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Estimation of Chinook Salmon Distribution and Run Timing in the Togiak River Watershed Using Radio Telemetry, Togiak National Wildlife Refuge, Alaska, 2009

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Cheryl A. Anderson

Abstract

Radio telemetry was used to determine distribution and run timing of Chinook salmon *Oncorhynchus tshawytscha* in the Togiak River watershed. This is the final year of a two year study to determine whether mark-recapture techniques are a viable approach for estimating Chinook salmon abundance. In 2009, 154 radio transmitters were implanted into Chinook salmon between 25 June and 28 July. A total of 118 fish (77%) were successfully tracked to spawning areas, 25 (16%) were not successfully tracked to a spawning location, one of which was never located, seven fish (4%) were harvested, and four (3%) were assigned a fate of dead/regurgitated. Ten tagged Chinook salmon were recaptured during the study. Eighty-eight percent (n = 104) of the tracked fish selected spawning locations in main stem areas of the Togiak River, and 12% (n = 14) selected spawning locations in tributaries, primarily Gechiak Creek (5%, n = 6). Six age classes were identified from scales collected in 2009, but the majority of the sample consisted of age 1.3 (26%), and 1.4 (49%) fish. Females comprised 59% of the total sexed for the season. Chinook salmon lengths ranged from 690 to 973 mm for females and from 465 to 993 mm for males. Based on results of this study, mark-recapture methods will be used to estimate Chinook salmon abundance in the Togiak River during 2010-2012.

Introduction

Chinook salmon *Oncorhynchus tshawytscha* returning to spawn in the Togiak River watershed are harvested in subsistence, sport, and commercial fisheries. The Alaska Department of Fish and Game (ADFG) established a sustainable escapement goal in the Togiak River watershed of 9,300 Chinook salmon based on aerial surveys (Baker et al. 2006). This goal has been regularly achieved since 1996 mainly through regulation of the commercial fishery (Sands et al. 2008). Average estimated Chinook salmon spawning escapement from 1996 to 2005 was 11,862 fish, and average harvest was 11,273 fish, representing a 49% exploitation rate. The harvest includes 9,213 fish harvested in the commercial fishery, 902 harvested in the sport fishery, and 1,158 harvested in the subsistence fishery (Sands et al. 2008).

Current monitoring of Chinook salmon escapement into the Togiak River watershed is limited to aerial surveys. Total escapement is estimated by expanding visual counts with correction factors. The accuracy of aerial survey counts is greatly affected by stream life, variable run timing, observer efficiency, weather, water conditions, aircraft characteristics (type, speed, altitude, and pilot experience), and other factors (Bue et al. 1998). Aerial survey estimates within the Togiak River watershed have not been verified or compared with other methods, and the accuracy with which the observations index actual abundance is unknown. Aerial survey efforts have been scaled back since 2005, and Chinook salmon total escapement estimates have not been calculated (Salomone et al. 2009).

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The Office of Subsistence Management, through its strategic planning process, has identified a need to obtain reliable escapement estimates for Chinook salmon in the Togiak River (OSM 2005). The Bristol Bay Regional Advisory Council has voiced support for this need since 2003, and development of a reliable estimate of Chinook salmon escapement into the Togiak River was explicitly requested in both the 2008 and 2010 Request for Proposals for the Fisheries Resource Monitoring Program. Improving long-term escapement monitoring of all species of adult Pacific salmon in the Togiak River has been a top priority issue with the Togiak National Wildlife Refuge, Togiak Traditional Council, and ADFG. Accurate monitoring of Chinook salmon abundance is needed to ensure that adequate escapements are achieved so that healthy Chinook salmon populations are sustained and subsistence harvests and other needs are maintained. Subsistence harvest and Chinook salmon spawning and rearing habitat in the Togiak River occur within the Federal Conservation System boundaries of the Togiak National Wildlife Refuge. Providing a harvest priority to subsistence users in these waters is mandated under Title VIII of ANILCA.

This is the final year of a two-year radio telemetry study to determine whether mark-recapture techniques can be developed to estimate Chinook salmon abundance in the Togiak River watershed.

Objectives for the project were:

1) Evaluate the effectiveness of using drift gillnets to capture Chinook salmon and determine the feasibility of radio tagging 200 Chinook salmon in the lower main stem Togiak River;
2) Describe the migratory timing patterns of Chinook salmon in the Togiak River from June to September 2009;
3) Detect the ultimate spawning destination upstream of the capture site, via the presence of at least two tagged fish, of a population comprising 10% or more of all the Chinook salmon passing the capture site during each temporal stratum with probability 0.8;
4) Document Chinook salmon spawning locations in the Togiak River watershed;
5) Test the hypothesis that the distributions of spawners among strata are equal;
6) Estimate the age, length, and sex composition of adult Chinook salmon in the Togiak River and,
7) Determine the feasibility of obtaining a spawning abundance estimate for Chinook salmon using mark-recapture techniques in the Togiak River watershed.

If mark-recapture techniques prove to be feasible for estimating abundance, then reliable estimates of Chinook salmon abundance can be made in future years. These estimates can be used to evaluate the use of aerial surveys for reliable long-term monitoring of Chinook salmon abundance.

Study Area

The Togiak River is located in southwest Alaska and lies within the Togiak National Wildlife Refuge (Figure 1). The watershed encompasses 5,178 km², comprises nine major lakes and five major tributaries, and is bounded on the east by the Wood River Mountains and on the west by the Ahklun Mountains. The Togiak River originates at the outlet of Togiak Lake and flows 93 km to Togiak Bay. The watershed upstream of Pungokepuk Creek is part of a congressionally designated Wilderness Area. Detailed descriptions of the lakes and tributaries can be found in the Togiak Refuge Fisheries Management Plan (USFWS 1990).

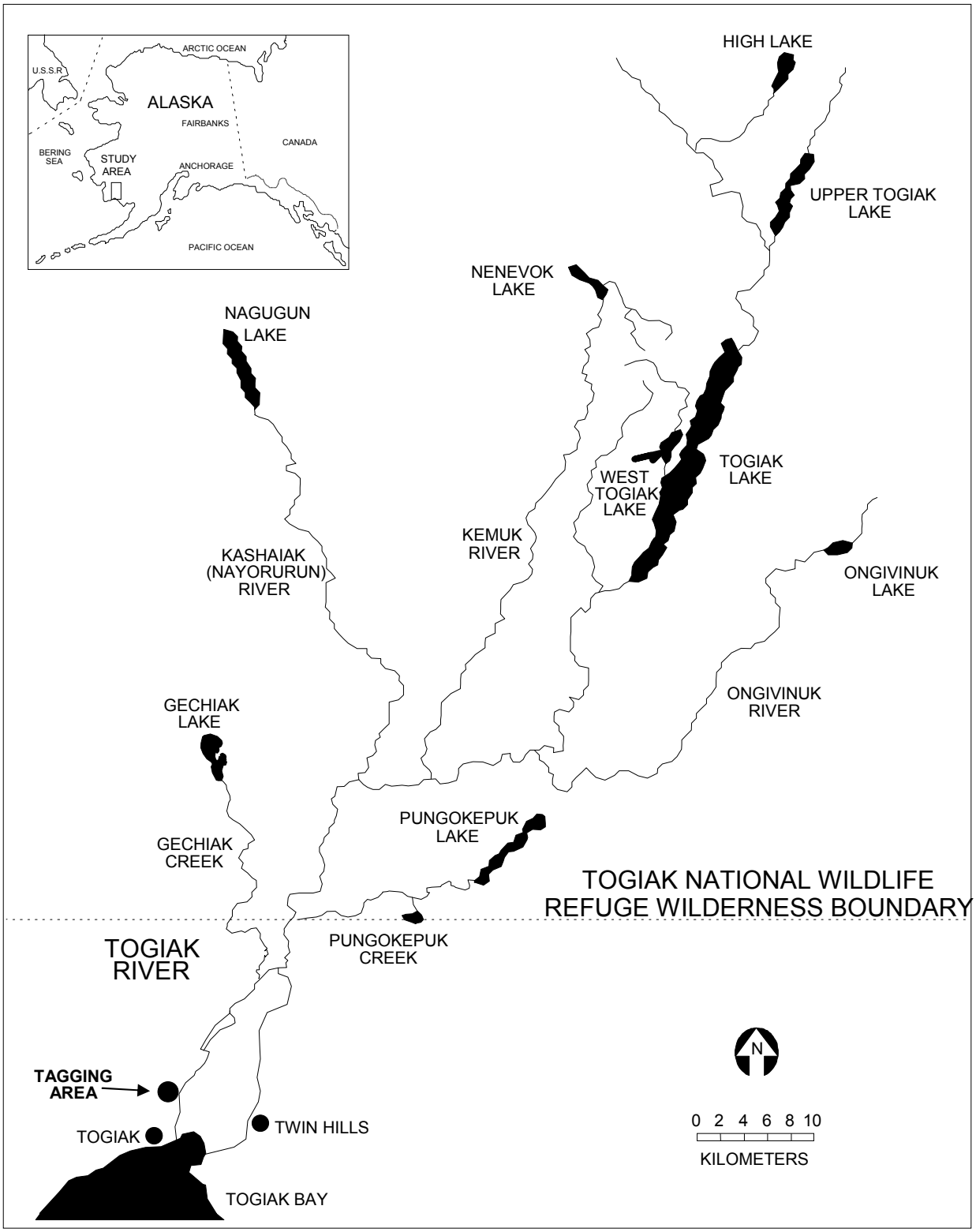

Figure 1. Map of the Togiak River watershed showing the approximate tagging area.

Five species of Pacific salmon *Oncorhynchus* spp. are found in the Togiak River watershed along with rainbow smelt *Osmerus mordax*, rainbow trout *O. mykiss*, Dolly Varden *Salvelinus malma*, Arctic char *S. alpinus* and Arctic grayling *Thymallus arcticus* (USFWS 1990).

Methods

A radio telemetry experiment was conducted to estimate the distribution and run timing of Chinook salmon in the Togiak River watershed. Fish were captured and marked with radio transmitters in the lower 5 km of the main stem. Movements and final spawning destinations of radio tagged fish were documented using a combination of fixed data logging receiver stations and aerial and ground based mobile tracking. Statistical weeks defining temporal strata were used for sampling (Table 1). Sampling was conducted six days a week.

Table 1. Allocation schedule for Chinook salmon radio transmitters in the Togiak River, 2009.

Strata Dates	Radio Transmitter Allocation
21 - 27 June	25
28 June - 4 July	25
5 - 11 July	25
12 - 18 July	25
19 - 25 July	25
26 July - 1 August	25
2 - 8 August	25
9-15 August	25
Total	200

A three person crew fished a drift gillnet (18.3 m long, 4.6 m deep, 20.3 cm stretched mesh size), with one crew member piloting the boat and the other two positioned in the bow tending the net. The gillnet was deployed from the bow of the boat, and the boat motor was idled in reverse to keep the net perpendicular to the shore while drifting downstream in the center or deepest sections of the river. Each sampling area was less than 1- km in length, and fishing continued until the end of the area was reached or a fish became entangled in the net. Drift time was monitored and recorded with a stopwatch. All fish except Chinook salmon caught in the net were identified to species, counted and immediately released.

Chinook salmon longer than 450 mm (mid-eye to tail fork) were tagged with radio transmitters manufactured by Advanced Telemetry Systems, Incorporated® (ATS, Model No. F1840B). Transmitters were encapsulated in a biologically inert polypropylene copolymer and equipped with a stainless steel nylon coated whip antenna. Transmitters weighed 22 g, which never exceeded 2% of the fish's body weight (Winter 1983). Radio transmitters were implanted through the esophagus using a plunger as described by Burger et al. (1985). Two hundred radio tags with unique pulse-codes were dispersed over 27 radio frequencies between 163.3 and 164.0 MHz and each frequency had from four to 12 different codes. The combination of codes on each

frequency allowed for the identification of individual fish. A mortality code was transmitted after 8 hours of inactivity.

Lengths of all Chinook salmon captured were measured to the nearest mm (mid-eye to fork of tail) and sex was determined from external characteristics. Three scales from the preferred area on the left side of each fish (Jearld 1983) were removed, cleaned, and mounted on gummed scale cards. After the field season, scale impressions from the gum cards were made on acetate blanks using a heated hydraulic press. Scale impressions were viewed with a microfiche reader and aged using standards and guidelines of Mosher (1968). Ages were reported according to the European method described by Jearld (1983) and Mosher (1968), where the number of winters the fish spent in fresh water and in the ocean are separated by a decimal. Four age classes of Chinook salmon were expected to occur in the Togiak River run (1.2, 1.3, 1.4, and 1.5), although only two of these (1.3 and 1.4) were expected to comprise the majority of the run. Age, sex, and length characteristics were summarized for the entire season.

Efforts were made to minimize stress to Chinook salmon during capture and handling. Captured fish were removed from gillnets as quickly as possible, and gillnet meshes were cut if the fish could not be easily removed from the net. Chinook salmon were then placed in a padded tagging cradle alongside the boat to allow the fish to be processed without being removed from the water. General health and appearance of each fish was recorded and injured or severely stressed fish were not tagged. Radio tagged Chinook salmon were immediately released into the river after tagging. Total handling time for each tagged fish was about two minutes or less.

The assumptions used for calculating sample size were that: 1) capture and tagging of Chinook salmon did not change their ultimate spawning locations, 2) fish destined for the various spawning locations had an equal probability of capture within each stratum, and 3) tagged fish behaved independently. The binomial probability distribution (Johnson et al. 1992) provided a useful model based on these assumptions, and allowed determination of the number of Chinook salmon that had to be observed at a particular spawning location to satisfy the statistical criteria specified in Objective 3. Prior to the season, 25 radio transmitters were allocated to each of eight tagging strata; however, strata were modified following the field season to account for weeks when few or no Chinook salmon were captured.

Radio transmitters were deployed over the shortest time period possible within each stratum. This was the most efficient deployment strategy given our limited knowledge of the abundance and run timing of Chinook salmon in the Togiak River. Tagging fish as quickly as the field crew could capture them increased the likelihood that all 25 tags could be deployed within each stratum, and if fewer than 25 tags were deployed in a particular stratum, the crew attempted to deploy the remaining tags in the subsequent stratum.

Radio tagged Chinook salmon were tracked throughout the Togiak River watershed using a combination of six fixed monitoring stations (Figure 2) and mobile tracking from boats and fixed-wing aircraft. Four of the fixed monitoring stations were located on the main stem, and two were located on tributaries. One station was located at the field camp site approximately one mile upstream of the mouth of Gechiak Creek, and the other station was located approximately one-half mile upstream of the mouth the Kashaiak (Nayorurun) River. The first fixed station on the main stem was placed above the capture and tag deployment site to help delineate lower main stem spawning locations. This was done because tracking results from 2008 raised the concern that capture and tag deployment activities may have occurred in spawning areas.

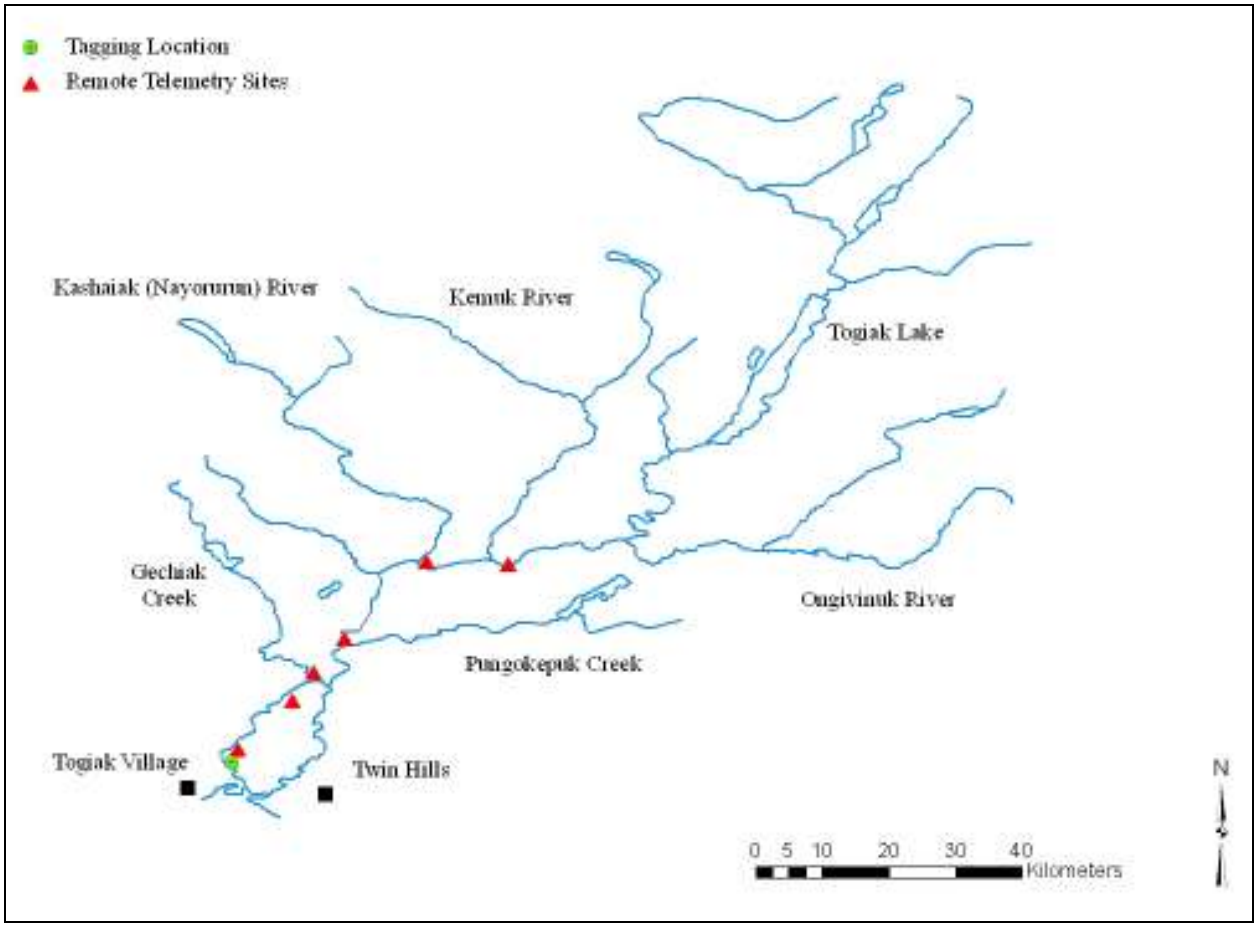

Figure 2. Remote data logging receiver station locations, and tagging area in the Togiak River, 2009.

Fixed monitoring stations were used to record up and downstream movement of individual tagged fish. Each fixed station included a single receiver-datalogger (ATS model R4500S), a single 4-element Yagi antenna, antenna mast, 12-volt deep cycle battery, solar panel, voltage regulator, and strongbox. A reference transmitter was located at each fixed station to verify that the receiver-datalogger was operating properly between visits. Data from fixed receiver stations were downloaded weekly to a notebook computer.

Aerial surveys were used to identify specific spawning locations in the Togiak River and its tributaries. Aerial surveys were conducted from a fixed-wing aircraft equipped with an H-antenna mounted on each wing strut. Aerial surveys were flown at altitudes of approximately 100–400 m above ground along the Togiak River and its tributaries. A global positioning system (GPS) built in to the receiver-datalogger (ATS model R4500S) was used during aerial surveys to record latitude and longitude coordinates of each transmitter located.

Boat surveys were used to more precisely locate spawning in the main stem Togiak River. Boat surveys were conducted using a portable receiver-datalogger (ATS model R4520C) and 4-element Yagi antenna. A hand held GPS was used during boat surveys to record latitude and longitude coordinates for each transmitter located. During tracking, the field crew also documented all spawning locations observed in the main stem Togiak River. A potential spawning location was defined as any area in which two or more tagged fish were detected for an extended period of time without activating their mortality sensor. The latitude and longitude coordinates for each spawning site was recorded with a hand held GPS.

Each radio tagged Chinook salmon was assigned one of five possible fates based on information collected from mobile and fixed receivers (Table 2). Fish whose spawning locations could be identified based on tracking results were assigned a fate of either main stem or tributary spawner. Main stem spawners were assigned to one of eight river sections (Figure 3). The boundary of six of these (A-F) corresponded with aerial survey segments used by ADFG (Brookover et al. 1996). To better understand spawning sites in the lower river, section A was subdivided into three sections (A1, A2 and A3), for this study. Tributary spawners were assigned to one of the five major tributaries. Chinook salmon whose spawning location could not be determined with reasonable certainty were placed into an unknown category. Fish assigned a fate of harvested or dead/regurgitated were censored from the sample.

The hypothesis that the distribution of spawners was the same among all tagging strata was tested using a chi-square test of homogeneity (Greenwood and Nikulin 1996). The Pearson chi-square test statistic was computed using Microsoft® Excel. The initial 13 x 8 contingency table based on 13 spawning components (eight river sections and five tributaries; Figure 3) and eight tag deployment time strata (Table 1) was reduced to a 12 x 4 contingency table after data collection was completed.

Results

Gillnet sampling for Chinook salmon was conducted over a total of 54.4 hours between 25 June and 8 August, and a total of 213 Chinook salmon were captured between 25 June and 31 July (Figure 4). The highest total catches occurred on 15 and 21 July when 24 Chinook salmon were caught, and the highest catch per unit effort occurred on 10 July (CPUE = 12 fish/hour, Figure 5). Fourteen Chinook salmon died during capture. Other species captured included chum *O. keta* (n = 334) and sockeye *O. nerka* (n = 104) salmon, rainbow trout (n = 1), Dolly Varden/Arctic char (n = 23), and starry flounder *Platichthys stellatus* (n = 2).

All fixed receiver stations were operational by 30 June and three stations (first, fourth and sixth stations upstream from the river mouth) remained operational until 3 September. Two fixed

Table 2. Fates assigned to radio tagged Chinook salmon in the Togiak River, 2009.

Fate	Description
Main stem Spawner	A fish that spawned in the Togiak River.
Tributary Spawner	A fish that spawned in a tributary of the Togiak River.
Unknown	A fish that could not be located by either fixed or mobile monitoring station, or a fish that could not be assigned a specific fate with reasonable certainty.
Harvested	A fish that was harvested in either the subsistence or sport fisheries.
Dead/Regurgitated	A fish that did not complete its spawning migration because it either died or regurgitated its radio tag.

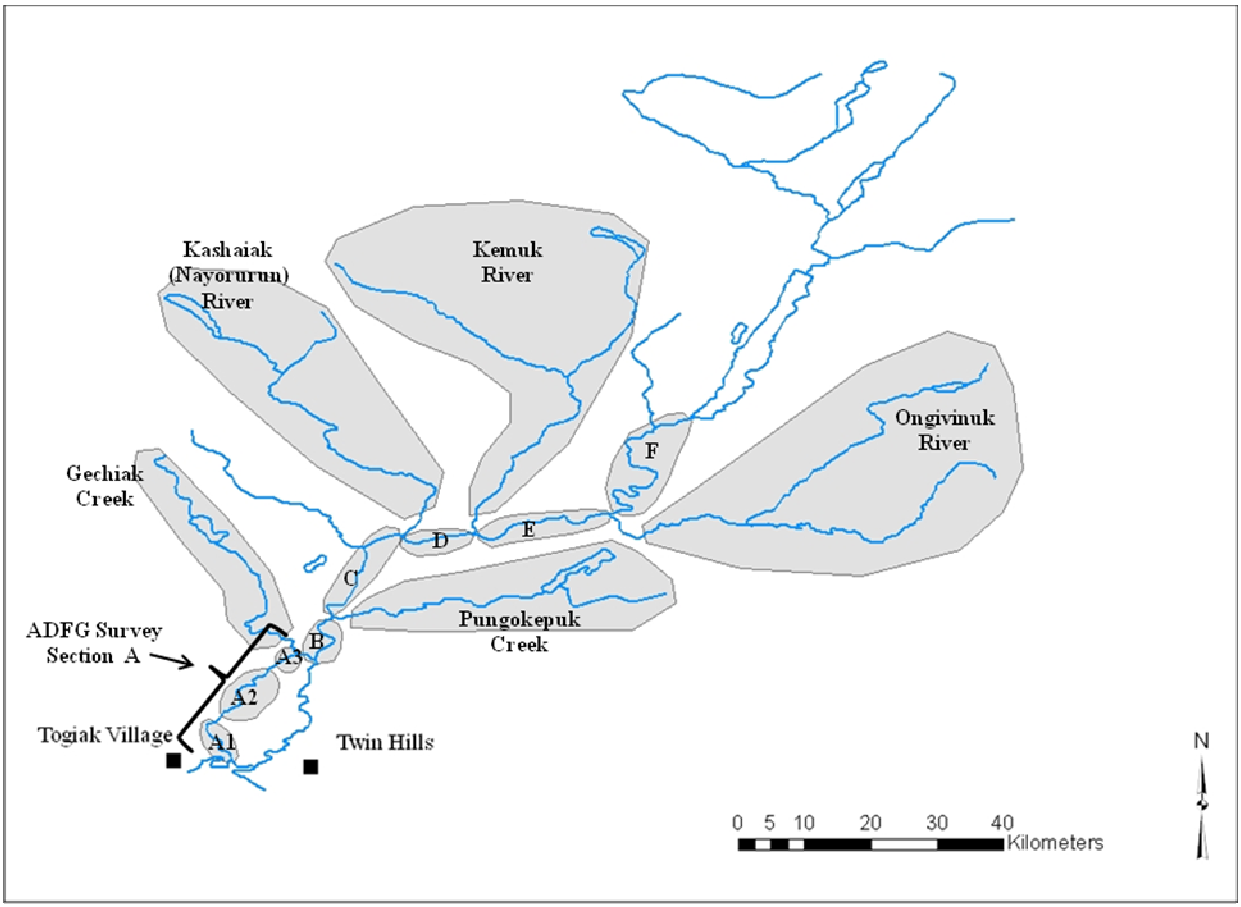

Figure 3. Main stem river sections corresponding to ADFG aerial survey delineations and tributary fates assigned to radio tagged Chinook salmon in the Togiak River, 2009. The lower main stem section A was subdivided into three sections (A1, A2, and A3) for the 2009 study.

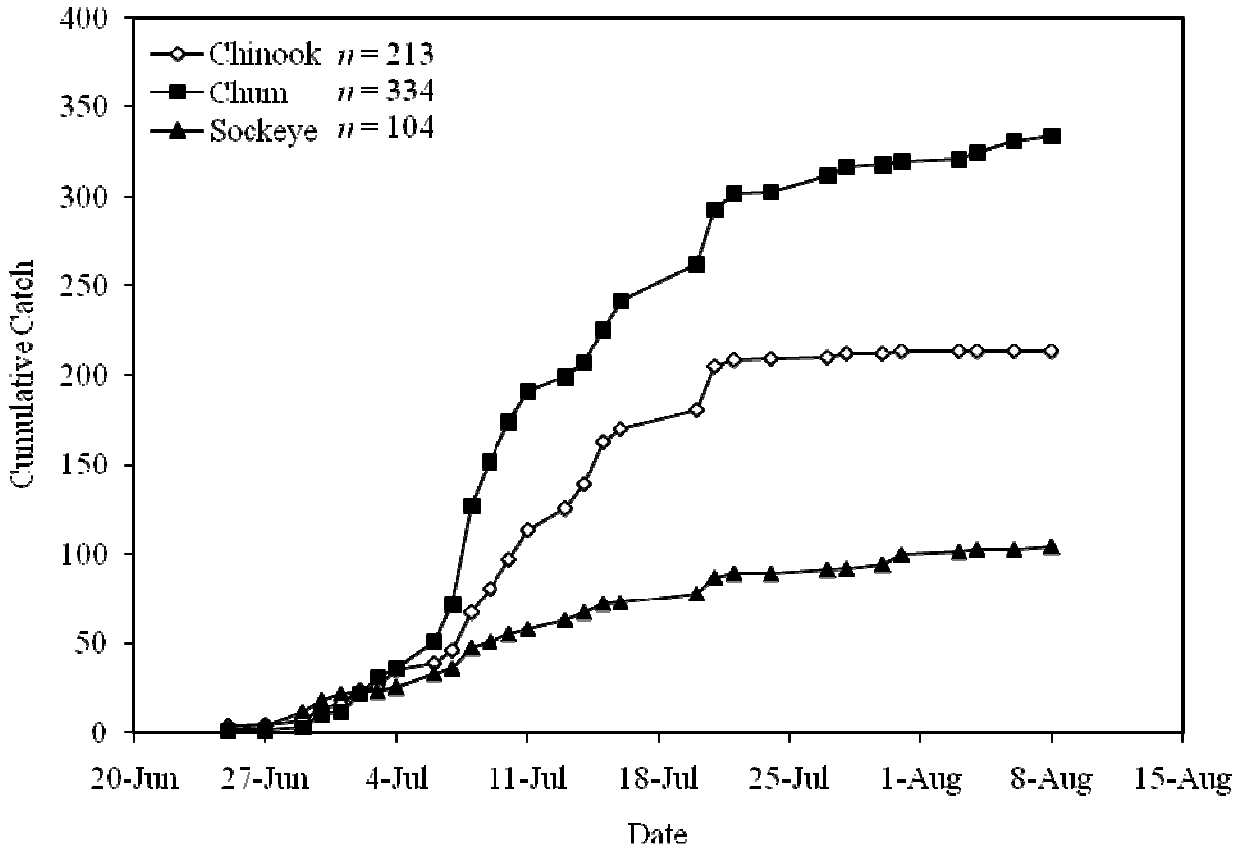

Figure 4. Cumulative total catch of Chinook, chum, and sockeye salmon caught by gillnet in the Togiak River, 2009.

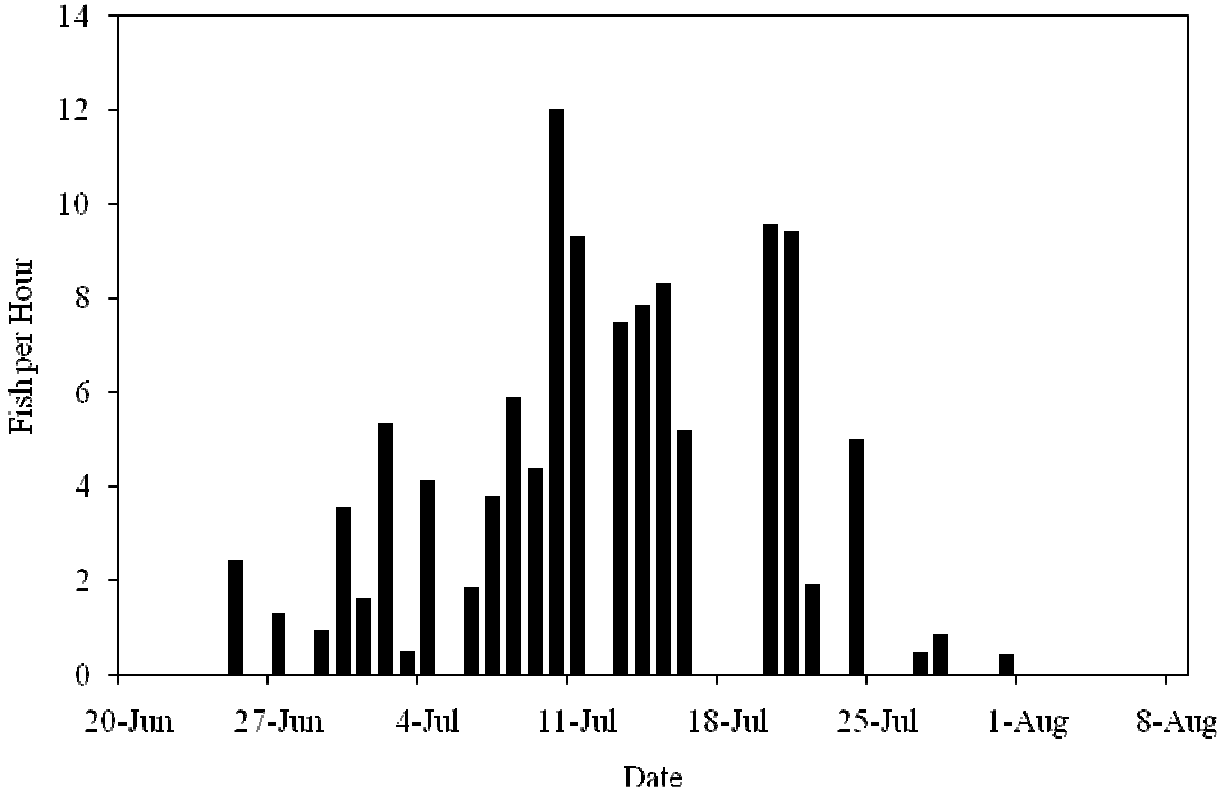

Figure 5. Catch per unit effort for Chinook salmon caught in the Togiak River, 2009.

stations (first and fifth) were damaged by flooding in early August. The receiver-datalogger used for the first station was damaged by water entering the battery box on 3 August. This unit was replaced with the second receiver-datalogger on 4 August. The Kashaiak (Nayorurun) River receiver-datalogger (fifth station) was damage by water after bears tampered with the battery box on 31 July, so no data was recorded at this station after 31 July. The receiver-dataloggers from station two and five were not replaced. The Gechiak Creek receiver-datalogger was removed on 29 August when the camp was closed. Data from the fixed receiver stations were downloaded from five to 11 times during the field season.

Twenty-nine boat searches were conducted between 11 July and 7 September, and four aerial searches were conducted between 22 July and 25 August.

Radio transmitters were implanted into 154 Chinook salmon between 25 June and 28 July. Initially, 25 radio transmitters were allocated to each of eight strata; however, strata were adjusted after the field season because few or no Chinook salmon were captured within some of the original strata (Table 3). Of the 154 tagged Chinook salmon, a total of 118 fish (77%) were successfully tracked to spawning areas, 25 (16%) were not successfully tracked to a spawning location, one of which was never located, seven (4%) were harvested, and four (3%) were assigned a fate of dead/regurgitated (Table 4, Appendix 1). Ten Chinook salmon were recaptured during sampling. Two pairs of Chinook salmon had tags with identical frequencies and codes. Fates could be assigned to only one fish from each pair because neither tag in a pair was ever detected at two different locations.

Eighty-eight percent (n = 104) of the Chinook salmon tracked selected spawning locations in main stem areas of the Togiak River, with 30% (n = 35) in the lower main stem below Gechiak Creek (Table 5). Twelve percent (n = 14) selected spawning locations in tributaries, with 5% (n = 6) selecting locations in Gechiak Creek.

The percentage of Chinook salmon tracked to main stem spawning locations in 2009 (88%) was greater than documented in 2008 (74%; Table 5). The percentage of fish tracked to main stem spawning locations in both these years was much greater than the 1987-2005 average distribution of main stem spawners based on ADFG aerial surveys (69%). The percentage of Chinook salmon tracked to Gechiak Creek in 2009 (5%) was less than that documented in 2008 (13%) or observed, on average during 1987-2005 ADFG aerial surveys (10%; Table 5).

Over the course of the study, 29% of tagged Chinook salmon were tracked to lower main stem spawning locations in river section A (Table 6). Percentages generally decreased in main stem sections farther upriver and were lowest in the tributaries. These trends were also evident for most individual tagging strata. Stratum 2 (July 5-11) contained the greatest percentage (39%) of tagged Chinook salmon recorded during the season.

The Pearson chi-square statistic used to test the distribution of spawners among the 10 river sections, did not differ significantly ($P \geq 0.05$) among the four tagging strata.

Twelve percent of the tagged fish that were identified as female, along with 11% that could not be assigned a sex, were tracked to lower main stem spawning locations in sections A1, A2, and A3 (Table 7).

During boat tracking surveys, spawning sites were observed at 117 locations (Figure 6). Sections C (26%) and A (20%) had the greatest percentage of spawning sites (Table 8). While some spawning occurred within the capture and tagging area in section A1, most spawning occurred above this section, within sections A2 and A3 (Figure 6). One spawning site was

Table 3. Adjusted sampling strata (time frames) for distribution of Chinook salmon radio transmitters in the Togiak River, 2009.

	Strata Dates		Transmitters	
Strata	Preseason	Post Season	Allocated	Deployed
1	6/21 - 6/27	6/21 - 7/4	25	21
2	6/28 - 7/4	7/5 - 7/11	25	61
3	7/5 - 7/11	7/12 - 7/18	25	38
4	7/12 - 7/18	7/19 - 8/1	25	34
5	7/19 - 7/25		25	
6	7/26 - 8/1		25	
7	8/2 - 8/8		25	
8	8/9 - 8/15		25	
Total			200	154

Table 4. Fate of Chinook salmon in the Togiak River, 2009

Fate	Number (%)
Spawning Location:	
Main Stem (1 of 7 river sections)	104 (68)
Tributary (1 of 5 tributaries)	14 (9)
Total	118 (77)
Unknown Fate:	
Never Located/Undetermined	25 (16)
Total	25 (16)
Removed From Study:	
Harvested	7 (4)
Dead/Regurgitated	4 (3)
Total	11 (7)
Total Tagged	154

Table 5. Distribution of Chinook salmon within ADFG spawning survey river sections in the Togiak River based on radio tracking in 2008 and 2009, and ADFG average aerial survey estimates during 1987 to 2005.

River Section	Number (Percent)		
	2008 Radio Tracking	2009 Radio Tracking	1987-2005 Aerial Surveys[a]
Main Stem			
Main Stem A[b]	26 (34)	35 (30)	162 (4)
Main Stem B	11 (14)	14 (11)	221 (6)
Main Stem C	17 (22)	22 (19)	547 (15)
Main Stem D	0 (0)	7 (6)	289 (7)
Main Stem E	2 (3)	18 (15)	503 (13)
Main Stem F	1 (1)	8 (7)	957 (24)
Total	57 (74)	104 (88)	2,679 (69)
Tributary			
Gechiak Creek	10 (13)	6 (5)	392 (10)
Pungokepuk Creek	2 (3)	3 (3)	159 (4)
Nayorurun River	6 (7)	3 (2)	213 (5)
Kemuk River	2 (3)	2 (2)	274 (7)
Ongivinuk River	0 (0)	0 (0)	202 (5)
Total	20 (26)	14 (12)	1,240 (31)
Drainage Total	77	118	3,919

[a]ADFG 1987-2005 average aerial survey estimates from Westing et al. (2007).
[b]Main Stem A includes Below area and section A for 2008, and sections A1, A2, and A3 for 2009.

Table 6. Percentage of radio tagged Chinook salmon tracked by strata to ADFG spawning survey river sections in the Togiak River, 2009.

	River Section										
	Main Stem						Tributaries				
Strata	A[a]	B	C	D	E	F	Gechiak	Pungokepuk	Kashaiak	Kemuk	Ongivinuk
1	2	2	3	1	2	1	--	1	1	1	--
2	9	6	4	2	8	5	2	--	2	--	--
3	9	2	6	1	2	--	1	1	--	1	--
4	9	2	5	2	3	1	2	1	--	--	--
Total	29	12	18	6	15	7	5	3	3	2	--

[a]Main stem section A includes fish tracked to sections A1, A2, and A3.

Table 7. Percentage of tagged Chinook salmon by sex tracked to ADFG spawning survey river sections in the Togiak River, 2009.

River Section	Female	Male	Unknown Sex[a]
Main Stem A1[b]	2	3	3
Main Stem A2[b]	7	2	8
Main Stem A3[b]	3	2	0
Main Stem B	5	3	3
Main Stem C	8	7	4
Main Stem D	1	2	3
Main Stem E	1	7	7
Main Stem F	2	3	2
Gechiak Creek	1	1	3
Kemuk River	2	0	0
Nayorurun River	0	2	0
Ongivinuk River	0	0	0
Pungokepuk Creek	0	0	3
Total	32	32	36

[a]Fish that could not be sexed using secondary characteristics.
[a]ADFG spawning survey section A was subdivided into three sections for 2009 telemetry study.

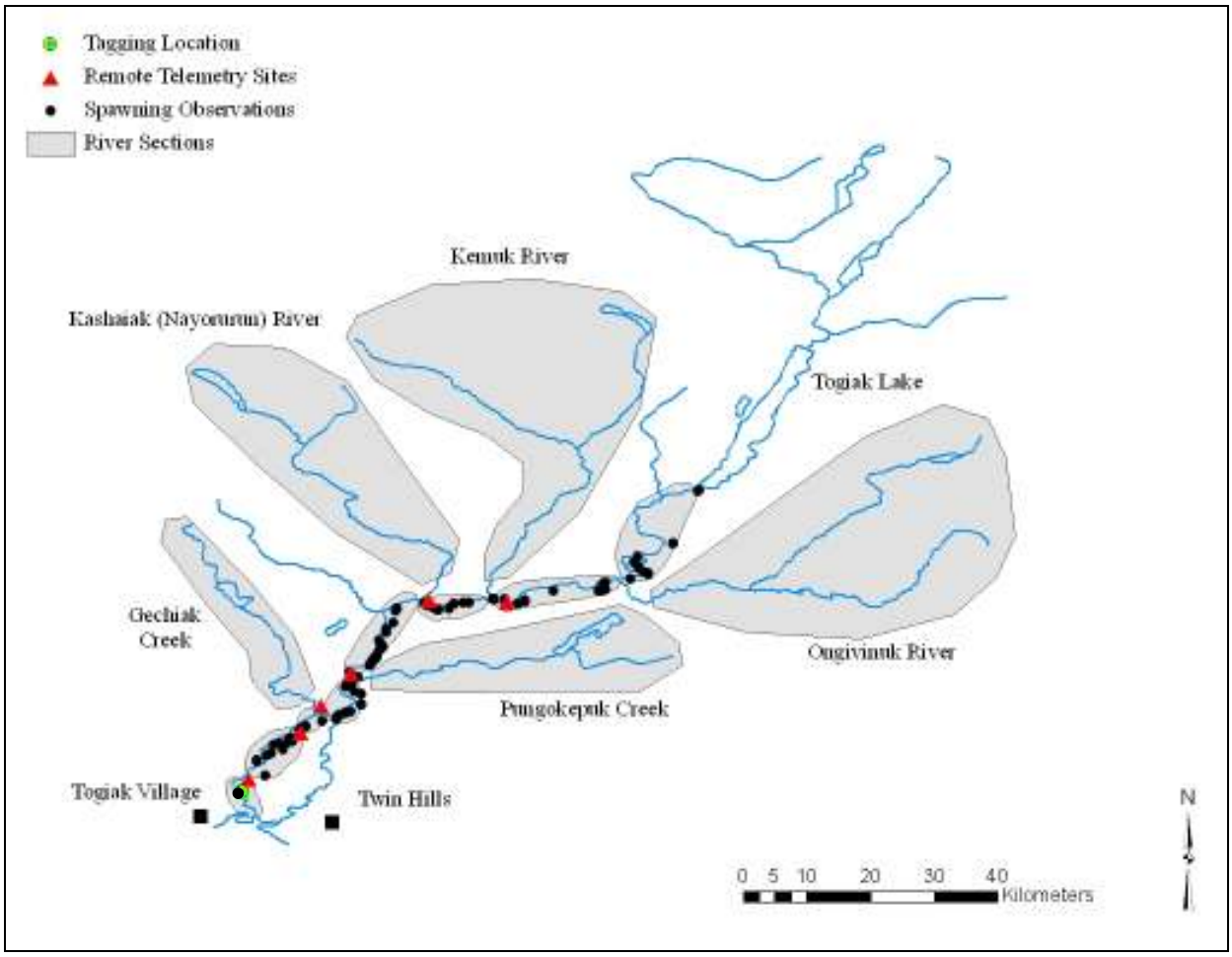

Figure 6. Map of observed Chinook salmon spawning sites, remote telemetry sites, and tagging area in the Togiak River, 2009.

Table 8. Distribution of Chinook salmon within ADFG main stem spawning survey river sections in the main stem Togiak River based on radio tracking in 2008 and 2009, spawning (boat) survey counts in 2009, and ADFG aerial surveys during 1987-2005.

River Section	Number (Percent)			
	2008 Radio Tagged	2009 Radio Tagged	2009 Spawning (Boat) Surveys	1987-2005 Aerial Surveys[a]
A[b]	26 (46)	35 (34)	24 (20)	162 (6)
B	11 (19)	14 (13)	20 (17)	221 (8)
C	17 (30)	22 (21)	30 (26)	547 (20)
D	0 (0)	7 (7)	14 (12)	289 (11)
E	2 (3)	18 (17)	15 (13)	503 (19)
F	1 (2)	8 (8)	14 (12)	957 (36)
Total	57	104	117	2,679

[a] ADFG 1987-2005 average aerial survey estimates from Westing et al. (2007).
[b]Main stem A includes Below area and section A for 2008, and sections A1, A2 and A3 for 2009.

observed near the tagging location in section A1, seven sites were observed in section A3, and the remaining 16 sites were observed in section A2.

Age data were obtained from 109 Chinook salmon, two fish escaped before scales were removed, and 43 (28%) fish could not be aged because of illegible or regenerated scales. Six age classes were present in 2009, with age 1.3 (26%), and 1.4 (49%) comprising 75% of the sample (Table 9). Sex was determined for 97 Chinook salmon, and 57 (36%) of the fish sampled could not be sexed using secondary sexual characteristics. Females comprised 59% of Chinook salmon sampled (Table 10). Lengths were measured from 107 Chinook salmon and three fish escaped prior to being measured for length. Chinook salmon lengths ranged from 690 to 973 mm for females and 465 to 993 mm for males (Table 11).

Discussion

Two Chinook salmon were captured the first day sampling began, but sampling continued well after the last Chinook salmon was caught. Therefore, it is likely sampling covered most of the run and that run timing was adequately described. While the initial goal of deploying 200 radio tags was not achieved, the information obtained from the 118 Chinook salmon that were tracked probably provides a good description of relative abundance and distribution among river spawning sections as well as run timing. The 2009 run was earlier than expected and slightly earlier than the 2008 run (Anderson 2009). ADFG was again unable to complete the aerial surveys and calculate an abundance estimate in 2009 and estimates for subsistence and sport fish harvest were not available in time for this writing. However, observations of sport and subsistence fishers during the course of the study suggested that Chinook salmon were not very abundant in the Togiak River in 2009. Chinook salmon runs in Bristol Bay as well as many other areas throughout the state were generally poor during 2009 and most commercial harvests were below average (Tim Sands, ADFG, personal communication).

In 2009, field personnel increased mobile tracking efforts and were able to document specific spawning sites in the lower Togiak River and throughout the main stem to Togiak Lake (Table 8, Figure 6). Distribution of tagged Chinook salmon among main stem and tributary river sections were similar in both 2008 and 2009, and most tagged fish spawned in the lower main stem (A and Below in 2008; sections A1, A2 and A3 in 2009) in both years (Table 5). The increase in percentages of fish tracked to sections D, E, and F in 2009 may have been due to the increased tracking effort. ADFG aerial observers have consistently documented greater proportions of Chinook salmon in the upper main stem of the watershed, especially in section F, and lower proportions of Chinook salmon in the lower main stem, especially section A (Westing et al. 2006). This discrepancy is most likely due to the turbidity conditions of the lower river that make it difficult to see Chinook salmon in these sections during aerial surveys.

Results of tracking in 2008 raised the concern that sampling could have occurred in spawning areas, which could bias study results. In 2009, 17% of Chinook salmon were tracked to section A2, the middle portion of the lower main stem, compared to 9% in section A1, which was in the tagging area (Appendix 1). This suggests that most tagged Chinook salmon had not been captured on their spawning grounds. The locations of observed spawning sites also suggest that capture and tagging was done below most spawning sites (Figure 6). However, because the lower river is turbid, it is possible that not all spawning sites in the capture and tagging area were detected.

An important underlying assumption in any tagging project is that the process of tagging and the presence of the tag do not induce behavioral changes in tagged fish. Other studies have shown that tagged fish may exhibit milling behavior (Stuby 2007) or may move down stream after

Table 9. Age composition of Chinook salmon radio tagged in the Togiak River, 2009.

Age	*n*	%	SE (%)
1.2	22	20	3.9
1.3	28	26	4.2
1.4	54	49	4.8
1.5	3	3	1.6
2.2	1	1	0.9
2.3	1	1	0.9
Total[a]	109		

[a]Total number sampled does not include 43 fish whose age could not be determined

Table 10. Sex composition of Chinook salmon radio tagged in the Togiak River, 2009.

Sex	*n*	%	SE (%)
Female	57	59	5.0
Male	40	41	5.0
Total[a]	97		

[a]Total number sampled does not include 57 fish whose sex could not be determined.

Table 11. Mean length (mm), SE, range, and sample size by age of Chinook salmon radio tagged in the Togiak River, 2009.

	Age Class				
Length	1.2	1.3	1.4	1.5	2.3
Mean	614	805	882	895	675

SE	68	97	59	43	--
Minimum	490	632	690	845	675
Maximum	717	977	1010	920	675
n[a]	21	28	54	3	1

[a]Number sampled does not include 47 fish whose length and age could not be determined.

being tagged (Palmer et al. 2008). However, tagging should not affect the spawning destination selected by tagged fish (Bernard et al. 1999). In 2009, roaming and milling behavior was not observed for any radio tagged fish, although some of this behavior was observed in 2008 (Anderson 2009). Most tagged Chinook salmon did remain in the lower main stem until about 20 July, but then moved rapidly upstream to various spawning destinations. I suspect that water temperatures and river flows were both factors that delayed and then triggered the upstream migration in 2009. The upriver movement did correspond to a noticeable drop in ambient air temperature.

The capture and tagging protocols should have reduced effects on behavior resulting from handling-induced stress. By immediately removing Chinook salmon from the net, never removing them from the water, using a padded tagging cradle to restrain them, and performing biological sampling and tagging in less than two minutes, there was a relatively low overall mortality (3%) of tagged fish again in 2009. However, the number of fish that could not be tracked to a spawning location was still fairly high (n = 24, 16%), compared to 25% (n = 32) in 2008 (Anderson 2009). A technical problem with four radio tags (duplicate frequency and codes) was responsible for failure to assign a spawning location to two tagged Chinook salmon. It is likely that most of the remaining tagged fish that could not be assigned a spawning location either left the system or were harvested and removed from the river. A few of these may have spawned in some tributaries without being detected due to the relatively long intervals between aerial tracking surveys, the absence of a fixed monitoring station on some tributaries, and the inability to conduct boat tracking surveys in some tributaries due to low water levels.

Lengths and ages of Chinook salmon in the Togiak River were similar to those reported from other studies done in the Togiak River (Nelson 1967, MacDonald and Lisac 1997). However, samples from previous studies were primarily comprised of males most years, while females were dominant in samples from both 2008 (69%; Anderson 2009) and 2009 (59%). This difference may be accurate, but it could also be due to the use of secondary sexual characteristics to determine sex for Chinook salmon that had only recently entered freshwater. Using secondary sexual characteristics resulted in an inability to identify the sex of a large percentage (36%) of the fish tagged in 2009 as well as the possibility that some tagged fish may have been incorrectly sexed.

Conclusions

- Drift gillnet and telemetry appear to adequately describe the spawning distribution of Chinook salmon in the Togiak River.

- A large proportion of Chinook salmon are selecting spawning sites in the main stem Togiak River (74% in 2008; 88% in 2009).

- A large proportion of Chinook salmon are selecting spawning sites below Gechiak Creek in the lower Togiak River (34% in 2008; 30% in 2009), which is contrary to ADFG aerial surveys average findings of 4% from 1987-2005.

- The largest proportion of Chinook salmon that selected spawning sites in tributaries selected sites in Gechiak Creek (13% in 2008: 5% in 2009).

- The spawning distribution in Gechiak Creek provides an adequate recapture site to conduct a mark-recapture study to estimate Chinook salmon abundance in the Togiak River.

Recommendations

In 2008 and 2009, we tracked a large percentage of tagged Chinook salmon to spawning locations in the lower main stem Togiak River. In 2009, we were also able to visually confirm that Chinook salmon are in fact spawning in the lower main stem of the Togiak River. In 2009, most tagged Chinook salmon remained in the lower river until about 20 July, but this may not be an annual occurrence and could be related to river flow and temperature conditions. Since both the subsistence and sport fisheries take place within these lower river areas during June and July, Chinook salmon that spawn in the lower river, as well as Chinook salmon bound for upstream spawning grounds that may remain in the lower river for extended periods, may be exposed to high fishing pressure. Because of this potential, it is imperative that estimates of abundance and escapement be calculated yearly to be able to determine the health and sustainability of the run.

Based on study results of run timing and distribution, mark-recapture will be a viable approach for estimating Chinook salmon abundance in the Togiak River and should be compared to aerial survey estimates. If a reliable relationship between mark-recapture and aerial survey estimates exists, it should be possible to develop an aerial survey program as the primary source of annual estimates. Mark-recapture experiments, which are more expensive to conduct than aerial surveys, could then be done periodically to ensure the continued reliability of estimates made from aerial survey data. If no reliable relationship is found between mark-recapture and aerial survey estimates, mark-recapture estimates should be conducted periodically to monitor the health of Chinook salmon run.

To increase the likelihood of deploying 200 radio tags for mark-recapture experiments to be conducted during 2010-2012, the project should be designed with a maximum of five tagging strata and a deployment goal of 40 tags per strata.

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Appendix 1. Summary of biological data, and tracking history for radio tagged Chinook salmon in the Togiak River, 2009.

ID Number	Tag Date	Tag Stratum	Length (mm)	Sex	Age	Fate[a]	Number of Detections
1	25-Jun	1	770	M	--	Harvested	1
2	25-Jun	1	870	U	1.4	Harvested	1
3	27-Jun	1	758	M	--	Kashaiak	12
4	29-Jun	1	770	U	1.3	Pungokepuk	11
5	29-Jun	1	1010	U	1.4	Dead/Regurgitated	12
6	30-Jun	1	665	U	1.3	E	27
7	30-Jun	1	720	U	--	B	9
8	30-Jun	1	940	F	1.4	C	17
9	30-Jun	1	830	U	1.4	C	17
10	30-Jun	1	730	U	1.3	B	11
11	1-Jul	1	585	M	1.2	E	16
12	1-Jul	1	707	F	1.3	Harvested	2
13	2-Jul	1	865	U	--	C	16
14	2-Jul	1	820	F	1.4	A2	21
15	2-Jul	1	632	M	1.3	F	20
16	2-Jul	1	945	U	1.3	A1	11
17	2-Jul	1	835	M	1.4	C	15
18	2-Jul	1	952	F	--	Kemuk	5
19	4-Jul	1	940	U	1.4	D	23
20	4-Jul	1	900	U	--	Unknown	2
21	4-Jul	1	590	U	--	Unknown	3
22	6-Jul	2	580	U	1.2	A2	22
23	6-Jul	2	833	F	1.4	Never Located	0
24[b]	6-Jul	2	800	U	1.4	Unknown	16
25	6-Jul	2	920	F	1.4	F	16
26	7-Jul	2	690	U	1.4	A2	15
27	7-Jul	2	750	U	1.3	E	18
28	7-Jul	2	870	F	--	Unknown	7
29	7-Jul	2	620	M	--	Harvested	1
30	7-Jul	2	880	U	--	A1	10
31	7-Jul	2	890	U	1.3	B	11
32	7-Jul	2	860	M	--	C	23
33	8-Jul	2	600	M	1.2	B	13
34[b]	8-Jul	2	860	F	1.4	Unknown	11

Appendix 1. Continued.

ID Number	Tag Date	Tag Stratum	Length (mm)	Sex	Age	Fate[a]	Number of Detections
35	8-Jul	2	465	M	--	D	14
36	8-Jul	2	675	U	1.2	E	24
37	8-Jul	2	830	M	1.4	C	8
38	8-Jul	2	670	U	--	F	10
39	8-Jul	2	920	F	--	A2	9
40	8-Jul	2	670	M	--	E	26
41	8-Jul	2	860	F	--	Unknown	2
42	8-Jul	2	740	U	1.3	Gechiak	12
43	8-Jul	2	660	M	--	Kashaiak	8
44	8-Jul	2	850	F	1.4	Unknown	1
45	8-Jul	2	830	U	1.3	Unknown	11
46	8-Jul	2	920	F	1.4	B	22
47	8-Jul	2	790	M	1.4	F	12
48	9-Jul	2	540	M	1.2	A1	13
49	9-Jul	2	790	U	--	Dead/Regurgitated	2
50	9-Jul	2	845	F	1.4	A2	15
51	9-Jul	2	857	F	1.4	E	20
52	9-Jul	2	580	M	1.2	E	17
53	9-Jul	2	550	U	--	F	15
54	9-Jul	2	900	F	1.3	Unknown	2
55	9-Jul	2	680	U	--	Harvested	1
56	9-Jul	2	490	U	1.2	Gechiak	8
57	9-Jul	2	--	U	--	Unknown	1
58	10-Jul	2	815	U	--	Gechiak	11
59	10-Jul	2	875	U	1.3	E	19
60	10-Jul	2	874	F	1.4	A1	39
61	10-Jul	2	780	U	1.3	Unknown	5
62	10-Jul	2	835	U	1.4	C	16
63	10-Jul	2	810	M	1.4	F	11
64	10-Jul	2	863	F	1.4	B	11
65	10-Jul	2	665	M	1.2	Kashaiak	20
66	10-Jul	2	850	F	1.3	Unknown	7
67	10-Jul	2	--	U	2.2	A2	22
68	10-Jul	2	820	U	1.3	Unknown	7
69	10-Jul	2	915	F	--	C	17

Appendix 1. Continued.

ID Number	Tag Date	Tag Stratum	Length (mm)	Sex	Age	Fate[a]	Number of Detections
70	10-Jul	2	490	M	1.2	A1	7
71	10-Jul	2	590	M	1.2	F	20
72	11-Jul	2	922	F	1.4	B	18
73	11-Jul	2	920	F	1.5	B	10
74	11-Jul	2	883	U	1.3	D	19
75	11-Jul	2	625	M	--	E	23
76	11-Jul	2	626	M	--	E	15
77	11-Jul	2	915	U	--	A2	9
78	11-Jul	2	875	U	1.3	C	15
79	11-Jul	2	895	M	--	A2	19
80	11-Jul	2	645	M	1.2	E	15
81	11-Jul	2	667	M	1.2	D	17
82	11-Jul	2	970	U	1.4	B	18
83	13-Jul	3	--	U	1.2	E	15
84	13-Jul	3	880	F	1.4	A3	11
85	13-Jul	3	910	F	1.3	Unknown	9
86	13-Jul	3	882	U	1.4	Gechiak	8
87	13-Jul	3	895	F	--	A2	9
88	13-Jul	3	650	U	1.2	Unknown	2
89	13-Jul	3	940	U	1.4	A2	12
90	13-Jul	3	993	M	1.4	B	17
91	13-Jul	3	840	U	1.4	A2	20
92	13-Jul	3	977	U	1.3	A2	10
93	14-Jul	3	810	U	1.3	E	22
94	14-Jul	3	800	F	1.4	Harvested	2
95	14-Jul	3	940	F	1.3	A2	15
96	14-Jul	3	820	F	1.3	A3	18
97	14-Jul	3	880	U	--	A1	7
98	14-Jul	3	755	U	1.3	A1	6
99	14-Jul	3	933	F	1.4	Unknown	7
100	14-Jul	3	683	U	1.2	E	21
101	14-Jul	3	710	M	1.2	D	15
102	14-Jul	3	890	F	1.4	Unknown	4
103	14-Jul	3	890	F	--	Unknown	6
104	15-Jul	3	860	F	--	C	18

Appendix 1. Continued.

ID Number	Tag Date	Tag Stratum	Length (mm)	Sex	Age	Fate[a]	Number of Detections
105	15-Jul	3	917	U	1.4	Pungokepuk	13
106	15-Jul	3	845	F	1.5	B	11
107	15-Jul	3	580	M	1.2	B	14
108	15-Jul	3	690	F	1.3	Harvested	2
109	15-Jul	3	960	F	1.3	Unknown	2
110	15-Jul	3	940	F	1.4	C	19
111	15-Jul	3	902	F	1.4	C	17
112	16-Jul	3	666	M	--	C	19
113	15-Jul	3	893	F	1.4	Kemuk	8
114	15-Jul	3	890	F	--	A3	16
115	15-Jul	3	920	U	--	Unknown	5
116	16-Jul	3	690	M	1.3	C	12
117	16-Jul	3	890	U	--	Unknown	6
118	16-Jul	3	917	M	1.4	A3	20
119	16-Jul	3	717	M	1.2	C	21
120	16-Jul	3	841	F	--	C	10
121	20-Jul	4	910	U	1.3	A2	11
122	20-Jul	4	940	U	1.4	Unknown	6
123	20-Jul	4	700	M	1.3	Gechiak	19
124	20-Jul	4	904	F	1.4	B	23
125	20-Jul	4	666	M	1.2	A2	18
126	20-Jul	4	650	U	--	C	19
127	20-Jul	4	790	F	1.4	B	8
128	20-Jul	4	819	F	1.4	E	17
129	20-Jul	4	675	U	2.3	D	15
130	20-Jul	4	830	F	--	A2	42
131	21-Jul	4	570	M	--	A2	16
132	21-Jul	4	860	F	1.4	C	14
133	21-Jul	4	940	F	1.4	Dead/Regurgitated	1
134	21-Jul	4	910	F	1.4	D	14
135	21-Jul	4	940	F	--	Unknown	5
136	21-Jul	4	900	F	1.4	C	17
137	21-Jul	4	670	M	--	E	20
138	21-Jul	4	890	F	--	A2	13
139	21-Jul	4	880	F	1.4	Unknown	2

Appendix 1. Continued.

ID Number	Tag Date	Tag Stratum	Length (mm)	Sex	Age	Fate[a]	Number of Detections
140	21-Jul	4	880	F	1.4	A2	17
141	21-Jul	4	891	M	--	E	11
142	21-Jul	4	920	U	1.5	Pungokepuk	8
143	21-Jul	4	855	F	1.4	A1	12
144	21-Jul	4	664	M	1.2	C	22
145	21-Jul	4	620	M	--	A1	10
146	21-Jul	4	938	F	1.4	F	5
147	21-Jul	4	690	U	1.2	E	21
148	21-Jul	4	550	M	1.2	A1	6
149	22-Jul	4	910	F	1.4	A1	10
150	22-Jul	4	713	M	--	C	18
151	24-Jul	4	973	F	1.4	Dead/Regurgitated	10
152	27-Jul	4	933	U	1.4	A2	11
153	28-Jul	4	904	F	1.4	Gechiak	9
154	28-Jul	4	853	F	1.4	C	19

[a]Main Stem spawning fates are as follows:
A1 = From Togiak Bay to the first fixed monitoring station
A2 = From the first fixed monitoring station to the second fixed monitoring station
A3 = From the second fixed monitoring station – Gechiak Creek
B = Gechiak Creek – Pungokepuk Creek
C = Pungokepuk Creek – Kashaiak (Nayorurun) River
D = Kashaiak (Nayorurun) River – Kemuk River
E = Kemuk River – Ongivinuk River
F = Ongivinuk River – Togiak Lake
[b]Fish with the same tag number (frequency and code) as another fish