Seasonal Distribution and Biological Characteristics of Dolly Varden in the Goodnews River, Togiak National Wildlife Refuge, Alaska, 2005 - 2006

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Mark J. Lisac

Abstract

The seasonal distribution of Dolly Varden *Salvelinus malma* was investigated in the Goodnews River using radio telemetry from August 2005 to June 2006. A total of 1,091 Dolly Varden were captured by seine or angling. Most (N = 1,024) of these fish were marked with individually number tags and released. Sixty mature Dolly Varden were implanted with radio transmitters between 24 July and 21 August 2005. Radio-tagged fish were relocated during 18 aerial tracking flights conducted between 1 August 2005 and 6 June 2006. Suspected spawning locations were identified for 49 (81.7%) radio-tagged Dolly Varden. The final fate of five (8.3%) transmitters is unknown leaving 55 transmitters that can be accounted for. Twenty-four fish (43.6%) survived spawning and overwintered in the Goodnews River watershed. Sixteen (29.1%) fish appeared to survive throughout the study. Fifteen fish are presumed to have emigrated from freshwater to the ocean between 22 May and 6 June 2006. Three (0.3%) of the 1,024 individually marked fish were reported caught in sport fisheries occurring in other drainages in southwest Alaska during the summer of 2006. These drainages included the Kulukak, Kanektok, and Aniak rivers which are located between 170 km and 510 km from the Goodnews River.

Introduction

Dolly Varden are important to subsistence users, the local sport fishery, and the ecosystem of the Goodnews River drainage in southwest Alaska. Although no quantitative harvest estimate is available for the Goodnews River Dolly Varden subsistence fishery, Dolly Varden are likely harvested in such quantities to match or exceed the harvest of salmon by weight (Wolfe et al.1984). The sport catch averaged 15,189 char (Dolly Varden and Arctic char combined) in the entire Goodnews River (Chythlook 2006) between 2001 and 2005. This catch is second to the Kanektok River among all estimated sport fisheries in the Kuskokwim region.

To aid in developing a long term monitoring program for Dolly Varden populations in southwest Alaska, the Togiak National Wildlife Refuge (Refuge) initiated research to learn more about the life history and habitat use of Dolly Varden throughout the Refuge (Lisac and Moran 1999; Lisac and Nelle 2000; Reynolds 2000; Lisac and Buchholtz 2001; Crane et al. 2003; Lisac 2002, 2004, 2006, 2007a, 2007b, 2008a, 2008b; Lisac and Bromaghin 2007). Radio telemetry, visual marking, genetic analysis, otolith microchemistry, and escapement monitoring have been used successfully to document aspects of the life history characteristics, and identify important spawning and overwintering habitat for anadromous Dolly Varden in the Togiak, Kanektok and Middle Fork Goodnews Rivers.

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These previous studies, as well as local knowledge and work by others (Whalen 1992; Larson 1997), suggest that anadromous Dolly Varden in southwest Alaska have the following life history traits: 1) fish return to the river from saltwater from July to late August; 2) spawning occurs in freshwater during late fall (September and October); 3) overwintering occurs in freshwater (either rivers or lakes); and 4) fish return to saltwater during the spring thaw and ice breakup usually beginning in late April or early May. Additionally, the annual Dolly Varden runs include both mature fish returning home to spawn and immature nonspawning fish. The later group is generally more numerous and is likely comprised of fish from various river stocks (Whalen 1992; Larson 1997; Lisac and Nelle 2000; Crane et al. 2003; Lisac 2004).

The purpose of this study was to conduct similar research on the Dolly Varden in the main fork of the Goodnews River. The specific objectives of this study were to: 1) describe the seasonal distribution of Dolly Varden in the Goodnews River watershed in order to identify spawning and freshwater overwintering areas, 2) describe length frequency distribution of Dolly Varden in the Goodnews River by sex and maturity, and 3) document any reported long distance migrations of Dolly Varden from the Goodnews River.

Study Area

The Goodnews River is considered the main or north fork of the larger Goodnews River watershed (Figure 1) that is located within the Togiak National Wildlife Refuge in southwest Alaska. The watershed consists of three river channels which drain approximately 2,600 km^2 in the Ahklun Mountains (USFWS 1990). The Goodnews River flows southwest for approximately 93 km from the outlet of Goodnews Lake to Goodnews Bay. The Middle Fork and South Fork rivers join the Goodnews River approximately 6.5 km and 4.0 km upstream of Goodnews Bay, respectively. The village of Goodnews Bay is located on the north shore where the river enters the bay.

The upper 40 km of the Goodnews River is primarily contained in single channels, while the lower 53 km is primarily braided with many sloughs and side channels. The river is approximately 36 m wide near the outlet of Goodnews Lake and reported velocities varied from 4.8 to 12.9 kph (Alt 1976). River substrate composition ranges from cobble in the upper most areas near the lake to mud and sand in the lowermost reaches near tidewater. Goodnews Bay and the lower river are tidally influenced with a maximum tide height of approximately 3 m at the entrance of Goodnews Bay.

There are several named and unnamed tributaries to the Goodnews River. The primary named tributaries below Goodnews Lake are Awayak, Nimgun, Canyon, Slate, Barnum, Granite and Puyulik creeks, and the Middle Fork and South Fork Rivers. Awayak, Nimgun and Canyon creeks have headwater lakes. Goodnews Lake is the largest lake in the drainage and is approximately 7.2 km long by 1.0 km wide with a surface area of 310 ha, and a maximum depth of 39.6 m. Goodnews Lake narrows down to a shallow outlet stream that flows for approximately 200 m before emptying into what is locally called lower Goodnews Lake which has a maximum depth of approximately 13 m.

Methods

Dolly Varden were captured by beach seine and angling methods between 13 July and 21 August, 2005. Capture efforts were concentrated in a 47 river km section of the Goodnews River, and in the lower reaches of Barnum, Slate and Canyon creeks (Figure 1). This area extended from approximately 26 km upstream of Goodnews Bay to a steep, rocky section between the confluence with Canyon and Nimgun Creeks. The lower boundary of the study area was selected to give fish ample time in freshwater to develop external maturity characteristics and to minimize the chance that fish would exit the drainage.

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 weighed to the nearest 0.25 kg. All Dolly Varden greater than 250 mm and not radio-tagged were marked with an individually numbered T-bar anchor tag.

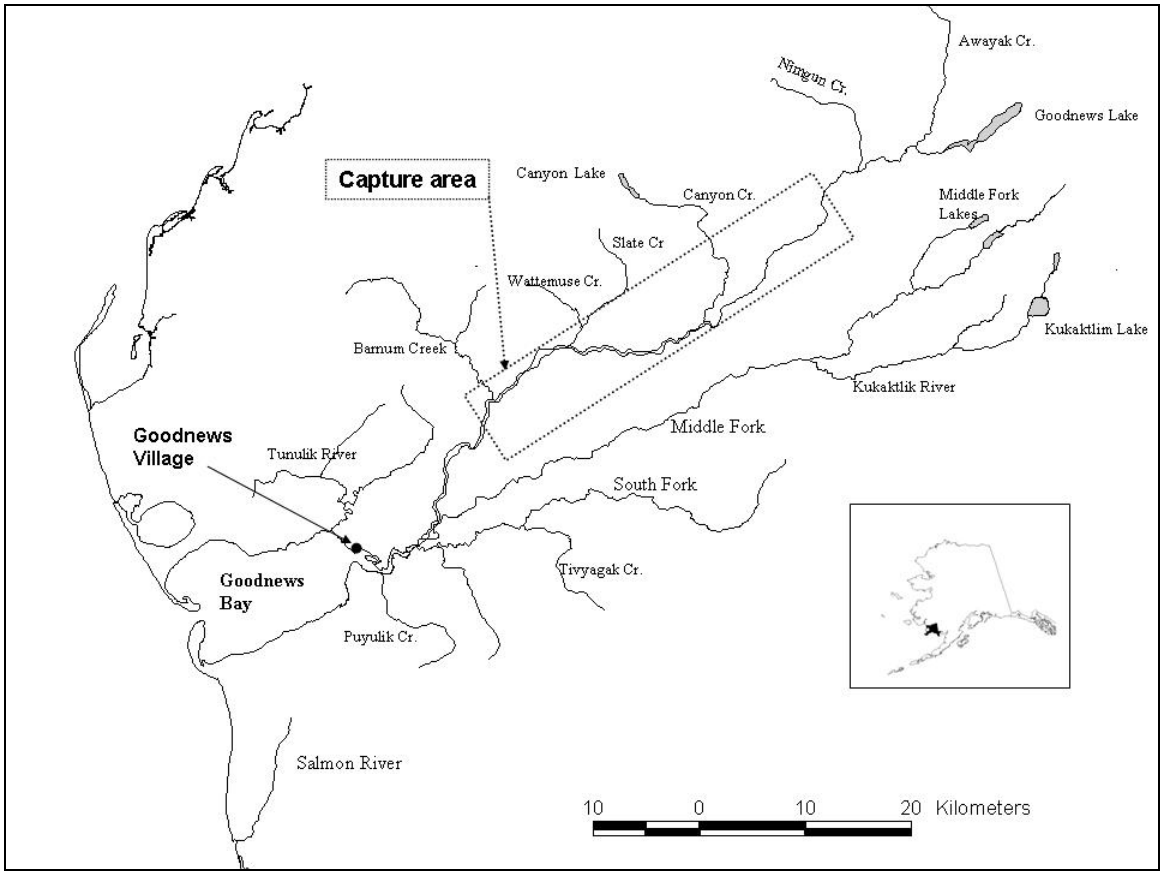

FIGURE 1.—Goodnews River drainage and Dolly Varden capture area, 2005.

Maturity of each fish was determined using external characteristics with periodic comparison to internal examination of gonad development as previously reported by Lisac (2006) and adapted from DeCicco (1985). The primary external characteristics used to determine maturity were the

coloration of the body, head, jaw and fins. Fish were classified as prespawning if they were exhibiting signs of color change (darkening opercle, head and jaws, reddening of fins with white leading edge, and spots becoming pink or red and well defined or with halo appearance). Fish that were primarily silver in color were classified as either unknown maturity or nonspawner. Head shape, kype formation, and a swollen ovipositor or abdomen were used as sex determinant characteristics.

Mean fork lengths were used to calculate length frequency distributions (10 mm increment) and were separated by sex and maturity for all sampled fish using a sex and maturity index. Cumulative fork length frequencies were compared between sexes and between maturities using a paired Kolmogorov-Smirnov test conducted using Number Cruncher Statistical Software (Hintze 2002).

Sixty radio transmitters were implanted in prespawning fish presumed to be in route to their natal waters to spawn. To represent the run and improve the chance of identifying as many potential discrete spawning locations as possible the tags were dispersed both temporally and spatially. Dolly Varden greater than 400 mm and with a minimum weight of 850 g (such that the radio tag was less than or equal to 2% of fish weight, Winter 1996) were targeted for radio-tagging. Because natural mortality is higher for spawning males (Blackett 1968; Kruger 1981; Armstrong 1984; Larson 1997), females were preferentially targeted for radio-tagging to increase the potential duration of telemetry data.

Upon capture, fish were anesthetized in a 25 to 30 mg/L solution of Aqui-S^{TM} (Investigational New Animal Drug (INAD) Exemption #10-541-05-27) as similarly described by Anderson et al. (1997). A radio transmitter was surgically implanted into the intra-peritoneal cavity of each fish once the fish lost total equilibrium and muscle control (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 photographed with a placard containing the radio frequency, date, and river name visible in the photograph.

We used radio transmitters manufactured by Advanced Telemetry Systems (model F1835) to transmit on individual frequencies in the 162 to 164 MHz range at 55 pulses-per-minute. The transmitters were equipped with mortality switches, which cause the pulse rate to increase to approximately 100 ppm if the transmitter was motionless for more than 12 hours. The transmitters weighed 15 g in air and trailed a plastic-coated wire antenna approximately 30 cm long. To increase the transmitter battery life to approximately 400 days, the duty cycle was set to be on for 12 hours per day (0900 to 2100 hrs).

The movements of radio-tagged fish were monitored using a programmable scanning receiver (ATS 1998). Aerial tracking occurred between August 2005 and June 2006. From August to November, when Dolly Varden were suspected of moving to their spawning destinations, tracking was scheduled to occur 2 or 3 times per month. During the winter months (December to April), tracking was scheduled approximately once each month. Beginning in May, when Dolly

Varden were suspected to begin emigrating to sea, the survey frequency was increased to 3 times per month.

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. The survey areas included the mainstem Goodnews River, headwater lakes, all major tributaries, and occasionally include searches of the Middle Fork and South Fork Rivers. Because salinity, conductivity and depth can effect radio signal transmission in water (Winter 1996) Goodnews Bay was included only during surveys that coincided with low ocean tide cycle.

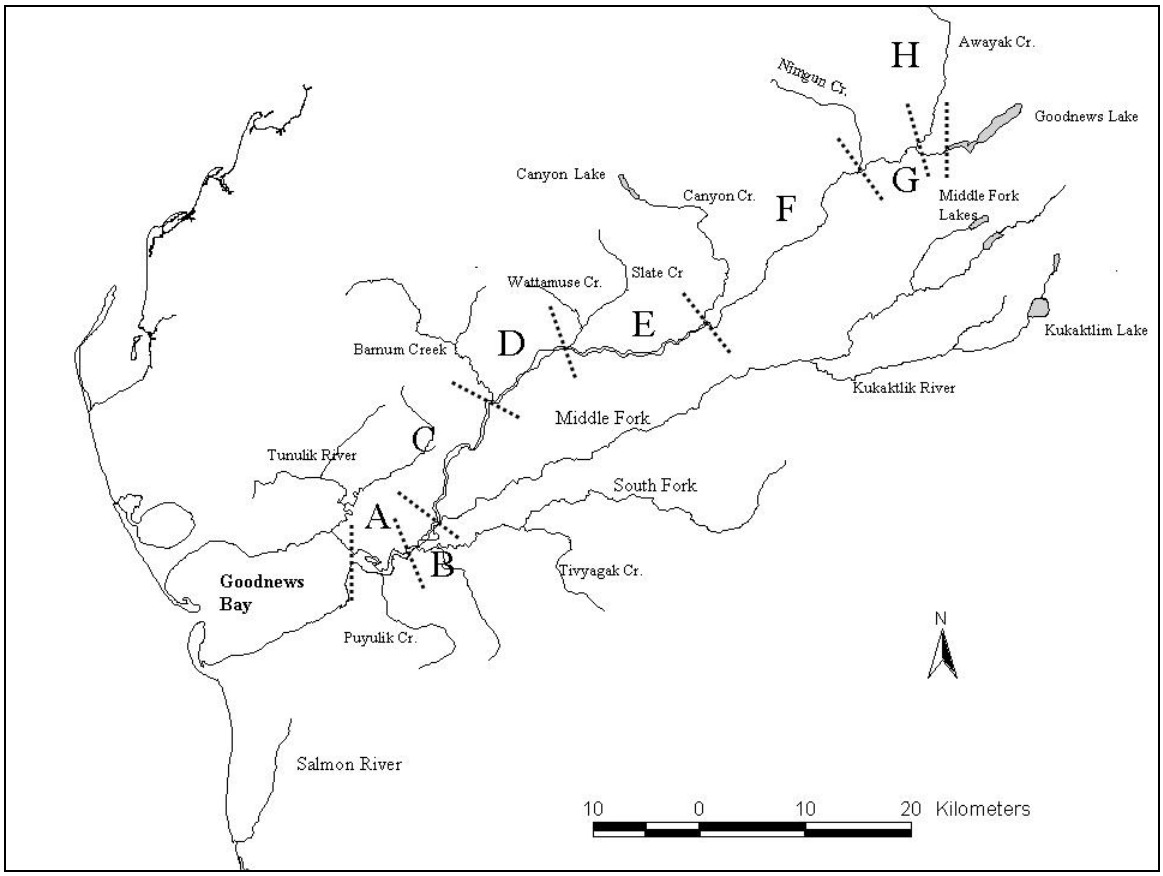

FIGURE 2.—Goodnews River study sections and prominent tributaries, 2005 - 2006.

Fish locations were recorded using the aircraft's GPS over the point when the audible signal was determined to be the loudest. Signal status was recorded as being in either live or mortality mode. Fish were considered mortalities if the transmitter was recovered from the river, or if the transmitter was operating in mortality mode during two or more consecutive tracking flights. The fish's location history was reviewed to determine when and where the mortality was likely to have occurred.

Telemetry 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 river drainage using Arcview™ GIS software. To facilitate the analysis and discussion of location data the mainstem river was divided into study subsections A through H (Figure 2). The boundaries of these sections were established using the confluences with major tributaries.

Suspected spawning areas and spawn timing were identified for each individual fish based on a subjective analysis of its location history. No grounds surveys were conducted to document actual spawning activity. The spawning locations and spawning timing were assigned based on the fish's furthest upstream location or where the fish was repeatedly located during the surveys conducted throughout August, September and October. Distances traveled to spawning locations were measured from the mouth of the Goodnews River at the village of Goodnews Bay. Overwintering areas were described for fish that appeared to survive spawning and were located alive at least once during late October 2005 through March 2006. It is presumed that radio-tagged fish emigrated from freshwater to the sea when they could no longer be located in the river, after having been located in live mode on previous surveys. The earliest possible date for individual fish to have emigrated to the sea was assumed to be the day after the last survey the fish was located in the river. Fish were listed as "departed the drainage" if at some time during the tracking history they were located in Goodnews Bay downstream from the village and not relocated in the Goodnews River.

Results

A total of 1,091 Dolly Varden were captured and sampled in the Goodnews River between 14 July and 21 August 2005. Seven fish suffered mortality from transmitter surgery. These transmitters were recovered and redeployed so that 60 fish were successfully implanted with radio transmitters between 24 July and 21 August 2005. Of the remaining 1,024 Dolly Varden caught there were 913 marked with a T-bar anchor tag and released.

Success of capturing Dolly Varden ranged from 0 to 160 fish per day. The sample was comprised of 31.2% (N = 340) males, 34.7% (N = 379) females, and 34.1% (N = 372) fish of unknown sex (Table 1). The maturity composition of the catch was 391 (35.8%) prespawners, 52 (4.8%) nonspawners, and 648 (59.4%) unknown maturity. All radio-tagged Dolly Varden were classified as prespawners and were comprised of 61.7% (N=37) females.

All of the 1,091 Dolly Varden captured were measured for fork length (Table 1, Figure 3). These fish ranged in fork length from 258 to 629 mm, and averaged 412.6 mm (SD = 54.48). Fork length for prespawners ranged from 331 to 629 mm and averaged 437.4 mm (SD = 46.15). Mean fork length for nonspawners was 463.2 mm (SD = 46.16; range 365 to 568 mm). Cumulative length frequency distributions were not significantly different (Dmax = 0.08478; $p > 0.05$) between prespawners and nonspawners.

Cumulative fork length frequencies were significantly different ($p < 0.05$) in all paired comparisons between gender categories (M vs F; M vs Unk; F vs Unk) as both sexes were larger than the unknowns (Figure 3). Male Dolly Varden were significantly larger than females in this sample (Dmax = .39964; p = 0.05).

TABLE 1.—Mean fork length by sex and maturity for Dolly Varden caught in the Goodnews River, 2005.

		Sex			
Maturity		Males	Females	Unknown	All
Prespawners	Mean	462.7	422.7		437.4
	SD	44.84	40.21		46.15
	min	365	331		331
	max	629	546		629
	N	144	247		391
Nonspawners	Mean	477.8	419.2		463.2
	SD	42.21	24.80		46.16
	min	396	365		365
	max	568	467		568
	N	39	13		52
Unknown	Mean	444.5	408.6	367.1	393.5
	SD	37.74	30.08	42.17	51.03
	min	353	343	258	258
	max	576	493	600	600
	N	157	119	372	648
All	Mean	456.0	418.2	367.1	412.6
	SD	42.87	37.37	42.17	54.48
	min	353	331	258	258
	max	629	546	600	629
	N	340	379	372	1,091
Radio-tagged DV	Mean	500.7	467.7		480.4
	SD	38.26	31.33		37.52
	min	435	430		430
	max	629	546		629
	N	23	37		60
Weight (g)	Mean	1,323.9	1,137.2		1,208.8
	SD	391.64	231.06		313.29
	min	1,000	850		850
	max	2,800	1,750		2,800
	N	23	37		60

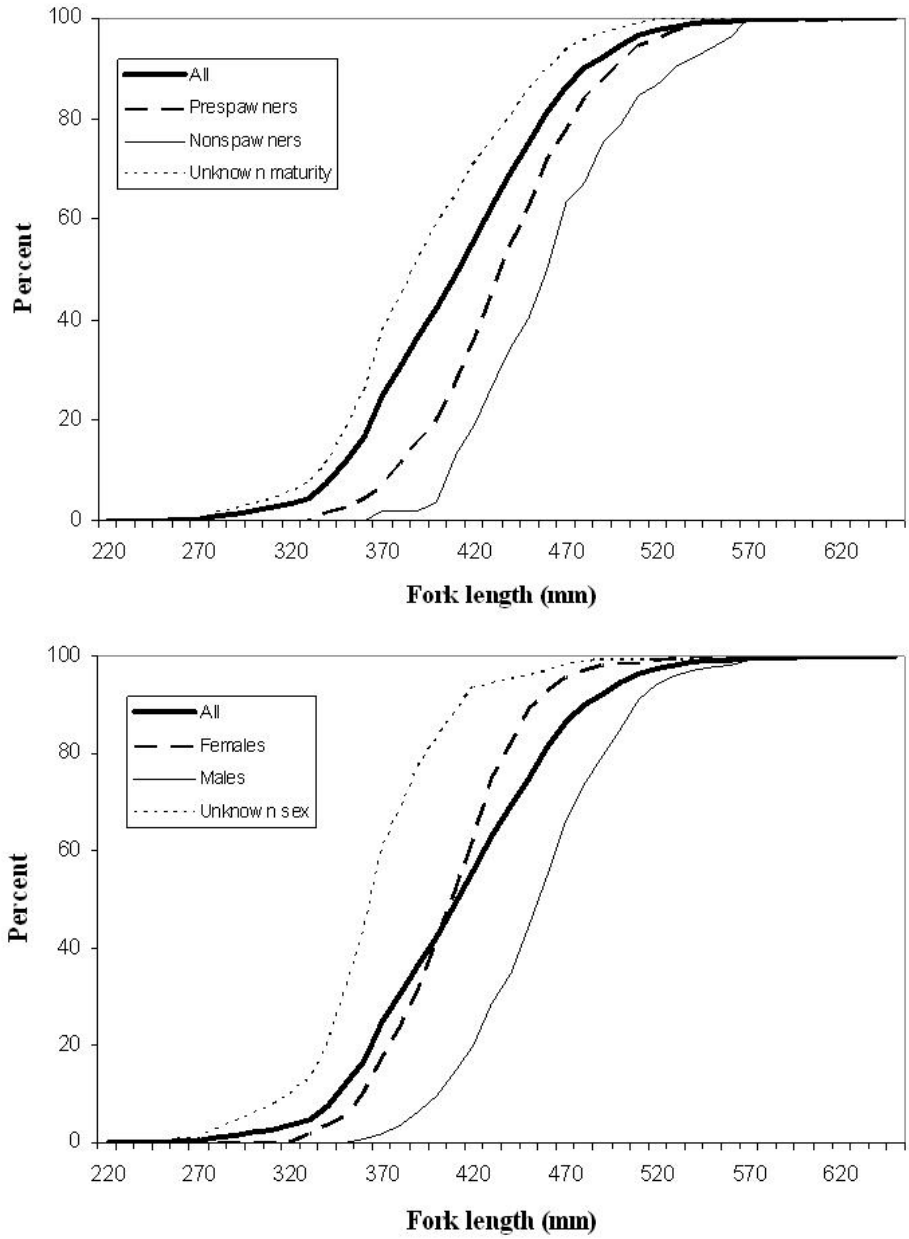

FIGURE 3.—Cumulative fork length frequencies by sex and maturity for Dolly Varden captured in the Goodnews River, 2005.

Aerial tracking events were conducted on 18 different occasions during a 307 day period between 3 August 2005 and 6 June 2006 (Table 2). Relocations of radio-tagged fish ranged from one to 17 times per fish with most (*N*=44) relocated less than eight times. A total of 415 location data points are included in this analysis.

Initial movements were determined for 47 (73.3%) of the radio-tagged Dolly Varden (Table 2). By the end of August, 40 fish had moved upstream and seven had moved downstream of the

capture area, three fish were mortalities, and 10 fish were not located. Of the 47 fish located most remained in the main river between the confluence with Barnum Creek and the confluence with Awayak Creek (sections D through G). Eleven fish ascended the tributary streams of Slate and Wattemuse Creeks (*N*=6), Canyon Creek (*N*=4), and Nimgun Creek (*N*=1). Of the seven fish that initially traveled downstream, six were later determined to be mortalities.

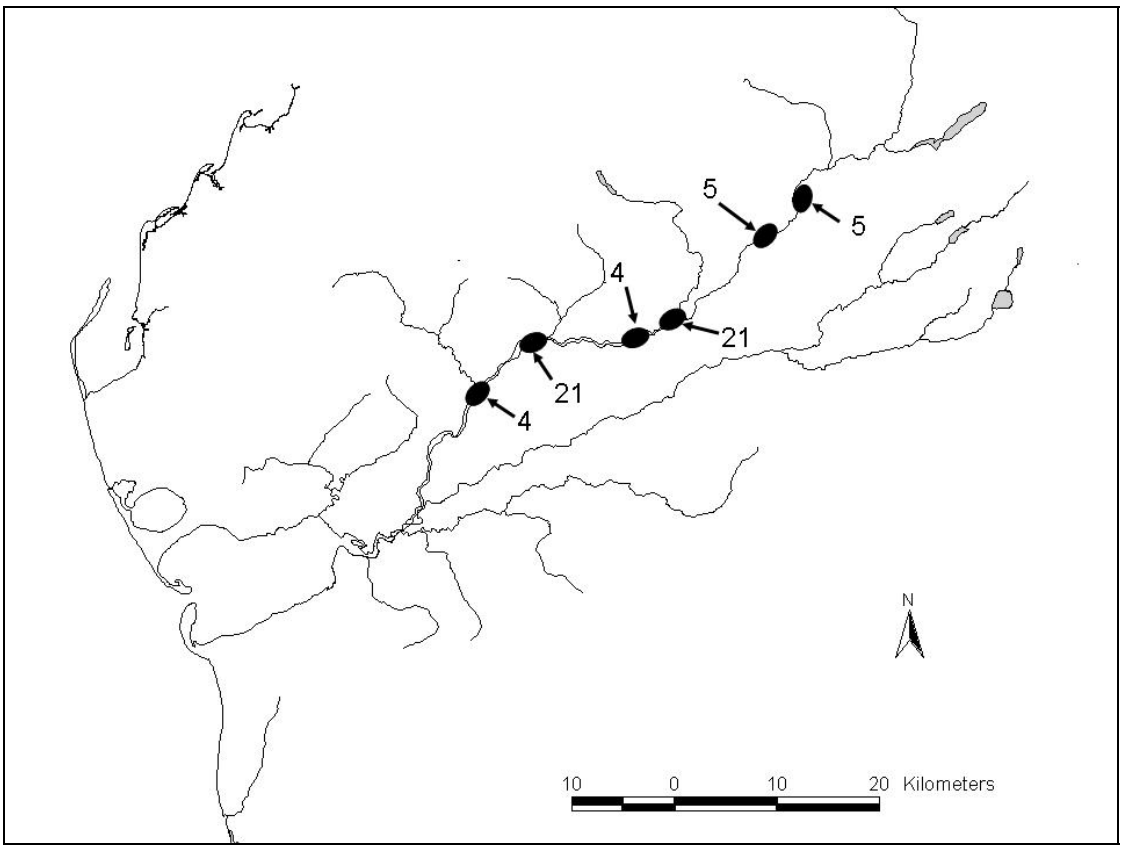

FIGURE 4.—Initial capture locations for 60 radio-tagged Dolly Varden in the Goodnews River between 24 July and 20 August 2005.

TABLE 2.—Number and fate of radio-tagged Dolly Varden located by survey in the Goodnews River between 3 August 2005 and 6 June 2006.

Survey	Date	Number available	Fate					Suspected spawning[d]
			Live	Mortality[a]	Departed[b]	To sea[c]	Unknown	
1	8/3/05	28	25	0	0		3	1
2	8/17/05	52	46	0	0		6	5
3	8/31/05	60	47	3	0		10	8
4	9/16/05	60	36	7	2		15	22
5	9/29/05	60	30	14	4		12	11
6	10/11/05	60	21	23	5		11	2
7	10/25/05	60	17	28	5		10	
8	11/8/05	60	17	29	5		9	
9	11/21/05	60	16	30	5		9	
10	12/27/06	60	16	31	5		8	
11	1/27/06	60	15	32	5		8	
12	2/23/06	60	15	32	5		8	
13	3/27/06	60	15	32	6		7	
14	4/18/06	60	16	32	6		6	
15	5/3/06	60	16	32	6	0	6	
16	5/22/06	60	18	33	6	0	3	
17	5/30/06	60	5	34	6	12	3	
18	6/6/06	60	1	34	6	15	4	

[a]Fish with transmitters in mortality mode.

[b]Fish that had departed the river and were located in Goodnews Bay or another drainage.

[c]Fish that are presumed to have gone to sea alive.

[d]Fish that were assigned spawning locations during these surveys.

Suspected spawning locations were assigned to 49 (81.7%) radio-tagged Dolly Varden between 3 August and 11 October (Table 3 and Figure 5). Spawning locations were located approximately 4 to 110 rkm upstream from the mouth of the Goodnews River and included the mainstem of the Goodnews River and tributary streams. Over half (61.2%) of the suspected spawners were located in the mainstem of the Goodnews River from the confluence with Awayak Creek downstream to below the confluence with the South Fork. Most (N = 12) of the mainstem fish were located in the section (F) between Canyon and Nimgun Creeks (Figure 2). Nineteen (38.8%) radio-tagged fish were assigned spawning locations in six different tributary streams which included Awayak (N=1), Nimgun (N=2), Canyon (N=7), Slate (N=4) Wattemuse (N=3), and Puyulik (N=2) creeks. The remaining fish (N=1) was relocated outside of the Goodnews River drainage in the Salmon River which enters Kuskokwim Bay nearly 20 km south of Goodnews Bay (Figure 5). This fish was located in the upper Goodnews River (section F) on 31 August 2005 but is presumed to have spawned in the Salmon River based on radio tracking results from16 and 29 September.

In addition to the one fish located in the Salmon River there were five other fish that departed the drainage between 3 August and 29 September 2005 and were located in Goodnews Bay. These transmitters were either on mortality mode or were later considered to be mortality due to lack of movement. Each of these fish were located in the Goodnews River during August after initial tagging event, but only two fish were assigned spawning locations.

TABLE 3.—Number of radio-tagged Dolly Varden located in each study subsection during tagging and assigned spawning and overwintering locations by study section in the Goodnews River, 2005 - 2006.

			Time period		
Section	Description	River km	Tagging	Spawning	Winter
	Main River				
A	Bay to South Fork	0 - 6		3	11
B	SF to Middle Fork	6 - 8		2	3
C	MF to Barnum Cr	8 - 27	4	1	3
D	Barnum Cr. to Slate Cr.	27 - 38	21	5	1
E	Slate Cr. to Canyon Cr.	38 - 54	25	6	2
F	Canyon Cr. to Nimgun Cr.	54 - 79	10	12	1
G	Nimgun Cr. to Awayak Cr.	79 - 90		1	
H	Awayak Cr. To Goodnews Lk.	90 - 93			
L	Goodnews Lk outlet upstream	93 +			2
	Tributaries	Distance to confluence (total)			
P	Puyulik Cr.	2 (10)		2	1
S	Slate Cr.	38 (48)		4	
W	Wattemuse Cr.	38 (44)		3	
CC	Canyon Cr.	54 (57)		7	
N	Nimgun Cr.	79 (109)		2	
AY	Awayak Cr.	90 (102)		1	
SR	Salmon River (Kuskokwim Bay)			1	
U	U - Unknown			10	36
Total			60	60	60

Fish located in the tributaries during the spawning season began descending to the mainstem Goodnews River between 16 September and 11 October 2005. All tributary spawners, except one, were located in the mainstem Goodnews River by the end of October. All radio-tagged fish appeared to have selected their overwintering location by the tracking flight on 21 November 2005. Eleven primary overwintering locations were assigned to 24 individual fish (Figure 6). Most fish had migrated downstream of their suspected spawning location except two fish that migrated upstream to Goodnews Lake. Seventeen (70.8%) of the 24 fish were located below the capture area in sections A, B and C with the highest concentration found in section A.

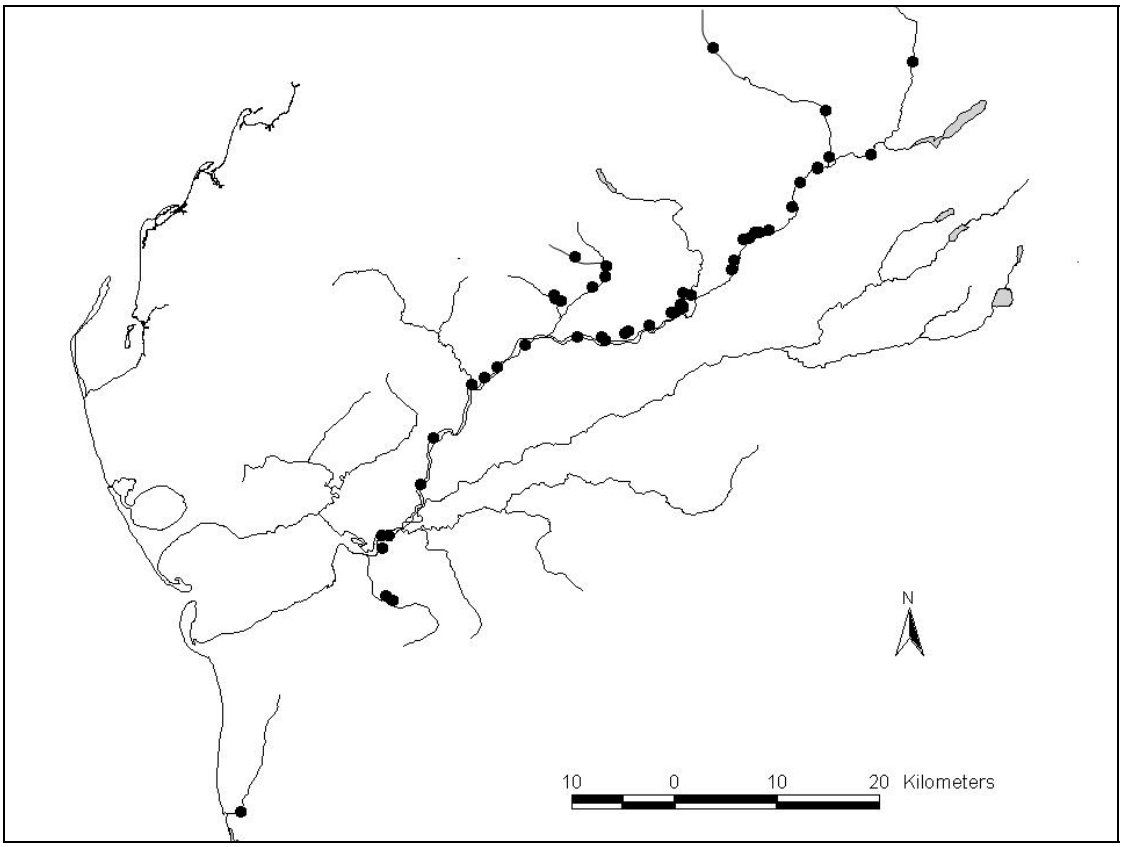

FIGURE 5.—Suspected spawning locations for 49 radio-tagged Dolly Varden in the Goodnews River, 3 August to 11 October 2005.

Only 18 transmitters (30% of the original 60) were still emitting a live signal during the tracking flight on 22 May 2006. Twelve of these fish are suspected to have gone to sea between 22 and 30 May 2006. Another three fish went to sea by the last survey on 6 June 2006. This included two fish still located in Goodnews Lake on 30 May 2006. The only live fish located in the Goodnews River drainage during the survey on 6 June was located in Puyulik Creek. The remaining two fish were found on mortality mode on the last survey in the same location they had spent the winter.

The final fate is known for 55 of the 60 radio-tagged Dolly Varden. Sixteen (29.1%) fish survived throughout the study period. Thirty nine (70.9%) fish were found emitting a mortality signal either within the Goodnews River drainage (N = 34) or in Goodnews Bay downstream of the village (N = 5). The one fish that had departed the drainage and was located in the Salmon River to the south of Goodnews Bay was included with the 5 fish of unknown fate. The survival rate for females (26.5%; 9 of 34) was actually lower than that observed for males (31.8%; 7 of 22).

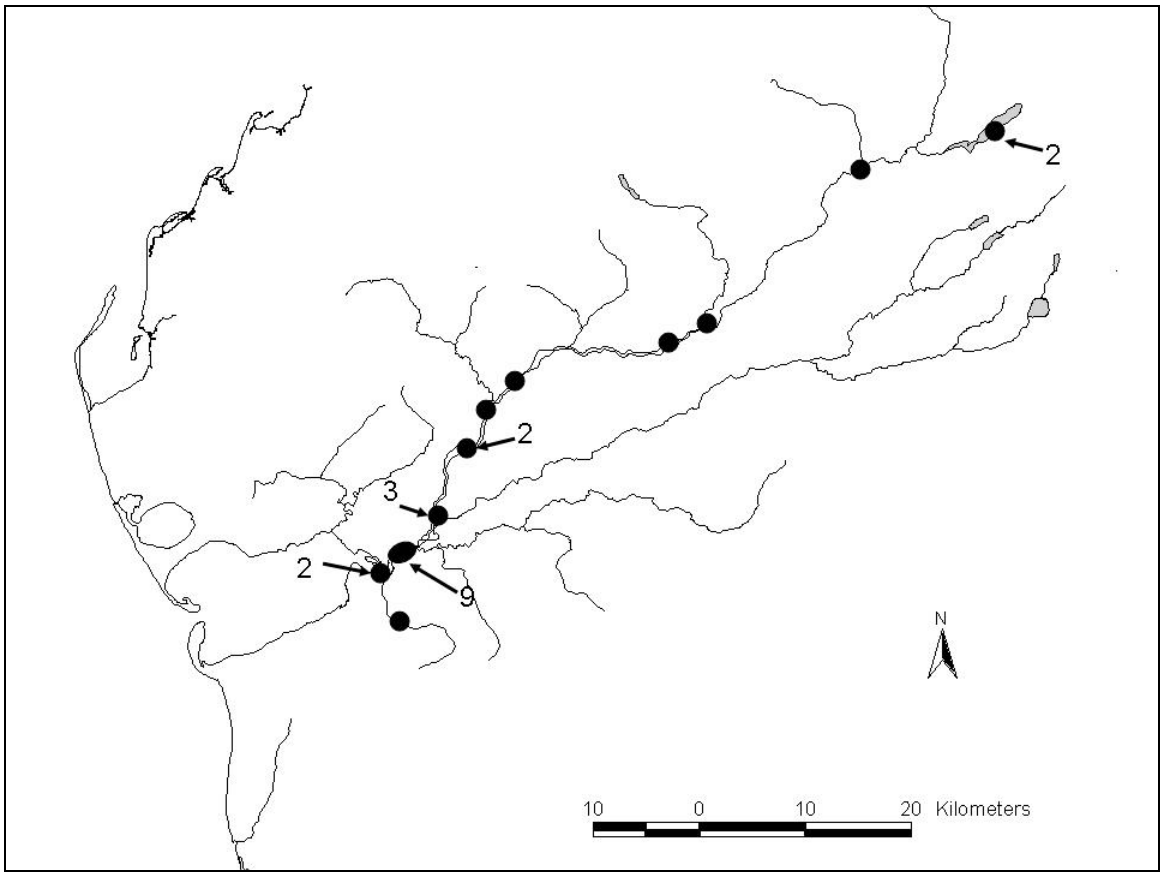

FIGURE 6.—Overwintering locations for 24 radio-tagged Dolly Varden in the Goodnews River, November 2005 to March 2006. Numbers and arrows indicate locations where more than one fish was located.

Nine of the 913 Dolly Varden marked with individually numbered T-bar tags and released were reported recaptured in various subsistence and sport fisheries (Table 4). Six of these were reported caught in the Goodnews River during this study. The three other marked fish were reported captured by sport fishers in the Kulukak, Kanektok and Aniak rivers during the August 2006 (Figure 7). If these fish did overwinter in the Goodnews River their recapture dates occurred approximately 90 days after the spring emigration period identified for radio-tagged Dolly Varden during 2006. The approximate travel distances from their tagging location to their reported recapture location ranged from 170 km to 510 km.

TABLE 4.—Location, date, distance traveled and number of days between events for Dolly Varden reported recaptured in the subsistence and sport fishery in southwest Alaska, 2005 – 2006.

Original capture					Recapture Event				Travel	
Sex	Maturity	Length	Date	Section	Fishery	Date	River	Section	Days	km
F	PR	403	07/20/05	D	Subsist.	12/01/05	Goodnews	A	134	35
M	NS	437	07/27/05	F	Subsist.	04/01/06	Goodnews	A	248	60
M	NS	467	08/17/05	E	Subsist.	02/27/06	Goodnews	A	194	50
F	U	381	07/24/05	D	Subsist.	09/27/05	Goodnews	D	65	0
M	PR	490	07/16/05	D	sport	07/18/05	Goodnews	E	2	18
F	U	357	08/02/05	D	sport	08/10/05	Goodnews	E	8	27
U	U	358	08/04/05	D	sport	08/05/06	Kanektok		366	170
M	PR	471	07/20/05	D	sport	08/01/06	Kulukak		377	315
F	PR	392	07/20/05	D	sport	08/28/06	Aniak		404	510

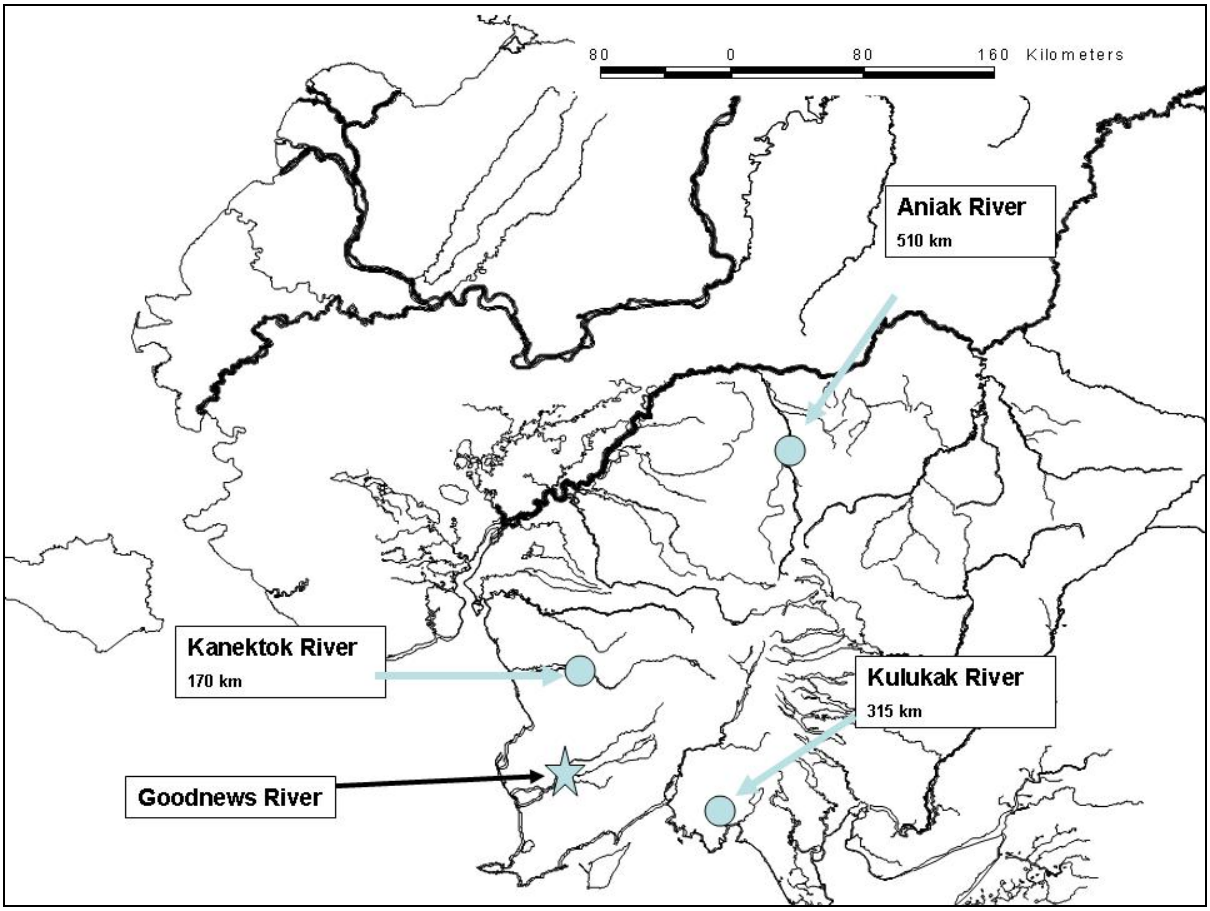

FIGURE 7.—Location and approximate distance traveled for individual Dolly Varden marked with numbered T-bar anchor tags in the Goodnews River during July and August 2005, and reported recaptured by sport fishers during August 2006.

Discussion

This study successfully identified the potential spawning and overwintering locations used by radio-tagged Dolly Varden in the Goodnews River although there were no ground observations to collaborate the telemetry observations. Based on the telemetry results, potential spawning habitat occurs throughout the mainstem Goodnews River primarily between the confluences of Barnum and Awayak Creeks, and in a few tributary streams. Overwintering primarily occurred in the lower 8 rkm of the mainstem river and in Goodnews Lake. This information is useful for designing future studies of potential discrete spawning stocks or overwintering aggregations.

The freshwater migration patterns of Dolly Varden from this study appear to be similar to results of other radio telemetry studies investigating Dolly Varden in southwest Alaska rivers. Fish primarily spawned in tributaries or in the main river 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, Lisac and Buchholtz 2001, Lisac and Bromaghin 2007). All 24 fish that were tracked to overwintering areas in the Goodnews River appeared to have remained in freshwater throughout the winter. Five of the fish that departed the Goodnews River were relocated in the bay transmitting a mortality signal and may have died in the river and washed out with the river current and tide. The only other fish documented to have departed the Goodnews River was relocated in a small coastal stream south of Goodnews Bay during September, but was never relocated again so it is not known whether this fish overwintered in fresh or salt water. As spring approached the fish gradually migrated downstream, became more concentrated in the lower river, and left freshwater beginning in May through early June. This emigration is consistent with the timing observed in the other studies, although the exact dates that fish leave the river can only be approximated with aerial tracking. Lisac and Nelle (2000) used a combination of aerial tracking with a fixed receiver station in the lower Togiak River and documented emigration of Dolly Varden occurring from 5 May to 21 June in 1999. Ice breakup and increased water levels appear to trigger the onset of Dolly Varden emigrating to the sea although no quantitative data on ice cover has been collected during these studies to substantiate this.

Capturing mature Dolly Varden of the desired size for this telemetry study was more difficult than in the other Refuge rivers. The mean length (480.4 mm) and weight (1,209 g) were the smallest for all radio-tagged Dolly Varden in these Refuge river studies. The mean length and weight of radio-tagged Dolly Varden in the other three rivers ranged from 511.8 mm and 1490 g in the Togiak River to 532 mm and 1843 g in the Middle Fork Goodnews River. The capture methods during 2005 were most similar to those used in the Togiak River study and not Middle Fork Goodnews or Kanektok River studies which included the use of a weir and live trap. Comparisons between gear type capture success and size range have indicated that seining is an effective method for catching the larger size Dolly Varden (Lisac 2004, 2006). It is possible that the Dolly Varden in the Goodnews River are actually smaller in size or that the larger fish entered the river before our capture efforts began. Other studies have demonstrated that the size of Dolly Varden and the proportion of mature fish can decline throughout the annual run (Larson 1997, Whalen 1992, Lisac and Nelle 2000, Lisac 2004, 2006, 2007a, 2007b, 2008a, 2008b). Our capture efforts were delayed and did not begin until 14 July and transmitter deployment did not begin until 24 July. The Dolly Varden run at the Middle Fork Goodnews River weir began on 26

June and the mid-point of the run occurred 13 July (Lisac 2007a). It is likely that we missed a significant number of fish that may have ascended beyond our capture area before our arrival.

Survival of radio-tagged Dolly Varden in the Goodnews River from surgery to suspected spawning locations (81.7%) was within the range observed in the other telemetry studies of Dolly Varden in southwest Alaska (67.8% to 91.0%). The survival of these fish to overwintering location (40.0%) and the overall proportion of radio-tagged fish that survived the entire study period (29.6%) was the lowest observed. The proportion of radio-tagged fish reported to have survived the entire study period was 40.4% for 52 fish in the Middle Fork Goodnews River (Lisac 2004), 42.0% for 50 fish in the Kanektok River (Lisac 2006) and 70.4% for 81 fish in the Togiak River (Lisac and Nelle 2000). The smaller average size of radio-tagged fish in the Goodnews River may have been a factor in the lower survival rate observed in this study. Mortality observed during all radio telemetry studies could have been caused from surgical procedures, prolonged effects from the radio transmitter, or natural causes.

The suspected spawning timing (3 August to 11 October) appears to be similar to timing reported for the Kanektok River in 2002 (Lisac 2004), but 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) (10 September to 19 October). Fourteen (28.6%) fish of the 49 suspected spawners were assigned spawning locations during August, but no ground observations were made to confirm whether these fish actually spawned that early. Most of the fish assigned spawning locations in the Goodnews River did begin downstream migration in September and concentrated in the mainstem river by the end of October. This is an earlier downstream migration than the timing observed for fish in the other studies where later spawn timing was reported, so it is possible that spawning did commence during August. Without actual ground observations and more frequent tracking surveys it is difficult to be more precise on exactly where and when spawning occurred.

Overwintering locations for the radio-tagged fish in the Goodnews River was similar to that in other Refuge studies. Although no overwintering in lakes had been documented in the Middle Fork Goodnews River or Kanektok River studies, there were several fish that had resided in Togiak Lake in the winter of 1998-1999 (Lisac and Nelle 2000). It has also been documented that Dolly Varden migrate to lakes during the winter in the Kenai River watershed (Palmer and King 2005) and in southeast Alaska (Armstrong 1984). Dolly Varden overwintering in mainstem river aggregations has been well documented in other southwest Alaska rivers (Lisac and Nelle 2000, Lisac 2004, 2006) and in northwest Alaska Dolly Varden populations (DeCicco 1985). The areas where the majority (14 of 24) of these Goodnews River fish spent the winter (sections A and B) were the same areas selected for overwintering by Dolly Varden that were radio-tagged in the Middle Fork Goodnews River in the winter of 2001-2002 (Lisac 2004). This area was also noted to be an area where local area residents concentrate for winter ice fishing.

The long distance movements observed for the three fish that were recaptured in other drainages is not unusual for this species. Dolly Varden tagged in the Togiak and Kanektok drainages have been caught in subsistence fisheries as far north as Norton Sound and in commercial fisheries on the east side of Bristol Bay. Thirty-one of 57 radio-tagged Dolly Varden that were recorded departing the Togiak River in the spring of 1999 returned to the river in July and August of that year after spending from 33 to 88 days (average = 40.5 days; SE = 4.45) at sea (Lisac and Nelle

2000). Two of the fish that did not return were captured 27 and 60 days later in drainages 365 km and 240 km distance from the Togiak River, respectively. Dolly Varden in southeast Alaska have been recorded as traveling as much as 115 km, and some have been documented using different drainages for spawning and overwintering during the same year (Morrow 1980, Armstrong 1984). Dolly Varden tagged in the Wulik River in northwest Alaska have been recaptured in other Alaska rivers and in Russian waters (DeCicco 1992). These fish travel between 530 km to 1,690 km between capture locations. One of these fish was recaptured in the Anadyr River in Russia approximately 60 days after leaving Alaskan waters. The average traveling speed would have been approximately 26 km per day to cover the straight line distance of 1,560 km. It has been well documented that Dolly Varden return to their natal waters for spawning, that stocks are mixed during overwintering and at sea, they do not always exhibit overwintering site fidelity, and they exhibit both skip and consecutive year spawning. There was no opportunity to examine the fish that we originally caught in the Goodnews River that were reported recaptured in the other drainages. Without further examination of these fish it is difficult to attain conclusive proof of their maturity state and origin. They may either be members of Goodnews River Dolly Varden population or were nonspawning wanderers when they were captured in 2005 that were returning to their natal streams in 2006. Further development of a regional and statewide Dolly Varden genetic stock identification baseline is currently underway. Genetics will eventually prove useful to determine the stock composition of these fluvial Dolly Varden runs and assist in interpreting these long distant migration observations.

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