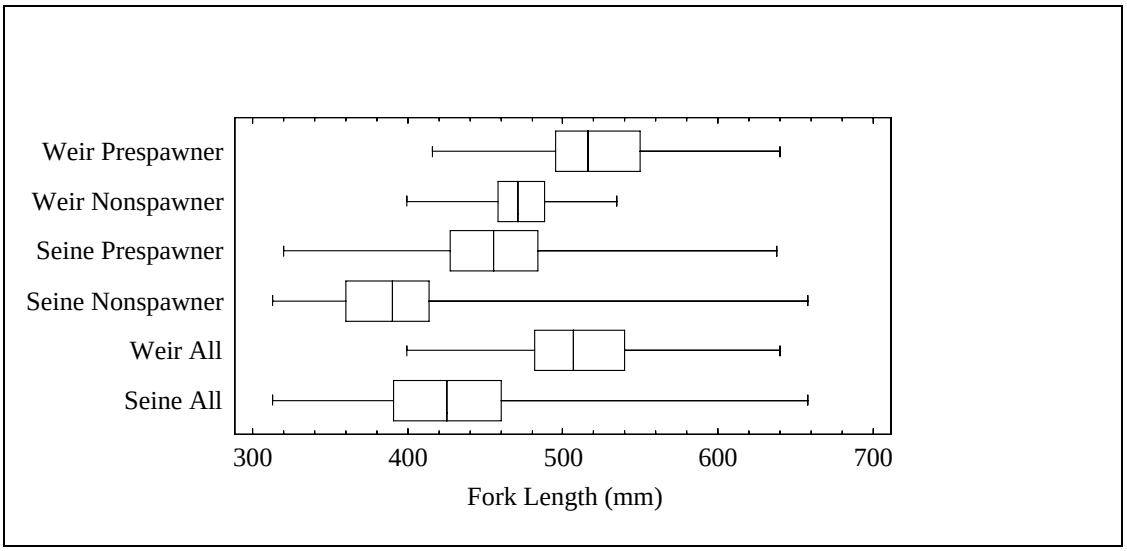

Figure 5. Mean, 95% confidence interval, and range of fork lengths for Dolly Varden by gear and maturity index Kanektok River, 2002.

Table 4. Mean fork length (mm) of Dolly Varden by sex and maturity index captured by seine from the Kanektok River, 2002.

Sex		Maturity Index			
		All	Prespawners	Nonspawners	Unknown
Unknown	*n*	106	1	43	62
	mean	377.8	452	364.2	386.0
	SD	41.59		49.33	31.40
	min	316		320	316
	max	645		645	467
Males	*n*	353	244	81	28
	mean	450.4	472.7	387.5	437.0
	SD	64.18	56.86	48.43	31.80
	min	315	320	315	373
	max	658	638	658	529
Females	*n*	829	463	188	178
	mean	424.4	451.6	373.6	407.4
	SD	46.56	36.44	28.49	29.03
	min	313	346	313	345
	max	590	590	455	498
All	*n*	1288	708	312	268
	mean	427.7	458.9	375.9	405.5
	SD	54.95	45.65	38.61	32.99
	min	313	320	313	316
	max	658	638	658	529

Table 5. Mean fork length (mm) of Dolly Varden by sample period, Kanektok River 2002.

Period	Dates	*n*	Mean FL	SD
1	20-24 July	480	450.4	48.20
2	25-29 July	215	443.4	55.08
3	30 July – 3 Aug.	593	403.6	50.02

Table 6. Kolmogorov-Smirnov two sample maximum difference and p value (in parenthesis) for cumulative length frequency distributions of Dolly Varden in the Kanektok River during three time periods, 2002.

Time period	1 20 - 24 July	2 25 - 29 July	3 30 July - 3 Aug
1		0.1190 (0.0297)	0.3125 (<0.001)
2			0.3268 (<0.001)

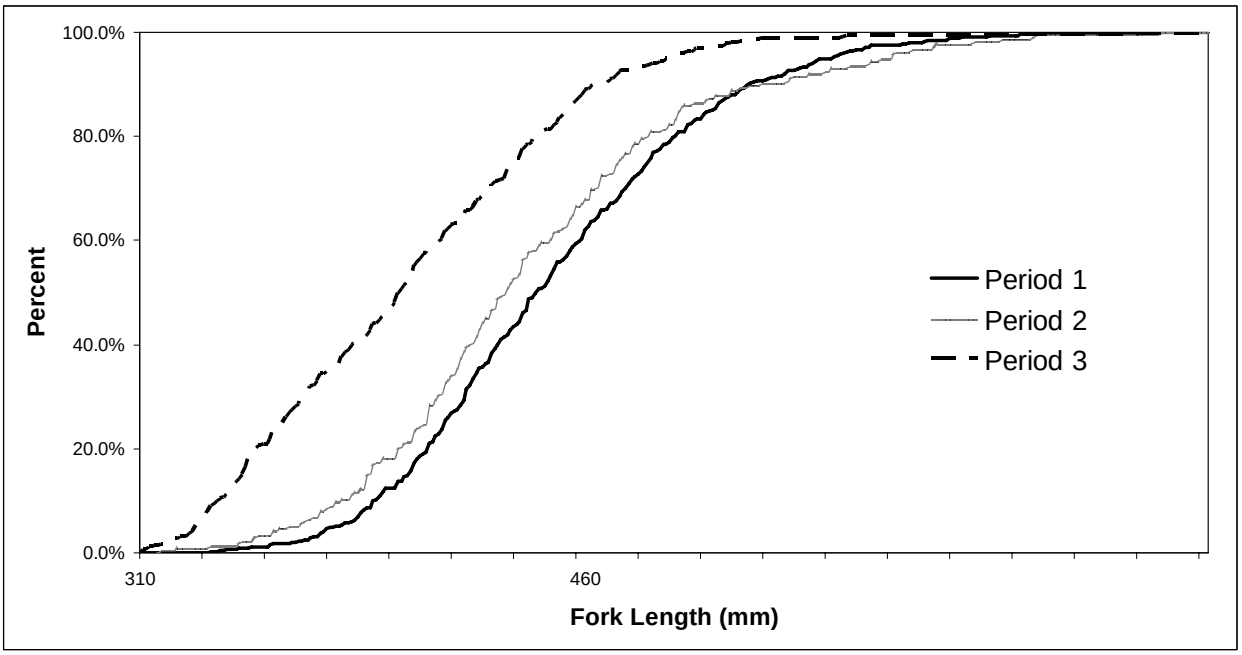

Figure 6. Cumulative fork length frequency for Dolly Varden sampled during three time strata from the Kanektok River, 20 July to 3 August 2002.

Table 7. Estimated number of prespawning (PR) Dolly Varden, Kanektok River 20 July to 3 August 2002.

Time strata	Weir count	Number sampled	Percent sampled	Number prespawners	Percent PR in sample	Estimated PR	SE
1	3,712	480	12.9%	310	64.6%	2,397.3	171.4
2	724	216	29.8%	143	66.2%	479.3	45.6
3	661	594	89.9%	256	43.1%	284.9	28.4
Total	5,097	1,290	25.3%	709	55.0%	3,161.5	179.6

Seasonal Distribution

Sixty Dolly Varden were radio-tagged and released between 10 and 28 July (Figure 7 and Appendix 1). Seven fish were identified as mortalities before tracking began and their tags were retrieved and redeployed in other fish.

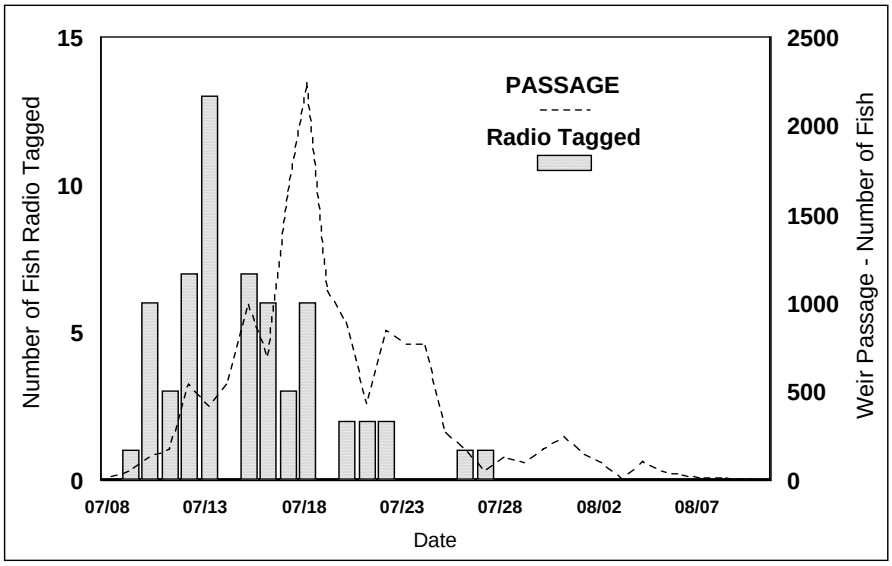

Figure 7. Daily weir passage and number of radio-tagged Dolly Varden per day, Kanektok River 2002.

Of the sixty fish included in this analysis, 65% (*n*=39) were females and 35% (*n*=21) were males (Appendix 3 and 4). All radio-tagged fish were classified as prespawners. Radio-tagged females ranged in fork-length from 416 to 640 mm, and averaged 509.2 mm (SD = 36.73). Radio tagged males ranged in fork-length from 503 to 615 mm, and averaged 558.4 mm (SD = 33.45). Radio-tagged female Dolly Varden ranged in weight from 1,300 to 2,850 g, and averaged 1648 g (SD = 274.24). Radio-tagged male Dolly Varden ranged in weight from 1,200 to 2,700 g and averaged 1,947 g (SD = 425.03).

Sixteen (16) tracking flights were conducted between 1 August, 2002 and 30 May, 2003 to locate radio-tagged Dolly Varden in the Kanektok River (Table 8). The entire Kanektok River drainage was surveyed during most of the surveys between August and October 2002. During the period November 2002 and April 2003, surveys were conducted only in those portions of the drainage where radio-tagged Dolly Varden were previously located.

On 23 August 2002, 47 (73.3%) of the radio-tagged Dolly Varden were presumed alive and successfully located (Table 8 and Figure 8). Nine (15%) of the original 60 fish were mortalities

and the status of four fish were unknown. Nine fish moved downstream of the weir by 23 August while all others had moved upstream. Most fish remained in the main Kanektok River between the confluence with Takshilik Creek and the confluence with Kanuktik Creek (study sections C, D and E). Of the nine fish that initially traveled downstream of the weir, two later moved upstream of the weir, 5 stayed downstream and became mortalities, l remained alive and spent the rest of the study in the lower river, and 1 was never located again.

Spawning potentially occurred between surveys on 1 August and 16 October. Suspected spawning locations were identified for 47 (73.3%) radio-tagged Dolly Varden (Figure 9). Spawning locations included Kanuktik, Klak and Nukluk creeks and the main Kanektok River

Table 8. Number of successful locations and fate of radio-tagged Dolly Varden by survey Kanektok River, 28 July 2002 to 27 June 2003.

				Fate		
Survey	Date	Live locations	Number available	Mortalities	Reported harvest	Unknown
1	8/1/02	58	59	1	0	1
2	8/23/02	47	51	9	0	4
3	9/10/02	26	46	14	0	20
4	10/2/02	38	44	16	0	6
5	10/16/02	32	41	19	0	9
6	10/31/02	33	40	20	0	7
7	11/21/02	31	37	23	0	6
8	12/10/02	31	37	23	0	6
9	2/18/03	27	34	24	2	7
10	3/10/03	27	33	25	2	6
11	3/27/03	26	32	26	2	6
12	4/18/03	24	30	28	2	6
13	5/3/03	21	27	29	4	8
14	5/14/03	19	27	29	4	8
15	5/23/03	2	27	29	4	25
16	5/30/03	0	27	29	4	27

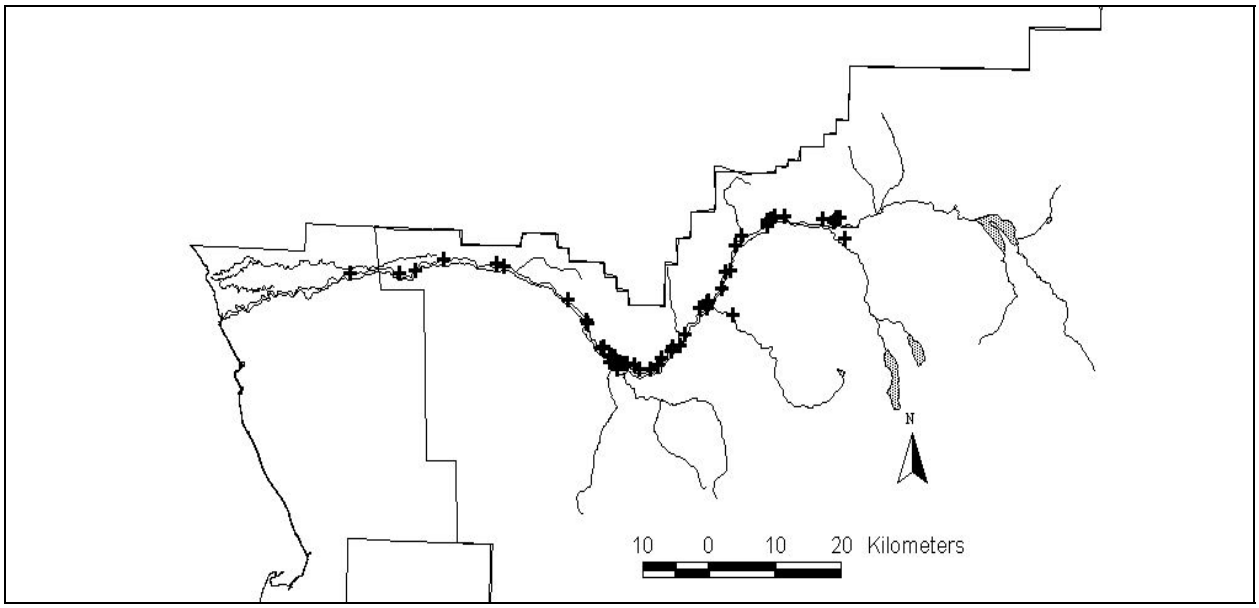

Figure 8. Locations of 47 radio tagged Dolly Varden in the Kanektok River, 23 August 2002.

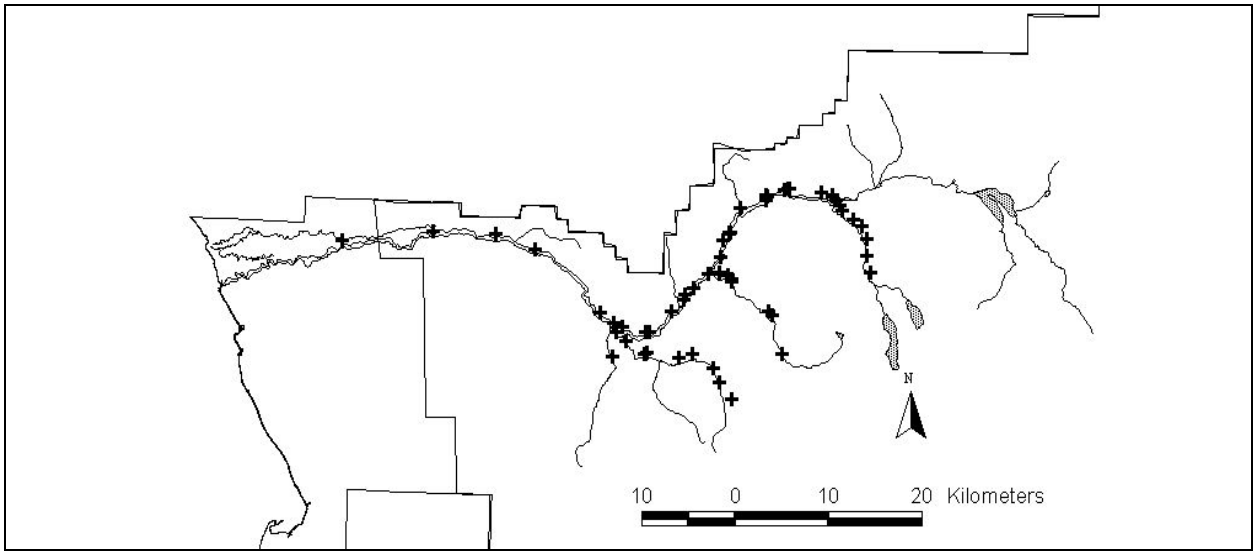

Figure 9. Suspected spawning locations for 47 radio-tagged Dolly Varden in the Kanektok River, 1 August to 16 October 2002.

primarily in the area from Takshilik Creek to just downstream of the confluence with Kanuktik Creek (study sections D and E). Three fish potentially spawned in Section B below the weir site, and one fish is suspected to have spawned in Section A. Only 2 fish are suspected to have spawned in the main channel near the confluence with Kanuktik Creek (Section F). No fish were ever located upstream of this confluence in Section F or above Kagati Lake.

Most fish migrated downstream during surveys conducted on 2 and 16 October. By the end of October 2002, 33 (55%) radio-tagged fish were still alive, 20 (33.3%) were mortalities and the fate of 7 (11.7%) fish was unknown. All radio-tagged Dolly Varden with active transmitters (n = 31; 51.7%) moved into the mainstem Kanektok River by 10 December 2002. Most fish appeared

to overwinter in the main Kanektok River in sections A and B below the weir site (Figure 10). One fish remained in Section E upstream of the Klak Creek confluence during December, but was designated as a mortality by the survey conducted on 10 March.

On the 3 May 2003 survey, 21 (35% of the original 60 fish) radio-tagged Dolly Varden were still alive in the Kanektok River (Figure 11). Twenty-nine (48.3%) others were mortalities, 4 (6.7%) were confirmed harvested in the local subsistence fishery, and the fates of 6 (10%) fish were unknown. All 21 live fish were located in the lower Kanektok River (study section A) and up to rkm 45 in section B. Emigration from freshwater began after the survey on 3 May 2003. Two fish were suspected to have gone to sea by 14 May. Seventeen of the remaining 19 fish emigrated between 14 and 23 May and all fish had left the Kanektok River by 30 May 2003.

Discussion

The number of Dolly Varden counted past the Kanektok River weir during 2002 (15,198) was much larger than returns observed at the Middle Fork Goodnews River weir in recent years (Lisac 2004; Estensen and Diesinger 2003). The Dolly Varden return in the Middle Fork Goodnews River, located 68 km to the south of the Kanektok River, has ranged from approximately 1,800 to 6,600 since 1997. This was the first full season of operation of the Kanektok River weir so it is not possible to interpret this number.

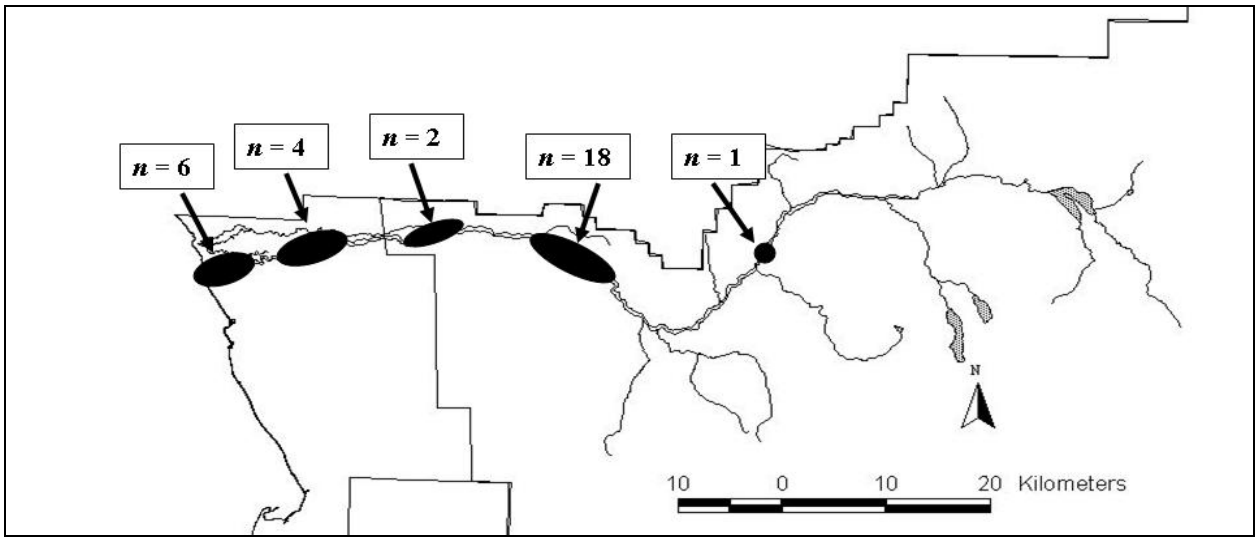

Figure 10. Overwintering locations for 31 radio-tagged Dolly Varden in the Kanektok River, November 2002 to March 2003.

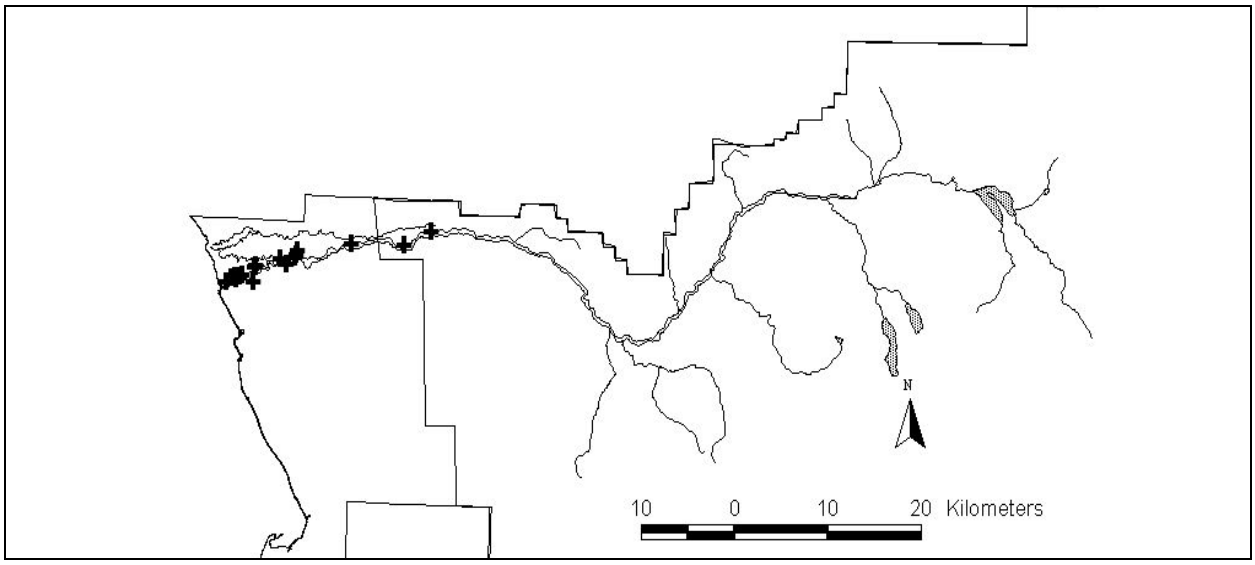

Figure 11. Locations of 21 radio-tagged Dolly Varden in the Kanektok River, May 2003.

In the Middle Fork Goodnews River there is also a strong component of late-run Dolly Varden. This was not observed in the Kanektok River in 2002. Other studies in the region and in Alaska have reported that late-returning Dolly Varden are primarily immature and non-spawning fish (Whalen 1992; Larson 1997). The proportion of immature and non-spawning fish did increase from 35.4% to 56.9% throughout the 2002 Kanektok River sample effort. The lack of a second peak in this Dolly Varden run may be because these late run fish may either have been absent from the 2002 run, they may not travel upstream as far as the weir site, they arrived after the weir was pulled on 20 September 2002, or they passed through the weir undetected. Additional years of monitoring this run will provide more insight into the actual reason for this observation.

The weir live trap was not effective in capturing large numbers of Dolly Varden. This method captured only 1.4% of the daily weir count and was more labor intensive than anticipated. Factors that may have affected our capture success at the weir were: the weir picket spacing may have allowed fish to pass through the weir; fish that entered the trap were able to exit before we could close it; and Dolly Varden either left the trap or tended to not enter the trap when there were salmon in it.

Comparison of the length frequency distribution between fish captured in the weir live trap and by beach seine indicates that fish smaller than 420 mm are capable of escaping the live trap and may pass through the weir pickets. This is likely a greater problem during times when the weir was closed to fish passage and possibly at other times. This weir is primarily comprised of PVC picket panels with a space between pickets of 4.3 cm. Similar work at a weir on the Middle Fork Goodnews River, where the gap between pickets is smaller (3.3 cm), found that the weir live trap was not successful at capturing fish less than 400 mm (Lisac 2004). Reducing the space between weir pickets or adding a mesh screen over the weir and live trap pickets would improve the capture success of smaller fish. The benefit of this modification would have to be weighed against the additional stress create on the weir.

Dolly Varden appear to be trap shy and are capable of exiting the trap when disturbed by netting efforts or as salmon crowd the trap. Efforts to modify the live trap to exclude salmon met with

mixed results. The most effective method involved closely monitoring the trap with the upstream gate open, allowing salmon to pass through, and closing the gates when Dolly Varden were observed entering. Designing a live trap that Dolly Varden will enter and are unable to exit freely would greatly enhance the utility of using a weir to estimate the proportion of mature fish in the daily weir count.

Beach seining was also labor intensive, but resulted in a much greater portion of the run being sampled (25.3%). This method is most effective when Dolly Varden daily weir counts are high (>/= 100 fish per day) and fish can be located in schools holding in water free of snags and debris. These areas are generally located along gravel bars on the inside of a river meander so this gear does not allow for sampling all habitat types. Because mature, prespawning fish may behave differently or hold in deeper water, they may not be vulnerable to capture by seining.

The estimate of total prespawning Dolly Varden (n = 3,161) that passed the weir during this study is difficult to interpret. The daily weir count includes all Dolly Varden that pass through the counting chute. Whether the proportion of fish less than 420 mm is equivalent between the weir count and our sample is not known. It is likely that using the seine sample would provide a conservative estimate of prespawning fish, while using the weir live box sample would inflate the estimate. To develop a long-term monitoring plan for Dolly Varden in the Kanektok River it is important to reliably estimate the proportion of spawners and nonspawners in these annual runs. Capturing a larger proportion of the daily fish passage at the weir would improve this estimate. Future efforts should be directed towards modification of the weir and live trap design to improve the capture and retention of Dolly Varden that represent the daily weir counts.

The telemetry component of this study successfully identified the seasonal distribution, important spawning tributaries, and overwintering locations used by radio-tagged Dolly Varden in the Kanektok River. This study has identified important areas in the Kanektok River drainage to concentrate future studies of potentially individual spawning stocks of Dolly Varden.

Known survival of radio-tagged fish was 42% (21 of 50 fish). Ten transmitters that were either harvested in the subsistence fishery, failed, or the fish left the system undetected are not included in this comparison of survival and mortality. The mortality rate (58%) observed in this study is comparable to that observe in a similar telemetry study in the Middle Fork Goodnews River (59.6%; 31 of 52 fish) (Lisac 2004). It is however, well above the reported mortality of 28.8% (23 of 80 fish) for radio-tagged Dolly Varden in the Togiak River (Lisac and Nelle 2000) or the 26% reported for Dolly Varden during their first year in the Kenai River (Palmer and King 2005). It is difficult to determine whether the range of mortality rates for radio-tagged Dolly Varden observed in these telemetry studies are a reflection of the invasive procedures, potential transmitter effects on the fish, the timing of field operation in relation to water levels and temperature, different population life history strategies, or to natural causes.

The suspected spawning timing (August to early October) appears to be earlier than the timing reported for radio-tagged Dolly Varden in the Togiak (Lisac and Moran 1999; Lisac and Nelle 2000) and Middle Fork Goodnews Rivers (Lisac 2004). The fish in the Kanektok River did begin downstream migration in early October and concentrated in the main river by the end of October. This is an earlier downstream migration than the timing observed for fish in the other studies, so it is possible that spawning did commence during August. Without ground-truthing

and more frequent tracking surveys it is difficult to be more precise on exactly where and when spawning occurred.

The freshwater migration patterns of these Dolly Varden appear to be similar to those of radio tracked Dolly Varden in the other two rivers. Fish primarily spawn in tributaries or in the upper portion of the main channel below headwater lakes. Only in the Togiak drainage have southwest Alaska Dolly Varden been reported to migrate upstream of the headwater lake (Lisac and Nelle 2000, and Lisac and Moran 1999). Most fish remain in one area of the main river channel throughout the winter. As spring approached the fish gradually migrated downstream, became more concentrated in the lower river, and left freshwater during May and June. This emigration appears to coincide with the event of spring breakup and ice out.

Acknowledgements

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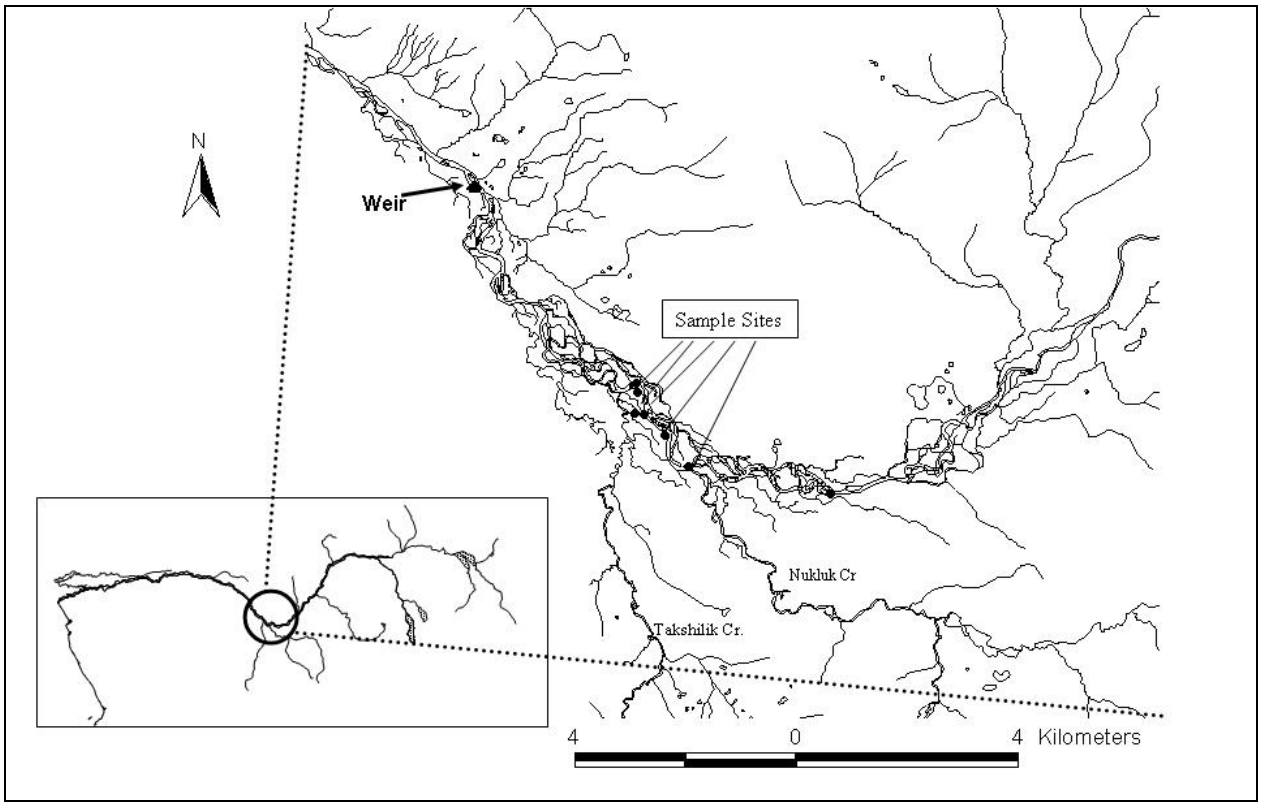
Appendix 1. Daily number of Dolly Varden counted, captured by gear type, and radio tagged in the Kanektok River, 2002.

Date	Weir count	Weir	Seine	Radio tagged	Mortalities
07/01	0				
07/02	18				
07/03	6				
07/04	0				
07/05	12				
07/06	10				
07/07	6				
07/08	21	0	0	0	0
07/09	53	0	0	0	0
07/10	128	1	0	1	0
07/11	177	11	0	6	1
07/12	543	5	0	3	0
07/13	418	10	0	7	0
07/14	551	17	0	13	2
07/15	993	0	0	0	0
07/16	700	10	0	7	0
07/17	1,623	17	0	6	0
07/18	2,245	20	0	3	0
07/19	1,071	27	0	6	3
07/20	893	2	114	0	1
07/21	430	21	69	2	1
07/22	848	15	88	2	1
07/23	771	15	209	2	0
07/24	770	6	0	0	0
07/25	271	0	58	0	0
07/26	178	3	32	0	0
07/27	53	1	91	1	1
07/28	128	0	35	1	0
07/29	94	5	0	0	0
07/30	175	0	0	0	0
07/31	242	4	47	0	0
08/01	154	0	248	0	0
08/02	90	0	172	0	0
08/03	0	0	127	0	0
08/04	109				
08/05	48				
08/06	24				
08/07	10				
08/08	15				
08/09	7				
08/10	1				
08/11	5				

Appendix 2. Daily number of Dolly Varden counted, captured by gear type, and radio tagged in the Kanektok River, 2002. Continued.

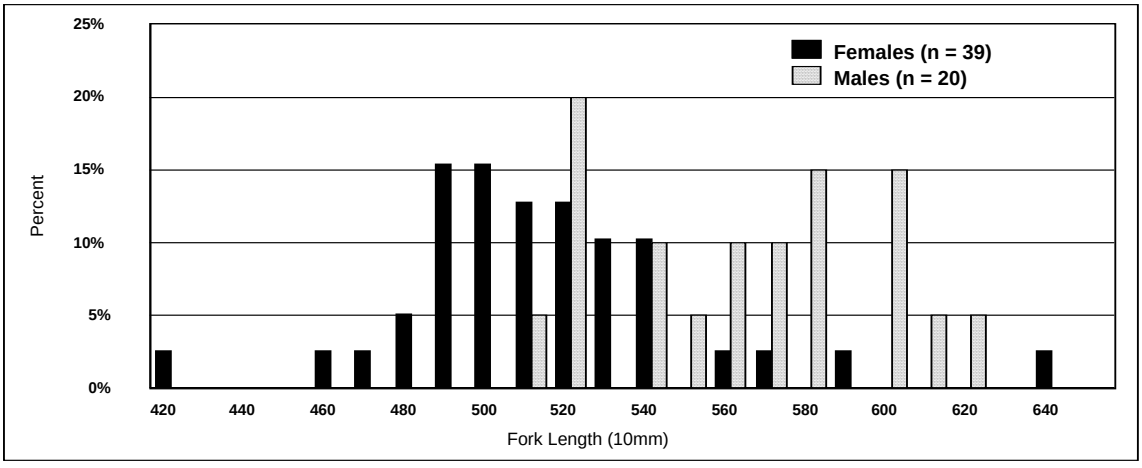
Date	Weir count	Weir	Seine	Radio tagged	Mortalities
08/12	12				
08/13	26				
08/14	46				
08/15	76				
08/16	91				
08/17	138				
08/18	157				
08/19	107				
08/20	46				
08/21	24				
08/22	8				
08/23	62				
08/24	32				
08/25	32				
08/26	23				
08/27	51				
08/28	6				
08/29	25				
08/30	2				
08/31	15				
09/01	18				
09/02	27				
09/03	5				
09/04	88				
09/05	13				
09/06	86				
09/07	28				
09/08	12				
09/09	27				
09/10	7				
09/11	2				
09/12	3				
09/13	3				
09/14	0				
09/15	4				
09/16	3				
09/17	1				
09/18	1				
09/19	0				
09/20	0				
Subtotal (7/10-8/03)	13,546	190	1,290	60	10
Totals	15,198	190	1290	60	10



Appendix 3. Location of beach seine sample sites Kanektok River 2002.

Appendix 4. Mean fork length (mm) and weight (g) of Dolly Varden radio-tagged in the Kanektok River, 2002.

Sex		Fork length (mm)	Weight (grams)
Males	*n*	20	21
	mean	558.4	1,947.6
	SD	33.45	425.03
	min	503	1,200
	max	615	2,700
Females	*n*	39	39
	mean	509.2	1,648.0
	SD	36.73	274.24
	min	416	1,300
	max	640	2,850
All	*n*	59	60
	mean	525.9	1,752.9
	SD	42.59	364.05
	min	416	1,200
	max	640	2,850



Appendix 5. Length frequency distribution of radio-tagged Dolly Varden from the Kanektok River, 2002.