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Feasibility of using fishwheels for long-term monitoring of chinook salmon escapement on the Copper River, 2003 annual report

Annual Report No. FIS01-020

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Feasibility of using fishwheels for long-term monitoring of chinook salmon escapement on the Copper River, 2003 Annual Report

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EXECUTIVE SUMMARY

The purpose of this project was to assess the feasibility of using fishwheels and two-sample mark-recapture methods for long-term monitoring of chinook salmon *Oncorhynchus tshawytscha* escapement on the Copper River. This report summarizes results from the third and final year of this project. Objectives for 2003 were to: (1) evaluate the efficacy of installing and operating two fishwheels in Baird Canyon and two fishwheels near Wood Canyon; (2) estimate the ability of these fishwheels to capture chinook salmon throughout the entire run; and (3) generate a system-wide abundance estimate for chinook salmon returning to the Copper River.

For the first sample event, two live-capture fishwheels were operated at Baird Canyon for 2,193 h from 16 May to 9 July. During this period, 2,251 adult chinook salmon were captured and 2,077 fish were marked (1,577 spaghetti tags and 500 radio tags). For the second sample event, two fishwheels were operated near the lower end of Wood Canyon for 2,475 h from 21 May to 20 July. A total of 1,928 chinook salmon were captured and 1,844 fish were examined, of which 100 were recaptures. A total of 354 fish sampled in the first event and 214 fish sampled in the second event were censored from the abundance calculations. The probability of a fish being marked at Baird Canyon and the probability of a marked fish being recaptured at Canyon Creek were not independent of time. Using a temporally stratified estimator, estimated abundance of chinook salmon measuring 810 to 1,070 mm FL that migrated upstream of Baird Canyon from 17 May to 1 July was 44,764 (SE = 12,506). This estimate was based on 1,723 marked fish available for recovery (1,325 spaghetti tags and 398 radio tags), 1,630 fish examined for marks during the second sample event and 97 recaptures (72 spaghetti tags and 25 radio tags). The median travel time of fish tagged at Baird Canyon and recaptured at Canyon Creek approximately 91 km upstream was 13.0 d (range = 5-30 d, n = 101).

Despite the numerous and often significant challenges encountered during this study, it has continued to meet or exceed all project objectives and expectations. Drainage-wide abundance estimates for chinook salmon were generated in two out of three years (2002 and 2003). The project has evolved into a long-term monitoring program that has made the Native Village of Eyak (NVE) an integral part of Copper River salmon research. In addition, this project has demonstrated that federal, state and tribal agencies can work cooperatively to collect stock-assessment data that will be used to assess current management practices. Based on the first three years of results, it appears that fishwheels and mark-recapture methods can be used to estimate the inriver abundance of chinook salmon on the Copper River.

INTRODUCTION

The Copper River supports one of the largest chinook salmon *Oncorhynchus tshawytscha* subsistence fisheries in Alaska. The importance of Copper River chinook salmon to subsistence users has focused attention on the lack of information about escapement levels and distribution among tributaries. Despite the importance of this fishery, fishery managers have found it difficult to obtain annual estimates of chinook salmon escapement to the drainage. Many stakeholders believe that escapement indices generated by conventional methods (aerial surveys and weirs on selected systems) have not adequately assessed the abundance of Copper River chinook salmon stocks.

From 1999-2003, the Alaska Department of Fish and Game (ADF&G) has conducted radiotelemetry studies to derive the first system-wide estimates of chinook salmon escapement to the Copper River (Evenson and Wuttig 2000; Wuttig and Evenson 2001; Savereide and Evenson 2002). Due to the project's high expense, biologists planned to terminate this telemetry-based, escapement-monitoring project after the 2001 season. The possible termination of the radio-tagging project created a need for the development of a long-term program to monitor chinook salmon escapement in the Copper River.

The use of fishwheels (Meehan 1961; Donaldson and Cramer 1971) and mark-recapture techniques can often be an effective method for estimating chinook salmon escapement. This technique has been used to generate system-wide salmon escapement estimates on numerous large rivers (Meehan 1961; Donaldson and Cramer 1971; Johnson et al. 1992; Arnason et al. 1996; Link et al. 1996; Cappiello and Bromaghin 1997; Gordon et al. 1998; Link and Nass 1999; Sturhahn and Nagtegaal 1999), and appears promising for use on the Copper River (Link et al. 2001; Smith et al. 2003). The purpose of this study was to assess the feasibility of using fishwheels as both the capture-tag and recapture phases of a mark-recapture study for long-term monitoring of chinook salmon escapement on the Copper River.

Objectives

Overall objectives for this three-year study were to:

(1) Evaluate the ability of fishwheels to capture chinook salmon on the Copper River;
(2) Generate annual system-wide abundance estimates for chinook salmon returning to the Copper River and estimate the precision of such estimates; and
(3) Develop a long-term program operated by the Native Village of Eyak (NVE) to estimate chinook salmon escapement to the Copper River.

In 2003, two tagging fishwheels were operated at Baird Canyon approximately 66 km (41 mi) upstream of where the Copper River enters the Gulf of Alaska. In addition, two recovery fishwheels were operated near Wood Canyon (river km, rkm 157) approximately 12 km downstream from Chitina, Alaska. This report documents the methods, results and conclusions from the 2003 field season.

Specific objectives for 2003 were to:

(1) Evaluate the efficacy of installing and operating two fishwheels in Baird Canyon and two fishwheels near the lower end of Wood Canyon;
(2) Estimate the ability of these fishwheels to capture chinook salmon throughout the entire run; and
(3) Generate a system-wide abundance estimate for chinook salmon returning to the Copper River.

Study Area

The Copper River, which drains an area of more than 62,100 km^2 (24,000 mi^2), flows southward through south-central Alaska and enters the Gulf of Alaska near the town of Cordova (Fig. 1). Between the ocean and Miles Lake (rkm 48), the river channel traverses the Copper River Delta which is a large, highly braided, alluvial flood plain. A relatively high proportion of the Copper River's headwaters are glaciated (18% in 1995), resulting in very high unit discharge (volume per square kilometer of drainage area) and sediment loads (Brabets 1997). From 1988 to 1995, the annual mean discharge on the lower Copper River was 1,625 m^3/s (57,400 ft^3/s), with the majority of flow occurring during the summer months from snowmelt, rainfall and glacier melt (Brabets 1997). Peak discharge in June ranged from 3,650 to 4,235 m^3/s while annual peak discharge ranged from 6,681 to 11,750 m^3/s. Water levels in Baird Canyon typically rise sharply from late May through June, level off in July and then peak in August. Sediment loads cause the water to be unusually turbid and fill the river with numerous ephemeral sandbars and channel braids for most of its length.

Two major channel constrictions in the lower Copper River between Miles Lake and the mouth of the Chitina River (rkm 172) offer the potential to capture substantial proportions of migrating chinook salmon using fishwheels. Baird Canyon is the first major channel constriction on the Copper River upstream of Miles Lake that is suitable for operating the capture-tag fishwheels (Fig. 2). The east bank of Baird Canyon is a steep, often sheer, rock wall that rises over 600 m (1,970 ft) above the river. The west bank slopes more moderately to a maximum height of 20 m above the river, is densely wooded and has a substrate ranging from sand to boulders. The land beyond the west bank is primarily a wetland area that drains the Allen Glacier to the west. The north branch of the Allen River enters on the west bank and is the only major tributary entering Baird Canyon.

Wood Canyon is the second major channel constriction on the Copper River upstream of Miles Lake and is located approximately 91 km upstream of Baird Canyon (Fig. 3). The lower end of Wood Canyon, below the mouth of Canyon Creek and the lower boundary of the Chitina Subdistrict dip net fishery, was considered a suitable location for operating the recapture fishwheels. The west bank in this area consists mostly of steep rock walls, whereas the east bank is a mix of sand bars, rock outcroppings and rock walls.

Chinook and sockeye *O. nerka* salmon begin to enter the Copper River in early to mid-May, as rising temperatures and water flush the ice from the river. The majority of the chinook salmon run returns to six main tributaries in the upper Copper River, all of which are upstream of

Baird and Wood canyons (Evenson and Savereide 1999; Evenson and Wuttig 2000). Nearly all chinook and sockeye salmon enter the river by early August (Merritt and Roberson 1986; Evenson and Savereide 1999; Morstad et al. 1999; Evenson and Wuttig 2000; Sharp et al. 2000). Since 1978, ADF&G has operated a sonar system to count salmon at the outlet of Miles Lake. An estimated 700,618 salmon passed the Miles Lake sonar site between 12 May and 31 July 2003 (ADF&G 2003).

From 1995 to 1999, an average of 76,028 Copper River chinook salmon were harvested in commercial (80%), personal use (7%), subsistence (3%) and sport (10%) fisheries (Taube and Sarafin 2001). During this period, commercial harvest of chinook salmon occurred in the Copper River District; personal use harvest occurred in the mainstem of the Copper River between Haley Creek and the mouth of the Chitina River; subsistence harvest occurred in the mainstem of the Copper River from just below the Chitina Bridge upstream to the mouth of the Slana River; and sport harvest occurred in tributaries to the Copper River upstream of Chitina (LaFlamme 1997).

METHODS

Project Mobilization

Hiring and Training

Preferred skills of potential candidates for the fisheries technician positions included: prior experience or formal education in either fisheries science or management, experience in salmon fisheries, experience working in a remote field camp, watercraft operation and maintenance or other technical skills, experience working with Alaska Native Tribes and computer skills or record-keeping abilities. Staff from NVE and LGL Alaska Research Associates, Inc. (Anchorage, AK) conducted interviews (9-10 April) and screened all the applicants. Six people were hired for the fisheries technician positions by mid-April, and an additional three people were hired inseason to work on the project when required. Preseason training consisted of an overview of the project and NVE policies, a first aid course and bear safety videos. Inseason training focused on fishwheel operation, maintenance and safety, boat operation, fish sampling, recording data and basic computer skills.

Permit Requirements

In order to access and operate both field camps and install the fishwheels on the Copper River (including anchoring them to the shore), land-use permits were obtained from the U.S. Forest Service (USFS), Alaska Department of Natural Resources (Division of Mining, Land and Water), Chugach Alaska Corporation, Eyak Corporation and Ahtna Incorporated. Permits were also acquired from ADF&G for fish collection and sampling. All permits were obtained prior to the start of the field season.

Fishwheel Design and Construction

One recommendation in the 2002 annual report was to evaluate options to increase the number of fish in the recovery sample at Canyon Creek. To meet this objective, a second, smaller-sized fishwheel (Fishwheel 4) was designed and fabricated in Cordova and then operated at Canyon Creek in 2003. In March, two aluminum pontoons (11.6 m long x 0.6 m wide x 0.5 m deep) for the new fishwheel were purchased in Cordova. Following a request for bids, Peterson Welding and Machine (Cordova, AK) was contracted to modify the pontoons and fabricate the live tanks and tower assembly used to lift the baskets. Unlike the other project fishwheels, the live tanks of Fishwheel 4 were secured to the outside of either pontoon using a hinge mechanism. Johnny Goodlataw (Tazlina, AK) was contracted in early April to construct four wooden baskets for the new fishwheel, which were similar in design to those he had used on subsistence fishwheels on the upper Copper River (Photo 1). The baskets were framed using lumber (2 m long x 1.8 m wide x 0.8 m deep) and the ribs of the baskets were made from spruce poles. The baskets were lined with knotless nylon mesh (6.4 cm stretch). Bill Webber (Webber Marine and Manufacturing, Inc., Cordova) designed and fabricated the escape panels for Fishwheel 4 which were slightly smaller than the escape panels used on the three large fishwheels.

The other three project fishwheels (fishwheels 1, 2 and 3) were made of two, welded aluminum pontoons (11.6 m long x 0.9 m wide x 0.5 m deep), a 3.7 m long axle, three baskets (3.0 x 3.0 m x 2.1 m) and a tower (6.1 m high) and boom (4.9 m long) assembly that was used to raise and lower the axle. The baskets were designed to fish up to about 3 m below the water surface and were lined with knotless nylon mesh (6.4 cm stretch). An aluminum tank (4.3 m long x 1.5 m deep x 0.6 m wide) for holding captured fish was fitted inside each pontoon. Similar to Fishwheel 4, the bottom of each live tank was fitted with windows of extruded aluminum mesh to allow for ample water circulation.

Mobilizing the Field Camps

At Baird Canyon, a cabin that NVE built in the fall of 2001 served as the field camp in 2003. The cabin was located on the west bank of the Copper River approximately 2 km upstream from the upper end of Baird Canyon (Fig. 2), and was supplied by boat or plane from Cordova. The Canyon Creek camp was located on the east bank of the Copper River approximately 12 km downstream from Chitina, which was the same location used during the 2002 season (Fig. 3). The upriver camp consisted of two Weatherport tents and small sleeping tents for crew members and it was supplied mainly by boat from Cordova and Chitina. Mobilization at both camps was timed to ensure that the fishwheels were operational as soon as the river ice cleared and the first chinook salmon began migrating past each location.

Camp Communication

The field crews followed a specific communication protocol to ensure that the camps were operated as safely and efficiently as possible. Each camp was equipped with a base-station VHF, at least one boat with a VHF radio and several handheld VHF radios for communication during field operations. Every morning at a prearranged time, one crew member from each camp was responsible for contacting the NVE office in Cordova via satellite phone or internet to exchange information (e.g., provide daily fishwheel catches, place food and supply orders,

arrange flights and crew changes). Both camps were equipped with a Starband satellite internet system (McLean, VA) that provided continuous high-speed internet access. These systems were powered by an array of 6-V batteries (wired to provide 12-V power) that were charged by solar panels and a gas-powered generator. The Starband units provided an excellent backup communication system in case of an emergency and the satellite phones did not work. The crew was also able to communicate camp needs in a timely and cost-effective manner, receive feedback on project operations from senior managers and provide daily catch and tag updates to ADF&G biologists and fishery managers.

Fishwheel Operation and Catch

Fishwheel Site Evaluation and Selection

Suitable fishwheel sites were selected based on water depth, water velocity, accessibility, bankfull width and protection from floating debris and rock fall. For the three large fishwheels used on this project, water depths greater than 3 m and velocities ranging from 0.5 to 1.5 m/s (1.6 to 4.9 ft/s) were needed to rotate the baskets at optimal speeds and force migrating fish to travel near shore and into the path of the fishwheels. Narrow, fast-flowing channels tend to concentrate migrating salmon close to shore and are thus preferred to wide, slow-flowing areas. The small, four-basket fishwheel used in 2003 could operate in slower water velocities and shallower depths than the large fishwheels. The basket assembly of Fishwheel 4 could also be raised or lowered as water levels changed throughout the season.

Fishwheel Operation

The three large fishwheels used in 2003 were installed and operated similar to the methods used in previous years (Link et al. 2001; Smith et al. 2003). A rock drill was used to set steel anchor pins into the rock walls at the Baird Canyon and Canyon Creek fishwheel sites. Anchor lines attached to these pins consisted of galvanized wire rope (1.3 cm dia) and polypropylene rope (1.9 cm dia). To hold Fishwheel 4 in place, a boat anchor was buried 1.5 m deep on the river bank approximately 30 m upstream of the fishing site. Wire rope (1.3 cm dia) was then attached to the fishwheel at one end and to the anchor at the other end. Two, propeller-driven, outboard motors were mounted on transoms at the stern of the fishwheel pontoons and were used to move the fishwheels between sites. Fishwheels were re-positioned upriver and downriver by adjusting the bow anchor lines, and laterally by adjusting the stern and side anchor lines. Fishwheel 3 at Canyon Creek had an aluminum spar pole mounted across the bow that was used to adjust the distance of the fishwheel from shore. Similarly, a 6-m long, aluminum plank was used to hold Fishwheel 4 offshore.

The fishwheels were operated 24 hours per day, except for stoppages when they were being re-positioned or repaired. Fishwheel speed (revolutions per minute, RPM) was determined one or more times each day by measuring the time required for the fishwheel baskets to complete three revolutions, thus mitigating for the effects of temporary surges in water velocity. If fishwheel speed was recorded more than once in a day, the arithmetic mean of the measurements was calculated. Daily water temperature (^{o}C) and water level (m) were recorded at the Baird

Canyon and Canyon Creek fishwheels. Water levels at both camps were measured from an aluminum staff gauge that was secured to the canyon wall near the fishwheels.

Fishwheel Catch and Effort

Two forms of fishwheel effort were calculated. First, *daily fishing effort* was computed as the number of hours that a fishwheel operated on a given calendar day from midnight to midnight. Second, *effort for calculating catch per unit effort (CPUE)* was computed as the number of hours that a fishwheel fished to obtain a given day's catch. These two effort values were often not the same for a given day because the live tanks were not always emptied of fish at the exact same times each evening. For example, if fish were last sampled at 2200 hours on day t and last sampled on day t+1 at 2000 hours, then only 22 hours of fishing effort was used to obtain the *effort for calculating CPUE* on day t+1 (assuming uninterrupted fishwheel operation). However, in this example, the *daily fishing effort* on day t+1 would be 24 hours because the fishwheel operated continuously for the entire calendar day. *Effort for calculating CPUE* on day t+1 could also exceed 24 hours if the last sampling session on day t was earlier in the day than the last sampling session on day t+1. To calculate CPUE (fish per fishwheel hour), the total number of fish captured on a given calendar day was divided by that day's effort for CPUE.

Escape panels

In order to reduce the potential for high densities and crowding of fish in the live tanks, escape panels were installed in the live tanks of all four fishwheels in 2003 (see Photo 6 on p. 84 in Smith et al. 2003). The escape panels consisted of two, adjustable vertical slots in a removable aluminum frame. When installed and opened to the appropriate width (6 to 7.5 cm), the escape panels allow smaller fish (e.g., sockeye and other by-catch species) to easily swim out of the live tanks while retaining chinook salmon. As a result, the escape panels reduce crowding and the potential for sampling mortalities during high-catch periods as well as the amount of crew labor for handling fish.

Tag Application and Recovery

Two to four times per day, depending on catches, crews at Baird Canyon and Canyon Creek removed all fish in the live tanks of each fishwheel. All adult chinook salmon were counted, sexed, measured for length, inspected for an adipose fin (a missing adipose fin indicated a coded-wire-tagged, or CWT fish) and examined for marks, scars or bleeding. Fork lengths, measured from the tip of the nose to the fork of the tail, were collected in 2003. Chinook salmon were transferred with a dip net from the live tanks to a V-shaped, water-filled, foam-lined trough (with a fixed measuring tape) for sampling. Water in the trough was changed repeatedly throughout each sampling session. All other captured fish were identified to species, counted and released.

Tag Application

At Baird Canyon, chinook salmon greater than 500 mm FL and in good condition were either marked with a radio tag and gray spaghetti tag, or they were marked with a yellow

spaghetti tag and right operculum punch. Since the fishwheels were expected to capture more fish than ADF&G had planned to radio tag (~ 500 fish), only a portion of each day's catch was radio-tagged. Once the daily radio-tagging goal was met, the remaining fish were marked with a yellow spaghetti tag and a right operculum punch.

The radio tags were Model Five transmitters made by Advanced Telemetry Systems (Isanti, MN). Each radio tag was identified by a frequency and pulse-encoded pattern. Chinook salmon that received a radio tag were supported in the trough while a radio tag was inserted into the upper stomach using a 45-cm piece of polyvinyl chloride (PVC) tubing. All marked fish received a uniquely-numbered spaghetti tag (Floy Tag and Manufacturing Co., Inc., Seattle, WA) constructed of a 5-cm section of Floy tubing shrunk onto a 38-cm piece of 80-lb monofilament fishing line. Using a 10-cm hypodermic needle (16 gauge), the monofilament was sewn through the musculature of the fish 1-2 cm ventral to the insertion of the dorsal fin between the third and fourth fin rays from the posterior of the dorsal fin. The tag was secured by crimping (1.3 mm crimps) the monofilament line.

Tag Recovery

In addition to the general sampling procedures described above (i.e., counting, recording length and sex, and examining for adipose fin and physical marks), all chinook salmon caught at the Canyon Creek fishwheels were examined for a radio tag, spaghetti tag and right operculum punch. If a fish was marked, the spaghetti-tag number was recorded. Prior to release, all unmarked fish received a left operculum punch in order to identify them as previously caught at the Canyon Creek fishwheels.

Chinook salmon tagged at the Baird Canyon fishwheels were recovered throughout the Copper River Basin (these recoveries were not used in the calculations of abundance). Recovery locations included the Chitina Subdistrict dip net (CSDN) fishery between Haley Creek and Chitina, Glennallen Subdistrict Subsistence (GSS) fishwheel fishery upstream of Chitina, sport fishery in upper Copper River tributaries and commercial gillnet fishery near the mouth of the Copper River. Recovered tags were sampled during ADF&G Creel surveys in Chitina and Glennallen or the tags were returned to NVE or ADF&G by fishery participants (addresses for the NVE or Fairbanks ADF&G offices were printed on the spaghetti tags).

Inriver Abundance Estimate

Conditions for a Consistent Abundance Estimate

Two-sample mark-recapture methods were used to estimate the inriver abundance of adult chinook salmon above the Baird Canyon fishwheels. These abundance estimates are potentially biased if any of the assumptions inherent to the mark-recapture model are violated (Ricker 1975; Seber 1982). The following assumptions are relevant to this study and are similar to those examined by ADF&G in recent chinook salmon radiotelemetry studies on the Copper River (Evenson and Wuttig 2000; Wuttig and Evenson 2001; Savereide and Evenson 2002; Savereide 2003).

Handling and tagging fish did not make them more or less vulnerable to recapture than untagged fish.

There was no explicit test for this assumption because the behavior of untagged fish could not be assessed. Sampling sessions were frequent (minimum of three times per day) to ensure that fish were not retained in the live tanks for long periods of time. Escape panels were used in 2003 to reduce fish densities in the live tanks, particularly during periods of high sockeye catches. Technicians were trained by experienced biologists on how to handle and sample fish in order to reduce the amount of stress on the fish. Visibly stressed or injured fish were not tagged. Also, the distance between the tag and recapture sites (91 km) was probably sufficient enough to reduce the potential of handling-induced "trap shyness" in tagged fish.

Tagged fish did not lose their tags, and there was no mortality of tagged fish between the tagging and recovery sites.

Only chinook salmon that received both a primary and secondary mark at Baird Canyon were included in the calculations of abundance, so the chance of a fish losing both marks between sampling events was assumed to be negligible. Similarly, only fish that were examined for both marks at Canyon Creek were included in the analysis. Radio-tagged fish that were not detected at or above Canyon Creek on fixed-station receivers or during aerial-tracking surveys were classified as "failures" and removed (or censored) from the study.

Tagged fish mixed completely with untagged fish between the sampling events.

Since both banks of the river were sampled during both events in 2003, the recapture rates for fish tagged on each bank were compared using contingency table analysis. Independence between bank of tagging and bank of recapture was also tested. Studies from 1999-2001 showed equal mixing of tagged and untagged chinook salmon between the lower end of Wood Canyon and the CSS fishery (Evenson and Wuttig 2000; Wuttig and Evenson 2001; Savereide and Evenson 2002), a much shorter distance than between the Baird Canyon and Canyon Creek fishwheels.

Fish had equal probabilities of being marked or equal probabilities of being recaptured regardless of size or sex.

Sex-selective sampling was tested by comparing the ratio of fish recaptured and not recaptured of each gender at the Canyon Creek fishwheels. To test for size-selective sampling at the fishwheels, Kolmogorov-Smirnov (K-S) two-sample tests (Zar 1984) were used to compare the cumulative length-frequency distributions of: (1) all fish tagged during the first sampling event and all fish recaptured during the second event; and (2) all fish tagged during the first sampling event and all fish examined during the second event (as presented in Bernard and Hansen 1992). If sex-selective sampling was detected, the tests for size selectivity would be performed for males and females separately, otherwise data were pooled for both sexes.

Fish had equal probabilities of being marked regardless of time of capture.

Apart from minor fishwheel stoppages for repairs and moves, fishing effort at the Baird Canyon fishwheels was continuous throughout the study period. Weekly mark rates in the second event were compared using contingency table analysis to determine whether this condition was met.

Marked fish had equal probabilities of being recaptured regardless of when they passed the recapture fishwheel.

Weekly recapture rates in the second event were compared using contingency table analysis. If both the mark rates and recapture rates varied among weeks, and a sufficient number of recaptures were available, a temporally stratified estimator would be used.

Abundance Estimate

A temporally stratified estimator using the method of (Darroch 1961) was used to estimate abundance above Baird Canyon. The computer program SPAS (Arnason et al. 1996) was used to calculate the abundance estimate, standard error and 95% confidence limits.

RESULTS

Project Mobilization

Mobilizing the Field Camps

Baird Canyon

Mobilization of the Baird Canyon camp began on 7 May 2003. Three round-trip flights (Cessna 206 on floats) were required to transport a crew of five people, equipment and supplies from Cordova to the NVE cabin. There was no snow on the ground or river ice present in the Baird Canyon area in early May (Photo 2). Both Baird Canyon fishwheels were stored at the cabin over the winter and re-assembled on site. Fishwheel 2 was floated downstream from the cabin to Baird Canyon and began fishing on 11 May, while Fishwheel 1 was floated downstream on 14 May and began fishing on 16 May. Overall, it took 7 d to mobilize the Baird Canyon camp and two fishwheels. The ADF&G radiotelemetry crew arrived at camp on 13 May to install two fixed stations upstream of the Baird Canyon fishwheels.

Canyon Creek

Mobilization of the Canyon Creek fishwheels began on 14 May with a three-person crew transporting Fishwheel 4 and supplies from Cordova to Chitina via the ferry to Valdez (Photo 3). From 15-20 May, several trips were made by truck to transport a boat and camp supplies from storage facilities in Glennallen to Chitina. The boat was then used to ferry personnel and

equipment from Chitina downstream to the field camp. Fishwheel 4 was assembled on the east bank of the Copper River near Chitina and floated downstream to its eventual fishing site near the lower end of Wood Canyon on 20 May. It became operational on 21 May. Fishwheel 3 was stored at the Canyon Creek camp over the winter. It was re-assembled on site and began fishing on 25 May. Mobilizing the two fishwheels and camp took approximately 11 d.

Fishwheel Operation and Catch

Fishwheel Operation

Baird Canyon

Copper River water levels at Baird Canyon varied by 5.2 m from 19 May to 9 July (Fig. A-1; Table A-1). Water levels increased gradually from 19 May to 8 June and showed dramatic increases from 9-15 June (+1.9 m) and 1-9 July (+2.4 m). From 15 May to 7 June, water levels at the Million Dollar Bridge (located at the outlet of Miles Lake) were below the 1982-2002 average and well below 2002 levels (Fig. A-2). Water levels were also lower than the 1982-2002 average from 22 June to 4 July and 28-31 July. Conversely, water levels at the Million Dollar Bridge were above the historical average from 8-21 June and 5-27 July, and exceeded the highest water levels seen in 21 years on 18 July. Average daily water temperature at Baird Canyon ranged from 6.1 to 10.6 ^{o}C from 17 May to 9 July.

Fishwheel 1 began fishing at Site 2 along the east bank of the Copper River at the upper end of Baird Canyon at 1120 hours on 16 May (Fig. 2; Photo 4; see Table B-1 for a description of the fishwheel sites used in 2003). Due to low water levels in mid-May, a spar log was used to hold the fishwheel approximately 3 m off the bank in deeper, faster-flowing water. By 13 June, water levels and velocities had increased substantially, so the spar log was removed and the fishwheel was moved closer to shore. Fishwheel 1 was shut down on 2 July because of problems with the camp boat and it was stopped for the season at 1030 hours on 9 July. Fishwheel 1 operated for 1,263 h from 16 May to 9 July or 98% of the time it was in place (Fig. B-1; Table B-2).

Fishwheel 2 began fishing at 1800 hours on 11 May. It was initially operated at Site 1 (The Rock), located along the west bank of Baird Canyon approximately 200 m upstream from the mouth of the north branch of the Allen River. However, low water velocity at the time would not turn the baskets. On 15 May, strong winds managed to turn the baskets enough to capture one chinook and one sockeye salmon (the first fish of the season at Baird Canyon). Fishwheel 2 was moved to Site 2 on 16 May and began fishing directly behind Fishwheel 1 at 0930 hours on 24 May. Due to low chinook salmon catches, Fishwheel 2 was moved to a new site (Site 3) on the west bank of the Copper River directly across from Site 1 (Photo 5). Fishwheel 2 began fishing at Site 3 at 1145 hours on 2 June. On 12 June, rising water levels caused the fishwheel to shift in shore and as a result the baskets sustained major damage. This led to a considerable amount of down time from 12-18 June while the baskets were being repaired. Site 3 eventually became unsuitable due to high water velocities, so Fishwheel 2 was moved back to Site 1 began fishing in tandem with Fishwheel 1 at 1500 hours on 3 July. Fishwheel 2 was stopped for the season at 0930 hours on 9 July. Fishwheel 2 operated for 930 h from 11 May to 9 July or 84% of

the time. Fishwheel speed averaged 2.4 and 2.5 RPM for fishwheels 1 and 2, respectively (Fig. B-1; Table B-2).

Canyon Creek

Water levels at the Canyon Creek fishwheels varied by 3.8 m from 26 May to 19 July, and water temperature ranged from 6.7 to 13.3 ^{o}C from 23 May to 18 July (Fig. A-1; Table A-1). Fishwheel 3 began operating at 1330 hours on 25 May at Site 4, located on the west bank of the Copper River approximately 2.3 km downstream from the mouth of Canyon Creek (Fig. 3). Due to low chinook salmon catches, Fishwheel 3 was moved on 31 May to a new site (Site 5) on the west bank approximately 2 km downstream from the mouth of Canyon Creek. It operated there from 1-4 June and was moved back to Site 4 on 4 June. On 22 June, Fishwheel 3 was moved to a new site (Site 6) located approximately 100 m upstream of Site 4 on the west bank of the river (Photo 6). The majority of down time was caused by damage to the axle on 1 July and 9 July. Catches remained low, so Fishwheel 3 was moved on 9 July to Site 7 on the east bank approximately 2.7 km downstream from the mouth of Canyon Creek and 300 m upstream from camp (Photo 7). A steady increase in water level and velocity led to substantial damage to the live tanks and baskets and the fishwheel was stopped at 1000 hours on 18 July. Fishwheel 3 operated for 1,160 h (90% of the time) and averaged 2.8 RPM (Fig. B-1; Table B-2).

Fishwheel 4 became operational at Site 8 at 1740 hours on 21 May. Site 8 was located along a gravel bar on the west bank of the Copper River approximately 500 m downstream from the mouth of Canyon Creek (Photo 8). Biologists from ADF&G recommended this site because of their success at dip netting chinook salmon there during a 1999-2001 radiotelemetry study (Evenson and Wuttig 2000; Wuttig and Evenson 2001; Savereide and Evenson 2002). A 6-m long aluminum plank was used to hold the fishwheel off the bank and keep it fishing in deep water. On a regular basis the fishwheel was moved in or offshore, and the basket assembly was raised or lowered, to keep the baskets fishing as close to the river bottom as possible. On 8 July, the river had reached a level where the gravel bar at Site 8 became completely submerged. The fishwheel was then moved to Site 9, located in front of the camp along the east bank of the river approximately 3 km downstream from the mouth of Canyon Creek (Photo 9). On 20 July, the baskets of the fishwheel were extensively damaged and it was shut down for the season. The majority of down time was caused by damage to the axle, baskets and slides. Fishwheel 4 operated for 1,315 h from 21 May to 20 July (92 % of the time) and averaged 5.5 RPM (Fig. B-1; Table B-2).

Fishwheel Catch and Effort

Baird Canyon

A total of 2,251 adult chinook salmon were captured at the Baird Canyon fishwheels. Fishwheel 1 captured 1,055 (47%) fish from 17 May to 9 July and Fishwheel 2 captured 1,196 (53%) fish from 15 May to 9 July (Fig. 4; Table C-1). Daily catches of chinook salmon exceeded 50 fish from 2-9 June and 18-26 June and peaked at 156 fish (51 in Fishwheel 1, 105 in Fishwheel 2) on 3 June. Daily CPUE peaked at 4.9 fish per hour on 4 June at Fishwheel 2 and 2.6 fish per hour on 19 June for Fishwheel 1 (Fig. 5; Table C-1). Similar to 2002, there were three pulses of fish migrating through Baird Canyon: a small pulse from 16-31 May, a large

pulse from 1-15 June and a moderate-sized pulse from 15 June to 2 July. One chinook salmon was coded-wire-tagged.

Sockeye salmon catches were low at Baird Canyon (1,495 in Fishwheel 1 and 353 in Fishwheel 2) as a result of using escape panels in the live tanks (Fig. 6; Table C-2). Other species captured included 9 Dolly Varden *Salvelinus malma*, 21 whitefish *Coregonus sp.*, 24 salmon smolts *Oncorhynchus sp.*, 1 Pacific lamprey *Lampetra tridentata*, 4 suckers *Catostomus sp.*, 1 burbot *Lota lota* and 1 Arctic grayling *Thymallus arcticus*.

Canyon Creek

A total of 1,928 chinook salmon were captured at the Canyon Creek fishwheels. Fishwheel 3 captured 446 (23%) fish from 25 May to 18 July and Fishwheel 4 captured 1,482 (77%) fish from 21 May to 20 July (Fig. 4; Table C-1). Daily catch peaked at 96 fish (9 in Fishwheel 3, 87 in Fishwheel 4) on 17 June. Daily CPUE peaked at 1.1 fish per hour on 28 June at Fishwheel 3 and 3.4 fish per hour on 17 June at Fishwheel 4 (Fig 5; Table C-1). Similar to Baird Canyon, although somewhat less distinct, there were three main pulses of chinook salmon migrating past the Canyon Creek fishwheels (21 May to 12 June, 13 June to 2 July and 3-20 July). Five chinook salmon were coded-wire-tagged. A total of 243 sockeye salmon, 10 salmon smolts, 1 Dolly Varden, 5 whitefish and 1 sucker were also captured (Fig. 6; Table C-2).

Escape panels

Escape panels were used in the live tanks of all four fishwheels (see Table D-1 for escape panel settings). Tests were conducted on 26 June and 27 June at Baird Canyon in order to more precisely estimate the efficiency of the escape panels. For each of these tests, the live tanks of both fishwheels were emptied, the escape panels were opened and then catches were visually monitored over a 3-h period. At the end of each monitoring period, all fish in the live tanks were counted and released. The proportion of sockeye salmon that escaped from each live tank ranged from 69% to 100%, while none of the eight chinook salmon that were captured during the tests escaped (Table D-2).

Tag Application and Recovery

Tag Application

Of the 2,251 adult chinook salmon captured at the Baird Canyon fishwheels, 2,077 (92%) fish were marked and released (Fig. 7; Table E-1). Of these marked fish, 1,577 (76%) received a spaghetti tag as the primary mark and 500 (24%) received a radio tag. The number of marks applied on a single day peaked at 149 (99 spaghetti tags, 50 radio tags) on 3 June. A total of 174 fish were not marked because they escaped prior to being sampled (72), were injured/stressed (96), were coded-wire-tagged (1) or were mortalities (5).

Tag Recovery

Of the 1,928 chinook salmon captured at the Canyon Creek fishwheels, 1,844 (96%) were examined for both primary and secondary marks (Fig. 7; Table E-1). Of those examined, 100 (5.4%; 73 spaghetti tags, 27 radio tags) were recaptures or fish that were marked at the Baird Canyon fishwheels. The first marked fish was captured at Canyon Creek on 26 May (tagged on 19 May), while the last marked fish was captured on 20 July (tagged on 20 June). The number of fish examined for marks at Canyon Creek peaked at 94 fish on 17 June and the number of recaptures peaked at 8 fish on 22 June. Eighty-four fish escaped prior to being examined for both marks. There were 347 marked fish (190 spaghetti tags, 157 radio tags) recovered in the various inriver fisheries and three spaghetti-tagged fish recovered in the commercial gillnet fishery.

Travel time

The median travel time of fish tagged at Baird Canyon and recaptured at Canyon Creek was 13 d (range = 5-30 d, n = 101, Fig. 8). Travel times for spaghetti-tagged fish (13.2 d, n = 75) and radio-tagged fish (17.5 d, n = 26) were significantly different (two-tailed *t*-test; df = 99, $P < 0.01$).

Inriver Abundance Estimate

Censored Tags

A total of 354 fish in the first event (Table 2) and 214 fish in the second event (Table 3) were censored from the abundance calculations. Twelve fish (3 spaghetti tags, 9 radio tags) were censored because they were tagged prior to 17 May or after 1 July when the Baird Canyon fishwheels were not operating effectively (due to low/high water levels and boat problems which prevented the crew from visiting the fishwheels). Only two tagged fish captured in the second sampling event measured less than 810 mm or greater than 1,070 mm FL. Since there was essentially no information on the probability of capture of these fish, an abundance estimate that included these size classes could not be calculated without bias. As a result, 316 fish sampled in the first event and 210 fish sampled in the second event that fell into these size classes were censored (this included 14 fish for which no length measurement was recorded). Only fish that measured 810 mm to 1,070 mm FL were included in abundance calculations. Of the remaining 424 uncensored radio-tagged fish, 26 (6.1%) were classified as "failures" by ADF&G because they were never detected at or above the Canyon Creek fishwheels on fixed-station receivers or during aerial-tracking surveys.

Conditions for a Consistent Estimator

The probability of capture for fish at Canyon Creek appeared to be unaffected by the handling and tagging procedures at Baird Canyon. Recapture rates of spaghetti-tagged (5.4%) and radio-tagged fish (6.3%) were not significantly different ($\chi^2 = 0.41$, df = 1, $P = 0.52$; Table F-1). There were no signs of significant migratory delays after release at Baird Canyon. Of the eight fish recaptured at the Baird Canyon fishwheels (for which the spaghetti-tag number was

recorded), six were recaptured within 24 h of being tagged, one was recaptured 2 d after being tagged and one was recaptured 4 d after being tagged. Tag loss and natural mortality were assumed to be negligible between the sampling events. One tagged fish captured at Canyon Creek had shed its spaghetti tag and a second fish had regurgitated its radio tag, but both were identified by the remaining mark.

Tagged fish appeared to move equally between banks after release ($\chi^2 = 4.74$, df = 2, P = 0.09; Table F-3). Of the 865 fish tagged on the west bank that were considered available for recovery, 46 (5.3%) were recaptured on the west bank and 12 (1.4%) were recaptured on the east bank. Of the 858 fish tagged on the east bank and available for recovery, 34 (3.9%) were recaptured on the west bank and 5 (0.6%) were recaptured on the east bank. Recapture rates of fish released on the west bank (6.7%) were not significantly different than recapture rates of fish released on the east bank (4.5%; $\chi^2 = 3.78$, df = 1, P = 0.05; Table F-3).

Recapture rates for male (4.9%) and female (6.0%) fish were not significantly different ($\chi^2 = 0.88$, df = 1, P = 0.35), indicating that the probability of a fish being recaptured was not influenced by gender. Cumulative length-frequency distributions of fish (≥ 530 mm FL; excluding radio-tag failures) marked in the first event and fish recaptured in the second event were not significantly different ($D_{max} = 0.11$, P = 0.20, Fig. 9). In contrast, the cumulative length-frequency distributions of fish marked in the first event and fish examined for marks in the second event were significantly different ($D_{max} = 0.07$, P = 0.00). Based on these tests, there was no size selectivity during the second sampling event but there was during the first sampling event. However, because escape panels were used and there were few small (< 810 mm FL) and large (> 1,070 mm FL) fish recaptured, abundance calculations were restricted to fish measuring 810 to 1,070 mm FL.

The probability of a fish being marked at Baird Canyon was not independent of time of capture. Capture statistics were summarized by week of marking and week of recapture over the study period (Table 3). Weekly mark rates were significantly different ($\chi^2 = 36$, df = 8, P < 0.01) and varied from 0.01 (28 May to 3 June) to 0.15 (16-20 July). Weekly recapture rates varied from 0.02 to 0.08 but were not significantly different ($\chi^2 = 10.3$, df = 7, P = 0.17). However, when consecutive weeks with similar mark and recapture rates were pooled, significant test statistics were obtained for both tests (Table 4). These results indicated that the capture probabilities during both sample events were not independent of time.

Abundance Estimate

One potential source of bias identified by the tests of consistency was unequal capture probabilities over the study period. Therefore, a temporally stratified estimator using the methods of Darroch (1961) was used to estimate abundance. Estimated abundance of chinook salmon measuring 810 to 1,070 mm FL that migrated upstream of Baird Canyon from 17 May to 1 July was 44,764 (SE = 12,506, Table 5). This estimate was based on 1,723 tagged fish available for recapture (1,325 spaghetti tags, 398 radio tags), 1,630 fish examined for tags and 97 recaptures (72 spaghetti tags, 25 radio tags).

DISCUSSION

Project Mobilization

Similar to 2002 there was some uncertainty in the days leading up to the field season about when to mobilize the field camps. If the fishwheels were mobilized too early (i.e., when river ice and snow cover were still present), then there was a risk of spending a substantial portion of the limited budget prior to tagging any fish. If the fishwheels were mobilized too late, then the first pulse of chinook salmon migrating through Baird Canyon may not have been captured and marked. Mobilization at Baird Canyon in 2003 took 7 d (7-14 May), which was half as long as it took in 2002 (9-23 May). Successful mobilization in 2003 was attributed to: (1) the absence of river ice and snow; (2) the experience gained from two prior field seasons assembling and installing fishwheels; (3) the availability of a cabin stocked with the majority of supplies needed for mobilization; and (4) the fact that several fishwheel sites were already selected and prepared for use.

Mobilization at Canyon Creek took 11 d in 2003 (14-25 May). This was similar in duration to the mobilization time required in 2002 (10-20 May); however, a second fishwheel was added to the recovery effort in 2003. There was no on-site storage at the Canyon Creek camp like there was at Baird Canyon, so the majority of time was spent transporting equipment and supplies from Cordova to Chitina by ferry, from a storage locker in Glennallen to Chitina by truck and from Chitina downstream to the camp by boat. In hindsight, the timing and execution of mobilization at both camps was suitable given the environmental conditions in early May.

Fishwheel Operation and Catch

Fishwheel Site Evaluation and Selection

Due to low water levels and velocities in May 2003, Site 2 at Baird Canyon was not as suitable for operating a fishwheel as it was in 2002. The fishwheel at Site 2 required frequent adjustments and a spar pole to hold it 2-3 m off the river bank in faster-flowing water. The gap between the fishwheel baskets and shore may have allowed chinook salmon to swim past the fishwheel without risk of capture. In addition, slow water velocities at Site 2 early in the season prevented two fishwheels from operating in tandem as effectively as they did in 2002. Despite these drawbacks, 1,137 chinook salmon were captured at Site 2 in 2003.

When it became apparent that Site 2 would not be suitable for operating two fishwheels in tandem in the early season, Fishwheel 2 was moved to a new location (Site 3) on the west bank of the river. Catches of chinook salmon were substantial during the first three days of operation at Site 3 (105 on 3 June, 108 on 4 June, 117 on 5 June). Fishwheel 2 captured a total of 1,112 chinook salmon at Site 3 in 2003. By 1 July, rising water levels and increasing velocities made it too difficult to operate the fishwheel at Site 3, so it was moved back to Site 2 and fished in tandem with Fishwheel 1. Based on the past three years of field work, it is recommended that at least one fishwheel be operated at Site 2 for the entire season, and one fishwheel be operated at Site 3 when water conditions are deemed suitable.

With the addition of a second recovery fishwheel (Fishwheel 4) in 2003, the efficiency of Fishwheel 3 could be assessed inseason. If catches were high for an extended period at Fishwheel 4, but not at Fishwheel 3, then the crew would either make minor adjustments or move Fishwheel 3 to a new site. Fishwheel 3 was operated at three sites (Sites 4, 5 and 6) on the west bank and one site on the east bank (Site 7) near the lower end of Wood Canyon in 2003. In total, 446 chinook salmon were captured at Fishwheel 3 in 2003, which was 34% fewer than in 2002 (676 fish). This difference was likely attributable to the anomalous water conditions seen in 2003. A 15-30 m wide, deep channel extended along the length of the west bank of the river where Fishwheel 3 was operated in 2003. At low water levels, the water velocity offshore was not high enough to force fish to migrate near shore and in the path of the fishwheel. At higher water levels the sites were simply too deep. Based on the relatively low catches at Fishwheel 3 in the past two years, it is recommended that either (1) a new site be used for Fishwheel 3 in 2004; (2) smaller baskets be built for Fishwheel 3 so that it can be operated at shallower sites and along gravel bars (similar to Fishwheel 4); or (3) a second small fishwheel be built and operated at Canyon Creek (and keep Fishwheel 3 as a backup).

The new fishwheel (Fishwheel 4) used at Canyon Creek in 2003 captured 1,288 chinook salmon. A large part of this success was due to the fact that the baskets could be raised and lowered with changes in water levels. As a result, the fishwheel was operated with little or no gap between the outer edge of the baskets and the river bottom. Since the pontoons and baskets were small, the fishwheel could also be operated close to shore. The main disadvantage of the new fishwheel was the amount of down time caused by damage to the axle and baskets. It is recommended that the same site be used again in future studies and that a stronger axle and more durable baskets be constructed to reduce the amount of down time.

Fishwheel Catch and Effort

Catches of chinook salmon at the Baird Canyon fishwheels were 48% greater in 2003 (2,251) than catches in 2002 (1,518). Daily catch peaked at 156 chinook salmon on 3 June in 2003 whereas the highest daily catch was only 98 fish (5 June) in 2002. The most significant factor in this increase was the discovery of a new and productive fishwheel site (Site 3) in 2003. At Canyon Creek, chinook salmon catches increased by 185% in 2003 (1,928 fish) relative to 2002 (676 fish). This difference was due entirely to the addition of a second, smaller-sized fishwheel that captured 1,482 fish. In contrast, Fishwheel 3 captured 35% fewer fish in 2003 (442) than it did in 2002 (676) despite operating at the same location for the majority of the season. As stated earlier, stage height of the Copper River at Canyon Creek probably contributed to this decrease in catch at Fishwheel 3, as water levels were below the historical average early in the season and then well above the historical average later on.

Inriver Abundance Estimate

One of the main goals for the 2003 season was to increase the sample sizes for both sample events, but particularly at Canyon Creek, with the addition of a second recovery fishwheel and making minor adjustments to existing fishwheel sites. Compared to 2002, 72% more fish were marked at Baird Canyon, 181% more fish were examined for marks at Canyon

Creek and five times as many fish were recaptured in 2003. Increased sample sizes made it easier to test the various model assumptions and identify potential sources of bias in the estimate.

For the estimate to be unbiased (consistent), every fish must have had an equal chance of being marked at Baird Canyon, or every fish must have had an equal chance of being examined at Canyon Creek, or marked and unmarked fish must have mixed completely between Baird Canyon and Canyon Creek. For the latter criteria, differences in migratory timing of fish bound for different tributaries (e.g., Chitina and Gulkana rivers) precluded complete mixing of marked and unmarked fish in the population. Weekly mark rates were significantly different (Tables 4 and 5) and tended to increase over the study period, indicating that fish were not marked at Baird Canyon in proportion to their passing abundance. Similarly, weekly recapture rates were significantly different (Table 5), indicating that marked fish did not have an equal probability of capture in the second sampling event. Abundance estimates can be sensitive to a failure of this assumption. For example, if the recapture rate were higher than expected under the assumption of equal catchability, then the abundance estimate would be biased high. Flow-related changes in fishwheel catchability have been shown to effect capture probability on fishwheel studies in other systems (Pahlke and Bernard 1996; McPherson et al. 1997; Hebert and Bruden 1998). Fishwheel sites, and the specific position of fishwheels at those sites, should continue to be refined to ensure that catchability remains relatively constant over a range of water levels.

The 2003 abundance estimate was calculated for fish passing through Baird Canyon from 17 May to 1 July; however, there were some fish moving through Baird Canyon both earlier and later than this period. The first chinook salmon was captured on 15 May at Baird Canyon (albeit the result of high winds and not water velocity turning the fishwheel baskets at Site 1) and 11 fish were captured from 3-8 July (none of which were recaptured). Since the fishwheels were not operating effectively during these times, these early and late-run fish had a low probability of being captured and marked. As a result, the 2003 abundance estimate may be biased low by an unknown but likely small amount. Only two fish were captured at Fishwheel 4 from 21-24 May so it was unlikely that many fish migrated past Canyon Creek before the recovery fishwheels became operational. Preventative maintenance and site refinements will help keep the fishwheels operating effectively throughout the entire run, particularly during periods of anomalous water conditions.

The abundance estimate also excluded fish measuring less than 810 mm FL or greater than 1,070 mm FL because there were too few recaptures in these size classes to determine their capture probabilities. Smaller-sized fish are often not reported in abundance estimates in Alaska because they consist mainly of three-year-old (2-ocean) males that are considered surplus to spawning requirements. However, the effects of censoring larger-sized fish could be more substantial. For example, 7.4% (292/3,937) of fish sampled at the fishwheels and 7.3% (58/794) of fish sampled in the Copper River District measured greater than 1,070 mm FL (Steve Moffitt, ADF&G, Commercial Fisheries Division, *personal communication*). If the estimate of 44,764 fish were expanded by 7.4% to account for these larger-sized fish, then the abundance of chinook salmon measuring 810 mm FL or more was 48,077.

CONCLUSIONS

This year (2003) was the third and final year of a project to examine the feasibility of using fishwheels for long-term monitoring of chinook salmon escapement on the Copper River. Notable achievements in 2003 included the design and fabrication of a new fishwheel using traditional knowledge of subsistence fishwheels, finding a new and productive fishwheel site at Baird Canyon and increasing the number of fish sampled during both events. Despite the numerous and often significant challenges encountered during this study, it has continued to meet or exceed all project objectives and expectations. Drainage-wide abundance estimates were generated in two out of three years, and the project has evolved into a long-term monitoring program that has made NVE an integral part of Copper River salmon research. In addition, this project has demonstrated that several agencies (e.g., USFWS, NVE, ADF&G) can work cooperatively to collect valuable data on Copper River salmon stocks that will be used to assess current management practices. Based on the first three years of results, it appears that fishwheels and mark-recapture methods can be used to estimate the inriver abundance of chinook salmon on the Copper River.

RECOMMENDATIONS

In light of the preceding discussion and the fact this project has been approved for continued funding by the Federal Subsistence Board, the following are recommended for the 2004 field season:

(1) Begin mobilization at Baird Canyon on 5 May; and on 12 May at Canyon Creek;
(2) Operate one fishwheel at Site 2 and one fishwheel at Site 3 at Baird Canyon;
(3) Find a new site for Fishwheel 3 and investigate whether smaller baskets would be more suitable for sites that are available downstream of Wood Canyon;
(4) Investigate whether a second small fishwheel would be suitable at Canyon Creek;
(5) Continue to operate Fishwheel 4 at Site 8 along the gravel bar upstream of camp;
(6) Modify the baskets and axle of Fishwheel 4 so that the amount of down time required for maintenance is reduced; and
(7) Continue to use the escape panels in each fishwheel with the openings set to a width of 6.5 to 7.0 cm.

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This project (FIS01-020) was approved by the Federal Subsistence Board, managed by the U.S. Fish and Wildlife Service, Office of Subsistence Management and funded by the USFS. This project was a cooperative effort between the USFS, NVE, LGL and ADF&G, and this annual report partially fulfills contract obligations for USFS Contract #53-0109-2-00591.

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FIGURES

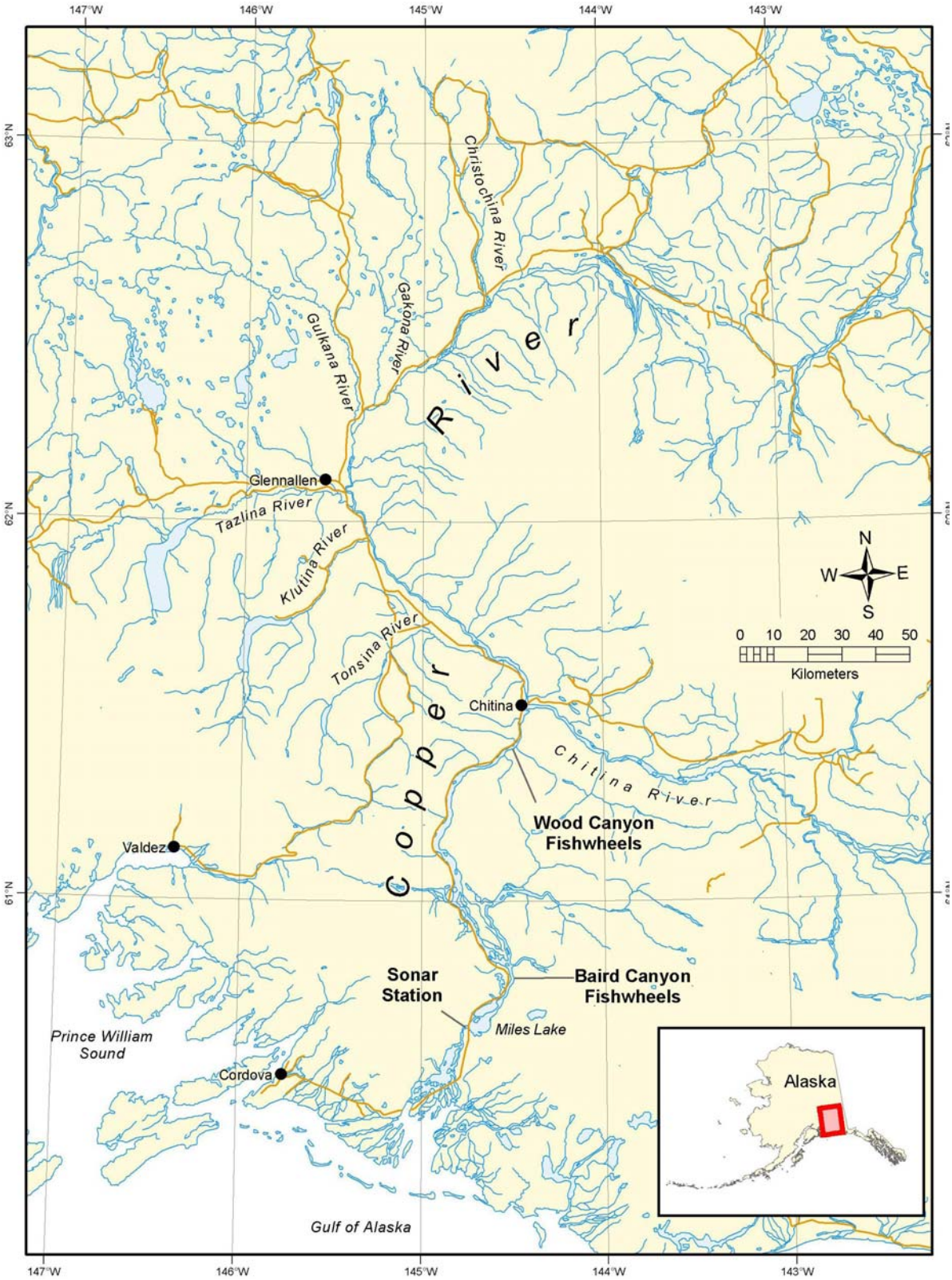


Figure 1. Map of the study area showing the location of the Baird Canyon and Wood Canyon fishwheels on the Copper River in Alaska, 2003.

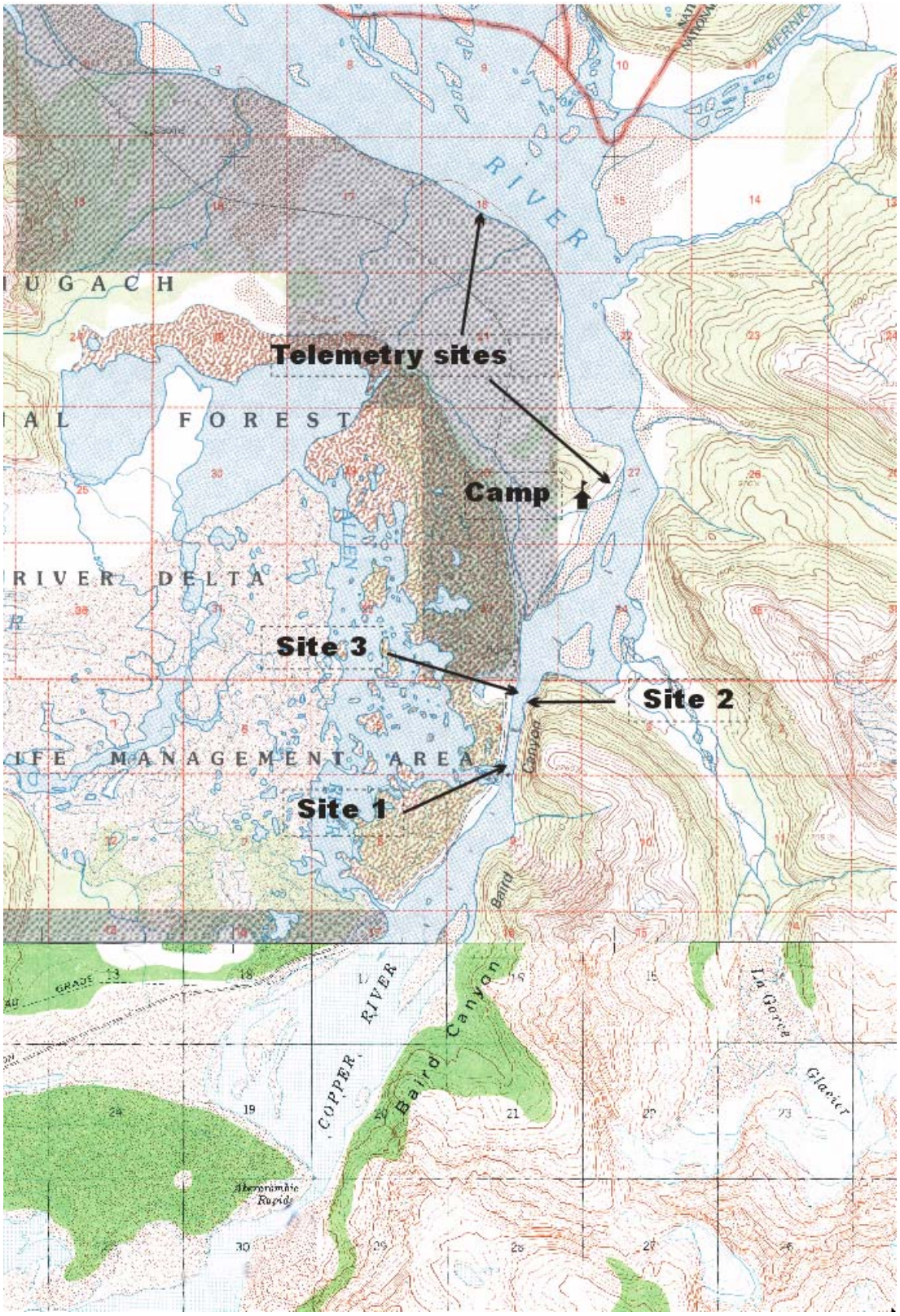


Figure 2. Map of Baird Canyon on the Copper River showing the location of three fishwheel sites used in 2003, the field camp and two telemetry sites.

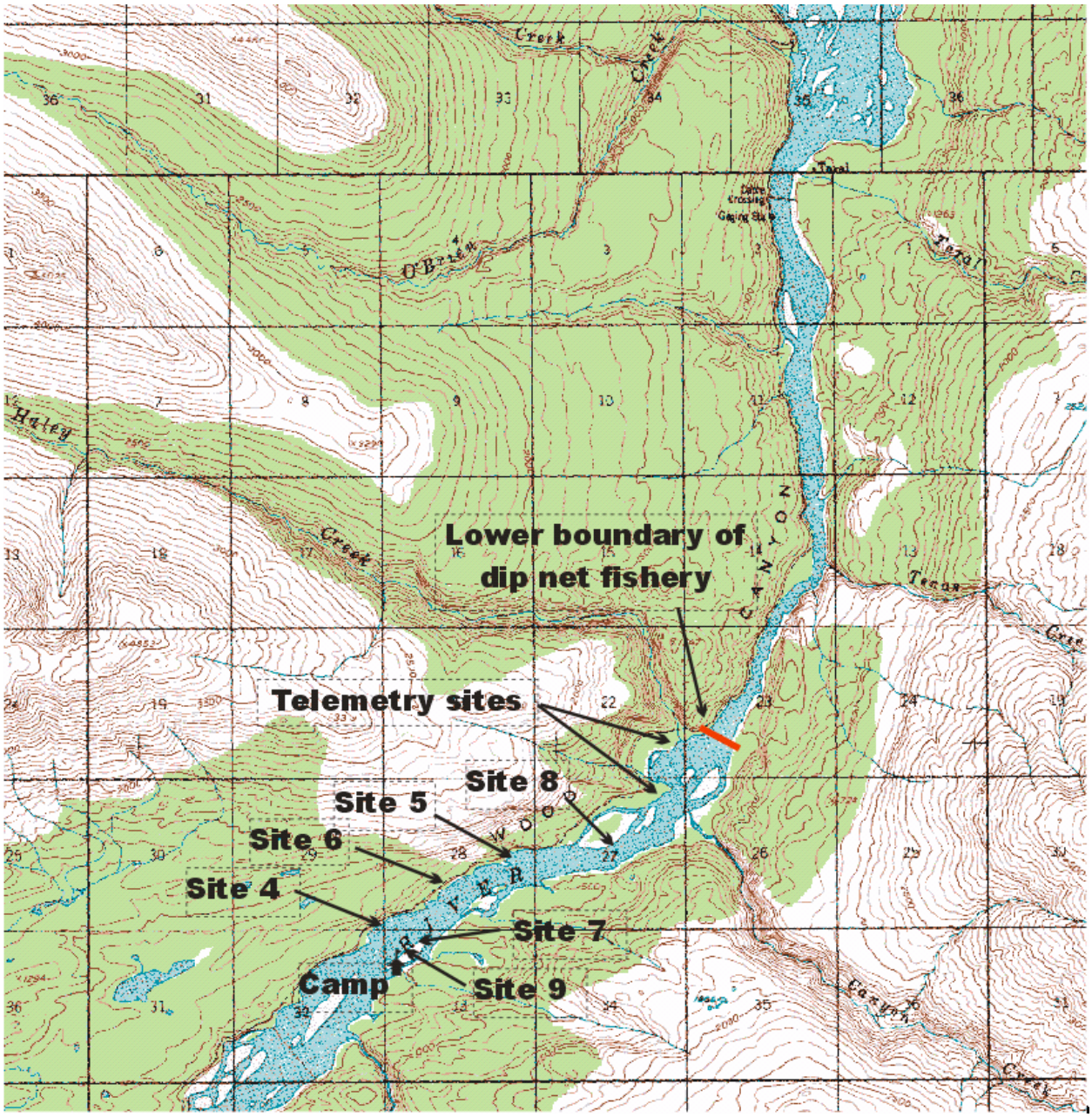


Figure 3. Map of Wood Canyon on the Copper River showing the location of six fishwheel sites used in 2003, the field camp, two telemetry sites and the lower boundary of the Chitina Subdistrict Subsistence (CSS) dip net fishery.

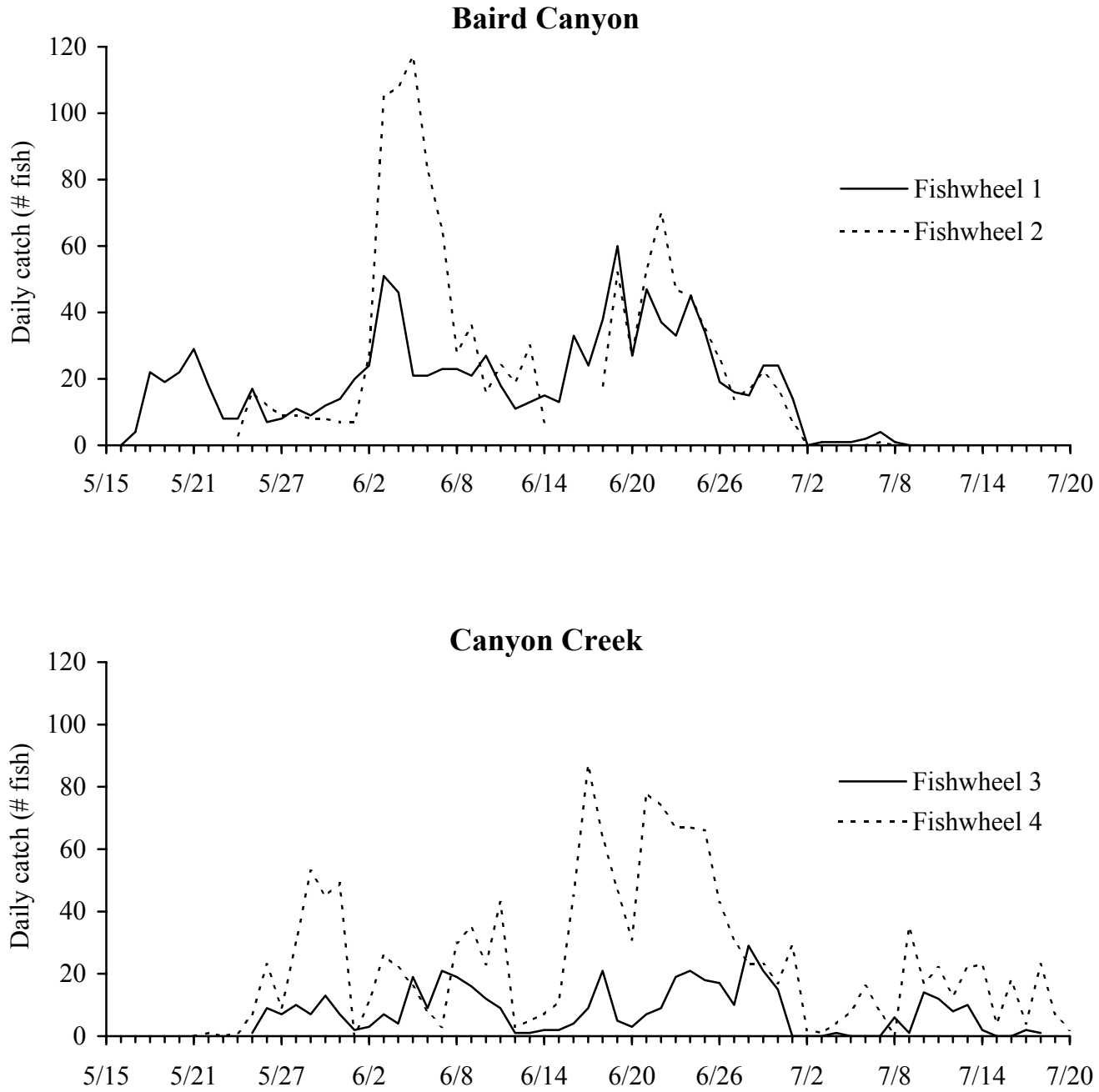
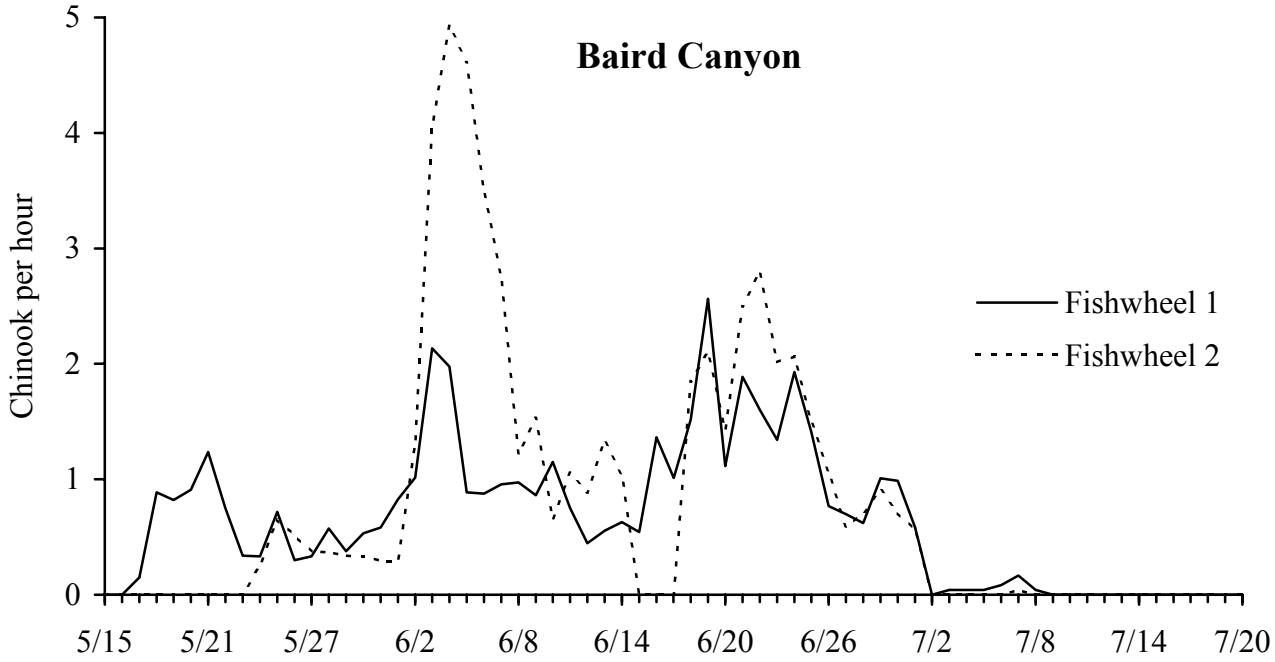


Figure 4. Daily catch of chinook salmon at the Baird Canyon and Canyon Creek fishwheels on the Copper River, 2003.



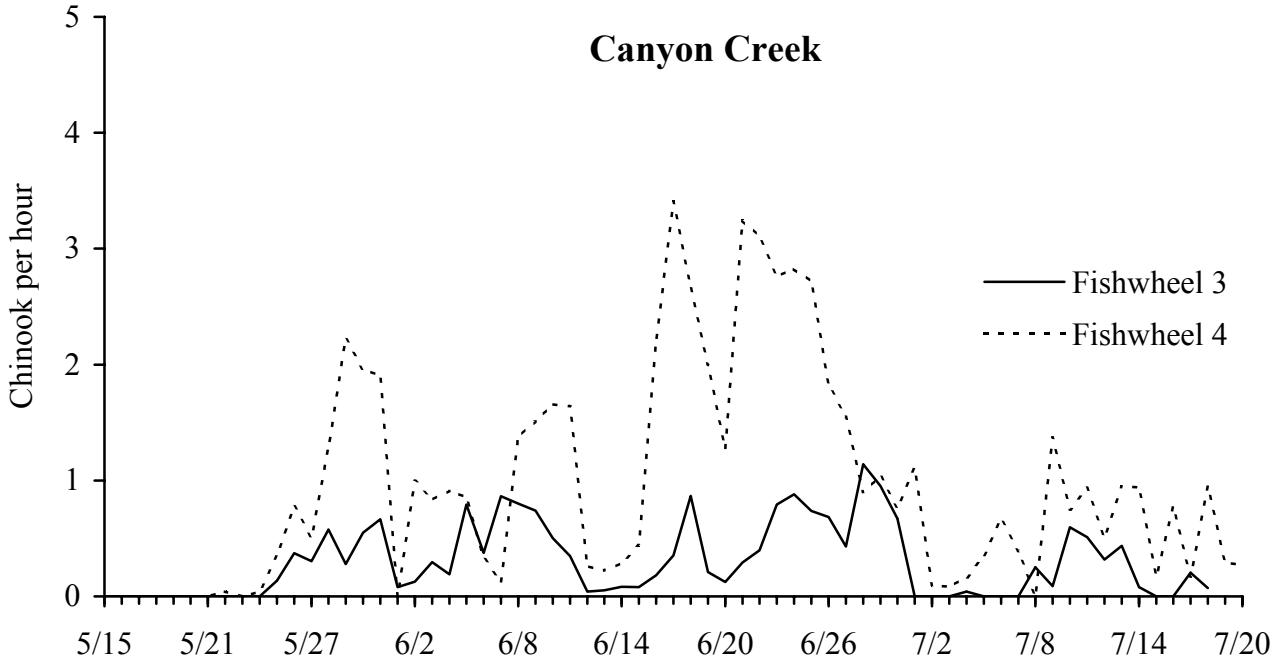


Figure 5. Catch per unit effort (fish per fishwheel hour) for chinook salmon at the Baird Canyon and Canyon Creek fishwheels on the Copper River, 2003.

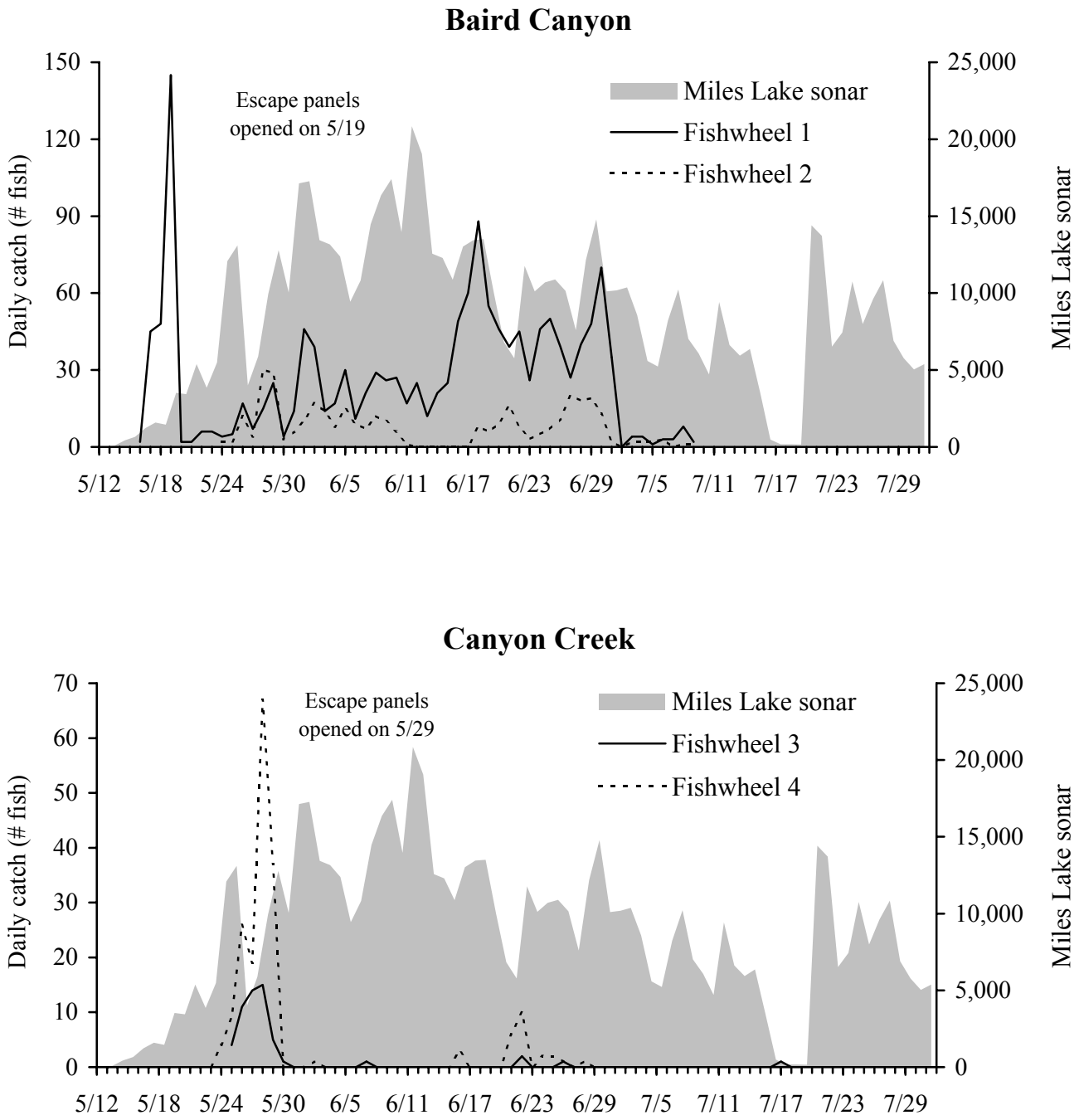


Figure 6. Daily catch of sockeye salmon at the Baird Canyon and Canyon Creek fishwheels on the Copper River, 2003.

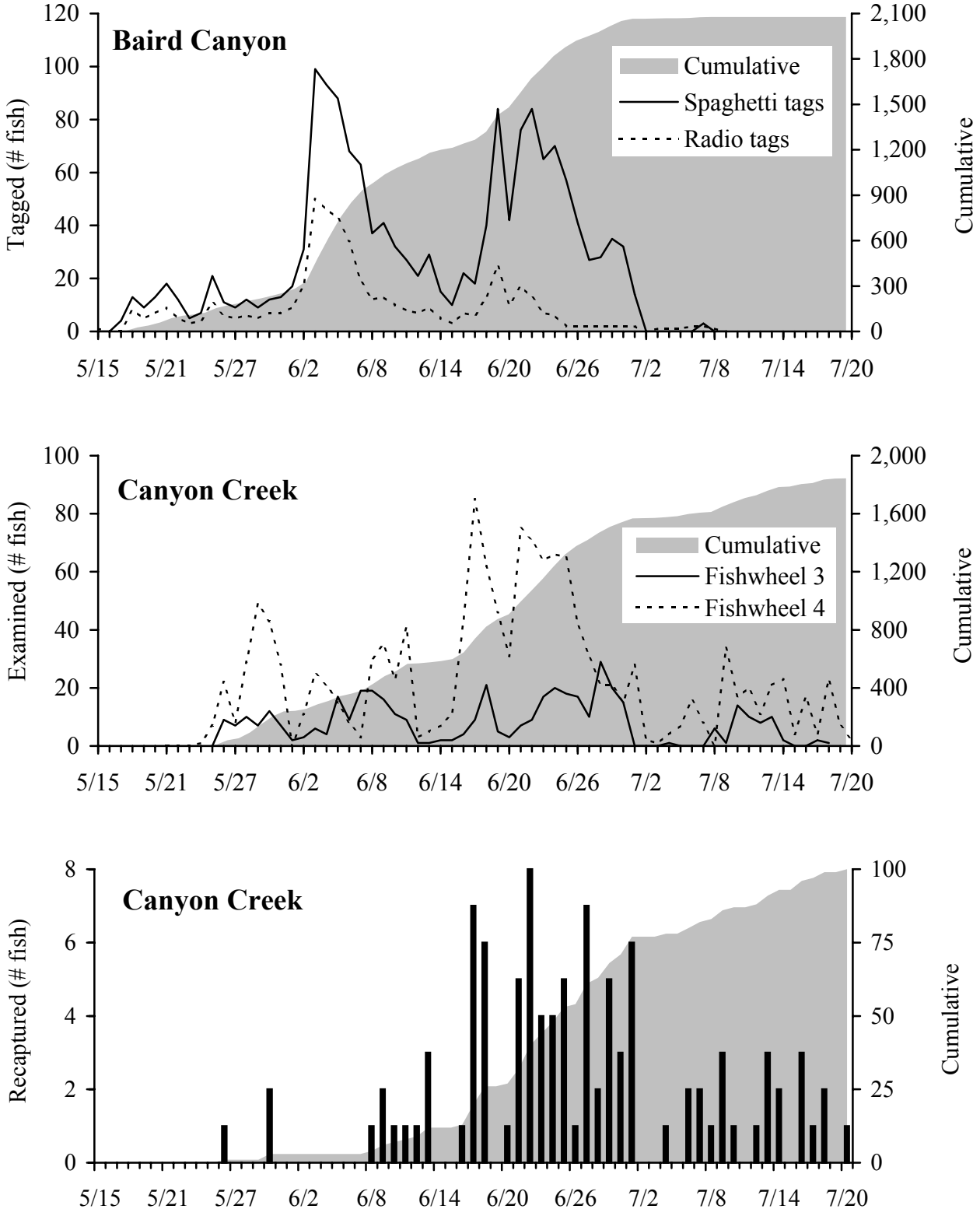


Figure 7. Number of chinook salmon tagged, examined and recaptured at the Copper River fishwheels, 2003.

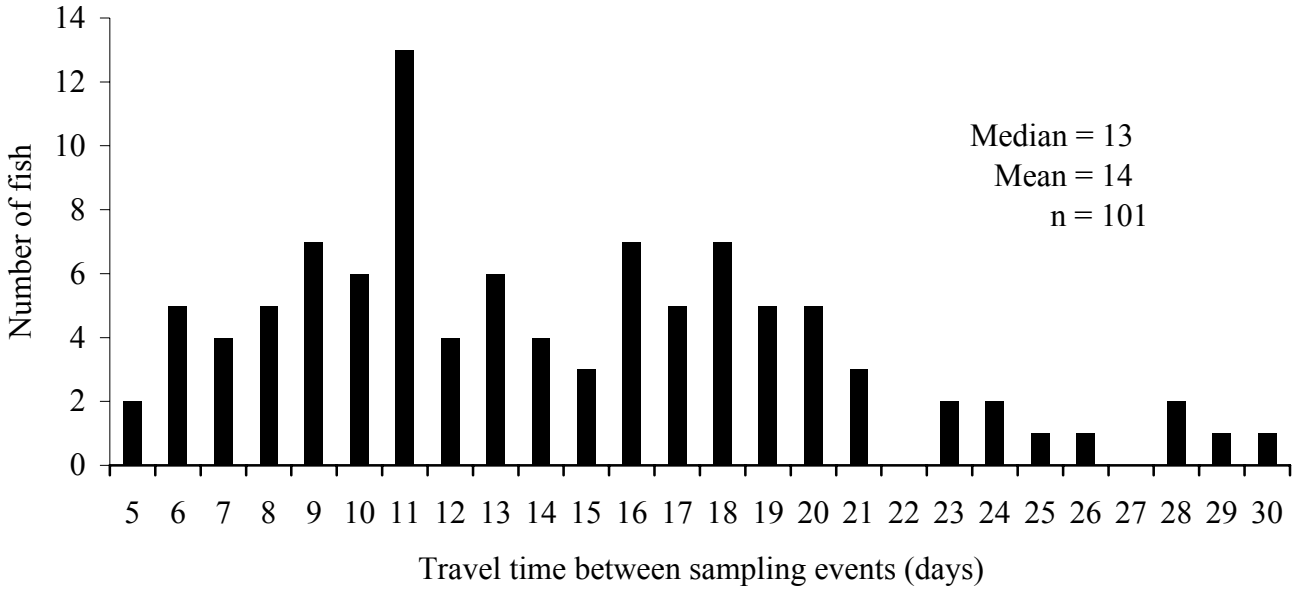


Figure 8. Travel time (days) of chinook salmon that were tagged at the Baird Canyon fishwheels and then recaptured at the Canyon Creek fishwheels, 2003.

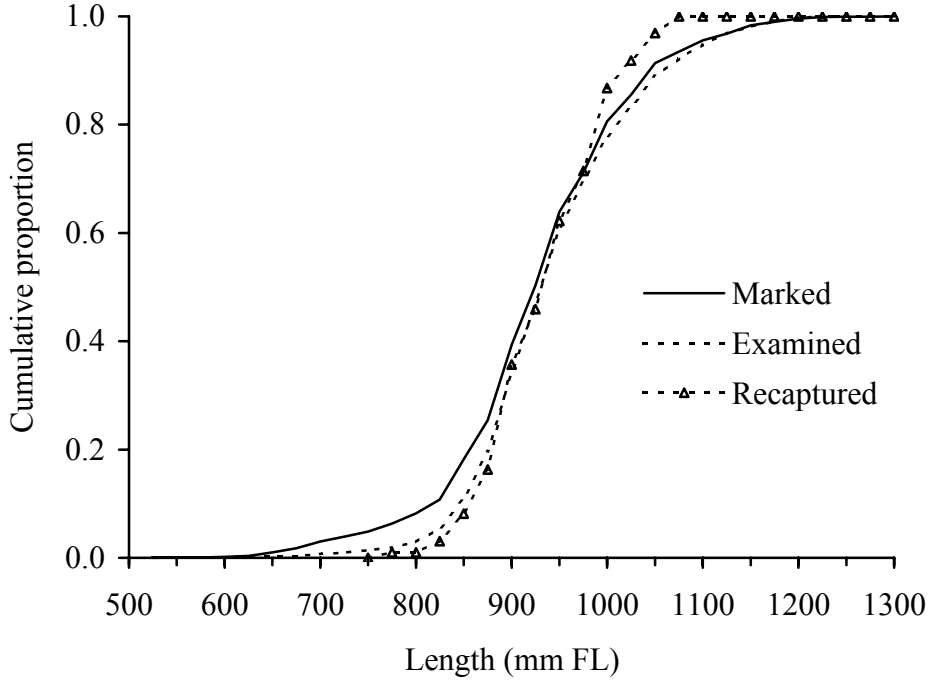


Figure 9. Cumulative length-frequency distributions of chinook salmon (≥ 530 mm FL) marked at Baird Canyon from 17 May to 1 July and examined and recaptured at Canyon Creek, 2003.

TABLES

Table 1. Capture history for chinook salmon sampled during the first event (Baird Canyon) that were used to estimate inriver abundance, 2003.

Capture history	Fishwheel 1	Fishwheel 2	Total
Total number captured	1,055	1,196	2,251
Untagged fish			
Escaped prior to applying both marks	32	40	72
Visible injury (e.g., net and bite marks) or stress	56	40	96
Coded-wire tag (CWT)	0	1	1
Mortality	4	1	5
Total untagged	92	82	174
Tagged fish (primary and secondary marks)			
Spaghetti tag and right operculum punch	727	850	1,577
Radio tag and spaghetti tag	236	264	500
Total tagged	963	1,114	2,077
Censored tags			
Radio-tagged fish			
Tagged prior to 17 May or after 1 July [a]	7	2	9
810 mm > FL > 1070 mm [b]	40	27	67
Known radio-tag failures [c]	16	10	26
Total radio tags censored	63	39	102
Spaghetti-tagged fish			
Tagged prior to 17 May or after 1 July [a]	3	0	3
810 mm > FL > 1070 mm [b]	123	126	249
Total spaghetti tags censored	126	126	252
Total tags censored	189	165	354
Number of fish available for recovery at Canyon Creek			
Spaghetti tag and right operculum punch	601	724	1,325
Radio tag and spaghetti tag	173	225	398
Total available for recovery	774	949	1,723

[a] Fish tagged during periods when the fishwheels were not operating effectively.

[b] Tagged fish that were censored because there were too few recaptures in these size classes.

[c] Radio-tagged fish that were never detected at or above the Canyon Creek fishwheels.

Table 2. Capture history for chinook salmon sampled during the second event (Canyon Creek) that were used to estimate inriver abundance, 2003.

Capture history	Fishwheel 3	Fishwheel 4	Total
Captured	446	1,482	1,928
Not examined			
Escaped before examination complete	14	70	84
Censored			
810 mm > FL > 1070 mm	61	149	210
Length not recorded [a]	0	4	4
Total tags censored	61	153	214
Number of fish examined at Canyon Creek	371	1,259	1,630
Recaptures			
Spaghetti tag and right operculum punch	17	55	72
Radio tag and spaghetti tag	5	20	25
Total	22	75	97

[a] Includes 3 tagged fish for which the length and/or tag number were not recorded upon recapture.

Table 3. Capture history for uncensored chinook salmon measuring 810 to 1070 mm FL that were tagged at the Baird Canyon fishwheels from 17 May to 1 July and examined at the Canyon Creek fishwheels, 2003.

	Period of recapture												
Period of marking	5/21-5/27	5/28-6/3	6/4-6/10	6/11-6/17	6/18-6/24	6/25-7/1	7/2-7/8	7/9-7/15	7/16-7/20	Recaptured	Marked	Not recaptured	Recapture rate
5/17-5/22	1	1								**2**	91	**89**	0.022
5/23-5/28		1			1					**2**	77	**75**	0.026
5/29-6/3			2	2	2	2				**8**	229	**221**	0.035
6/4-6/9			1	10	19	6				**36**	477	**441**	0.075
6/10-6/15				1	5	4				**10**	147	**137**	0.068
6/16-6/21					1	11	3	3	1	**19**	297	**278**	0.064
6/22-6/27						5	2	6	4	**17**	313	**296**	0.054
6/28-7/1								1	2	**3**	92	**89**	0.033
Recaptured	**1**	**2**	**3**	**13**	**28**	**28**	**5**	**10**	**7**			χ^2 = 10.3, df=7,P=0.17	
Unmarked	**49**	**209**	**203**	**188**	**409**	**261**	**32**	**141**	**41**				
Examined	50	211	206	201	437	289	37	151	48				
Mark rate	0.020	0.009	0.015	0.065	0.064	0.097	0.135	0.066	0.146	χ^2 = 36, df=8,P<0.01			

Table 4. Capture history for chinook salmon that were marked and examined at the Copper River fishwheels for which consecutive weeks with similar mark and recapture rates were pooled (see Table 4 for non-pooled weekly data).

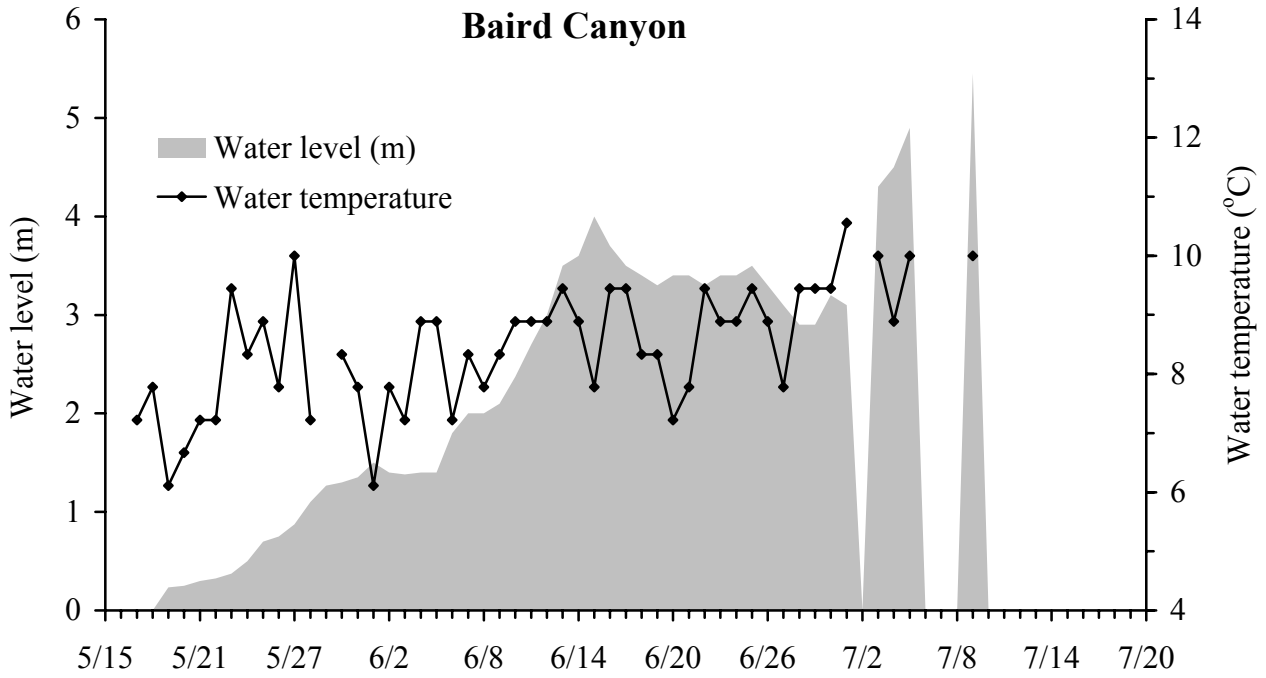
Period of marking	Period of recapture 5/21-6/10	6/11-7/20	Recaptured	Marked	Not recaptured	Recapture rate
5/17-6/3	5	7	**12**	397	**385**	0.030
6/4-7/1	1	84	**85**	1,326	**1,241**	0.064
Recaptured	**6**	**91**			$\chi^2 = 6.6$, df = 1, P = 0.01	
Unmarked	**461**	**1,072**				
Examined	467	1,163				
Mark rate	0.013	0.078	$\chi^2 = 25.5$, df = 1 , P < 0.01			

Table 5. Estimated abundance of chinook salmon measuring 810 to 1070 mm FL that migrated upstream of Baird Canyon from 17 May to 1 July 2003.

Period of marking	Abundance[a]	P(capture) First Event	Period of recapture 5/21-6/10	Period of recapture 6/11-7/20
5/17-6/3	36,590	0.011	26,853	9,737
6/4-7/1	8,174	0.162	359	7,815
Total	44,764		27,212	17,552
P(capture) Second Event			0.017	0.067

[a] Calculated using the computer program SPAS (Arnason et al. 1996) and the methods of Darroch (1961).

APPENDICES



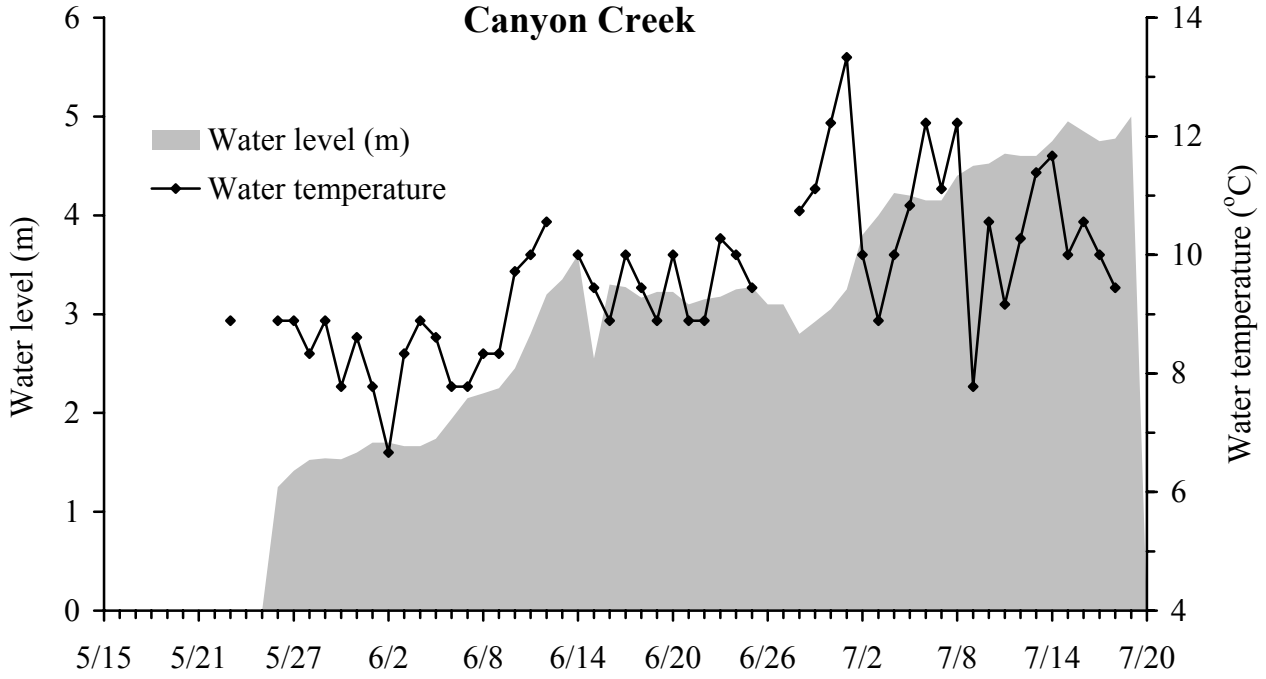


Figure A-1. Average daily water level and water temperature of the Copper River near the Baird Canyon and Canyon Creek fishwheels, 2003.

Table A-1. Average daily water level and water temperature of the Copper River near the Baird Canyon and Canyon Creek fishwheels, 2003.

	Baird Canyon (FW1&2)		Canyon Creek (FW3&4)	
Date	Depth (m)	Temp. (^{o}C)	Depth (m)	Temp. (^{o}C)
15-May				
16-May				
17-May		7.2		
18-May		7.8		
19-May	0.2	6.1		
20-May	0.3	6.7		
21-May	0.3	7.2		
22-May	0.3	7.2		
23-May	0.4	9.4		8.9
24-May	0.5	8.3		
25-May	0.7	8.9		
26-May	0.8	7.8	1.3	8.9
27-May	0.9	10.0	1.4	8.9
28-May	1.1	7.2	1.5	8.3
29-May	1.3		1.5	8.9
30-May	1.3	8.3	1.5	7.8
31-May	1.4	7.8	1.6	8.6
1-Jun	1.5	6.1	1.7	7.8
2-Jun	1.4	7.8	1.7	6.7
3-Jun	1.4	7.2	1.7	8.3
4-Jun	1.4	8.9	1.7	8.9
5-Jun	1.4	8.9	1.7	8.6
6-Jun	1.8	7.2	1.9	7.8
7-Jun	2.0	8.3	2.2	7.8
8-Jun	2.0	7.8	2.2	8.3
9-Jun	2.1	8.3	2.3	8.3
10-Jun	2.4	8.9	2.5	9.7
11-Jun	2.7	8.9	2.8	10.0
12-Jun	3.0	8.9	3.2	10.6
13-Jun	3.5	9.4	3.4	
14-Jun	3.6	8.9	3.6	10.0
15-Jun	4.0	7.8	2.6	9.4
16-Jun	3.7	9.4	3.3	8.9
17-Jun	3.5	9.4	3.3	10.0
18-Jun	3.4	8.3	3.2	9.4
19-Jun	3.3	8.3	3.2	8.9

Table A-1. Average daily water level and water temperature of the Copper River near the Baird Canyon and Canyon Creek fishwheels, 2003.

	Baird Canyon (FW1&2)		Canyon Creek (FW3&4)	
Date	Depth (m)	Temp. (^{o}C)	Depth (m)	Temp. (^{o}C)
20-Jun	3.4	7.2	3.2	10.0
21-Jun	3.4	7.8	3.1	8.9
22-Jun	3.3	9.4	3.2	8.9
23-Jun	3.4	8.9	3.2	10.3
24-Jun	3.4	8.9	3.3	10.0
25-Jun	3.5	9.4	3.3	9.4
26-Jun	3.3	8.9	3.1	
27-Jun	3.1	7.8	3.1	
28-Jun	2.9	9.4	2.8	10.7
29-Jun	2.9	9.4	2.9	11.1
30-Jun	3.2	9.4	3.1	12.2
1-Jul	3.1	10.6	3.3	13.3
2-Jul			3.8	10.0
3-Jul	4.3	10.0	4.0	8.9
4-Jul	4.5	8.9	4.2	10.0
5-Jul	4.9	10.0	4.2	10.8
6-Jul			4.2	12.2
7-Jul			4.2	11.1
8-Jul			4.4	12.2
9-Jul	5.5	10.0	4.5	7.8
10-Jul			4.5	10.6
11-Jul			4.6	9.2
12-Jul			4.6	10.3
13-Jul			4.6	11.4
14-Jul			4.8	11.7
15-Jul			5.0	10.0
16-Jul			4.9	10.6
17-Jul			4.8	10.0
18-Jul			4.8	9.4
19-Jul			5.0	
20-Jul				
Mean	2.4	8.5	3.2	9.6
Median	2.8	8.9	3.2	9.4
Max	5.5	10.6	5.0	13.3
Min	0.2	6.1	1.3	6.7

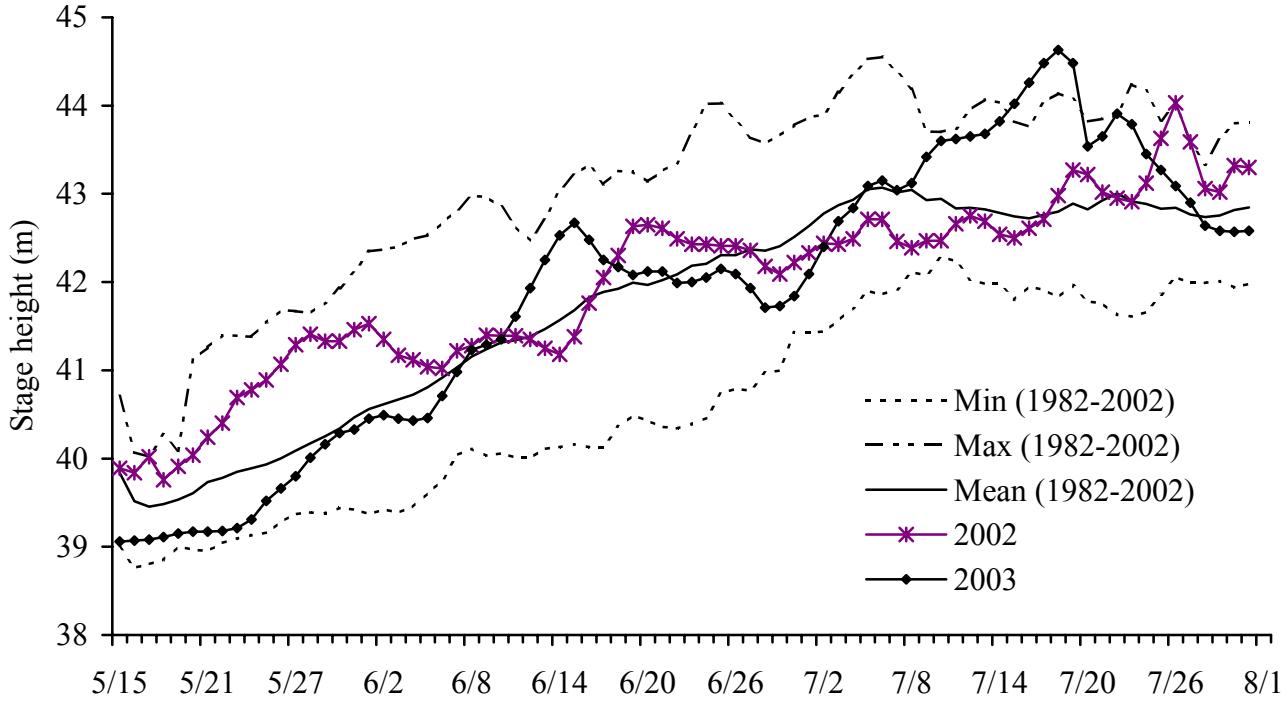


Figure A-2. Stage height at the Million Dollar Bridge on the Copper River (1982-2003).

Table B-1. Description of the sites and operational periods for the fishwheels used on the Copper River, 2003.

Location	Fishwheel	Site #	Bank	Operational period From:	Operational period To:
Baird Canyon	1	2	East	11:20 h 16-May	10:30 h 9-Jul
	2	1	West	18:00 h 11-May	12:00 h 16-May
		2	East	9:30 h 24-May	8:20 h 2-Jun
		3	West	11:45 h 2-Jun	1-Jul
		2	East	15:00 h 3-Jul	9:30 h 9-Jul
Canyon Creek	3	4	West	13:30 h 25-May	17:00 h 31-May
		5	West	12:00 h 1-Jun	9:00 h 4-Jun
		4	West	12:10 h 4-Jun	13:30 h 22-Jun
		6	West	15:30 h 22-Jun	8:00 h 9-Jul
		7	East	22:00 h 9-Jul	10:00 h 18-Jul
	4	8	West	17:40 h 21-May	7-Jul
		9	East	16:45 h 8-Jul	4:00 h 20-Jul

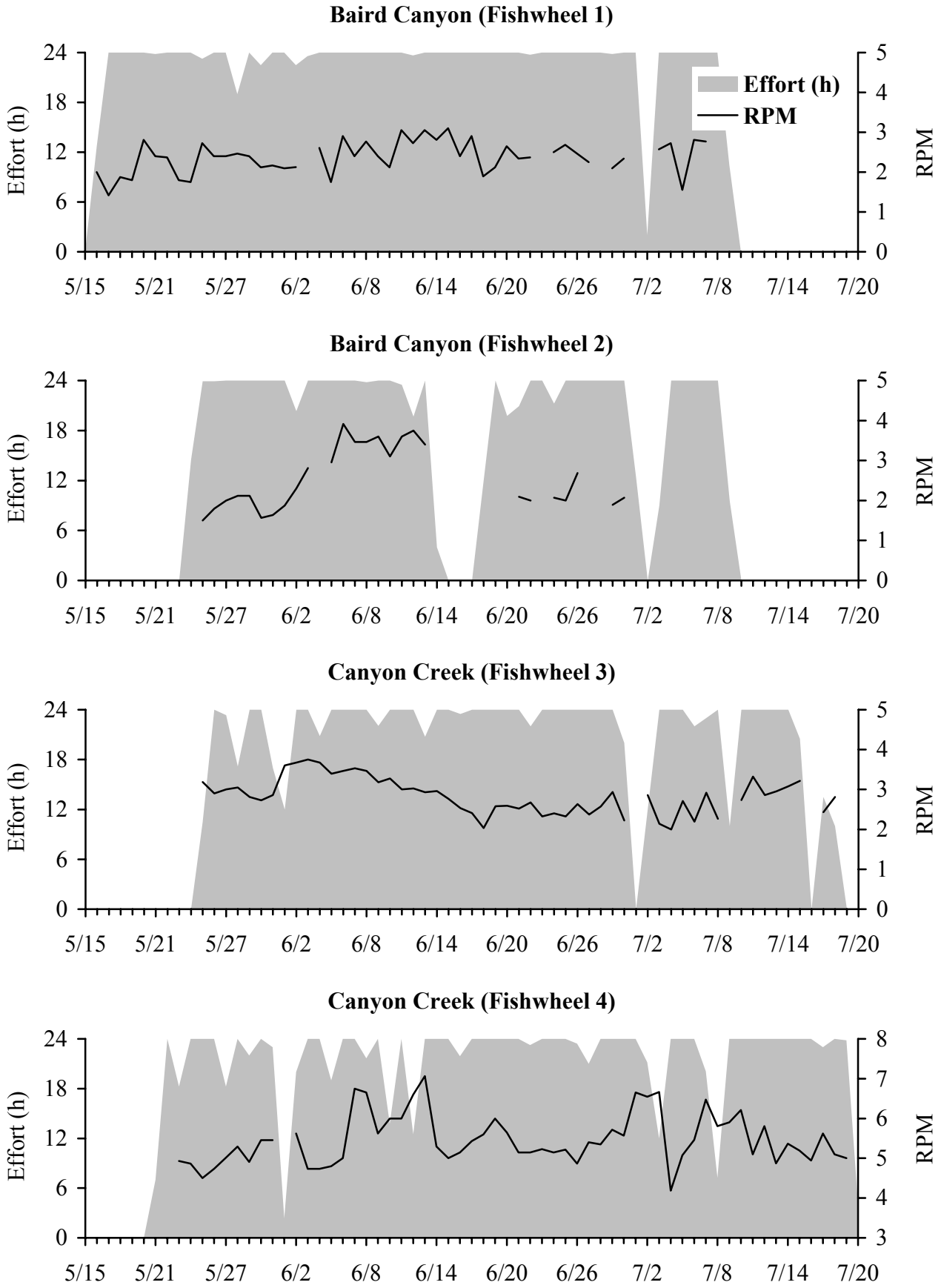


Figure B-1. Fishwheel effort (h) and speed (RPM) at the Baird Canyon and Canyon Creek fishwheels on the Copper River, 2003.

Table B-2. Summary of daily fishwheel effort (h), effort used to calculate catch per unit effort (CPUE), and fishwheel speed (RPM) for the Copper River fishwheels, 2003.

	Fishwheel 1 (Baird Canyon)			Fishwheel 2 (Baird Canyon)			Fishwheel 3 (Canyon Creek)			Fishwheel 4 (Canyon Creek)		
Date	Total effort (h)	CPUE effort (h)	RPM	Total effort (h)	CPUE effort (h)	RPM	Total effort (h)	CPUE effort (h)	RPM	Total effort (h)	CPUE effort (h)	RPM
15-May												
16-May	12.7	7.8	2.0									
17-May	24.0	26.6	1.4									
18-May	24.0	24.8	1.9									
19-May	24.0	23.2	1.8									
20-May	24.0	24.2	2.8									
21-May	23.8	23.5	2.4							7.0		
22-May	24.0	24.1	2.4							24.0	24.6	
23-May	24.0	23.7	1.8							18.3	20.8	4.9
24-May	24.0	24.0	1.7	14.5	11.9					24.0	23.8	4.9
25-May	23.3	23.7	2.7	23.9	24.6	1.5	10.5	7.4	3.2	24.0	20.1	4.5
26-May	24.0	23.4	2.4	23.9	23.3	1.8	24.0	24.1	2.9	24.0	29.6	4.7
27-May	24.0	24.1	2.4	24.0	24.0	2.0	23.3	23.1	3.0	18.3	17.7	5.0
28-May	19.0	19.2	2.5	24.0	24.4	2.1	17.2	17.4	3.1	24.0	23.4	5.3
29-May	24.0	23.8	2.4	24.0	23.6	2.1	24.0	25.0	2.8	22.0	23.8	4.9
30-May	22.5	22.5	2.1	24.0	24.1	1.6	24.0	23.6	2.7	24.0	23.0	5.5
31-May	24.0	24.0	2.2	24.0	23.8	1.6	17.0	10.5	2.9	23.0	25.7	5.5
1-Jun	24.0	24.2	2.1	24.0	24.4	1.9	12.0	25.3	3.6	2.3		
2-Jun	22.5	23.7	2.1	20.3	20.7	2.3	24.0	23.8	3.7	20.0	11.1	5.6
3-Jun	23.6	23.9		24.0	25.9	2.8	24.0	23.6	3.8	24.0	31.2	4.7
4-Jun	24.0	23.3	2.6	24.0	21.9		20.8	21.1	3.7	24.0	24.1	4.7
5-Jun	24.0	23.7	1.7	24.0	25.4	3.0	24.0	24.0	3.4	19.0	18.8	4.8
6-Jun	24.0	24.0	2.9	24.0	23.7	3.9	24.0	23.9	3.5	24.0	24.1	5.0
7-Jun	24.0	24.0	2.4	24.0	23.6	3.5	24.0	24.3	3.5	24.0	24.4	6.8

Table B-2. Summary of daily fishwheel effort (h), effort used to calculate catch per unit effort (CPUE), and fishwheel speed (RPM) for the Copper River fishwheels, 2003.

	Fishwheel 1 (Baird Canyon)			Fishwheel 2 (Baird Canyon)			Fishwheel 3 (Canyon Creek)			Fishwheel 4 (Canyon Creek)		
Date	Total effort (h)	CPUE effort (h)	RPM	Total effort (h)	CPUE effort (h)	RPM	Total effort (h)	CPUE effort (h)	RPM	Total effort (h)	CPUE effort (h)	RPM
8-Jun	24.0	23.6	2.8	23.8	23.0	3.5	24.0	23.8	3.5	21.7	21.8	6.7
9-Jun	24.0	24.4	2.4	24.0	23.5	3.6	22.1	21.7	3.2	24.0	23.1	5.6
10-Jun	24.0	23.5	2.1	24.0	24.5	3.1	24.0	23.8	3.3	13.8	13.9	6.0
11-Jun	24.0	24.0	3.1	23.5	22.8	3.6	24.0	25.9	3.0	24.0	26.2	6.0
12-Jun	23.7	24.6	2.7	19.7	21.4	3.8	24.0	23.7	3.0	12.5	11.5	6.6
13-Jun	24.0	23.4	3.1	24.0	22.5	3.4	20.8	19.2	2.9	24.0	22.3	7.1
14-Jun	24.0	23.9	2.8	4.0	6.8		24.0	24.1	3.0	24.0	24.3	5.3
15-Jun	24.0	23.9	3.1				24.0	24.9	2.8	24.0	25.0	5.0
16-Jun	24.0	24.2	2.4				23.5	21.9	2.5	21.9	20.4	5.1
17-Jun	24.0	23.8	2.9				24.0	25.5	2.4	24.0	25.6	5.4
18-Jun	24.0	25.1	1.9	12.0	9.7		24.0	24.2	2.0	24.0	24.0	5.6
19-Jun	24.0	23.4	2.1	24.0	24.8	2.1	24.0	23.7	2.6	24.0	23.5	6.0
20-Jun	24.0	24.2	2.6	19.8	18.9		24.0	24.1	2.6	24.0	24.3	5.6
21-Jun	24.0	24.9	2.3	20.9	21.2	2.1	24.0	23.9	2.5	24.0	24.1	5.1
22-Jun	23.8	23.1	2.4	24.0	25.0	2.0	22.0	22.7	2.7	23.3	23.8	5.1
23-Jun	24.0	24.6		24.0	23.3		24.0	24.0	2.3	24.0	24.3	5.2
24-Jun	24.0	23.3	2.5	21.3	21.8	2.1	24.0	23.9	2.4	24.0	23.7	5.1
25-Jun	24.0	24.2	2.7	24.0	23.3	2.0	24.0	24.4	2.3	24.0	24.3	5.2
26-Jun	24.0	24.8	2.5	24.0	24.5	2.7	24.0	24.8	2.6	23.4	23.6	4.9
27-Jun	24.0	23.0	2.3	24.0	23.7		24.0	23.3	2.4	21.0	20.0	5.4
28-Jun	24.0	24.1		24.0	24.1		24.0	25.5	2.6	24.0	25.5	5.4
29-Jun	23.8	23.8	2.1	24.0	24.2	1.9	24.0	22.1	2.9	24.0	22.1	5.7
30-Jun	24.0	24.3	2.3	24.0	24.0	2.1	20.0	22.4	2.2	24.0	22.3	5.6
1-Jul	24.0	23.9		12.3	12.4		0.0			24.0	26.2	6.7

Table B-2. Summary of daily fishwheel effort (h), effort used to calculate catch per unit effort (CPUE), and fishwheel speed (RPM) for the Copper River fishwheels, 2003.

	Fishwheel 1 (Baird Canyon)			Fishwheel 2 (Baird Canyon)			Fishwheel 3 (Canyon Creek)			Fishwheel 4 (Canyon Creek)		
Date	Total effort (h)	CPUE effort (h)	RPM	Total effort (h)	CPUE effort (h)	RPM	Total effort (h)	CPUE effort (h)	RPM	Total effort (h)	CPUE effort (h)	RPM
2-Jul	2.0			0.0			12.0	8.9	2.9	21.2	20.5	6.5
3-Jul	24.0	24.0	2.6	9.0	7.0		24.0	24.0	2.1	12.0	12.1	6.7
4-Jul	24.0	24.0	2.7	24.0	24.0		24.0	24.5	2.0	24.0	24.7	4.2
5-Jul	24.0	24.1	1.6	24.0	24.1	2.4	24.0	23.0	2.7	24.0	23.0	5.1
6-Jul	24.0	24.0	2.8	24.0	23.9		22.0	22.4	2.2	24.0	23.9	5.5
7-Jul	24.0	24.0	2.8	24.0	24.0		23.0	22.9	2.9	20.1	20.4	6.5
8-Jul	24.0	23.7		24.0	23.6		24.0	24.0	2.3	7.3	3.1	5.8
9-Jul	10.5	12.8	3.6	9.5	12.8		10.0	11.2		24.0	25.6	5.9
10-Jul							24.0	23.5	2.7	24.0	22.7	6.2
11-Jul							24.0	23.5	3.3	24.0	23.6	5.1
12-Jul							24.0	25.2	2.9	24.0	25.6	5.8
13-Jul							24.0	22.9	3.0	24.0	23.2	4.9
14-Jul							24.0	24.6	3.1	24.0	24.4	5.4
15-Jul							20.5	23.1	3.2	24.0	22.9	5.2
16-Jul							0.0			24.0	23.3	4.9
17-Jul							13.5	9.8	2.4	23.0	23.3	5.6
18-Jul							10.0	13.8	2.8	24.0	24.3	5.1
19-Jul										23.8	23.6	5.0
20-Jul										4.0	7.5	
Effort (h)	1263		2.4	930		2.5	1160		2.8	1315		5.5
Effort (d)	52.6			38.8			48.3			54.8		
Percent operational:	98%			84%			90%			92%		

Table C-1. Total catch and catch per unit effort (chinook per fishwheel hour) at the Copper River fishwheels, 2003.

	Baird Canyon						Canyon Creek					
	Fishwheel 1			Fishwheel 2			Fishwheel 3			Fishwheel 4		
Date	Catch	Cum.	CPUE	Catch	Cum.	CPUE	Catch	Cum.	CPUE	Catch	Cum.	CPUE
15 May				1	1							
16 May	0	0	0.0									
17 May	4	4	0.2									
18 May	22	26	0.9									
19 May	19	45	0.8									
20 May	22	67	0.9									
21 May	29	96	1.2							0	0	
22 May	18	114	0.7							1	1	0.0
23 May	8	122	0.3							0	1	0.0
24 May	8	130	0.3	3	4	0.3				1	2	0.0
25 May	17	147	0.7	16	20	0.7	1	1	0.1	7	9	0.3
26 May	7	154	0.3	12	32	0.5	9	10	0.4	23	32	0.8
27 May	8	162	0.3	9	41	0.4	7	17	0.3	9	41	0.5
28 May	11	173	0.6	9	50	0.4	10	27	0.6	30	71	1.3
29 May	9	182	0.4	8	58	0.3	7	34	0.3	53	124	2.2
30 May	12	194	0.5	8	66	0.3	13	47	0.6	45	169	2.0
31 May	14	208	0.6	7	73	0.3	7	54	0.7	49	218	1.9
1 Jun	20	228	0.8	7	80	0.3	2	56	0.1	0	218	
2 Jun	24	252	1.0	27	107	1.3	3	59	0.1	11	229	1.0
3 Jun	51	303	2.1	105	212	4.1	7	66	0.3	26	255	0.8
4 Jun	46	349	2.0	108	320	4.9	4	70	0.2	22	277	0.9
5 Jun	21	370	0.9	117	437	4.6	19	89	0.8	16	293	0.9
6 Jun	21	391	0.9	83	520	3.5	9	98	0.4	8	301	0.3
7 Jun	23	414	1.0	65	585	2.8	21	119	0.9	3	304	0.1
8 Jun	23	437	1.0	28	613	1.2	19	138	0.8	30	334	1.4
9 Jun	21	458	0.9	36	649	1.5	16	154	0.7	35	369	1.5
10 Jun	27	485	1.2	16	665	0.7	12	166	0.5	23	392	1.7
11 Jun	18	503	0.8	24	689	1.1	9	175	0.3	43	435	1.6
12 Jun	11	514	0.4	19	708	0.9	1	176	0.0	3	438	0.3
13 Jun	13	527	0.6	30	738	1.3	1	177	0.1	5	443	0.2
14 Jun	15	542	0.6	7	745	1.0	2	179	0.1	7	450	0.3
15 Jun	13	555	0.5	0	745		2	181	0.1	11	461	0.4
16 Jun	33	588	1.4	0	745		4	185	0.2	45	506	2.2
17 Jun	24	612	1.0	0	745		9	194	0.4	87	593	3.4
18 Jun	38	650	1.5	18	763	1.8	21	215	0.9	64	657	2.7
19 Jun	60	710	2.6	52	815	2.1	5	220	0.2	47	704	2.0

Table C-1. Total catch and catch per unit effort (chinook per fishwheel hour) at the Copper River fishwheels, 2003.

	Baird Canyon						Canyon Creek					
	Fishwheel 1			Fishwheel 2			Fishwheel 3			Fishwheel 4		
Date	Catch	Cum.	CPUE	Catch	Cum.	CPUE	Catch	Cum.	CPUE	Catch	Cum.	CPUE
20 Jun	27	737	1.1	27	842	1.4	3	223	0.1	31	735	1.3
21 Jun	47	784	1.9	53	895	2.5	7	230	0.3	78	813	3.2
22 Jun	37	821	1.6	70	965	2.8	9	239	0.4	74	887	3.1
23 Jun	33	854	1.3	47	1012	2.0	19	258	0.8	67	954	2.8
24 Jun	45	899	1.9	45	1057	2.1	21	279	0.9	67	1021	2.8
25 Jun	34	933	1.4	35	1092	1.5	18	297	0.7	66	1087	2.7
26 Jun	19	952	0.8	26	1118	1.1	17	314	0.7	43	1130	1.8
27 Jun	16	968	0.7	14	1132	0.6	10	324	0.4	31	1161	1.5
28 Jun	15	983	0.6	17	1149	0.7	29	353	1.1	23	1184	0.9
29 Jun	24	1007	1.0	22	1171	0.9	21	374	1.0	23	1207	1.0
30 Jun	24	1031	1.0	17	1188	0.7	15	389	0.7	17	1224	0.8
1 Jul	14	1045	0.6	7	1195	0.6	0	389		29	1253	1.1
2 Jul	0	1045		0	1195		0	389	0.0	2	1255	0.1
3 Jul	1	1046	0.0	0	1195	0.0	0	389	0.0	1	1256	0.1
4 Jul	1	1047	0.0	0	1195	0.0	1	390	0.0	4	1260	0.2
5 Jul	1	1048	0.0	0	1195	0.0	0	390	0.0	8	1268	0.3
6 Jul	2	1050	0.1	0	1195	0.0	0	390	0.0	16	1284	0.7
7 Jul	4	1054	0.2	1	1196	0.0	0	390	0.0	8	1292	0.4
8 Jul	1	1055	0.0	0	1196	0.0	6	396	0.3	0	1292	0.0
9 Jul	0	1055	0.0	0	1196	0.0	1	397	0.1	35	1327	1.4
10 Jul							14	411	0.6	17	1344	0.8
11 Jul							12	423	0.5	22	1366	0.9
12 Jul							8	431	0.3	13	1379	0.5
13 Jul							10	441	0.4	22	1401	0.9
14 Jul							2	443	0.1	23	1424	0.9
15 Jul							0	443	0.0	4	1428	0.2
16 Jul							0	443		18	1446	0.8
17 Jul							2	445	0.2	4	1450	0.2
18 Jul							1	446	0.1	23	1473	0.9
19 Jul										7	1480	0.3
20 Jul										2	1482	0.3

Table C-2. Other species captured at the Baird Canyon and Canyon Creek fishwheels on the Copper River, 2003.

	Baird Canyon		Canyon Creek		
Species	Fishwheel 1	Fishwheel 2	Fishwheel 3	Fishwheel 4	Total
Sockeye	1,495	354	55	188	2,092
Salmon smolts	16	8	8	2	34
Dolly Varden	9	0	1	0	10
Whitefish	20	1	4	1	26
Burbot	1	0	0	0	1
Arctic grayling	0	2	0	0	2
Pacific lamprey	1	0	0	0	1
Sucker	4	0	0	1	5

Table D-1. Escape panel settings at the Copper River fishwheels, 2003.

Location	Date	Time	Setting	Width of opening (cm) Port	Star.	Comments
Baird Canyon						
Fishwheel 1	16-May	19:00	Closed	-	-	Fishwheel activated
	19-May	21:45	Opened	7.5	6.0	
	26-Jun	2 h 25 min	Closed	-	-	Closed for testing (1350-1615 h)
	27-Jun	3 h 6 min	Closed			Closed for testing (0830-1136 h)
Fishwheel 2	24-May	9:30	Open	NR	NR	Fishwheel activated
	26-Jun	2 h 50 min	Closed			Closed for testing (1335-1625 h)
	27-Jun	2 h 42 min	Closed			Closed for testing (0850-1132)
Canyon Creek						
Fishwheel 3	25-May	15:40	Closed	-	-	Fishwheel activated
	29-May	8:33	Opened	7.5	7.5	
Fishwheel 4	21-May	17:40	Closed			Fishwheel activated
	29-May	10:08	Opened	7.5	7.5	

NR = Not Recorded

Table D-2. Results of two escape panel tests performed at the Baird Canyon fishwheels on 26 and 27 June, 2003.

	Test 1 (26 June)				Test 2 (27 June)			
	Fishwheel 1		Fishwheel 2		Fishwheel 1		Fishwheel 2	
	Port	Star.	Port	Star.	Port	Star.	Port	Star.
Width of opening (cm)	7.5	6.0	NR	NR	7.5	6.0	NR	NR
Test period (hh:mm)	2:25		2:50		3:06		2:42	
Sockeye (# fish)								
Captured	101	33	26	13	68	24	15	18
Retained	13	8	8	0	2	6	2	2
Escaped	88	25	18	13	66	18	13	16
Percent escaped	87	76	69	100	97	75	87	89
Chinook (# fish)								
Captured		1	3		3			1
Retained		1	3		3			1
Escaped		0	0		0			0
Percent escaped		0	0		0			0

NR = Not Recorded

Table E-1. Number of chinook salmon tagged, examined and recaptured at the Copper River fishwheels, 2003.

	Baird Canyon								Canyon Creek							
	Fishwheel 1				Fishwheel 2				Fishwheel 3				Fishwheel 4			
Date	Spag	Radio	Total	Cum	Spag	Radio	Total	Cum	Exam	Cum	Recap	Cum	Exam	Cum	Recap	Cum
15 May					0	1	1	1								
16 May	0	0	0	0												
17 May	4	0	4	4												
18 May	13	8	21	25												
19 May	9	5	14	39												
20 May	13	7	20	59												
21 May	18	9	27	86									0	0	0	0
22 May	12	5	17	103									0	0	0	0
23 May	5	3	8	111									0	0	0	0
24 May	6	2	8	119	1	2	3	4					1	1	0	0
25 May	11	6	17	136	10	5	15	19	0	0	0	0	7	8	0	0
26 May	3	2	5	141	8	4	12	31	9	9	1	1	22	30	0	0
27 May	5	2	7	148	4	3	7	38	7	16	0	1	8	38	0	0
28 May	7	3	10	158	5	3	8	46	10	26	0	1	29	67	0	0
29 May	4	3	7	165	5	2	7	53	7	33	0	1	49	116	0	0
30 May	7	5	12	177	5	2	7	60	12	45	2	3	43	159	0	0
31 May	8	5	13	190	5	2	7	67	7	52	0	3	28	187	0	0
1 Jun	12	7	19	209	5	2	7	74	2	54	0	3	0	187	0	0
2 Jun	13	9	22	231	18	8	26	100	3	57	0	3	11	198	0	0
3 Jun	33	15	48	279	66	35	101	201	6	63	0	3	25	223	0	0
4 Jun	27	13	40	319	66	33	99	300	4	67	0	3	21	244	0	0
5 Jun	14	6	20	339	74	37	111	411	17	84	0	3	15	259	0	0
6 Jun	13	7	20	359	55	27	82	493	9	93	0	3	8	267	0	0
7 Jun	16	6	22	381	47	13	60	553	19	112	0	3	3	270	0	0
8 Jun	16	5	21	402	21	7	28	581	19	131	0	3	30	300	1	1

Table E-1. Number of chinook salmon tagged, examined and recaptured at the Copper River fishwheels, 2003.

	Baird Canyon								Canyon Creek							
	Fishwheel 1				Fishwheel 2				Fishwheel 3				Fishwheel 4			
Date	Spag	Radio	Total	Cum	Spag	Radio	Total	Cum	Exam	Cum	Recap	Cum	Exam	Cum	Recap	Cum
9 Jun	15	5	20	422	26	8	34	615	16	147	1	4	35	335	1	2
10 Jun	20	6	26	448	12	4	16	631	11	158	0	4	23	358	1	3
11 Jun	13	4	17	465	14	4	18	649	9	167	1	5	41	399	0	3
12 Jun	9	2	11	476	12	5	17	666	1	168	1	6	3	402	0	3
13 Jun	9	2	11	487	20	7	27	693	1	169	0	6	5	407	3	6
14 Jun	10	3	13	500	5	2	7	700	2	171	0	6	7	414	0	6
15 Jun	10	3	13	513	0	0	0	700	2	173	0	6	11	425	0	6
16 Jun	22	7	29	542	0	0	0	700	4	177	0	6	43	468	1	7
17 Jun	18	6	24	566	0	0	0	700	9	186	2	8	85	553	5	12
18 Jun	28	9	37	603	12	4	16	716	21	207	2	10	62	615	4	16
19 Jun	45	13	58	661	39	12	51	767	5	212	0	10	46	661	0	16
20 Jun	19	7	26	687	23	3	26	793	3	215	1	11	31	692	0	16
21 Jun	33	9	42	729	43	8	51	844	7	222	0	11	75	767	5	21
22 Jun	29	4	33	762	55	9	64	908	9	231	0	11	71	838	8	29
23 Jun	26	3	29	791	39	4	43	951	17	248	0	11	64	902	4	33
24 Jun	34	4	38	829	36	2	38	989	20	268	1	12	66	968	3	36
25 Jun	27	0	27	856	30	2	32	1021	18	286	1	13	65	1033	4	40
26 Jun	18	0	18	874	23	2	25	1046	17	303	0	13	42	1075	1	41
27 Jun	13	2	15	889	14	0	14	1060	10	313	1	14	31	1106	6	47
28 Jun	11	2	13	902	17	0	17	1077	29	342	2	16	21	1127	0	47
29 Jun	16	2	18	920	19	0	19	1096	20	362	4	20	21	1148	1	48
30 Jun	20	1	21	941	12	1	13	1109	15	377	0	20	15	1163	3	51
1 Jul	10	2	12	953	4	0	4	1113	0	377	0	20	28	1191	6	57
2 Jul	0	0	0	953	0	0	0	1113	0	377	0	20	2	1193	0	57
3 Jul	0	1	1	954	0	0	0	1113	0	377	0	20	1	1194	0	57

Table E-1. Number of chinook salmon tagged, examined and recaptured at the Copper River fishwheels, 2003.

	Baird Canyon								Canyon Creek							
	Fishwheel 1				Fishwheel 2				Fishwheel 3				Fishwheel 4			
Date	Spag	Radio	Total	Cum	Spag	Radio	Total	Cum	Exam	Cum	Recap	Cum	Exam	Cum	Recap	Cum
4 Jul	0	1	1	955	0	0	0	1113	1	378	1	21	4	1198	0	57
5 Jul	0	1	1	956	0	0	0	1113	0	378	0	21	7	1205	0	57
6 Jul	0	2	2	958	0	0	0	1113	0	378	0	21	16	1221	2	59
7 Jul	3	1	4	962	0	1	1	1114	0	378	0	21	8	1229	2	61
8 Jul	0	1	1	963	0	0	0	1114	6	384	1	22	0	1229	0	61
9 Jul	0	0	0	963	0	0	0	1114	1	385	0	22	34	1263	3	64
10 Jul									14	399	1	23	17	1280	0	64
11 Jul									10	409	0	23	20	1300	0	64
12 Jul									8	417	0	23	11	1311	1	65
13 Jul									10	427	0	23	21	1332	3	68
14 Jul									2	429	0	23	23	1355	2	70
15 Jul									0	429	0	23	4	1359	0	70
16 Jul									0	429	0	23	17	1376	3	73
17 Jul									2	431	0	23	4	1380	1	74
18 Jul									1	432	0	23	23	1403	2	76
19 Jul													7	1410	0	76
20 Jul													2	1412	1	77
Total	727	236	963		850	264	1114		432		23		1412		77	

Only fish that received both a primary and secondary mark or were examined for both a primary and secondary mark were included in this table.

Censored tags (i.e., radio-tag failures, fish tagged prior to 17 May or after 1 July and fish measuring less than 810 mm or greater than 1070 mm FL) were not removed from this table.

Table F-1. Comparison of recapture rates by tag type at the Canyon Creek fishwheels, 2003.

Recapture history	Tag type	
	Spaghetti	Radio
Recaptured	72	25
Not recaptured	1,253	373
Total available	1,325	398
Chi-square =	0.41	
df =	1	
P-value =	0.520	

Table F-2. Number of chinook salmon recaptured by bank of release and bank of recapture and the results of a test to compare for equal movement across the river, 2003.

	Bank of release	
Bank of recapture	West	East
West	46	34
East	12	5
Not recaptured	807	819
Chi-square =	4.74	
df =	2	
P-value =	0.093	

Table F-3. Number of chinook salmon recaptured by bank of release and the results of a test to compare recapture rates for fish marked on the east and west banks, 2003.

	Bank of release	
History of recapture	West	East
Recaptured	58	39
Not recaptured	807	819
Chi-square =	3.78	
df =	1	
P-value =	0.052	

PHOTO PLATES

Photo 1. Johnny Goodlataw (Tazlina, AK) was contracted to design and construct the wooden baskets for Fishwheel 4 which was operated at the lower end of Wood Canyon on the Copper River, 2003.

Photo 2. Launching the pontoon assembly of Fishwheel 2 during mobilization at Baird Canyon on 10 May 2003.

Photo 3. Transporting Fishwheel 4 by truck and trailer from Valdez to Chitina, May 2003.

Photo 4. Fishwheel 1 in operation at Site 2 along the east bank of the Copper River near the upper end of Baird Canyon, 2003.

Photo 5. Fishwheel 2 in operation at Site 3 along the west bank of the Copper River near the upper end of Baird Canyon, 2003.

Photo 6. Fishwheel 3 in operation at Site 6 along the west bank of the Copper River approximately 2.4 km downstream from the mouth of Canyon Creek and 100 m upstream of Site 4, 2003.

Photo 7. Fishwheel 3 in operation at Site 7 along the east bank of the Copper River approximately 2.7 km downstream from the mouth of Canyon Creek and 300 m upstream of camp, 2003.

Photo 8. Fishwheel 4 in operation at Site 8 along the west bank of the Copper River approximately 0.5 km downstream from the mouth of Canyon Creek, 2003.

Photo 9. Fishwheel 4 in operation at Site 9 along the east bank of the Copper River approximately 3.0 km downstream from the mouth of Canyon Creek, 2003.

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