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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, 2008

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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 information will be used to determine if mark-recapture techniques are a viable approach for estimating Chinook salmon abundance. The calculated estimates will be used to evaluate the effectiveness of aerial surveys for monitoring abundance. In 2008, 127 radio transmitters were implanted into Chinook salmon between 29 June and 5 August. Seventy-seven fish were successfully tracked to spawning areas, five fish were never located, 11 fish were harvested, 27 fish were not successfully tracked to a spawning location, and seven fish were assigned a fate of dead/regurgitated. Two Chinook salmon were recaptured during the study. Seventy-four percent (n = 57) of the tracked fish selected spawning locations in main stem areas of the Togiak River and 26% (n = 20) selected spawning locations in tributaries, primarily Gechiak Creek (13%, n = 10). Four age classes were identified from scales collected in 2008. The majority of the run consisted of age 1.3 (54.2%), and 1.4 (39.3%) fish. Females comprised 69% of the total sampled for the season. Chinook salmon lengths ranged from 641 to 970 mm for females and from 591 to 1,020 mm for males. We recommend a second year of spawning distribution surveys to further develop the capture site and determine main stem spawning areas.

Introduction

Chinook salmon *Oncorhynchus tshawytscha* are important for subsistence, sport, and commercial harvest in the Togiak River. The Alaska Department of Fish and Game (ADFG) has 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 in the Togiak River watershed is limited to aerial surveys. 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. Chinook salmon escapement estimates since 2005 have not been calculated or were based on partial surveys (Sands et al. 2008).

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The Office of Subsistence Management, through its strategic planning process, has identified the need to obtain reliable escapement estimates for Chinook salmon in the Togiak River (OSM 2005). The Bristol Bay Regional Advisory Council has supported the need for improved monitoring of salmon escapement into the Togiak River since 2003, and development of a reliable estimate of Chinook salmon escapement into the Togiak River was explicitly requested in the 2008 and 2010 Request for Proposals for the Fisheries Resource Monitoring Program. Improving long-term escapement monitoring to include all species of adult Pacific salmon has been identified as a top priority with the Togiak National Wildlife Refuge, Togiak Traditional Council, and the ADFG. Accurate monitoring of Chinook salmon abundance is necessary for managers to maintain adequate escapements to provide for future subsistence needs. Subsistence harvest of, and spawning and rearing habitat for Chinook salmon 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.

Radio telemetry was used to determine run timing and distribution of Chinook salmon in the Togiak River watershed in 2008. This information will be used to determine if mark-recapture techniques are a viable approach for estimating Chinook salmon abundance. If mark-recapture techniques prove to be feasible for estimating abundance, the calculated estimates will be used to evaluate the effectiveness of aerial surveys for monitoring abundance. Verifying and evaluating the aerial survey data will aid in the long term management of Chinook salmon in the Togiak River watershed.

The objectives for the project are:

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 2008;
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.

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 has been designated as wilderness area. Detailed descriptions of these lakes and tributaries can be found in the Togiak Refuge Fisheries Management Plan (USFWS 1990).

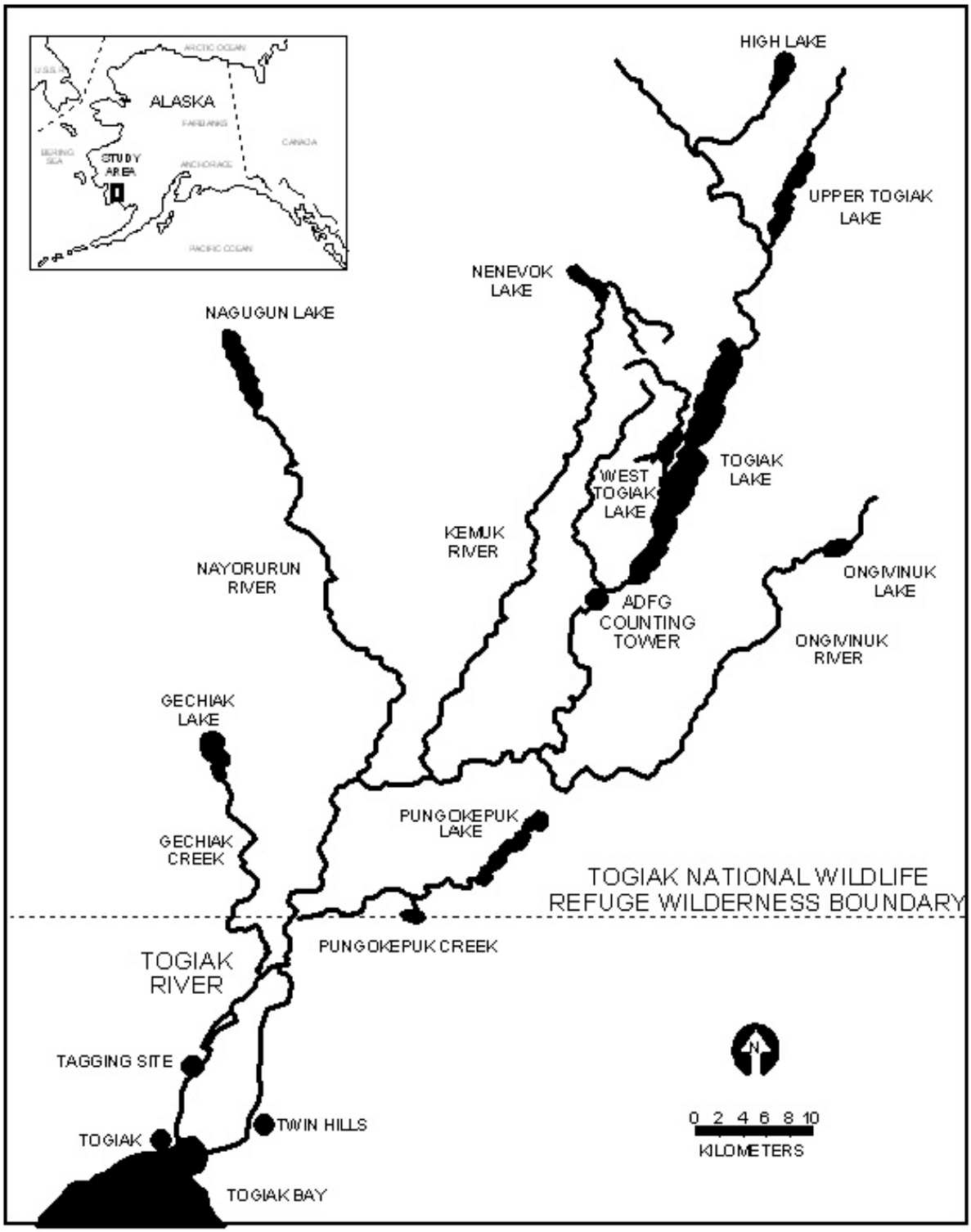

Figure 1. Map of the Togiak River watershed showing the tagging site.

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 river. 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. Schedule for allocating radio transmitters during 2008 Chinook salmon study.

Radio Tagging Strata	Radio Transmitter Allocation
22 - 28 June	25
29 June - 5 July	25
6 - 12 July	25
13 - 19 July	25
20 - 26 July	25
27 July - 2 August	25
3 - 9 August	25
10-16 August	25
Total	200

A three person crew fished a drift gillnet (18.3 m by 4.6 m, 20.3 cm stretch), 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 reach was approximately 1-km in length and fished until the end was reached or until a fish became entangled in the net. Drift time was monitored and recorded with a stopwatch. All non-target fish caught in the net were identified to species, counted and immediately released.

Chinook salmon greater than 450 mm in length were tagged using radio transmitters developed 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 unique pulse-coded tags were dispersed over 10 radio frequencies between 163.8 and 163.9 MHz with 20 codes per frequency. The combination of codes on each frequency allowed for the identification of individual fish and a mortality code was activated after 8 hours of inactivity. A matrix of tag frequency codes was developed to minimize the number of same frequency tags being deployed in a single day.

Lengths of all Chinook salmon captured were measured to the nearest mm (mid-eye to fork of tail) and the sex of the fish was determined from external characteristics. Three scales from each fish were removed from the preferred area on the left side (Jearld 1983), cleaned, and mounted on gummed scale cards. Scales were pressed and aged following the field season by U. S. Fish and Wildlife Service (USFWS) personnel. Standards and guidelines of Mosher (1968) were used in aging scales and 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. Five age classes of Chinook salmon were expected in the Togiak River (1.1, 1.2, 1.3, 1.4, and 1.5), although age 1.2 and 1.3 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 during capture and handling. Fish that could not be easily removed were cut from gillnets. Captured fish were placed in a padded tagging cradle alongside the boat, allowing the fish to be processed without being removed from the water. Total handling time for each tagged fish was about two minutes. Radio tagged fish were immediately released into the river after tagging. Injured or severely stressed fish were not tagged.

To calculate sample sizes, we assumed that capture and tagging of Chinook salmon does not cause them to change their ultimate spawning locations, fish destined for the various spawning locations have an equal probability of capture within each stratum, and tagged fish behave independently. The binomial probability distribution (Johnson et al. 1992) provides a useful model based on these assumptions and for the number of fish to be observed at a particular spawning location, satisfying the statistical criteria specified in Objective 3. Initially, 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 in as short a time period as 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 and our unknown ability to capture them. Tagging fish as quickly as we could capture them increased the likelihood that all 25 tags were deployed within each stratum, and if the target number of tags could not be deployed within a particular stratum, we attempted to deploy remaining tags in the subsequent stratum. Although it was possible that this type of sampling could result in a population of tagged fish that did not represent all spawning components actually present within each stratum, we felt that any resulting bias would be small and not compromise our ability to achieve project objectives.

Radio tagged salmon were tracked throughout the Togiak River watershed using a combination of fixed data logging receiver stations and mobile tracking using boats and fixed-wing aircraft. Radio telemetry receivers and loggers manufactured by ATS were used for all tracking. Fixed receiver stations were used to automatically identify and record fish movements at the mouths of Gechiak Creek and the Nayorurun and Kemuk rivers, and one station was located about 1 km upstream of the capture site. Fixed receiver stations included a single data logging receiver (model R4500) or a separate receiver (model R2100) and data logger (model D5041), a single 4-element Yagi antenna, antenna masts, 12-volt deep cycle battery, solar panel, voltage regulator, and strongbox. A reference transmitter was located at each fixed station to allow us to monitor operation of the receiver and data logger 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 300–400 m above ground along the Togiak River and tributary watersheds. A global positioning

system (GPS) built in to the data logging receiver was used during aerial surveys to record latitude and longitude coordinates of each transmitter located.

Boat surveys were used to more precisely locate fish spawning in the main stem Togiak River. Boat surveys were conducted using a portable receiver and 4-element Yagi antenna. A hand held GPS was used during boat surveys to record latitude and longitude coordinates for each transmitter located.

Each radio tagged salmon was assigned one of five possible fates based on information collected from mobile and fixed radio receivers (Table 2). Fish whose spawning locations could be identified based on the tracking results were assigned a fate of either main stem or tributary spawner. A potential spawning location was defined as an area in which two or more tagged fish were detected for an extended period of time without activating the mortality sensors. Main stem spawners were assigned to one of seven river sections that corresponded with ADFG aerial survey delineations (Brookover et al. 1996) (Figure 2). Tributary spawners were assigned to one of the five major tributaries. Fish 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 identical among all tagging strata was tested using a chi-square test of homogeneity (Greenwood and Nikulin 1996). A total of ten spawning components were recognized for the test, corresponding to seven river sections and five tributaries. A Pearson chi-square test statistic was computed using the chisq.test function of R version 2.8.1 (RDCT 2008) and bootstrap resampling with 100,000 replications was used to estimate the significance of the test.

Two Hobo® temperature data loggers were installed in the lower river and set to record water temperature every 30 minutes. At the end of the season we intended to summarize the collected data as daily maximum, minimum, and mean temperatures (˚C). However, we were unable to do this because one of the temperature data loggers was lost mid-season and the other malfunctioned.

Results

We fished for Chinook salmon a total of 117 hours between 20 June and 22 August and captured a total of 143 Chinook salmon between 26 June and 5 August (Figure 3). The highest total catch and catch per unit effort occurred on 6 July when 17 Chinook salmon were caught (CPUE = 4 fish/hour) and 7 July when 13 Chinook salmon were caught (CPUE = 6.7 fish/hour) (Figure 4). Other species captured included chum *O. keta* (n = 471), sockeye *O. nerka* (n = 88), coho *O. kisutch* (n = 29), and pink *O. gorbuscha* (n = 1) salmon, rainbow trout (n = 2), rainbow smelt (n = 4), Dolly Varden (n = 7), and starry flounder *Platichthys stellatus* (n = 1).

Fixed receiver stations operated from 20 June to 14 September and were downloaded six times during the course of the study. Fifteen boat searches were conducted between 22 July and 15 September, and six aerial searches were conducted between 19 July and 29 September.

Radio transmitters were implanted into 127 Chinook salmon between 29 June and 5 August (Table 3). 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 the original strata (Table 3). Seventy-seven fish (61%) were successfully tracked to spawning areas, five fish (4%) were never located, 27 fish (21%) were not successfully tracked to a spawning location, 11 fish (9%) were harvested, and seven fish (5%) were assigned a fate of dead/regurgitated (Table 4, Appendix 1). Two Chinook salmon were recaptured in our sampling

Table 2. Fates assigned to radio tagged fish in the Togiak River, 2008.

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 data loggers 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.

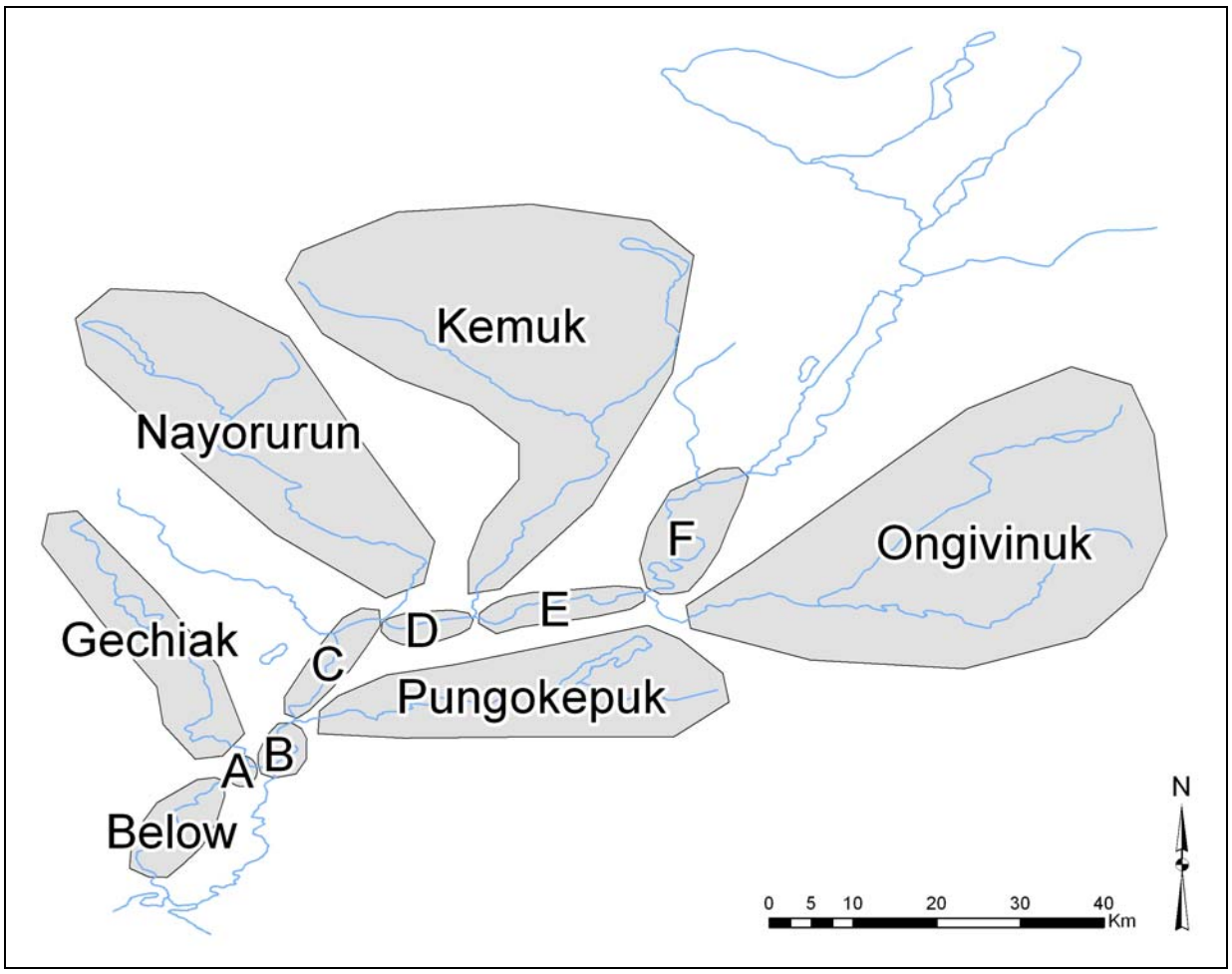

Figure 2. Main stem river sections and tributary fates assigned to radio tagged fish in the Togiak River, 2008.

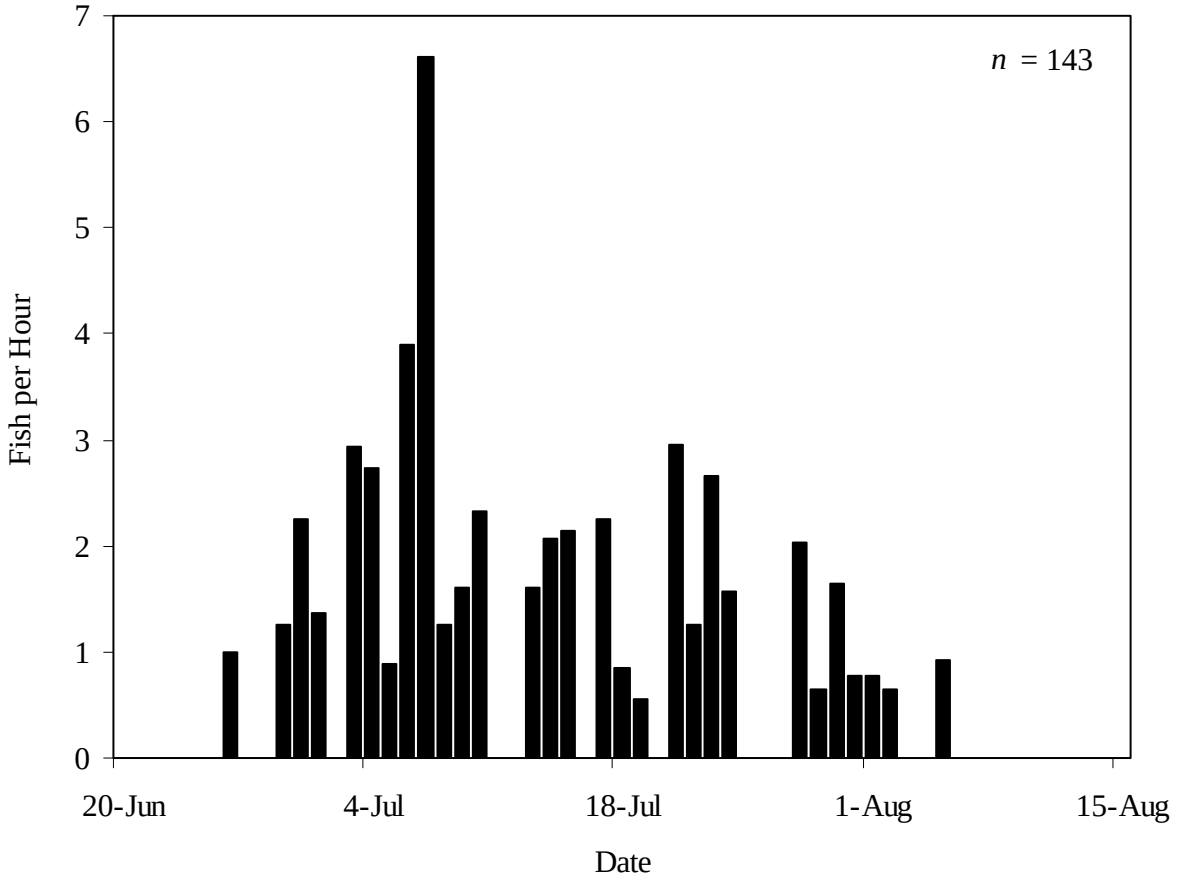

Figure 3. Catch per unit effort for Chinook salmon caught in the Togiak River, 2008.

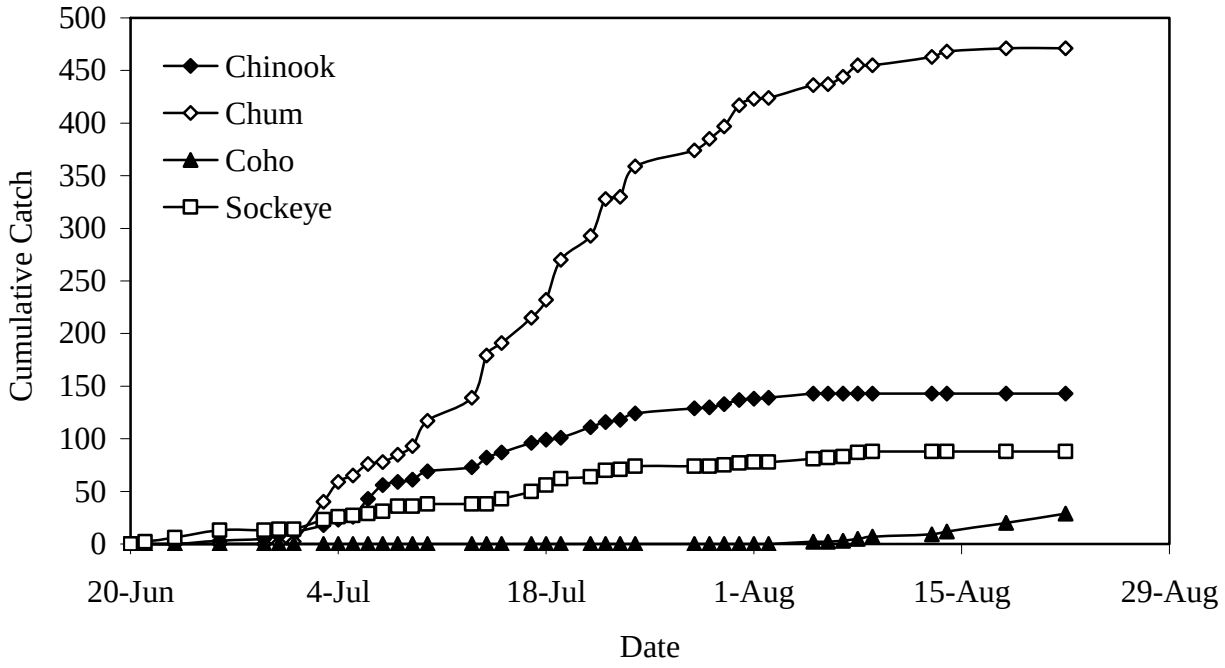

Figure 4. Cumulative total catch of Chinook (*n*=143), chum (*n*=471), sockeye (*n*=88), and coho (*n*=9) salmon caught by gillnet in the Togiak River, 2008.

Table 3. Adjusted sampling strata (time frames) for distribution of Chinook salmon radio transmitters in the Togiak River, 2008.

	Strata Dates		Transmitters	
Stratum	Preseason	Post Season	Allocated	Deployed
1	6/22 – 6/28	6/23 -7/6	25	33
2	6/29 – 7/5	7/7 - 7/13	25	28
3	7/6 – 7/12	7/14 - 7/20	25	28
4	7/13 – 7/19	7/21 - 7/27	25	22
5	7/20 – 7/26	7/28 - 8/10	25	16
6	7/27 – 8/2		25	
7	8/3 – 8/9		25	
8	8/10-8/16		25	
Total			200	127

Table 4. Fate of Chinook salmon in the Togiak River, 2008

Fate	Number of Fish (%)
Spawning Location:	
Main Stem (1 of 7 river sections)	57 (45)
Tributary (1 of 5 tributaries)	20 (16)
Total	77 (61)
Unknown Fate:	
Never Located/Undetermined	32 (25)
Total	32 (25)
Removed From Study:	
Harvested	11 (9)
Dead/Regurgitated	7 (5)
Total	18 (14)
Total Tagged	127

nets. Seventy-four percent (n = 57) of the fish tracked selected spawning locations in main stem areas of the Togiak River, with 34% (n= 26) in the lower main stem below Gechiak Creek (Table 5). Twenty-seven percent (n = 20) selected spawning locations in tributaries, and 13% (n = 10) selected Gechiak Creek. Bears tampered with battery boxes at two fixed stations but did not damage equipment. The separate receiver and data logger station at the mouth of the Kemuk River malfunctioned and no data could be extracted.

The Pearson chi-square statistic used to test the hypothesis that the distribution of spawners was equal among all tagging strata was not significant (P = 0.13), indicating that the distribution of spawners were equal among all tagging strata.

Age, sex, and length data were collected from all 127 Chinook salmon that were tagged. Twenty (15.7%) of these fish could not be aged because of illegible or regenerated scales, nine (7%) could not be sexed using secondary sexual characteristics, and one escaped prior to being measured for length. While four age classes were present, age 1.3 (54.2%), and 1.4 (39.3%) Chinook salmon comprised 93% of the sample (Table 6). Females comprised 69% of the Chinook salmon sampled (Table 7). Chinook salmon lengths ranged from 641 to 970 mm for females and 591 to 1,020 mm for males (Table 8).

Discussion

The first Chinook salmon were captured six days after sampling began and sampling continued well after the last Chinook salmon was caught. Therefore, it is likely that we sampled over the course of the entire run and were able to satisfactorily describe run timing. We were able to capture an adequate number of Chinook salmon in good condition for tagging, although we did not meet our tagging goal of 200 fish. It appeared that Chinook salmon escapement into the Togiak River was low from our observations of sport and subsistence fishers and that the run was later than we expected. ADFG was not able to make complete aerial surveys and were unable to calculate an abundance estimate in 2008 (Tim Sands, ADFG, personal communication). However, Chinook salmon commercial harvests in Bristol Bay and throughout the state were below average and most runs were also characterized as being later than average (Volk et al. 2009).

Chinook salmon movement and behavior in the Togiak River watershed are not well known and the distribution patterns of Chinook salmon in the Togiak River watershed were not what we expected. During aerial surveys, ADFG has consistently observed greater numbers of fish in the upper main stem of the watershed, especially in section F (Westing et al. 2006). However, we found only 1% of the tagged Chinook salmon we classified as spawners in section F and 34% in section A, the lower main stem (Table 5). This discrepancy could be due to the turbidity of the water in the lower river sections that prevents observers from counting all fish present during aerial surveys. The poor water clarity also prohibited us from visually confirming that these fish were actually spawning in the lower main stem of the river.

In any telemetry project there is an assumption that tagging does not induce behavioral changes in the fish, but this cannot be discounted as a plausible reason for fish distribution. Studies have shown that tagged fish may exhibit milling behavior (Stuby 2007) or will move back down stream after being tagged (Palmer et al. 2008). However, tagging should not affect the spawning destination of tagged fish (Bernard et al. 1999). We attempted to reduce behavior effects resulting from handling-induced stress by immediately removing fish from the net, never removing the fish from the water, using a padded tagging cradle to restrain fish, and performing

Table 5. Percentage of Chinook salmon radio transmitters tracked to spawning areas in the Togiak River, 2008 compared to ADFG average (1987 to 2005) aerial survey estimates in the Togiak River.

Fate	Percent Fish (Number)	ADFG Percent Fish (Number)[a]
Main Stem		
Main Stem A[b]	34 (26)	4 (162)
Main Stem B	14 (11)	6 (221)
Main Stem C	22 (17)	15 (547)
Main Stem D	0	7 (289)
Main Stem E	3 (2)	13 (503)
Main Stem F	1 (1)	24 (957)
Total	74 (57)	69 (2,679)
Tributary		
Gechiak Creek	13 (10)	10 (392)
Pungokepuk Creek	3 (2)	4 (159)
Nayororun River	8 (6)	5 (213)
Kemuk River	3 (2)	7 (274)
Ongivinuk River	0	5 (202)
Total	26 (20)	31 (1,240)
Total	77	3,919

[a]ADFG 1987-2005 average aerial survey estimates (Westing et al. 2007).
[b]Main Stem A includes Below area for 2008 telemetry study.

Table 6. Age composition of Chinook salmon radio tagged in the Togiak River, 2008.

Age	*n*	%	SE (%)
1.2	3	3	1.6
1.3	58	54	4.8
1.4	42	39	4.7
1.5	4	4	1.8
Total[a]	107		

[a]Total number sampled does not include fish whose age could not be determined (*n*=20).

Table 7. Sex composition of Chinook salmon radio tagged in the Togiak River, 2008.

Sex	*n*	%	SE (%)
Female	81	69	4.6
Male	37	31	4.6
Total[a]	118		

[a]Total number sampled does not include fish whose sex could not be determined (*n*=9).

Table 8. Mean length (mm), SE, range, and sample size by sex and age of Chinook salmon radio tagged in the Togiak River, 2008.

Length	Ages			
	1.2	1.3	1.4	1.5
		Female		
Mean	724	802	861	922
SE	--	65	63	30
Minimum	724	641	711	890
Maximum	724	914	970	950
n[a]	1	31	35	3
		Male		
Mean	686	793	826	1020
SE	18	85	115	--
Minimum	673	675	679	1020
Maximum	699	1003	978	1020
n[a]	2	22	6	1
		Total		
Mean	699	798	856	947
SE	26	73	72	55
Minimum	673	641	679	890
Maximum	724	1003	978	1020
n[a]	3	53	41	4

[a]Number sampled does not include fish whose length, sex, and age could not be determined (*n*=26).

biological sampling and tagging in less than three minutes. Our efforts also resulted in relatively low overall mortality of tagged fish (5%).

We did observe roaming and milling behavior for several of our radio tagged fish similar to that reported by Stuby (2007) in the Kuskokwim River. Of the tagged Chinook salmon assigned a known fate, five traveled well up and down stream of their eventual spawning location. Most of these fish were male. Twelve of the known-fate fish moved up and down stream between several stream sections throughout the study, which prevented us from assigning them to a spawning location.

Although Chinook salmon tagging or handling mortality was relatively low, the number of fish that could not be tracked to a spawning location was high (*n*=27, 21%). Most of these fish were not located enough times to be assigned to a spawning location with any confidence. While this might be due to roaming behavior, it could also be due to limitations in our tracking efforts including relatively long intervals between aerial surveys, not enough receivers for all tributaries, and our inability to access some tributaries because of low water levels. Some fish could have entered tributaries not being continuously monitored by receivers, spawned in them, and returned to the main stem river without having been detected during either boat or aerial surveys.

Lengths and ages of Chinook salmon in the Togiak River were similar to other studies in the Togiak River (Nelson 1967, MacDonald and Lisac 1997). However, sex composition from previous studies were primarily comprised of males most years, while the sample from our study was dominated by females (69%). If Chinook salmon are in fact spawning in the lower reaches of the main stem as our results suggest, then more of our sampling occurred on the spawning grounds and we would expect our data to be biased towards females because they tend to remain near their redds to defend them.

Recommendations

Based on results from the 2008 study, I recommend the following for 2009:

- Increase gill net size to 21 or 22 cm stretch to reduce incidental catch of chum salmon and other salmon with over lapping run timings.
- Intensify boat tracking and add more stationary receivers, especially in the lower river to more accurately identify spawning locations.
- Schedule aerial flights more consistently throughout the project.

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Appendix 1. Summary of biological data and tracking history for radio tagged Chinook salmon in the Togiak River, 2008.

Fish ID	Tag Date	Tag Stratum	Sex	Length (mm)	Age	Fate[a]	Number of Detections
1	6/29	1	U	635	1.3	Kemuk River	5
2	6/30	1	F	673	--	Main Stem A	7
3	6/30	1	M	889	1.3	Unknown	3
4	6/30	1	U	800	--	Gechiak Creek	7
5	7/1	1	F	724	--	Gechiak Creek	6
6	7/3	1	M	591	--	Gechiak Creek	10
7	7/3	1	M	718	1.3	Dead/Regurgitated	9
8	7/3	1	U	724	--	Unknown	0
9	7/3	1	M	679	1.4	Main Stem C	10
10	7/4	1	F	641	1.3	Main Stem B	7
11	7/4	1	F	864	1.3	Below	8
12	7/4	1	U	673	1.3	Main Stem C	12
13	7/4	1	F	787	1.4	Harvested	2
14	7/5	1	M	711	1.3	Unknown	2
15	7/5	1	F	800	1.3	Gechiak Creek	7
16	7/5	1	U	851	--	Harvested	1
17	7/6	1	M	806	1.3	Unknown	0
18	7/6	1	F	826	1.4	Harvested	0
19	7/6	1	M	800	--	Gechiak Creek	1
20	7/6	1	F	775	1.3	Unknown	0
21	7/6	1	F	775	1.3	Unknown	1
22	7/6	1	M	699	--	Below	3
23	7/6	1	F	699	1.3	Unknown	2
24	7/6	1	M	775	1.3	Never Located	0
25	7/6	1	F	813	1.4	Below	13
26	7/6	1	M	787	--	Gechiak Creek	0
27	7/6	1	F	787	1.3	Pungokepuk Creek	8
28	7/6	1	U	800	1.3	Unknown	0
29	7/6	1	F	902	--	Dead/Regurgitated	11
30	7/6	1	M	749	1.3	Main Stem C	6
31	7/6	1	F	762	1.3	Unknown	3
32	7/6	1	M	826	1.4	Main Stem A	7
33	7/6	1	M	978	1.4	Unknown	2
34	7/7	2	M	699	1.2	Main Stem B	7

Appendix 1. Continued.

Fish ID	Tag Date	Tag Stratum	Sex	Length (mm)	Age	Fate[a]	Number of Detections
35	7/7	2	F	800	1.3	Harvested	0
36	7/7	2	U	800	1.4	Unknown	5
37	7/7	2	F	711	1.4	Unknown	4
38	7/7	2	F	730	1.3	Harvested	0
39	7/7	2	M	711	1.3	Harvested	1
40	7/7	2	F	762	1.4	Never Located	0
41	7/7	2	F	895	1.4	Unknown	0
42	7/7	2	F	775	1.4	Below	2
43	7/7	2	F	762	1.3	Gechiak Creek	1
44	7/7	2	F	800	1.4	Never Located	0
45	7/7	2	M	724	1.3	Harvested	1
46	7/8	2	F	851	1.4	Main Stem F	6
47	7/8	2	M	749	1.3	Nayorurun River	10
48	7/8	2	M	673	1.2	Main Stem B	7
49	7/9	2	M	775	1.3	Main Stem B	9
50	7/9	2	F	927	1.4	Main Stem C	10
51	7/10	2	U	718	1.3	Unknown	0
52	7/10	2	F	838	1.4	Gechiak Creek	0
53	7/10	2	F	927	1.5	Below	4
54	7/10	2	F	838	1.4	Main Stem C	12
55	7/10	2	F	889	1.4	Unknown	0
56	7/10	2	F	889	--	Below	1
57	7/10	2	F	787	1.3	Unknown	1
58	7/13	2	M	845	1.3	Main Stem E	8
59	7/13	2	F	838	1.3	Below	1
60	7/13	2	F	794	--	Harvested	10
61	7/13	2	M	768	1.3	Nayorurun River	5
62	7/14	3	F	813	1.3	Below	1
63	7/14	3	M	1003	1.3	Below	3
64	7/14	3	F	787	1.3	Nayorurun River	12
65	7/14	3	F	895	1.4	Main Stem B	8
66	7/14	3	F	927	--	Below	10
67	7/14	3	F	724	1.2	Below	10
68	7/14	3	F	902	1.3	Unknown	0
69	7/14	3	F	864	1.3	Never Located	0

Appendix 1. Continued.

Fish ID	Tag Date	Tag Stratum	Sex	Length (mm)	Age	Fate[a]	Number of Detections
70	7/14	3	M	845	1.4	Nayorurun River	5
71	7/14	3	F	737	1.3	Main Stem C	8
72	7/15	3	M	914	1.3	Unknown	0
73	7/15	3	M	889	1.3	Main Stem C	6
74	7/15	3	M	762	1.3	Below	9
75	7/15	3	M	724	1.3	Nayorurun River	10
76	7/15	3	F	749	1.4	Unknown	0
77	7/17	3	F	914	1.3	Dead/Regurgitated	9
78	7/17	3	F	876	1.3	Gechiak Creek	0
79	7/17	3	F	889	1.4	Unknown	0
80	7/17	3	M	711	1.4	Main Stem B	8
81	7/17	3	F	902	1.3	Harvested	1
82	7/17	3	F	940	1.4	Unknown	4
83	7/17	3	F	914	1.4	Unknown	0
84	7/17	3	F	914	1.4	Unknown	1
85	7/17	3	F	876	1.3	Unknown	0
86	7/18	3	F	813	1.4	Main Stem B	12
87	7/18	3	M	921	1.3	Main Stem C	11
88	7/19	3	F	902	1.4	Pungokepuk Creek	2
89	7/19	3	F	880	1.4	Main Stem C	11
90	7/21	4	F	720	1.3	Main Stem C	11
91	7/21	4	F	900	1.4	Main Stem B	10
92	7/21	4	M	720	1.3	Gechiak Creek	6
93	7/21	4	F	890	1.5	Main Stem C	10
94	7/21	4	F	875	--	Below	3
95	7/21	4	F	925	1.4	Below	3
96	7/21	4	F	775	1.3	Below	12
97	7/21	4	F	820	1.3	Main Stem C	10
98	7/21	4	F	890	1.4	Main Stem B	4
99	7/22	4	F	950	1.5	Main Stem B	11
100	7/22	4	M	900	--	Main Stem C	6
101	7/22	4	F	850	1.4	Main Stem E	1
102	7/22	4	M	710	--	Dead/Regurgitated	11
103	7/22	4	F	800	--	Below	8
104	7/23	4	M	1020	1.5	Main Stem C	11

Appendix 1. Continued.

Fish ID	Tag Date	Tag Stratum	Sex	Length (mm)	Age	Fate[a]	Number of Detections
105	7/23	4	F	935	1.4	Harvested	1
106	7/24	4	F	790	--	Unknown	2
107	7/24	4	M	675	1.3	Below	7
108	7/24	4	F	895	1.3	Main Stem C	2
109	7/24	4	F	970	1.4	Main Stem B	7
110	7/24	4	F	805	1.3	Below	3
111	7/24	4	M	915	1.4	Unknown	1
112	7/28	5	F	820	--	Unknown	2
113	7/28	5	F	780	1.4	Dead/Regurgitated	6
114	7/28	5	F	805	1.4	Below	13
115	7/28	5	M	800	1.3	Below	4
116	7/28	5	F		--	Dead/Regurgitated	11
117	7/29	5	F	745	1.3	Below	3
118	7/30	5	F	855	1.3	Main Stem C	3
119	7/30	5	F	755	1.3	Never Located	0
120	7/30	5	M	810	1.3	Dead/Regurgitated	4
121	7/31	5	F	885	1.4	Below	4
122	7/31	5	F	800	1.3	Nayorurun River	6
123	7/31	5	U	805	1.3	Below	3
124	8/5	5	F	905	1.4	Below	2
125	8/5	5	F	935	1.4	Kemuk River	5
126	8/5	5	F	840	1.4	Main Stem C	2
127	8/5	5	F	900	1.4	Harvested	3

[a]Below: Below the Entry logger
[a]Main Stem A: Entry logger – Gechiak Creek
[a]Main Stem B: Gechiak Creek – Pungokepuk Creek
[a]Main Stem C: Pungokepuk Creek – Nayorurun River
[a]Main Stem D: Nayorurun River – Kemuk River
[a]Main Stem E: Kemuk River – Ongivinuk River
[a]Main Stem F: Ongivinuk River – Togiak Lake