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Feasibility of using fishwheels for long-term monitoring of chinook salmon escapement on the Copper River, 2002 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, 2002 Annual Report

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ANNUAL REPORT SUMMARY PAGE

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Investigators/Affiliations: Michael R. Link and Jason J. Smith / LGL Alaska Research Associates, Inc., Robert Henrichs / Native Village of Eyak.

Management Region: Gulf of Alaska

Information types: Stock status and trends; distribution, abundance, and life history of fish species

Issues addressed: (1) Annual system-wide escapement estimates of chinook salmon in the Copper River, (2) Build capacity of tribal organizations to conduct needed fisheries assessment.

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EXECUTIVE SUMMARY

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 (*Oncorhynchus tshawytscha*) escapement on the Copper River. The project was conducted by the Native Village of Eyak (NVE), and funding was provided by the U.S. Fish and Wildlife Service through the Office of Subsistence Management, and the U.S. Department of the Interior, Bureau of Indian Affairs. This report summarizes results from the second year (2002) of this three-year project. Objectives for the 2002 season were to:

(1) Evaluate the efficacy of installing and operating two large aluminum fishwheels in Baird Canyon and a third fishwheel near Wood Canyon;
(2) Estimate the ability of these fishwheels to capture chinook salmon throughout the entire run;
(3) Develop and evaluate escape panels that allow sockeye salmon (*O. nerka*) to escape from the fishwheel live tanks while retaining chinook salmon; and
(4) Generate a system-wide escapement estimate for chinook salmon returning to the Copper River.

In late May 2002, two live-capture fishwheels were re-assembled and installed in Baird Canyon (river km 66) on the Copper River. These fishwheels comprised the capture-tag phase of the study, and were operated for a total of 2,390 h from 21 May to 13 July 2002. Catches included 1,518 chinook, 12,496 sockeye, 3 steelhead (*O. mykiss*), 9 Dolly Varden (*Salvelinus malma*), 26 whitefish (*Coregonus sp.*), 40 salmon smolts, 85 Pacific lamprey (*Lampetra tridentata*), 31 suckers (*Catostomus sp.*), 1 burbot (*Lota lota*), 3 Arctic grayling (*Thymallus arcticus*), and 1 beaver (*Castor canadensis*). A total of 1,205 adult chinook salmon measuring 750 mm NF or greater were marked with either a radio (410 fish) or spaghetti tag (795 fish), of which 1,137 were available for recovery upstream.

A third fishwheel was installed in late May 2002 below Canyon Creek in Wood Canyon on the Copper River (river km 97). This fishwheel comprised the recapture phase of the study, and was operated for 1,598 h from 23 May to 1 August 2002. Catches included 676 chinook, 3,689 sockeye, 2 steelhead, 2 Dolly Varden, 16 whitefish, 42 salmon smolts, 6 Pacific lamprey, 10 suckers, and 7 Arctic grayling. Sixteen (8 radio and 8 spaghetti tags) of the 580 chinook salmon examined at the Canyon Creek fishwheel measuring 750 mm NF or greater had been tagged at the Baird Canyon fishwheels.

Escape panels that were installed in the live tanks of each fishwheel in 2002 worked exceptionally well (74-92% of captured sockeye escaped during a two-hour test). Use of the escape panels reduced the potential for mortalities, as well as the amount of crew labor required to handle fish that were not sampled, and also allowed less frequent sampling sessions.

Estimated abundance of chinook salmon measuring 750 mm NF or greater above Canyon Creek was 38,893, with 95% confidence intervals ranging from 24,487 to 61,002. To improve the precision of this estimate in the future, several options will be considered for increasing the number of fish in the recovery sample (and tag sample), including: (1) refining the current fishwheel sites, (2) supplementing fishwheel catches with a dip net operation, (3) operating an additional, smaller fishwheel, and (4) examining fish caught in the Chitina and Glennallen subsistence fisheries.

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 1999-2002, the Alaska Department of Fish and Game (ADF&G) has conducted radio-telemetry 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; Link et al. 1996; McPherson 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).

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. In early 2001, the U.S. Fish and Wildlife Service (USFWS), through the Office of Subsistence Management (OSM), funded the Native Village of Eyak (NVE) to undertake this three-year study.

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 escapement 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 NVE to estimate chinook salmon escapement to the Copper River.

In 2001 and 2002, two fishwheels were operated in Baird Canyon, located approximately 66 km (41 miles) upstream of where the Copper River enters the Gulf of Alaska. In 2002, a third

fishwheel was operated near Wood Canyon (river km, rkm 157), approximately 12 km downstream from Chitina, Alaska. The purpose of this report is to document the methods, results and conclusions from the 2002 field program. Specific objectives for 2002 were to:

(1) Evaluate the efficacy of installing and operating two large aluminum fishwheels in Baird Canyon and a third fishwheel near Wood Canyon;
(2) Estimate the ability of these fishwheels to capture chinook salmon throughout the entire run;
(3) Develop and evaluate escape panels that allow sockeye salmon (*O. nerka*) to escape from the fishwheel live tanks while retaining chinook salmon; and
(4) Generate a system-wide escapement 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 southcentral 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, 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 snow, 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, located approximately 91 km upstream of Baird Canyon, is the second major channel constriction on the Copper River upstream of Miles Lake (Fig. 3). The lower end of Wood Canyon, below the mouth of Canyon Creek and the lower boundary of the Chitina Subdistrict Subsistence (CSS) fishery, was considered a suitable location for operating the

recapture fishwheel. The west bank of Wood Canyon in this area consists mostly of steep rock walls, whereas the east bank consists of a mix of sand bars, rock outcroppings and rock walls.

Chinook and sockeye salmon generally 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). ADF&G has operated a sonar system to count salmon at the outlet of Miles Lake since 1978. In 2002, an estimated 816,825 salmon passed the Miles Lake sonar site between 15 May and 30 July (ADF&G 2002).

From 1995-1999, 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). Commercial harvest for 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

An announcement for the fisheries technician positions was circulated in February 2002. Preferred skills of potential candidates 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. NVE and LGL staff conducted interviews (26-27 March) and screened all the applicants. Six people were hired for the fisheries technician positions by 15 April, and an additional four 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, 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 (9 May 2002).

Fishwheel Fabrication

Following a request for bids, Peterson Welding and Machine (Cordova, Alaska) was contracted on 26 February 2002 to manufacture a fishwheel (Fishwheel 3) for use on the Copper River near Canyon Creek. This fishwheel was designed similar to the two fishwheels used at Baird Canyon in 2001. The fishwheel was 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 (3.1 x 3.1 m), and a tower (6.1 m high) and boom (4.9 m long) assembly that was used to raise and lower the axle (Fig. 4). Baskets were designed to fish up to about 3 m below the water surface and were lined with 4.4 cm (1.75 in) knotless nylon net. A tank for holding captured fish (4.3 m long x 1.5 m deep x 0.6 m wide) was fitted inside each pontoon, and the base was fitted with windows of extruded aluminum mesh to allow ample water circulation. The fabricated fishwheel components (pontoons, axle, tower and hoist assembly, live tanks) and unassembled materials were shipped on 3 May by flatbed truck to Glennallen via the ferry to Valdez.

Mobilizing the Field Camps

Baird Canyon

In the fall of 2001, a cabin was built on the west bank of the Copper River, approximately 2 km upstream of Baird Canyon (Fig. 2; Photo 1). This cabin served as the field camp for the Baird Canyon field crew in 2002. On 8 May, a reconnaissance flight was made over Baird Canyon to assess river ice conditions, snow pack at the cabin and fishwheels, and potential landing sites for aircraft. Due to the substantial amount of ice in the river, and over 1 m of snow on the ground, it was decided a helicopter was the safest mode of transportation to use to initially mobilize the camp. From 9-15 May, nine trips were made from the Cordova Airport and/or the Million Dollar Bridge to the cabin to transport crew, two live tanks, and other supplies needed for mobilization.

From 9-17 May, three to seven people at Baird Canyon worked to set up camp and shovel snow from buried items. The crew also mobilized Fishwheel 2 during this time. Fishwheel 2 was stored over the winter at a site approximately 500 m upstream of the cabin on the east bank. Once the fishwheel was dug out from the snow, the crew spent 2.5 d pulling it 60 m down the bank to the river. On 14 May, Fishwheel 2 was floated downstream to the cabin, and it began operating on 21 May (Photo 2).

On 15 May, an ice jam that was blocking river access from the field camp to Baird Canyon and Fishwheel 1 broke free. The following day, a large ice jam upstream of the cabin (on Bremner Flats) broke free, and after several hours of heavy ice flow the entire river became clear of ice. The crew then worked from 18-23 May on mobilizing Fishwheel 1, which was stored over the winter on the west bank of the Copper River in Baird Canyon. Fishwheel 1 was launched on 23 May and operational on 24 May (Photo 3).

Canyon Creek

On 11 May, Fishwheel 3 was transported from Glennallen to Chitina where a crew of 5-7 people assembled the pontoons and fishwheel superstructure from 11-19 May. Fishwheel 3 was then floated downstream from Chitina on 19 May to the expected fishing site (rkm 157), located on the west bank of the Copper River approximately 3 km downstream from the mouth of Canyon Creek (Fig. 3). One outboard motor (15 HP) was mounted on each transom and they were used to propel and steer the fishwheel downstream. The fishwheel was trimmed for river transport by elevating the live-tanks and installing only two baskets on the axle. The third basket was taken downstream by boat and installed once the fishwheel was in place. Assembly continued until 23 May when the fishwheel became operational (Photo 4).

The field crew established the Canyon Creek field camp on 19 May on the east bank of the Copper River directly across from the fishwheel site (Photo 5). Criteria used to evaluate potential camp sites included proximity to the expected fishwheel site, elevation above river level, distance from the river, availability of clear stream water, anticipated bear activity, proximity to boat and float plane landing sites and exposure to wind. The Canyon Creek camp was supplied by boat from Chitina or by float plane from Cordova. The camp consisted of two Weatherport tents and small sleeping tents for crew members.

Camp Communication

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

One of the most significant improvements in camp communication in 2002 was the addition of a Starband satellite internet system (McLean, Virginia) to the Baird Canyon camp. This system provided continuous, high-speed internet access and was powered by a 12-V, battery-powered system that was charged by an array of solar panels and a gas-powered generator. Using the Starband system, the crew was able to:

(1) Communicate camp and personnel needs in a timely and cost-effective manner;
(2) Receive feedback on project operations from senior managers;
(3) Provide daily catch and tag summaries to ADF&G biologists who were managing the radiotelemetry project; and
(4) Provide daily catch summaries to ADF&G fishery managers in Cordova.

It also provided an excellent backup communication system in case of an emergency and the satellite phones did not work.

Fishwheel Operation and Catch

Fishwheel Site Evaluation and Selection

Wood Canyon, downstream of Canyon Creek, was scouted by air and boat to locate potential fishwheel sites. Sites were rated based on water depth, water velocity, accessibility, bankfull width, and protection from floating debris and rock fall. Water depths greater than 3 m and velocities ranging from 0.5-1.5 m/s (1.6-4.9 ft/s) were needed to rotate the fishwheel baskets at optimal speeds and force migrating fish to travel near shore and into the path of the fishwheel. Narrow, fast-flowing channels tend to concentrate migrating salmon close to shore, and are thus preferred to wide, slow-flowing areas.

Fishwheel Operation

The three fishwheels used in 2002 were installed and operated similar to those used at Baird Canyon in 2001 (Link et al. 2001). At Canyon Creek, anchor pins were drilled into cliff walls using a rock drill, whereas at Baird Canyon the anchor pins were left in place from 2001. Anchor lines attached to these pins consisted of galvanized wire rope (1.3 cm diameter) and polypropylene rope (1.9 cm diameter). Two, propeller-driven, outboard motors (40 HP each) were used to move the Baird Canyon and Canyon Creek fishwheels during high-water periods (two 15-HP motors were used at Canyon Creek at the start of the season).

The fishwheels were operated 24 hours per day, except for stoppages when adjustments or repairs were required. 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 also had an aluminum spar pole mounted across the bow that was used to adjust the distance of the fishwheel from shore. Fishwheel speed, measured in 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. The fishwheels were re-positioned until target speeds of 1.5-3 RPM were obtained. When fishwheel speed was measured more than once in a day, the arithmetic mean of the measurements was calculated.

Daily water temperatures (^{o}C) and levels (m) were recorded at the Baird Canyon and Canyon Creek fishwheels. Water levels were recorded at both sites using aluminum staff gauges that were secured to the canyon walls 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 the 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 the fishwheel fished to obtain a given day's catch. These two effort values were often not the same for a given day because the fishwheel 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 h because the fishwheel operated continuously for the entire calendar day. *Effort for calculating CPUE* on day *t*+1 could also exceed 24 h if the last sampling session on day *t* was earlier in the day than the last sampling session on day *t*+1. Catch per unit effort (CPUE) in fish per fishwheel hour was calculated by dividing the total number of fish captured on a given calendar day 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 designed and installed in all three fishwheels in 2002 (Photo 6). These devices consisted of two, adjustable, vertical slots in a removable, aluminum frame. When installed and opened to the appropriate width (6-7.5 cm), the escape panels allowed smaller fish (i.e., sockeye and other by-catch species) to easily swim out of the live tanks while retaining chinook salmon. As a result, the escape panels reduced crowding and the potential for sampling mortalities, as well as the amount of crew labor for handling fish, particularly during high-catch periods.

Sampling and Tag Recovery

Sampling

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 (if possible), 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. Mid-eye-fork (MEF; measured from the middle of the eye to the fork of the tail) and nose-fork (NF; measured from the tip of the nose to the fork of the tail) lengths were collected in 2002. 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 sampling trough was changed repeatedly throughout each sampling session. All other captured fish were identified to species, counted and released back to the river.

Baird Canyon

At Baird Canyon, chinook salmon greater than 570 mm NF 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. It was expected that the fishwheels would catch two or three times as many chinook salmon as ADF&G planned to radio tag (500), so only a portion of each day's catch was radio-tagged. ADF&G biologists based their radio-tagging schedule on the 1999-2001 relative abundance of chinook salmon at Haley Creek in order to apply the radio tags in proportion to the run size (Table A-1). Once the daily radio-tagging goal was met, the remaining chinook salmon were marked with a yellow spaghetti tag and a right operculum punch (secondary mark).

The radio tags were Model Five, pulse-encoded transmitters made by Advanced Telemetry Systems (Isanti, MN). Each radio tag was identified by a frequency and encoded pulse pattern. Chinook salmon implanted with 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. The radio tag was then seated into the upper stomach using a plunger, which was a second piece of smaller-diameter tubing that fit through the center of the first tube.

All marked chinook salmon 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 then secured by crimping (1.3 mm crimps) the monofilament line.

Three scales were removed from the left side of radio-tagged fish approximately two rows above the lateral line along a diagonal line from the posterior insertion of the dorsal fin to the anterior insertion of the anal fin. The entire sampling procedure took approximately two minutes per fish.

Canyon Creek

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 in the Canyon Creek fishwheel were examined for a radio tag, spaghetti tag, and right operculum punch. If a marked fish was found, the spaghetti tag number and mark type were recorded. Prior to release, a left operculum punch was applied to the majority of captured chinook salmon in order to identify them, if recovered later, as previously caught at the Canyon Creek fishwheel.

Tag Recovery

Chinook salmon tagged at the Baird Canyon fishwheels were recovered throughout the Copper River Basin. Recovery locations included the Chitina Subdistrict Subsistence (CSS) dip net 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. Tags recovered in the various fisheries were either sampled directly by ADF&G Creel personnel in Chitina and Glennallen, or the tag numbers were voluntarily returned to NVE and ADF&G offices by fishery participants (addresses for the NVE or Fairbanks ADF&G offices were printed on the spaghetti tags). Only tagged fish recaptured at the Canyon Creek fishwheel were used to generate a mark-recapture abundance estimate. The travel time of fish from release at Baird Canyon to recovery at these various locations were also calculated.

Inriver Abundance Estimate

Conditions for a Consistent Abundance Estimate

Population 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).

Handling and tagging fish at the Baird Canyon fishwheels did not make them more or less vulnerable to capture at the Canyon Creek fishwheel than untagged fish.

There was no explicit test for this assumption in this study because the behavior of untagged fish could not be assessed. However, several steps were taken to ensure tagged fish were released in excellent condition. Sampling sessions were frequent (minimum of three times per day) to ensure that captured fish were not held in the live tanks for long periods of time. The installation of escape panels in 2002 reduced fish densities in the live tanks, particularly during periods of high sockeye catches. All technicians were trained by experienced biologists on how to handle and sample fish in order to reduce the amount of stress on the fish. Stressed or injured fish were not tagged, and the sampling procedure was the same throughout the study period. Also, the large distance between the tag and recapture sites (90 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.

All tagged chinook salmon received both a primary and secondary mark at Baird Canyon, so the chance of a fish losing both marks between sampling events was assumed to be negligible. Only fish that were examined for both a primary and secondary mark at Canyon Creek were included in the calculations of abundance. In addition, any fish that were tagged and then recaptured at the Baird Canyon fishwheels were examined for tag loss.

All radio-tagged chinook salmon that were released at Baird Canyon, but never detected at or above the Canyon Creek fishwheel, were removed from the total number of fish available to be recaptured. These radio tag failures were probably due to post-tagging mortality, tag regurgitation, or tag malfunction, but differentiating amongst these or any other potential causes was not possible. The post-tagging mortality rate in spaghetti-tagged fish was not tested directly, so it was assumed to be the same as the failure rate observed in radio-tagged fish (even although a portion of the radio tag failures may have been due to tag regurgitation or malfunction). Sensitivity analyses were performed on the failure rate of spaghetti-tagged fish.

Tagged fish mixed completely with untagged fish across the river and no fish had a zero probability of capture.

The fishwheels used to capture chinook salmon in this study were bank-oriented, so fish swimming in the center of the river may have been excluded in the abundance estimate. This assumption was not tested because the Baird Canyon fishwheels were installed on the east bank of the river, and the Canyon Creek fishwheel was installed on the west bank. However, it was assumed that the distance between the tag and recapture sites (90 km) was sufficient to allow for adequate mixing between the sampling events. Results from ADF&G radiotelemetry studies (1999-2001) support this assumption, as marked fish were found to mix with unmarked fish 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 Baird Canyon and Canyon Creek.

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

To determine whether fish had equal probabilities of being marked and recaptured regardless of their size, a Kolmogorov-Smirnov (K-S) two-sample test (Zar 1984) was used to compare the cumulative length-frequency distributions of: Test A – all fish marked during the first sampling event and recaptured during the second event; and Test B – all fish marked during the first sampling event and examined during the second event. The null hypothesis (H_o) was no difference between the length distributions for Test A or for Test B. There were four possible outcomes for these two tests (as presented in Bernard and Hansen 1992):

(1) Case I: *Accept H_o(Test A), Accept H_o(Test B).* There was no size-selectivity during either sampling event.
(2) Case II: *Accept H_o(Test A), Reject H_o(Test B).* There was no size-selectivity during the second sampling event, but there was during the first event.
(3) Case III: *Reject H_o(Test A), Accept H_o(Test B).* There was size-selectivity during both sampling events.
(4) Case IV: *Reject H_o(Test A), Reject H_o(Test B).* There was size-selectivity during the second sampling event, but the status of size-selectivity during the first event was unknown.

Depending on the outcome of the tests, one of the following procedures would be used to estimate the abundance of chinook salmon:

(1) Case I and II: Calculate an unstratified estimate of abundance.
(2) Case III and IV: Stratify the fish in both sampling events by size, and estimate abundance for each stratum. Add the abundance estimates across strata to get a single estimate for the population.

Even if the hypothesis tests indicate that there has been size-selective sampling (Case III or IV), there is still a chance that the bias in estimates of abundance from this source is negligible. In this case, a second, unstratified estimate of abundance would be calculated. If the two estimates (stratified and unbiased vs. biased and unstratified) were dissimilar, the bias is meaningful, and the stratified estimate would be used. If the estimates were similar, the bias is negligible in the unstratified estimate, and analysis can proceed as if there were no size-selective sampling during the second event.

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

Fishing effort at the Baird Canyon fishwheels was continuous throughout the study period to ensure equal probability of capture of migrating chinook salmon. Marked to unmarked ratios in the second sampling event were compared among weeks to evaluate if this condition was met.

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

Catchability over time at the Canyon Creek fishwheel was tested by comparing recapture rates by week. If both recapture rates and marked to unmarked ratios were significantly different over the study period, and a sufficient number of recaptures were available, a temporally stratified estimator such as the method of Darroch (1961) would be used. Consecutive strata having similar recapture rates would be pooled.

Abundance Estimate

Chinook salmon abundance above Baird Canyon was estimated using the Petersen two-sample model (Ricker 1975; Seber 1982):

$$N = \frac{(M+1)(C+1)}{(R+1)} \qquad (1)$$

where N is the estimate of abundance, M is the number of tagged fish available for recovery, C is the number of fish examined for tags in the recovery sample, and R is the number of tagged fish recaptured.

Confidence limits for the abundance estimate were obtained using fiducial limits for the Poisson distribution as described in Ricker (1975):

For $1 - P = 0.95$: $$N = \frac{(M+1)(C+1)}{R+1.92 \pm 1.96\sqrt{R+1}+1} \qquad (2)$$

RESULTS

Fishwheel Operation and Catch

Fishwheel Operation

Baird Canyon

The water level of the Copper River at Baird Canyon varied by 2.4 m from 26 May to 13 July 2002 (Table B-1; Fig. B-1); the most noticeable increase occurred from 15-19 June. Water levels at the Million Dollar Bridge (located at the outlet of Miles Lake) in 2002 were above the average levels observed from 1982-2001 for the majority of the season (S. Moffitt, Alaska Department of Fish and Game, Division of Commercial Fisheries, Cordova, *personal communication*; Fig. B-2). Water temperature at Baird Canyon ranged from 5.4 to 9.4 ^{o}C from 21 May to 13 July.

Fishwheel 2 was operated for a 24-h period (21-22 May) at Site 1 along the west bank of Baird Canyon (Fig. 2; Photo 2). On 22 May, as water levels began to rise, Fishwheel 2 was moved to Site 2, located on the east bank of the river immediately downstream from the upper end of Baird Canyon. Due to the lack of potential fishing sites early in the season when water levels were low, Fishwheel 1 was operated directly behind Fishwheel 2 at Site 2 (Fig. 2; Photo 3). Fishwheel 2 was operated closer to the bank, and in shallower water than Fishwheel 1, and thus caught the majority of passing salmon. Fishwheel 1 began fishing on 24 May.

Fishwheels 1 and 2 were operated until 10 July and 13 July, respectively. They were operated for a total of 2,390 h, and fished essentially 100% of the time that they were in operation (Table C-1; Fig. C-1). Both fishwheels operated at average speeds of 2 RPM.

Canyon Creek

Water levels of the Copper River at the Canyon Creek fishwheel varied by 2.3 m from 31 May to 1 August 2002 (Table B-1; Fig. B-1). Water temperature ranged from 6.1 to 11.7 ^{o}C from 23 May to 1 August.

Fishwheel 3 was operated from 21 May to 31 August along the west bank of the Copper River at the lower end of Wood Canyon (Fig. 3; Photo 4). Fishwheel 3 was operated for 1,598 h and fished 95% of the time it was in place (Table C-1; Fig. C-1). Fishwheel 3 was stopped on occasion to repair damage caused by woody debris during high water periods. Also, small changes (less than 10 m) in the position of Fishwheel 3 relative to the bank were common as a result of fluctuating water levels. Fishwheel speed averaged 2.2 RPM at Canyon Creek, which was slightly faster than at Baird Canyon.

Fishwheel Catch and Effort

In 2002, the three fishwheels that operated on the Copper River captured a combined total of 2,194 adult chinook and 16,185 sockeye salmon (Table 1).

Baird Canyon

A total of 1,518 adult chinook salmon were caught in the two Baird Canyon fishwheels (Table 1). Fishwheel 2 caught 1,184 (78%) of the chinook salmon from 22 May to 12 July and Fishwheel 1 captured 334 (22%) from 24 May to 9 July (Table D-1). Catches were highest from 1-18 June and peaked on 5 June at 98 chinook salmon between the two fishwheels (Fig. 5). As in 2001, the majority of chinook salmon (64% for Fishwheel 1 & 2) were captured in the live tank furthest from shore.

The peak daily chinook salmon CPUE at Baird Canyon came in the first half of the season. Daily CPUE peaked at 3.0 fish per hour on 2 June and 7 June at Fishwheel 2, and 1.3 fish per hour on 6 June at Fishwheel 1 (Fig. 6; Table D-1). Three distinct events are evident in the graph of CPUE at Fishwheel 2. Daily CPUE was highest from 2-8 June and ranged from 2.2 to 3.0 fish per hour (average = 2.7) during the same period. A second peak in CPUE (2.7 fish per hour) occurred on 16 June. From 22 June to 2 July, CPUE at Fishwheel 2 remained fairly high, ranging from 0.7 to 1.5 fish per hour (average = 1.1). CPUE was consistently lower at Fishwheel 1 than Fishwheel 2 throughout the season, but changes in CPUE at both fishwheels tended to follow the same pattern.

Five (0.3%) of the chinook salmon caught at Baird Canyon were missing their adipose fin, which indicated they were coded-wire-tagged. The snouts of coded-wire-tagged fish were delivered to ADF&G for further analysis. Few mortalities or injuries to fish were observed during the 2002 field season. One chinook salmon was found dead in the live tank of Fishwheel 2 on 5 June, and a second chinook salmon was released on 17 June with an injury caused during the tagging procedure.

A total of 12,496 sockeye salmon were also caught in the two Baird Canyon fishwheels (Fig. 5; Table D-1). From 21 May to 13 July, Fishwheel 2 captured 7,970 (64%) sockeye, and from 24 May to 10 July, Fishwheel 1 captured 4,526 (36%) sockeye. Sockeye catches were highest from 27 May to 9 June and from 7-9 July, with a peak catch of 880 fish on 4 June. CPUE for Fishwheel 1 peaked on 1 June at 26 fish per hour, while CPUE for Fishwheel 2 peaked on 7 June at 19.3 fish per hour (Fig. 6). Similar to chinook salmon, the majority of sockeye salmon at each fishwheel (73% for Fishwheel 1 & 2) were caught in the live tank furthest from shore. Sockeye catches were dramatically reduced when escape panels were installed in the live tanks of each fishwheel on 4 June (see Escape panels below for results).

Catches of other salmonid species at the Baird Canyon fishwheels included 3 steelhead (*O. mykiss*), 9 Dolly Varden (*Salvelinus malma*), 26 whitefish (*Coregonus sp.*) and 40 salmon smolts (*Oncorhynchus sp.*; Table D-2). Catches of non-salmonid species included 85 Pacific lamprey (*Lampetra tridentata*), 31 suckers (*Catostomus sp.*), 1 burbot (*Lota lota*), 3 Arctic grayling (*Thymallus arcticus*), and 1 beaver (*Castor Canadensis*; Table D-3).

Canyon Creek

The Canyon Creek fishwheel captured 676 adult chinook salmon from 29 May to 1 August (Fig. 5; Table D-1). No chinook salmon were caught from 23-28 May, despite the fishwheel being operational during this period. Catches were high from 3-12 June and 23 June to 1 July, and peaked on 30 June at 56 fish. Six (0.9%) of the chinook salmon captured were coded-wire tagged.

Daily CPUE for chinook salmon at the Canyon Creek fishwheel peaked on 30 June at 2.3 fish per hour (Fig. 7; Table D-1). Two periods of high CPUE occurred from 3-12 June and 21 June to 2 July, where CPUE ranged from 0.5 to 1.3 fish per hour (average = 0.8) and 0.5 to 2.3 fish per hour (average = 1.1), respectively.

A total of 3,689 sockeye were also caught at the Canyon Creek fishwheel. Sockeye CPUE increased to 1.3 fish per hour on 8 June, and peaked at 2.3 fish per hour on 30 June (Fig. 7). The majority (64%) of sockeye salmon at Fishwheel 3 were caught in the live tank furthest from shore (starboard side).

Catches at Fishwheel 3 also included 2 steelhead, 2 Dolly Varden, 16 whitefish, 42 salmon smolts, 6 Pacific lamprey, 10 suckers, and 7 Arctic grayling (Table D-2 and D-3).

Escape panels

The escape panels on Fishwheel 2 were first opened at 2230 hours on 28 May with the openings set at a width of 6.0 cm (Table E-1). On 29 May, after 16 h of use, it was clear from the decrease in sockeye catches that the escape panels were successful at allowing sockeye to escape the live tanks (Fig. E-2). At this time, the panels were removed and a sockeye was found gilled in one of the vertical slots. The sockeye gills were caught on the exterior square, smooth walls of the panel opening as it tried to swim out of the live tank. Both escape panels were closed until modifications (providing a half v-slot on exterior wall) were made to minimize or eliminate the potential of more sockeye being gilled.

Re-configured panels were installed on Fishwheel 2 on 4 June. On 28 June, the opening of the escape panels was widened to 7.0 cm. The panels on the starboard and port live tanks of Fishwheel 1 were opened on 7 and 9 June, respectively, and remained open for the remainder of the season. The panels were set at a width of 6.5 cm. At Canyon Creek, the escape panels on Fishwheel 3 were open from 10-24 July with the openings set at a width of 6.0 cm. No fish were found gilled in any of the panels after the single-fish incident on 29 May at Fishwheel 2.

In order to more precisely estimate the efficiency of the escape panels, a test was conducted on 8 July at the Baird Canyon fishwheels. The live tanks of both fishwheels were first emptied. The escape panels were then opened (6.5 cm openings on Fishwheel 1 and 7.0 cm openings on Fishwheel 2) and catches were visually monitored for each live tank for approximately 2.5 h (1345-1615 h). After this monitoring period, all fish were counted and released. At Fishwheel 1, 74% (23 out of 31 fish) of the sockeye that were caught escaped from the port tank and 76% (19 out of 25 fish) of the sockeye escaped from the starboard tank. At

Fishwheel 2, where the panels were spaced slightly wider, 81% (91 out of 113 fish) of the sockeye escaped from the port live tank and 92% (66 out of 72 fish) escaped from the starboard live tank. The 27 sockeye that did not escape from Fishwheel 2 during the monitoring period averaged 670 mm NF, and ranged from 580-720 mm NF. This test may have underestimated the efficiency of the panels because some of the remaining sockeye may not have had enough time to find the panel openings and escape.

To further illustrate the effects of the escape panels, CPUE was plotted as a percent of the Miles Lake sonar counts for sockeye and chinook salmon in the port tank of Fishwheel 2 at Baird Canyon over time (Fig. E-2). This index of sockeye CPUE was much lower when the escape panel was open than when it was closed, even during periods of high sockeye abundance. However, this trend was not evident for chinook salmon, which was expected if chinook were unable to escape the live tanks. Based on the dramatic decline in sockeye catches, and stable or increasing chinook catches, it was clear that the escape panels were working well.

Sampling and Tag Recovery

Sampling

Of the 1,518 adult chinook salmon captured at Baird Canyon, 1,344 (88.5%) fish measuring 570 mm NF or greater received both a primary and secondary mark (Table 2; Table D-1). Of these 1,344 tagged fish, 461 (34.3%) received a radio tag, and 883 (65.7%) received a spaghetti tag as the primary mark. The remaining 174 chinook salmon caught were not tagged because they either escaped prior to both marks being applied or had visible injuries (153 fish), were less than 570 mm NF (14 fish), were CWT fish (5 fish), or were mortalities (2 fish).

Of the 2,194 chinook salmon captured at all three fishwheels, 2,025 fish (92%) were measured for length. In order to standardize all length measurements, a subsample of 102 fish were measured for both MEF and NF length. These data were used to derive a relationship for converting between the two measurement types (MEF = NF * 0.9132 + 10.9179, $r^2 = 0.98$; Fig. F-1). Lengths of male and female fish were pooled due to the difficulties of reliably identifying sex at the Baird Canyon fishwheels.

The average length of all adult chinook salmon measured at Baird Canyon (897 mm NF; n = 1393) was smaller than fish measured at Canyon Creek (913 mm NF, n = 632; Table 3). Lengths ranged from 300-1258 mm NF at Baird Canyon and from 309-1222 mm NF at Canyon Creek. As in 2001, there appeared to be three modes (300-500 mm, 500-775 mm, and 775-1258 mm NF) in the length frequency distribution of chinook salmon at both Baird Canyon and Canyon Creek in 2002 (Fig. 8).

Tag Recovery

Of the 676 chinook salmon caught at the Canyon Creek fishwheel, 650 (97.7%) were examined for primary and secondary marks (Table 4). Of those examined, 16 (2.5%) were recaptures (8 spaghetti and 8 radio tags), or fish that were previously tagged and released at the Baird Canyon fishwheels. The smallest chinook salmon recaptured at the Canyon Creek

fishwheel was 750 mm NF, despite the fact that 136 marked fish were released at Baird Canyon that were greater than or equal to 570 mm NF and less than 750 mm NF. Since none of these smaller fish were recaptured at the Canyon Creek fishwheel, a length threshold of 750 mm NF was established, and only fish marked, examined, and recaptured that measured 750 mm NF or greater were included in the estimate of abundance.

There were 410 radio-tagged fish released at the Baird Canyon fishwheels that measured 750 mm NF or greater (Table 4). Twenty-three (5.6%) of these radio-tagged fish were classified as failures (due to post-tagging mortality, tag regurgitation, or tag malfunction), because they were never detected at or above the Canyon Creek fishwheel on fixed-station receivers or during aerial tracking surveys. Therefore, 387 radio-tagged fish measuring 750 mm NF or greater were available for recapture at the Canyon Creek fishwheel, and 2.1% (8 out of 387) of them were recaptured.

A total of 795 spaghetti-tagged measuring 750 mm NF or greater were released at Baird Canyon (Table 4). It was assumed that the post-tagging mortality rate of spaghetti-tagged fish was equal to the failure rate of radio-tagged fish (5.6%). As a result, 45 spaghetti-tagged fish were removed, which left 750 spaghetti-tagged fish available for recovery at Canyon Creek. Thus, the tag recovery rate of spaghetti-tagged fish was 1.1% (8 out of 750).

Despite nearly a two-fold difference in the recapture rate of radio and spaghetti-tagged fish measuring 750 mm NF or greater at the Canyon Creek fishwheel, the difference was not significant ($?^2 = 1.84$, df = 1, P = 0.17; Table G-1). However, tests of significance for chi-squared tests are sensitive to sample size. For example, if only three additional radio-tagged fish were recaptured, the test would have been significant ($?^2 = 4.82$, P = 0.03). The recapture rates of each tag type were also compared with data collected in the CSS and GSS fisheries (using only fish directly sampled by ADF&G creel personnel). Again, the recapture rates of radio and spaghetti-tagged fish measuring 750 mm NF or greater were not statistically different in the CSS ($?^2 = 2.17$, P = 0.14; Table G-2) or GSS ($?^2 = 0.24$, P = 0.62; Table G-3) fisheries.

Mark rates (# recaptures / # examined) of each tag type at the Canyon Creek fishwheel were then compared to those observed in the CSS and GSS fisheries. The mark rate of radio-tagged fish measuring 750 mm NF or greater at the Canyon Creek fishwheel was not significantly different than the mark rate in the CSS ($?^2 = 0.12$, P = 0.73; Table G-4) or GSS ($?^2 = 1.99$, P = 0.16; Table G-5) fisheries. Conversely, the mark rate of spaghetti-tagged fish at the Canyon Creek fishwheel was significantly different from the mark rate in the CSS ($?^2 = 14.4$, P < 0.01; Table G-6) and GSS ($?^2 = 5.7$, P = 0.02; Table G-7) fisheries.

In addition to the 16 recaptures at the Canyon Creek fishwheel, 273 chinook salmon measuring 570 mm NF or greater with both primary and secondary marks were recovered in the various fisheries throughout the Copper River Basin (Table 5). Recoveries were made in the CSS dip net fishery (111 fish), GSS fishwheel fishery (90 fish), sport fishery (45 fish), and commercial gillnet fishery (3 fish). There were 24 tags returned by the public to NVE and ADF&G from unknown locations. Two tagged fish that were recaptured at the Canyon Creek fishwheel were subsequently recovered in an inriver fishery upstream.

Travel time

Recaptured fish were tagged from 26 May to 1 July at Baird Canyon and recovered at Canyon Creek from 5 June to 14 July (Table G-8). The median travel time of chinook salmon from release at Baird Canyon to their subsequent recovery at the Canyon Creek fishwheel was 11 d (n = 15), and ranged from 7-30 d (Table 6). From Baird Canyon to Canyon Creek, the median travel time for recaptured fish that were tagged prior to 19 June (low water conditions) was 13 d (n = 11), whereas the median travel time for fish tagged after 19 June (high water conditions) was 9 d (n = 4). The mean travel time of spaghetti-tagged fish (11.3 days, n = 7) was not significantly different (*t*-test; df = 13, P = 0.45) than the mean travel time of radio-tagged fish (13.5 d, n = 8).

The travel time of tagged chinook salmon (= 570 mm NF) from release at Baird Canyon to recovery upstream averaged 15.1 d (range = 5-42 d, n = 107) for the CSS dip net fishery, 22.2 d (range = 6-49 d, n = 93) for the GSS fishwheel fishery, and 29.7 d (range = 12-52 d, n = 40) for the sport fishery (Table 6). Three fish recovered in the commercial fishery were caught 17, 20, and 31 d after being tagged at the Baird Canyon fishwheels.

Inriver Abundance Estimate

Conditions for a Consistent Estimator

Handling and tagging fish at the Baird Canyon fishwheels did not make them more or less vulnerable to capture at the Canyon Creek fishwheel than untagged fish.

The probability of capture of chinook salmon at Canyon Creek was assumed to be unaffected by the handling and tagging procedures at Baird Canyon. Fifty-eight chinook salmon that were captured and tagged at the Baird Canyon fishwheels were subsequently recaptured in the same fishwheels (42 in Fishwheel 1, 16 in Fishwheel 2). Although these recaptures were not part of the information used to estimate abundance, they did provide insight into the amount of time fish delay their migration after handling. The majority of these fish (52 fish, 90%) were recaptured within one sampling session of being tagged (less than a 24-hr delay), and only six were recaptured two or more days after being tagged (range = 2-29 d, median = 7 d). Twelve chinook salmon were captured twice at the Canyon Creek fishwheel, and all were within one sampling session. Based on these data, it appeared that fish did not delay their upstream migration due to handling and/or tagging at the fishwheels.

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

There was no evidence of tag loss from the 16 tagged fish recaptured at the Canyon Creek fishwheel, or the 58 fish tagged and then recaptured at the Baird Canyon fishwheels.

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

Since there were only 15 recaptured fish with length measurements (Table G-8), a KS-test was not used to compare the length-frequency distributions of marked and recaptured fish (Test A; Fig. 9). However, the average length of recaptured fish (958 mm NF; n = 15) was larger than that of marked fish (901 mm NF; n = 1338). The length distribution of fish tagged at Baird Canyon was significantly different (D = 0.13, P < 0.01) than the length distribution of fish examined at Canyon Creek (Test B; Fig. 9). These results indicated there was size-selective sampling at Canyon Creek, but the status of size-selectivity at Baird Canyon was unknown.

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

The marked to unmarked ratio of chinook salmon at the Canyon Creek fishwheel varied throughout the study period, with the highest ratios occurring from 25 June to 15 July (0.04-0.07; Table 7). Testing this assumption with confidence was difficult due to the small number of recaptured fish, however, this pattern suggested that the probability of a chinook salmon being marked at Baird Canyon was not independent of time of capture.

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

Marked fish did not have equal probabilities of being recaptured over time. Recapture rates, grouped by the week that fish were tagged at Baird Canyon from 21 May to 15 June, were significantly different ($?^2$ = 23.1, df = 8, P = 0.01; Table 7). One major discrepancy was the fact that none of the 614 fish tagged at Baird Canyon from 28 May to 10 June were recaptured at Canyon Creek. Assuming these 614 fish took 11 d to travel the distance between Baird Canyon and Canyon Creek, they would have migrated passed the Canyon Creek fishwheel from 8-21 June. Unfortunately, environmental conditions at Canyon Creek changed dramatically during this period. Stage height increased by 1.2 m from 12-20 June (and water temperature increased by 2.2 ^{o}C from 12-16 June; Table B-1) and fishwheel speed increased by 0.7 RPM. As a result, the Canyon Creek fishwheel was stopped for 20.7 h (17-18 June) to repair damage caused by debris and to move the fishwheel to a more suitable location (Table C-1; Fig. C-1). These factors led to a decrease in fishwheel catchability at a time when a large pulse of tagged chinook salmon were migrating passed the Canyon Creek fishwheel. In addition, the majority of this large pulse of fish were spaghetti-tagged, which helps explain why the recapture rate of radio-tagged fish was nearly twice that for spaghetti-tagged fish.

Abundance Estimate

Due to the small number of recaptures, a temporally stratified estimator was not used to account for variability in recapture rates and marked to unmarked ratios over the study period. Despite the fact that several of the conditions necessary for a consistent estimate were not met, a pooled Petersen estimate was used to estimate the abundance of chinook salmon measuring 750 mm NF or greater above the Canyon Creek fishwheel. Estimated abundance was 38,893 with a 95% confidence interval ranging from 24,487 to 61,002 (Table 8). This estimate was based on 1,137 tagged fish available for recovery, 580 fish examined for tags in the recovery sample, and

16 recaptures. Sensitivity analysis showed that reducing the post-tagging mortality rate of spaghetti-tagged fish by half (5.6 to 2.8%) increased the abundance estimate by 2% (786 fish). In comparison, if all the conditions necessary for a consistent estimate were met, the estimated abundance of chinook salmon measuring 570 mm NF or greater would have been 50,128 with a 95% confidence interval ranging from 31,560 to 78,623 (Table 8).

DISCUSSION

Project Mobilization

Mobilizing the Field Camps

In 2002, there was a considerable amount of uncertainty over when to mobilize the field camps and begin operating the fishwheels. If the fishwheels were mobilized too late, the first pulse of chinook salmon migrating through Baird Canyon may not have been captured and marked. If the fishwheels were mobilized too early, then there was the risk of spending a substantial portion of the limited budget prior to tagging any fish. At Baird Canyon, the heavy snow conditions on land and ice conditions in the river made early mobilization difficult and expensive. Following is a summary of snow, ice, water depth (and velocity) and run timing information from 2002. These data were compared to historical information and a prescription for when to mobilize the field camps in the future was developed.

Baird Canyon

When the crew first arrived at the cabin on 9 May there was approximately 1.5 m of snow on the ground and river ice was blocking boat access to Baird Canyon. It took about 11.5 d (9-21 May) to mobilize Baird camp and Fishwheel 2, and an additional 2.5 d (21-23 May) to mobilize Fishwheel 1. River ice in and above Baird Canyon did not clear until 16 May.

Water velocity and depth at Site 1 were suitable on 21 May when a fishwheel first began operating there, and may have been suitable earlier. Due to low water velocity, Site 2 was not suitable for fishing until 22 May when the water level at the Million Dollar Bridge reached 40.40 m. On average (1982-2002), water levels at the Million Dollar Bridge have reached 40.40 m on 31 May; the earliest was 15 May and the latest was 19 June. In only 8 of the 21 years (38%) on record have water levels reached 40.40 m earlier than 31 May (including 2002). In 2001, a fishwheel was operated at Site 1 from 29 May to 7 June, at which time rising water levels created a back eddy at the site and the fishwheel stopped turning. A fishwheel was first operated at Site 2 on 4 June 2001, and water velocities any earlier than this would probably have been too slow to turn the baskets.

It is unlikely that many chinook salmon were migrating through Baird Canyon prior to 21 May. No chinook salmon were caught at Site 1 on 21 May, one chinook at Site 1 on 22 May, and three chinook salmon at Site 2 on 23 May. This statement is also supported by data on the date chinook salmon were first caught in ADF&G dip nets (30 May in 1999 and 24 May in 2000)

(Evenson and Wuttig 2000; Wuttig and Evenson 2001) and the Canyon Creek fishwheel (29 May 2002), assuming a 7-10 day travel time for fish migrating between Baird and Wood canyons.

Based on the experience gained in 2002, the estimated time required to mobilize Baird camp in future years could be reduced by 35% or more. Therefore, it should be possible to mobilize in 5-7 d, depending on how conditions compare to those in 2002. In order to begin fishing at about the same time next year (21 May), a crew of similar size to that in 2002 should begin mobilization around 14 May. As soon as the river is clear of ice and water levels are still low at Site 2, one fishwheel should be operated at Site 1. The second fishwheel should be placed at Site 2 as soon as ice flows are gone in anticipation of more suitable water conditions. When water levels at the Million Dollar Bridge reach approximately 40.40 m, the fishwheel at Site 1 should be moved to Site 2 because it becomes exceedingly difficult to move a fishwheel upstream of Site 1 when the river raises much above this level.

Canyon Creek

Similar to Baird Canyon, it took about 11 days (10-20 May) to mobilize the Canyon Creek camp and begin operating Fishwheel 3. The first chinook salmon was caught on 29 May and only three chinook were caught prior to 2 June. Assuming a 35% reduction in mobilization time due to experience, and a similar crew size and environmental conditions, Canyon Creek should be mobilized around 22 May to ensure the fishwheel is operational by 29 May. The Canyon Creek fishwheel should be operated until at least 1 August in 2003 to ensure the entire run is encompassed.

Fishwheel Operation and Catch

Fishwheel Site Evaluation and Selection

The Baird Canyon fishwheels were both operated at Site 2 in 2002 primarily because it was an exceptional fishwheel site, but also because there were no other suitable sites early in the season for the second fishwheel. In hindsight, operating both fishwheels at Site 2 was extremely effective. Fishwheel 1 captured a large number of sockeye (sockeye-to-chinook ratio = 13.6:1) that otherwise might have been captured in Fishwheel 2 (sockeye-to-chinook ratio = 6.7:1). This occurred because Fishwheel 1 was operated in deeper water than Fishwheel 2 and chinook tend to swim closer to the river bottom than sockeye. In effect, Fishwheel 1 may have reduced the amount of crowding in the live tanks of Fishwheel 2 and likely reduced stress on chinook salmon.

On 24 May, an attempt was made to operate Fishwheel 1 on the west bank of Baird Canyon, approximately 300 m upstream of Site 2. This location proved too shallow and was not used again in 2002, although but it may be suitable at higher water levels.

Fishwheel sites at the lower end of Wood Canyon were limited in 2002. There were potential sites near the mouth of Haley Creek, but operating a fishwheel within Wood Canyon where the personal use dip net fishery takes place was not a desirable option. Small fishwheels were operated near the mouth of Haley and Canyon creeks from 1966-68 to capture sockeye

salmon, but these sites caught almost no chinook salmon (Greenough 1971). Despite occasional stoppages due to damage from woody debris or changes in water level, the Canyon Creek fishwheel remained operational throughout the entire season.

Fishwheel Catch and Effort

Catches of chinook salmon at the Baird Canyon fishwheels met or exceeded preseason expectations. Sixty-six percent more chinook salmon were captured in 2002 (1,518 fish) than in 2001 (914 fish). The difference between years was attributed to less down time to move and repair the fishwheels, operating two fishwheels instead of one, and operating them over a longer period. Minor changes in fishwheel position at Baird Canyon may lead to increased chinook catches in the future, but the increase will not likely be as significant as what was seen in 2002.

In 2002, 55% fewer chinook salmon were captured at the Canyon Creek fishwheel (676 fish) than at Baird Canyon. Apart from the obvious difference of only operating one recovery fishwheel, catches may have been affected by higher water velocities and greater depth at the Canyon Creek site. In fast flowing rivers, salmon tend to migrate close to the bottom or shore and avoid faster moving water near the surface; presumably this is done to minimize the energy requirements of traveling a given distance upstream. Also, high water velocities at the site may simply exceed the sustained swimming speed of some chinook salmon, thereby precluding upstream movement. The greater distance between the fishwheel baskets and river bottom at Canyon Creek provided fish with more room to pass beneath the fishwheel without being caught. In addition, the Canyon Creek fishwheel was shut down during high water periods to repair damage and move the fishwheel to a more suitable location. To address these issues in 2003 and ensure the catchability of the fishwheel is constant over the study period, depth and flow measurements will be collected at all sites and fishwheel positioning will continue to be refined.

Escape panels

One of the recommendations that arose from the 2001 field season was to design a way to reduce fish densities in the live tanks during high catch periods, which at times led to mortalities. Preseason investigations ruled out using mechanical and/or electronic sorting devices on the fishwheel slides due to their high cost, logistical challenges and complexity. Instead, escape panels were designed and installed in the live tanks of all three fishwheels that allowed smaller fish to simply swim out of the live tanks while retaining the chinook salmon. Six escape panels, two for each fishwheel, were fabricated in Cordova prior to the field season.

Apart from the period of time when the escape panels were being modified, the panels were kept open on the Baird Canyon fishwheels for the majority of the season. The escape panels at Canyon Creek were closed more often than at Baird Canyon because their sockeye catches were much smaller. Based on the results of a test on 8 July (with relatively small sample sizes), the escape panels removed 74-92% of captured sockeye at the Baird Canyon fishwheels. Given that 5,606 sockeye were caught at Baird Canyon when the escape panels were open, over 15,000 sockeye were estimated to have escaped through the panels during the season.

A disadvantage of using the escape panels was that an accurate count of the number of sockeye captured in the fishwheels was not obtained. The number of sockeye netted out of the live tanks was recorded, but aside from one, two-hour test to determine the efficiency of the escape panels, the number of sockeye that swam out of the live tanks during the study was unknown. This information could be of value to fishery managers. To address this issue in 2003, a video-monitoring system will be investigated to see if it can be used to maintain a time-series of chinook and sockeye catches in the fishwheels without the need to physically handle most of the sockeye.

Overall, the escape panels appear to have worked exceptionally well. The panels allowed less frequent sampling sessions, reduced the amount of stress due to crowding and handling on captured fish, and reduced crew effort to release unwanted fish. It is recommended that the escape panels continue to be used at all three fishwheels with the openings set to a width of 7.0 cm or less.

Inriver Abundance Estimate

The abundance estimate for chinook salmon developed in 2002 was relatively imprecise and probably biased. Since this was the second year of operating two capture-tag fishwheels at Baird Canyon, and the first year of operating an upstream recovery fishwheel at Canyon Creek, these problems were not entirely unexpected. The abundance estimate was imprecise because of the relatively small number of fish examined and recaptured at the Canyon Creek fishwheel. Others have encountered difficulties in capturing large numbers of chinook salmon in this area (Greenough 1971; Evenson and Wuttig 2000; Wuttig and Evenson 2001; Savereide and Evenson 2002), and a catch of 676 fish at the Canyon Creek fishwheel in 2002 was quite good in comparison.

In 2003, the amount of fishing effort at Canyon Creek will be increased in order to increase the number of fish in the recovery sample and improve the precision of the abundance estimate. If the population of chinook salmon is assumed to be 50,000 fish, and 3% of the run (1,500 fish) is tagged, then 777 fish (15% more than in 2002) must be examined to derive an abundance estimate with 95% confidence intervals within 50% of the point estimate (Robson and Regier 1964). To derive an abundance estimate with 95% confidence intervals within 25% of the point estimate, the number of fish examined at Canyon Creek, and/or the proportion of the run tagged at Baird Canyon, would have to be increased substantially (e.g., by 140% if 4% of the run tagged). The following table summarizes Table H-1 and presents a range of tagging and recovery targets required to meet various levels of precision assuming a run of 50,000 chinook salmon.

Percent of N that 95% C.I. are within	Percent of run tagged at Baird Canyon	Number of fish examined at Canyon Creek	Percent change from 2002
50%	3%	777	15
	4%	579	-14
	5%	459	-32
	6%	379	-44
	7%	322	-52
25%	3%	2159	219
	4%	1621	140
	5%	1292	91
	6%	1070	58
	7%	910	35

Prior to the 2003 season, several options will be considered for increasing the number of fish in the recovery and tag samples, including:

(1) Refining the current fishwheel sites;
(2) Supplementing fishwheel catches with a dip net operation;
(3) Operating an additional, smaller fishwheel; and
(4) Examining fish caught in the Chitina and Glennallen subsistence fisheries.

The 2002 abundance estimate was most likely biased because several of the conditions required for a consistent estimate were not met. One source of potential bias was size-selectivity at the Canyon Creek fishwheel. Chinook salmon measuring 570 mm NF or greater that were examined and recaptured at the Canyon Creek fishwheel were larger than those tagged at the Baird Canyon fishwheels. Fortunately, variation in vulnerability with size is common in mark-recapture studies, and it requires substantial differences to create a meaningful problem (Ricker 1975). Another source of potential bias in the estimate was variability in the probability of a fish being tagged or recaptured over time. It appeared that fishwheel catchability, particularly at the Canyon Creek site, decreased during periods of increasing water velocity and depth.

Technical and Community Workshops 2002

Technical and community workshops (12-13 November) were held in Cordova to review project progress and results prior to completion of the annual report (Table I-1). Posters were prepared that explained the concept and preliminary results from the second year of the study (Appendix I). Biologists, managers and administrators from several agencies were able to attend and information exchanged among participants was very worthwhile. In addition, several fishermen and other local residents from around the Copper River Basin provided input and local traditional knowledge to the study team. These workshops were an excellent means of presenting the results to those who manage and depend on Copper River salmon. Moreover, input from these people clearly improved the synthesis of the results presented in this report.

CONCLUSIONS

In 2002, the capture and tagging operation at Baird Canyon continued to be refined, and a recovery fishwheel was installed and operated at the lower end of Wood Canyon. Estimated abundance of chinook salmon measuring 750 mm NF or greater above the Canyon Creek fishwheel was 38,893. This estimate was relatively imprecise due to small sample sizes at Canyon Creek, and probably biased because several of the conditions necessary for a consistent estimator were not met. Given the amount of progress made on this project since the 2001 season, and the potential improvements outlined in this report, it is anticipated that 2003 will be another year of successful research to examine the feasibility of using fishwheels for long-term monitoring of chinook salmon escapement on the Copper River.

RECOMMENDATIONS

In light of the preceding discussion, the following are recommended for the 2003 season:

(1) Evaluate options for increasing the number of fish in the upstream recovery sample, such as refining the current fishwheel site, supplementing catches with a dip net operation, operating an additional, smaller fishwheel, and examining fish caught in subsistence fisheries;
(2) Continue to use the escape panels, particularly during high-catch periods;
(3) Investigate whether a video-monitoring system can be used to maintain a time-series of sockeye catches in the fishwheels while the escape panels are installed; and
(4) Install a Starband satellite internet system at the Canyon Creek camp; and
(5) Collect depth and flow measurements at all fishwheel sites.

ACKNOWLEDGEMENTS

Organizations

This project was a collaboration among several organizations: The Native Village of Eyak (NVE), LGL Alaska Research Associates, Ltd. (LGL), the Alaska Department of Fish and Game (ADF&G), and the U.S. Fish and Wildlife Service (USFWS).

Field technicians (NVE)

Field technicians were hired locally by NVE to assist with fishwheel construction, transportation, installation, operation, inseason maintenance, fish sampling, and data collection. Technicians included Brad Aspelund, Crystal DeVille, Roger Johnson, Scott Metzger, Iris O'Brien, Clifford Olsen, Jerry Patton, Jack Reilly, Lawrence Stephens, Robert Thompson and Ed Vlasoff.

Field/office logistics

Bruce Cain, Seawan Gehlbach, and Kate Williams (NVE) assisted with project logistics. In addition to their lead role in the radio-telemetry component of the project, James Savereide and Ron Burr (ADF&G, Division of Sport Fish) assisted with fishwheel installation and maintenance, fish sampling, and data collection. Dan Sharp and Steve Moffitt (ADF&G, Division of Commercial Fisheries) loaned and donated camp gear and provided valuable inseason fishery information. Air support was provided by Cordova Air (Terry Kennedy and Dave Erby), Jim Air, Inc., and Fishing and Flying (John Tucker). Lenny Peterson (Peterson Welding and Machine, Cordova) fabricated the fishwheel used at Canyon Creek and Bill Webber (Webber Marine & Mfg, Inc.) constructed the escape panels used on all three fishwheels. Kate Williams, Seahwan Gehlbach, and Erica McCall (NVE) reviewed this report.

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FIGURES

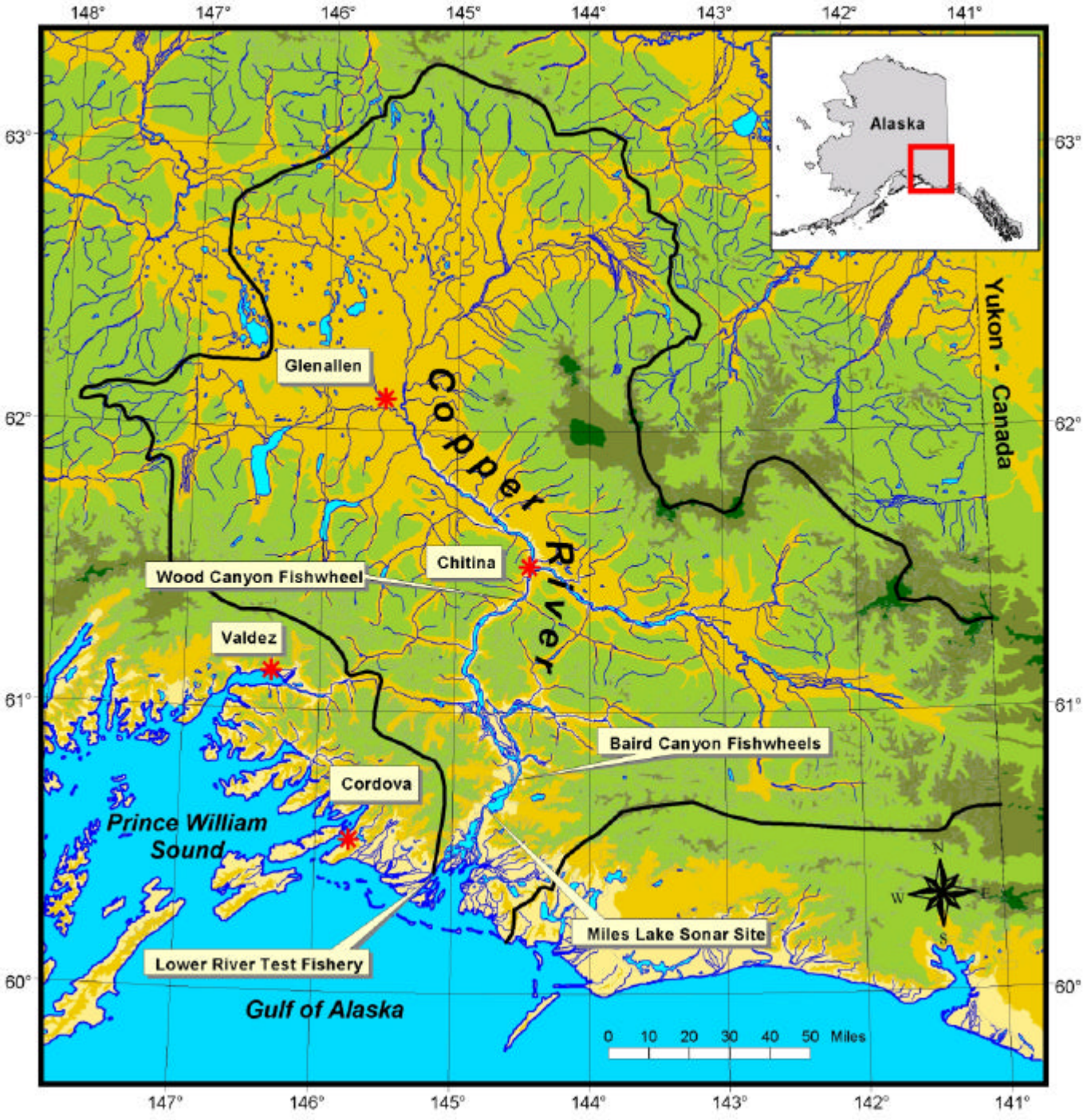

Figure1. Map of thestudy areashowingthelocation of the Copper River inAlaska.

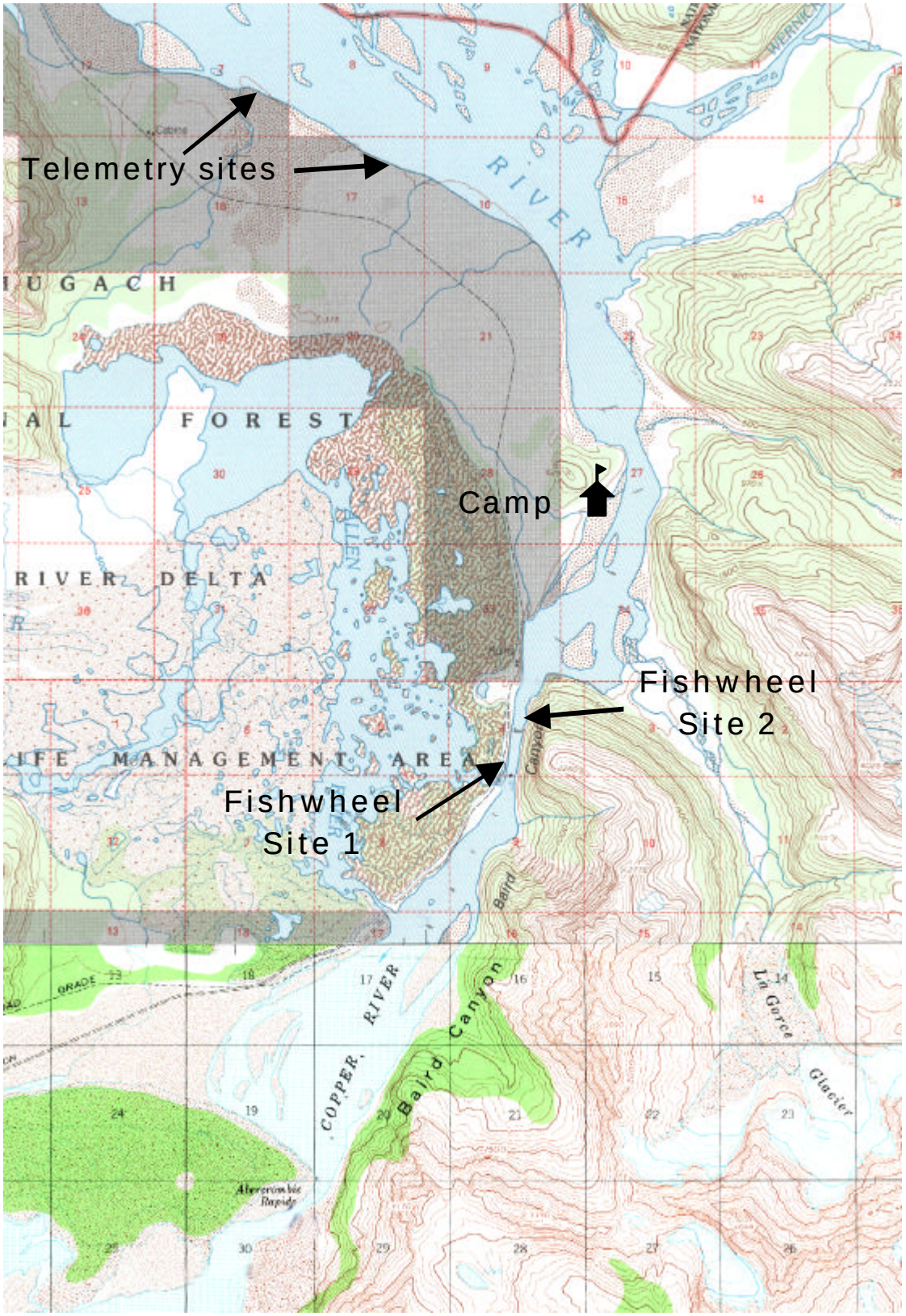

Figure2. MapofBairdCanyonontheCopperRivershowingthelocationofthetwo capture-tagfishwheels(Fishwheel1and2)andthe field camp,2002.

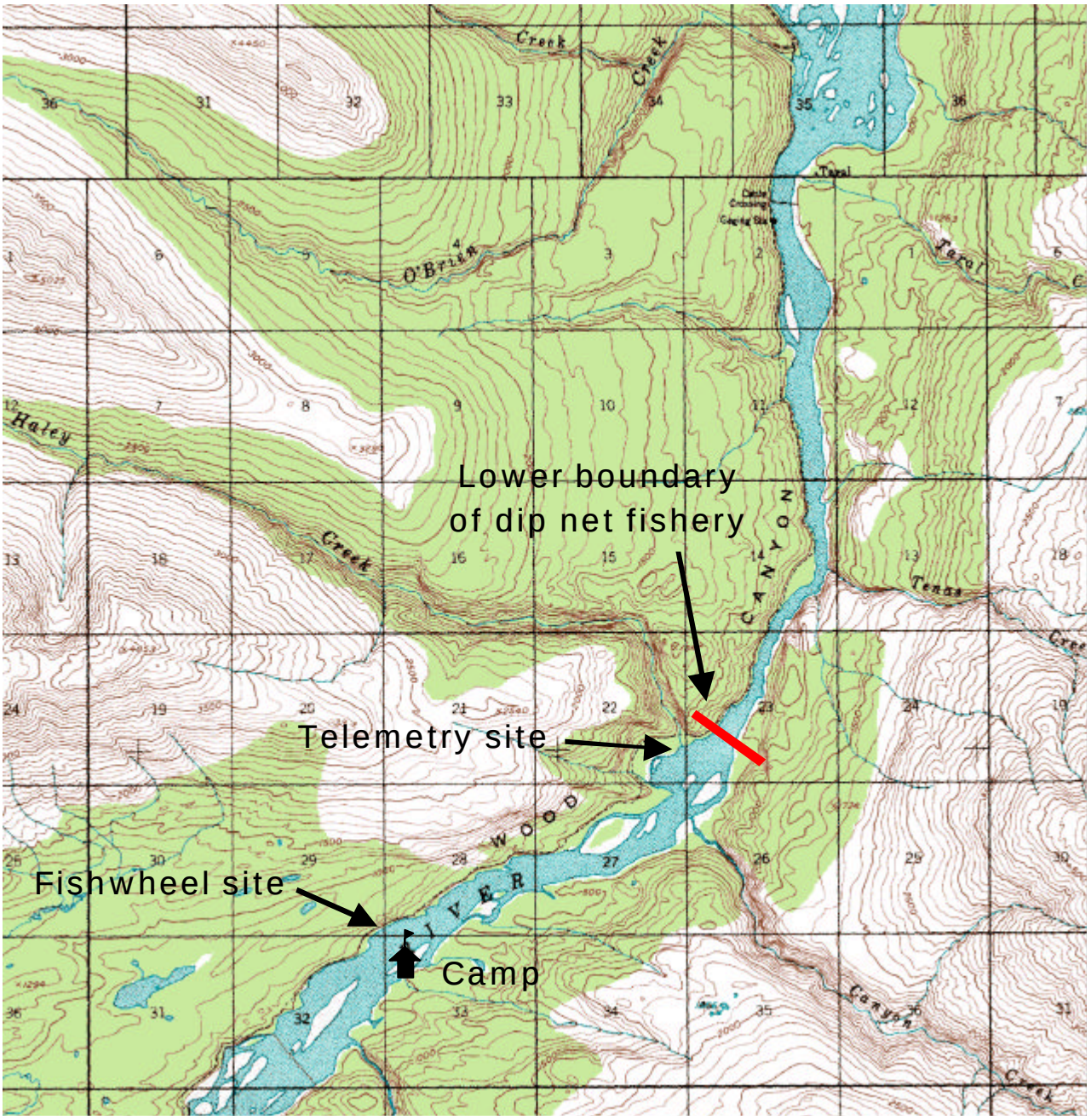

Figure3. MapofWoodCanyonontheCopperRivershowingthelocationoftherecovery fishwheel(Fishwheel3) and theCanyonCreekfieldcamp,2002.

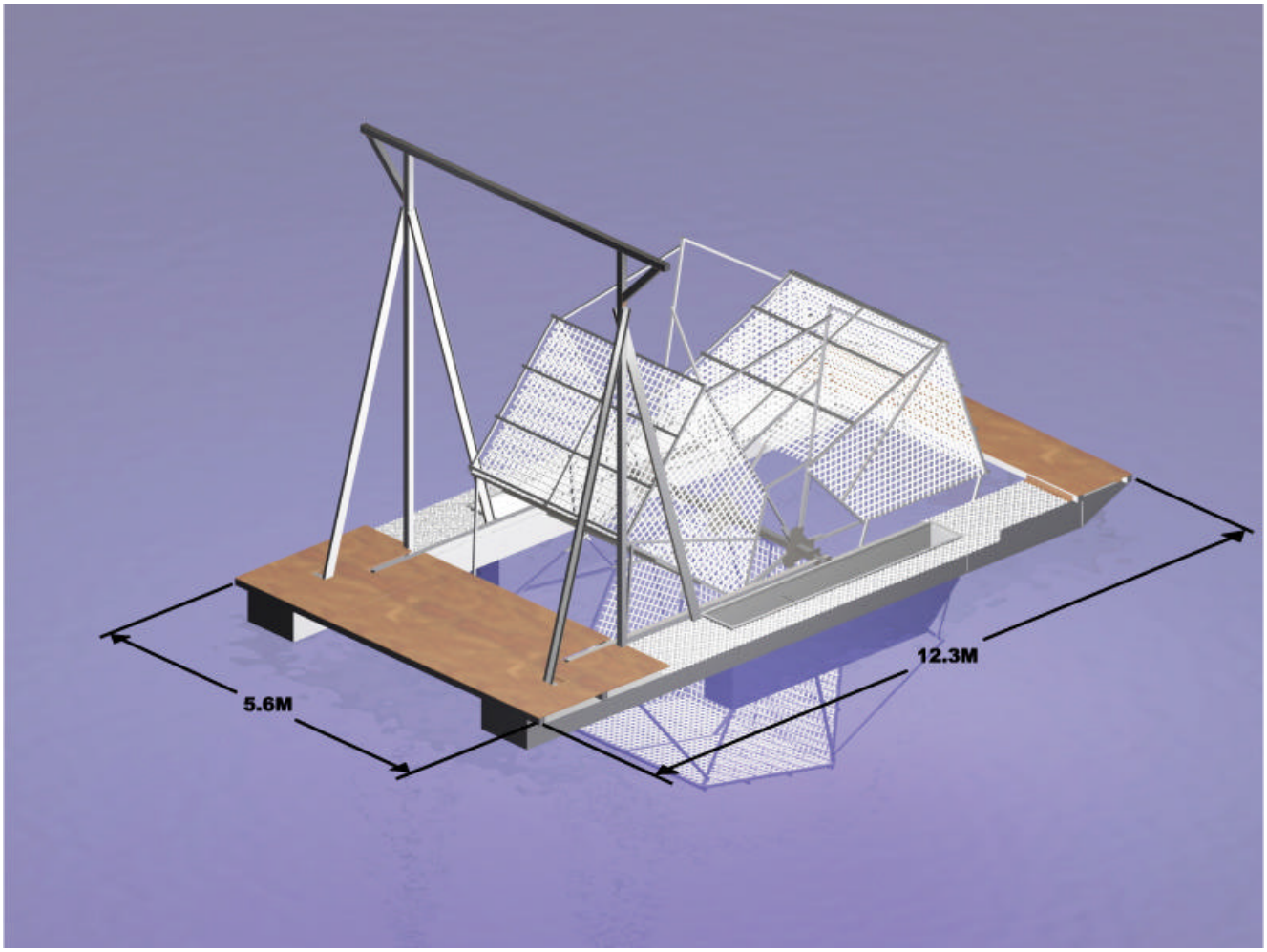

Figure4. Drawingofathree-basketaluminumfishwheelsimilartothatusedontheCopperRiverin 2001and2002.

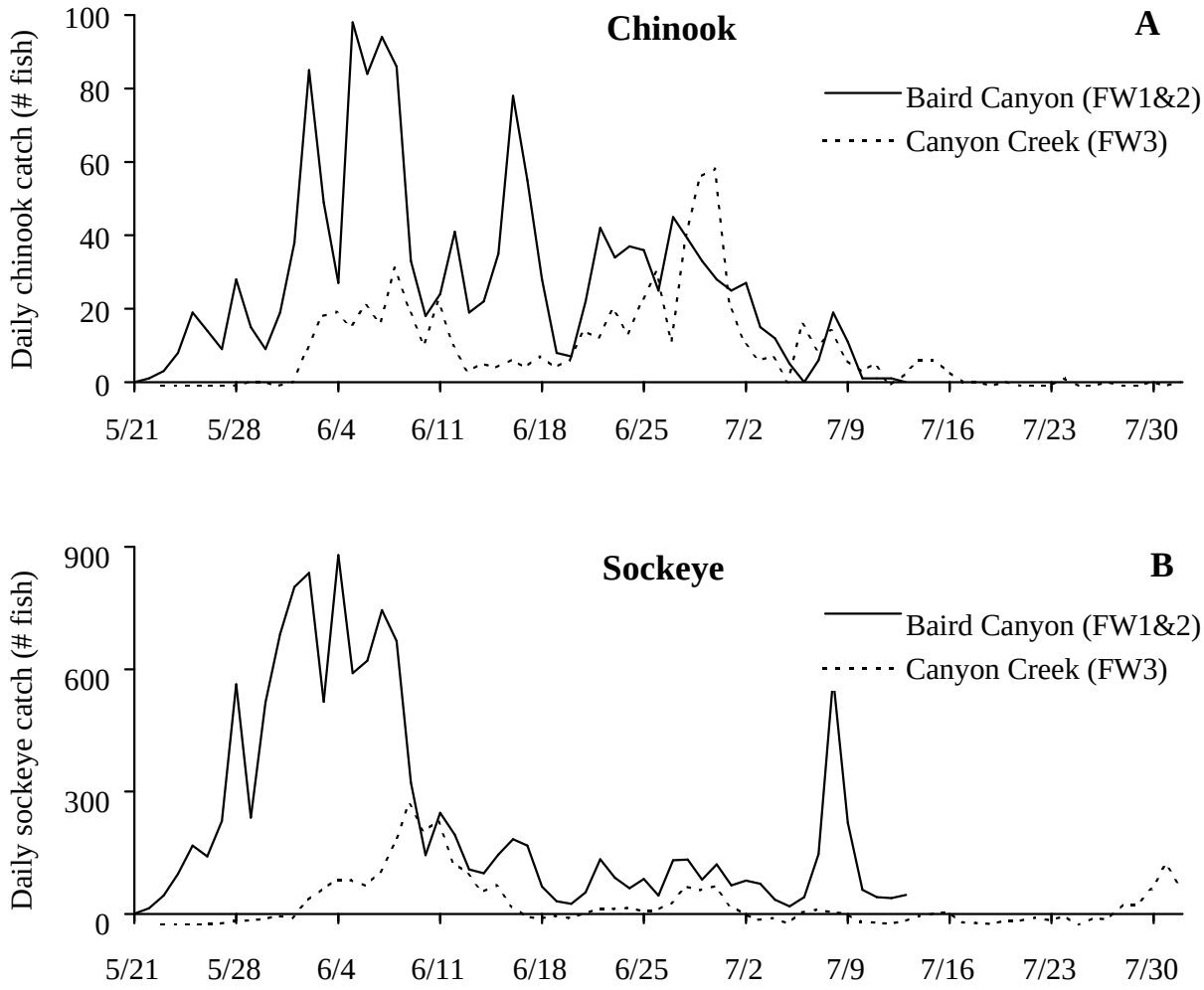

Figure 5. Daily catch of chinook (Panel A) and sockeye (Panel B) salmon at the Copper River fishwheels, 2002.

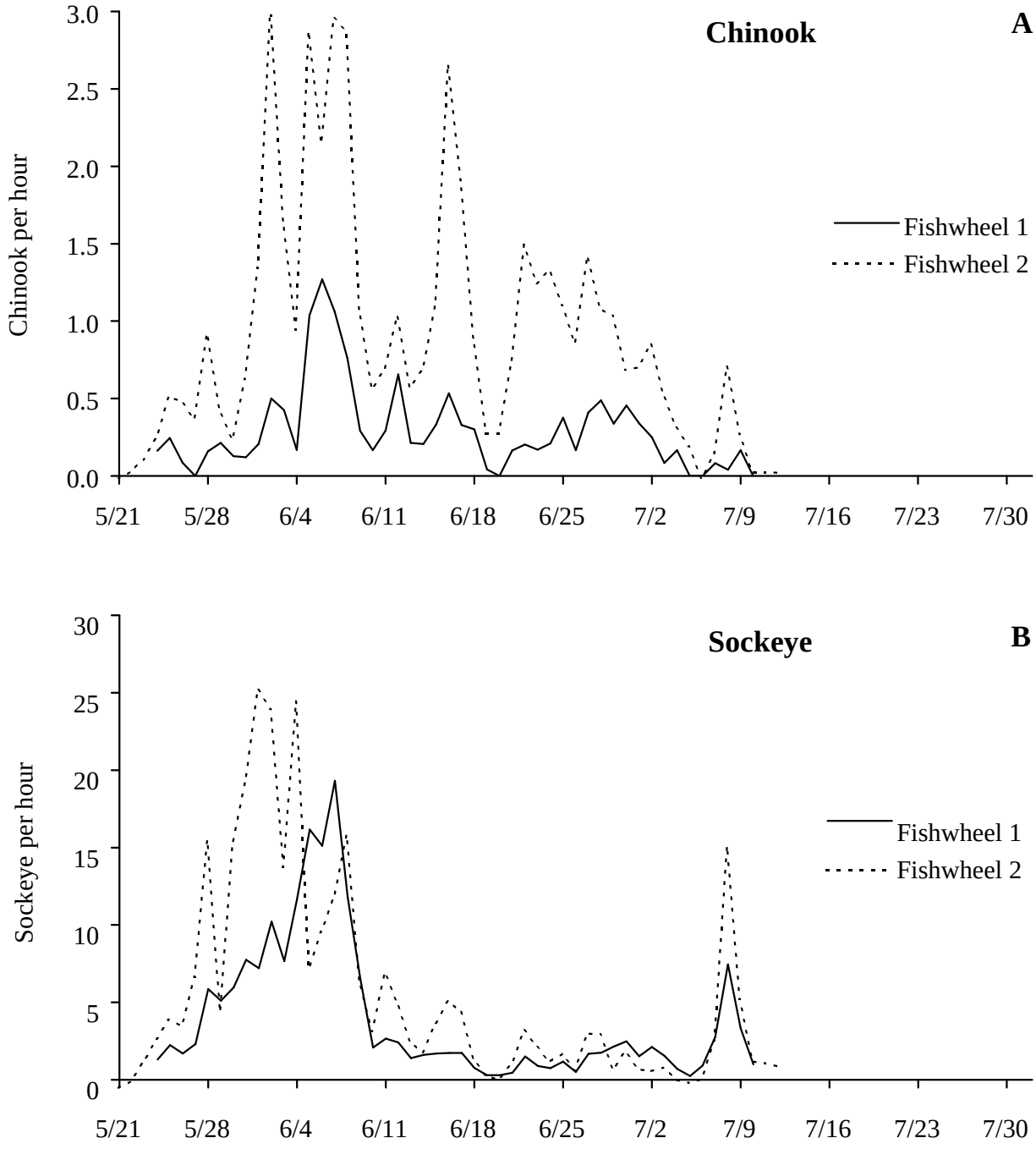

Figure 6. Fishwheel CPUE (catch per fishwheel hour) for chinook (Panel A) and sockeye (Panel B) salmon captured at the Baird Canyon fishwheels on the Copper River, 2002.

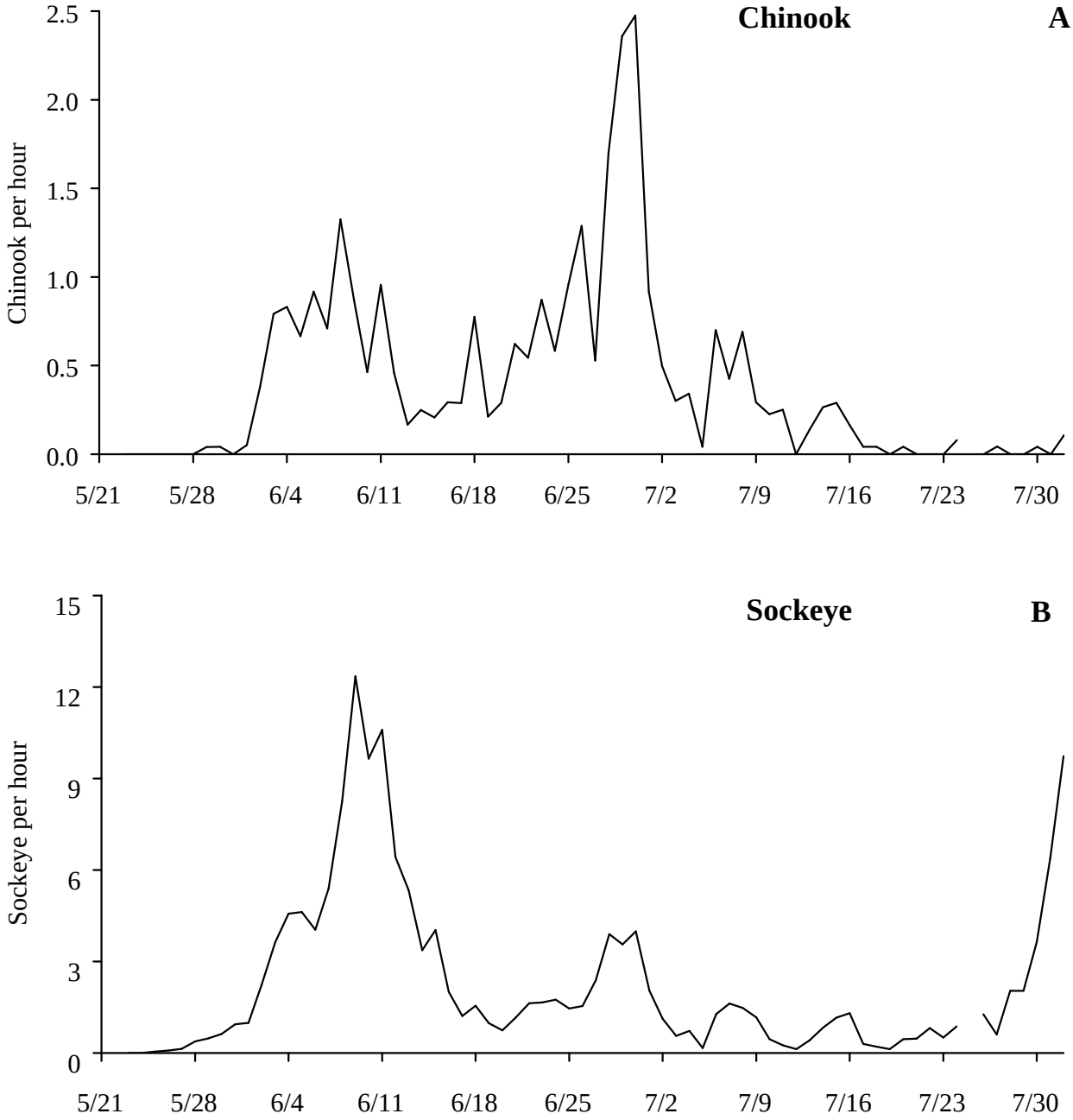

Figure 7. Fishwheel CPUE (catch per fishwheel hour) for chinook (Panel A) and sockeye (Panel B) salmon captured at the Canyon Creek fishwheel on the Copper River, 2002.

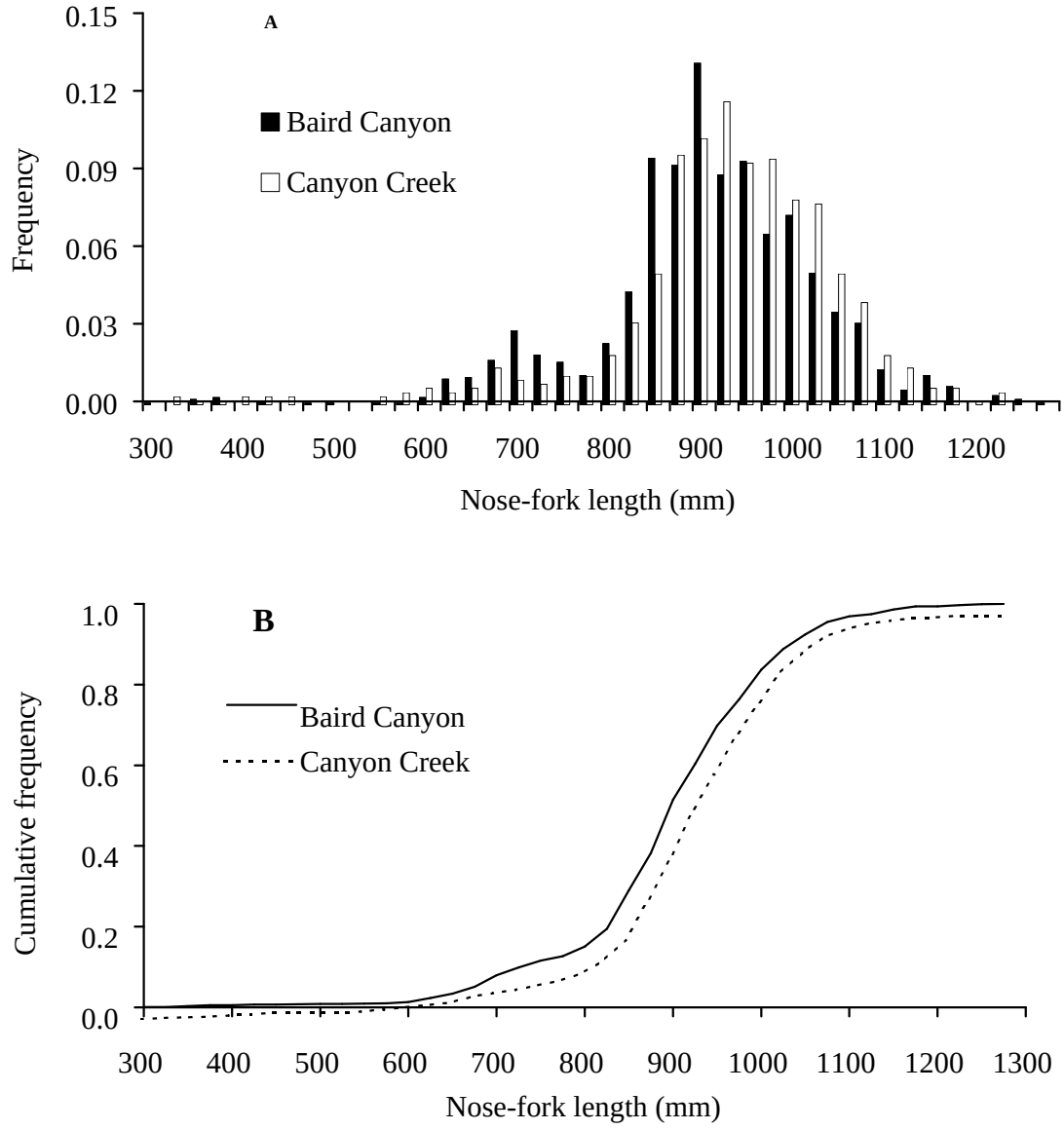

Figure 8. Length frequency (Panel A) and cumulative length frequency (Panel B) distributions of adult chinook salmon measured at the Copper River fishwheels, 2002.

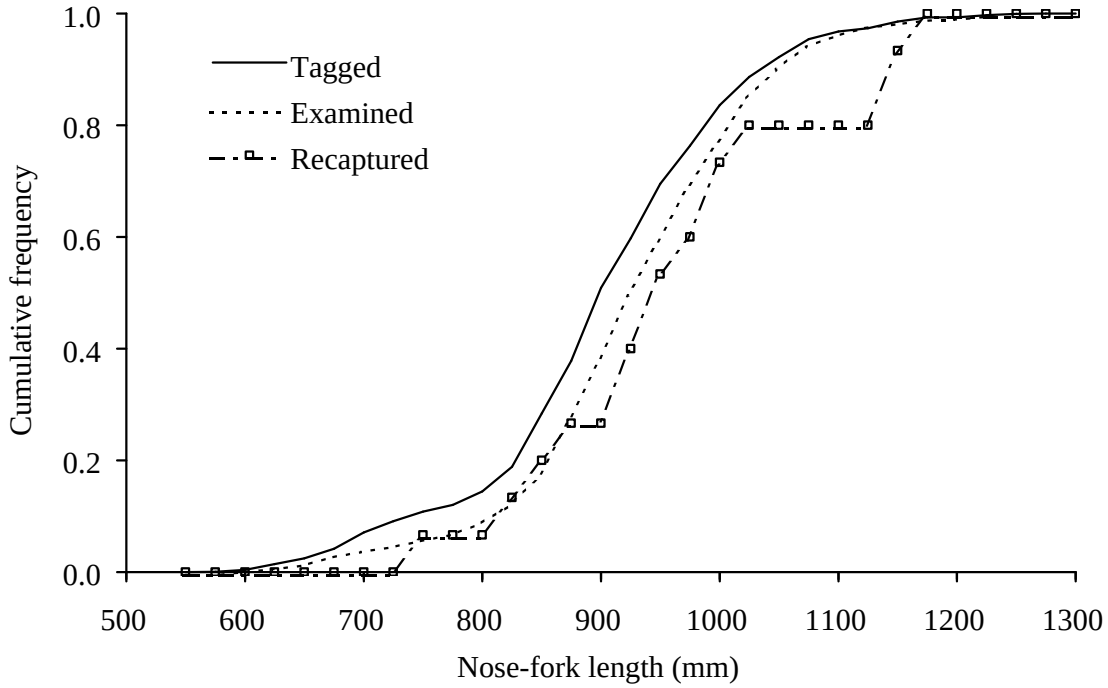

Figure 9. Cumulative length frequency distributions of fish tagged at Baird Canyon and examined and recaptured at Canyon Creek, 2002. Only fish that measured 570 mm NF or greater were included.

TABLES

Table 1. Number of adult chinook and sockeye salmon caught at the three fishwheels on the Copper River, 2002.

	Baird Canyon			Canyon Creek
Species	FW1	FW2	Total	FW3
Chinook	334	1,184	1,518	676
Sockeye	4,526	7,970	12,496	3,689
Total	4,860	9,154	14,014	4,365

Table 2. Number of chinook salmon measuring 570 mm NF or greater that were caught and released (tagged and untagged) at the Baird Canyon fishwheels, 2002.

Release type	Number of fish	Percent of catch
Tagged fish (primary and secondary marks)		
Spaghetti tag and right operculum punch	883	58.2
Radio tag and spaghetti tag	461	30.4
Total	1,344	88.5
Untagged fish		
Released or escaped prior to applying both marks [a]	153	10.1
Nose-fork length < 500 mm	14	0.9
Adipose fin was clipped (coded-wire tagged)	5	0.3
Mortality	2	0.1
Total	174	11.5
Total number of fish caught	1,518	

[a] Includes fish with visible injuries (e.g., gillnet/lamprey marks, seal bites). A radio tag was removed from one fish when it was recaptured at Baird Canyon.

Table 3. Nose-fork length (mm) of chinook salmon measured at the Copper River fishwheels, 2002.

Location	Sample size (# fish)	Mean length [a] (mm)	Standard deviation (mm)	Min. length (mm)	Max. length (mm)
Baird Canyon	1,393	897	121	300	1,258
Canyon Creek	632	913	127	309	1,222
All fish	2,025	902	123	300	1,258

[a] Nose-fork length measured from the tip of the snout to the fork of the tail.

Table 4. Number of chinook salmon measuring 750 mm NF or greater that were available for recovery, examined for tags, and recaptured at the Canyon Creek fishwheel, 2002.

	Primary tag type		
Fate of tagged fish (length = 750 mm NF)	Spaghetti	Radio	Total
Fish tagged at the Baird Canyon fishwheels	795	410	1,205
Tags unavailable for upstream recovery [a]	45	23	68
Tagged fish available for upstream recovery	750	387	1,137
Fish examined for marks at the Canyon Creek fishwheel			580
Tagged fish recaptured at the Canyon Creek fishwheel	8	8	16
Mark rate (recaptures/examined; %)	1.4	1.4	2.8
Tag recapture rate (recaptures/available; %)	1.1	2.1	1.4

[a] Radio tags that were never detected by fixed stations, or during aerial tracking, in or above the Chitina Subdistrict Subsistence (CSS) fishery were considered unavailable for recapture at the Canyon Creek fishwheel. We assumed a similar proportion (23/410 = 0.056) of spaghetti-tagged fish were also unavailable.

Table 5. Number of tagged chinook salmon measuring 570 mm NF or greater that were recovered in the various fisheries throughout the Copper River Basin, 2002.

Data source / Tag type	CSS dipnet fishery	GSS fishwheel fishery	Upriver sport fishery	Inriver fishery unknown[a]	Comm. gillnet fishery	Total recovered
Sampled by ADF&G Creel						
Radio tag and spaghetti tag	7	7				14
Spaghetti tag and operculum punch	26	10				36
Total recovered	33	17				50
Number sampled	535	281				816
Recovery rate (%)	6.2	6.0				6.1
Public response[b]						
Radio tag and spaghetti tag	39	34	20	1	1	95
Spaghetti tag and operculum punch	38	39	25	23	2	127
Total recovered	77	73	45	24	3	222
Based on radiotelemetry detections[c]						
Radio tag and spaghetti tag	1	0	0	0	0	1
Total recovered[d]	111	90	45	24	3	273

[a] The recovery location of these tags was not recorded.

[b] These tags were returned to NVE or ADF&G, or were collected by ADF&G Creel personnel, but they were not directly sampled.

[c] 1 tagged fish (#1687) was assumed harvested in the CSS fishery based on radiotelemetry detections.

[d] Excludes 8 tagged fish recovered in the various fisheries (3-fishwheels, 1-sport, 1-dipnet, 1-unknown fishery) that only received a primary or secondary mark.

Table 6. Travel time of chinook salmon that were tagged at Baird Canyon and recovered at various locations throughout the Copper River Basin, 2002.

Travel time (days)	Canyon Creek fishwheel (FW3)	CSS dipnet fishery	GSS fishwheel fishery [a]	Inriver sport fishery	Commercial gillnet fishery
Spaghetti-tagged fish					
Sample size	7	63	49	23	2
Minimum	8	5	8	12	17
Maximum	15	42	41	48	31
Mean	**11.3**	**14.6**	**21.8**	**29.8**	**24.0**
Radio-tagged fish					
Sample size	8	44	44	17	1
Minimum	7	6	6	12	20
Maximum	30	38	49	52	20
Mean	**13.5**	**16.0**	**22.5**	**29.6**	**20.0**
All fish					
Sample size	15	107	93	40	3
Minimum	7	5	6	12	17
Maximum	30	42	49	52	31
Mean	**12.5**	**15.1**	**22.2**	**29.7**	**22.7**

[a] One spaghetti-tagged fish was recaptured in the Canyon Creek fishwheel and subsequently recovered in the Glennallen subsistence fishwheel fishery. The travel time of this fish was included for the Canyon Creek fishwheel data, but excluded in the Glennallen fishwheel fishery data.

Table 7. Number of fish marked and recaptured (length = 570 mm NF), by week, and the corresponding marked to unmarked ratios and recapture rates at the Copper River fishwheels, 2002.

		Period of recapture [a]										Number	Number	Number not	Recapture
Period of marking		1	2	3	4	5	6	7	8	9	10	recaptured [c]	marked	recaptured	rate
1	5/21 - 5/27	0	0	1	0	0	0	0	0	0	0	1	51	50	2.0
2	5/28 - 6/3		0	0	0	0	0	0	0	0	0	0	222	222	0.0
3	6/4 - 6/10			0	0	0	0	0	0	0	0	0	392	392	0.0
4	6/11 - 6/17				0	0	6	1	1	0	0	8	245	237	3.3
5	6/18 - 6/24					0	3	0	0	0	0	3	150	147	2.0
6	6/25 - 7/1						0	2	1	0	0	3	199	196	1.5
7	7/2 - 7/8							0	0	0	0	0	73	73	0.0
8	7/9 - 7/15								0	0	0	0	12	12	0.0
9	7/16 - 7/22									0	0	0	0	0	-
10	7/23 - 8/1 [b]										0	0	0	0	-
Total recaptured [c]		0	0	1	0	0	9	3	2	0	0	15	1344	1329	1.1
Unmarked in 2nd event		1	32	133	64	81	222	60	30	6	5	634			
Examined for marks		1	32	134	64	81	231	63	32	6	5	649			
Marked:unmarked		-	0.000	0.008	0.000	0.000	0.041	0.050	0.067	0.000	0.000	0.02			

[a] Week of recapture was the same as week of marking.

[b] Period 10 was 3 days longer than the other periods.

[c] 1 fish recaptured 30 June (Period 6) was not included here because the date it was tagged was unknown.

Table 8. Abundance estimates for chinook salmon derived from fish tagged at Baird Canyon and recovered at Canyon Creek, 2002.

Size-class	Estimated spaghetti-tag failure rate	M	C	R	N	Lower	Upper
Length = 750 mm NF	5.6%	1,137	580	16	38,893	24,487	61,002
	2.8%	1,160	580	16	39,679	24,982	62,234
Length = 570 mm NF	5.6%	1,341	634	16	50,128	31,560	78,623

APPENDICES

Table A-1. Schedule of the number of radio tags to release at the Baird Canyon fishwheels, 2002.

Day	Number of tags	Cumulative number of tags	Day	Number of tags	Cumulative number of tags
1	2	2	35	11	386
2	3	5	36	11	397
3	3	8	37	5	402
4	8	16	38	5	407
5	8	24	39	5	412
6	15	39	40	5	417
7	15	54	41	5	422
8	15	69	42	5	427
9	15	84	43	5	432
10	15	99	44	5	437
11	15	114	45	5	442
12	15	129	46	5	447
13	15	144	47	5	452
14	11	155	48	5	457
15	11	166	49	5	462
16	11	177	50	2	464
17	11	188	51	2	466
18	11	199	52	2	468
19	11	210	53	2	470
20	11	221	54	2	472
21	11	232	55	2	474
22	11	243	56	2	476
23	11	254	57	2	478
24	11	265	58	2	480
25	11	276	59	2	482
26	11	287	60	2	484
27	11	298	61	2	486
28	11	309	62	2	488
29	11	320	63	2	490
30	11	331	64	2	492
31	11	342	65	2	494
32	11	353	66	2	496
33	11	364	67	2	498
34	11	375	68	2	500

Table B-1. Water level and temperature collected at the three fishwheels operated on the Copper River, 2002.

	Baird Canyon (FW1&2)		Canyon Creek (FW3)	
Date	Depth (m)	Temp. (^{o}C)	Depth (m)	Temp. (^{o}C)
21-May		5.6		
22-May				
23-May		5.6		10.0
24-May		5.6		
25-May		7.2		7.8
26-May	0.50	8.9		6.7
27-May	0.65	6.9		8.1
28-May	0.62	6.1		6.1
29-May	0.50	6.1		6.9
30-May	0.62	5.6		6.7
31-May	0.78	5.4	2.87	6.1
01-Jun	0.75	6.1	2.64	6.7
02-Jun	0.55	6.1	2.45	7.6
03-Jun	0.44	6.1	2.43	8.3
04-Jun	0.39	6.1	2.37	7.2
05-Jun	0.35	5.8	2.32	8.5
06-Jun	0.42	6.1	2.49	8.1
07-Jun	0.52	6.1	2.63	8.5
08-Jun	0.65	6.7	2.72	9.1
09-Jun	0.67	5.6	2.69	8.3
10-Jun	0.67	5.7	2.72	9.1
11-Jun	0.64	5.9	2.66	8.5
12-Jun	0.46	6.7	2.52	8.5
13-Jun	0.40	6.7	2.42	9.1
14-Jun	0.43	7.8	2.48	10.2
15-Jun	0.82	8.6	2.71	10.6
16-Jun	1.18	8.6	2.95	10.7
17-Jun	1.55	8.6	3.14	10.6
18-Jun	1.89	8.1	3.44	10.4
19-Jun	2.27	6.9	3.59	9.1
20-Jun	2.33	6.9	3.62	8.9
21-Jun	2.28	7.2	3.57	9.3
22-Jun	2.10	6.9	3.51	9.8
23-Jun	2.15	7.5	3.53	9.4
24-Jun	2.12	7.2	3.53	9.4
25-Jun	2.17	6.7	3.54	9.4
26-Jun	2.12	6.7	3.52	9.4
27-Jun	2.00	6.7	3.28	8.5
28-Jun	1.77	5.8	3.13	9.8

Table B-1. Water level and temperature collected at the three fishwheels operated on the Copper River, 2002.

	Baird Canyon (FW1&2)		Canyon Creek (FW3)	
Date	Depth (m)	Temp. (^{o}C)	Depth (m)	Temp. (^{o}C)
29-Jun	1.82	5.6	3.17	11.3
30-Jun	2.03	8.3	3.31	10.6
01-Jul	2.23	7.2	3.49	10.4
02-Jul	2.25	8.3	3.53	10.2
03-Jul	2.28	8.3	3.60	10.4
04-Jul	2.48	9.4	3.83	9.8
05-Jul	2.73	8.9	3.90	9.3
06-Jul	2.47	8.3	3.61	9.3
07-Jul	2.18	8.6	3.51	10.6
08-Jul	2.24	8.9	3.62	10.0
09-Jul	2.45	9.2	3.77	10.4
10-Jul	2.53	8.3	3.81	11.7
11-Jul	2.74	8.9	3.82	9.3
12-Jul	2.75	6.7	3.92	9.4
13-Jul	2.70	6.7	3.73	10.7
14-Jul			3.68	11.5
15-Jul			3.78	11.5
16-Jul			3.93	10.7
17-Jul			4.13	11.7
18-Jul			4.31	10.4
19-Jul			4.33	10.0
20-Jul			4.13	10.0
21-Jul			3.75	8.5
22-Jul			3.96	7.2
23-Jul			3.87	7.8
24-Jul			4.41	7.2
25-Jul			4.62	7.0
26-Jul			4.64	7.8
27-Jul			4.26	7.0
28-Jul			3.82	6.9
29-Jul			3.46	7.4
30-Jul			3.29	8.5
31-Jul			3.31	8.9
01-Aug			3.25	8.3
Mean	1.50	7.1	3.41	9.0
Median	1.82	6.7	3.53	9.2
Max	2.75	9.4	4.64	11.7
Min	0.35	5.4	2.32	6.1

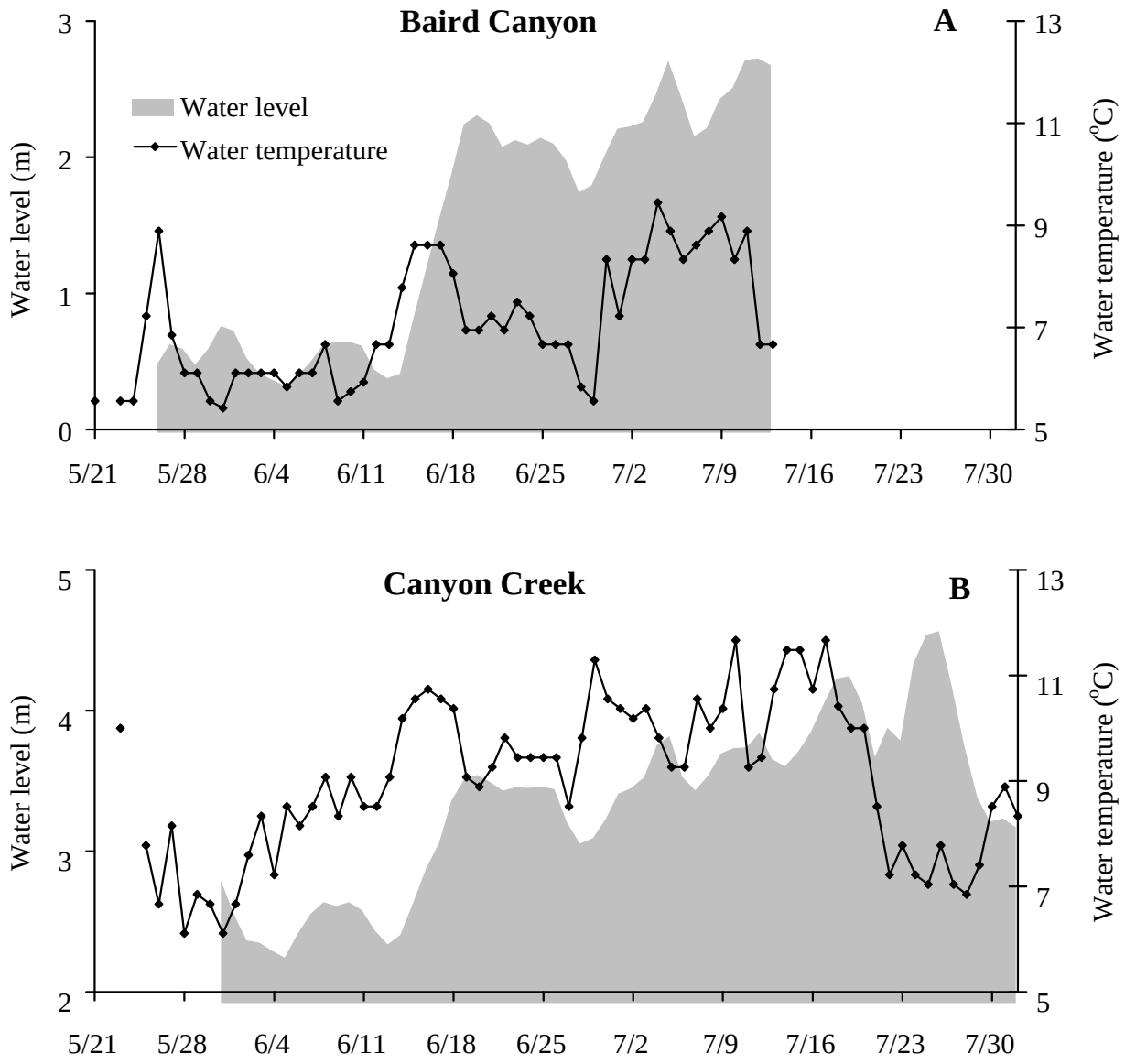

Figure B-1. Average daily water level and water temperature at the Baird Canyon (Panel A) and Canyon Creek (Panel B) fishwheels, 2002.

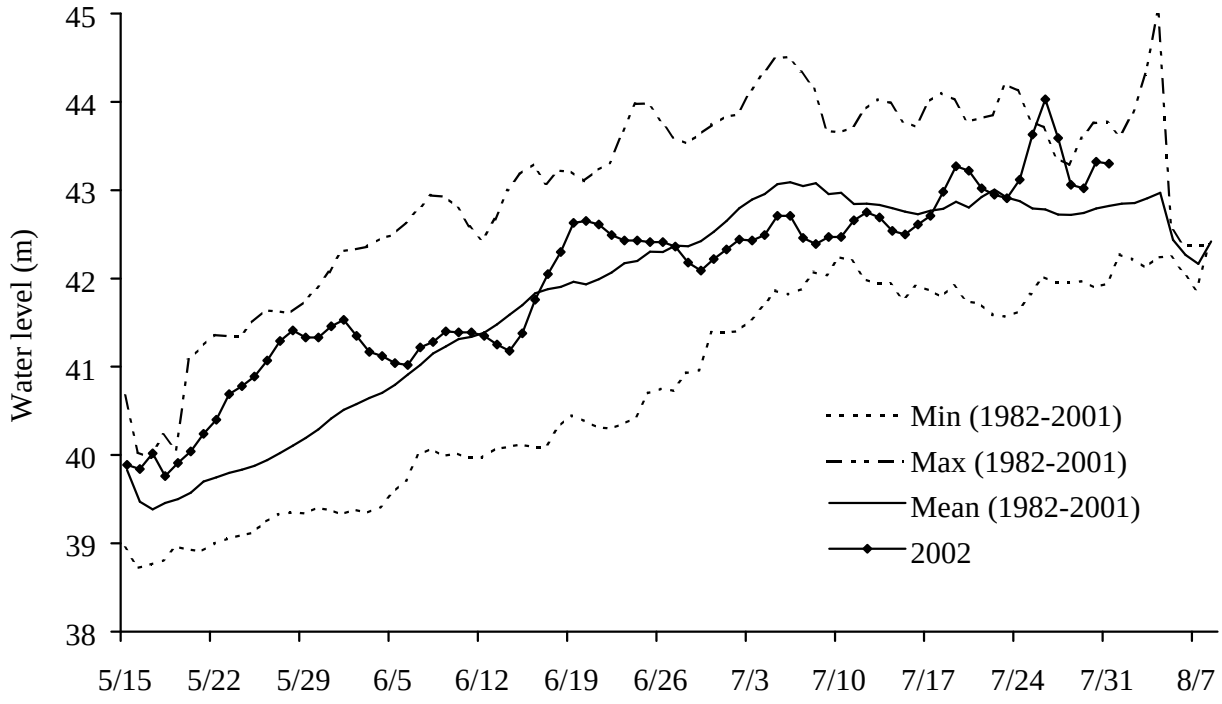

Figure B-2. Water levels at the Million Dollar Bridge on the Copper River (1982-2002).

Table C-1. Summary of daily fishwheel effort (hours), effort used to calculate catch per unit effort (CPUE), and fishwheel speed (RPM) for the three Copper River fishwheels, 2002.

	Fishwheel 1 (Baird Canyon)			Fishwheel 2 (Baird Canyon)			Fishwheel 3 (Canyon Creek)		
Date	Total effort (h)	CPUE effort (h)	RPM	Total effort (h)	CPUE effort (h)	RPM	Total effort (h)	CPUE effort (h)	RPM
21 May				8.0	4.6	1.9			
22 May				22.7	21.3	2.1			
23 May				24.0	23.5	1.8	7.0	3.8	3.2
24 May	8.8	6.1	1.5	24.0	26.6	1.7	24.0	20.7	2.9
25 May	24.0	24.5	1.8	24.0	24.5	1.7	23.8	23.3	2.8
26 May	24.0	23.5	2.3	24.0	23.9	2.0	24.0	23.8	2.7
27 May	24.0	23.8	2.2	24.0	23.4	2.4	24.0	28.8	2.5
28 May	24.0	25.3	2.2	24.0	25.6	2.2	24.0	23.4	2.4
29 May	24.0	23.3	2.0	24.0	22.8	1.8	24.0	24.9	2.4
30 May	24.0	23.5	2.0	24.0	23.6	1.9	24.0	23.9	2.2
31 May	24.0	24.8	1.8	24.0	24.8	2.2	24.0	24.4	2.1
1 Jun	24.0	24.2	2.2	24.0	24.2	1.8	21.8	19.3	2.2
2 Jun	24.0	24.0	2.1	24.0	24.0	1.9	24.0	26.2	2.1
3 Jun	24.0	23.5	1.9	24.0	23.5	1.8	24.0	24.0	2.1
4 Jun	24.0	23.9	1.7	24.0	23.9	1.8	24.0	24.1	2.1
5 Jun	24.0	24.1	1.4	24.0	25.3	1.3	24.0	24.0	2.0
6 Jun	24.0	24.4	1.3	24.0	24.5	1.4	24.0	24.0	2.1
7 Jun	24.0	23.6	1.8	24.0	23.2	1.9	24.0	23.9	2.2
8 Jun	24.0	23.7	2.0	24.0	23.5	2.2	24.0	24.1	2.1
9 Jun	24.0	24.0	1.9	24.0	23.8	1.6	24.0	24.1	2.2
10 Jun	24.0	24.1	2.0	24.0	24.2	1.7	24.0	23.7	2.1
11 Jun	24.0	24.0	1.7	24.0	24.0	1.6	24.0	24.1	2.1
12 Jun	24.0	24.4	1.7	24.0	23.8	1.3	24.0	24.0	2.0
13 Jun	24.0	23.5	1.7	24.0	23.8	1.8	24.0	24.0	2.0
14 Jun	24.0	24.3	1.4	24.0	24.2	1.6	24.0	24.1	2.3
15 Jun	24.0	24.1	1.8	24.0	24.2	2.1	24.0	24.1	2.2
16 Jun	24.0	24.3	2.4	24.0	24.3	2.4	24.0	23.9	2.5
17 Jun	24.0	24.3	1.9	24.0	24.4	2.1	15.5	17.3	2.7
18 Jun	24.0	23.3	2.2	24.0	23.3	2.6	11.8	10.3	2.0
19 Jun	24.0	23.8	1.9	24.0	23.8	2.2	24.0	23.6	2.1
20 Jun	24.0	24.0	2.1	24.0	24.0	2.2	24.0	24.1	2.1
21 Jun	24.0	24.3	1.8	24.0	24.2	2.0	24.0	24.1	2.2
22 Jun	24.0	24.6	2.0	24.0	24.6	2.1	24.0	23.9	1.9
23 Jun	24.0	23.6	1.8	24.0	23.8	2.1	24.0	24.1	2.2
24 Jun	24.0	23.8	1.7	24.0	23.8	2.1	24.0	24.0	2.1
25 Jun	24.0	24.0	1.6	24.0	24.1	1.8	24.0	24.0	2.1
26 Jun	24.0	24.1	1.9	24.0	24.0	2.2	24.0	24.1	2.4
27 Jun	24.0	24.4	1.7	24.0	24.4	1.5	22.9	22.7	2.0
28 Jun	24.0	24.6	1.7	24.0	24.6	2.0	24.0	24.1	2.2
29 Jun	24.0	23.7	1.7	24.0	23.8	2.3	24.0	24.2	2.4
30 Jun	24.0	24.2	1.9	24.0	24.1	2.2	24.0	23.8	2.4
1 Jul	24.0	23.5	1.9	24.0	23.6	2.3	24.0	23.9	2.7
2 Jul	24.0	24.0	1.8	24.0	24.1	2.2	24.0	24.1	2.7
3 Jul	24.0	24.0	1.7	24.0	24.0	2.2	23.3	23.3	2.8
4 Jul	24.0	24.0	2.2	24.0	24.0	2.4	23.8	23.4	2.5
5 Jul	24.0	23.7	2.3	24.0	23.9	2.6	24.0	24.2	2.4
6 Jul	24.0	24.0	2.2	24.0	24.1	2.1	24.0	24.3	2.5
7 Jul	24.0	24.2	2.3	24.0	24.3	2.3	23.7	23.5	2.3
8 Jul	24.0	25.1	2.2	24.0	24.7	2.4	21.7	21.7	1.9
9 Jul	24.0	24.1	1.9	24.0	24.2	2.2	24.0	23.9	1.8

Table C-1. Summary of daily fishwheel effort (hours), effort used to calculate catch per unit effort (CPUE), and fishwheel speed (RPM) for the three Copper River fishwheels, 2002.

	Fishwheel 1 (Baird Canyon)			Fishwheel 2 (Baird Canyon)			Fishwheel 3 (Canyon Creek)		
Date	Total effort (h)	CPUE effort (h)	RPM	Total effort (h)	CPUE effort (h)	RPM	Total effort (h)	CPUE effort (h)	RPM
10 Jul	13.0	14.0	2.4	24.0	23.2	3.1	17.6	17.7	1.8
11 Jul				23.8	22.5	2.7	24.0	24.0	1.9
12 Jul				24.0	24.3	2.2	24.0	24.0	1.9
13 Jul				10.1	12.9	2.4	24.0	21.6	1.9
14 Jul							24.0	26.3	2.0
15 Jul							24.0	24.1	1.8
16 Jul							24.0	24.5	1.8
17 Jul							24.0	23.6	1.9
18 Jul							23.6	23.5	2.3
19 Jul							23.0	23.0	2.2
20 Jul							24.0	24.1	2.1
21 Jul							23.0	23.4	2.0
22 Jul							24.0	23.3	2.1
23 Jul							24.0	23.8	2.1
24 Jul							22.0	25.2	2.1
25 Jul							0.0	0.0	0.0
26 Jul							15.0	13.4	2.1
27 Jul							23.5	23.1	1.9
28 Jul							24.0	24.0	1.8
29 Jul							24.0	24.5	1.8
30 Jul							24.0	23.9	2.0
31 Jul							23.5	23.3	2.2
1 Aug							7.6	9.4	2.6
Totals	1126			1265			1598		

Total hours of effort for all fishwheels combined:	3988
Total number of days operated:	166
Overall percent operational while fishing:	98.1%

Total number of days operated by each fishwheel:		
47	53	67
Percent operational:		
100.0%	100.0%	95.3%

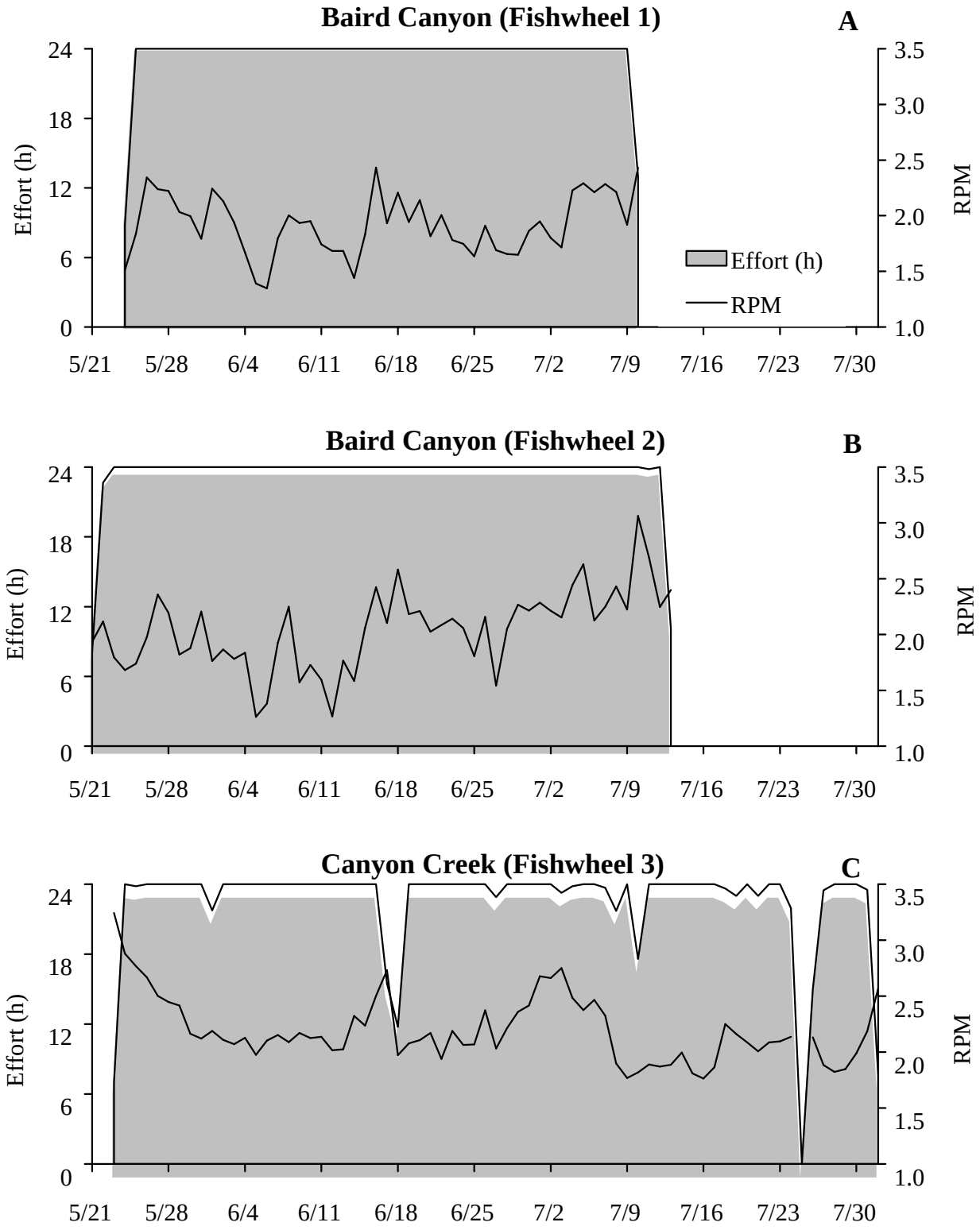

Figure C-1. Fishwheel effort (hours) and speed (RPM) at Fishwheel 1 (Panel A) and Fishwheel 2 (Panel B) at Baird Canyon, and Fishwheel 3 (Panel C) at Canyon Creek, 2002.

Table D-1. Total catch, CPUE (catch per hour), and the number of chinook salmon (= 570 mm NF) that were marked, examined, and recaptured at the Copper River fishwheels, 2002.

	Baird Canyon										Canyon Creek						
	Fishwheel 1			Fishwheel 2			Fishwheel 1 & 2				Fishwheel 3						
Date	Catch	Cum.	CPUE	Catch	Cum.	CPUE	Catch	Cum.	Marks	Cum.	Catch	Cum.	CPUE	Exam.	Cum.	Recap	Cum.
21 May				0	0	0.0	0	0	0	0							
22 May				1	1	0.0	1	1	1	1							
23 May				3	4	0.1	3	4	3	4	0	0	0.0	0	0	0	0
24 May	1	1	0.2	7	11	0.3	8	12	8	12	0	0	0.0	0	0	0	0
25 May	6	7	0.2	13	24	0.5	19	31	18	30	0	0	0.0	0	0	0	0
26 May	2	9	0.1	12	36	0.5	14	45	13	43	0	0	0.0	0	0	0	0
27 May	0	9	0.0	9	45	0.4	9	54	8	51	0	0	0.0	0	0	0	0
28 May	4	13	0.2	24	69	0.9	28	82	25	76	0	0	0.0	0	0	0	0
29 May	5	18	0.2	10	79	0.4	15	97	14	90	1	1	0.0	1	1	0	0
30 May	3	21	0.1	6	85	0.3	9	106	6	96	1	2	0.0	1	2	0	0
31 May	3	24	0.1	16	101	0.6	19	125	18	114	0	2	0.0	0	2	0	0
1 Jun	5	29	0.2	33	134	1.4	38	163	34	148	1	3	0.1	1	3	0	0
2 Jun	12	41	0.5	73	207	3.0	85	248	78	226	10	13	0.4	10	13	0	0
3 Jun	10	51	0.4	39	246	1.7	49	297	47	273	19	32	0.8	19	32	0	0
4 Jun	4	55	0.2	23	269	1.0	27	324	26	299	20	52	0.8	20	52	0	0
5 Jun	25	80	1.0	73	342	2.9	98	422	87	386	16	68	0.7	15	67	1	1
6 Jun	31	111	1.3	53	395	2.2	84	506	73	459	22	90	0.9	21	88	0	1
7 Jun	25	136	1.1	69	464	3.0	94	600	81	540	17	107	0.7	17	105	0	1
8 Jun	18	154	0.8	68	532	2.9	86	686	79	619	32	139	1.3	30	135	0	1
9 Jun	7	161	0.3	26	558	1.1	33	719	31	650	21	160	0.9	21	156	0	1
10 Jun	4	165	0.2	14	572	0.6	18	737	15	665	11	171	0.5	11	167	0	1
11 Jun	7	172	0.3	17	589	0.7	24	761	20	685	23	194	1.0	19	186	0	1
12 Jun	16	188	0.7	25	614	1.1	41	802	36	721	11	205	0.5	11	197	0	1
13 Jun	5	193	0.2	14	628	0.6	19	821	18	739	4	209	0.2	4	201	0	1
14 Jun	5	198	0.2	17	645	0.7	22	843	19	758	6	215	0.2	6	207	0	1
15 Jun	8	206	0.3	27	672	1.1	35	878	32	790	5	220	0.2	5	212	0	1

Table D-1. Total catch, CPUE (catch per hour), and the number of chinook salmon (= 570 mm NF) that were marked, examined, and recaptured at the Copper River fishwheels, 2002.

	Baird Canyon										Canyon Creek						
	Fishwheel 1			Fishwheel 2			Fishwheel 1 & 2				Fishwheel 3						
Date	Catch	Cum.	CPUE	Catch	Cum.	CPUE	Catch	Cum.	Marks	Cum.	Catch	Cum.	CPUE	Exam.	Cum.	Recap	Cum.
16 Jun	13	219	0.5	65	737	2.7	78	956	71	861	7	227	0.3	7	219	0	1
17 Jun	8	227	0.3	47	784	1.9	55	1011	49	910	5	232	0.3	4	223	0	1
18 Jun	7	234	0.3	21	805	0.9	28	1039	26	936	8	240	0.8	8	231	0	1
19 Jun	1	235	0.0	7	812	0.3	8	1047	6	942	5	245	0.2	5	236	0	1
20 Jun	0	235	0.0	7	819	0.3	7	1054	6	948	7	252	0.3	7	243	0	1
21 Jun	4	239	0.2	18	837	0.7	22	1076	19	967	15	267	0.6	13	256	0	1
22 Jun	5	244	0.2	37	874	1.5	42	1118	39	1006	13	280	0.5	12	268	0	1
23 Jun	4	248	0.2	30	904	1.3	34	1152	25	1031	21	301	0.9	20	288	0	1
24 Jun	5	253	0.2	32	936	1.3	37	1189	29	1060	14	315	0.6	13	301	0	1
25 Jun	9	262	0.4	27	963	1.1	36	1225	31	1091	23	338	1.0	23	324	0	1
26 Jun	4	266	0.2	21	984	0.9	25	1250	22	1113	31	369	1.3	29	353	3	4
27 Jun	10	276	0.4	35	1019	1.4	45	1295	37	1150	12	381	0.5	12	365	0	4
28 Jun	12	288	0.5	27	1046	1.1	39	1334	32	1182	41	422	1.7	40	405	1	5
29 Jun	8	296	0.3	25	1071	1.1	33	1367	30	1212	57	479	2.4	56	461	2	7
30 Jun	11	307	0.5	17	1088	0.7	28	1395	25	1237	59	538	2.5	56	517	3	10
1 Jul	8	315	0.3	17	1105	0.7	25	1420	22	1259	22	560	0.9	22	539	1	11
2 Jul	6	321	0.3	21	1126	0.9	27	1447	25	1284	12	572	0.5	12	551	1	12
3 Jul	2	323	0.1	13	1139	0.5	15	1462	12	1296	7	579	0.3	7	558	0	12
4 Jul	4	327	0.2	8	1147	0.3	12	1474	10	1306	8	587	0.3	8	566	0	12
5 Jul	0	327	0.0	5	1152	0.2	5	1479	5	1311	1	588	0.0	1	567	0	12
6 Jul	0	327	0.0	0	1152	0.0	0	1479	0	1311	17	605	0.7	14	581	0	12
7 Jul	2	329	0.1	4	1156	0.2	6	1485	6	1317	10	615	0.4	9	590	1	13
8 Jul	1	330	0.0	18	1174	0.7	19	1504	15	1332	15	630	0.7	15	605	1	14
9 Jul	4	334	0.2	7	1181	0.3	11	1515	9	1341	7	637	0.3	7	612	0	14
10 Jul	0	334	0.0	1	1182	0.0	1	1516	1	1342	4	641	0.2	4	616	0	14
11 Jul				1	1183	0.0	1	1517	1	1343	6	647	0.3	6	622	1	15

Table D-1. Total catch, CPUE (catch per hour), and the number of chinook salmon (= 570 mm NF) that were marked, examined, and recaptured at the Copper River fishwheels, 2002.

	Baird Canyon										Canyon Creek						
	Fishwheel 1			Fishwheel 2			Fishwheel 1 & 2				Fishwheel 3						
Date	Catch	Cum.	CPUE	Catch	Cum.	CPUE	Catch	Cum.	Marks	Cum.	Catch	Cum.	CPUE	Exam.	Cum.	Recap	Cum.
12 Jul				1	1184	0.0	1	1518	1	1344	0	647	0.0	0	622	0	15
13 Jul				0	1184	0.0	0	1518	0	1344	3	650	0.1	3	625	0	15
14 Jul											7	657	0.3	7	632	1	16
15 Jul											7	664	0.3	7	639	0	16
16 Jul											4	668	0.2	4	643	0	16
17 Jul											1	669	0.0	1	644	0	16
18 Jul											1	670	0.0	0	644	0	16
19 Jul											0	670	0.0	0	644	0	16
20 Jul											1	671	0.0	1	645	0	16
21 Jul											0	671	0.0	0	645	0	16
22 Jul											0	671	0.0	0	645	0	16
23 Jul											0	671	0.0	0	645	0	16
24 Jul											2	673	0.1	2	647	0	16
25 Jul											0	673		0	647	0	16
26 Jul											0	673	0.0	0	647	0	16
27 Jul											1	674	0.0	1	648	0	16
28 Jul											0	674	0.0	0	648	0	16
29 Jul											0	674	0.0	0	648	0	16
30 Jul											1	675	0.0	1	649	0	16
31 Jul											0	675	0.0	0	649	0	16
1 Aug											1	676	0.1	1	650	0	16
Totals	334			1184			1518		1344		676			650		16	

[a] Recaptures were included in the number of chinook salmon caught and examined at Canyon Creek.

Table D-2. Catches of other salmonids captured in the Copper River fishwheels, 2002.

	Sockeye				Steelhead				Juvenile salmon				Dolly Varden				Whitefish			
Date	FW1	FW2	FW3	Total	FW1	FW2	FW3	Total	FW1	FW2	FW3	Total	FW1	FW2	FW3	Total	FW1	FW2	FW3	Total
21 May		1		1		0		0		0		0		0		0		0		0
22 May		14		14		0		0		0		0		0		0		0		0
23 May		45	0	45		0	0	0		1	0	1		0	0	0		1	0	1
24 May	8	90	0	98	0	1	0	1	0	1	0	1	0	0	0	0	0	0	0	0
25 May	55	113	1	169	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	1
26 May	40	101	2	143	0	0	0	0	3	1	0	4	0	0	0	0	1	1	0	2
27 May	55	173	4	232	0	0	0	0	2	4	0	6	2	0	0	2	0	0	0	0
28 May	148	415	9	572	0	1	0	1	4	4	0	8	0	0	0	0	1	0	0	1
29 May	119	117	12	248	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1
30 May	140	379	15	534	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1	1
31 May	192	494	23	709	0	0	0	0	1	3	0	4	0	0	0	0	0	0	0	0
1 Jun	174	628	19	821	0	0	0	0	0	2	0	2	0	0	0	0	0	1	0	1
2 Jun	245	591	59	895	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	3
3 Jun	180	340	87	607	0	0	0	0	0	2	0	2	0	0	0	0	1	2	0	3
4 Jun	279	601	110	990	0	0	0	0	0	3	4	7	0	0	0	0	1	4	1	6
5 Jun	390	200	111	701	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0	0
6 Jun	369	252	97	718	0	0	0	0	0	1	0	1	0	0	0	0	2	1	2	5
7 Jun	455	290	129	874	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
8 Jun	280	389	199	868	0	0	0	0	0	0	1	1	0	0	0	0	2	0	0	2
9 Jun	156	166	298	620	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	1
10 Jun	50	94	229	373	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11 Jun	64	184	255	503	0	0	0	0	0	0	10	10	0	0	0	0	0	1	0	1
12 Jun	59	135	154	348	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
13 Jun	33	76	128	237	0	0	0	0	0	1	3	4	0	0	0	0	0	0	2	2
14 Jun	39	61	81	181	0	0	0	0	0	1	0	1	0	0	0	0	2	0	1	3
15 Jun	41	105	97	243	0	0	0	0	0	1	4	5	0	0	0	0	0	0	1	1
16 Jun	42	141	48	231	0	0	0	0	0	2	0	2	0	0	0	0	0	0	0	0
17 Jun	42	126	21	189	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18 Jun	18	49	16	83	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
19 Jun	7	24	23	54	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0	0
20 Jun	7	18	18	43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21 Jun	11	42	28	81	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0
22 Jun	37	97	39	173	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1
23 Jun	21	68	40	129	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24 Jun	18	45	42	105	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
25 Jun	28	58	35	121	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
26 Jun	12	33	37	82	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
27 Jun	41	91	54	186	0	0	0	0	0	0	1	1	0	1	0	1	0	0	0	0

Table D-2. Catches of other salmonids captured in the Copper River fishwheels, 2002.

	Sockeye				Steelhead				Juvenile salmon				Dolly Varden				Whitefish			
Date	FW1	FW2	FW3	Total	FW1	FW2	FW3	Total	FW1	FW2	FW3	Total	FW1	FW2	FW3	Total	FW1	FW2	FW3	Total
28 Jun	43	90	94	227	1	0	0	1	0	0	3	3	0	0	0	0	0	0	1	1
29 Jun	51	33	86	170	0	0	0	0	0	0	1	1	0	0	0	0	0	0	2	2
30 Jun	60	62	95	217	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
1 Jul	36	34	49	119	0	0	0	0	0	0	0	0	0	1	1	2	0	0	0	0
2 Jul	51	31	27	109	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3 Jul	37	37	13	87	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0
4 Jul	17	18	17	52	0	0	0	0	0	0	0	0	0	2	0	2	0	0	0	0
5 Jul	6	13	4	23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6 Jul	22	19	31	72	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
7 Jul	67	80	38	185	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8 Jul	187	391	32	610	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
9 Jul	80	144	28	252	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0
10 Jul	14	45	8	67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11 Jul		41	6	47		0	0	0		0	0	0		0	0	0		0	1	1
12 Jul		39	3	42		0	0	0		0	0	0		0	0	0		0	0	0
13 Jul		47	9	56		0	0	0		0	0	0		0	0	0		0	0	0
14 Jul			22	22			0	0			0	0			0	0			0	0
15 Jul			28	28			0	0			0	0			0	0			0	0
16 Jul			32	32			0	0			0	0			0	0			0	0
17 Jul			7	7			0	0			0	0			0	0			0	0
18 Jul			5	5			0	0			0	0			0	0			0	0
19 Jul			3	3			0	0			0	0			0	0			0	0
20 Jul			11	11			0	0			0	0			0	0			0	0
21 Jul			11	11			0	0			0	0			0	0			0	0
22 Jul			19	19			0	0			0	0			0	0			0	0
23 Jul			12	12			0	0			0	0			0	0			0	0
24 Jul			22	22			0	0			0	0			0	0			0	0
25 Jul			0	0			0	0			0	0			0	0			0	0
26 Jul			17	17			0	0			0	0			0	0			0	0
27 Jul			14	14			0	0			0	0			0	0			0	0
28 Jul			49	49			0	0			0	0			0	0			0	0
29 Jul			50	50			0	0			0	0			0	0			0	0
30 Jul			87	87			0	0			0	0			0	0			0	0
31 Jul			149	149			0	0			0	0			0	0			0	0
1 Aug			91	91			0	0			0	0			0	0			0	0
Totals	4526	7970	3689	16185	1	2	2	5	12	28	42	82	3	6	2	11	11	15	16	42

Table D-3. Catches of non-salmonids captured in the Copper River fishwheels, 2002.

	Sucker spp.				Burbot				Grayling				Pacific lamprey			
Date	FW1	FW2	FW3	Total	FW1	FW2	FW3	Total	FW1	FW2	FW3	Total	FW1	FW2	FW3	Total
21 May		0		0		0		0		0		0		0		0
22 May		0		0		0		0		0		0		1		1
23 May		6	0	6		0	0	0		0	0	0		2	0	2
24 May	1	4	0	5	0	1	0	1	0	0	0	0	1	3	0	4
25 May	0	0	0	0	0	0	0	0	0	0	0	0	5	3	0	8
26 May	1	1	0	2	0	0	0	0	0	0	0	0	19	12	0	31
27 May	0	3	0	3	0	0	0	0	0	0	0	0	7	4	0	11
28 May	0	3	0	3	0	0	0	0	0	0	0	0	1	1	0	2
29 May	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	1
30 May	0	2	0	2	0	0	0	0	0	0	0	0	0	1	0	1
31 May	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
1 Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2 Jun	0	1	0	1	0	0	0	0	0	0	0	0	6	4	0	10
3 Jun	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
4 Jun	0	3	1	4	0	0	0	0	0	0	1	1	0	4	0	4
5 Jun	0	0	1	1	0	0	0	0	0	1	1	2	4	0	0	4
6 Jun	0	1	0	1	0	0	0	0	2	0	0	2	4	0	2	6
7 Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8 Jun	0	1	1	2	0	0	0	0	0	0	0	0	0	0	2	2
9 Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10 Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11 Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
12 Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13 Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14 Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15 Jun	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0
16 Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17 Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18 Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19 Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20 Jun	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
21 Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22 Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23 Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24 Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25 Jun	0	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0
26 Jun	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
27 Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28 Jun	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
29 Jun	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0

Table D-3. Catches of non-salmonids captured in the Copper River fishwheels, 2002.

	Sucker spp.				Burbot				Grayling				Pacific lamprey			
Date	FW1	FW2	FW3	Total	FW1	FW2	FW3	Total	FW1	FW2	FW3	Total	FW1	FW2	FW3	Total
30 Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1 Jul	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
2 Jul	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3 Jul	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4 Jul	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5 Jul	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6 Jul	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7 Jul	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8 Jul	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
9 Jul	0	1	0	1	0	0	0	0	0	0	2	2	0	0	0	0
10 Jul	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11 Jul		0	0	0		0	0	0		0	0	0		0	0	0
12 Jul		0	0	0		0	0	0		0	0	0		0	0	0
13 Jul		0	0	0		0	0	0		0	0	0		0	0	0
14 Jul			0	0			0	0			0	0			0	0
15 Jul			0	0			0	0			0	0			0	0
16 Jul			0	0			0	0			0	0			0	0
17 Jul			0	0			0	0			0	0			0	0
18 Jul			0	0			0	0			0	0			0	0
19 Jul			0	0			0	0			0	0			0	0
20 Jul			0	0			0	0			0	0			0	0
21 Jul			0	0			0	0			0	0			0	0
22 Jul			0	0			0	0			0	0			0	0
23 Jul			0	0			0	0			0	0			0	0
24 Jul			0	0			0	0			0	0			0	0
25 Jul			0	0			0	0			0	0			0	0
26 Jul			0	0			0	0			0	0			0	0
27 Jul			1	1			0	0			0	0			0	0
28 Jul			1	1			0	0			0	0			0	0
29 Jul			0	0			0	0			0	0			0	0
30 Jul			0	0			0	0			0	0			0	0
31 Jul			0	0			0	0			0	0			0	0
1 Aug			0	0			0	0			0	0			0	0
Totals	2	29	10	41	0	1	0	1	2	1	7	10	48	37	6	91

Table E-1. Escape panel settings on the Copper River fishwheels, 2002.

Location	Date	Time	Excluder adjustment	Width of opening (cm)	Comments
Baird	24-May	14:36	Closed		Fishwheel 1 activated at the start of the season
Canyon	07-Jun	22:20	Opened	6.5	Opened excluder on starboard live tank
(FW1)	09-Jun	16:00	Opened	6.5	Opened excluder on port live tank
	08-Jul	13:50			Temporarily (2 hours) closed excluders for testing
Baird	21-May	16:00	Closed		Fishwheel 2 activated at the start of the season
Canyon	28-May	22:30	Opened	6.0	Original configuration
(FW2)	29-May	14:45	Closed		One sockeye mortality gilled in slot of excluder
	04-Jun	21:30	Opened	6.0	Re-configured slots to prevent gilling sockeye
	12-Jun				Starboard excluder closed for uknown period
	28-Jun	7:30	Widened	7.0	Widened opening on both excluders to 7.0 cm
	08-Jul	13:50			Temporarily (2 hours) closed excluders for testing
Canyon	23-May	17:00	Closed		Fishwheel 3 activated at the start of the season
Creek	10-Jul	22:00	Opened	6.0	
(FW3)	24-Jul	15:00	Closed		Closed excluders for remainder of season

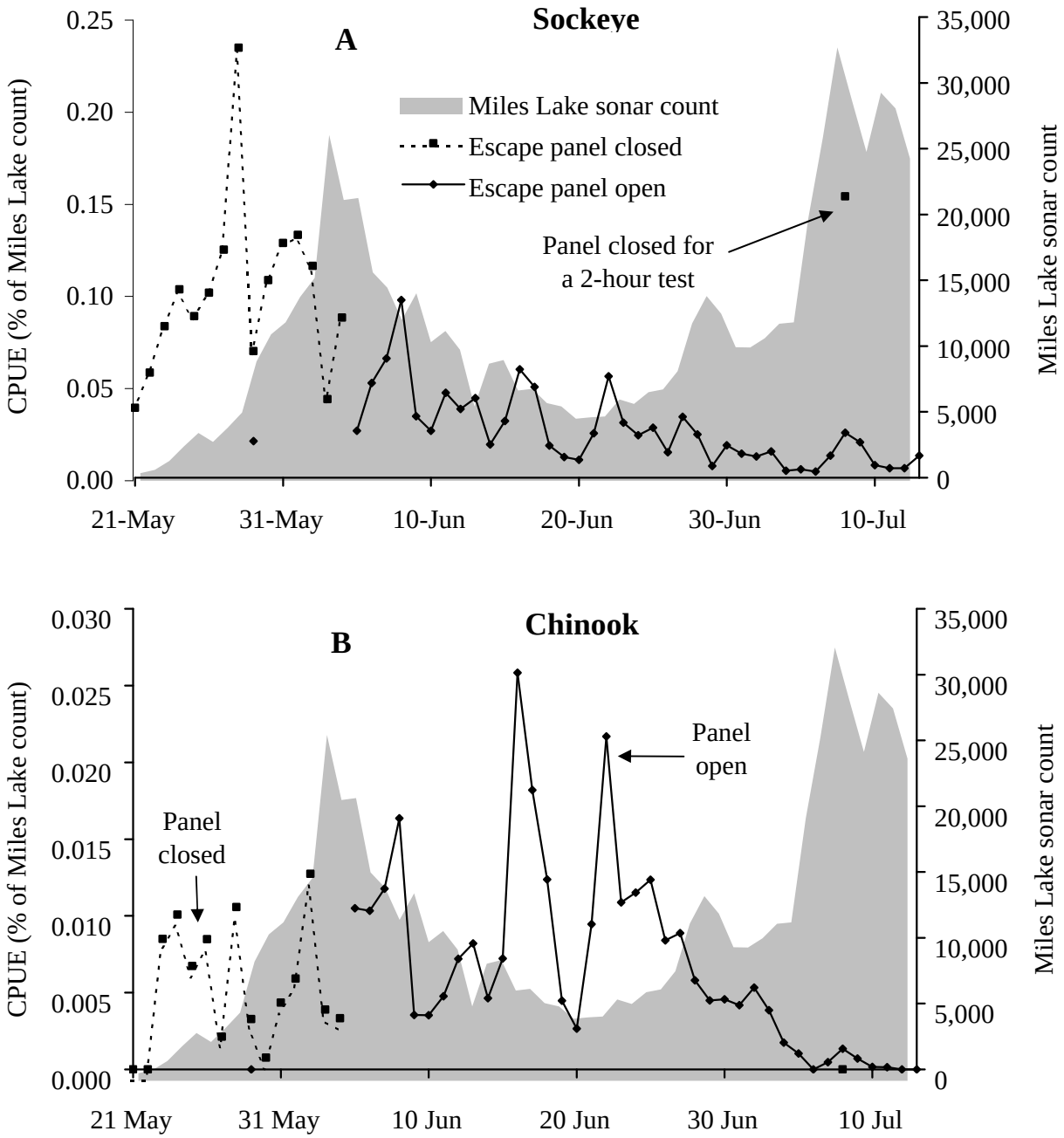

Figure E-2. Catch per unit effort, expressed as a percent of the Miles Lake sonar counts, for sockeye (Panel A) and chinook (Panel B) salmon captured in the port live tank of Fishwheel 2 at Baird Canyon, 2002.

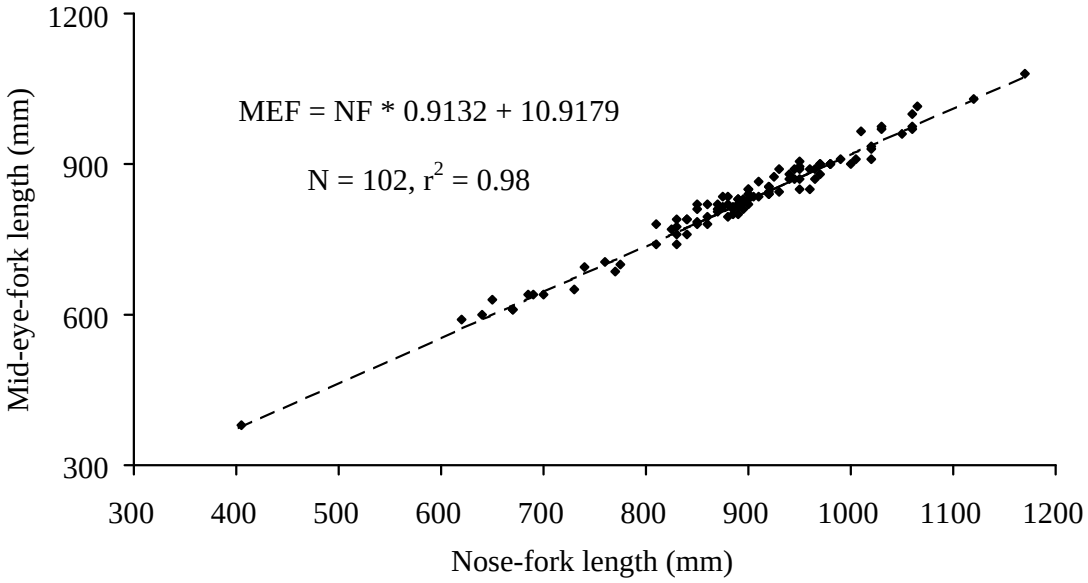

Figure F-1. Regression equation used to convert between mid-eye-fork (MEF) and nose-fork (NF) lengths for chinook salmon, 2002.

Table G-1. Comparison of recapture rates by tag type for fish measuring 750 mm NF or greater at the Canyon Creek fishwheel.

Recapture history	Tag type	
	Spaghetti	Radio
Recaptured	8	8
Not recaptured	742	379
Total available	750	387
Chi-square =	1.84	
df =	1	
P-value =	0.17	

Table G-2. Comparison of recapture rates by tag type for fish measuring 750 mm NF or greater in the CSS fishery.

Recapture history	Tag type	
	Spaghetti	Radio
Recaptured	25	7
Not recaptured	725	380
Total available	750	387
Chi-square =	2.17	
df =	1	
P-value =	0.14	

Only tagged fish sampled during ADF&G creel survey were included.

Table G-3. Comparison of recapture rates by tag type for fish measuring 750 mm NF or greater in the GSS fishery.

Recapture history	Tag type	
	Spaghetti	Radio
Recaptured	9	6
Not recaptured	741	381
Total available	750	387
Chi-square =	0.24	
df =	1	
P-value =	0.62	

Table G-4. Comparison of mark rates for radio-tagged fish measuring 750 mm NF or greater at the Canyon Creek fishwheel and in the CSS fishery.

Recapture history	Recovery location	
	Canyon Creek	CSS fishery
Tagged	8	7
Not tagged	572	418
Examined	580	425
Chi-square =	0.12	
df =	1	
P-value =	0.73	

Table G-5. Comparison of mark rates for radio-tagged fish measuring 750 mm NF or greater at the Canyon Creek fishwheel and in the GSS fishery.

Recapture history	Recovery location	
	Canyon Creek	GSS fishery
Tagged	8	7
Not tagged	572	243
Examined	580	250
Chi-square =	1.99	
df =	1	
P-value =	0.16	

Table G-6. Comparison of mark rates for spaghetti-tagged fish at the Canyon Creek fishwheel and in the CSS fishery.

Recapture history	Recovery location	
	Canyon Creek	CSS fishery
Tagged	8	25
Not tagged	572	400
Examined	580	425
Chi-square =	14.40	
df =	1	
P-value =	< 0.01	

Table G-7. Comparison of mark rates for spaghetti-tagged fish at the Canyon Creek fishwheel and in the GSS fishery.

Recapture history	Recovery location	
	Canyon Creek	GSS fishery
Tagged	8	10
Not tagged	572	240
Examined	580	250
Chi-square =	5.66	
df =	1	
P-value =	0.02	

Table G-8. Travel time (days) of fish tagged at the Baird Canyon fishwheels and recaptured at the Canyon Creek fishwheel, 2002.

Tag #	Length (mm NF)	Date tagged	Date recaptured	Time from release to recapture (days)
1473	1170	26-May	05-Jun	10
3482	980	12-Jun	26-Jun	14
1678	815	13-Jun	26-Jun	13
1691	908	14-Jun	14-Jul	30
1698	985	15-Jun	30-Jun	15
3530	750	16-Jun	26-Jun	10
3595	945	16-Jun	28-Jun	12
1718	963	17-Jun	30-Jun	13
3577	910	17-Jun	02-Jul	15
1734	842	18-Jun	29-Jun	11
1751	930	20-Jun	29-Jun	9
1801	1006	24-Jun	01-Jul	7
3790	1140	28-Jun	08-Jul	10
3806	870	29-Jun	07-Jul	8
3855	1150	01-Jul	11-Jul	10
3--- [a]	-	-	30-Jun	-
Mean	958			12.5
Median	945			11.0

[a] One yellow spaghetti-tagged fish was recaptured but it escaped prior to the crew reading the tag number.

Table H-1. Numbers of fish to examine (C) to derive Petersen mark-recapture estimates with 95% confidence intervals of 10, 25, and 50% (100*p) of N across a range of population abundance.

Estimated abundance (N)	Number marked (M)	Percent marked	Number of fish to examine (C)	
			p = 0.5	p = 0.25
20,000	1,000	5.0	453	1,244
20,000	1,250	6.3	359	995
20,000	1,500	7.5	296	825
30,000	1,000	3.3	691	1,896
30,000	1,250	4.2	551	1,524
30,000	1,500	5.0	457	1,270
40,000	1,000	2.5	930	2,549
40,000	1,250	3.1	742	2,053
40,000	1,500	3.8	617	1,715
50,000	1,000	2.0	1,168	3,201
50,000	1,250	2.5	934	2,582
50,000	1,500	3.0	777	2,159
60,000	1,000	1.7	1,406	3,854
60,000	1,250	2.1	1,125	3,111
60,000	1,500	2.5	937	2,604

Table I-1. List of participants (and posters displayed) at the project technical and community workshops held on 12 and 13 November 2002, in Cordova, Alaska.

The Native Village of Eyak (NVE) hosted a technical meeting and public symposium (12-13 November 2002) to review three fisheries projects completed in 2002 on the Copper River. The two projects implemented by NVE were designed to examine the feasibility of monitoring sockeye salmon escapement in the Copper River Delta and the other project was designed to estimate the annual escapement of chinook salmon to the Copper River. The third study was initiated by ADF&G with NVE in 2002 and was designed to monitor chinook salmon spawning and distribution and migratory timing.

Participants at the technical meeting included:

Ash, Dan (ADFG)
Cain, Bruce (NVE)
Degan, Don (Aquacoustics)
Evenson, Matt (ADFG)
Gehlbach, Seawan (NVE)
Gove, Nancy (ADFG)
Gray, Dan (ADFG)
Henrichs, Bob (NVE)
Johnson, Roger (NVE)
Joyce, Tim (USFS)
King, Mark (NVE)
Lambert, Michael (NVE)
Marston, Brian (ADFG)
McBride, Doug (USFWS)
McCall, Erica (NVE)
Merizon, Rick (ADFG)
Moffitt, Steve (ADFG)
Mueller, Anna Maria (Aquacoustics)
O'Brien Iris (NVE)
Savereide, James (ADFG)
Smith, Jason (LGL)
Williams, Kate (NVE)

PHOTO PLATES

Photo 1. A project cabin built by NVE in the fall of 2001, located approximately 2 km upstream of Baird Canyon on the west bank of the Copper River.

Photo 2. Fishwheel 2 in operation at Site 1 along the west bank of the Copper River, approximately 200 m upstream from the mouth of the north branch of the Allen River, 2002.

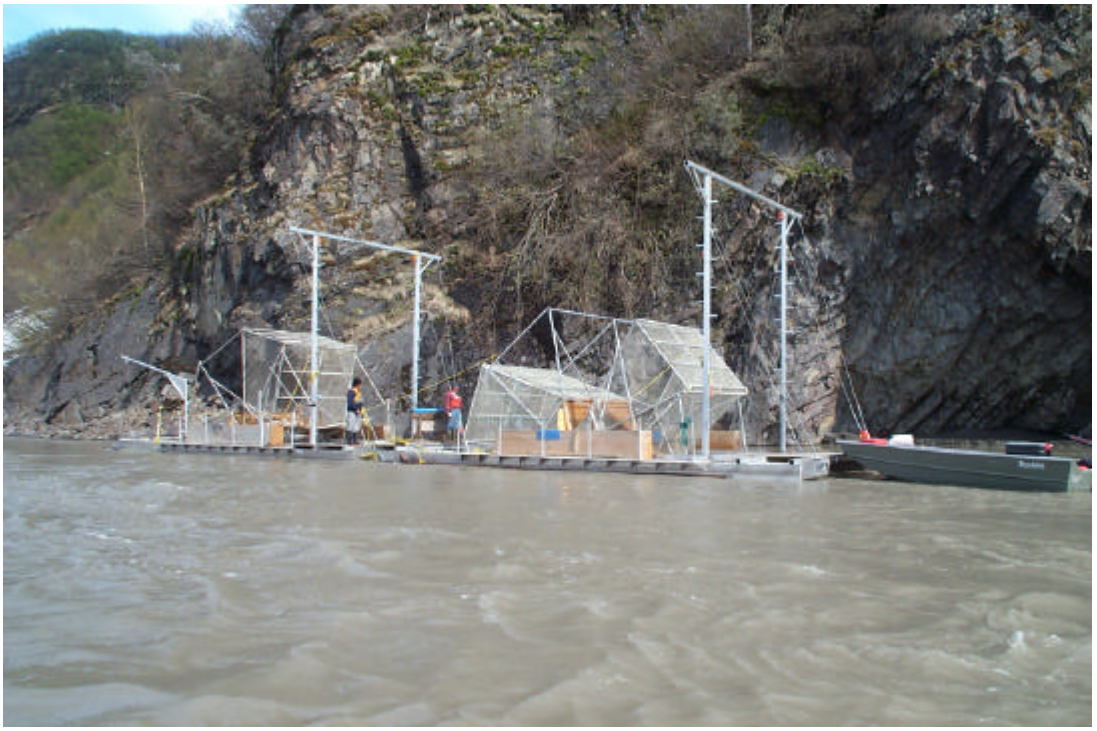

Photo 3. Fishwheel 1 (downstream) and Fishwheel 2 (upstream) in operation at Site 2 along the east bank of the Copper River near the upper end of Baird Canyon, 2002.

Photo 4. Fishwheel 3 in operation along the west bank of the Copper River, approximately 3 km downstream from the mouth of Canyon Creek in Wood Canyon, 2002.

Photo 5. Aerial view of the Canyon Creek field camp, located on the east bank of the Copper River directly across from the fishwheel site, 2002.

Photo 6. An escape panel that was installed in each of the fishwheel live tanks in 2002 to allow sockeye salmon to escape without being handled.