U.S. Fish and Wildlife Service
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Fisheries Resource Monitoring Program

Assessing Methods to Index Inseason Salmon Abundance in the Lower Copper River, 2002 Annual Report

Annual Report No. FIS01-021

Alaska Research Associates, Inc.

March 2003

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Annual Report Summary Page

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EXECUTIVE SUMMARY

The U.S. Fish and Wildlife Service (USFWS), Office of Subsistence Management, funded the Native Village of Eyak (NVE) to undertake a three-year study (2001-2003) to develop and assess methods of monitoring salmon escapement in the lower Copper River. The ultimate goal of this project was to develop an annual monitoring program that could provide fishery managers with more timely indices of salmon escapement than those currently available from the Miles Lake sonar site (river km 52). A multi-faceted research design was developed to (1) significantly shorten the development time of a lower river test fishery; (2) study fish migratory behavior; and (3) compare the utility of acoustics and drift gillnets as test fishing tools.

The majority of acoustic sampling was conducted at Flag Point Channel, located just downstream of Bridge 331 on the Copper River Highway. A total of 563 h of acoustic data were collected from 16 May to 10 June 2002. Different methods of counting fish (directly from echograms and tracked with acoustic software) and sampling (full and subsampled hours) from the acoustic data were compared. The tracked net upstream count (i.e., tracking software, full hours sampled, net upstream targets) was 25,261 salmon with a peak count of 3,234 salmon on 4 June. A second acoustic system was deployed periodically (3-4 h per day on 26 and 29 May, and 1, 4, and 7 June) at the Mile-37 Channel (Bridge 342) in 2002.

Drift gillnetting was conducted by the Alaska Department of Fish and Game (ADF&G) personnel at Flag Point Channel for a total of 27 days from 15 May to 10 June 2002. A total of 418 sockeye (*Oncorhynchus nerka*) and 34 chinook (*O. tshawytscha*) salmon were captured during 1,174 min of fishing. Daily test fishing indices (fish per 100 fathom hours) for sockeye salmon peaked at 684 on 2 June, and the season cumulative index was 6,159.

As in 2001, results from 2002 indicated that the acoustic and drift gillnetting sample sites at Flag Point Channel were suitable for developing a lower river test fishery. Both gear types detected similar pulses of fish and produced daily indices at Flag Point Channel that were correlated with indices generated from the Miles Lake sonar. In 2002, fish appeared to take 2-3 days early in the season, and closer to 1 day starting in late May, to migrate upstream from Flag Point Channel to the Miles Lake sonar site. Maximum likelihood estimation and regression analyses were used to compare the escapement indices generated at Flag Point Channel to those at the Miles Lake sonar site. Results indicated that both the catchability of the drift gillnet and the travel time of fish between the two sites varied over the study period.

Plans for 2003 include the continued use of both acoustic and drift gillnetting techniques in Flag Point Channel from early May to early June. It was recommended that sampling at the 37-Mile Channel be discontinued in 2003. Variability within and among years in catchability and travel time will continue to be evaluated. And lastly, the relative strengths and weaknesses of acoustics and drift gillnetting will be compared to determine which technique is most appropriate for future use in the lower Copper River.

INTRODUCTION

In early 2001, the U.S. Fish and Wildlife Service (USFWS), Office of Subsistence Management (OSM), funded the Native Village of Eyak (NVE) to undertake a three-year study to develop and assess methods of monitoring salmon escapement in the lower Copper River (Fig. 1). The ultimate goal of this lower river test fishery project was to develop an annual monitoring program that could provide fishery managers with a more timely index of salmon escapement than is currently available from the Miles Lake sonar site.

The Copper River subsistence and commercial salmon fisheries are of great value to both native and non-native participants. In 2001, the Alaska Department of Fish and Game (ADF&G) gave permits to more than 10,000 people to fish the Copper River subsistence fisheries with an estimated total harvest of chinook (*Oncorhynchus tshawytscha*), sockeye (*O. nerka*), and coho (*O. kisutch*) salmon of 226,420 (Gray et al. 2002). In the Copper River District, the exvessel value of commercial, common property, salmon landings exceeded $14 million in 2002. Recent (1991-2000) average commercial harvests of sockeye and chinook salmon have been 1,521,641 and 48,640, respectively (Gray et al. 2002). From 1990-99, sport harvests for sockeye and chinook salmon have averaged 12,000 (Taube and Sarafin 2001).

Most of the Copper River subsistence harvest is taken in the upper river and its tributaries, 150 km or more upstream of the ocean commercial fishery. Therefore, migrating fish are exposed to commercial fishing activity from two to four weeks (depending in part on river discharge) before they arrive in subsistence fishing areas (Merritt and Roberson 1986). The lack of early run assessment information can make it difficult for managers to meet escapement goals while providing a sufficient number of fish for subsistence and commercial harvesters. The commercial salmon fishery also covers a large area (~1,200 km^2), and the rate at which salmon migrate through this area during the early part of the season varies among years. For example, if fish move quickly from the Copper River District into the river, the commercial fishery may forego harvests at a time when the landed value of the fish is 100-200% greater than it is later in the season. On the other hand, if fish mill in the Copper River District while waiting for appropriate conditions to move into the river, they may be subject to excess commercial fishing pressure.

Much effort has been expended over the last 40 years to develop a timely method of estimating salmon escapement for the Copper River. In 1978, a Bendix sonar system was placed 52 km (33 miles) upriver of the Copper River District, just below the outlet of Miles Lake where the river is confined to a single channel (Fig. 2). This sonar system has provided a daily index of salmon abundance since 1978. However, the data gathered by ADF&G suggests it can take anywhere from three to nine days for sockeye salmon to travel from the Copper River District to the Miles Lake sonar site. As a result, fishery managers sometimes face difficult decisions early in the season because the timing of river entry is highly variable among years (Schaller et al. 1984). In late June 1984, ADF&G assessed the utility of using a Bendix sonar counter about half way between Miles Lake and the commercial fishery (S. Moffitt, ADF&G, Division of Commercial Fisheries, *personal communication*). The counts were generally 10-100 fish per

day, but the work was hindered by high water levels and debris. A more extensive survey planned for 1985 was not funded.

Miles Lake sonar provides relatively reliable daily and annual indices of salmon abundance and will probably do so well into the future. However, the early commercial fishing periods could be managed with greater confidence if escapement estimates were available earlier in the season. In 2000, under renewed pressure from commercial and subsistence users, ADF&G initiated a study to assess the feasibility of an early-season, test-netting program in the Copper River Delta (Moffitt et al. 2000). Both drift dip netting and gillnetting were investigated as possible means to index salmon returns in the lower part of the river. ADF&G found that dip nets would not catch enough fish to provide a reliable index without a significant increase in fishing effort.

With many Tribal members heavily reliant upon subsistence and commercial fisheries, NVE understood the value and importance of improving early season indices of salmon abundance in the Copper River. NVE worked with LGL Alaska Research Associates, Ltd. and ADF&G to design a multi-faceted study design to (1) significantly shorten the development time of a lower river test fishery; (2) study fish migratory behavior; and (3) compare the utility of acoustics and drift gillnets as test fishing tools. Given the potential for changes in fish behavior among years, and the expected changes in discharge among river channels of the Copper River (Brabets 1997), statistical relationships between test fishing indices and subsequent Miles Lake sonar indices could take many years to develop.

Study Area

The Copper River flows through the Chugach Mountains of Alaska and drains into the northern limits of the Gulf of Alaska, east of Prince William Sound (Fig. 1). Including its tributaries, the Copper River stretches more than 466 km and has created a 70-km wide delta of primarily glacial silt (Brabets 1997). The average annual discharge of the Copper River is 1,625 m^3/s, the second largest in Alaska. Despite carrying a very high sediment load, the Copper River is the largest salmon-producing river in Central Alaska (Merritt and Roberson 1986) and supports healthy stocks of sockeye and chinook salmon.

Objectives

The purpose of this project was to generate a timely, inseason index of salmon abundance that could be used to improve the management of the fishery and ensure an adequate number of fish escape upriver for spawning requirements and subsistence users. Overall goals for this three-year project were to:

1) Determine the migratory behavior and stream channel use of early-run sockeye salmon in the lower Copper River to gauge the sampling effort that is required to index inseason salmon abundance;

2) Assess the efficacy of sonar and drift gillnetting to provide a daily inseason index of early run salmon abundance in the lower Copper River; and
3) Assess the feasibility, benefits, and costs of operating sonar and drift gillnetting operations.

Specific objectives for the second year of this three-year project were to:

1) Train technicians to operate and maintain acoustic equipment, count from echograms, and manage sonar data;
2) Collect a continuous data set at Flag Point Channel;
3) Collect acoustic data from the Mile-37 Channel; and
4) Evaluate the efficacy (accuracy versus cost) of different methods of counting fish from acoustic data.

METHODS

Acoustics

Site Selection

Daily sampling of a consistent portion of the total fish run is required for successful and economical indexing of salmon abundance. The portion of a run sampled by a "test fishery" (e.g., 0.01 or 1%) for a given level of effort (e.g., 30 m of gillnet for 30 min or 15 min of acoustic sampling) is referred to as the catchability coefficient of the test fishery. The catchability coefficient is usually determined by comparing the daily (or cumulative) test fishing indices with an independent measure of the total daily (or cumulative) fish passage. The catchability coefficient of a test fishery must be consistent both within and among years for the test fishery to be useful. Therefore, it is best to sample at times and locations where the catchability coefficient is expected to be consistent among days and among years.

In 2001, local fishermen, biologists, and fishery managers were consulted to locate a suitable site for sampling the salmon run in the lower Copper River. Aerial surveys were flown along the lower river during low-water periods when river topography and potential sites were more evident. In addition, site-specific data were collected at several locations in 2001 (Link et al. 2001). In 2002, acoustic sampling sites were selected based on the following criteria:

1) A continuous, moderately steep bank extending onshore and above the water line;
2) An ice-free channel with flowing water;
3) The absence of debris, boulders, or other objects that could interfere with the acoustic beam;
4) Ease of access;
5) Past knowledge of salmon migrating passed the site; and

6) Coverage of multiple migration routes (i.e., away from diverging or converging sections of the river).

The efficacy of riverine acoustics to count upstream migrating salmon is heavily dependent on the cross-sectional profile of the river bottom. Ideally, the slope of the river bottom offshore from a stationary transducer should have a smooth and continuous grade. This ensures that the cone-shaped acoustic beams can effectively ensonify areas where fish migrate (i.e., close to the bottom). The range where fish can be counted along the river bottom extends from about 1 m (3.3 ft) in front of the transducer out to the first significant break in the gradient of the bank.

Flag Point Channel (Bridge 331 on the Copper River Highway)

In order to find a site for continuous sampling that would provide a greater acoustic range than the site used in 2001, a bathymetry (or bottom topography) survey was conducted over a 180-m long stretch of Flag Point Channel, approximately 400 m downstream of Bridge 331 (Fig. 3 and 4).

Similar to 2001, the acoustic gear used for the bathymetry survey was a BioSonics DE system with a 6-degree 201 kHz transducer and Visual Acquisition 4 software. Depth data were processed with the bathymetry module of EchoView 2.25. Positional information was collected with a differential global positioning system (GPS) with sub-meter accuracy and a 10 Hz positioning rate. Differential corrections were obtained from the U.S. Coast Guard beacon on Hinchinbrook Island. XY-positions were recorded as a separate data stream and were later matched by timestamp to the corresponding depth records. To ensure accurate timestamps, the computer clock was synchronized with the GPS time to the nearest 10 ms both before, and periodically during, data collection.

During the bathymetry survey, transects were as uniformly spaced as river conditions would allow. Real-time plotting of boat tracks gave feedback on the boat position during the survey. Transects were made perpendicular to the river bank, in S-shapes (to define cross-channel patterns), and parallel to the river bank (to add definition of along-channel patterns). Additional position data were also collected, opportunistically, while walking along the shoreline with the GPS receiver. XYZ position data were interpolated, mapped, and analyzed using ArcView 3.2.

Mile-37 Channel (Bridge 342 on the Copper River Highway)

At the Mile-37 Channel, the site chosen for periodic sampling in 2002 corresponded to site 5 that was used in 2001 (Link et al. 2001). This site was located on the west bank of the Copper River approximately 13 m downstream of Bridge 342 on the Copper River Highway (Fig. 2 and 3; Photo 1). Since the river bank at this site was protected by heavy riprap, it was assumed that the bottom profile had not changed since 2001. As a result, no bathymetry surveys were performed in 2002.

Setup and Operation

Flag Point Channel

The acoustic system used for monitoring fish passage at Flag Point Channel was a BioSonics DE echosounder with a 201 kHz splitbeam transducer and a 4 x 8 degree elliptical beam. The transducer was aimed with the wide axis of the beam in the horizontal plane and the narrow axis in the vertical plane. The vertical position and tilt angle of the transducer could be adjusted as desired. An attitude sensor was attached to the transducer to provide heading, pitch, and roll information.

A streamside data acquisition computer was linked through a wireless Ethernet connection to a remote data retrieval and processing station. Due to concerns over potentially rapidly rising water levels, a platform for the streamside equipment was erected at the top of a 10-m high bluff. The echosounder, data acquisition computer, wireless Ethernet components, and a 12 V battery bank were placed in a plastic container (1.2 x 0.9 x 0.8 m) on the platform. The plastic container protected the equipment from wind, rain, and sand. Solar panels and the wireless Ethernet antenna were mounted on top of the platform (Photo 2). The remote data retrieval and processing station was set up in a trailer parked next to Bridge 1187 on the Copper River Highway, in clear line-of-sight of, and about 1 km away from, the acoustic sampling site (Fig. 4).

Prior to the field season, the acoustic system was calibrated to US Navy standards at the BioSonics, Inc. laboratory (Seattle, WA). The system was also calibrated inseason (13 May, 23 May, and 10 June) at Flag Point Channel using a tungsten-carbide, reference sphere of known target strength. The reference sphere was suspended 3 m from the transducer, and approximately 1,000 pings were collected and processed.

When sampling fish, the transducer was aimed along the river bottom. The aim of the transducer was verified using a plastic reference sphere (10.1 cm dia.) with a target strength similar to an adult sockeye salmon. The sphere was lowered in front of the transducer using a fishing rod, raised 15 cm off the river bottom, and then moved in- and offshore as much as the water depth and velocity allowed. The aim of the transducer was confirmed when the target echoes were clearly visible and strong enough to qualify as sockeye salmon over at least every 0.5 m of the range. Fish were sampled at a ping rate of 12 per second, a pulse length of 0.2 ms, and a data collection threshold of -50 dB.

A weir made of rebar and construction fence was used to keep fish from passing too close to the transducer, where the acoustic beam was not coherently formed or too small to efficiently detect fish. Early in the season, pieces of rebar were placed 3 m upstream of the transducer to deflect ice floes. Technicians regularly removed debris from the weir and transducer mount (Photo 3).

Mile-37 Channel

The acoustic system used for periodic sampling in the Mile-37 Channel was a BioSonics DTX echosounder with a 200 kHz splitbeam transducer and 4 x 8 degree elliptical beam. This system allowed real-time remote operation and data retrieval. The streamside echosounder was linked through a wireless Ethernet to a data acquisition computer in a vehicle parked on the bridge.

Acoustic Counts

Flag Point Channel

Technicians were trained to count fish echo traces off echograms, to retrieve and backup data, and to maintain the acoustics equipment. On a daily basis, counts were generated from 20-min data sets of each hour and made available to ADF&G fishery managers. On days when fishery announcements were made, counts were provided to ADF&G in time for their internal pre-announcement meeting.

In 2002, three counting methods (visual, tracked, and tracked net upstream counts) and two sampling schemes (full and subsampled) were used to generate counts from acoustic data collected at Flag Point Channel:

Counting method	Description
Visual	Made directly from echograms
Tracked	Made with acoustic target-tracking software Disregards the direction of target movements
Tracked net upstream	Made with acoustic target-tracking software The number of downstream-moving targets are subtracted from the number of upstream-moving targets
Sampling Scheme	**Description**
Full	Based on sampling complete hours of data
Subsampled	Based on sampling only 20 min per hour of data

Visual counts were made from echo traces seen on echograms and did not account for the direction of target movement. Echograms were displayed in EchoView 2.25 software. Technicians followed specific guidelines to identify different targets such as salmon, eulachon (*Thaleichthys pacificus*), and non-fish objects, and to distinguish between broken, single-fish tracks and multiple fish tracks (Fig. A-1). Visual counts were based on sampling the first 20-min file of every hour. If the first file of the hour was less than 20-min long, the second or third file was sampled. The 20-min counts for each hour were multiplied by three to obtain an estimate of the total hourly counts. The hourly counts were expanded by the proportion of missing hours (if any) in a day to obtain daily counts. This expansion method ensured that visual counts were consistent with the other counting methods. A different method was used to generate counts

inseason. Visual counts that were reported during the season were expanded for missing hours by taking the average of the last complete hour before and after the data gap.

Tracked counts used EchoView 2.25 software to automatically track echo traces using an alpha-beta, track-detection algorithm (see Table A-1 for parameter values). Similar to visual counts, tracked counts did not account for the direction of target movement. Tracked files were reviewed and edited manually by removing obvious, non-salmon targets (e.g., rocks and eulachon), merging split tracks, and splitting merged tracks when necessary. The size distribution of tracked targets was examined to determine a suitable threshold for separating eulachon, some of which were included in the tracking output, from salmon. Only tracks with an average target strength greater than the threshold value were included in tracked counts. A subset of tracked counts was generated from the same files used to generate visual counts. Daily tracked counts were expanded by the proportion of time not sampled on a given day.

Tracked net upstream counts were generated from tracked counts by subtracting the number of downstream-moving targets from the number of upstream-moving targets. Classification of targets as moving upstream or downstream was based on the slope of a linear regression of x-position (i.e., upstream-downstream) and time. Tracks with a positive slope were classified as moving upstream, whereas tracks with a negative slope were classified as moving downstream.

Mile-37 Channel

The data files collected at the Mile-37 Channel were converted from ".rtp" to ".DT4" format using a BioSonics conversion module. The files were then opened in EchoView 2.25 software and fish echo traces were counted directly off the echograms. Daily counts were expanded by the proportion of time not sampled in a given day.

Drift Gillnetting

As in 2001, ADF&G used drift gillnets to index the abundance of sockeye salmon in the lower Copper River in 2002. Most of the net sampling occurred in Flag Point Channel below Bridge 331 on the Copper River Highway, and above the fork of the Pete Dahl Slough (Fig. 5; Photo 4).

Site Selection

Flag Point Channel was selected for drift gillnetting because it was a constriction point where most of the west side of the Copper River was contained within a single channel. The channel reach starts approximately 21.6 km above the Copper River District markers at Castle Island Channel, and there is no apparent tidal influence.

Flag Point Channel was the preferred site for drift gillnetting because:

1) It is road accessible most years by early to mid-May;
2) It has a good beach for launching boats;
3) It can be fished on a daily basis without a field camp; and
4) The water velocity is significantly slower than in other channels.

In 2001, the west side of Flag Point Channel was selected for more intensive sampling because of the channel morphology and because the majority of fish caught during a test fishery in 2000 were near the west bank. Results from the 2001 field season also supported the continued use of this sample area. The east side of the channel is a shallow mud bar that is difficult to fish effectively.

Initially, preliminary observations were made within 2 km of Bridge 331 to identify potential sampling stations that were free from snags. A chart-plotting, depth finder was used to record the bottom contour at each station to ensure the net would cover the entire water column available for fish passage. Suitable stations were (1) as free of snags as possible; (2) of sufficient depth and velocity to drift the net; and (3) shallow enough so the net was not suspended off the bottom.

Three stations were selected for use in 2002 that corresponded to Stations 1, 2, and 4 from the 2001 study (Link et al. 2001). Station 3 from the 2001 study was not selected because of insufficient water depth and velocity in 2002. One other station (Station 5) was used once in 2002 when river ice limited access to the other sites.

Setup and Operation

The drift gillnets used in 2002 were 18.3 m (10 fathoms) long and 20 meshes deep with a 13.7 cm (5 3/8 in), stretched-mesh web. Although dip nets were used in 2000 and 2001 to capture sockeye salmon in Flag Point Channel (Link et al. 2001), only drift gillnets were used in 2002.

Three different stations (Stations 1, 2, and 4) were sampled on a regular basis by the ADF&G crew in 2002 (Fig. 5). Each station was sampled daily in two separate rounds. In the first round, four sets were made at each of Stations 1 and 2. These stations had broad, deep channels, so two sets were made along the west bank and two in the middle of the channel at each station. Two sets were then made along the west bank of Station 4, which consisted of a narrow, deep channel. This cycle was then repeated, starting again at Station 1.

Most drift gillnet sets were made perpendicular to shore and as close to the bank as possible because most sockeye salmon travel upriver near the bank (Burgner 1991). Tension was placed on the net as required to keep it from bunching up in the current. The starting and stopping points for each drift were marked with surveyors flagging on bank vegetation. Due to the numerous snags embedded in the river bottom along the west bank, each set was limited to approximately 2 min in fishing time.

For each set, the following data were recorded: set location, distance offshore at the start and end of a drift, time the net started out, time the net was completely out, time the net started in, time the net was completely in, and number of fish captured by species. All captured fish were marked by clipping the adipose fin and then released if in good condition. Unreleased fish were sampled for length, weight, sex, and age.

River stage height and weather information were recorded on most sampling days. Stage height was measured at a U.S. Geological Survey (USGS) gauge mounted on Bridge 331 and provided a relative measure of river elevation (the elevation of the bridge above sea level was not known). Weather information collected each day included cloud cover, precipitation, and wind velocity (km/h) and direction.

Test Fishing Index

The daily test fishing index for drift gillnetting at Flag Point Channel was calculated as in Gray (2000). Mean fishing time (*M*, minutes) was computed for each set:

$$MT = SI - FO + \frac{(FO - SO) + (FI - SI)}{2}, \tag{1}$$

where *SO* was the time the gillnet first entered water, *FO* the time the gillnet was fully deployed, *SI* the time gillnet retrieval began, and *FI* the time gillnet retrieval was completed. Catch-per-unit-effort (CPUE, C_j), or the number of sockeye salmon caught per 100 fathom hours, was computed for set *j* by the following equation:

$$C_j = 6{,}000 \frac{N}{G \times MT}, \tag{2}$$

where *N* was the number of sockeye salmon caught and *G* the gillnet length in fathoms. The daily test fishing index at Flag Point Channel, I_i, for day *i* was computed as the mean of the CPUE values from the number of sets (S_i) made on day *i*:

$$I_i = \frac{\sum_{j=1}^{s} C_j}{S_i}, \tag{3}$$

Test Fishing Index and Miles Lake Sonar Counts

Two methods were used to examine the effectiveness of the lower Copper River test fishing index as a management tool. Maximum likelihood estimation (MLE) and regression analysis were used to compare the Miles Lake sonar index to the test fishing index at Flag Point Channel. Analysis of the 2001 data by ADF&G showed that the traditional method for estimating escapement at the Miles Lake sonar from the test fishing indices at Flag Point

Channel was not as effective as the MLE and regression estimates. These data also demonstrated that while the cumulative indices produced a better fitting model, the daily index values were better for forecasting. Thus, only the MLE and regression models, and the daily indices, were used for this analysis.

Miles Lake escapement data were lagged to account for the travel time of sockeye salmon from the test fishing site at Flag Point Channel to the Miles Lake sonar site. Different lag times were tried in the models to determine which one produced the best model fit. Travel times that appeared unrealistic based on results of past studies, or produced unreasonable escapement estimates (e.g., less than observed escapement), were rejected even if they produced the best statistical fit of the data.

For the MLE model, the escapement per index point (*EPI*), was estimated by minimizing the sums of squares (*SS*) of the difference between the test fishing index and the observed and predicted escapements:

$$SS = \sum_{i=1}^{t} (EPI \cdot I_i - E_{i+d})^2 \text{, where} \tag{4}$$

1) *EPI* represents the number of sockeye salmon passing the Miles Lake sonar for each test fishing index point at Flag Point Channel;
2) E_i represents the number of sockeye salmon passing the Miles Lake sonar on day i;
3) t represents the day of the most recent estimate at the Miles Lake sonar; and
4) d represents the travel time between the Miles Lake sonar and test fishing locations.

If the model errors are assumed to be normally distributed, then minimizing the sums of squares will maximize the following equation, resulting in an MLE of *EPI*:

$$L(EPI, s^2 \mid E_i, I_i) = \prod_{i=1}^{n} \frac{1}{s\sqrt{2p}} e^{-\frac{(E_{i+d} - EPI \cdot I_i)^2}{2s^2}}, \tag{5}$$

where σ^2 is the variance of E_i. This method is the same as fitting a regression line with intercept equal to zero and slope of *EPI*:

$$E_{i+d} = EPI \cdot I_i. \tag{6}$$

For the regression approach, a linear regression model was fit both with and without covariates for river stage height and change in stage height to find the best linear relationship between the test fishing index and Miles Lake escapement:

$$E_i = a + bI_{i-d} + e_i, \tag{7}$$

where α and β were estimates of the intercept and slope, respectively, and ε_i was the error.

Both the MLE and regression approaches assumed that error was constant and normally distributed. This assumption appeared reasonable for the 2002 data.

Forecasting

The real need on the Copper River is a tool for determining the escapement levels between the Copper River District and Miles Lake sonar, particularly at the beginning of the fishing season. Therefore, the ability of the Flag Point Channel test fishing index to provide inseason forecasts of Miles Lake sonar counts was examined. To emulate inseason forecasting, only the data collected up to the day of the forecast were used. Other factors such as stage height were not used in forecasting because one really needs more data points to estimate that many parameters. Forecasting began once there were a sufficient number of days of data. For example, the first opportunity to forecast assuming a 1-day lag was on day 5, when there were 4 days of Miles Lake sonar counts to pair with the test fishing index. Assuming a 2-day lag, the first day a forecast could be made was on day 6. For each day, the lag was determined by which one produced the best model fit between the predicted and observed escapements (as measured by the R^2 value). Early in the season, a regression analysis with few data points may not generate a reliable forecast, but this estimate may be better than none at all to managers who need to make important decisions regarding commercial fishing openings.

RESULTS

Acoustics

Site Selection

Flag Point Channel

Early in 2002, river conditions were monitored by frequent road trips along the Copper River Highway and by an aerial survey on 8 May. Cold and dry weather in late April and early May of 2002 slowed the ice breakup of the lower Copper River. The river had limited ice with a good flow of water for sampling near Flag Point Channel by 14 May. In 2001, the river thawed as early as 4 May.

A bathymetry survey on 11 May 2002 identified a suitable sampling site approximately 35 m below the first creek entering the west side of the Copper River downstream of Bridge 331 (Fig. 6). The river bank at this site had a steep (7°) and relatively uniform gradient along a 25 m section. These features yielded an effective, underwater counting range of 24 m at a stage height of 4.2 m, and 19 m at a stage height of 2.9 m (Fig. 7). This site was free of debris and provided a longer sampling range than the site used in 2001.

Stage height of the Copper River was monitored throughout the study period at Flag Point Channel (USGS gauge at Bridge 331) and the Million Dollar Bridge (Table B-1). In 2002, ADF&G operated the Miles Lake sonar site from 14 May to 31 July, and an estimated 220,000 salmon passed the site from 15 May to 10 June (Table C-1).

Mile-37 Channel

No new bathymetry information was collected in 2002 at the Mile-37 Channel. The same site used in 2001 was used again in 2002.

Setup and Operation

Flag Point Channel

The acoustic system was operated continuously at Flag Point Channel from 16 May to 10 June 2002 (Table 1). Counts were provided for 563 h out of a total of 598 h, or 94% of the time the equipment was in place. Counts were interrupted for a total of 29 h. Down time included 11 h early in the season (17 and 19 May) when the transducer was knocked off aim by ice, 11 h on 19 May following the break up of an ice jam and subsequent 1 m drop in water level at Flag Point Channel, 5 h due to the power supply being depleted, and 2 h in total for transducer moves and aiming procedures.

The heading, pitch, and roll (HPR) sensor recorded a transducer pitch of -5° throughout the sampling period. This placed the bottom edge of the acoustic beam, which was 4° wide in the vertical dimension, along the river bottom, which sloped at -7°. The slope of the bank and the aiming angle from the HPR sensor matched the observations made while lowering the target sphere down near the bottom. Based on these observations, it was concluded that fish were sampled on and near the bottom with the acoustic system.

Mile-37 Channel

Starting on 26 May, a second acoustic system was deployed for periodic sampling (3-4 h every third day) on the west bank of the Mile-37 Channel (Table 2). This site was operated for a total of 18.2 h (26 and 29 May, and 1, 4, and 7 June). Data were collected for 12-17% of any given day.

Acoustic Counts

Flag Point Channel

Four different counts were generated from the acoustic data collected at Flag Point Channel in 2002 (Table 3; Fig. 8). For subsampled counts, totals were 25,812, 30,189, and 25,272 for the visual, tracked, and tracked net upstream methods, respectively. When hourly data were fully sampled, the tracked net upstream count was 25,261 fish.

The tracked count was 17% higher (4337 fish) than the visual count. Visual counts were within 10% of tracked counts on 13 out of 26 sampling days, 10-20% on 8 days, and 20-30% on 5 days. Hourly counts for the visual and tracked subsampled methods were compared using regression analysis (R^2 = 0.91; Panel A in Fig. D-1).

The subsampled, tracked net upstream count was 2.1% lower (540 fish) than the visual count. Visual counts were within 10% of tracked net upstream counts on 10 out of 26 sampling days, 10-20% on 9 days, 20-30% on 1 day, and more than 30% on 7 days. Fig. D-1 (Panel B) shows a regression analysis of these methods (R^2 = 0.90). Counts from these two methods were substantially different early in the season when less than 300 fish/day passed the site. On days when more than 1,500 fish were counted, visual counts were more comparable to tracked net upstream counts than to tracked counts.

For the tracked net upstream method, subsampled (25,272) and fully sampled (25,261) counts were very similar (R^2 = 0.91; Fig. D-2).

The amount of time required to process the acoustic data varied with the different counting methods, the sampling schemes, and technician experience. For example, subsampled tracked counts (including editing, output to database, and preparation of counts) took 2.5 h per day, whereas full tracked counts took 6.5 h per day. Additional one-time effort was required for setting up echograms, tracking, and entering calibration parameters. The differences in processing times for visual and tracked counts are summarized below:

	Sampling scheme		Time required
Method	Subsampled (20 min/h)	Full (60 min/h)	once per season
Visual counts	1 h	3 h	3 h
Tracked counts	2.5 h	6.5 h	8 h

Mile-37 Channel

Tracked counts at the Mile-37 Channel were lower on the second sampling day (312 fish/day on 29 May), and both higher and relatively constant on the other sampling days (624-912 fish/day on 26 May, 1 June, 4 June, and 7 June; Table 2).

Fish Behavior

As in 2001, the distribution of target strength for all tracked targets showed two distinct modes in 2002 (Fig. 9). Based on this distribution, a threshold value of -41 dB was used to separate eulachon from salmon. Only tracks with an average target strength greater than -41 dB were included in tracked counts.

The distribution of x-speed (i.e., upstream or downstream speed), direction of movement, and target strength for all tracked targets showed three distinct clusters (Fig. 10). The predominant cluster consisted of salmon-sized targets between -41 and -27 dB with x-speeds between -0.2 and 0.7 m/s (-0.7 and 2.3 ft/s). A small cluster, possibly eulachon, fell between -46

and -41 dB with x-speeds between -0.2 and 0.2 m/s. A third cluster, possibly some eulachon and debris, was formed by small targets between -46 and -40 dB moving downstream at x-speeds between -1.2 and -0.2 m/s.

Fish were detected throughout the ensonified water column for most of the counting range (Fig. 7), and thus showed no obvious preference for swimming close to the river bottom within the sample area.

The distribution of upstream and downstream moving targets at Flag Point Channel was plotted over range (Fig. 11). Approximately half of the upstream moving fish (13,296) were detected within the first 10 m of the counting range, and the remainder (13,918) were detected more than 10 m from the transducer (10-22 m). In contrast, only 24% (565) of downstream moving targets were detected within the first 10 m of the counting range, and 76% (1,815) of downstream moving targets were detected in the offshore half (10-22 m) of the counting range.

Drift Gillnetting

Setup and Operation

Drift gillnetting in Flag Point Channel was conducted over a 27-day period from 15 May to 10 June 2002 (Table 4). In the first few days of the season, the test fish samplers were faced with challenges, such as high wind days, high flows associated with the break up of an ice dam upstream, and possible changing fish behavior. Therefore, patterns in the first few days of data were not as distinct or consistent as the remainder of the data. The analyses were performed with both the full data set (starting 15 May) and a truncated data set (starting 21 May). Total daily fishing time of all drifts was approximately 40 min (Mean = 43, SE = 1). Due to the abundance of snags in the river, each drift was limited to approximately 2 min.

Test Fishing Index

A total of 418 sockeye and 34 chinook salmon were captured in 528 standardized drifts (total fishing time = 19.6 h; Table 4). The daily test fishing index for sockeye salmon peaked at 684 on 2 June and the cumulative index was 6159.

Comparing the Test Fishing and Miles Lake Sonar Indices

Fig. 12 shows the daily Miles Lake sonar indices, lagged from 0-5 days, and the Flag Point Channel test fishing indices plotted over time. For lags of 1-6 days, there was a positive relationship between the Miles Lake sonar and Flag Point Channel test fishing indices (Fig. E-1). Using the full data set, a 1-day lag of the Miles Lake sonar indices produced the best fit with the test fishing indices, for both the MLE and regression approaches. More specifically, the best fit was produced by a 2-3 day lag early in the season, and a 1-day lag starting in late May (Table E-1).

For 1-3 day lags, the estimate of *EPI* for the MLE model was 36. The regression equation for a 1-day lag using the full data set was:

$$E = 582.5 + 34.9I \,. \tag{8}$$

For the truncated data set, *EPI* was 37 and the regression equation was:

$$E = 1998.5 + 32.0I \,. \tag{9}$$

Using the truncated data set and the regression approach, covariates of river stage height and change in stage height were significant as represented by the following model:

$$E = 32412.4 + 18.8I + 11065.5Stage - 32100.8Change.in.stage \tag{10}$$

The lag time of Miles Lake sonar indices and the catchability of the drift gillnets at Flag Point Channel were assumed to be constant during the study period. If there were constant catchability at Flag Point Channel, then *EPI* should be constant over time. However, an examination of *EPI* for drift gillnetting showed that it varied with time (Panel A in Fig. E-2). Similarly, *EPI* for acoustic sampling at Flag Point Channel varied over time, and was highest during periods of lower inriver abundance (19-22 May and 6-10 June; Fig. E-3). *EPI* for drift gillnetting also increased with Miles Lake sonar counts and decreased with mean fishing time per drift (Panels A and B in Fig. E-2).

Forecasting

Daily forecasts from the MLE and regression models were quite similar over the study period, and the largest differences occurred on days when the two models selected different lags (Table E-1). In the second half of the season, the truncated data set provided better forecasts than the complete data set, which may be attributable to changes in the lag and/or fish behavior. Lag selection was also sensitive to the addition of a single point that did not fit the previous pattern of data. For example, a 4-day lag produced the best fit on 1 June, even though it appeared the actual travel time between Flag Point Channel and Miles Lake at that time was considerably less than 4 days.

Acoustic and Test Fishing Indices at Flag Point Channel

Acoustics and drift gillnetting provided comparable indices of salmon abundance at Flag Point Channel in the lower Copper River in 2002 (Fig. 13). The relative catch efficiency of these methods, as measured by the ratio of the daily acoustic and test fishing indices, was plotted with stage height at Flag Point Channel over time (Fig. 14). Apart from early in the season, the catch efficiency of acoustics relative to drift gillnetting was highest during periods of increasing stage height from 23-24 May and 27-31 May. As stage height increased at Flag Point Channel, fish may have become more shore-oriented, and thus more susceptible to detection by the acoustic equipment, and/or less vulnerable to capture by the drift gillnet.

Daily acoustic (Fig. 15) and test fishing indices (Fig. 12) at Flag Point Channel were also compared to the Miles Lake sonar index lagged from 0-5 days. The Miles Lake sonar index was lagged to account for the time that fish took to travel the distance between Flag Point Channel and the Miles Lake sonar site. In general, these data suggest the travel time of fish between the two sites in 2002 was approximately 2-3 days early in the season, and probably closer to 1 day starting in late May (similar to the results observed in the MLE and regression analyses seen earlier).

Daily acoustic and test fishing indices at Flag Point Channel appeared to decrease about 1-2 days after the start of a commercial fishing opening in the Copper River District (Fig. 16). This suggests that salmon migrated upriver from the Copper River District to Flag Point Channel in about 1-2 days in 2002.

The indices generated by acoustics and drift gillnetting were quite similar at Flag Point Channel even though the techniques apparently differed in their sampling power. For example, there was a 28-fold difference in the amount the time spent sampling between the acoustic equipment (563 h) and drift gillnets (19.6 h) at Flag Point Channel. In addition, relative to the number of fish counted at the Miles Lake sonar from 15 May to 10 June, the acoustic gear sampled 11% over the same period, whereas the drift gillnetting operation sampled only 0.2%.

DISCUSSION

Acoustics

Flag Point Channel

A bathymetric survey in May of 2002 identified an acoustic sampling site at Flag Point Channel with a longer continuous gradient, and thus longer counting range than the site used in 2001. This site was free from debris, provided adequate sampling power regardless of river discharge, and proved to be an excellent location for operating a splitbeam acoustic system almost continuously from 16 May to 10 June 2002. Once the acoustic system was set up, relatively inexperienced technicians were able to continuously monitor the site (24 hours per day, 7 days per week) and conduct the basic operations of the system. Technicians quickly learned how to count echo traces directly from echograms and to manage acoustic data. A travel trailer was located in line-of-sight of the acoustic site so the crew could observe the transducer and river conditions throughout the day. Early in the season when ice floes were prevalent at Flag Point Channel, a technician remained at the sample site all day. A major improvement in 2002 was the addition of a wireless Ethernet connection that linked a streamside data acquisition computer to a remote data processing station located 1 km away.

Overall, the different counting methods and sampling schemes used in 2002 generated very similar results. The visual counting method was easily learned, required relatively little

training, and required no expensive software modules. It was a relatively inexpensive method of providing a timely, inseason index of salmon abundance in the lower Copper River. However, visual counts tend to be less accurate than tracked counts because target strength is not corrected for the targets position in the beam (targets at the edge of the beam can thus be overlooked). Visual counts do not account for the direction of target movement. In addition, there was a tendency to undercount with this method because some head-to-tail tracks cannot be resolved in the two-dimensional, range-time image of echograms, particularly at high fish densities.

Conversely, tracked counts tend to be more accurate than visual counts because target strength is corrected for the targets position in the beam. Tracked counts can provide information on whether targets are moving upstream or downstream, and they can better resolve head-to-tail fish tracks. This method can also be used to provide valuable feedback on sonar aim and the quality of counts. The disadvantages of tracked counts are that they require more processing time and training, as well as more expensive software than visual counts.

Similar to 2001, fish behavior in Flag Point Channel in 2002 was suitable for conducting a test fishing operation. There was no evidence of milling as most fish appeared to move quickly through the sample area. Eulachon did not interfere with the ability to count salmon in Flag Point Channel in 2002. A target strength threshold of -41 dB effectively eliminated eulachon from the counts.

Fish did not appear to be bottom-oriented, at least not at the relatively low flows encountered in Flag Point Channel during the study period. This suggested that aiming the transducer along the river bottom is perhaps less critical than previously thought. In addition, approximately the same number of upstream-moving fish were tracked in the onshore and offshore sections of the counting range, which suggested the fish were bank-oriented. Without bank orientation, one would expect more fish to be sampled at farther ranges, as the sample volume increases due to beam spreading and the fact that fish showed no vertical preference.

Mile-37 Channel

The decision to sample at the Mile-37 Channel in 2002 was based on two considerations. First, it was thought that acoustic data collected at the Mile-37 Channel could help explain trends in fish passage at Flag Point Channel. For example, a decrease in counts at Flag Point Channel, accompanied by an increase in counts at the Mile-37 Channel, might suggest that fish are continuing to enter the river but are perhaps switching to the east side of the delta. On the other hand, a decrease in counts at Flag Point Channel, accompanied by a decrease in counts at the Mile-37 Channel, might suggest fewer fish are entering the river. Second, the Mile-37 Channel was sampled to determine whether it could be used as a site to index salmon abundance in the lower Copper River.

The value of sampling at the Mile-37 Channel was less than anticipated. Results from 2001 and 2002 showed that the travel time of salmon between Flag Point Channel and Miles Lake was only 1-2 days. At about the same migration speed, fish would take one day or less to travel between the Mile-37 Channel and Miles Lake. Thus, the incremental benefits of sampling at the Mile-37 Channel instead of Flag Point Channel would be marginal. In addition, ice floes

at the 37-Mile Channel prevented the deployment of acoustic equipment until 26 May, which was too late for obtaining early run information. The Mile-37 Channel also opened up at about the same time as at least three other channels in the same area, thereby reducing the effectiveness of each as a site for indexing abundance. And lastly, fish passage at Flag Point Channel by itself appeared to be a sufficient indicator of passage by the Miles Lake sonar site. Based on these findings, it is recommended that sampling at the Mile-37 Channel be discontinued.

Drift Gillnetting

The test fishing index generated from drift gillnetting in Flag Point Channel was compared to the Miles Lake sonar index using both MLE and regression analyses. Both models produced similar results. However, it appears that the assumptions of a constant lag time between Flag Point Channel and Miles Lake and constant catchability of the drift gillnetting were violated in 2002. One explanation for this was that during periods of high fish densities in the river, the drift gillnet saturated quickly and shortened the time of the drifts. For such short drifts, a small change in fishing time will impact the CPUE and daily test fishing index. Other factors that may have affected the *EPI* are changes in fish behavior and changes in detection rates at the Miles Lake sonar site.

Flag Point Channel Indices as a Management Tool

Fishery managers recognize two broad but useful levels of precision for escapement data from a lower river test fishery in the Copper River: presence/absence and a more quantitative measure such as more than a few hundred fish, less than 20,000 fish, etc. Each year, in the earliest stages of the Copper River District commercial fishery (mid-May), managers simply want to know whether or not there are fish present in the river upstream of the fishery. In this situation, a test fishery need only detect if fish are present (or absent) in channels that fish are known to use. This may sometimes be enough information to influence management decisions.

Results from the 2001 and 2002 studies indicate that it is possible to develop a test fishery in the lower Copper River that is capable of providing an index of Miles Lake sonar counts from mid-May to early June. Daily inseason counts were produced in a timely manner and provided to ADF&G prior to their internal meetings to discuss upcoming fishery announcements. In fact, fishery managers used both the acoustics and drift gillnetting indices from Flag Point Channel to assist in making management decisions during the 2002 commercial fishing season (D. Gray and D. Ash, ADF&G, Division of Commercial Fisheries, *personal communication*). The Flag Point Channel data provided an additional level of confidence to fishery managers that was not previously available from using the Miles Lake sonar data by itself. In addition, ice break typically occurs earlier at Flag Point Channel, so sampling can begin sooner than at Miles Lake. Early in the season, when the catch value of sockeye is high, this additional information could be beneficial to the management of the fishery.

Methods for using the Flag Point Channel test fishing indices to forecast Miles Lake escapement continued to be refined in 2002. The travel time of sockeye salmon from Flag Point Channel to the Miles Lake sonar site ranged from 1-3 days in 2002 and 1-2 days in 2001. Fish also appeared to move quickly (1-2 days) through the 16-km section of the lower Copper River from the Copper River District to Flag Point Channel. The value of the lower river test fishery as a forecasting tool for fishery managers would undoubtedly be greater in years when the lag time between Flag Point Channel and the Miles Lake sonar site was longer.

Assuming that both acoustics and drift gillnetting produce similar results, one objective of the upcoming season should be to compare the relative strengths and weaknesses of the two techniques in order to identify which one is most suited for continued use on the lower Copper River. Criteria for this comparison should include the project costs, type/value of data collected, reliability of the sampling gear, sampling power, and the robustness of the technique to variability in environmental factors.

Among- and Within-Year Changes to Flow in River Channels

To develop a test fishery on the lower Copper River, it is important to consider among- and within-year changes in the river channels and flows in the Copper River Delta. During the technical and community workshops in the fall of 2002, concerns were raised that changes in channel dynamics could have a detrimental effect on acoustic and drift gillnetting sample sites and fish migration routes at Flag Point Channel. Link et al. (2001) provided a brief summary of recent changes observed in the Flag Point Channel. It was suggested that the study team identify alternative sites in case this happened. However, it is impossible to now determine what sites will be suitable for sampling in the future after unpredictable changes have occurred that were drastic enough to render the Flag Point Channel site unsuitable for sampling. Trying to find future sites now would withdraw resources from the current sampling effort and provide information of uncertain future value. Instead, it was proposed to focus on adapting the acoustics setup to remote operation as much as possible to allow a smoother transition in the event a change in sampling site becomes necessary. Minimizing the amount of equipment, power, and staff presence required at the actual sampling site will be key elements of this approach.

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 (Appendix F). Biologists, managers, and administrators from several agencies were able to attend. In addition, several fishermen and other residents from the Copper River Basin provided input and local 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.

Fieldwork for 2003 Season

Several improvements to the acoustic operation will be evaluated during the 2003 field season. Higher Ethernet antennas will be installed to compensate for moving the trailer (which contains the data processing computer) to a new location that is more acceptable to the public. A wireless Ethernet connection will be used to minimize the amount of power required at the streamside and to ensure the data can be accessed remotely. An electronic control system will be implemented that automatically shuts down the acoustic system if it runs out of power or the transducer becomes exposed to air. A power meter will also be incorporated into the system to aid in reducing power consumption.

CONCLUSIONS

1) Acoustics and drift gillnetting were effective test fishing tools in the lower Copper River in 2002, and have the potential to be useful tools for inseason management;
2) There was no evidence of fish milling in Flag Point Channel during the study period;
3) Eulachon did not interfere with counting salmon in 2002;
4) Fish were detected throughout the ensonified water column for most of the counting range, indicating that fish were not bottom-oriented in Flag Point Channel;
5) Fish took 2-3 days early in the season, and closer to 1 day starting in late May, to travel the distance between Flag Point Channel and the Miles Lake sonar site;
6) Based on changes in the acoustic index at Flag Point Channel, it appeared that fish took from 1-2 days to travel the 16 km upstream from the Copper River District; and
7) Using acoustics and drift gillnetting in tandem should reduce the development time of a test fishery, in whatever form it may take.

RECOMMENDATIONS

It is recommended that the following activities be conducted in 2003:

1) Similar to 2002, use both acoustics and drift gillnetting to index the abundance of salmon in Flag Point Channel;
2) Continue to monitor the among-year variability in travel times and fish behavior;
3) Discontinue sampling at the Mile-37 Channel;
4) Compare the relative strengths and weaknesses of acoustics and drift gillnetting and decide which is the best technique for use in the lower Copper River.

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FIGURES

Figure 1. Map of the Copper River watershed showing the location of the Miles Lake sonar site.

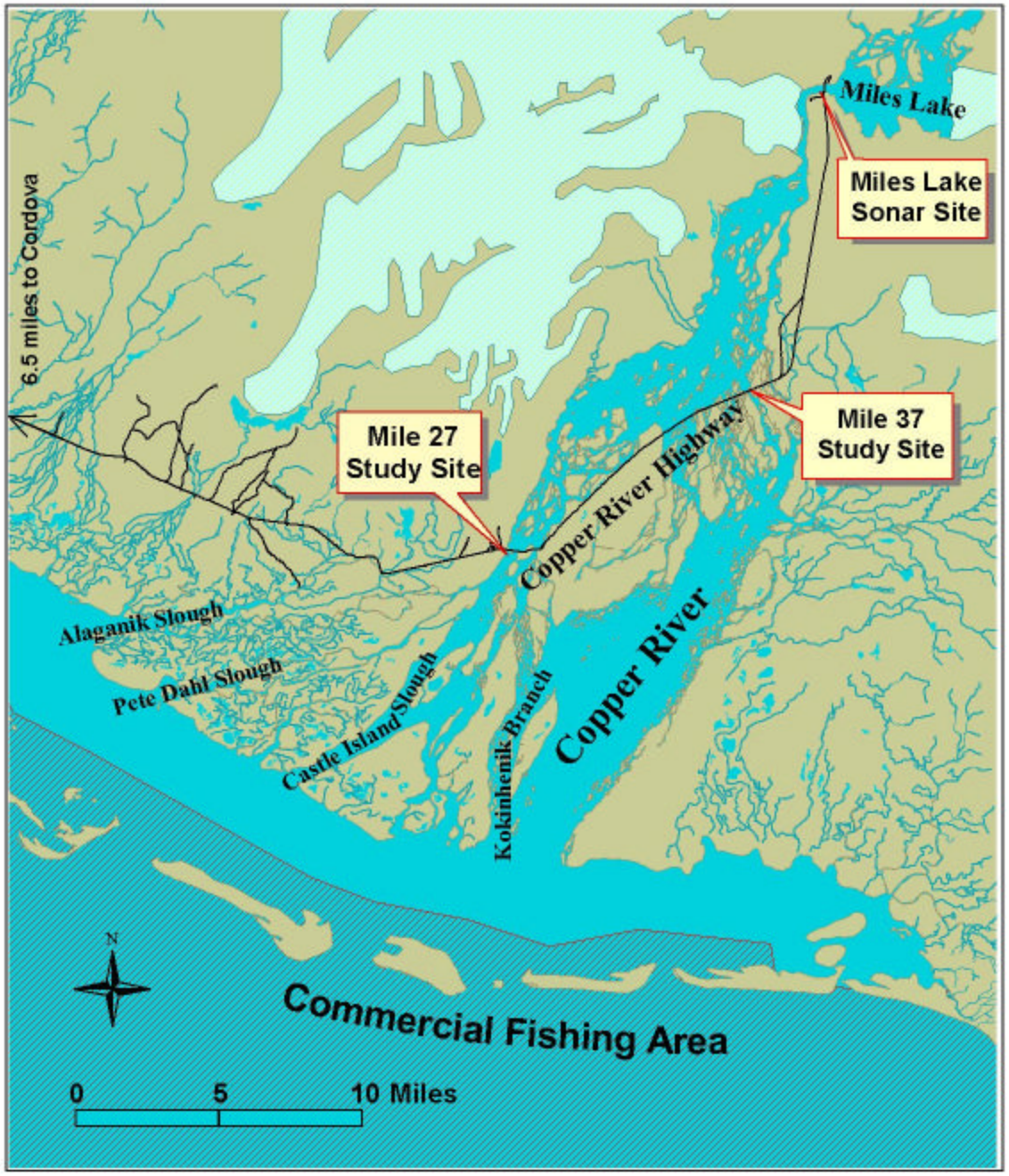

Figure 2. Map of the lower Copper River showing the test fishing sites used in 2002, the Miles Lake sonar site, and the commercial fishing area (Copper River District).

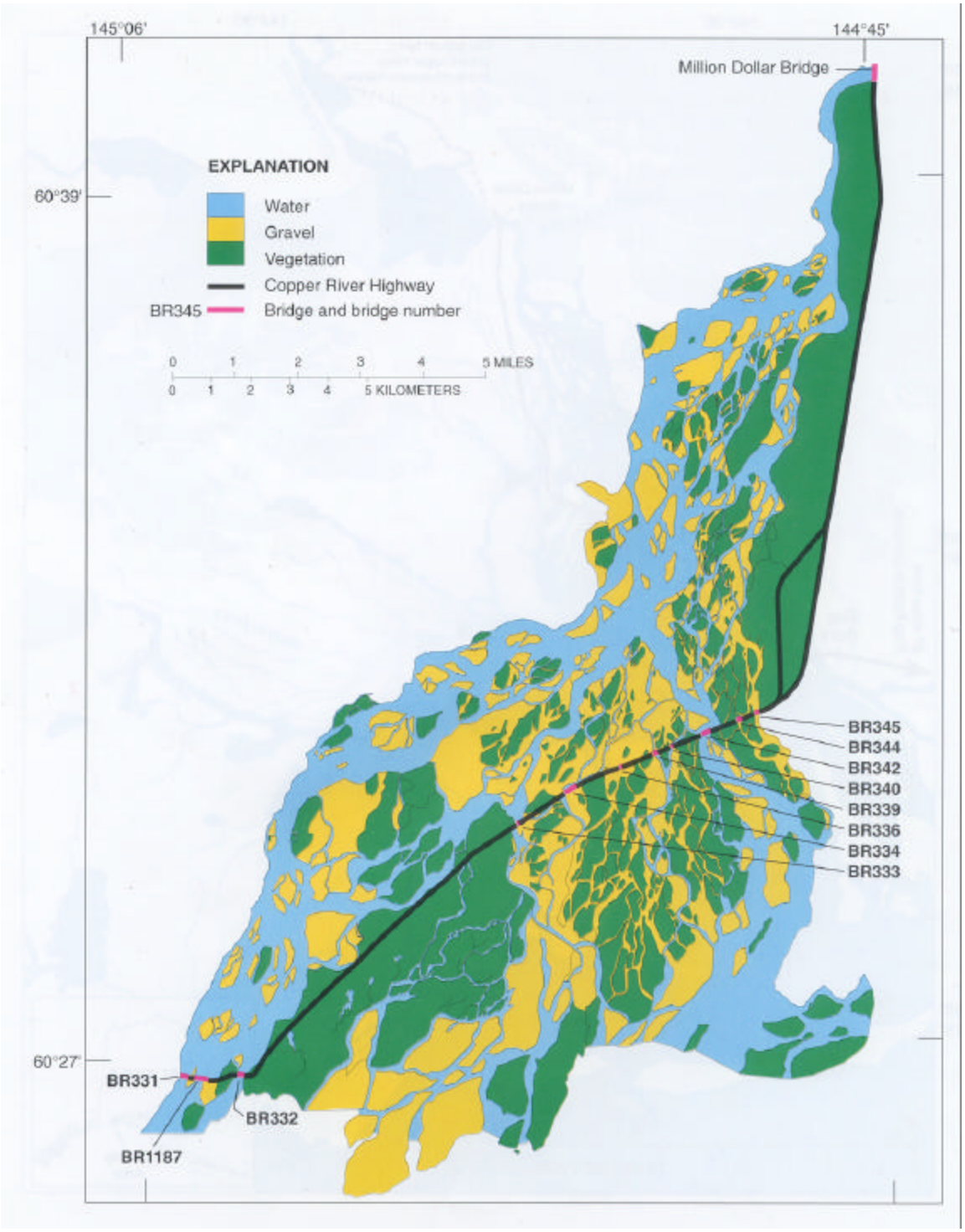

Figure 3. Locations of bridges (BR) along the Copper River Highway that cross the Copper River, 1991 (from Brabets 1997). Flag Point Channel is fed from flow through BR331 and BR1187, and the Mile-37 Channel is fed from flow through BR342.

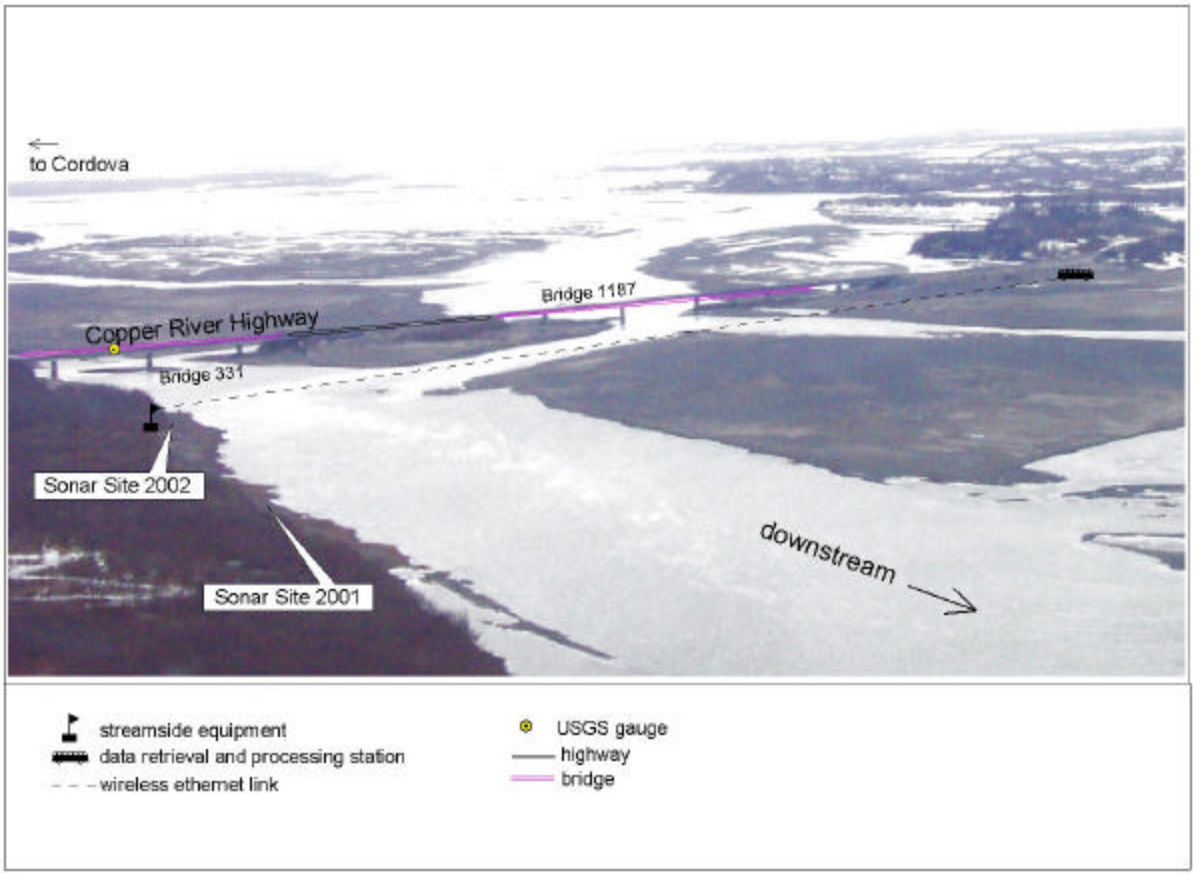

Figure 4. Aerial view of Flag Point Channel showing the location of the acoustic sampling sites used on the Copper River, 2001-2002.

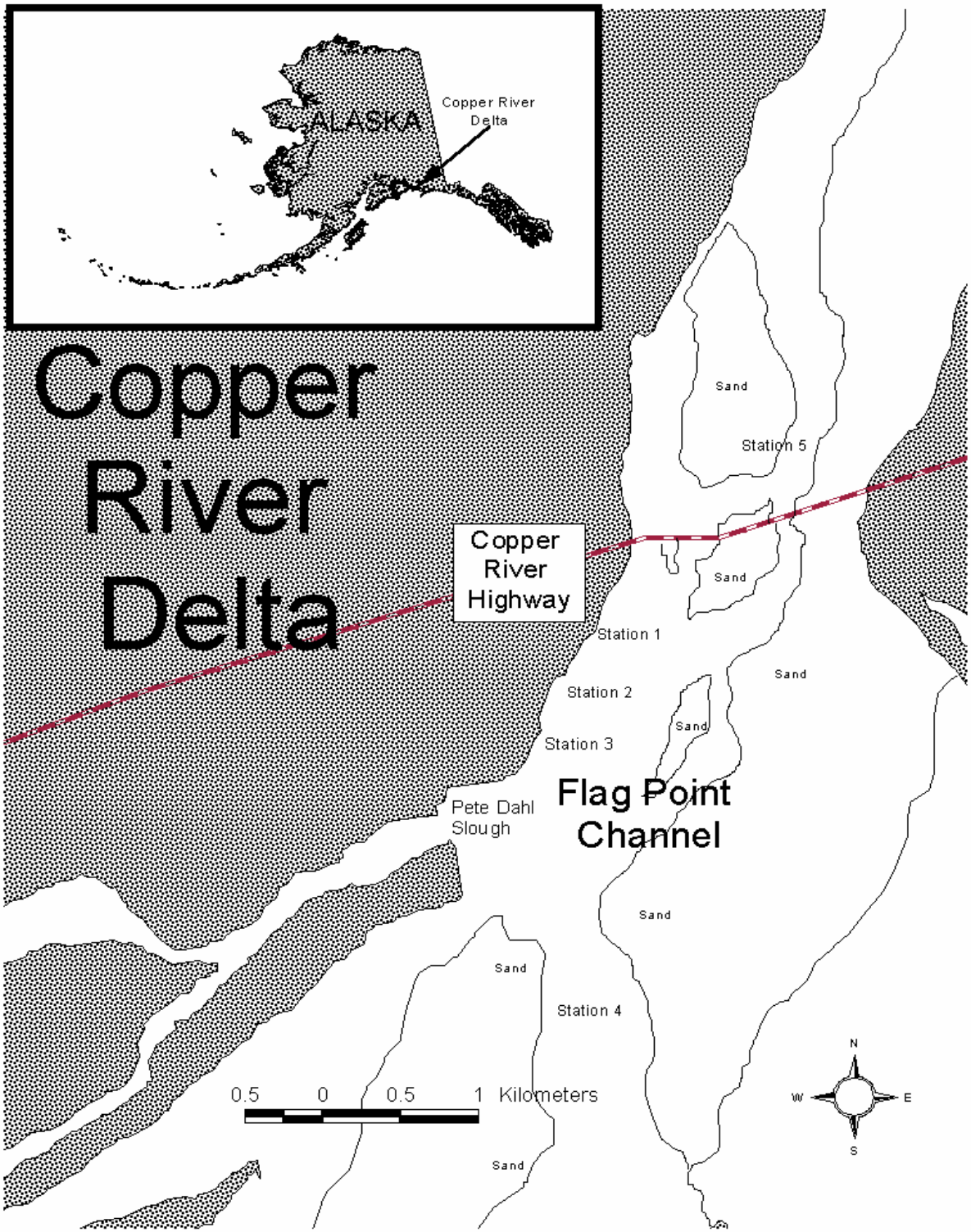

Figure 5. Drift gillnet stations at Flag Point Channel used by ADF&G to index the abundance of sockeye salmon in the lower Copper River, 2002.

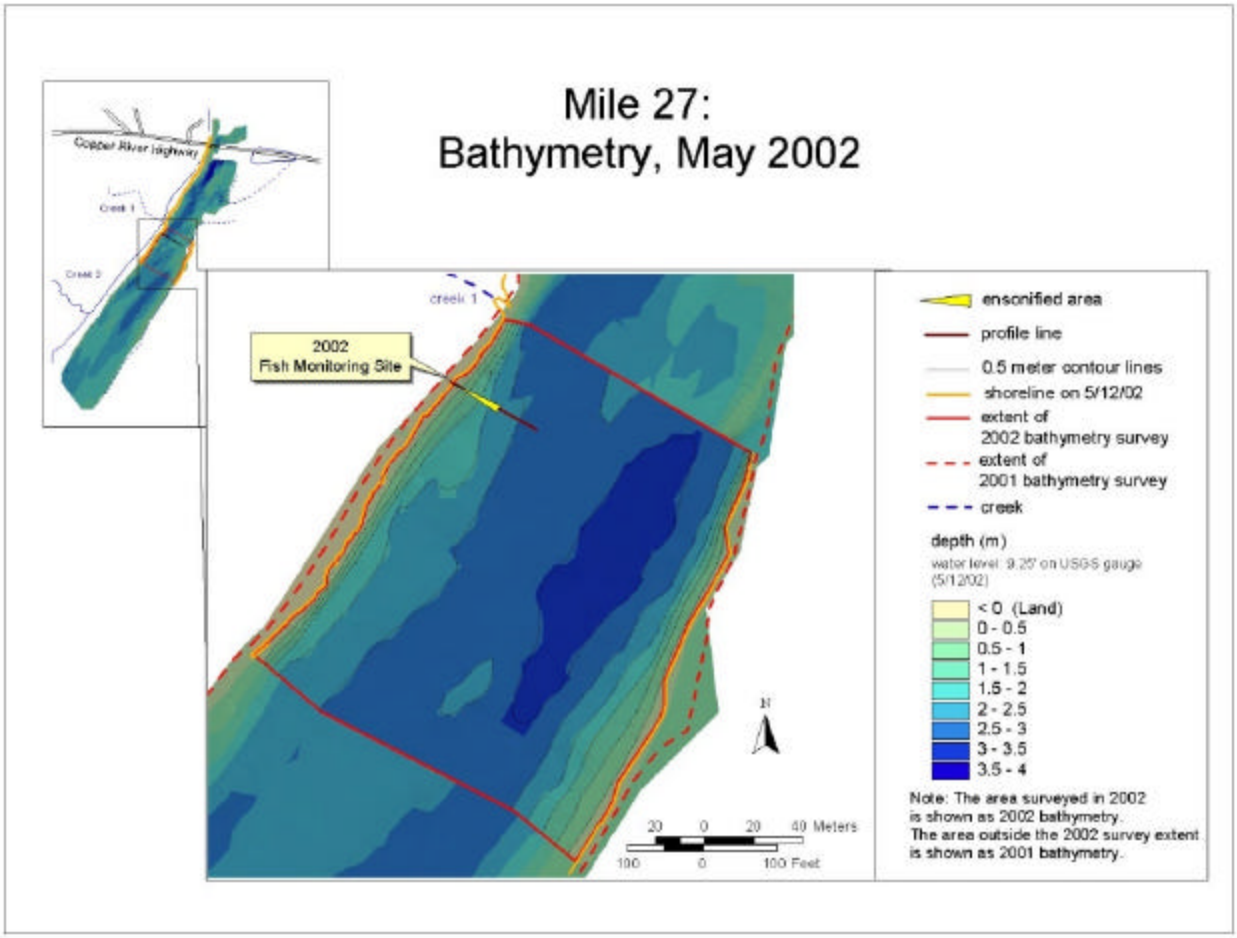

Figure 6. Bathymetry of the acoustic sampling site at Flag Point Channel that was used in 2002, which was located downstream of Bridge 331 on the Copper River Highway.

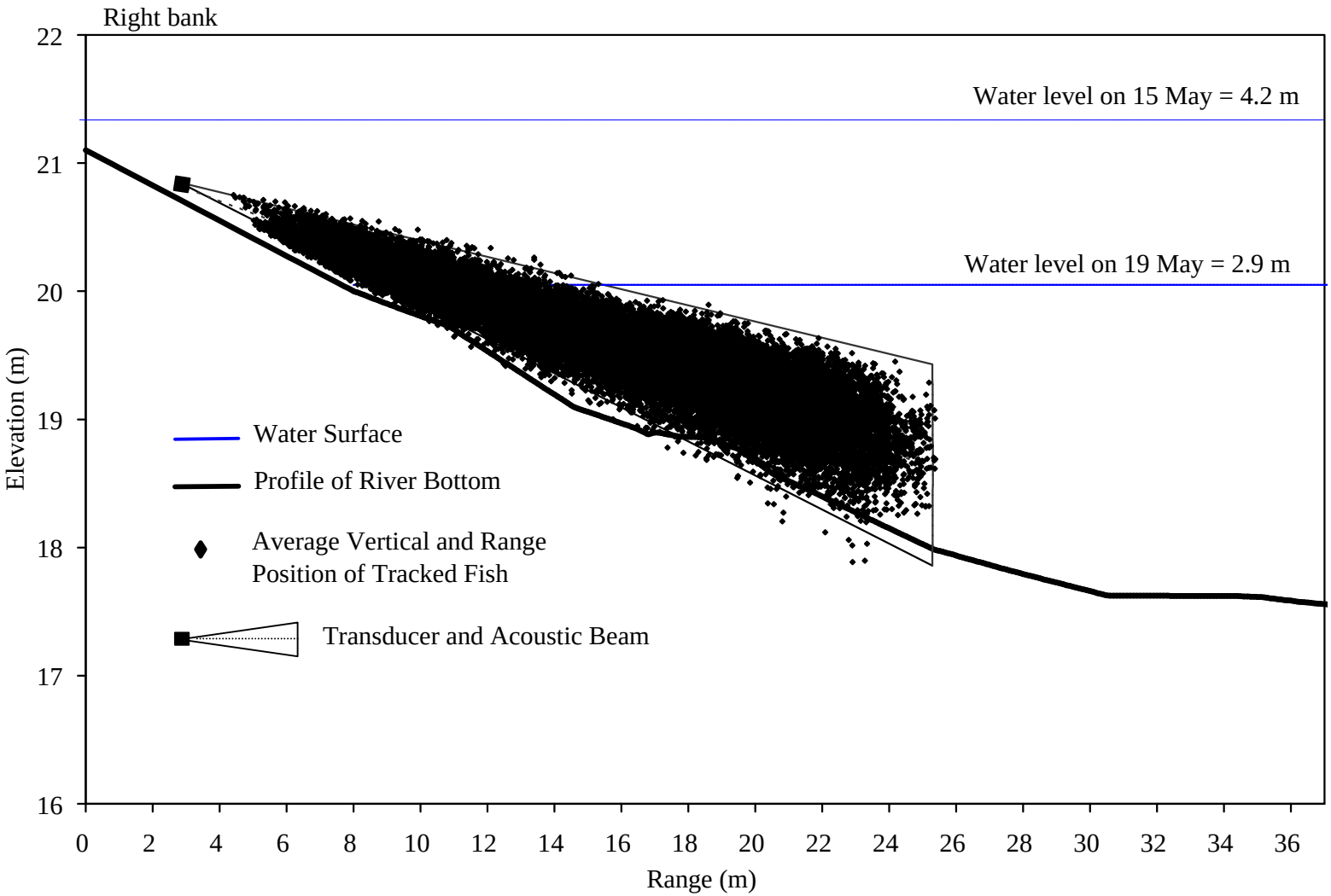

Figure 7. Profile of the river bottom and the vertical distribution of fish over range at the acoustic sampling site at Flag Point Channel, 2002. All range data is referenced to the transducer position used at the beginning of the season (16 May).

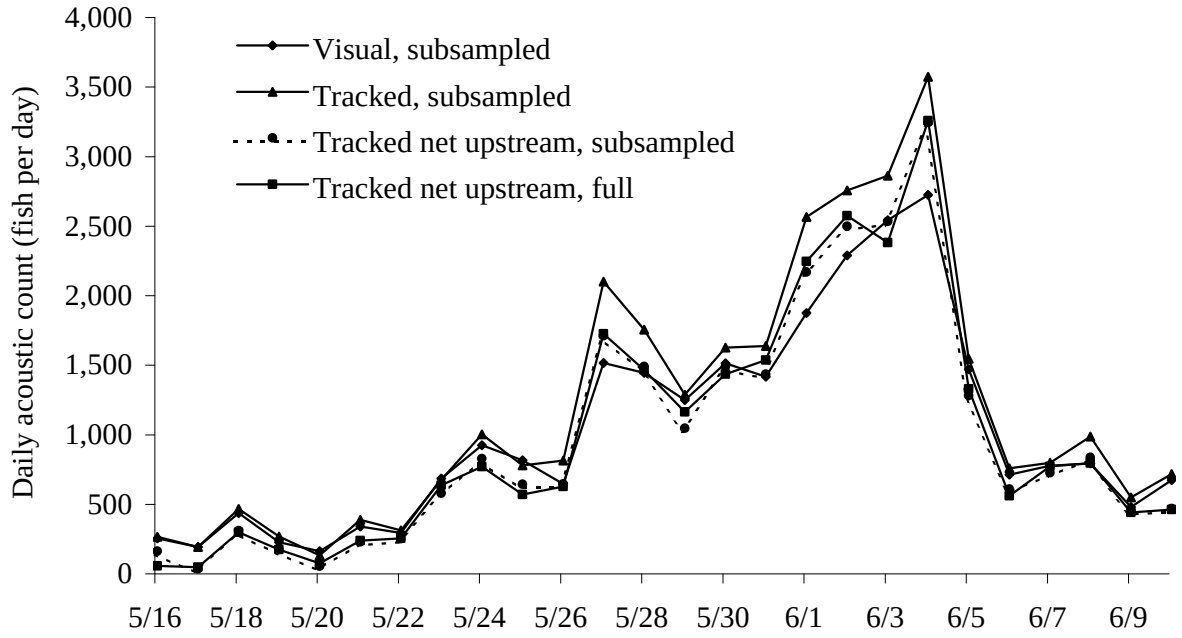

Figure 8. Daily acoustic counts generated from different counting methods and sampling schemes at Flag Point Channel, 2002.

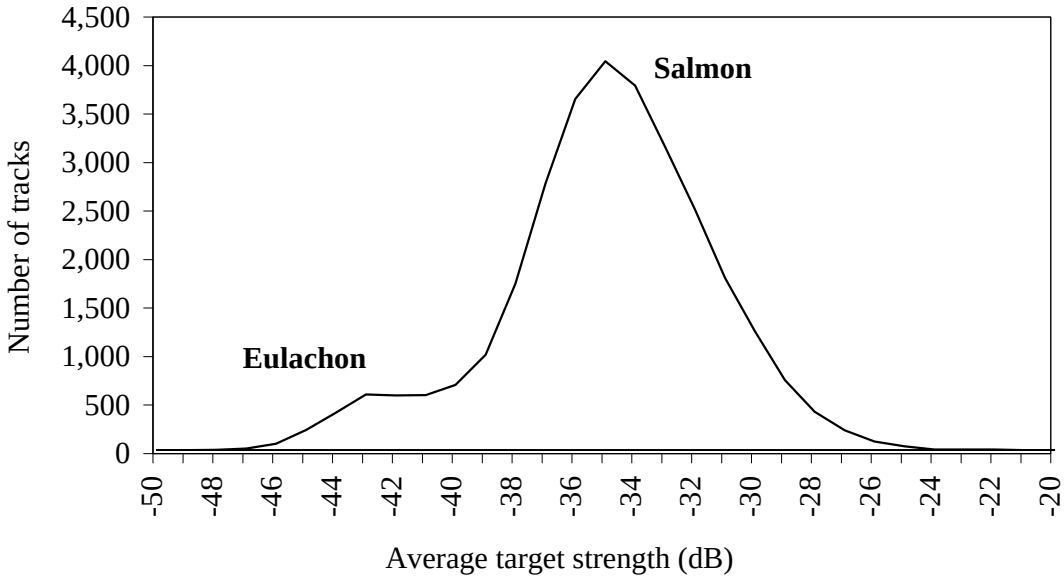

Figure 9. Frequency distribution of the average target strength of fish tracked at Flag Point Channel, 2002.

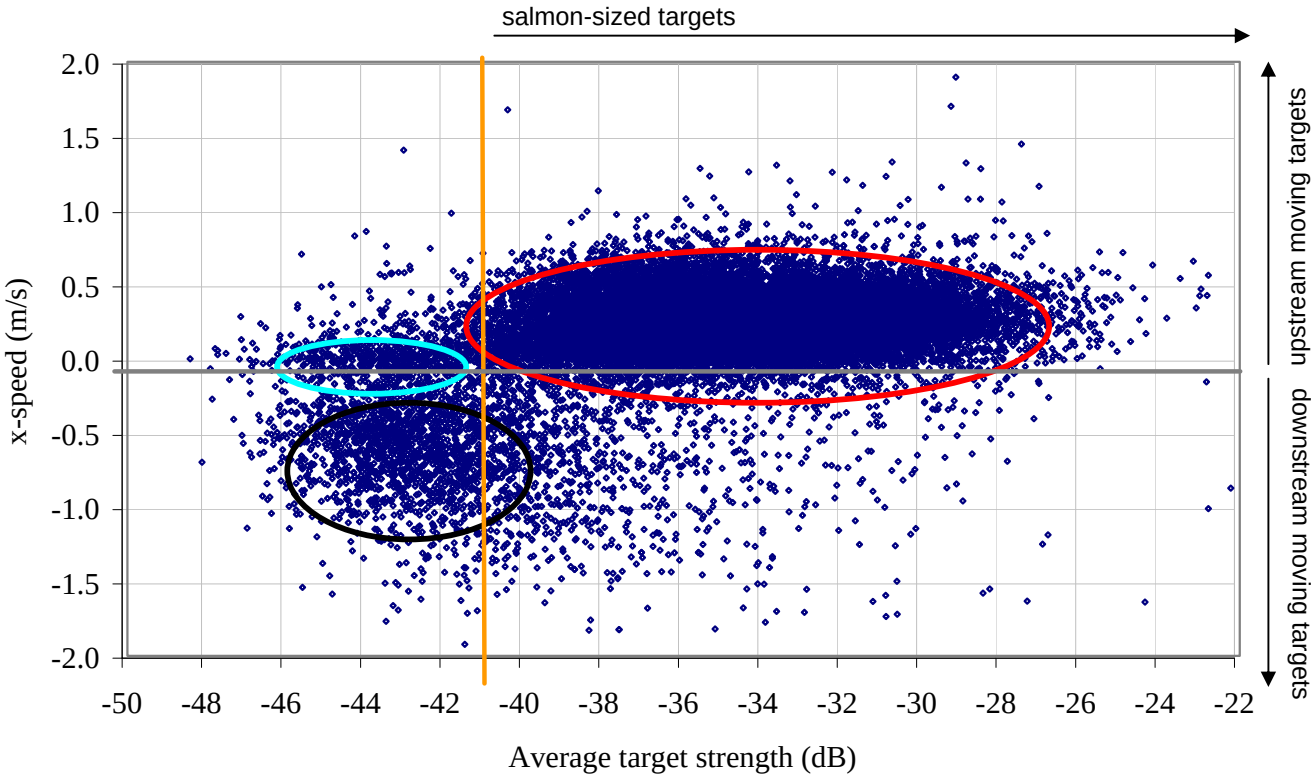

Figure 10. Distribution of x-speed and average target strength of all tracked targets at the Flag Point Channel, 2002. Positive x-speed indicates upstream movement, and negative x-speed indicates downstream movement.

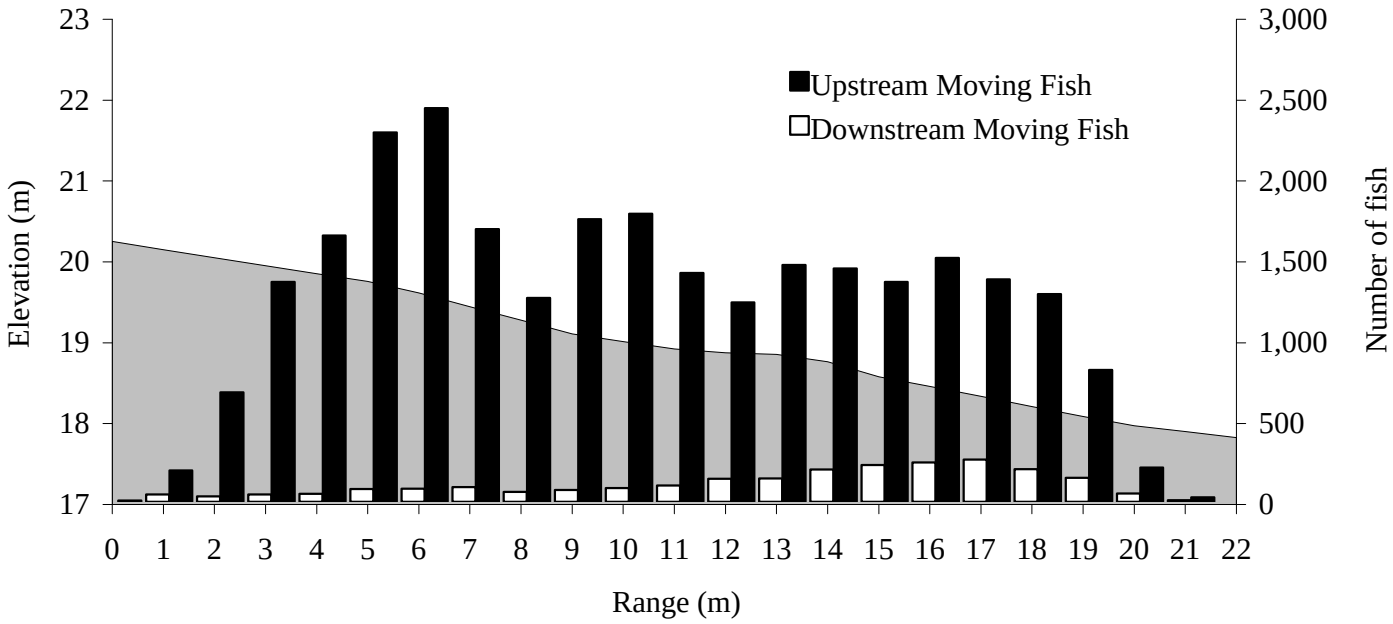

Figure 11. Distribution of upstream and downstream moving fish over range at Flag Point Channel on the Copper River, 2002. All range data is referenced to the transducer position used at the beginning of the season (16 May).

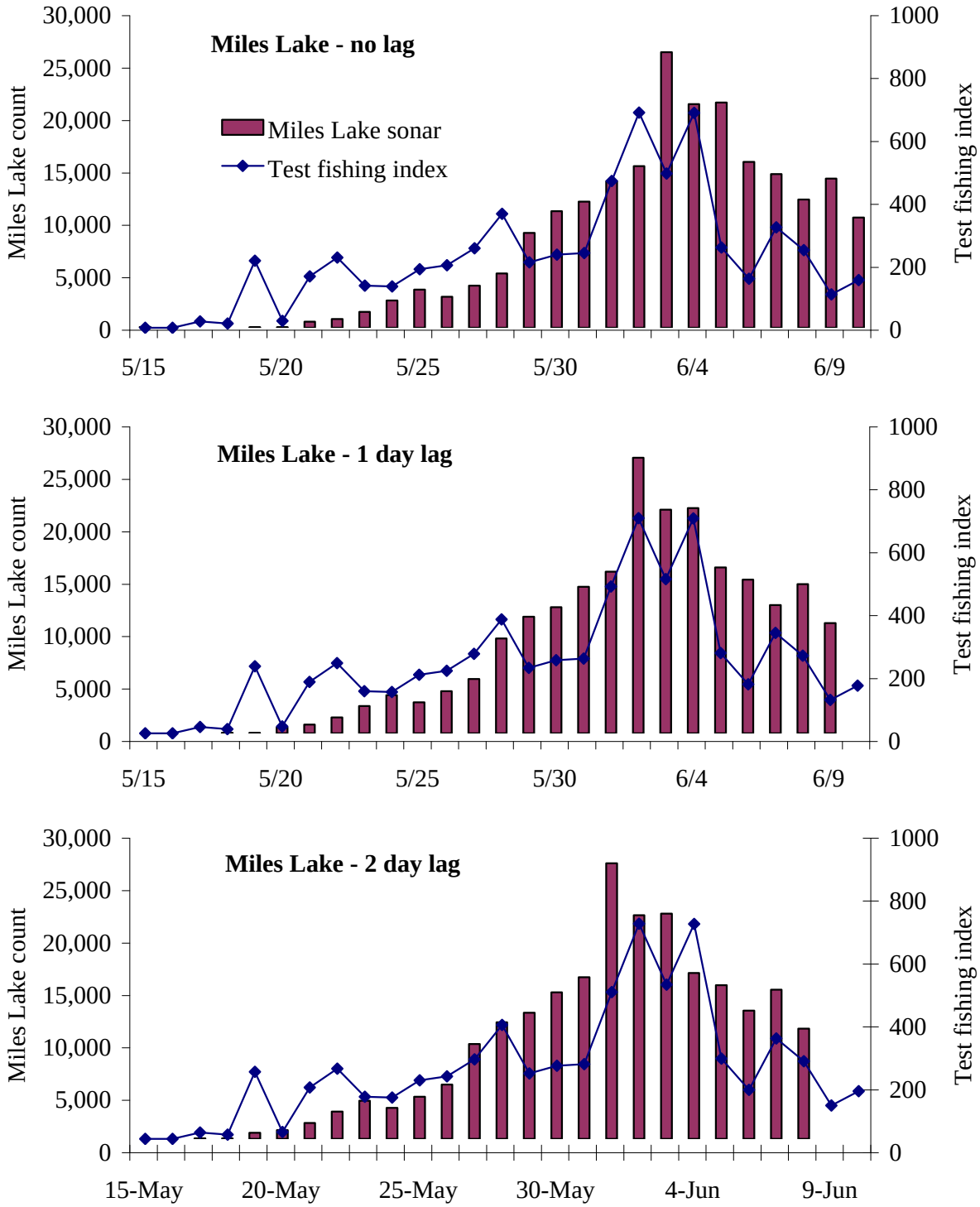

Figure 12. Comparison of the daily Miles Lake sonar indices (lagged from 0 to 5 days) and the test fishing indices at Flag Point Channel, 2002.

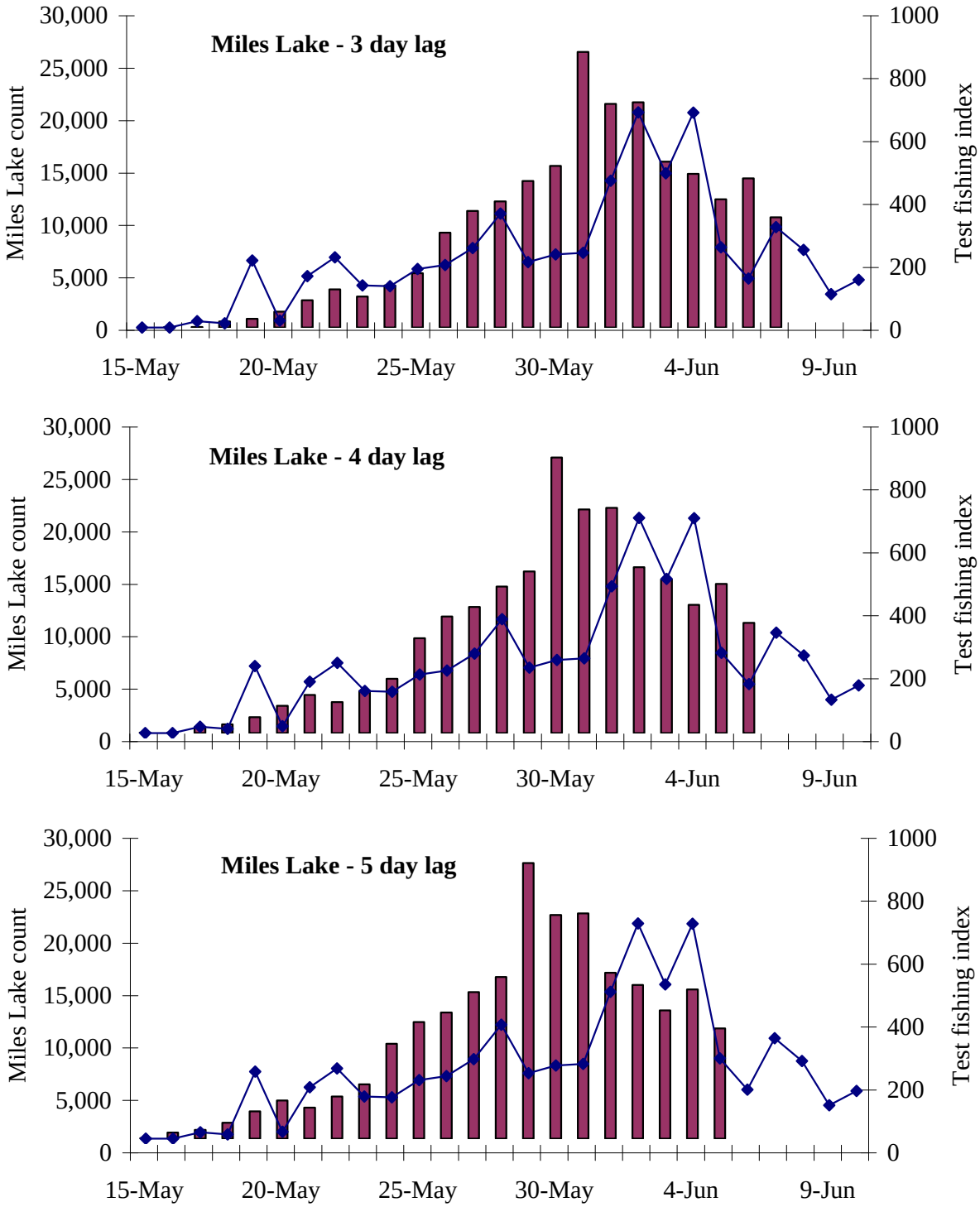

Figure 12. Comparison of the daily Miles Lake sonar indices (lagged from 0 to 5 days) and the test fishing indices at Flag Point Channel, 2002.

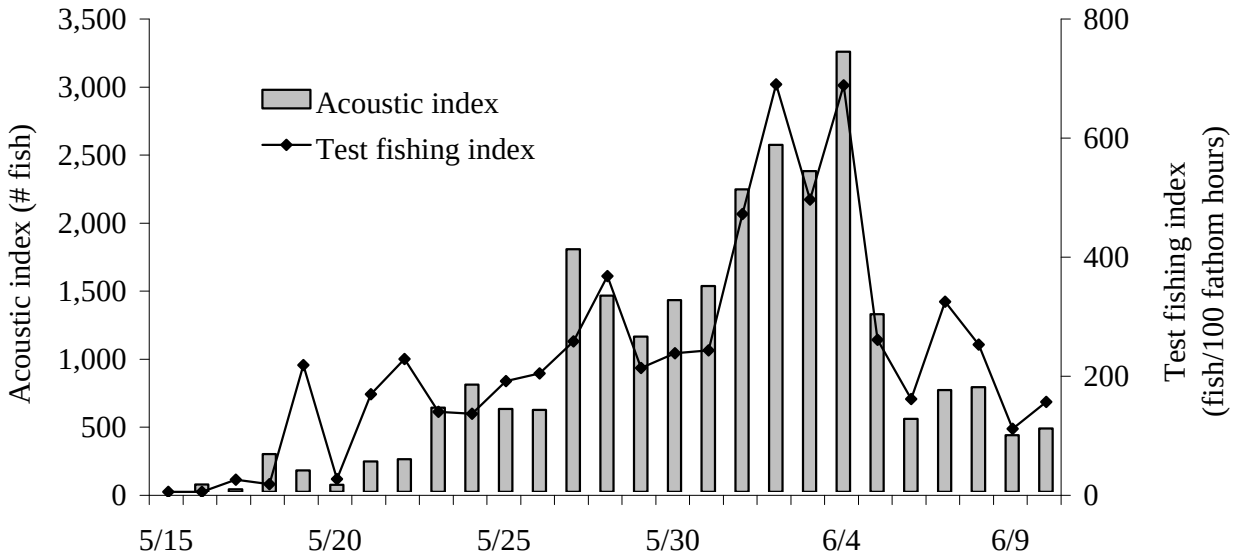

Figure 13. Comparison of daily acoustic and test fishing indices from Flag Point Channel, 2002.

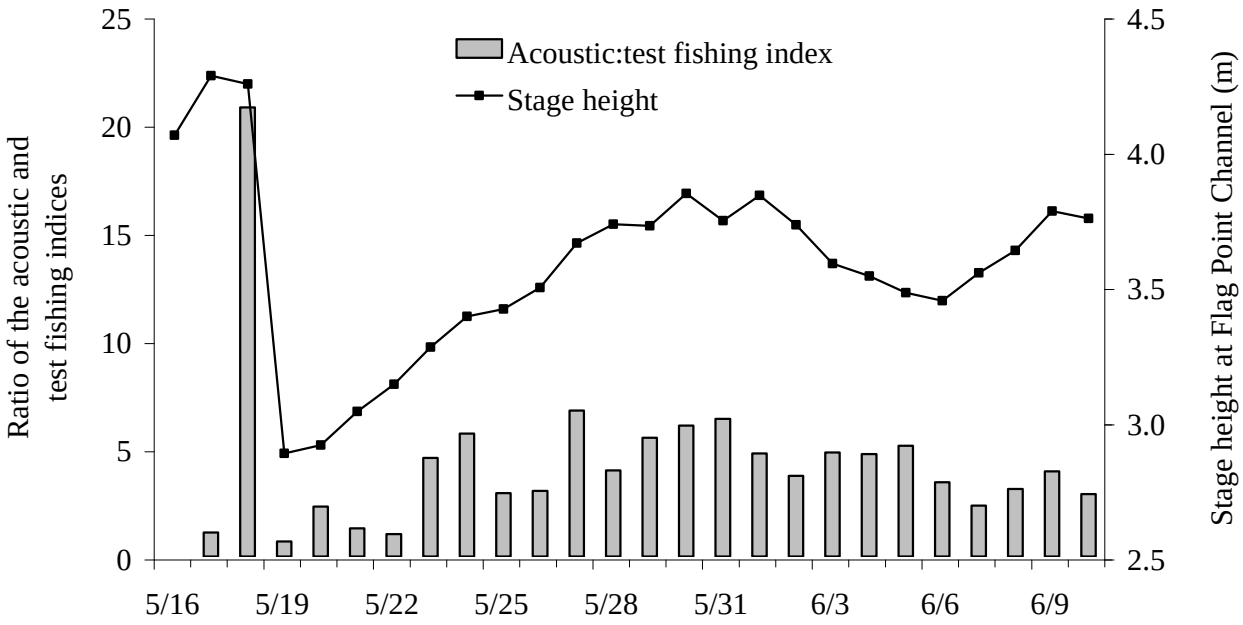

Figure 14. Comparison of the relative catch efficiency of acoustics and drift gillnetting, as measured by the ratio of acoustic and test fishing indices, and stage height at Flag Point Channel, 2002.

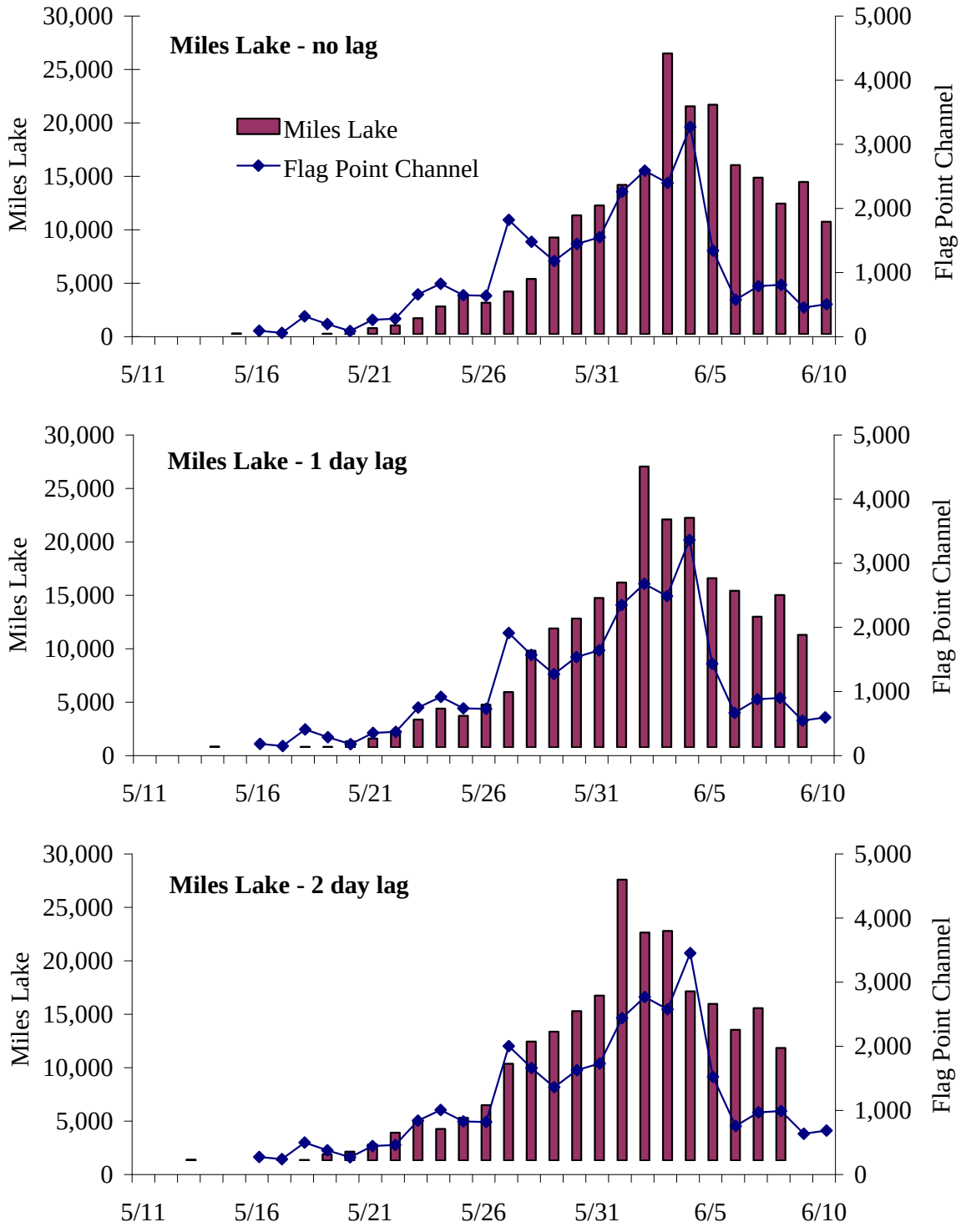

Figure 15. Comparison of the daily Miles Lake sonar indices (lagged from 0 to 5 days) and the acoustic indices Flag Point Channel, 2002.

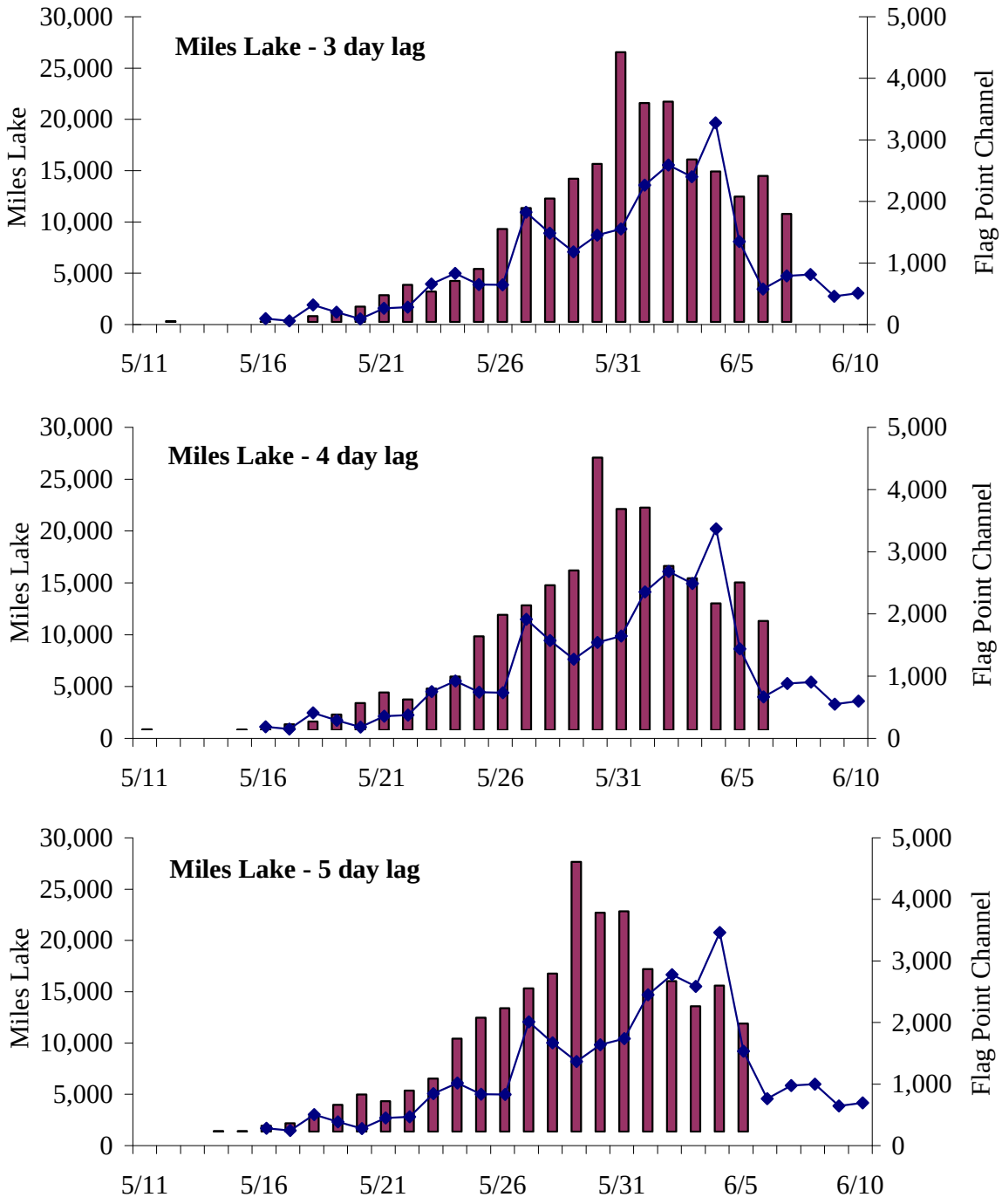

Figure 15. Comparison of the daily Miles Lake sonar indices (lagged from 0 to 5 days) and the acoustic indices at Flag Point Channel, 2002.

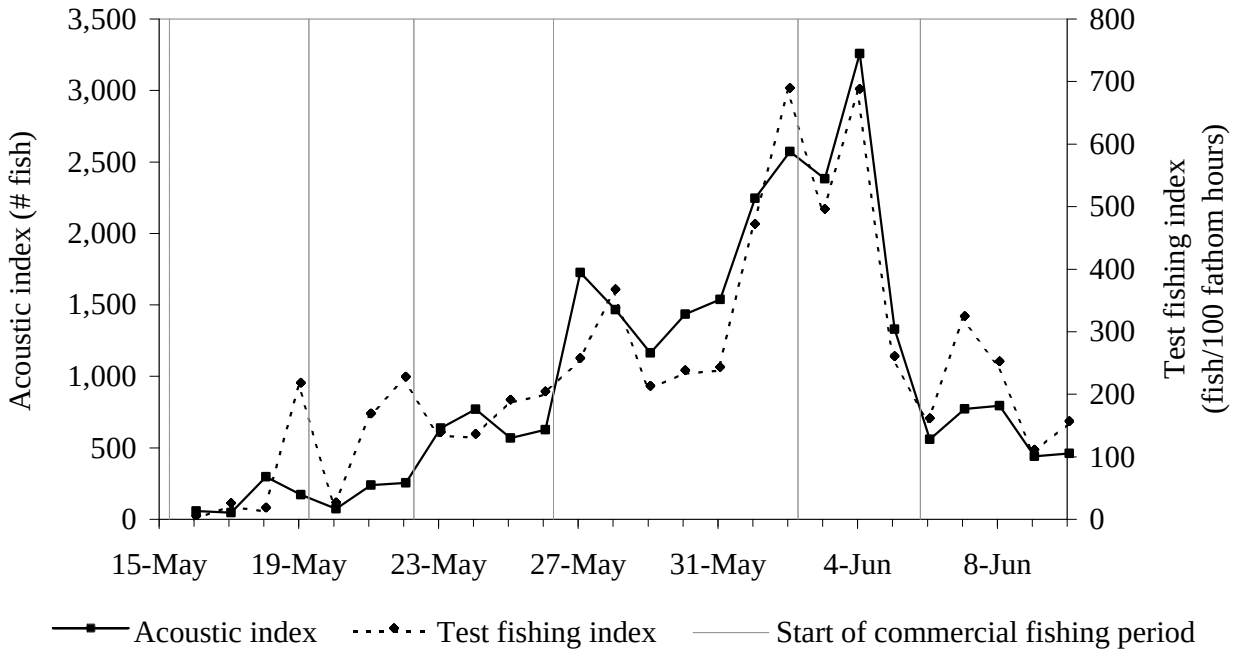

Figure 16. Daily acoustic and test fishing indices at Flag Point Channel and the starting dates of commercial fishing openings in the Copper River District, 2002.

TABLES

Table 1. Sampling effort and range of the acoustic equipment operated at Flag Point Channel on the Copper River, 2002.

Date	Range of beam (m)	Period of time data were collected (h)	Percent of the day data were collected	Comments
16-May	24	10.9	45	13:00 start of data collection
17-May	24	13.7	57	2:00-12:00 transducer off aim
18-May	24	22.0	92	rapidly dropping water level; 22:00 end of good data
19-May	19	13.7	57	1 m drop in water level overnight; moved transducer 5 m offshore; resumed data collection at 9:30
20-May	19	23.6	98	6:00 aim check
21-May	19	18.2	76	10:00-15:00 power supply depleted
22-May	19	23.4	97	17:40-18:00 aim check
23-May	19	22.7	95	12:30-13:30 in situ calibration
24-May	19	23.1	96	13:30-14:30 in situ calibration
25-May	19	21.4	89	17:00-19:15 transducer moved 3 m inshore; water rising
26-May	22	24.0	100	
27-May	22	23.6	98	11:50-12:15 aim check
28-May	22	24.0	100	
29-May	22	24.0	100	
30-May	22	24.0	100	
31-May	22	24.0	100	
01-Jun	22	23.0	96	18:15 transducer moved 3 m inshore; water rising
02-Jun	23	24.0	100	
03-Jun	23	23.9	99	15:00 transducer moved 3 m offshore; water dropping
04-Jun	21	24.0	100	
05-Jun	21	24.0	100	
06-Jun	21	24.0	100	
07-Jun	21	24.0	100	
08-Jun	21	24.0	100	
09-Jun	21	24.0	100	
10-Jun	21	11.5	47	11:30 end of data collection
Total		563		

Table 2. Acoustic sampling effort and daily tracked counts at the 37-Mile Channel on the Copper River, 2002.

Date	Time	Length of time data were collected (h)	Percent of day data were collected	Daily count (fish/h * 24)
26-May	12:28-15:26	3.0	12.4	624
29-May	12:15-16:00	3.8	15.6	312
01-Jun	12:28-16:30	4.0	16.8	792
04-Jun	12:16-15:50	3.6	14.9	864
07-Jun	13:33-17:25	3.9	16.1	912
Total		18.2		3,504

Table 3. Acoustic counts generated from different counting methods and sampling schemes at Flag Point Channel, 2002.

Date	Visual Subsampled	Tracked Subsampled	Tracked Net Upstream Subsampled	Tracked Net Upstream Full
16-May	229	242	137	33
17-May	168	168	12	23
18-May	412	442	285	273
19-May	202	245	149	149
20-May	138	108	30	50
21-May	315	364	205	214
22-May	270	288	228	230
23-May	660	651	555	613
24-May	900	978	804	746
25-May	792	756	619	544
26-May	621	789	621	602
27-May	1,491	2,076	1,686	1,702
28-May	1,419	1,731	1,467	1,441
29-May	1,224	1,263	1,023	1,140
30-May	1,488	1,602	1,464	1,410
31-May	1,392	1,614	1,410	1,513
1-Jun	1,851	2,541	2,145	2,222
2-Jun	2,265	2,733	2,475	2,549
3-Jun	2,517	2,838	2,508	2,358
4-Jun	2,700	3,549	3,219	3,234
5-Jun	1,446	1,521	1,257	1,306
6-Jun	687	735	585	536
7-Jun	753	774	702	749
8-Jun	768	963	813	770
9-Jun	456	525	429	417
10-Jun	648	694	445	438
Total	25,812	30,189	25,272	25,261

Table 4. Effort, catch, and the test fishing index for the drift gillnetting operation at Flag Point Channel, 2002.

Date	Fishing time (min)	Number of drifts	Sockeye catch		Test fishing index		Chinook catch	
			Daily	Cum.	Daily	Cum.	Daily	Cum.
15-May	26.9	10	0	0	0	0	0	0
16-May	40.1	18	0	0	0	0	0	0
17-May	42.7	20	1	1	20	20	0	0
18-May	58.7	20	1	2	13	34	0	0
19-May	63.3	25	19	21	213	247	3	3
20-May	54.3	20	2	23	22	268	0	3
21-May	50.4	20	11	34	164	432	0	3
22-May	47.3	20	17	51	223	655	0	3
23-May	45.2	20	9	60	134	789	0	3
24-May	45.4	20	11	71	131	920	1	4
25-May	42.0	20	13	84	186	1106	2	6
26-May	39.1	20	12	96	199	1305	1	7
27-May	41.9	20	16	112	253	1558	6	13
28-May	42.5	20	23	135	363	1920	1	14
29-May	43.0	20	15	150	208	2128	2	16
30-May	42.9	20	16	166	233	2361	2	18
31-May	40.5	19	16	182	238	2599	2	20
1-Jun	42.7	20	33	215	467	3066	3	23
2-Jun	42.5	20	46	261	684	3750	2	25
3-Jun	34.0	16	27	288	491	4241	0	25
4-Jun	40.9	20	48	336	683	4924	0	25
5-Jun	39.2	20	18	354	256	5179	2	27
6-Jun	48.6	20	11	365	156	5335	5	32
7-Jun	40.6	20	20	385	319	5654	2	34
8-Jun	40.9	20	16	401	247	5902	0	34
9-Jun	39.1	20	7	408	106	6008	0	34
10-Jun	39.9	20	10	418	151	6159	0	34
Total	1174	528						

APPENDICES

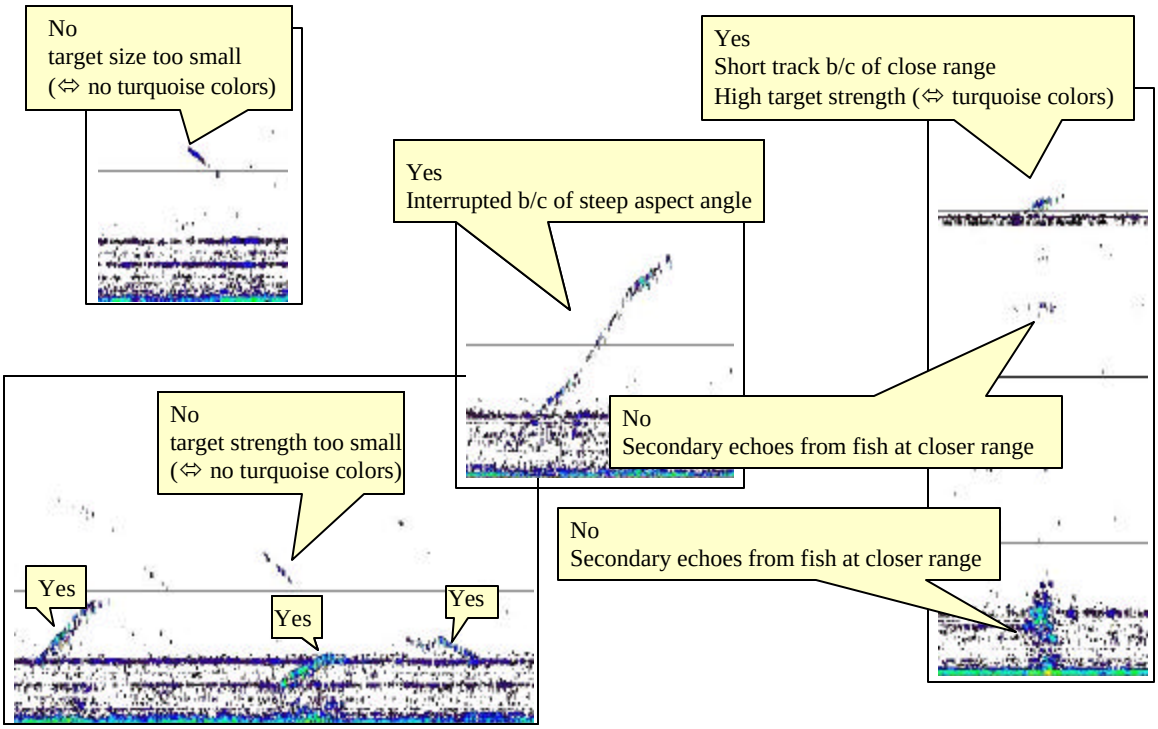

Figure A-1. Track examples used by field technicians as guidelines for counting salmon-sized fish off echograms at Flag Point Channel, 2002.

Table A-1. Single target-detection algorithm and calibration parameters for the acoustic equipment at Flag Point Channel, 2002.

Category Parameter	Parameter value		
Single target detection operator algorithm parameter			
Target strength (TS) threshold (dB)	-55		
Pulse length determination level (dB)	6		
Minimum normalized pulse length	0.2		
Maximum normalized pulse length	4		
Maximum beam compensation (dB)	10		
Maximum standard deviation of minor-axis angles (degrees)	3		
Maximum standard deviation of major-axis angles (degrees)	3		
Calibration parameter			
3 dB beam width in alongship direction	6		
3 dB beam width in athwartship direction	12		
Algorithm data			
4D (range, angles and time)			
Algorithm track detection	Athwartship	Alongship	Range
Alpha	0.30	0.30	0.20
Beta	0.05	0.05	0.04
Algorithm target gates			
Exclusion distance (m)	2.0	1.0	0.2
Missed ping expansion (%)	0.0	0.0	0
Weights			
All parameters	0		
Track acceptance			
Minimum number of single targets in a track	15		
Minimum number of pings in a track (pings)	1		
Maximum gap between single targets (pings)	8		

[a] Range for exclusion distance was 0.4 during editing.

[b] Minimum number of single targets in a single track was 8 during editing.

Table B-1. Stage height of the Copper River at Flag Point Channel and the Million Dollar Bridge, 2002.

		Flag Point Channel				Million Dollar Bridge			
		Stage height [a]		Change		Stage height [a]		Change	
Date		ft	m	ft	m	ft	m	ft	m
05-01	[b]	9.8	3.0						
05-02	[b,c]								
05-03	[b,c]								
05-04	[b,c]								
05-05	[b]	8.9	2.7	-0.9	-0.3				
05-06	[b,c]								
05-07	[b]	9.3	2.8	9.3	2.8				
05-08	[b]	8.4	2.5	8.4	2.5				
05-09	[b]	8.2	2.5	-0.7	-0.2				
05-10	[b]	8.4	2.5	8.4	2.5				
05-11	[b,c]								
05-12	[b,c]								
05-13	[b]	9.0	2.7	0.8	0.2				
05-14	[b]	12.0	3.7	3.6	1.1				
05-15		13.7	4.2	13.7	4.2	130.9	39.9		
05-16		13.3	4.1	13.3	4.1	130.7	39.8	-0.2	0.0
05-17		14.0	4.3	5.0	1.5	131.3	40.0	0.6	0.2
05-18		13.9	4.2	1.9	0.6	130.4	39.8	-0.9	-0.3
05-19		9.5	2.9	-4.3	-1.3	130.9	39.9	0.5	0.1
05-20		9.6	2.9	-3.8	-1.1	131.4	40.0	0.4	0.1
05-21		10.0	3.0	-4.1	-1.2	132.0	40.2	0.7	0.2
05-22		10.3	3.1	-3.6	-1.1	132.5	40.4	0.5	0.2
05-23		10.7	3.3	1.3	0.4	133.5	40.7	1.0	0.3
05-24		11.1	3.4	1.6	0.5	133.8	40.8	0.3	0.1
05-25		11.2	3.4	1.2	0.4	134.2	40.9	0.4	0.1
05-26		11.5	3.5	1.2	0.4	134.7	41.1	0.6	0.2
05-27		12.0	3.7	1.3	0.4	135.5	41.3	0.7	0.2
05-28		12.2	3.7	1.1	0.3	135.9	41.4	0.4	0.1
05-29		12.2	3.7	1.0	0.3	135.6	41.3	-0.3	-0.1
05-30		12.6	3.8	1.1	0.3	135.6	41.3	0.0	0.0
05-31		12.3	3.7	0.3	0.1	136.0	41.5	0.4	0.1
06-01		12.6	3.8	0.4	0.1	136.3	41.5	0.2	0.1
06-02		12.2	3.7	0.0	0.0	135.7	41.4	-0.6	-0.2

Table B-1. Stage height of the Copper River at Flag Point Channel and the Million Dollar Bridge, 2002.

	Flag Point Channel				Million Dollar Bridge			
	Stage height [a]		Change		Stage height [a]		Change	
Date	ft	m	ft	m	ft	m	ft	m
06-03	11.8	3.6	-0.9	-0.3	135.1	41.2	-0.6	-0.2
06-04	11.6	3.5	-0.7	-0.2	134.9	41.1	-0.2	-0.1
06-05	11.4	3.5	-1.2	-0.4	134.6	41.0	-0.3	-0.1
06-06	11.3	3.4	-0.9	-0.3	134.6	41.0	-0.1	0.0
06-07	11.6	3.5	-0.1	0.0	135.2	41.2	0.7	0.2
06-08	11.9	3.6	0.3	0.1	135.4	41.3	0.2	0.1
06-09	12.4	3.8	1.0	0.3	135.8	41.4	0.4	0.1
06-10	12.3	3.8	1.0	0.3	135.8	41.4	0.0	0.0

[a] Stage height measured using USGS gage. This is a relative measurement as the current bridge elevations above mean sea level are unknown.

[b] No data was collected at the Million Dollar Bridge.

[c] No data was collected at the 27-Mile Bridge.

Table C-1. Estimated daily escapement and escapement objectives for salmon at the Miles Lake sonar, 2002.

		Estimated Escapement				Escapement Objective			Projected
Date	Water Level [a]	North Bank	South Bank	Daily	Cumulative	Daily	Cumulative	0600 count	Daily Count
05-15	39.89	71 [a]		71	71	0	0		
05-16	39.84	2		2	73	0	0		
05-17	40.02	4		4	77	405	405		
05-18	39.76	2	0 [c]	2	79	971	1,376		
05-19	39.91	0	17	17	96	1,365	2,741		
05-20	40.04	2	32	34	130	1,558	4,300		
05-21	40.24	98	477	575	705	1,556	5,856	78	312
05-22	40.4	23	802	825	1,530	2,133	7,989	166	664
05-23	40.69	75	1,429	1,504	3,034	3,122	11,111	244	976
05-24	40.78	288	2,324	2,612	5,646	4,797	15,908	414	1,656
05-25	40.89	146	3,488	3,634	9,280	4,914	20,822	822	3,288
05-26	41.07	169	2,787	2,956	12,236	5,231	26,053	608	2,432
05-27	41.29	261	3,748	4,009	16,245	7,554	33,607	830	3,320
05-28	41.41	119	5,054	5,173	21,418	9,900	43,507	862	3,448
05-29	41.33	238	8,817	9,055	30,473	6,981	50,488	1,584	6,336
05-30	41.33	266	10,848	11,114	41,587	8,330	58,818	2,260	9,040
05-31	41.46	838	11,204	12,042	53,629	11,013	69,831	3,247	12,988
06-01	41.53	1,030	12,945	13,975	67,604	11,490	81,321	2,749	10,996
06-02	41.35	818	14,597	15,415	83,019	13,132	94,453	3,577	14,308
06-03	41.17	2,564	23,723	26,287	109,306	12,684	107,137	7,508	30,032
06-04	41.12	1,339	19,995	21,334	130,640	14,409	121,546	5,406	21,624
06-05	41.04	1,011	20,462	21,473	152,113	15,924	137,470	4,118	16,472
06-06	41.02	1,194	14,637	15,831	167,944	14,380	151,850	2,870	11,480
06-07	41.22	636	14,024	14,660	182,604	14,087	165,937	2,720	10,880
06-08	41.28	529	11,705	12,234	194,838	16,446	182,383	3,359	13,436
06-09	41.4	769	13,470	14,239	209,077	15,738	198,121	3,636	14,544
06-10	41.39	646	9,876	10,522	219,599	15,101	213,222	3,050	12,200
06-11	41.39	569	10,803	11,372	230,971	14,518	227,740	2,804	11,216
06-12	41.35	619	9,327	9,946	240,917	13,425	241,165	2,733	10,932
06-13	41.25	550	5,098	5,648	246,565	11,782	252,947	1,896	7,584
06-14	41.18	358	8,545	8,903	255,468	11,285	264,232	1,716	6,864
06-15	41.38	464	8,698	9,162	264,630	12,115	276,346	2,774	11,096
06-16	41.76	553	6,300	6,853	271,483	10,818	287,165	2,137	8,548
06-17	42.05	247	6,738	6,985	278,468	10,784	297,949	2,002	8,008
06-18	42.3	146	5,764	5,910	284,378	9,243	307,192	1,652	6,608
06-19	42.63	251	5,400	5,651	290,029	8,134	315,325	1,373	5,492
06-20	42.65	210	4,499	4,709	294,738	8,436	323,762	1,266	5,064
06-21	42.61	171	4,640	4,811	299,549	7,639	331,400	1,317	5,268

Table C-1. Estimated daily escapement and escapement objectives for salmon at the Miles Lake sonar, 2002.

		Estimated Escapement				Escapement Objective			Projected
Date	Water Level [a]	North Bank	South Bank	Daily	Cumulative	Daily	Cumulative	0600 count	Daily Count
06-22	42.49	189	4,693	4,882	304,431	7,687	339,087	1,475	5,900
06-23	42.43	125	6,060	6,185	310,616	8,015	347,101	1,632	6,528
06-24	42.43	95	5,752	5,847	316,463	7,797	354,898	1,473	5,892
06-25	42.41	250	6,473	6,723	323,186	7,685	362,583	1,491	5,964
06-26	42.41	213	6,737	6,950	330,136	6,734	369,317	1,700	6,800
06-27	42.36	337	7,988	8,325	338,461	6,530	375,846	1,948	7,792
06-28	42.18	509	11,438	11,947	350,408	6,471	382,317	2,821	11,284
06-29	42.09	579	13,448	14,027	364,435	6,873	389,191	2,760	11,040
06-30	42.22	548	12,148	12,696	377,131	6,482	395,672	3,841	15,364
07-01	42.33	151	9,995	10,146	387,277	6,627	402,299	2,677	10,708
07-02	42.44	350	9,784	10,134	397,411	7,074	409,373	2,016	8,064
07-03	42.43	494	10,332	10,826	408,237	7,536	416,910	2,820	11,280
07-04	42.49	351	11,572	11,923	420,160	8,044	424,954	3,108	12,432
07-05	42.71	298	11,731	12,029	432,189	8,343	433,297	3,003	12,012
07-06	42.71	562	19,389	19,951	452,140	8,205	441,502	4,093	16,372
07-07	42.46	1,157	24,904	26,061	478,201	7,812	449,314	4,467	17,868
07-08	42.39	1,015	31,897	32,912	511,113	8,438	457,752	7,339	29,356
07-09	42.47	1,643	27,275	28,918	540,031	9,197	466,950	8,208	32,832
07-10	42.47	1,282	23,692	24,974	565,005	10,122	477,072	5,235	20,940
07-11	42.66	1,899	27,572	29,471	594,476	9,341	486,412	5,287	21,148
07-12	42.75	2,345	25,954	28,299	622,775	10,421	496,834	7,182	28,728
07-13	42.69	1,416	23,062	24,478	647,253	9,478	506,312	5,875	23,500
07-14	42.54	2,575	26,463	29,038	676,291	9,926	516,238	6,617	26,468
07-15	42.5	1,789	24,863	26,652	702,943	9,022	525,260	7,175	28,700
07-16	42.61	1,081	18,706	19,787	722,730	9,908	535,168	5,784	23,136
07-17	42.71	941	15,644	16,585	739,315	8,697	543,865	4,482	17,928
07-18	42.98	480	13,003	13,483	752,798	9,104	552,969	2,935	11,740
07-19	43.27	220	6,896	7,116	759,914	9,968	562,937	2,209	8,836
07-20	43.22	385	7,129	7,514	767,428	10,622	573,559	1,378	5,512
07-21	43.02	477	8,340	8,817	776,245	8,423	581,982	1,484	5,936
07-22	42.95	604	8,463	9,067	785,312	7,062	589,045	2,210	8,840
07-23	42.91	1,121	9,610	10,731	796,043	6,876	595,921	3,103	12,412
07-24	43.12	455	4,638	5,093	801,136	5,943	601,864	1,362	5,448
07-25	43.63	277	2,929	3,206	804,342	5,277	607,141	1,144	4,576
07-26	44.03	85	786	871	805,213	4,703	611,844	230	920
07-27	43.59	237	1,933	2,170	807,383	4,615	616,459	119	476
07-28	43.06	1,083	3,090	4,173	811,556	4,508	620,968	862	3,448
07-29	43.02	572	2,737	3,309	814,865	4,056	625,024	910	3,640
07-30	43.32	530	1,430	1,960	816,825	3,874	628,898	593	3,640

Table C-1. Estimated daily escapement and escapement objectives for salmon at the Miles Lake sonar, 2002.

		Estimated Escapement				Escapement Objective			Projected
Date	Water Level [a]	North Bank	South Bank	Daily	Cumulative	Daily	Cumulative	0600 count	Daily Count
07-31	43.3	1,290	1,771	3,061	819,886	3,393	632,291	497	2,982
08-01	Sonar counter pulled at			0	819,886	3,177	635,467		
08-02	midnight on 31 July			0	819,886	2,929	638,397		
08-03				0	819,886	2,514	640,911		
08-04				0	819,886	2,127	643,038		
08-05				0	819,886	1,647	644,685		

[a] Stage height measured using USGS gage. This is a relative measurement because the current bridge elevation above mean sea level is unknown.

[b] North Bank counter started operation May 13.

[c] South Bank counter started operation May 18 (1700).

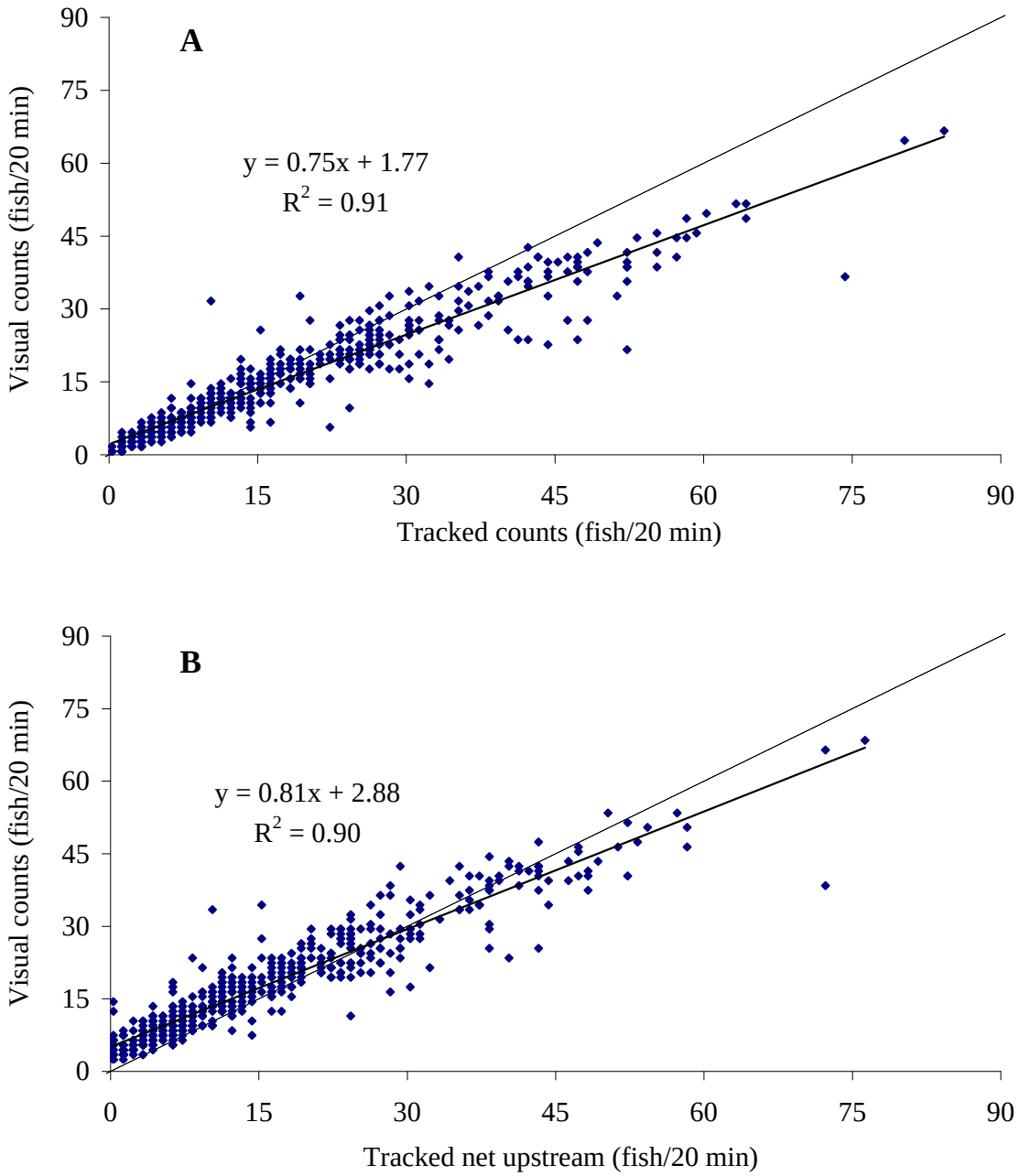

Figure D-1. Regression analyses of visual versus tracked counts (Panel A) and visual versus tracked net upstream counts (Panel B) at the Flag Point Channel, 2002.

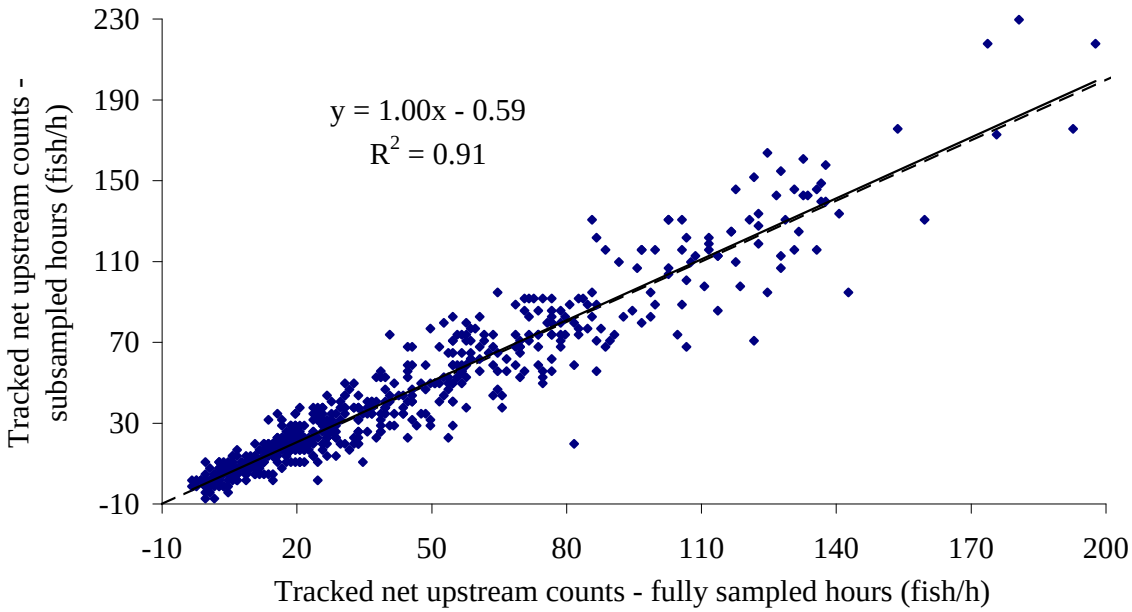

Figure D-2. Regression analysis of the subsampled (20 min/h) and fully sampled (60 min/h) sampling schemes using hourly net upstream counts at the Flag Point Channel, 2002.

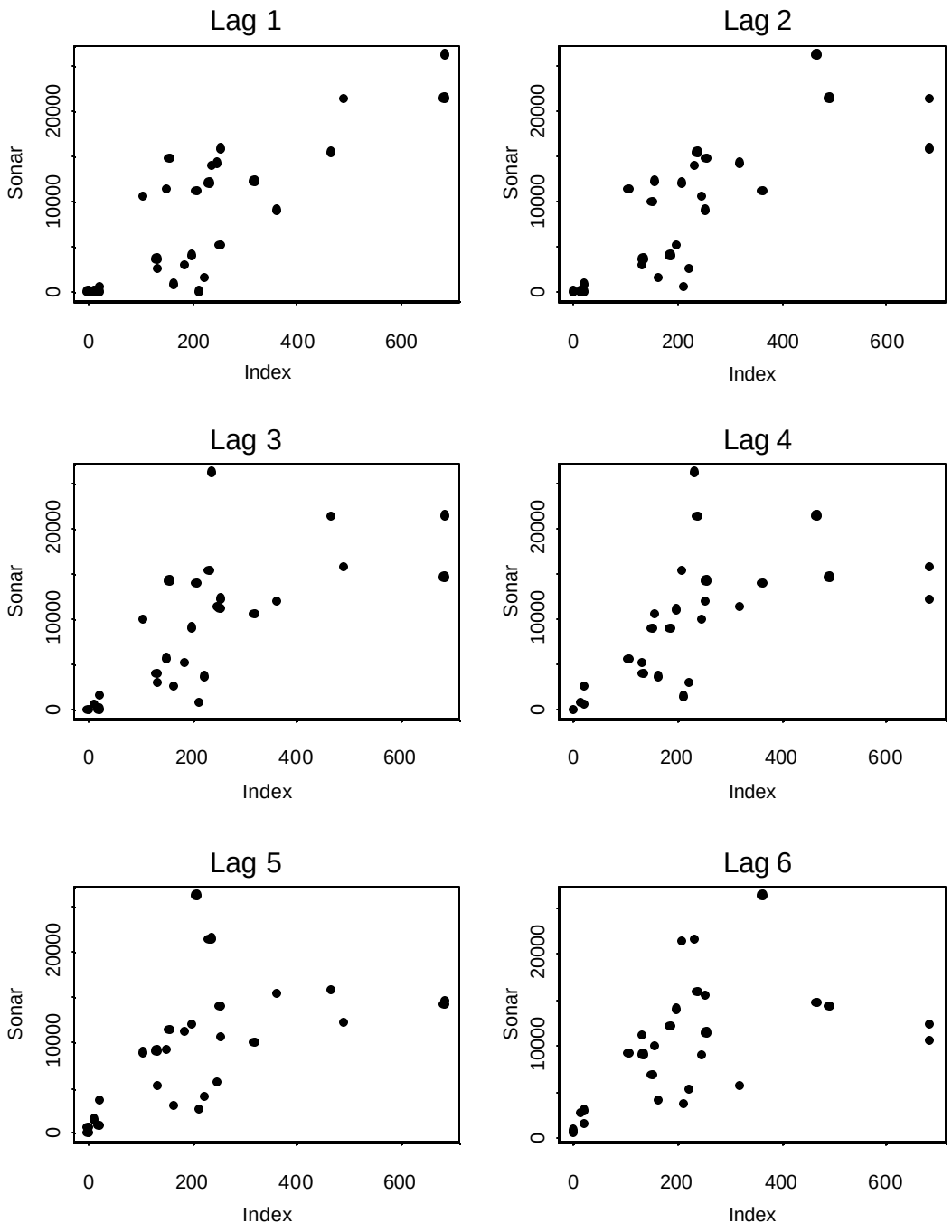

Figure E-1. Scatterplots of the daily Miles Lake sonar indices (lagged from 1-6 days) and the daily test fishing index obtained by drift gillnetting at Flag Point Channel, 2002.

Table E-1. Inseason estimation of lag, forecast, and error for the drift gillnet test fishing index at Flag Point Channel, 2002. To emulate inseason estimation, only the data available up to the given date were used for determining the best lag and forecast. The "best lag" is the lag that produced the best fit for the different methods. The forecast is of the expected number of salmon at the Miles Lake sonar for the next day. Error was calculated assuming the best lag was correct.

		Best Lag				1 day forecast				1 day forecast - error			
Day of run	Date	MLE (complete)	MLE (trunc)	Regression (complete)	Regression (trunc)	MLE (complete)	MLE (trunc)	Regression (complete)	Regression (trunc)	MLE (complete)	MLE (trunc)	Regression (complete)	Regression (trunc)
5	19-May	1		1		95		42		-61		-8	
6	20-May	1		1		4		8		571		567	
7	21-May	2		2		498		506		327		319	
8	22-May	4		4		3027		2791		-1523		-1287	
9	23-May	4		4		1807		2018		805		594	
10	24-May	2		2		1357		1418		2277		2216	
11	25-May	3	1	3	1	2793	2158	2753	1722	163	798	203	1234
12	26-May	3	2	3	1	3445	3330	3379	1849	564	679	630	2160
13	27-May	3	3	3	1	5589	6690	5452	2098	-416	-1517	-279	3075
14	28-May	3	3	3	4	9730	11225	9787	15205	-675	-2170	-732	-6150
15	29-May	1	1	1	1	3527	3945	3500	3757	7587	7169	7614	7357
16	30-May	2	2	2	2	6152	6747	6178	6791	5890	5295	5864	5251
17	31-May	3	3	3	3	8522	9241	8543	9304	5453	4734	5432	4671
18	1-Jun	4	4	4	4	23492	25181	23543	26104	-8077	-9766	-8128	-10689
19	2-Jun	4	4	4	1	33647	35358	33298	23327	-7360	-9071	-7011	2960
20	3-Jun	1	1	1	1	15821	16414	16487	17435	5513	4920	4847	3899
21	4-Jun	1	1	1	1	23246	23974	24813	26511	-1773	-2501	-3340	-5038
22	5-Jun	1	1	1	1	8540	8743	8019	7939	7291	7088	7812	7892
23	6-Jun	1	1	1	1	5358	5481	4679	4651	9302	9179	9981	10009
24	7-Jun	1	1	1	1	11186	11440	11102	11455	1048	794	1132	779
25	8-Jun	1	1	1	1	8700	8888	8538	8929	5539	5351	5701	5310
26	9-Jun	1	1	1	1	3799	3878	3620	4271	6723	6644	6902	6251
27	10-Jun	1	1	1	1	5466	5581	5616	6455	5906	5791	5756	4917

trunc = truncated

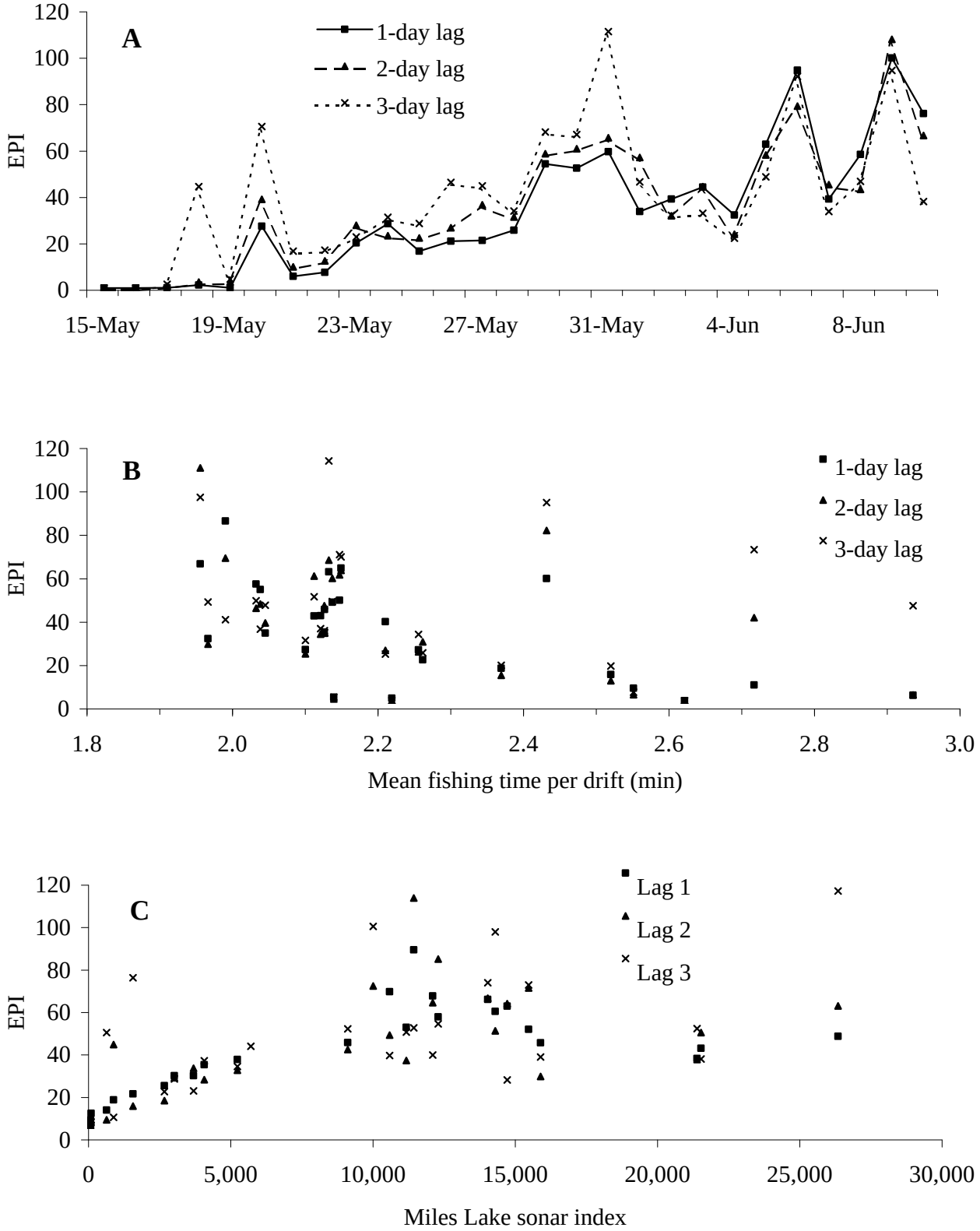

Figure E-2. Change in the escapement per index point (EPI) as a function of time (Panel A), mean fishing time per drift (Panel B), and the Miles Lake sonar index (Panel C), 2002.

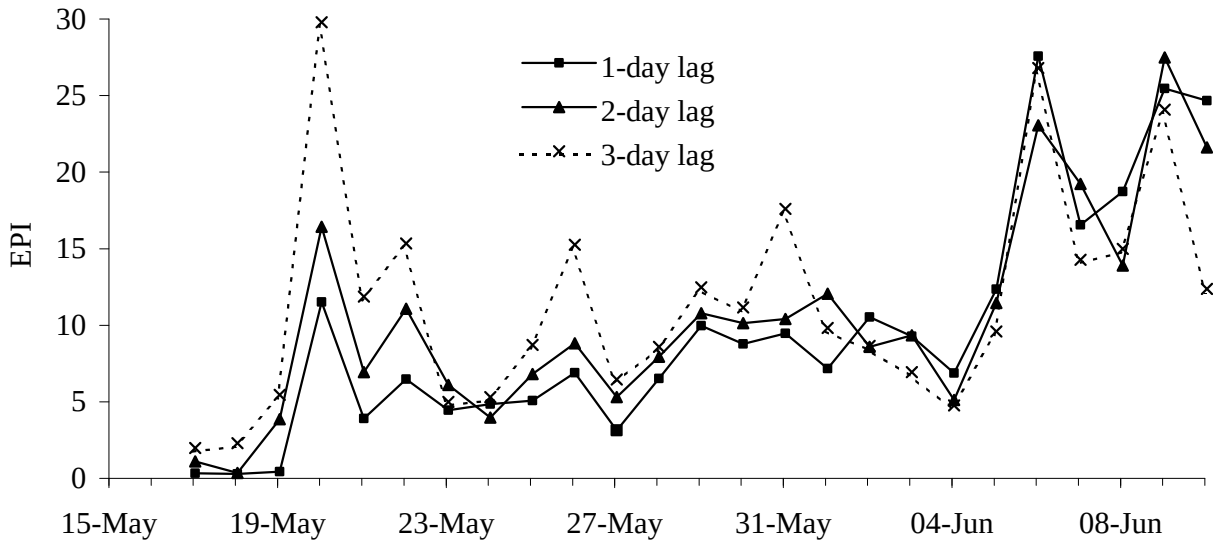

Figure E-3. Change in escapement per index point (EPI) for acoustic sampling at Flag Point Channel as a function of time, 2002.

Appendix F – Technical and Community Workshop Summary (12-13 November 2002)

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

PHOTO PLATES

Photo 1. The acoustic sampling location in the Mile-37 Channel, located downstream of Bridge 342 on the Copper River Highway.

Photo 2. Streamside platform at Flag Point Channel containing the acoustic data acquisition computer and related equipment, 2002.

Photo 3. Field technician removing debris from the weir installed upstream of the transducer at Flag Point Channel, 2002.

Photo 4. ADF&G technicians drift gillnetting in Flag Point Channel on the lower Copper River, 2002.

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