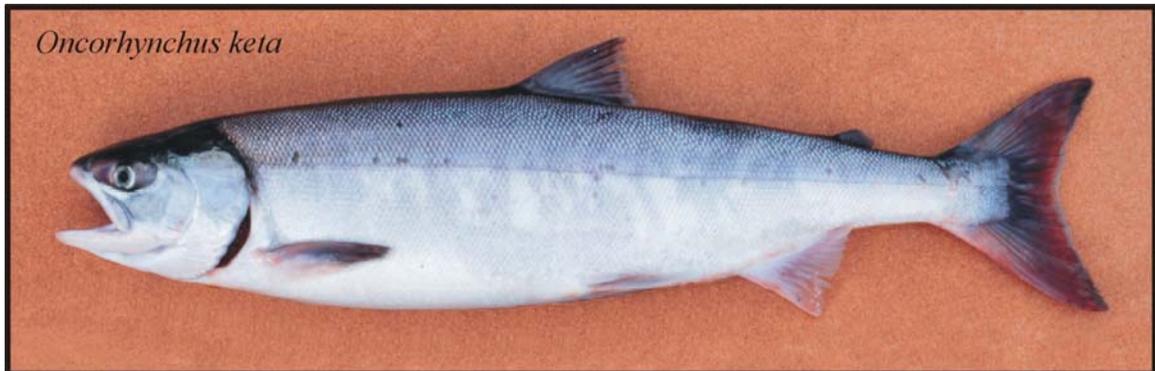


U.S. Fish & Wildlife Service

A Radio Telemetry Investigation of Suspected Chum Salmon Spawning Activity in the Kashunuk River Drainage, Yukon Delta National Wildlife Refuge, 2002 and 2003

Alaska Fisheries Data Series Number 2005-19



Fairbanks Fish and Wildlife Field Office
Fairbanks, Alaska
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A Radio Telemetry Investigation of Suspected Chum Salmon Spawning Activity in the Kashunuk River Drainage, Yukon Delta National Wildlife Refuge, 2002 and 2003

Randy J. Brown and John H. Eiler

Abstract

Chum salmon *Oncorhynchus keta* caught in the coastal district of the Yukon River fisheries management area are considered to be Yukon River stocks for management purposes. Coastal district residents who fish in the lower Kashunuk River believe they harvest locally spawning chum salmon stocks, and suggest that a less restrictive management strategy be applied to their fishery. A radio telemetry project was conducted in 2002-2003 to determine if chum salmon spawn in the Kashunuk River drainage. A total of 17 fish were captured and radio tagged during the local fishery, and tracked with remote radio receiving stations and aerial surveys. Eight tagged fish (47%) were harvested in the Kashunuk River fishery, one tagged fish migrated into the Bonasila River, a known chum salmon spawning tributary of the Yukon River, and eight fish were not harvested or located during the aerial surveys. No potential chum salmon spawning areas were discovered in the Kashunuk River drainage.

Introduction

The village of Chevak lies just north of the Kashunuk River mouth on the far western edge of the delta formed by the Yukon and Kuskokwim rivers. Residents of Chevak and other villages in the area harvest chum salmon *Oncorhynchus keta* and other Pacific salmon species each summer for personal use (Borba and Hamner 2001). The area is classified as the coastal district of the Yukon River fisheries management area and is subject to the same fishing regulations as the Yukon River (Bergstrom et al. 2001).

Many Chevak residents fish for chum salmon in the Kashunuk River, which is the major drainage south of the village (Figure 1). The Kashunuk River is not a closed drainage, as Yukon River water flows into the upper Kashunuk River through Kashunuk Slough approximately 190 km upstream from the Yukon River mouth. According to local residents, boat travel through the slough is possible for most or all of the summer. It is therefore possible for chum salmon to migrate from the Bering Sea to the Yukon River through the Kashunuk River. Local residents, however, believe that fish caught in the Kashunuk River are preparing to spawn locally, and contend that their subsistence fishing should not be subject to closures effective in the Yukon River. Kerkvliet (1986) lent some support to the idea of local spawning when she observed chum salmon in apparent spawning condition in two tributaries of the Kashunuk River, although no adequate spawning habitat was identified.

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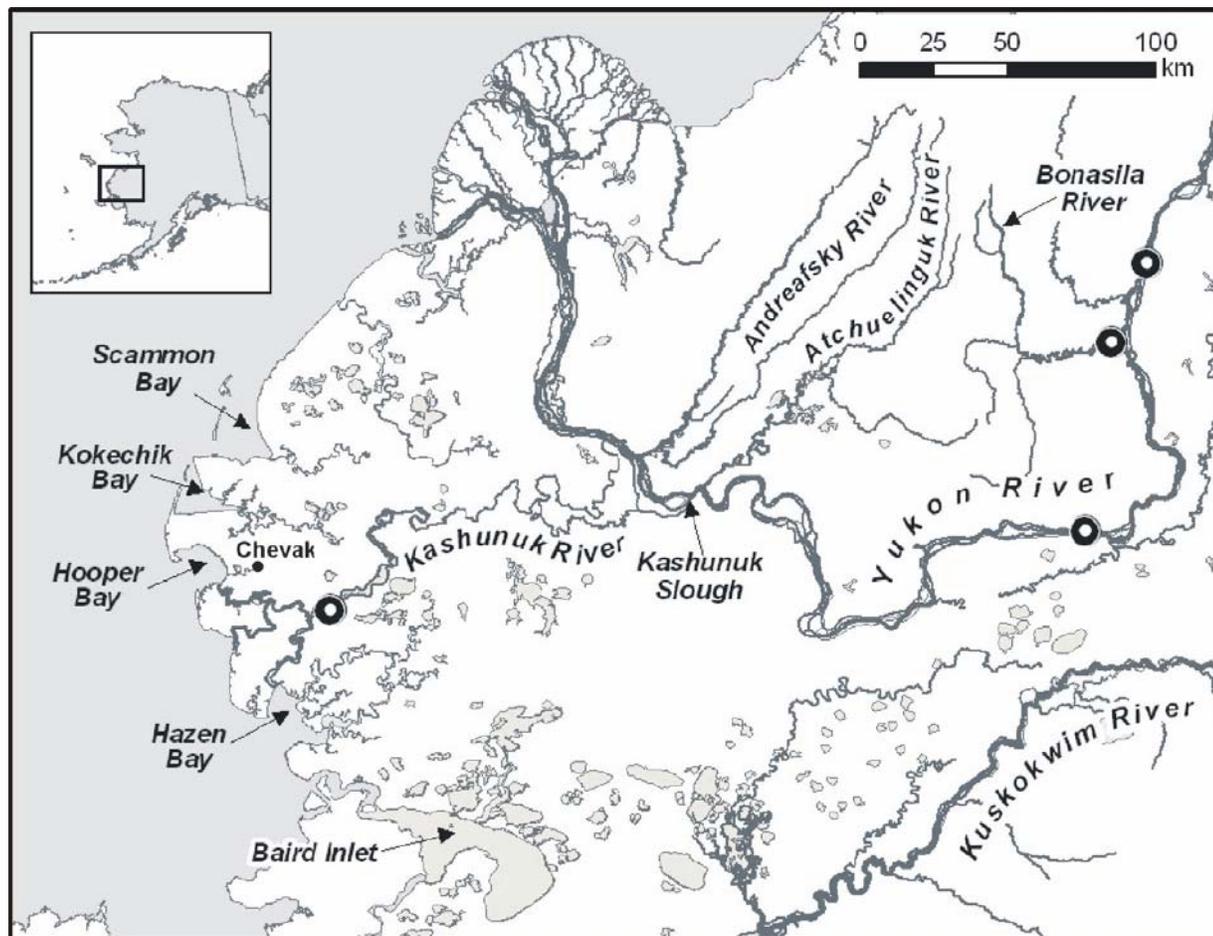


Figure 1. The Kashunuk River and other pertinent geographic features in the Yukon-Kuskokwim Delta region in western Alaska. The circles indicate the locations of remote radio receiving stations utilized in this project.

Radio telemetry has been used effectively to locate fish spawning habitats in many situations. Eiler et al. (1992) identified many previously known and new sockeye salmon *O. nerka* spawning areas in the Taku River drainage in southeastern Alaska and British Columbia by tracking radio-tagged fish to their final destinations. Of the 253 fish tracked upriver, 204 were tracked to spawning areas. In other situations, relatively few transmitters have been effective in locating fish spawning areas. Chang-Kue and Jessop (1983) located broad whitefish *Coregonus nasus* spawning areas on the Mackenzie River by deploying 20 radio transmitters on prespawning fish. Similarly, Underwood (2000) located spawning habitat used by Selawik River inconnu (sheefish) *Stenodus leucichthys* by deploying 22 radio transmitters. Spawning areas in all three of these examples were later confirmed by on-site sampling.

It was expected that chum salmon encountered in the lower Kashunuk River were preparing to migrate to upstream spawning areas. Salo (1991) cautioned however, that it may be erroneous to assume that adult salmon captured at the mouths of particular streams originated there, suggesting that fish may simply be probing freshwater outlets they encounter along the coast while searching for the scent of their own home stream. Despite this uncertainty, it was reasoned that if a high percentage of the chum salmon in the lower Kashunuk River during June were migrating to spawning areas within the drainage, as suggested by local residents, radio telemetry

could be used effectively to locate these areas. The U.S. Fish and Wildlife Service conducted radio telemetry projects in 2002 and 2003, specifically to locate chum salmon spawning habitats within the Kashunuk River drainage. In addition, observations of other fish species present were recorded, and data were collected on tidal influence, river depth, water temperature, and salinity in the lower Kashunuk River.

Study Area

The outer region of the Yukon-Kuskokwim Delta is a low-relief, wetland habitat cut by tidal sloughs and streams (USFWS 1992). Rivers flowing through the region divide into multiple channels upon approaching the coast, hereafter defined as distributaries, distributing the freshwater from individual rivers to several ocean mouths. In this study, we were working on the Kashunuk River and its distributaries, the Aphrewn and Keoklevik rivers (Figure 2). The Aphrewn River splits from the Kashunuk River approximately 50 km from the sea, and flows south of the Kashunuk River into Hazen Bay. The Keoklevik River splits from the Kashunuk River approximately 40 km from the sea, and flows north of the Kashunuk River into Hooper Bay. The Kashunuk River flows into Angyoyaravak Bay, midway along the coast between Hazen and Hooper bays. The chum salmon fishery of concern in this study occurs primarily in the Kashunuk and Aphrewn rivers in the vicinity of their divergence. To simplify discussion in the text, we referred to the entire Kashunuk River drainage and its distributaries as the "Kashunuk River" unless the specific location was important.

Methods

Seventeen radio transmitters were deployed on chum salmon during the course of this project: 11 in 2002 and 6 in 2003. Chum salmon were captured at several locations in the lower Kashunuk River drainage. The capture operation was conducted coincidentally with the local fishery to ensure that tagged fish came from the same population as the local harvest. Constantly monitored set gill nets (30 m length, 6 m deep, 14 cm stretch mesh, constructed of braided twine) or drift gill nets (45 m length, 6 m deep, 14 cm stretch mesh, constructed of braided twine) were used for capture. Fish were removed from the net immediately following capture and placed into a neoprene-lined cradle in a water-filled tub for tagging. Chum salmon were measured (mid-eye to fork of tail length), tagged with stomach implant radio transmitters (Eiler et al. 1992), and released.

Digitally coded radio transmitters were deployed in chum salmon during late June of both years. Transmitters were approximately 5 cm in length and 2 cm in diameter, and were designed to last for approximately 150 days. They were inserted through the mouth and into the stomach, a procedure described in detail and used with success on adult migrating salmon by Eiler et al. (1992) and Evenson and Wuttig (2000). Anesthesia was not used and tagged fish were released immediately following tagging.

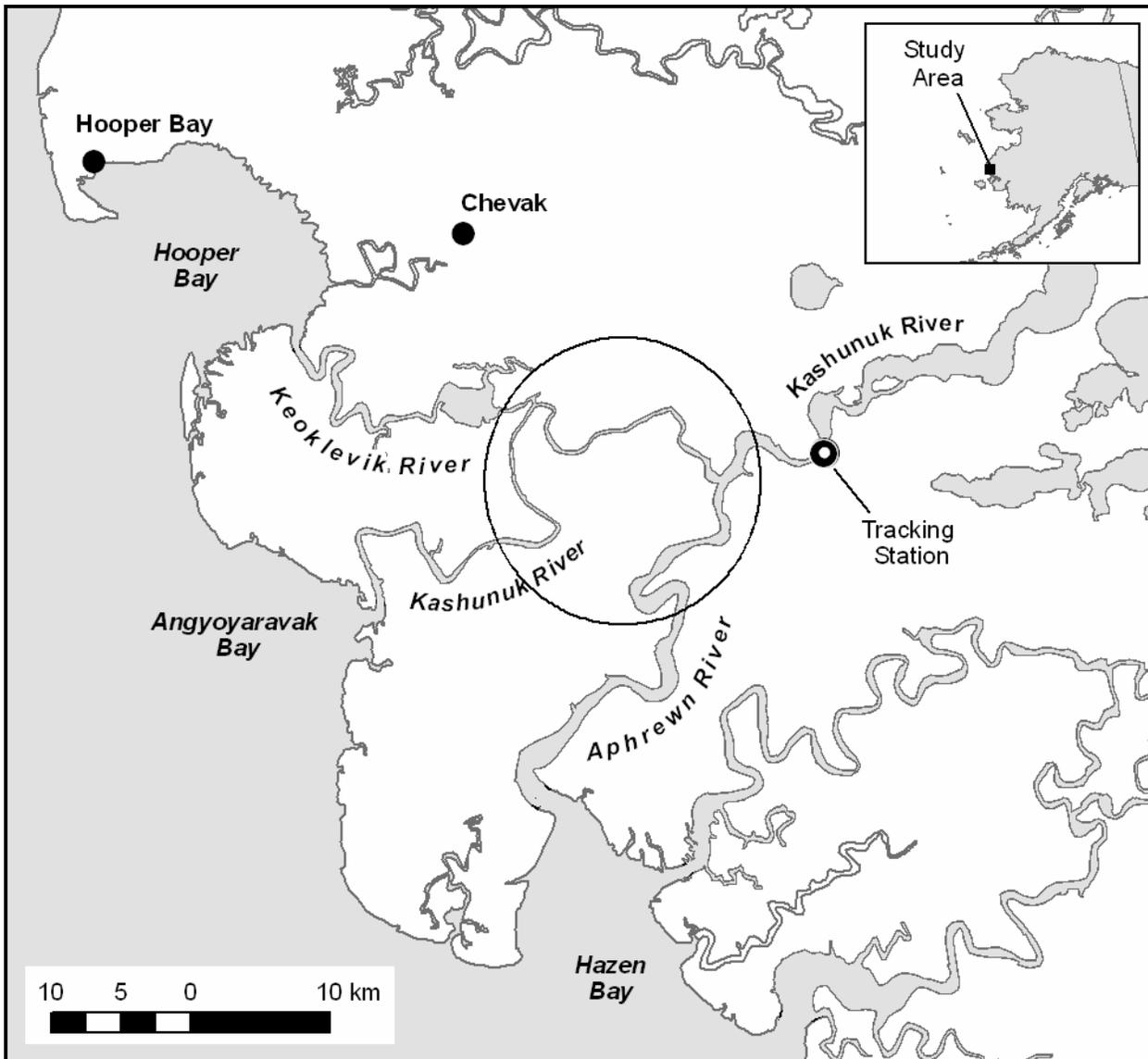


Figure 2. Geographic details of the lower Kashunuk River and its distributaries. The June chum salmon fishery occurred primarily within the large circle above, radio-tagging took place in the Aphrewn River, and the tracking station was located at the small circle.

A data-logging radio receiving station (tracking station) was established in the lower Kashunuk River, upstream from the tagging operations (Figure 2), to record fish movements into the drainage. The antenna system was omni-directional, which identified fish presence near the tracking station but not direction of travel. The transmitters were compatible with a tracking station network in the Yukon River basin (Eiler et al. 2004), making it possible to detect Kashunuk River chum salmon that ultimately migrated to the Yukon River.

Two aerial surveys were conducted each year to locate tagged fish: one in mid-July three weeks after tagging, and the other in early August six weeks after tagging. On July 16, 2002 a comprehensive survey was flown covering the entire Kashunuk River drainage, and the Andreafsky and Atchuelinguk rivers in the lower Yukon River basin (Figure 1). On August 7, 2002 a survey was flown of all the coastal waterways and villages from north of Baird Inlet to

Scammon Bay. On July 17, 2003 a comprehensive survey was flown of the entire Kashunuk River drainage and adjacent coastal waterways and villages. On August 6, 2003 a survey was flown of the lower Kashunuk River and its tributaries, and of the coastal waterways and villages.

The main objective of the study was to identify potential spawning destinations within the Kashunuk River drainage based on locations of radio-tagged fish. Four possible fates were considered for radio-tagged fish in this project, including fish that: 1) ascended the Kashunuk River and were located at potential spawning sites within the drainage; 2) were recorded moving into the Yukon River; 3) were harvested in a fishery, and either reported or located in fish camps or villages during aerial surveys; and 4) were never relocated. Fish located in terminal areas of the Kashunuk River drainage were considered to be possible spawners. Site visits to these locations would be required to determine if spawning was actually occurring. Fish located or harvested in the Yukon River were designated as members of Yukon River spawning stocks. Fish harvested and reported in the lower Kashunuk River were considered to be of unknown origin. Fish harvested and reported elsewhere were considered to be of non-Kashunuk River origin. Fish that were not relocated or harvested were considered to be of unknown origin.

Records were kept of other fish species encountered during the course of the tagging project in the lower Kashunuk River. These species were incidentally caught while fishing for chum salmon for radio tagging, observed in the catches of other local fishers, or captured in a 5 cm stretch-mesh gill net that was used to identify smaller species present in the area. Biological data were collected from fish captured in the small-mesh net including species, fork length (cm), weight (g), and feeding activity (food present or absent in stomach).

Information on river and water quality parameters, including tidal influence (present or not), depth (m), water temperature ($^{\circ}\text{C}$), and salinity (ppt), was recorded at fishing sites in the lower Kashunuk River. Tidal influence was recorded as being present or absent, based on observed daily water level variations accompanied by alternating flow patterns. Detailed measurements of timing and amplitude of the tides were not done, but anecdotal observations were recorded. A Garmin 168 depth sounder with a transducer mounted to the transom of the boat was used to take depth readings. The sounder reported depth to a precision of ± 0.1 m, but the effective precision given wave action and the transom mounting of the transducer was probably in the range of ± 0.5 m. No comprehensive effort was undertaken to plot bottom topography, but maximum depths were recorded along horizontal transects of the river. Water temperature and salinity were measured with a YSI 85 meter; temperature was measured to a precision of ± 0.1 $^{\circ}\text{C}$, and salinity to a precision of ± 0.1 ppt. Measurements were taken in surface waters and at depths of 7 m during both high and low tide cycles. These data were collected as isolated records of the habitat conditions encountered during the course of the project.

Results

Seventeen chum salmon were captured during the course of this study: 11 in 2002 and 6 in 2003. Set gillnetting was the primary fishing method employed in 2002. Approximately 10 hours of fishing were conducted each day for eight days between June 18 and June 26. Two or three slack tides were fished with set gill nets each day and drift gill nets were used on three occasions. Daily chum salmon catches ranged from 0-3 fish. Approximate catch per hour of net time (standardized to a 30 m gill net) in 2002 was 0.13 chum salmon. Drift gillnetting was the primary fishing method employed in 2003. Approximately 10 hours of fishing were conducted

each day for five days between June 24 and June 29. Slack tides were fished with set gill nets on two occasions. Daily chum salmon catches ranged from 0-3 fish. Approximate catch per hour of net time (standardized to a 30 m gill net) in 2003 was 0.09 chum salmon.

All captured chum salmon were radio tagged. They were uniformly bright silver in color, with little or no evidence of spawning colors. They averaged 58 cm mid-eye to fork length (range 55 to 60 cm) (Table 1). Sea lice *Lepeophtheirus salmonis* (Pike and Wadsworth 1999) were present on all chum salmon.

Table 1. Details of the tagging dates, mid-eye to fork of tail lengths, tracking station records, and the fates or destinations of all radio-tagged chum salmon in this study.

| Tagging date | Mid-eye to fork of tail length | Tracking station records ¹ | Elapsed time between tagging and last tracking station record (hrs (days)) | Fate/Destination |
|--------------|--------------------------------|---------------------------------------|--|------------------|
| 6/20/02 | 58 | 1 | 113 (4.71) | Harvested |
| 6/21/02 | 59 | 2 | 19 (0.79) | Unknown |
| 6/21/02 | 59 | 3 | 30 (1.25) | Harvested |
| 6/21/02 | 60 | 0 | | Harvested |
| 6/22/02 | 58 | 7 | 73 (3.04) | Bonasila River |
| 6/22/02 | 58 | 2 | 83 (3.46) | Unknown |
| 6/22/02 | 56 | 4 | 112 (4.67) | Unknown |
| 6/23/02 | 56 | 3 | 152 (6.33) | Unknown |
| 6/24/02 | 59 | 0 | | Harvested |
| 6/25/02 | 59 | 5 | 248 (10.33) | Harvested |
| 6/25/02 | 59 | 10 | 192 (8.00) | Harvested |
| 6/25/03 | 57 | 1 | 74 (3.08) | Harvested |
| 6/26/03 | 60 | 2 | 48 (2.00) | Unknown |
| 6/26/03 | 59 | 0 | | Unknown |
| 6/26/03 | 56 | 6 | 239 (9.96) | Harvested |
| 6/27/03 | 57 | 1 | 21 (0.88) | Unknown |
| 6/29/03 | 55 | 3 | 71 (2.96) | Unknown |

¹ Presence of radio-tagged fish at the Kashunuk River tracking station during a discrete period.

Fourteen of 17 radio-tagged chum salmon were recorded by the Kashunuk River tracking station (Table 1). These fish moved within range of the tracking station from 1-10 times, with a median of 3 times. The time between tagging and the last record at the Kashunuk River tracking station ranged from 0.79 days (approximately 19 hours) to 10.33 days, with a median of 3.27 days.

Only one radio-tagged chum salmon was recorded by the Yukon River network of tracking stations. This fish was recorded by the Kashunuk River receiving station seven times within 3 days of tagging, and arrived in the Bonasila River (Figure 1) 21 days after tagging. The July 16, 2002 aerial survey, conducted 3 days after this fish arrived in the Bonasila River, confirmed that Yukon River water was flowing freely into the Kashunuk River via Kashunuk Slough. The distance from the Kashunuk River tracking station to the Bonasila River via the Kashunuk River is about 631 km, and via the mouth of the Yukon River is about 754 km. The time between the

last record at the Kashunuk River tracking station and arrival at the Bonasila River tracking station was 18.1 days. Possible migration rates were 34.9 km/day if the fish traveled via the Kashunuk River and 41.7 km/day via the mouth of the Yukon River. Radio-tagged chum salmon migrated from 30 to 50 km per day in the upper Yukon River (unpublished data, National Marine Fisheries Service), so it was not possible to use migration speed to determine which route the fish utilized.

Eight of 17 radio-tagged chum salmon (47%) were harvested in the lower reaches of the Kashunuk River, including two fish not detected by the Kashunuk River tracking station and six fish that initially moved up to or beyond the tracking station and subsequently moved back downstream to where they were captured. The date of capture is known for only two of the harvested fish. All others were located in fishcamps or villages during aerial surveys of the region, and were reported without capture details. One fish was recorded once by the tracking station, approximately 5 days following tagging, and was later harvested in the lower Kashunuk River 30 days following tagging. Another fish was recorded by the tracking station 5 times, with the last time being more than 10 days following tagging. This fish was harvested in the lower Kashunuk River the following day. Four other fish were recorded by the tracking station from 1 to 10 times over time periods of 1 to 10 days prior to being harvested.

Eight of 17 radio-tagged chum salmon (47%) were not harvested, were not located during aerial surveys, and were not located in the Yukon River. Seven of these fish were recorded by the Kashunuk River tracking station from 1 to 4 times before disappearing. The median time between tagging and the final tracking station record for these fish was 3 days and ranged from 0.8 to 6.3 days. One fish was tagged and then disappeared without being recorded by the tracking station.

Despite comprehensive aerial surveys of the entire Kashunuk River and its tributary streams, conducted three weeks after tagging events in both 2002 and 2003, no free-ranging radio-tagged fish were found in the drainage. Only fish harvested in local fisheries were located. Similarly, no tagged fish were found in the Andreafsky or Atchuelinguk rivers, known chum salmon spawning destinations in the lower Yukon River drainage downstream from the first Yukon River tracking station (Figure 1), or elsewhere north or south of the Kashunuk River region.

The spawning origin of only 1 of 17 radio-tagged chum salmon was determined during the course of this study. That fish migrated into the Bonasila River, a lower Yukon River tributary (Figure 1). Based on these data, the other 16 fish could only be classified as being of unknown origin.

Nine fish species were captured or observed in the Kashunuk River delta during the course of this project. Chum salmon, sockeye salmon, broad whitefish, and starry flounder *Platichthys stellus* were captured in our chum salmon nets. These same four species plus humpback whitefish *Coregonus pidschian*, least cisco *C. sardinella*, and Bering cisco *C. laurettae* were observed in the catches of local fishers. Directed sampling with small mesh gill nets captured Bering cisco, rainbow smelt *Osmerus mordax*, and ninespine stickleback *Pungitius pungitius*. Ninespine sticklebacks were too small to be captured directly by the net but a few became tangled in frayed string ends of the nets.

Lengths and weights were recorded from samples of Bering cisco ($n = 17$) and rainbow smelt ($n = 5$). Bering cisco averaged 28.3 cm and 244 g and ranged from 22.0 to 38.0 cm and 115 to 530 g. All except two of the Bering cisco had food in their stomachs, and sex could only be

determined for the largest four fish. All others appeared to be immature based on the minute size of their gonads. Rainbow smelt averaged 28 cm and 179 g and ranged from 24.5 to 30.0 cm and 100 to 225 g. Three of five rainbow smelt were feeding and their sex could not be determined.

Examinations of river and water quality parameters revealed a dynamic environment in the lower Kashunuk River. At the junction of the Kashunuk and Aphrewn rivers tides occurred approximately 3 hours earlier than those monitored at the Kokechik Bay (Figure 1) tide station. The amplitude during some tide cycles was at least 1.5 to 2 m. Tides were observed in Nanvaranak Lake (Figure 3), approximately 80 km from the sea, and it was possible that they reached even farther inland. Soundings along horizontal transects in the lower Kashunuk River (Figure 4) revealed maximum depths ranging from 5.5 to 30.0 m (Table 2). Water temperature remained relatively stable throughout the sampling periods of both years, ranging between 13°C and 15°C. The temperature differences between high and low tide stages on a particular day, or between surface and subsurface measurements at a particular time and place were less than 1°C. Salinity varied from undetectable levels to 10 ppt depending on tide stage, distance from the sea, and day on which the measurement was taken (Figure 3). In locations where salinity was measured at 8 to 10 ppt during a high tide on one day, the salinity might be only 3 or 4 ppt during the same tide cycle the next day. In general, salinity was greater during high tides than low tides, and greater closer to the sea than farther from the sea. The salinity difference between surface and subsurface measurements down to 7 m at a particular time and place was less than 0.1 ppt. The fact that temperature and salinity were essentially constant with depth indicated thorough mixing of salt and freshwater.

Discussion

This project began with the expectation that at least 30 chum salmon could be captured and tagged in the lower Kashunuk and Aphrewn rivers during a 10 to 14 day sampling period. This expectation was based on catch rates presented by Kerkvliet (1986), who reported CPUE values for similar sized gill nets in Hooper Bay ranging from 0.2 to 0.3 chum salmon per hour during late June. These capture rates were not experienced during the two years of this project, so the sample size is smaller than was anticipated. Despite this, data from the 17 fish that were successfully radio-tagged provide insights into the behavior of chum salmon in the lower Kashunuk and Aphrewn rivers, and the efficiency of the local fishery that occurs there.

Anadromous fish must go through fundamental physiological transitions to regulate their fluid solute levels as they migrate from fresh to saltwater as young fish (smolt) and when they return to freshwater as adults (Black 1957). McCormick and Saunders (1987) identify the physiological changes that occur as salmon fry prepare to smolt and contend that the process takes several weeks to accomplish. The time required for transition back from a salt to a freshwater environment is less well documented. However, Salo (1991) cited a number of studies reporting extended estuarine residence times for returning adult chum salmon. Eames et al. (1981, 1983), for example, reported that many chum salmon tagged in Skagit and Bellingham bays, within Puget Sound, spent from one to three weeks in the estuary before proceeding to upstream spawning destinations. Some radio-tagged chum salmon in this study exhibited estuarine residence times similar to chum salmon in Puget Sound drainages (Eames et al. 1981, 1983). Salinity data from the lower Kashunuk River confirmed that these habitats were brackish environments. The presence of sea lice on the chum salmon suggested that they had not

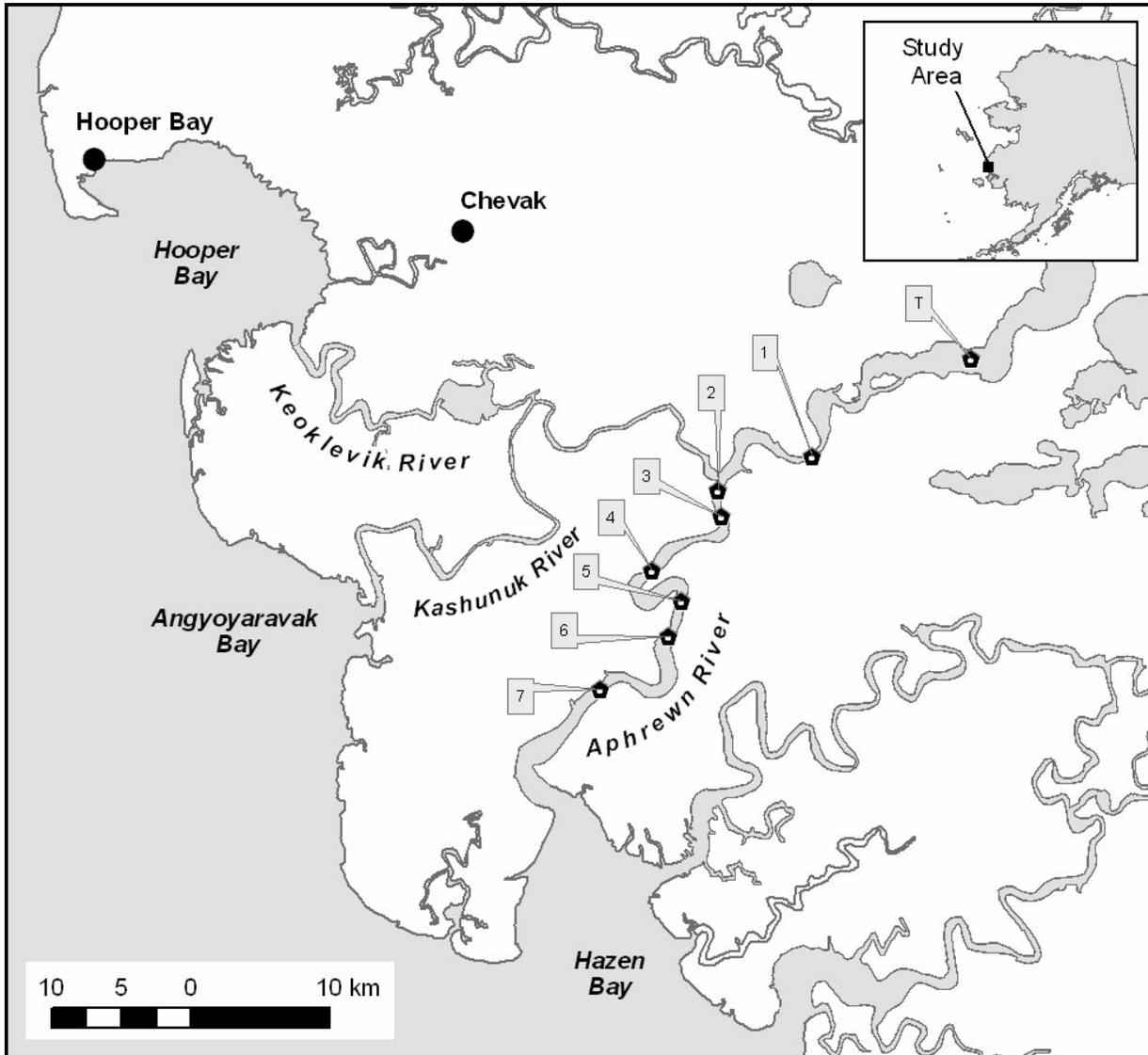


Figure 3. Sampling sites in the lower Kashunuk and Aphrewn rivers during late June, 2003. Tidal flows were observed as far upstream as Nanvaranak Lake (T). River depth, water temperature, and salinity measurements were taken at sites indicated by the pointers numbered 1-7, and are presented in Table 2.

Table 2. River depth, water temperature, and salinity records collected during periods of high tide at various sampling sites in the lower Kashunuk River in late June, 2003. The locations of the sampling sites are indicated in Figure 3.

| Sample site | Depth (m) | Temperature (°C) | Salinity (ppt) |
|-------------|-----------|------------------|----------------|
| 1 | 5.0 | 13.5 | 0.2 |
| 2 | 5.0 | 13.5 | 1.2 |
| 3 | 5.5 | 13.9 | 0.3 |
| 4 | 31.0 | 13.8 | 1.3 |
| 5 | 18.0 | 14.0 | 3.9 |
| 6 | 10.0 | 14.0 | 10.0 |
| 7 | 10.0 | 13.8 | 8.9 |

completed the transition from a saltwater to a freshwater environment. Also, the multiple records of many of the radio-tagged fish at the Kashunuk River tracking station revealed that they were not engaged in a direct migration to an upstream spawning destination. These data suggest that the radio-tagged chum salmon in this study were milling in the estuary, perhaps searching for their home stream scent or physiologically transitioning back to a freshwater environment.

During 1986, Kerkvliet (1986) conducted a spaghetti tagging study designed to determine the spawning destination of chum salmon captured in the marine waters of Hooper Bay, where the northern distributary of the Kashunuk River ends. Over 1,900 fish were tagged between mid-June and mid-July, and 141 tags were returned by fishers during the following few weeks. A few tags were returned by Hooper Bay residents, and a few were reported from Norton Sound and Kotzebue Sound to the north. The majority of returns, however, were from fishers within the Yukon River itself. Kerkvliet (1986) concluded that chum salmon taken in Hooper Bay were primarily of Yukon River origin. Our data show that at least some Yukon River chum salmon migrate through the lower Kashunuk River.

Kerkvliet (1986) reported that Ray Baxter, a retired ADF&G fishery biologist who worked in the region for many years, believed that many of the salmon encountered in the tidal streams of the Yukon-Kuskokwim Delta were lost due to the confusing mix of smells seeping through the region. Data from this project did not clarify whether radio-tagged chum salmon were lost, searching for their home streams, or in the process of adapting to freshwater. However, their extended estuarine residence time made them repeatedly available to the fishery, which was located primarily downstream from the tracking station in the lower Kashunuk River. This behavior increased the probability that they would be captured, which resulted in a harvest rate of 0.47, almost half of all tagged fish.

One of the strengths of radio telemetry is that when a radio signal is identified during an aerial survey, one can be certain that the tagged fish is present at that location. However, the absence of a radio signal does not necessarily imply that the tagged fish is not present. It is possible, but unusual, for fish to be missed during an aerial survey. In this study, 8 of 17 radio-tagged chum salmon were not harvested, not located during aerial surveys, and not recorded by tracking stations in the Yukon River. Technically, their spawning destinations are unknown. However, it is extremely unlikely that all eight radio-tagged fish with unknown spawning destinations were present in the Kashunuk River drainage and were not located during the aerial surveys, particularly considering the relatively small size of the area surveyed, and the small number of fish being tracked.

Aerial surveys are highly efficient procedures for locating radio-tagged fish in river drainages. In 1998, Evenson and Wuttig (2000) accounted for 149 of 153 radio-tagged Chinook salmon in the Unalakleet River drainage using aerial surveys, a location rate of approximately 97% (Table 3). As part of the 2002 and 2003 Chinook salmon radio telemetry study in the Yukon River basin (Eiler et al. 2004), aerial surveys were conducted by the U. S. Fish and Wildlife Service in the Innoko, Nowitna, and Black River drainages. Fifteen of 16 fish were located during the surveys resulting in an overall relocation rate of 94%. These results are normal for experienced aerial survey crews.

Table 3. Aerial survey location rates from the Unalakleet River (Evenson and Wuttig 2000), Yukon River tributaries (unpublished data, U.S. Fish and Wildlife Service), and the Kashunuk River drainage.

| Drainage | Mainstem length | Tagged fish | Fish located | Percent located |
|-------------------------|-----------------|-------------|--------------|-----------------|
| Unalakleet River | 140 km | 153 | 149 | 97 |
| Yukon River tributaries | | | | |
| Innoko River | 600 km | 9 | 8 | 89 |
| Nowitna River | 350 km | 4 | 4 | 100 |
| Black River | 350 km | 3 | 3 | 100 |
| Tributaries combined | 1,400 km | 16 | 15 | 94 |
| Kashunuk River | 300 km | 8 | 0 | 0 |

The radio telemetry equipment and aerial survey techniques used during the projects on the Kashunuk, Unalakleet, and Yukon rivers were virtually the same. The distinct difference between the Kashunuk River location data and those from other river systems of similar or greater complexity (Table 3) suggests that the eight radio-tagged chum salmon with unknown spawning destinations migrated to spawning areas somewhere other than the Kashunuk River. The results of this investigation do not support the notion that a large proportion of chum salmon encountered in the lower Kashunuk River during late June, originate from spawning areas within the Kashunuk River itself.

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