Fishery Data Series No. 05-67

# Estimation of Chum Salmon Abundance, Migration Timing, and Spawning Distribution in the Fish River Complex, Norton Sound Alaska, 2002-2004

by

Gary L. Todd,

Carlos S. Monsivais,

and

David F. Kaplan

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Alaska Department of Fish and Game
Divisions of Sport Fish and Commercial Fisheries

## Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in the following reports by the Divisions of Sport Fish and of Commercial Fisheries: Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figure or figure captions.

**Weights and measures (metric)**

| | |
|---|---|
| centimeter | cm |
| deciliter | dL |
| gram | g |
| hectare | ha |
| kilogram | kg |
| kilometer | km |
| liter | L |
| meter | m |
| milliliter | mL |
| millimeter | mm |

**Weights and measures (English)**

| | |
|---|---|
| cubic feet per second | $ft^3/s$ |
| foot | ft |
| gallon | gal |
| inch | in |
| mile | mi |
| nautical mile | nmi |
| ounce | oz |
| pound | lb |
| quart | qt |
| yard | yd |

**Time and temperature**

| | |
|---|---|
| day | d |
| degrees Celsius | °C |
| degrees Fahrenheit | °F |
| degrees kelvin | K |
| hour | h |
| minute | min |
| second | s |

**Physics and chemistry**

| | |
|---|---|
| all atomic symbols | |
| alternating current | AC |
| ampere | A |
| calorie | cal |
| direct current | DC |
| hertz | Hz |
| horsepower | hp |
| hydrogen ion activity (negative log of) | pH |
| parts per million | ppm |
| parts per thousand | ppt, ‰ |
| volts | V |
| watts | W |

**General**

| | |
|---|---|
| Alaska Administrative Code | AAC |
| all commonly accepted abbreviations | e.g., Mr., Mrs., AM, PM, etc. |
| all commonly accepted professional titles | e.g., Dr., Ph.D., R.N., etc. |
| at | @ |
| compass directions: | |
| east | E |
| north | N |
| south | S |
| west | W |
| copyright | © |
| corporate suffixes: | |
| Company | Co. |
| Corporation | Corp. |
| Incorporated | Inc. |
| Limited | Ltd. |
| District of Columbia | D.C. |
| et alii (and others) | et al. |
| et cetera (and so forth) | etc. |
| exempli gratia (for example) | e.g. |
| Federal Information Code | FIC |
| id est (that is) | i.e. |
| latitude or longitude | lat. or long. |
| monetary symbols (U.S.) | \$, ¢ |
| months (tables and figures): first three letters | Jan,...,Dec |
| registered trademark | ® |
| trademark | ™ |
| United States (adjective) | U.S. |
| United States of America (noun) | USA |
| U.S.C. | United States Code |
| U.S. state | use two-letter abbreviations (e.g., AK, WA) |

**Measures (fisheries)**

| | |
|---|---|
| fork length | FL |
| mideye-to-fork | MEF |
| mideye-to-tail-fork | METF |
| standard length | SL |
| total length | TL |

**Mathematics, statistics**

| | |
|---|---|
| *all standard mathematical signs, symbols and abbreviations* | |
| alternate hypothesis | $H_A$ |
| base of natural logarithm | *e* |
| catch per unit effort | CPUE |
| coefficient of variation | CV |
| common test statistics | (F, t, $\chi^2$, etc.) |
| confidence interval | CI |
| correlation coefficient (multiple) | R |
| correlation coefficient (simple) | r |
| covariance | cov |
| degree (angular ) | ° |
| degrees of freedom | df |
| expected value | *E* |
| greater than | > |
| greater than or equal to | ≥ |
| harvest per unit effort | HPUE |
| less than | < |
| less than or equal to | ≤ |
| logarithm (natural) | ln |
| logarithm (base 10) | log |
| logarithm (specify base) | $log_2$, etc. |
| minute (angular) | ' |
| not significant | NS |
| null hypothesis | $H_O$ |
| percent | % |
| probability | P |
| probability of a type I error (rejection of the null hypothesis when true) | α |
| probability of a type II error (acceptance of the null hypothesis when false) | β |
| second (angular) | " |
| standard deviation | SD |
| standard error | SE |
| variance | |
| population | Var |
| sample | var |

*FISHERY DATA SERIES NO. 05-67*

# ESTIMATION OF CHUM SALMON ABUNDANCE, MIGRATION TIMING, AND SPAWNING DISTRIBUTION IN THE FISH RIVER COMPLEX, NORTON SOUND ALASKA, 2002-2004

by
Gary L. Todd,
Alaska Department of Fish and Game, Division of Commercial Fisheries, Nome

Carlos S. Monsivais,
Alaska Department of Fish and Game, Division of Commercial Fisheries, Anchorage

and

David F. Kaplan
formerly with Alaska Department of Fish and Game, Division of Commercial Fisheries, Nome

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518-1599

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*Gary L. Todd*
*Alaska Department of Fish and Game, Division of Commercial Fisheries*
*Pouch 1148, Nome, AK 99762, USA*

*Carlos S. Monsivais,*
*Alaska Department of Fish and Game, Division of Commercial Fisheries*
*333 Raspberry Road, Anchorage, AK 99508, USA*

*and*

*David F. Kaplan*
*formerly with Alaska Department of Fish and Game, Division of Commercial Fisheries,*
*Pouch 1148, Nome, AK 99762, USA*

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# ABSTRACT

Chum salmon *Oncorhynchus keta* were seined in the lower Fish River for age, sex, and length sampling and tagged with radio transmitters to monitor upriver movement into tributary rivers and creeks, and to estimate drainage-wide abundance. A stationary radiotelemetry receiver site placed below the tagging locations monitored tagged chum salmon that backed-out or left the drainage and therefore were removed from the analysis, and was used to estimate possible mortality caused by handling and tagging. Upriver receiver sites, above tagging locations, were used to estimate the proportion of chum salmon that entered Niukluk River drainage or that continued up Fish River to spawn, and to estimate migration rates and timing. Aerial radiotelemetry surveys were conducted to locate and estimate drainage-wide distribution and document spawning areas.

Mark–recapture methodology, using Niukluk River counting tower as the recapture location, was used to estimate total chum salmon abundance in Fish River. Niukluk River yearly proportion was 30.7%, 34.4%, and 33.8%, for 2002, 2003, and 2004, respectively, and weighted average was 33.1%. Using Niukluk tower expanded chum salmon counts and expanding by mark–recapture proportion the drainage-wide abundance estimates were 107,921 chum salmon in 2002, 57,018 in 2003, and 31,421 for 2004. Excluding Niukluk River, average drainage distribution in major tributaries determined from aerial surveys was 18.4% Boston Creek, 12.7% Etehepuk River, and 10.1% Fox River. Average migration rates from tagging to arrival at the confluence of Fish and Niukluk rivers was 48.9 h for upper Fish River spawning fish, and to Niukluk counting tower was 96.0 h for fish spawning above the counting tower. Niukluk River bound fish migrated slower (57.6h to confluence) than upper Fish River destined fish.

Key words: chum salmon, *Oncorhynchus keta*, Fish River, Niukluk River, Norton Sound Subdistrict 2, Golovnin Bay, radiotelemetry, abundance, distribution, mark–recapture, age, sex, length, ASL composition.

# INTRODUCTION

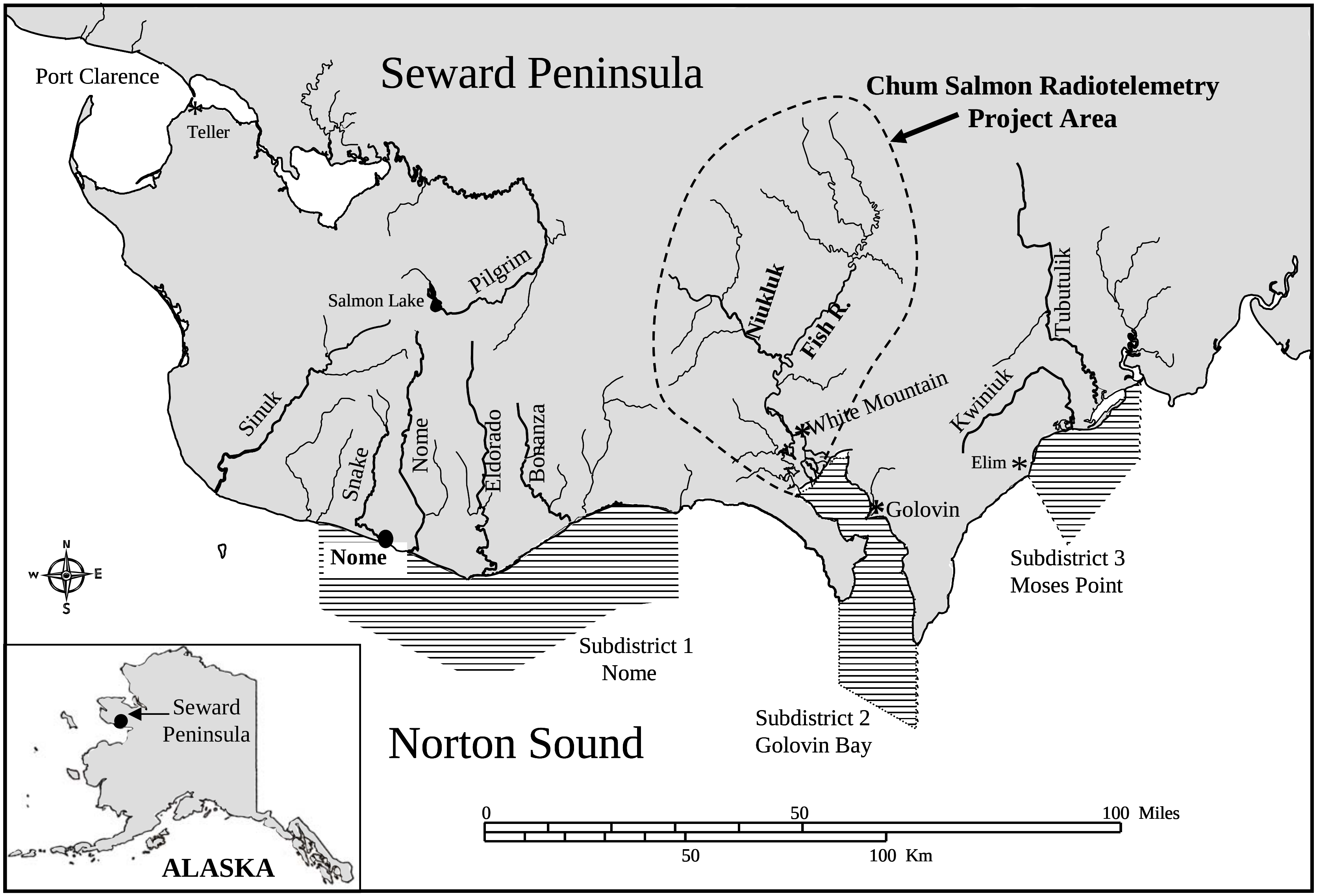
Data presented in this report supersedes project data previously reported in interim progress reports and presentations:

Todd, G. L. 2004. Estimation of chum salmon abundance and spawning distribution in the Fish River complex, 2002. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 3A04-28, Anchorage.

Todd, G L. 2005. Estimation of chum salmon abundance and distribution in the Fish River complex, 2004. Preliminary report presentation to the Norton Sound Research and Restoration Scientific-Technical, and Steering Committees. Nome, Alaska, January 2005.

Todd, G. L. and C. S. Monsivais. 2005. Norton Sound chum salmon stock status and estimation of chum salmon abundance and distribution in the Fish River complex using radio telemetry. 22nd Northeast Pacific Pink and Chum Salmon Workshop. Ketchikan, Alaska, February 2005.

Norton Sound harvest management can benefit from improvements to existing programs for the collection of catch and escapement data (NSSRR STC 2002), and Norton Sound chum salmon *Oncorhynchus keta* returns have declined since the early 1980s. The Norton Sound Salmon Management District includes all waters between the southern boundary at Point Romanof (near the village of Stebbins) and northern boundary at Cape Douglas, which is northwest of the Sinuk River mouth. This district is divided into 6 commercial salmon fishing subdistricts, 3 of which are in northern Norton Sound (Figure 1). In 2000 the Alaska Board of Fisheries (Board) classified the Subdistrict 2 (Golovnin Bay) chum salmon stock as a stock of concern under the yield concern definition (Bue 2000). In 2001, the Board adopted the Alaska Department of Fish and Game's (ADF&G) management plan to address the stock of concern designation (Menard and Bergstrom 2003). Stocks of concern guidelines are included in the Policy for the Management of Sustainable Salmon Fisheries (5 AAC 39.222).




*Note*: project area inside dashed line.

**Figure 1.–**Southern Seward Peninsula area showing northern Norton Sound commercial fishery management subdistricts and Golovnin Bay (Subdistrict 2), White Mountain village, and Fish River drainage.

Fish River drainage encompasses approximately 6,200 $km^2$ and is believed to be the second largest producer of chum salmon in the region after Unalakleet River. Chum salmon in this area are a major subsistence resource in the villages of White Mountain and Golovin, and contribute to small local commercial fisheries (Appendix A1), although commercial fisheries have been restricted in the last decade in Golovnin Bay (Subdistrict 2) because of continued weak returns and concerns for protecting chum salmon stocks (Figure 1). The previous Fish River drainage chum salmon aerial survey escapement goals were adopted prior to the 1982 season and were as follows: 17,500 for Fish River, 8,000 for Niukluk River, 2,500 for Boston River, and 2,500 for Kachavik River (Buklis 1993). A combined aerial survey goal range of 23,200–46,400 included Fish and Niukluk rivers and Boston Creek, with a Niukluk River goal of 8,000 (Appendix A2) which was recommended in 1999 (Fair et al. 1999), but never formally adopted. In 2001 ADF&G adopted a regulatory escapement goal policy (Policy for Statewide Salmon Escapement Goals; 5 AAC 39.223) however the Fish River goal remained classified as an escapement objective (EO) because the data was not reviewed after adoption of the escapement policy. After ADF&G review for the 2004 Board meetings the Arctic Yukon Kuskokwim (AYK) Escapement Goal Review Team recommended discontinuing the Fish River chum salmon aerial survey escapement objective and setting a Niukluk River counting tower sustainable escapement goal (SEG) minimum of 30,000 chum salmon (ADF&G 2004).

Niukluk River is the largest Fish River tributary and is approximately 55 km long from its confluence with Fish River up to Libby Creek, the area where chum salmon are known to spawn. This tributary also supports subsistence fisheries, and is thought to provide spawning habitat for a significant, but previously unknown, portion of Fish River chum salmon. Improved escapement enumeration was needed for harvest management and to evaluate spawning distribution, run timing, and productivity of chum salmon throughout the drainage. Coupled with characterization of age, sex, and length (ASL) composition, this information will assist managers in setting scientifically based escapement goals to improve stock specific harvest management and to address conservation issues. Niukluk River counting tower has operated yearly since 1995, and is used as an index count for chum salmon in the Fish River drainage for purposes of harvest management (Kohler and Todd 2003). Escapements and run timing to other portions of the Fish River drainage are monitored in season by airplane. A goal for the Fish River system would be to understand the changes in productivity of its chum salmon population to contribute to analyses for sustainable subsistence, commercial, and sport fisheries.

Because subsistence fishing has been restricted around the Nome area, more people from Nome and summer residents of Council are now using Fish River resources to help fill their subsistence needs, primarily because of road access to Niukluk River at Council. ADF&G Division of Subsistence monitored subsistence harvests at White Mountain (Georgette et al. 2002) and Golovin, and Kawerak, Inc. monitored harvests by people from the Nome area during 2000 and 2001. The amount of subsistence harvest above Niukluk tower and at road access point at Council was also unknown but thought to have increased during the last 5 years (Magdanz et al. 2003); so the Niukluk River total escapement remained unknown. Because of declining funding to conduct annual subsistence surveys in most communities, the Board required annual subsistence permits and harvest records for northern Norton Sound subsistence fishers. Permits were issued beginning in 2004 and Subdistrict 2 fishers were asked to report harvests above or below the tower if fishing the Niukluk River.

If a consistent proportion of the Fish River population spawns in the Niukluk River, expansion of past and future data to estimate total Fish River escapement and harvest rates in subsistence and commercial fisheries would be possible. The primary objective of the Fish River chum salmon radiotelemetry project was to determine if Niukluk River tower counts could be expanded to estimate total chum salmon escapements in Fish River drainage (improve the drainage-wide estimate). Additional objectives were to gather ASL data, determine migration timing and holding patterns, locations and relative importance of major spawning areas. Specific project objectives were:

1. Estimate the proportion of chum salmon fitted with radio tags in the lower Fish River that migrate upriver and pass the Niukluk River counting tower.
2. Estimate drainage-wide chum salmon escapement in the Fish River, such that with 90% confidence, the estimate is within ±25% of the true value. Drainage wide escapement would be estimated as the ratio of the Niukluk tower count and the estimated proportion of total tagged.
3. Estimate the ASL composition of chum salmon entering the Fish River drainage such that all estimated proportions are within 5 percentage points of the actual proportions 95% of the time, and compare to Niukluk River ASL sampled, and tagged fish that migrate into the Niukluk River.
4. Estimate run timing and passage rates of chum salmon and compare to Niukluk River salmon timing and rates.
5. Determine tributary distribution and major spawning locations, represented by salmon fitted with radio tags and tracked to their final spawning location, and using those tagged fish to estimate peak spawning timing.
6. Estimate short term tagging mortality and tag retention.

# METHODS

## APPROACH

This study employed radiotelemetry and mark–recapture methodology to estimate abundance, migration timing, drainage-wide distribution, and to locate major spawning areas. Radiotelemetry is a common method for fishery stock assessment (Todd et al. 2001; Wuttig and Evenson 2002), estimating fish abundance (Evenson and Wuttig 2000; Hasbrouck et al. 2000; Wuttig 1998) and for distribution and movement studies (Boyce and Eiler 2000; Holder and Eiler 2000; Meka et al. 2000; Milligan et al. 1986). Stationary radiotelemetry receiver sites (receiver sites) were used to monitor tagged fish passage and holding patterns, and the Niukluk River counting tower was used for estimating escapement in the Niukluk River. Aerial radio tracking surveys were conducted to determine drainage-wide distribution and to locate major spawning areas.

## RADIOTELEMETRY EQUIPMENT

Advanced Telemetry Systems, Inc.[1] (ATS; Isanti, MN) manufactured the radiotelemetry equipment used during this study. In 2002 an ATS model R4000 receiver was interfaced by serial cable with an ATS model DCC II D5401 data collection computer at receiver sites. When

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[1] Product names used in this report are included for scientific completeness but do not constitute product endorsement by the Alaska Department of Fish and Game.

interfaced, the DCC controls the receiver's operations, frequencies to scan, and draws power from the receiver. An internal backup battery is supplied in the DCC to prevent recorded data files from being lost if battery power is interrupted or becomes low. A 12-V marine battery and solar panel, wired through a solar charge controller, was used to power receiver equipment at each site. Yagi 4-element antennae were used at all receiver sites and for aerial survey tracking. Antennae (at 6 m) and solar panel (at 3 m) were mounted to a 6 m high aluminum mast, which was bolted to a locked water resistant equipment box containing the receiver, DCC, and battery. All cables were run inside the antenna mast to the equipment box to avoid possible damage from animals. At all receiver sites during all study years, antenna 1 monitored downriver direction of tagged fish, antenna 2 upriver, and if at a tributary confluence, a third antenna covered the tributary. An antenna switchbox allowed scanning on all antennae simultaneously until a tag was received. The receiver would scan on each antenna for the amount of time programmed into the DCC setting: set to scan frequency for 5 s, with 2 s time out (if no frequency was found would go to next frequency). Before site deployment, all frequencies were entered manually into the DCC and scanning parameters set according to site-specific criteria. Each time we accessed a site to download recorded data or conduct site testing (determine receiver coverage) with a radio tag, battery voltages were checked using the DCC volt test feature.

During 2003 and 2004 ATS model R4500C receiver/data loggers were used at all sites and during aerial tracking flights. The R4500C combines the receiver and data logger into one unit and has an internal global positioning system (GPS). Operations and programmable settings for the R4500Cs were similar to the receiver/DCC combination. Antennae, solar panel, and other equipment installation remained the same as described in the previous paragraph unless noted elsewhere. An ATS model R4100 receiver was used during aerial tracking flights in 2002 because this receiver model can de-code, or identify, pulse coded tags without having to interface with a DCC. GPS coordinates were stored in a handheld GPS in 2002, which were downloaded to a computer after each flight and then later referenced to the respective tag entry. In aerial mode R4500C receivers record GPS coordinates with tag information when a tag was coded and stored to memory.

ATS model F2110 pulse-coded radio transmitter tags (Eiler 1995; Stuehrenberg et al. 1990) were attached externally to chum salmon (hereafter referred to as tags or tagged fish), on the left side near the posterior edge of the dorsal fin. Tags were equipped with a mortality switch, which activated when a fish remained motionless for approximately 4 h. The tags weigh approximately 15 g, and have an expected operational life in excess of 45 d. In 2002 ten frequencies in 149-150 MHz range with 10 pulse codes each, allowed detection of 100 unique identifiable tags. During 2003 and 2004 we had 16 frequencies in the 150–150.1 MHz range with 10 pulse codes on each frequency.

## STATIONARY RECEIVER SITES

Receiver sites were set up at 3 locations, tested with radio tags, and operated before deployment of any tags (Figure 2). We selected sites based on river morphology, surrounding terrain, and acceptable receiver coverage. At each site water depth was measured perpendicular across the river along transects located at, above, and below each site, and down the middle of the river and along each bank. While conducting depth bathymetry transects, we suspended a tag 20–30 cm above the river bottom to approximate a tagged fish swimming along the river bottom to assess completeness of receiver coverage. All sites were tested again mid season to assess completeness of coverage. In 2003 and 2004 we used 2 or 3 tags on different frequencies

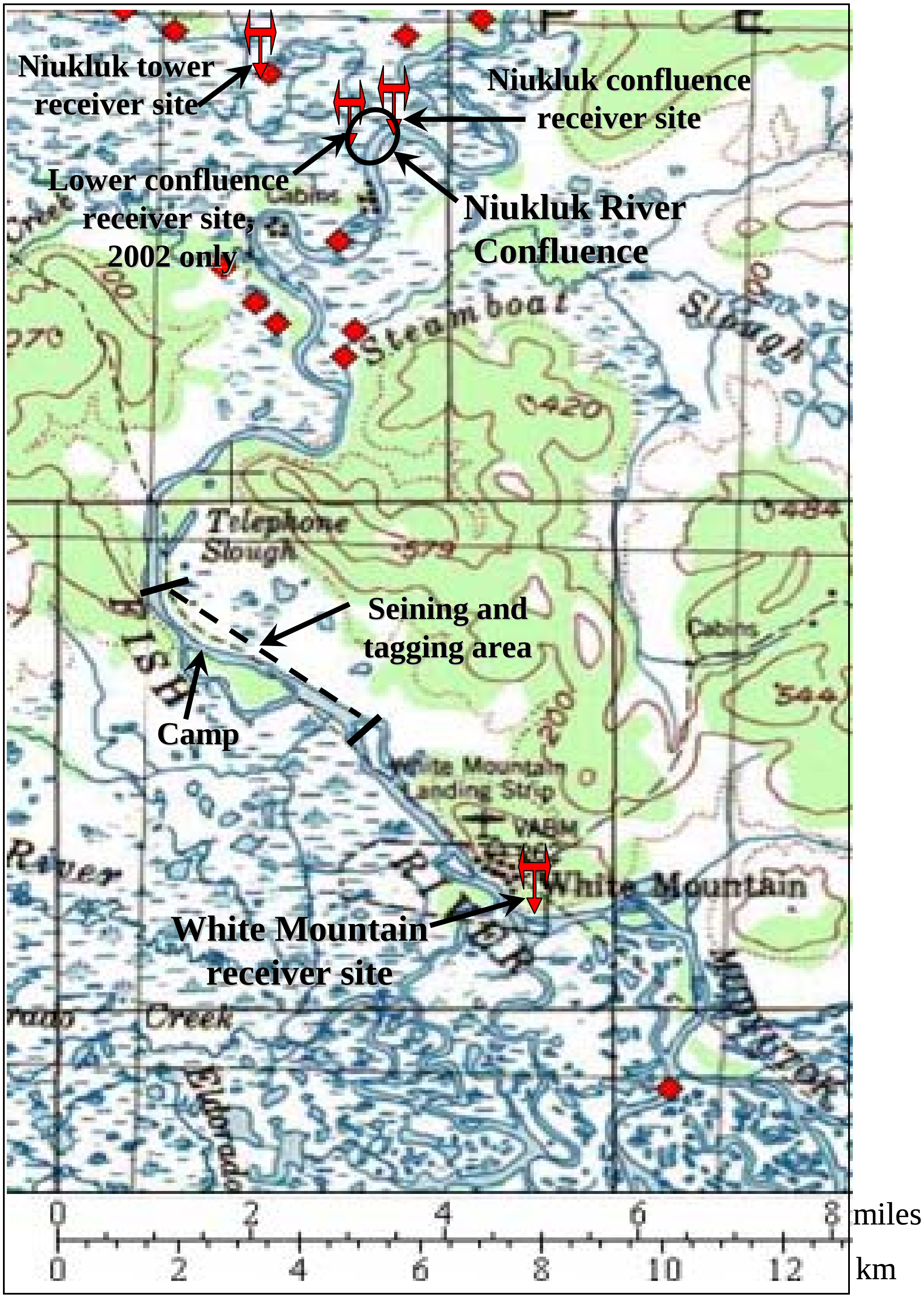



**Figure 2.–**Lower Fish River drainage showing locations of seining and tagging area, stationary receiver sites, Niukluk River confluence and counting tower, 2002–2004.

when testing coverage during installation and each time sites were retested, approximately every 2½ weeks, while personnel were stationed in the field deploying tags and sampling fish.

White Mountain receiver site was located 1 km downriver from the village of White Mountain and was installed on a hillside approximately 15 m above the river (Figure 2). This site had 2 antennae and the receiver was programmed to scan all frequencies and store data continuously. Data were downloaded approximately once a week. Maximum water depths at the White Mountain site were 3.2 m across river transect, 4.0 m at above site transect, and 2.5 m at the below site transect. Objective 6 was assessed at this receiver site: estimate short term tagging mortality and tag retention, along with additional objectives of: 1) record tagged fish that moved downstream, or backed out, after release and were not available to upriver sites, 2) record tagged fish that moved downstream after initially moving upstream and that were recorded at upstream sites, and 3) record tagged fish that backed out but then returned upstream. Fish detected and recorded at this site and not recorded as moving back upstream at a later date were removed from the data.

During 2002 at Fish and Niukluk Rivers confluence, we operated 2 receiver sites to cover both Niukluk River channels (Figure 2). The Niukluk (main) confluence receiver site was used during all study years, and was placed on the east river bank at the confluence, approximately 19 km upriver from the tagging location, and assessed objective 4: estimate run timing and passage rates of chum salmon and compare to Niukluk River salmon timing and rates, and objective 6: mortality and tag retention. Niukluk confluence site had 3 antennae to monitor fish passage both up (antenna 2) and down river (antenna 1) in Fish River and up Niukluk River (antenna 3). Lower Niukluk (secondary) confluence receiver site was located in the lower Niukluk River channel in 2002 only and was approximately 100 m up the secondary channel and approximately 18 km upriver from the tagging location and had 2 antennae; antenna 1 for Fish River (no direction) and antenna 2 up Niukluk side channel. In 2002, both Niukluk receiver sites were programmed to store individual tag data every 3 minutes initially, and later to store every 15 minutes. Water depths were shallow at both Niukluk confluence sites and maximum depths encountered during all bathymetry transects were 3–3.5 m in Fish River and 2.5 m in Niukluk River. Both receiver sites were downloaded at approximately 10 d intervals.

The Niukluk River counting tower receiver site was operated in 2003 and 2004 only (Figure 2) and assessed objective 1: estimate the proportion of chum salmon fitted with radio tags in the lower Fish River that migrate upriver and pass the Niukluk River counting tower, and objective 4: run timing and passage rates. The antennae (#1 down and #2 up river) and solar panel were mounted on the counting tower structure. Niukluk tower site was programmed to store tag data continuously.

## TAGGING AND AGE, SEX, AND LENGTH SAMPLING

Chum salmon were captured using a 45 m (150 ft length by 2¼ in mesh) beach seine. The lower end of our seining area was approximately 3 km above White Mountain village, and extended upriver for approximately 5 km (Figure 2). After both ends of the seine were pulled on shore, we anchored our boat off shore in 1 m deep water. We then pulled the top of the offshore side of the seine over the side of the boat forming a “net pen” to hold fish while tagging and sampling. Chum salmon were netted and placed into a tagging/sampling cradle, modified from Larson (1995); a sliding meter stick was attached outside the cradle for length measurements, and side notches were deeper for tagging and scale collection. During netting and while sampling and tagging, fish remained under water except when the back of the cradle was lifted out of water to attach a tag or collect scales. All fish were released at the seining locations without further holding. Tag deployment schedules were determined from historic chum salmon run timing in Kwiniuk and Niukluk rivers. Since we did not have any timing data for Golovnin Bay or lower Fish River, we adjusted tagging schedules to approximate a bell shaped curve. Tags were scheduled to be deployed every other day, to allow fish previously tagged to migrate upriver out of the seining area and to possibly avoid recapture the following day. The sample number (tagging) was calculated using Tortora's method in which the simultaneous 95% confidence interval is within 10% of the true range. Tortora's formula derived a sample number of 144, and then allowing for tag loss the sample size was set at 160. During 2002, first year feasibility, the Norton Sound Salmon Research and Restoration fund Steering Committee approved 100 radio tags, the initial project feasibility plan included only 25 tags.

Tortora (1978) Method:

$$n = 1 + \text{int}\left(\frac{N \cdot s^2 \cdot z_{a/2k}^2}{(N-1) \cdot d^2 + s^2 \cdot z_{a/2k}^2}\right) \quad (1)$$

where:

$z$ = z-value from normal distribution N(0,1),

$a$ = alpha value (alpha = 0.05 = 95%),

$d$ = desired CI distance at 1-alpha %,

$k$ = number of categories (age class), and

$s^2$ = maximum variance = 0.5·(1-0.5) = 0.25.

Chum salmon tagging followed yearly schedules unless insufficient numbers of fish were captured and tagged, then seining and tagging continued during following days until numbers to be tagged were achieved. Only healthy vibrant fish minimally impacted by capture and with no external wounds were tagged. Yearly tagging goals were 100 in 2002, and 160 for both 2003 and 2004. All tagged fish were also sampled for ASL except during 2002 when we only sexed and measured tagged fish to reduce handling and additional stress. Tags were activated by removing the magnet and shaking the tag to activate the mortality switch prior to attachment to the fish. Tagging needles were placed over the tag cables, and tags were dipped in a Betadine solution. Needles were inserted through the flesh approximately 2 cm down on left side of body; the anterior needle was inserted between pterygiophore bones near the posterior edge of the dorsal fin, and the second needle was inserted through musculature posterior of the dorsal fin (Barton 1992). Next, needles were removed and Peterson disk tags and sleeves were placed over the protruding cables, held firmly against the fish, and sleeves were crimped tight on the cable and excess cable removed (Winter et al. 1978). The anterior disk tag was sequentially numbered so if a fish was later caught or released, a record would exist. ADF&G posted an informational letter at several locations in White Mountain and Nome explaining the project and asking people to please release tagged fish, and to record tag number, date, time, and location where the fish was released or harvested. We recorded tag information and date and time tagged, along with ASL information for each fish. A receiver/DCC was in the tagging boat during tagging, with a coaxial cable suspended overboard as an underwater antenna (10 cm of insulation was stripped from the underwater end) (McCleave et al. 1977; Solomon 1982). As fish were tagged and released the receiver automatically recorded all tag and time information which was later checked against written records for correctness and additionally as a check to ensure the tag was active with the correct frequency and pulse code. Tags were released in sequence by pulse code then frequency. The lowest pulse code tags were all released in order by increasing frequency; then the second pulse code tags were released in order by increasing frequency, etc. until all tags were deployed.

Additional chum salmon were seined and sampled for ASL composition. ASL sampling goals were 3 pulses of 160 fish each during both 2002 and 2003, and 3 pulses of 120 fish during 2004, with pulses representing early, middle, and late portions of the run. This sample size was selected so that simultaneous 95% confidence interval estimates of age composition proportions would be no wider than 0.10 (Bromaghin 1993), and to account for unusable scales the sample size was increased an additional 8 to 9%. Each pulse sample was used to estimate ASL composition of the run for a given temporal stratum. For ageing, one scale was collected from the primary growth area (Koo 1955); left side of fish, 3 scale rows above the midline along a line from the trailing edge of the dorsal fin to the leading edge of the anal fin. Scales were cleansed of slime and placed on labeled gummed cards. The gummed cards were later pressed onto acetate cards with a scale press, and read with a microfiche scale reader for age determination (Tobias et al. 1994). Salmon ages are reported in European notation (e.g. age-0.4 chum salmon). The first digit refers to the freshwater age not including the year spent in gravel; second digit is the ocean age. Sex is determined from visual observations such as body shape, vent, and kype development. Length was measured from mideye to tailfork (METF) within 0.5 cm. Standard methods were used to estimate ASL compositions and means.

## AERIAL SURVEYS

During aerial telemetry surveys, tagged fish locations were recorded to within 0.5 km accuracy. Final destinations of tagged fish were assigned to the most upstream location where a fish was recorded. Tags were not assigned a final destination if only located once during aerial surveys or if recorded receiver site data was contradictory to aerial survey records. Two Yagi antennae were attached to the survey plane; each was mounted side looking with a 30° tilt down from horizontal on the aircraft wing lift strut (Gilmer et al. 1981; Kenward 1987). An aircraft switch box inside the fuselage (connected to both antennae) allowed the observer to switch between left, right, or both antennae to better locate the direction of tagged fish (Winter et al. 1978). During 2002, when a tagged fish was identified by the R4100 receiver, the frequency and pulse, date and time, mortality if activated, and river location was recorded in the aerial survey log. Latitude and longitude of each coded tag was stored in a GPS receiver by the aircraft pilot upon request of the observer. On subsequent scan cycle, if the tag signal strength was greater than previous cycle, new coordinates were stored. If the receiver was not able to decode a tag, the antenna switchbox was used to determine which antenna had the strongest reception; if we had already passed the fish, the plane proceeded back until the tag was identified. Receivers were set to scan a frequency for 4 s, which allowed all frequencies to be scanned within 1 minute if no tags were received. If a tag signal was received, scanning was paused until the tag was decoded, and if multiple tags on same frequency were received the plane would circle until all tags were decoded. During 2003 and 2004 surveys, a GPS antenna was connected to the R4500C receiver and allowed coordinates to be stored with each tag record. The R4500C stored all tag data and date and time data when the observer keyed the store button on receiver. All data (except GPS coordinates) was also recorded in the written survey log. Final GPS coordinates (2003 and 2004) for each fish for plotting on maps were averaged coordinates from the highest received tag signal strength coordinates at uppermost location.

Aerial telemetry flights were conducted at altitudes of 150–300 m (500–1,000 ft) above ground level; 150 m in areas where numerous tagged fish were received at the same time (such as the confluence of Fish and Niukluk rivers), and 300 m in upper tributaries or areas where fish were widely dispersed. Weather permitting, 2 tracking surveys were conducted most weeks; one survey covered Niukluk River and tributaries, Fox Creek, and lower Fish River (below Niukluk confluence), while the other survey covered Fish River above Niukluk confluence and upper drainage tributaries. Length of the main river and tributary drainages exceeded aircraft range to cover the whole drainage during one flight. Upper Fish River surveys were flown to determine tributary distribution and spawning timing, to locate primary spawning areas, and as a secondary check of confluence receiver site data. Niukluk River surveys were also conducted for the above reasons, and to determine the number of tagged fish in the Niukluk River for estimating the drainage-wide population, and as a secondary check of Niukluk tower receiver site data. Lower Fish River area surveys were also a secondary check of White Mountain receiver site records. Occasionally we flew along Northern Norton Sound to the head of Golovnin Lagoon when accessing lower Fish River, to monitor for tagged fish that may have exited Fish River drainage and entered more westerly river systems. During all years, surveys flights were conducted using a Piper Super Cub PA-18 aircraft, except for a partial survey on August 7, 2002 using a Cessna 207 aircraft. During 2002, 4 surveys were conducted: July 15, 20, and 27, and the August 7 partial survey. In 2003, we flew 6 tracking surveys: July 11, 14, 21, 24, 28, and 31. During 2004, we conducted 5 surveys: July 17, 22, 25, 30 and August 10. Some tags were recorded during coho salmon enumeration survey flights during September and October 2004.

## MIGRATION RATES AND TIMING

Migration rates and times were computed from Niukluk confluence and Niukluk tower receiver site records. Migration rates were calculated as the difference between date/time tagged and date/time of first record at site on antenna 1 (downriver monitoring). Fish were placed in 4 h time blocks (beginning at midnight) for diel migratory timing, and times were for both the first record (antenna 1) and last record (antennae 2 or 3) at each site for each recorded fish. Passage times at sites were from last record on upriver antennae, and holding time at sites was the difference between first and last records. Entry into Niukluk River was computed from the last record on antennae 3 (tributary monitoring) at Niukluk confluence (main) site and antennae 2 at Lower confluence site (2002 only). Times and rates were also computed by final destination to determine if differences exist; upper Fish River (above confluence) compared to Niukluk River (above tower) spawning fish. Migration rates in km $h^{-1}$ were calculated using 19 km to confluence and 24 km to tower from tagging site, and km $d^{-1}$ was the hour rate expanded to 24 h and was based on average for each site. Additionally, migrations were calculated for fish under 120 h (5d) to confluence and 192 h (8 d) to tower, assuming fish taking longer than these hours were milling and not actively migrating.

## ABUNDANCE ESTIMATE

Peterson's mark–recapture method, as modified by Chapman (1951), and reported in Seber (1982) was used to estimate total Fish River chum salmon population each study year.

The Niukluk River counting tower expanded chum salmon count (a 20 min count each hour is multiplied by 3 to estimate hourly passage; Kohler and Todd 2003) was expanded by the proportion of marked (radio tagged) chum salmon that passed the tower site to estimate abundance. In 2002, Niukluk River tagged fish were all fish recorded at both Niukluk confluence sites as migrating into Niukluk River except for fish located below the tower on aerial tracking surveys and assigned as spawning below the tower. For 2003 and 2004, only tagged chum salmon that migrated past Niukluk tower receiver site for at least 6 days were used in the expansion.

Chapman's estimation:

$$\hat{N} = \frac{(m+1)(c+1)}{(r+1)} - 1 \qquad (2)$$

where:

$\hat{N}$ = estimated chum salmon population in Fish River drainage,

$c$ = recaptured chum salmon sample, not including marked fish,

$m$ = marked and released chum salmon, and

$r$ = marked and recaptured chum salmon.

The variance of total abundance was estimated using the following formula:

$$v(\hat{N}) = \frac{(m+1)(c+1)(m-r)(c-r)}{(r+1)^2(r+2)} \qquad (3)$$

where:

$v(\hat{N})$ = variance of the estimate.

# RESULTS

Receiver/DCC equipment problems were encountered during the 2002 season and did not allow collection of complete records from any site. We used available data records to compute migration times and rates, so rates and times could be off somewhat.

## TAGGING AND AGE, SEX, AND LENGTH SAMPLING

Chum salmon tagging began on June 28 and finished on July 18, 2002 when all 100 tags were deployed (Table 1; Figure 3). Sex ratio of tagged fish was equal in 2002, 50 each. In 2002, counts from more southern Norton Sound drainages indicated chum salmon run timing might be early, so additional tags were deployed the first week. In 2003 tagging began on June 28 and finished July 23, even though only 103 of the 160 available radio tags were deployed. Additional seining was conducted throughout the season by tagging personnel but low numbers of chum salmon were caught. Sex ratio in 2003 was 1.15 male/female, 55 males and 48 females. Between June 26 and July 23, 2004, 162 tags were deployed, and the sex ratio was 0.91 male/female, 77 males and 85 females.

**Table 1.–**Radio tag deployment on chum salmon in the Fish River by date, cumulative tagged, and sex ratio (male/female), 2002–2004.

| Date | No. Tags | 2002 Cumulative | m/f | No. Tags | 2003 Cumulative | m/f | No. Tags | 2004 Cumulative | m/f |
|---|---|---|---|---|---|---|---|---|---|
| 26-Jun | | | | | | | 10 | 10 | 1.0 |
| 27-Jun | | | | | | | | | |
| 28-Jun | 13 | 13 | 0.4 | 2 | 2 | 0.0 | 16 | 26 | 0.5 |
| 29-Jun | | | | | | | 14 | 40 | 1.3 |
| 30-Jun | 6 | 19 | 1.0 | 10 | 12 | 1.5 | 3 | 43 | |
| 1-Jul | | | | 9 | 21 | 0.5 | 7 | 50 | 0.8 |
| 2-Jul | 11 | 30 | 1.2 | 4 | 25 | 0.3 | 10 | 60 | 1.0 |
| 3-Jul | | | | 1 | 26 | | 8 | 68 | 1.0 |
| 4-Jul | | | | | | | | | |
| 5-Jul | 12 | 42 | 0.5 | | | | | | |
| 6-Jul | 16 | 58 | 1.0 | 31 | 57 | 2.9 | 16 | 84 | 1.3 |
| 7-Jul | | | | | | | 6 | 90 | 1.0 |
| 8-Jul | | | | | | | 2 | 92 | 0.0 |
| 9-Jul | 12 | 70 | 2.0 | | | | 3 | 95 | 2.0 |
| 10-Jul | | | | 3 | 60 | 0.5 | 11 | 106 | 1.2 |
| 11-Jul | 10 | 80 | 1.5 | | | | | | |
| 12-Jul | | | | 1 | 61 | 0.0 | 10 | 116 | 0.7 |
| 13-Jul | 10 | 90 | 1.0 | 13 | 74 | 1.6 | 5 | 121 | 4.0 |
| 14-Jul | | | | 12 | 86 | 1.0 | 5 | 126 | 4.0 |
| 15-Jul | | | | | | | 5 | 131 | 1.5 |
| 16-Jul | 5 | 95 | 4.0 | | | | 5 | 136 | 0.7 |
| 17-Jul | | | | 6 | 92 | 1.0 | 3 | 139 | 2.0 |
| 18-Jul | 5 | 100 | 0.7 | | | | | | |
| 19-Jul | | | | 8 | 100 | 0.3 | 6 | 145 | 0.5 |
| 20-Jul | | | | | | | 7 | 152 | 0.4 |
| 21-Jul | | | | | | | 3 | 155 | 0.5 |
| 22-Jul | | | | | | | 4 | 159 | 0.0 |
| 23-Jul | | | | 3 | 103 | 0.5 | 3 | 162 | 0.0 |
| Total | 100 | | 1.00 | 103 | | 1.15 | 162 | | 0.91 |

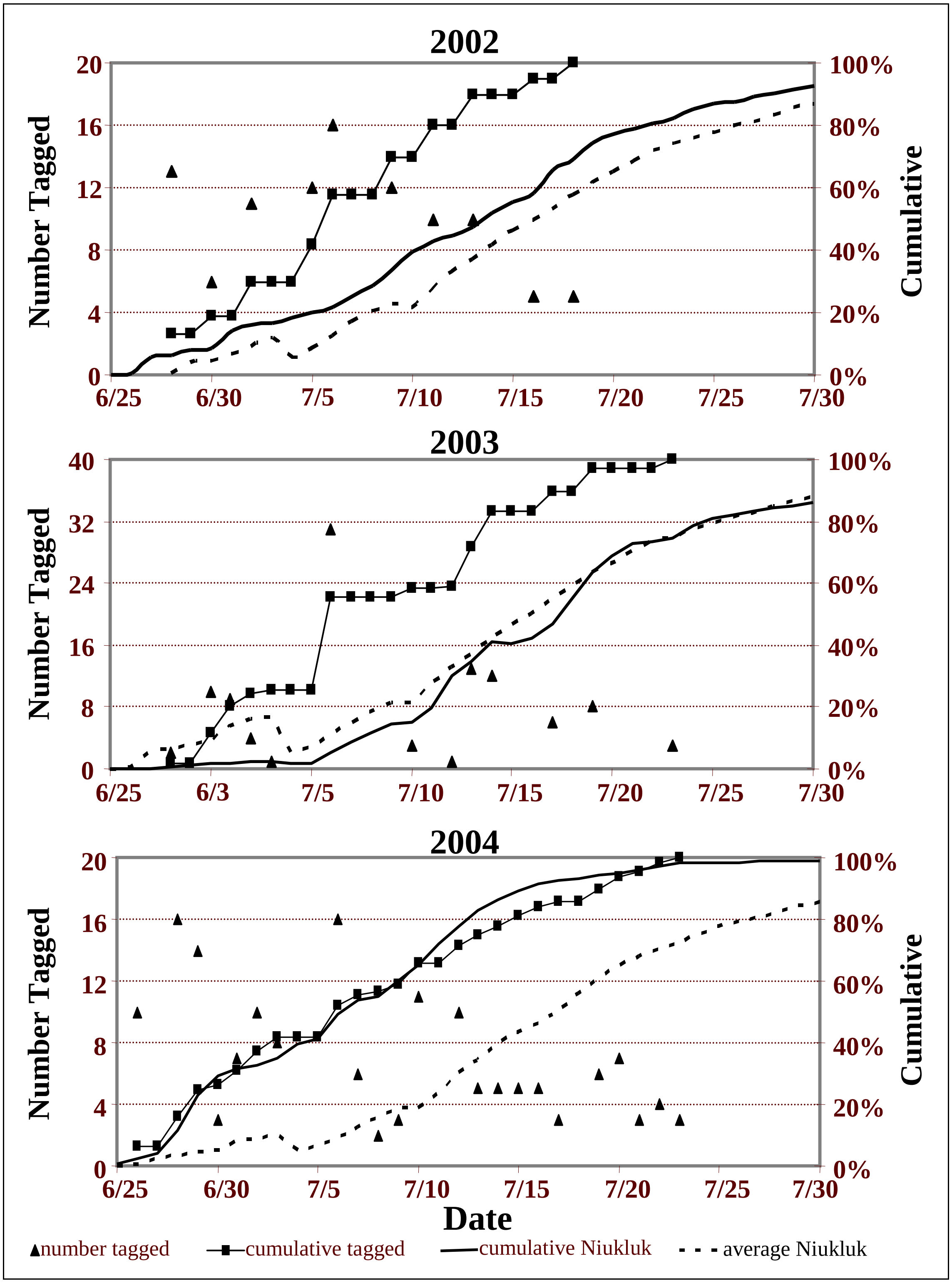



**Figure 3.–**Fish River chum salmon radiotelemetry, number and cumulative radiotagged fish, cumulative chum salmon passage at Niukluk River counting tower, and cumulative average passage (previous 5 years) for 2002, 2003, and 2004.

## 2002

Fish River chum salmon were sampled during 3 pulses for ASL composition over the course of the run during 2002, for a combined total of 472 fish sampled; 403 were aged and these were used in analyses and reported data. Combining all period samples, male mean lengths and age compositions were: 59.2 cm and 67.4% age-0.3, 61.4 cm and 27.6% age-0.4, and 62.8 cm and 5.0% age-0.5 chum salmon (Table 2). Female mean lengths and age composition were: 56.0 cm and 73.0% age-0.3, and 57.5 cm and 23.0% age-0.4 chum salmon. Males comprised 44.9% and females 55.1%. Age composition was 70.5% age-0.3, and 25.1% age-0.4 for aged 2002 chum samples. In comparison, Niukluk River sex composition during 2002 sampling comprised more males, 54.5% and 45.5% female (Table 2), and predominant age class compositions were slightly different, 76.0% age 0.3 and 16.8% age 0.4. Mean length for radio tagged males and females was 61.5 cm and 57.6 cm, respectively (Table 3). Results of parametric and T-test comparisons of two means for mean lengths by sampled group by sex (Fish River radio tagged, Fish River ASL, and Niukluk River ASL) were significant for both males and females in all tests except for female Fish ASL to Niukluk ASL group (Table 3).

## 2003

Only radiotagged chum salmon were ASL sampled (103 tagged) in 2003 and since the tagging goal of 160 fish was not reached, no additional ASL samples were collected (Table 1; Figure 3). Total age class composition of sampled fish (87 fish were aged and data used) was comprised of 39.1% age-0.3, 57.5% age-0.4, and 3.4% age-0.5 fish (Table 4), and sex ratio was 1.18 male/female (males comprised 54.0% and females 46.0%). Male mean lengths and age compositions were 60.1 cm and 38.3% age-0.3, and 62.6 cm and 59.6% age-0.4 chum salmon. Female lengths and ages were 53.8 cm and 40.0% age-0.3, and 57.6 cm and 55.0% age-0.4 fish. Niukluk River 2003 sampled fish were comprised of 58.5% males, and total age class composition was almost split between age 0.3 at 50.8% and age 0.4 at 47.7% (Table 4). Parametric and T-test comparisons of mean lengths were significant for males between the two groups, but not for females (Table 3).

## 2004

We ASL sampled 162 radiotagged chum salmon (Table 1; Figure 3) and 228 additional fish were also sampled during pulse sampling throughout the run in 2004. Age class composition of radiotagged fish (147 fish were aged and data used) was comprised of 5.4% age 0.2, ages 0.3 and 0.4 were almost equal 44.9% and 45.6%, respectively (Table 5), and sex ratio was 0.93 male/female (males comprised 48.3% and females 51.7%). Fish River ASL sampled chum salmon (205 were aged and data used) age composition was comprised of 8.3% age 0.2, 42.4% age 0.3, and 48.8% age 0.4 (Table 6), and sex ratio was 0.99 male/female (males made up 49.8% and females 50.2%). Sex composition for Fish River ASL chum was similar to Niukluk River ASL sampled fish, 52.0% male and 48.0% female in Niukluk (Table 6). Male mean lengths and age compositions for dominant age classes were 58.6 cm and 40.2% age 0.3, and 59.1 cm and 52.0% age 0.4. Female lengths and ages were 54.1 cm and 44.7% age 0.3, and 56.3 cm and 45.6% age 0.4. Age compositions were similar between Fish River radiotagged, Fish River ASL and Niukluk River ASL sampled fish; age 0.4 was dominant age class for all, with Fish radiotag 45.6%, Fish ASL 48.8%, and Niukluk 50.1% (Tables 5 and 6). Parametric and T-test comparisons of mean lengths were significant for males for Fish radiotagged and Niukluk groups, and for Fish radiotagged and Fish ASL females groups (Table 3).

**Table 2.–**Chum salmon ASL, age and sex composition, and mean lengths (METF cm) by age class and sex from Fish River and Niukluk River counting tower samples, 2002.

| | | Brood Year and (Age Class)[a] | | | | |
|---|---|---|---|---|---|---|
| | | **1999 (0.2)** | **1998 (0.3)** | **1997 (0.4)** | **1996 (0.5)** | **Total** |
| Sampling dates: 6/28–7/18/2002 | | | **Fish River ASL** [b, c, d] | | | |
| Male | Percent | | 67.4% | 27.6% | 5.0% | 44.9% |
| | Number | 0 | 122 | 50 | 9 | 181 |
| | Mean length | | 59.2 | 61.4 | 62.8 | |
| | SD length | | 2.528 | 4.036 | 2.969 | |
| | Length range | | 53.0–65.5 | 52.0–69.0 | 59.0–67.5 | |
| Female | Percent | 0.9% | 73.0% | 23.0% | 3.2% | 55.1% |
| | Number | 2 | 162 | 51 | 7 | 222 |
| | Mean length | 52.5 | 56.0 | 57.5 | 58.7 | |
| | SD length | | 2.575 | 2.670 | 5.330 | |
| | Length range | | 48.5–63.5 | 52.0–63.0 | 51.0–65.5 | |
| Total | Percent | 0.5% | 70.5% | 25.1% | 4.0% | |
| | Number | 2 | 284 | 101 | 16 | 403 |
| | Mean length | 52.5 | 57.4 | 59.5 | 61.0 | |
| | SD length | | 3.013 | 3.923 | 4.529 | |
| | Length range | | 48.5–66.5 | 52.0–69.0 | 51.0–67.5 | |
| Sampling dates: 7/3–26/2002 | | | **Niukluk River ASL** [e, f, g, h] | | | |
| Male | Percent | | 74.9% | 16.9% | 8.2% | 54.5% |
| | Number | 0 | 182 | 41 | 20 | 243 |
| | Mean length | | 58.7 | 60.8 | 62.1 | |
| | SD length | | 3.055 | 2.960 | 3.347 | |
| | Length range | | 46.5–68.5 | 50.9–65.5 | 55.4–68.2 | |
| Female | Percent | 0.5% | 77.3% | 16.7% | 5.4% | 45.5% |
| | Number | 1 | 157 | 34 | 11 | 203 |
| | Mean length | 55.7 | 56.1 | 57.7 | 58.5 | |
| | SD length | | 2.497 | 2.430 | 3.376 | |
| | Length range | | 50.0–65.0 | 52.0–63.0 | 55.0–65.0 | |
| Total | Percent | 0.2% | 76.0% | 16.8% | 7.0% | |
| | Number | 1 | 339 | 75 | 31 | 446 |
| | Mean length | 55.7 | 57.5 | 59.4 | 60.8 | |
| | SD length | | 3.088 | 3.142 | 3.751 | |
| | Length range | | 46.5–68.5 | 50.9–65.5 | 55.4–68.2 | |

[a] Brood years corrected from what was previous reported in Todd 2004.

[b] A total of 472 Fish River chum salmon were sampled for ASL data. Only 403 were used for age class composition and corresponding sex and lengths, 69 fish had age errors from scales collected, or scales were missing.

[c] Mean lengths for all Fish River chum salmon samples were 60.1 cm males and 56.5 cm females.

[d] Fish River chum salmon sex composition for all samples was 44.7% male and 53.3% female.

[e] Niukluk River chum salmon lengths were measured in mm, and are reported in cm.

[f] A total of 487 Niukluk River chum salmon were sampled for ASL data. Only 446 were used for age class composition and corresponding sex and lengths, 41 fish had age errors from scales collected, or scales were missing.

[g] Mean lengths for all Niukluk River chum salmon samples were 59.3 cm males and 56.5 cm females.

[h] Niukluk River chum salmon sex composition for all samples was 53.6% male and 46.4% female.

**Table 3.–**Chum salmon length comparisons (METF cm) by sex for Fish River radiotagged, and Fish and Niukluk Rivers ASL sampled chum salmon, 2002, 2003, and 2004.

| | | | **Mean Length (cm)** | | | **Parametric Comparison of 2 Means Reject if ($\tilde{y}_1$-$\tilde{y}_2$) is more than $s^2$** | | | | **T-test Comparison of 2 Means Reject if $t$ greater than $t_a$** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **No.** | **Percent** | | **SD ln.** | **var ln.** | | ***s*** | **$s^2$** | **$\tilde{y}_1$-$\tilde{y}_2$** | | ***s*** | ***t*** | **$\tilde{y}_1$-$\tilde{y}_2$** | |
| **2002** | **Fish River Radiotagged** | | | | | | | | | | | | | |
| Male | 50 | 50.0% | 61.5 | 3.116 | 9.709 | Mfrt-fr | 0.493 | 0.986 | 1.400 | Mfrt-fr | 3.193 | 2.787 | 1.400 | Fish radio to Fish ASL |
| Female | 50 | 50.0% | 57.6 | 2.707 | 7.328 | Ffrt-fr | 0.420 | 0.839 | 1.100 | Ffrt-fr | 2.769 | 2.573 | 1.100 | |
| | **Fish River ASL** | | | | | | | | | | | | | |
| Male | 211 | 44.7% | 60.1 | 3.211 | 10.311 | Mfr-n | 0.299 | 0.598 | 0.800 | Mfr-n | 3.237 | 2.670 | 0.800 | Fish ASL to Niukluk. ASL |
| Female | 261 | 55.3% | 56.5 | 2.781 | 7.734 | Ffr-n | 0.244 | 0.488 | **0.000** | Ffr-n | 2.699 | **0.000** | 0.000 | |
| | **Niukluk River ASL** | | | | | | | | | | | | | |
| Male | 261 | 53.6% | 59.3 | 3.257 | 10.608 | Mfrt-n | 0.485 | 0.969 | 2.200 | Mfrt-n | 3.235 | 4.405 | 2.200 | Fish radio to Niukluk. ASL |
| Female | 226 | 46.4% | 56.5 | 2.601 | 6.765 | Ffrt-n | 0.420 | 0.840 | 1.100 | Ffrt-n | 2.620 | 2.686 | 1.100 | |
| **2003** | **Fish River Radiotagged** | | | | | | | | | | | | | |
| Male | 55 | 53.4% | 61.6 | 3.4983 | 12.238 | Mfrt-fr | 0.516 | 1.032 | 1.648 | Mfrt-fr | 3.448 | 3.231 | 1.648 | Fish radio to Niukluk. ASL |
| Female | 48 | 46.6% | 55.8 | 3.2343 | 10.461 | Ffrt-fr | 0.511 | 1.023 | **0.113** | Ffrt-fr | 2.968 | **0.236** | 0.113 | |
| | **Niukluk River ASL** | | | | | | | | | | | | | |
| Male | 270 | 58.3% | 60.0 | 3.438 | 11.817 | | | | | | | | | |
| Female | 193 | 41.7% | 55.7 | 2.899 | 8.404 | | | | | | | | | |
| **2004** | **Fish River Radiotagged** | | | | | | | | | | | | | |
| Male | 77 | 47.5% | 59.3 | 3.701 | 13.695 | Mfrt-fr | 0.505 | 1.010 | **0.522** | Mfrt-fr | 3.289 | **1.079** | 0.522 | Fish radio to Fish ASL |
| Female | 85 | 52.5% | 55.9 | 3.025 | 9.148 | Ffrt-fr | 0.453 | 0.906 | 0.969 | Ffrt-fr | 3.198 | 2.111 | 0.969 | |
| | **Fish River ASL** | | | | | | | | | | | | | |
| Male | 115 | 50.4% | 58.8 | 2.984 | 8.902 | Mfr-n | 0.355 | 0.709 | **0.372** | Mfr-n | 3.100 | **1.032** | 0.372 | Fish ASL to Niukluk. ASL |
| Female | 113 | 49.6% | 54.9 | 3.322 | 11.034 | Ffr-n | 0.376 | 0.752 | **-0.316** | Ffr-n | 3.067 | **-0.870** | -0.316 | |
| | **Niukluk River ASL** | | | | | | | | | | | | | |
| Male | 207 | 51.6% | 58.4 | 3.162 | 10.000 | Mfrt-n | 0.476 | 0.951 | **0.894** | Mfrt-n | 3.316 | 2.021 | 0.894 | Fish radio to Niukluk. ASL |
| Female | 194 | 48.4% | 55.2 | 2.909 | 8.460 | Ffrt-n | 0.389 | 0.778 | **0.654** | Ffrt-n | 2.944 | **1.707** | 0.654 | |

Bold numbers are not significant, $a$=0.025, $ta$=1.960.

**Table 4.–**Chum salmon ASL, age and sex composition, and mean lengths (METF cm) by age class and sex from Fish River radiotagged and Niukluk River counting tower samples, 2003.

| | | Brood Year and (Age Class) | | | | | |
|---|---|---|---|---|---|---|---|
| | | **2000 (0.2)** | **1999 (0.3)** | **1998 (0.4)** | **1997 (0.5)** | **1996 (0.6)** | **Total** |
| Sampling dates: 6/28–7/23/2003 | | | | **Fish River Radiotagged [a, b, c]** | | | |
| Male | Percent | | 38.3% | 59.6% | 2.1% | | 54.0% |
| | Number | | 18 | 28 | 1 | | 47 |
| | Mean length | | 60.1 | 62.6 | 62.0 | | |
| | SD length | | 2.259 | 3.781 | | | |
| | Length range | | 57.0–66.0 | 54.0–68.0 | | | |
| Female | Percent | | 40.0% | 55.0% | 5.0% | | 46.0% |
| | Number | | 16 | 22 | 2 | | 40 |
| | Mean length | | 53.8 | 57.6 | 57.8 | | |
| | SD length | | 2.785 | 3.129 | | | |
| | Length range | | 51.0–61.5 | 52.5–63.0 | | | |
| Total | Percent | | 39.1% | 57.5% | 3.4% | | |
| | Number | | 34 | 50 | 3 | | 87 |
| | Mean length | | 57.2 | 60.4 | 59.2 | | |
| | SD length | | 4.030 | 4.307 | | | |
| | Length range | | 51.0–66.0 | 52.5–68.0 | 56.5–62.0 | | |
| Sampling dates: 7/5–8/1/2003 | | | | **Niukluk River ASL [d, e, f, g]** | | | |
| Male | Percent | 0.4% | 50.0% | 48.8% | 0.4% | 0.4% | 58.5% |
| | Number | 1 | 122 | 119 | 1 | 1 | 244 |
| | Mean length | 58.8 | 58.4 | 61.7 | 52.8 | 62.5 | |
| | SD length | | 2.793 | 3.306 | | | |
| | Length range | | 50.0–66.0 | 54.9–69.5 | | | |
| Female | Percent | | 52.0% | 46.2% | 1.7% | | 41.5% |
| | Number | | 90 | 80 | 3 | | 173 |
| | Mean length | | 54.7 | 56.8 | 58.2 | | |
| | SD length | | 2.494 | 3.001 | | | |
| | Length range | | 49.2–60.0 | 50.5–64.2 | 55.5–62.0 | | |
| Total | Percent | 0.2% | 50.8% | 47.7% | 1.0% | 0.2% | |
| | Number | 1 | 212 | 199 | 4 | 1 | 417 |
| | Mean length | 58.8 | 56.8 | 59.7 | 56.8 | 62.5 | |
| | SD length | | 3.249 | 3.997 | | | |
| | Length range | | 49.2–66.0 | 50.5–69.5 | 52.8–62.0 | | |

[a] A total of 103 Fish River chum salmon were sampled for ASL data. Only 87 were used for age class composition and corresponding sex and lengths, 16 fish had age errors from scales collected, or scales were missing.

[b] Mean lengths for all Fish River chum salmon samples were 61.6 cm males and 55.8 cm females.

[c] Fish River chum salmon sex composition for all samples was 53.4% male and 46.6% female.

[d] Niukluk River chum salmon lengths were measured in mm, and are reported in cm.

[e] A total of 463 Niukluk River chum salmon were sampled for ASL data. Only 417 were used for age class composition and corresponding sex and lengths, 46 fish had age errors from scales collected, or scales were missing.

[f] Mean lengths for all Niukluk River chum salmon samples were 60.0 cm males and 55.7 cm females.

[g] Niukluk River chum salmon sex composition for all samples was 58.3% male and 41.7% female.

**Table 5.–**Fish River radiotagged chum salmon ASL, age and sex composition, and mean lengths (METF cm) by age class and sex, 2004.

| | | Brood Year and (Age Class) | | | | |
|---|---|---|---|---|---|---|
| | | **2001 (0.2)** | **2000 (0.3)** | **1999 (0.4)** | **1998 (0.5)** | **Total** |
| Sampling dates: 6/26–7/23/2004 | | | **Fish River Radiotagged [a, b, c]** | | | |
| Male | Percent | 5.6% | 45.1% | 45.1% | 4.2% | 48.3% |
| | Number | 4 | 32 | 32 | 3 | 71 |
| | Mean length | 54.3 | 58.7 | 60.9 | 62.0 | |
| | SD length | | 3.566 | 3.384 | | |
| | Length range | 53.0–56.0 | 48.5–67.0 | 53.0–66.0 | 60.5–63.0 | |
| Female | Percent | 5.3% | 44.7% | 46.1% | 3.9% | 51.7% |
| | Number | 4 | 34 | 35 | 3 | 76 |
| | Mean length | 55.9 | 55.0 | 56.8 | 58.0 | |
| | SD length | | 2.788 | 3.236 | | |
| | Length range | 54.0–57.5 | 45.0–60.0 | 45.5–63.0 | 57.5–58.5 | |
| Total | Percent | 5.4% | 44.9% | 45.6% | 4.1% | |
| | Number | 8 | 66 | 67 | 6 | 147 |
| | Mean length | 55.1 | 56.8 | 58.8 | 60.0 | |
| | SD length | 1.613 | 3.661 | 3.863 | 2.366 | |
| | Length range | 53.0–57.5 | 45.0–67.0 | 45.5–66.0 | 57.5–63.0 | |

[a] A total of 162 Fish River chum salmon were sampled for ASL data. Only 147 were used for age class composition and corresponding sex and lengths, 15 fish had age errors from scales collected, or scales were missing.

[b] 2004 mean lengths for all Fish River chum salmon samples were 59.3 cm males and 55.9 cm females.

[c] 2004 Fish River chum salmon sex composition for all samples was 47.5% male and 52.5% female.

**Table 6.–**Chum salmon ASL, age and sex composition, and mean lengths (METF cm) by age class and sex from Fish River and Niukluk River counting tower samples, 2004.

| | | Brood Year and (Age Class) | | | | |
|---|---|---|---|---|---|---|
| | | **2001 (0.2)** | **2000 (0.3)** | **1999 (0.4)** | **1998 (0.5)** | **Total** |
| Sampling dates: 6/26–7/22/2004 | | | **Fish River ASL** [a, b, c] | | | |
| Male | Percent | 6.9% | 40.2% | 52.0% | 1.0% | 49.8% |
| | Number | 7 | 41 | 53 | 1 | 102 |
| | Mean length | 54.6 | 58.6 | 59.1 | 59.5 | |
| | SD length | 2.322 | 2.785 | 2.742 | | |
| | Length range | 50.0–56.5 | 50.5–63.5 | 52.5–64.0 | | |
| Female | Percent | 9.7% | 44.7% | 45.6% | | 50.2% |
| | Number | 10 | 46 | 47 | | 103 |
| | Mean length | 52.0 | 54.1 | 56.3 | | |
| | SD length | 2.211 | 2.604 | 3.491 | | |
| | Length range | 47.5–54.0 | 49.5–60.5 | 43.0–63.5 | | |
| Total | Percent | 8.3% | 42.4% | 48.8% | 0.5% | |
| | Number | 17 | 87 | 100 | 1 | 205 |
| | Mean length | 53.1 | 56.2 | 57.8 | 59.5 | |
| | SD length | 2.563 | 3.519 | 3.407 | | |
| | Length range | 47.5–56.5 | 49.5–63.5 | 43.0–64.0 | | |
| Sampling dates: 7/5–26/2004 | | | **Niukluk River ASL** [d, e, f, g] | | | |
| Male | Percent | 8.2% | 36.1% | 54.6% | 1.0% | 52.0% |
| | Number | 16 | 70 | 106 | 2 | 194 |
| | Mean length | 54.3 | 57.8 | 59.6 | 54.2 | |
| | SD length | 2.688 | 2.940 | 2.725 | | |
| | Length range | 49.5–61.0 | 49.4–65.7 | 51.6–66.0 | | |
| Female | Percent | 10.1% | 44.1% | 45.3% | 0.6% | 48.0% |
| | Number | 18 | 79 | 81 | 1 | 179 |
| | Mean length | 51.5 | 55.1 | 56.1 | 60.4 | |
| | SD length | 3.014 | 2.555 | 2.556 | | |
| | Length range | 46.0–57.8 | 49.5–61.0 | 50.4–65.2 | | |
| Total | Percent | 9.1% | 39.9% | 50.1% | 0.8% | |
| | Number | 34 | 149 | 187 | 3 | 373 |
| | Mean length | 52.8 | 56.4 | 58.1 | 56.2 | |
| | SD length | 3.154 | 3.049 | 3.161 | | |
| | Length range | 46.0–61.0 | 49.4–65.7 | 50.4–66.0 | 53.4–60.4 | |

[a] A total of 228 Fish River chum salmon were sampled for ASL data. Only 205 were used for age class composition and corresponding sex and lengths, 23 fish had age errors from scales collected, or scales were missing.

[b] Mean lengths for all Fish River chum salmon samples were 58.8 cm males and 54.9 cm females.

[c] Fish River chum salmon sex composition for all samples was 50.4% male and 49.6% female.

[d] Niukluk River chum salmon lengths were measured in mm, and are reported in cm.

[e] A total of 401 Niukluk River chum salmon were sampled for ASL data. Only 373 were used for age class composition and corresponding sex and lengths, 28 fish had age errors from scales collected, or scales were missing.

[f] Mean lengths for all Niukluk River chum salmon samples were 58.4 cm males and 55.2 cm females.

[g] Niukluk River chum salmon sex composition for all samples was 51.6% male and 48.4% female.

## MIGRATION RATES AND TIMING

Tagged fish spawning in Fish River above the Niukluk River confluence and upper drainages migrated to the confluence faster than tagged fish spawning above Niukluk tower for all study years (2002–2004), and weighted average and median were 48.9 h and 39.9 h for above confluence and 57.6 h and 48.0 h for above tower spawning fish (Table 7; Figure 4a). Above confluence spawning fish also held less and passed upriver of the confluence quicker; average 56.5 h (from time tagged to passage) compared to 93.9 h for Niukluk fish. Although migration times were similar to the confluence for 2002 and 2004, equipment (data logger) problems in 2002 prevented recording complete records for all fish so times may be off. Fish also migrated faster to the confluence during 2003, 75% arrived in less than 50 h whereas it took 75 h for 75% in 2004 (Figures 4a and 5). And whereas almost all 2003 above confluence spawning fish had arrived at the confluence in 75 h, all 2002 and 2004 fish had not arrived after 150 h.

Average migration times for tagged fish to, and passage, at Niukluk tower were similar during 2003 and 2004; times to tower were 92.6 h and 98.1 h respectively, and passage was 106.5 h and 107.1 h (Table 7; Figure 4a). For both years, cumulative migration times to the tower were similar; 50% in approximately 80 h, and 75% in less than 125 h (Figure 5). Some fish made several passes up and down at the tower both years before committing upriver to spawn. At both sites median holding hours was much less than averages (Figure 4b). Some tagged fish that migrated to the tower (and some passed) later went back down river to spawn below the tower or in Fish River and tributaries; 5 fish in 2003 and 12 in 2004. This also occurred at the confluence, with many of the down river returning fish going up Fox Creek, which is 2 km below the confluence (Figure 4c).

The calculated average migration rate (km $h^{-1}$) to the confluence was 0.36 ($n$ = 30), 0.56 ($n$ = 45), and 0.34 ($n$ = 75) for 2002, 2003, and 2004 respectively, and the fastest fish each year was 1.5, 1.8 and 1.4. Expanded to km $d^{-1}$ average migrations were 8.7 km, 13.4 km, and 8.1 km $d^{-1}$, and fastest migrating fish were 36.8 km for both 2002 and 2003, and 44.6 km in 2004. For fish < 120 h to confluence km $h^{-1}$ were 0.46 ($n$ = 27) 2002 and 0.40 ($n$ = 68) 2004. All recorded fish in 2003 migrated to the confluence in under 120 h. Migration averages to Niukluk tower were slower than to the confluence and were 0.26 km $h^{-1}$ in 2003 and 0.24 in 2004, and fastest fish were 1.4 and 0.78. Expanded to km $d^{-1}$ averages were 6.2 km for 2003 and 5.9 km for 2004. For fish < 192 h rates were not much faster than average rates and was 0.28 km $h^{-1}$ both years ($n$ = 34 in 2003 and $n$ = 53 in 2004).

Diel migration timing by 4-hour time intervals was similar at both upriver sites and similar to Niukluk River counting tower passage (Figure 6) during all study years. The majority of fish migrated at night from late evening to early morning. Fish migration was lowest from midmorning to early afternoon, 0800–1600 hours. Differences between sites were small except for first and last records for fish recorded at a site that later went back down river to spawn.

Tag deployment timing was earlier than Niukluk tower chum salmon passage during 2002 and 2003 (Figure 3). Cumulative and average (previous 5 year) tower passage were similar during both 2002 and 2003. Tag deployment in 2004 tracked chum salmon tower passage throughout the run, and the 2004 run was earlier than average.

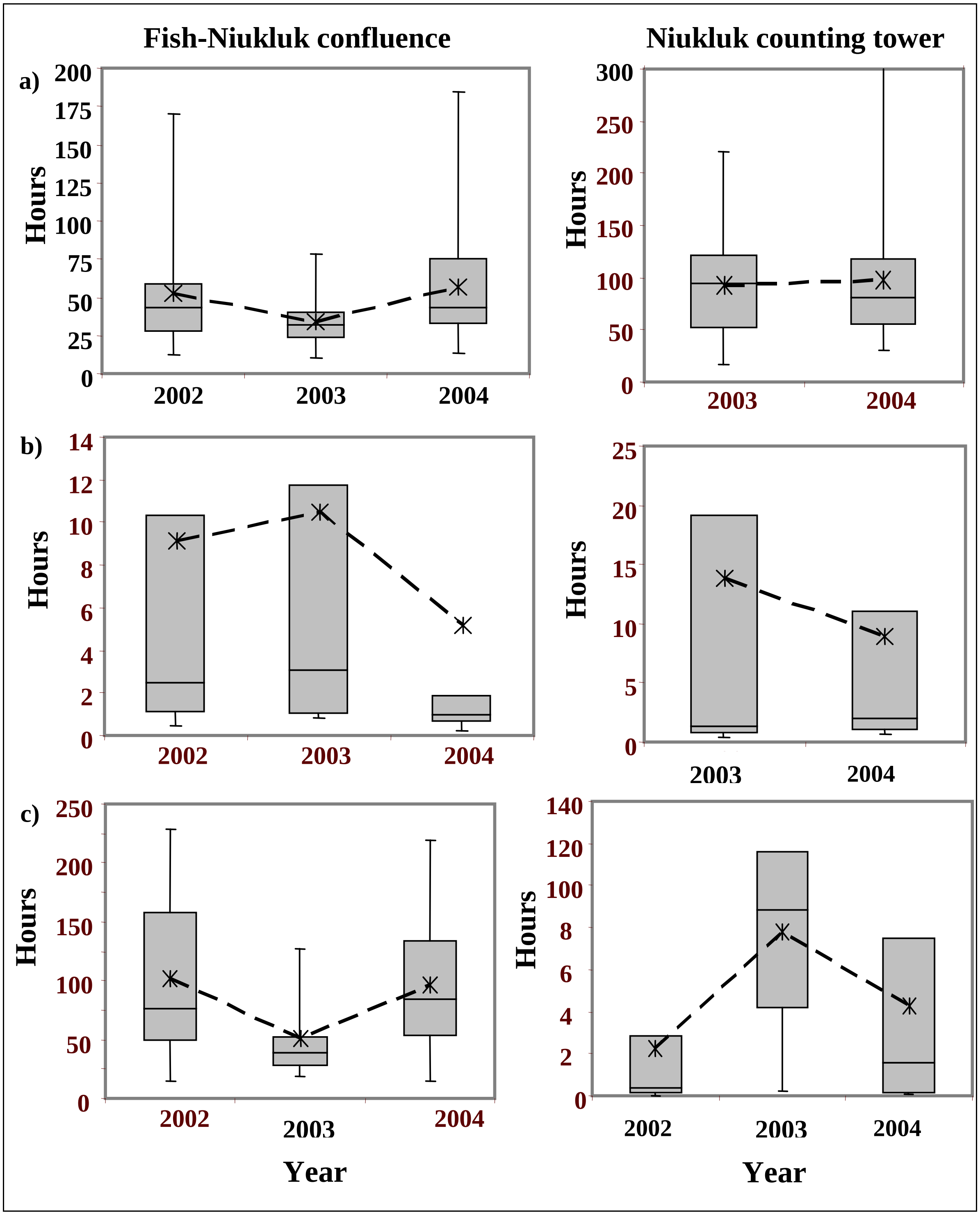
**Table 7.–**Fish River radiotagged chum salmon migration rates in hours, time tagged to arrival and passage at sites by final destination (above confluence or Niukluk tower), 2002–2004 for confluence, and 2003 and 2004 for tower.

| | **To Fish-Niukluk confluence** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 2002 | | 2003 | | 2004 | | Weighted Average | |
| Parameter | confluence | tower | confluence | tower | confluence | tower | confluence | tower |
| *N* | *30* | *14* | *45* | *33* | 75 | *53* | | |
| Mean | 52.2 | 62.2 | 33.9 | 51.2 | 56.6 | 60.4 | 48.9 | 57.6 |
| S.D. | 39.0 | 34.6 | 15.6 | 37.7 | 38.4 | 35.0 | | |
| Median | 43.1 | 53.8 | 32.3 | 37.0 | 43.1 | 53.4 | 39.9 | 48.0 |
| Minimum | 12.4 | 18.1 | 10.2 | 9.1 | 13.2 | 14.0 | | |
| Maximum | 170.1 | 127.8 | 78.8 | 155.6 | 184.9 | 157.0 | | |

| | **Pass Fish-Niukluk confluence** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 2002 | | 2003 | | 2004 | | Weighted Average | |
| Parameter | confluence | tower | confluence | tower | confluence | tower | confluence | tower |
| *N* | *30* | *14* | *45* | *33* | 75 | *53* | | |
| Mean | 61.4 | 109.4 | 44.4 | 89.8 | 61.8 | 92.4 | 56.5 | 93.9 |
| S.D. | 45.7 | 41.4 | 24.8 | 52.3 | 40.6 | 79.0 | | |
| Median | 54.6 | 108.2 | 37.0 | 85.4 | 51.7 | 71.5 | 47.9 | 81.2 |
| Minimum | 21.1 | 50.1 | 12.1 | 13.8 | 13.7 | 14.7 | | |
| Maximum | 184.8 | 185.1 | 154.0 | 224.8 | 185.6 | 361.7 | | |

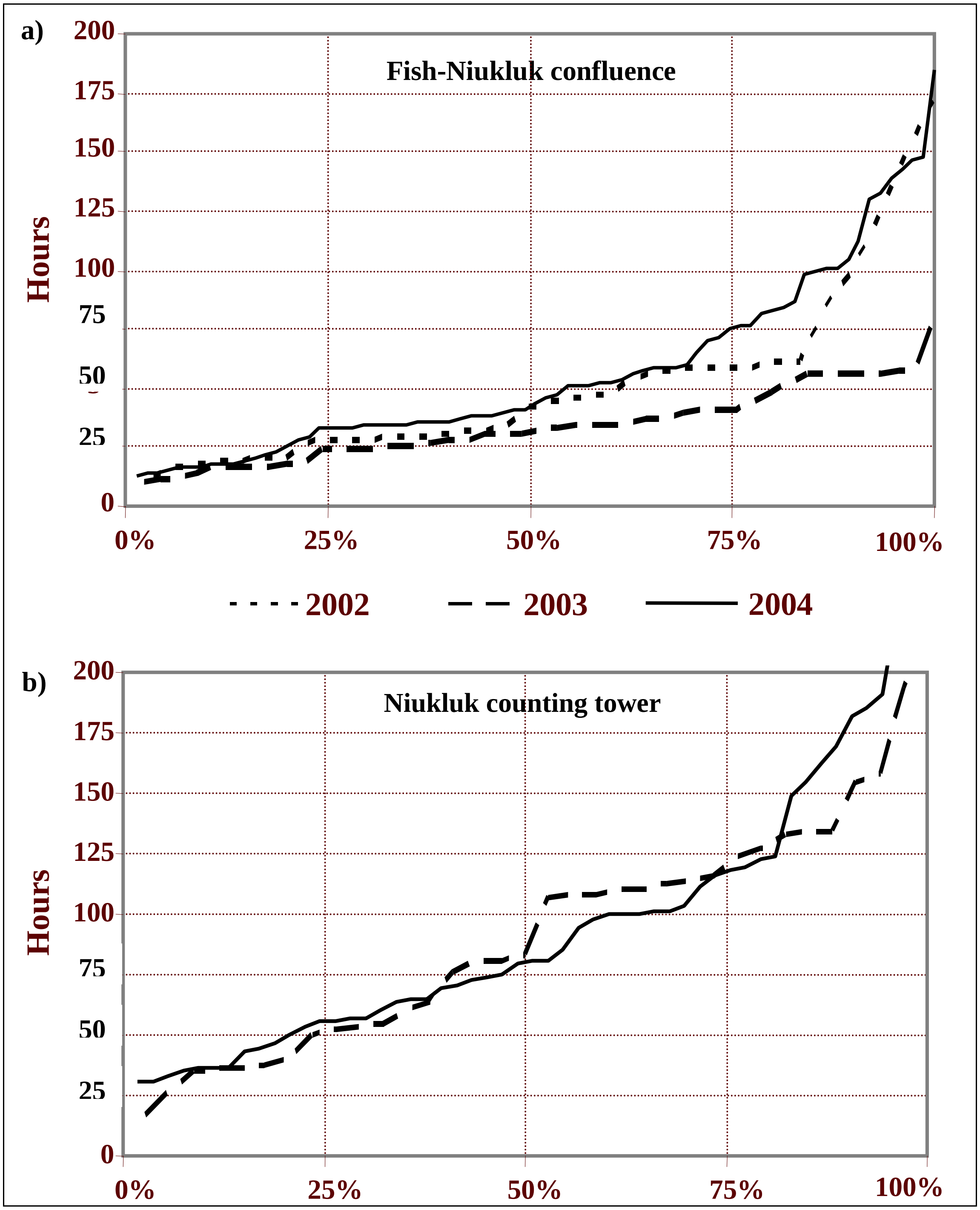
| | **To Niukluk tower** | | | **Pass Niukluk tower** | | |
|---|---|---|---|---|---|---|
| Parameter | 2003 | 2004 | Weighted Average | 2003 | 2004 | Weighted Average |
| *N* | *34* | *53* | | *34* | *53* | |
| Mean | 92.6 | 98.1 | 96.0 | 106.5 | 107.1 | 106.8 |
| S.D. | 48.8 | 63.9 | | 51.7 | 66.4 | |
| Median | 95.1 | 80.3 | 86.1 | 109.2 | 83.2 | 93.3 |
| Minimum | 17.3 | 30.8 | | 28.8 | 32.1 | |
| Maximum | 220.0 | 356.3 | | 223.0 | 357.4 | |

*Note*: Times for 2002 may be off because of receiver problems.



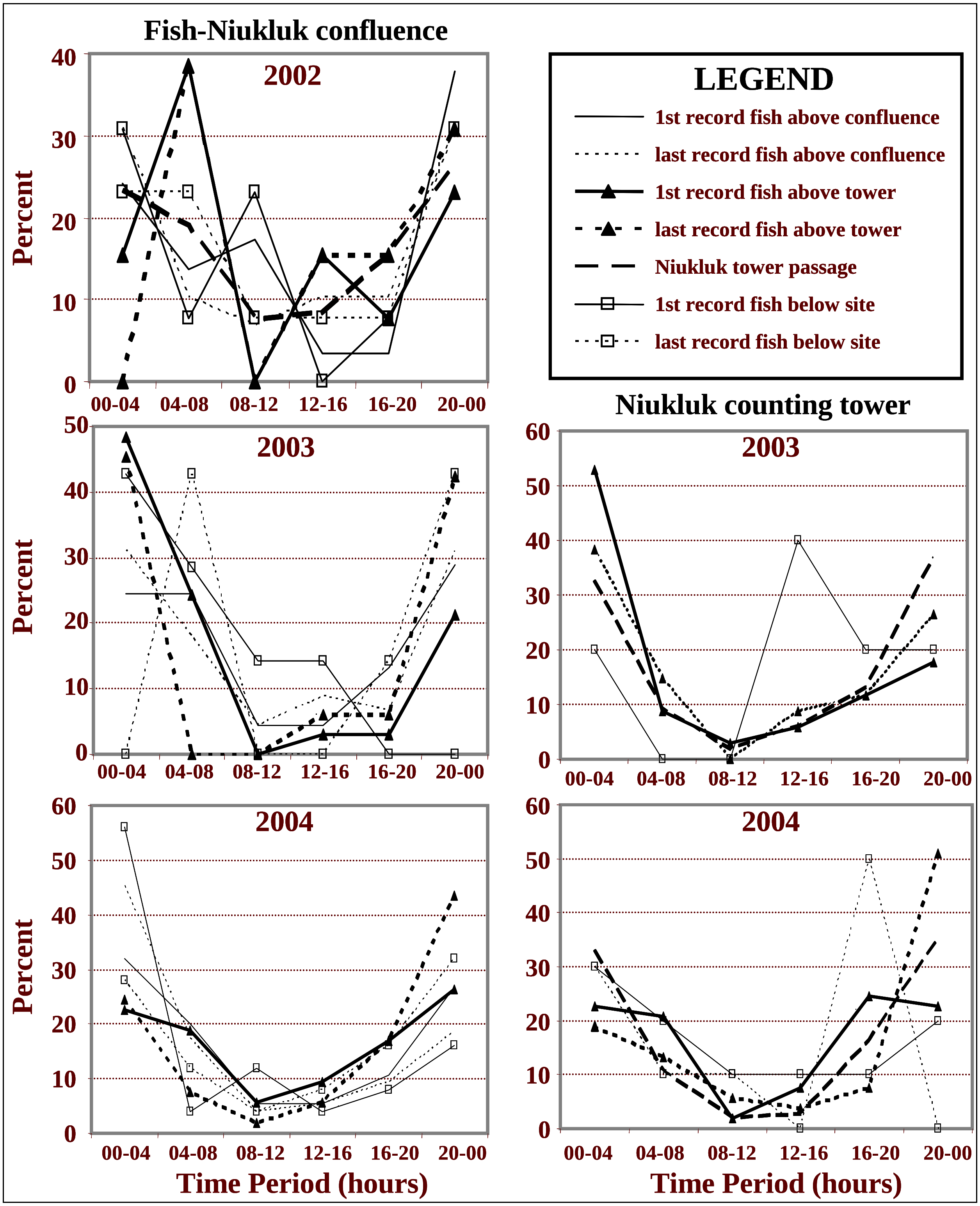

*Note*: The box identifies 50% of the data (25$^{th}$ to 75$^{th}$ percentile), the median is the line across each box, vertical lines represent the range of data (upper range not shown when very large), and the dashed line with asterisks represent the average.

**Figure 4.–**Box-plots of Fish River radiotaggged chum salmon migration rates (a), holding times before upriver migration (b), and holding time for fish that migrated to site but left and spawned downstream (c); Fish-Niukluk rivers confluence and Niukluk River counting tower, 2002–2004.




*Note*: Niukluk tower, chart b, does not show fish greater than 200 hours; one in 2003, and three in 2004.

**Figure 5.–**Cumulative migration rates (hours) for radiotagged chum salmon, from time tagged to first record at Fish-Niukluk rivers confluence 2002-2004 for fish spawning upriver of the confluence (a), and Niukluk counting tower 2003-2004 for fish spawning upriver of the tower (b).




*Note*: First and last records for radiotagged fish by site and final destination, and chum salmon expanded tower passage.

**Figure 6.–**Fish River chum salmon migratory (diel) timing at Fish-Niukluk rivers confluence 2002–2004 and Niukluk river counting tower 2003–2004.

### AERIAL SURVEY DISTRIBUTIONS

Drainage-wide distribution of tagged chum salmon was determined from aerial telemetry survey flights and receiver site records. Tributary proportions were determined using 88 tags in 2002, 96 tags in 2003 and 157 tags in 2004, and 12, 7, and 5 tags respectively, were censored because data from receiver sites and aerial surveys was conflicting or tags were only located once during aerial surveys. Percent of Fish River (not including Niukluk above tower) chum salmon above Niukluk River confluence averaged (weighted) 70.6% for all years, with a low of 62.3% in 2002 and high of 75.0% in 2004 (Table 8). Chum salmon below Niukluk River confluence averaged 29.4%. After Niukluk River, the 2 upper tributaries with the most tagged fish were Boston (18.4% average) and Etchepuk (12.7%) creeks (Figure 7). Prior to this study, Pargon Creek was not thought to be a good chum salmon spawning creek, yet we found an average of 6.6% tagged fish. Fox River (below Niukluk confluence) had the most tagged fish (10.1%) of lower river tributaries (Figure 8). Two tagged fish (one each in 2002 and 2004) migrated below Site 1 after tagging and then migrated up Klokerblok River, which enters Fish River in the lower braided section just above Golovnin Lagoon.

Total Fish River and tributaries (excluding Niukluk above tower) tagged fish weighted average was 66.9% (Table 8). Niukluk River above the counting tower proportion of total tagged chum salmon was similar all 3 years and weighted average was 33.1%; 2002 proportion was 30.7%, 2003 was 34.4% and 2004 was 33.8% (Table 9; Figure 8).

### ABUNDANCE ESTIMATE

We used Carlson's method to estimate Fish River drainage yearly chum salmon escapements for 2002–2004. In 2002 recapture (27) expanded by chum salmon tower counts (33,979) derived an estimate of 107,921 chum salmon with a 95% CI of ± 32,506 (Table 9.) The 2003 abundance estimate was 57,018 with 95% CI of ± 15,211, with tower count 20,018 and recapture of 33 fish. Recapture in 2004 was 53 fish and the tower count was 10,791, which resulted in an estimated 31,421 chum salmon for the entire drainage. The weighed average proportion for all years was 33.1% with SE of 0.020. Using the weighted average and expanding historic tower counts the estimated average abundance of chum salmon for the entire drainage for years 1995 through 2001 was 157,273 and the average tower count for same period was 52,117 (Table 9).

## DISCUSSION AND CONCLUSION

During all 3 project study years, lower than normal river levels were encountered (local residents of White Mountain and Niukluk River resource users; personal communication). Drainage distribution may differ during normal or high water years (C. Lean, former ADF&G Area Management Biologist; personal communication). Also this study should be repeated in 5 years for 1 or 2 years duration to verify if Niukluk River proportion remains similar.

Fish River chum salmon total production, spawning escapement and harvest, and chum salmon age composition would need to be known for enough years to develop brood year tables and escapement goals. The Fish River drainage chum salmon escapement goal will be reviewed by ADF&G for the upcoming 2007 BOF meeting and analyses will incorporate all available data, including our study findings. Accompanying ASL data will allow us to estimate return-per-spawner and quantify spawner success, and determine the proportion of chum salmon migrating to all major tributaries of the Fish River system, and determine main spawning areas. Understanding

**Table 8.–**Radiotagged chum salmon distribution in Fish River drainage by tributary and Niukluk River tagged fish above counting tower from aerial telemetry surveys and stationary receiver site records, by number and percent for 2002, 2003, and 2004, and weighted average for all years.

| 2002 [a] | | 2003 [a] | | 2004 [b] | | Weighted Average [c] | Tributary or Location |
|---|---|---|---|---|---|---|---|
| 1 | 1.6% | 3 | 4.8% | 5 | 4.8% | 3.9% | Omalik, Mosquito, Rathlatulik |
| 3 | 4.9% | 4 | 6.3% | | | 3.1% | Lava,Telephone, Windy |
| 13 | 21.3% | 15 | 23.8% | 14 | 13.5% | 18.4% | Boston |
| 11 | 18.0% | 4 | 6.3% | 14 | 13.5% | 12.7% | Etchepuk |
| 1 | 1.6% | 4 | 6.3% | 5 | 4.8% | 4.4% | Cache |
| 4 | 6.6% | 6 | 9.5% | 5 | 4.8% | 6.6% | Pargon |
| | | 3 | 4.8% | 4 | 3.8% | 3.1% | Upper Fish River Flats |
| 2 | 3.3% | 5 | 7.9% | 7 | 6.7% | 6.1% | Fish Flats (not assigned to tributary) |
| 3 | 4.9% | 1 | 1.6% | 24 | 23.1% | 12.3% | above Niukluk River confluence |
| 38 | 62.3% | 45 | 71.4% | 78 | 75.0% | 70.6% | **Total Fish River above Niukluk confluence** |
| | | | | | | | |
| 2 | 3.3% | 5 | 7.9% | 10 | 9.6% | 7.5% | Fish-Niukluk confluence and below |
| 6 | 9.8% | 4 | 6.3% | 6 | 5.8% | 7.0% | Niukluk River below tower |
| 5 | 8.2% | 9 | 14.3% | 9 | 8.7% | 10.1% | Fox |
| 9 | 14.8% | | | | | | Fish River (not assigned tributary or river "area") |
| 1 | 1.6% | | | 1 | 1.0% | 0.9% | Klokerblok |
| 23 | 37.7% | 18 | 28.6% | 26 | 25.0% | 29.4% | **Total Fish River at or below Niukluk confluence** |
| | | | | | | | |
| 61 | 69.3% | 63 | 65.6% | 104 | 66.2% | 66.9% | Fish River and tributaries |
| 27 | 30.7% | 33 | 34.4% | 53 | 33.8% | 33.1% | Niukluk River above counting tower |
| 88 | | 96 | | 157 | | | **Total "good" tags** |
| | | | | | | | |
| 12 | | 7 | | 5 | | | **Censored radio tags** |

[a] Aerial telemetry surveys not conducted drainage wide after July 31.

[b] First aerial telemetry survey conducted 17 July.

[c] Averages except Fish River total and Niukluk above tower are percent of Fish River total fish and do not include Niukluk River fish above counting tower.

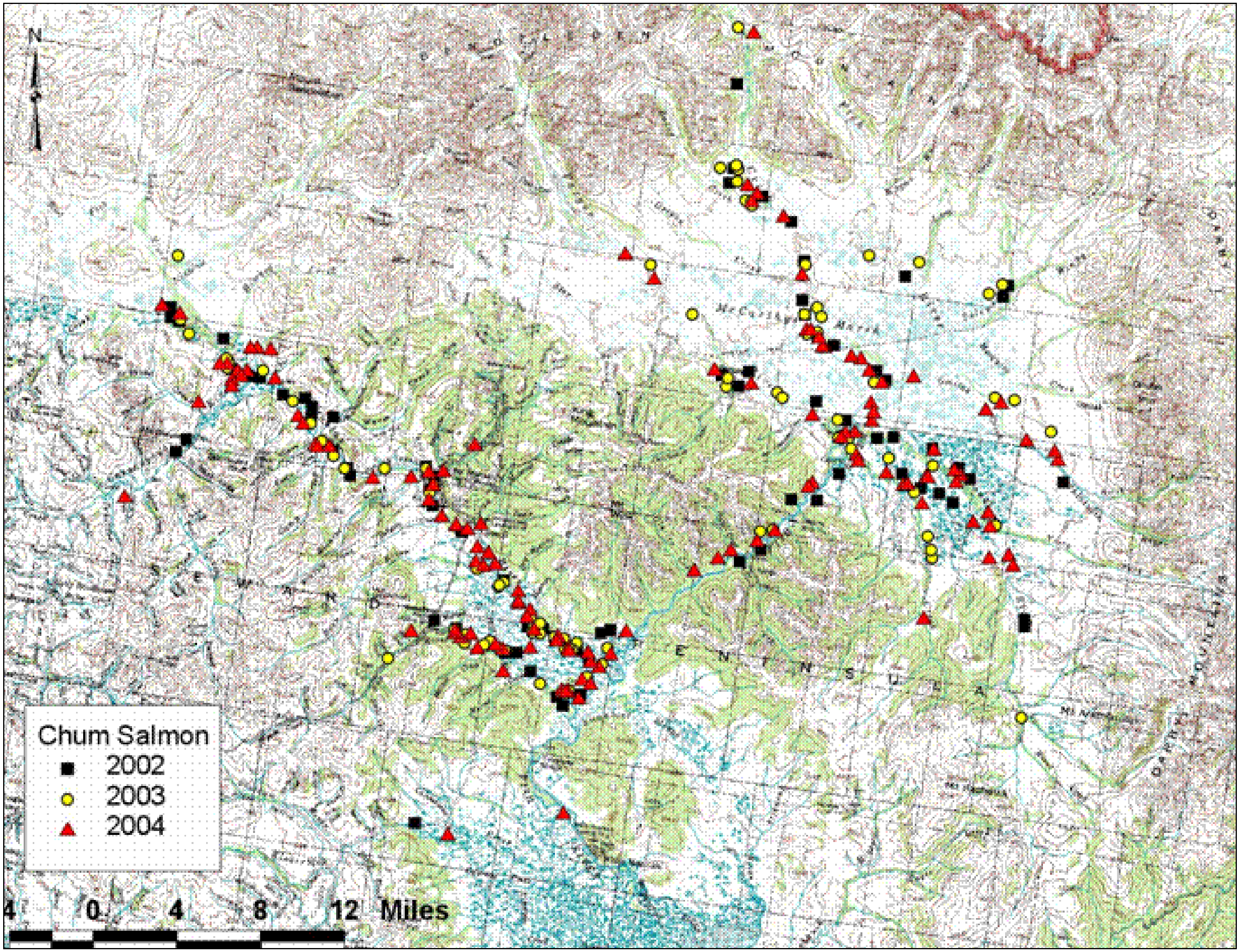



**Figure 7.–**Fish River drainage showing final locations for radiotagged chum salmon from aerial survey tracking flights, 2002–2004.

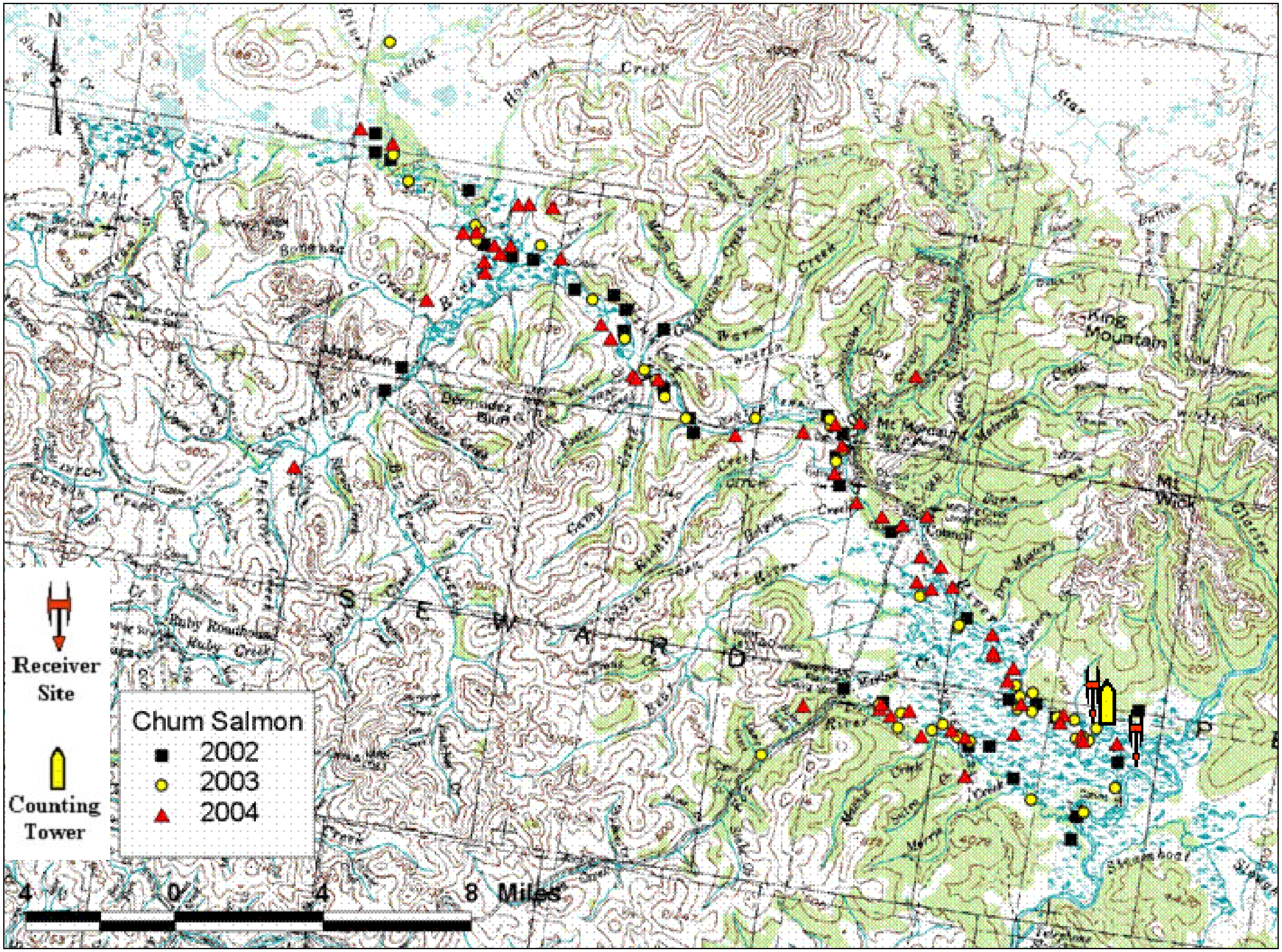



**Figure 8.–**Niukluk River drainage and Fox River showing final locations for radiotagged chum salmon from aerial survey tracking flights, 2002–2004, and Niukluk counting tower and telemetry receiver sites.

**Table 9.–**Fish River chum salmon mark–recapture (radiotagged) results with drainage-wide abundance estimates and 95% confidence interval (95% CI ±) for years 2002–2004 (Top). Historic Niukluk River counting tower expanded chum salmon passage and Fish River drainage estimated abundance; tower counts expanded by weighted average (33.1%) recapture for years 1995–2001 (Below).

| | 2002 | 2003 | 2004 | Weighted | |
|---|---|---|---|---|---|
| Marked | 88 | 96 | 157 | | |
| Recapture | 27 | 33 | 53 | | |
| % Recapture | 30.7% | 34.4% | 33.8% | 33.1% | average |
| Tower count | 33,979 | 20,018 | 10,791 | 0.0004 | var |
| Abundance estimate | 107,921 | 57,018 | 31,421 | 0.020 | SE |
| 95% CI ± | 32,506 | 15,211 | 6,720 | 3.9% | 95% CI ± |

Niukluk tower chum salmon counts and estimated drainage abundance

| Year | Tower count | Drainage estimate |
|---|---|---|
| 1995 | 86,333 | 260,527 |
| 1996 | 80,121 | 241,781 |
| 1997 | 57,304 | 172,926 |
| 1998 | 45,587 | 137,568 |
| 1999 | 35,240 | 106,344 |
| 2000 | 29,572 | 89,239 |
| 2001 | 30,662 | 92,529 |
| 2002 | 33,979 | 107,921 |
| 2003 | 20,018 | 57,018 |
| 2004 | 10,791 | 31,421 |
| Average 1995–2001 | 52,117 | 157,273 |

spawning ground usage, spawning success, and freshwater survival are important to understanding productivity. In the future, we may use knowledge of habitat availability and usage for more precise escapement goal development. In addition, Northwest Alaska summer chum salmon have high genetic similarity, therefore sampling has not been able to define or determine sub-stocks to drainages (Seeb and Crane 1999), which precludes offshore marine studies for stock separation and abundance estimators.

The chum salmon abundance proportions above Niukluk River counting tower were similar during the 3 study years, 30.7% to 34.4% with weighted averaged 33.1% (Table 8). This similarity in proportions increases our confidence that we can now reliably estimate the whole drainage abundance, although expanding prior years tower data back to 1995 to estimate abundance should be preceded with some caution. Differences in mean lengths between sampled groups were small and although statistically significant may not be biologically significant, and may be a factor of small sample sizes; the data does not determine any significant biases in sampling or tagging.

Tagging was approximately a week earlier than Niukluk River chum salmon run timing (based on counting tower passage) at the beginning and finished approximately 2 weeks earlier during 2002 (Figure 3). In 2003, tagging was similar to Niukluk at the beginning and finished about 1½ weeks early, and during 2004 tagging closely tracked Niukluk passage. Based on our study results of migration rates and holding patterns tagging should be 4–5 days ahead of tower passage.

During 2003, we were not able to reach our tagging goal of 160 fish even with increased seining effort and therefore additional fish were not sampled for ASL. 2003 was an odd year and pink salmon abundance was low, the tower count was 75,000, so it was not an effect of too many pink salmon hampering our ability to catch chum salmon but low chum salmon abundance. In 2004, over 975,000 pink salmon were counted past the tower, yet we were able to achieve our tagging goal and almost meet our ASL pulse sampling goals. Our estimated drainage-wide abundance in 2004 was approximately half of the 2003 estimate. Three of the four telemetry project field personnel were on the project all years and their assessment of run strength (based on time spent seining, number of seines conducted, and visual observations) was that the 2004 run was similar in strength to the 2003 chum salmon run; same areas were seined all study years. Also in 2003, management staff closed Subdistrict 2 marine waters and Fish and Niukluk rivers to subsistence fishing for chum salmon mid July because of the weak run, and additional aerial enumeration surveys confirmed low abundance. Because inriver subsistence fishers were targeting pink salmon in 2004, no subsistence restrictions were implemented, even though chum salmon assessments again showed another weak run. Chum salmon counts past the tower in 2004 could have been underestimated because of a very large pink salmon return and possibly misidentification of fish by new (inexperienced) counting personnel, although 3 other even years had a very large pink salmon return; 1.2 million in 1996, 1.6 million in 1998, and 0.9 million in 2000.

Niukluk River chum salmon migrated slower and held longer at Fish-Niukluk confluence than chum salmon spawning in Fish River drainages above the confluence: chum salmon bound for Niukluk River held 1.5 d on average and upper Fish River drainage fish held less than ½ d at confluence (Table 7). In future years if a run is very low, and the tower passage run timing model predicts final escapement will be way below the established minimum escapement goal, management staff may want to consider possibly restricting harvests at Fish-Niukluk rivers confluence as a stock protection or conservation measure, so fishers harvest migrating and not holding fish. Average holding durations are relatively short and may not affect overall harvest totals.

The new R4500C receivers used during 2003 and 2004 were easier to use, changing preprogrammed settings were similar, and downloading recorded data with the ATS program WinRec to a laptop computer was much easier and faster and also allowed the current receiver setting (scan time, store time, number of antennae, etc.) to be downloaded along with the data. In addition, GPS coordinates were stored with each record when recording in aerial mode; when aerial or boat tracking.

External tag placement was easily accomplished and took approximately 2 to 2 ½ minutes to dip net a fish in the seine, place in cradle, tag and release, and record data. Wuttig and Evenson (2002) found no differences in coho salmon tagged with external or internal (esophageal or implanted) radio tags by proportion tagged that resumed migration upriver or average time to recover and resume migration after tagging. Brown and Eiler (2000) found internal tagged female inconnu *Stenodus leucichthys* traveled greater distances, delayed less after tagging, and a greater proportion resumed upriver migration than external tagged fish. Only a few deployed tags remained near the seining and tagging location, which indicates the tags may have dropped off; while other studies using internal tags report regurgitated tags (Evenson and Wuttig 2000; Wuttig and Evenson 2002). Because we only had 2 upriver receivers (19 km confluence and 24 km tower), we could not accurately determine daily migration rates, and calculated the rate based on time tagged to time recorded at receivers (km $h^{-1}$) and expanded the km $h^{-1}$ to 24 h for km $d^{-1}$ distance. Cappiello and Bromaghin (1997) calculated migration rates for spaghetti tagged chum salmon captured in fish wheels at 26 km $d^{-1}$, which is much higher than yearly averages we found but lower than the fastest migrating fish.

In summary, this study was successful: a) fish were easily seined, b) external tag placement did not seem to adversely affect fish behavior or migration, and c) distribution throughout the drainage was documented from the aerial tracking surveys, although we did not achieve our sampling and tagging goals each year. Project objectives were also achieved: a) the proportion of tagged chum salmon that migrated up the Niukluk River was determined from receiver site records and aerial telemetry flights, and expanded to estimate drainage-wide escapement, b) some new spawning locations were documented in most tributaries from aerial telemetry flights, c) some spawning locations were determined to be more important than previously thought, and d) age, sex, and length compositions were documented for main Fish River chum salmon and compared to Niukluk River chum salmon.

## ESCAPEMENT DATA AND MANAGEMENT IMPLICATIONS

The Norton Sound District chum salmon management plan as adopted by the Alaska Board of Fisheries for Subdistrict 2, Golovnin Bay, regulations (5 AAC 04.390. (b) (1) (B) and (C)) states that the commercial fishery harvest may not exceed 15,000 chum salmon before ADF&G's mid July run assessment, and may occur only if the projected escapement goal will be achieved and harvestable surplus will exceed subsistence needs. ADF&G assessment of run strength is partially based on more southern and eastern Norton Sound drainages with earlier run timing than Fish River, and parent year escapements.

Aerial survey assessments for chum salmon in Fish River drainage are usually "poor" because chum salmon color is not contrasting enough against river bottom color; tannin water coloration and normal higher water levels than were encountered during our study years; and more numerous pink salmon masking our ability to count chum salmon (normally during even years). During even years surveys are flown earlier to try and get a chum salmon count before increasing pink salmon numbers mask our ability to count chum salmon. Aerial survey data is used if the overall survey rating is 1 or 2; excellent or good. On Fish River we have 37 years of surveys (from 1963 through 2004) of which 28 were rated 1 or 2 (five rated 3 or had no rating), and 12 were masked by pink salmon (pink salmon count greater than 3 times chum salmon count) (Appendix A2). Niukluk River had 38 survey years which 24 were considered useable, 10 years of chum salmon counts were masked by pink salmon. In 2003 the Niukluk River cumulative tower passage was 8,191 by 14 July and the peak aerial chum salmon count was 2,315 (15 July) of which 999 were between confluence and tower, so above tower survey count was 1,316 or 16.1% of tower count. Again in 2004 the aerial survey count was very low, only 173 on 14 July survey and 13 July cumulative tower count was 8,916. The pink salmon aerial count of over 275,000 masked our ability to count chum salmon during 2004.

Our ability to assess chum salmon run strength in season for opening commercial fishing is not very good. The early 15,000 allowable harvest is usually a best guess by management and research staff that the run will be average or above and is supported by more southern and easterly runs and parent year escapements. Aerial surveys are more an initial indicator and not a "good" tool for overall abundance, and when fish passage at Niukluk tower indicates the run to be above sufficient abundance to open further periods it may be too late. Chum salmon travel time from Golovnin Bay to White Mountain is currently unknown, and then adding an additional 5 d (based on our study results) to Niukluk tower, it is probable that 7 d minimum would pass before we could confidently assess run strength. If we assess run strength based on the historic 25% cumulative passage the earliest date would be July 11, and after this date fish flesh may be of lower quality than buyers will accept. Also, currently there is no market for Norton Sound chum salmon, and no local buyer or processors willing to purchase local chum salmon. Historical commercial harvests in Subdistrict 2 averaged 38,589 chum salmon for years 1962–1991, and 2,189 for years 1992 through 2001, which was the last year ADF&G had a directed chum salmon commercial opening (Appendix A1; Kohler et al. 2005). Average reported subsistence harvest for the 2 periods, 1962–1991 and 1992–2001 were similar, 3,181 and 3,683, respectively.

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# APPENDIX A

**Appendix A1.–**Chum salmon commercial and subsistence harvests by year in Golovin Subdistrict (Subdistrict 2), Norton Sound District, 1962–2004.

| Year | Commercial | Subsistence | Total |
|---|---|---|---|
| 1962 | 68,720 | - | 68,720 |
| 1963 | 49,850 | 9,319 | 59,169 |
| 1964 | 58,301 | - | 58,301 |
| 1965 | - | 3,847 | 3,847 |
| 1966 | 29,791 | 3,520 | 33,311 |
| 1967 | 31,193 | 4,803 | 35,996 |
| 1968 | 10,011 | 1,744 | 11,755 |
| 1969 | 20,949 | 2,514 | 23,463 |
| 1970 | 20,566 | 2,614 | 23,180 |
| 1971 | 33,824 | 1,936 | 35,760 |
| 1972 | 27,097 | 2,028 | 29,125 |
| 1973 | 41,689 | 74 | 41,763 |
| 1974 | 30,173 | 205 | 30,378 |
| 1975 | 41,761 | 2,025 | 43,786 |
| 1976 | 30,219 | 1,128 | 31,347 |
| 1977 | 53,912 | 2,915 | 56,827 |
| 1978 | 41,462 | 1,061 | 42,523 |
| 1979 | 30,201 | 2,840 | 33,041 |
| 1980 | 52,609 | 4,057 | 56,666 |
| 1981 | 58,323 | 5,543 | 63,866 |
| 1982 | 51,970 | 1,868 | 53,838 |
| 1983 | 48,283 | - [a] | - |
| 1984 | 54,153 | - [a] | - |
| 1985 | 55,781 | 9,577 [a] | 65,358 |
| 1986 | 69,725 | - [a] | - |
| 1987 | 44,334 | - [a] | - |
| 1988 | 33,348 | - [a] | - |
| 1989 | 0 | - [a] | - |
| 1990 | 15,993 | - [a] | - |
| 1991 | 14,839 | - [a] | - |
| 1992 | 1,002 | - [a] | - |
| 1993 | 2,803 | - [a] | - |
| 1994 | 111 | 1,337 [b] | 1,448 |
| 1995 | 1,987 | 10,373 [b] | 12,360 |
| 1996 | 0 | 2,867 [b] | 2,867 |
| 1997 | 8,003 | 4,891 [b] | 12,894 |
| 1998 | 723 | 1,893 [b] | 2,616 |
| 1999 | 0 | 3,656 [b] | 3,656 |
| 2000 | 164 | 1,155 [b] | 1,319 |
| 2001 | 7,094 | 3,291 [b] | 10,385 |
| 2002 | 0 | 1,882 [b] | 1,882 |
| 2003 | 0 | 1,477 [b] | 1,477 |
| 2004 | 0 | 874 [c] | 874 |
| 30-year average [d] | 38,589 | 3,181 | 41,001 |
| 10-year average [e] | 2,189 | 3,683 | 5,943 |

*Source*: Kohler et al. 2005.

[a] Subsistence survey not conducted.

[b] Harvest estimated from ADF&G Division of Subsistence survey.

[c] Preliminary. 2004 was the first year a subsistence permit was required for Golovin Subdistrict.

[d] 1962–1991.

[e] 1992–2001, last directed chum salmon commercial fishery was in 2001.

**Appendix A2.–**Aerial survey counts of chum and pink salmon in Fish River drainage including Niukluk River, Boston Creek, and Fish River main stem, and total chum salmon count for 1963–2004.

| Niukluk River-Fish River 64-49-00N 163-27-00W | | | | Boston Creek-Fish River 65-02-00N 163-02-00W | | | | Fish River-Golvnin Bay 64-35-00N 163-21-00W | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Survey Total | | Survey | | Survey Total | | Survey | | Survey Total | | Survey | Chum |
| Date | Chum | Pink | Rating | Date | Chum | Pink | Rating | Date | Chum | Pink | Rating | Total |
| 07/19/63 | 13687 | 4103 | | 07/18/63 | 1669 | | 1 | 07/12/63 | | **25728** | 2 | 15,356 |
| 07/19/64 | 8395 | 10495 | 1 | 07/18/64 | 3315 | | 1 | 07/18/64 | 18670 | 10935 | 2 | 30,380 |
| 07/23/66 | 21300 | 8600 | 1 | 07/22/66 | 761 | | 2 | 07/19/66 | | **17955** | 1 | 22,061 |
| 07/22/67 | 20546 | | 2 | | | | | 07/22/67 | 4083 | 9527 | **3** | 24,629 |
| 07/12/68 | 87093 | | 1 | 07/12/68 | 2500 | 2500 | | 07/12/68 | | **164000** | 2 | 89,593 |
| 07/26/69 | 10240 | 92650 | 2 | 07/26/69 | 7000 | 16000 | 2 | 07/26/69 | 2080 | **124000** | 2 | 19,320 |
| 07/23/70 | 7300 | **60350** | 2 | 07/23/70 | 8200 | 12900 | 1 | 07/23/70 | 76550 | 198000 | 2 | 92,050 |
| 07/20/71 | 22605 | 8370 | 1 | 07/20/71 | 7045 | | 2 | 07/20/71 | 13185 | | 2 | 42,835 |
| 07/23/72 | 10500 | 22600 | **3** | 07/23/72 | 4252 | 3950 | 2 | 07/23/72 | 3616 | **13050** | **3** | 18,368 |
| 07/28/73 | 15156 | 14326 | 2 | 08/03/73 | 3014 | 3213 | 1 | 08/03/73 | 6887 | 15564 | 1 | 25,057 |
| 07/08/74 | 8720 | 8915 | 1 | 08/13/74 | 2426 | 749 | 1 | 08/03/74 | 10945 | 15690 | 1 | 22,091 |
| 07/01/75 | 10089 | 16453 | 1 | 07/31/75 | 1885 | 2556 | 1 | 07/19/75 | 20114 | 15840 | 1 | 32,088 |
| 07/12/76 | 4134 | 7190 | 1 | | | | | 07/12/76 | 8390 | 15850 | 1 | 12,524 |
| 07/13/77 | 10456 | 1921 | 1 | 07/19/77 | 1325 | 385 | 1 | 07/08/77 | 9664 | 2430 | 2 | 21,445 |
| 07/20/78 | 14365 | 14790 | **3** | 07/07/78 | 2655 | | 1 | 07/07/78 | 26797 | 6913 | 2 | 43,817 |
| 07/11/79 | 1282 | 2119 | 1 | 07/11/79 | 882 | 271 | 1 | 07/11/79 | 6893 | 9132 | | 9,057 |
| 07/12/80 | 8915 | **75770** | 1 | 07/12/80 | 2450 | 1510 | 1 | 07/12/80 | 19100 | 33500 | 2 | 30,465 |
| 07/03/81 | 7249 | | 1 | 07/03/81 | 1985 | | 1 | 07/03/81 | 24095 | 450 | 1 | 33,329 |
| 07/19/82 | 2557 | **227440** | 1 | 07/19/82 | 1730 | **22020** | 1 | 06/21/82 | 1038 | | 2 | 5,325 |
| 07/08/83 | 8886 | 50 | 1 | 07/08/83 | 704 | | 1 | 07/08/83 | 19837 | 300 | 1 | 29,427 |
| 07/11/84 | 34572 | 22636 | 1 | 07/11/84 | | **47850** | 1 | 07/11/84 | | **293245** | 1 | 34,572 |
| 07/16/85 | 11140 | | 1 | 07/16/85 | 3450 | | 1 | 07/16/85 | 21080 | 7365 | 1 | 35,670 |
| 07/03/86 | 2442 | | 1 | 07/03/86 | 220 | | 1 | 07/03/86 | 25190 | 140 | 1 | 27,852 |
| 07/15/87 | 4145 | | 1 | | | | | 07/15/87 | 7886 | | 1 | 12,031 |
| 07/12/88 | 6521 | 8160 | 1 | 07/20/88 | 1040 | **7400** | 1 | 07/20/88 | 1240 | **29950** | 2 | 8,801 |

-continued-

**Appendix A2.–**Page 2 of 2.

| | Niukluk River-Fish River 64-49-00N 163-27-00W | | | | Boston Creek-Fish River 65-02-00N 163-02-00W | | | | Fish River-Golvnin Bay 64-35-00N 163-21-00W | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Survey Total | | Survey | | Survey Total | | Survey | | Survey Total | | Survey | Chum |
| **Date** | **Chum** | **Pink** | **Rating** | **Date** | **Chum** | **Pink** | **Rating** | **Date** | **Chum** | **Pink** | **Rating** | **Total** |
| 07/23/90 | 6200 | **115450** | 1 | 07/23/90 | 1455 | **8440** | 1 | | | | | 7,655 |
| 07/25/91 | 10700 | **37410** | 1 | 07/25/91 | 2560 | 3210 | 1 | 07/10/91 | 10470 | 2940 | 1 | 23,730 |
| 07/22/92 | 7770 | **803200** | 1 | 07/22/92 | 1540 | **50850** | 1 | 07/22/92 | 390 | **1387000** | 1 | 9,700 |
| 07/21/93 | 19910 | 2840 | 1 | 07/21/93 | 4563 | 1930 | 1 | 07/13/93 | 12695 | 50 | **3** | 37,168 |
| 07/28/94 | 16470 | **1294100** | 2 | 07/09/94 | 4270 | 2180 | 1 | 07/09/94 | 16500 | **164300** | | 37,240 |
| 07/21/95 | 25358 | 200 | 1 | 07/21/95 | 4221 | | 1 | 07/21/95 | 13433 | 630 | 1 | 43,012 |
| 07/09/96 | 9730 | **153150** | 1 | 07/09/96 | 3505 | **35980** | 1 | 07/09/96 | 5840 | **684780** | 1 | 19,075 |
| 07/16/97 | 16550 | | 1 | 07/16/97 | 4545 | | 1 | 07/16/97 | 19515 | 800 | 1 | 40,610 |
| 07/21/98 | 2556 | **205110** | 2 | 07/07/98 | 1570 | 780 | 1 | 07/07/98 | 28010 | **166930** | 1 | 32,136 |
| 08/24/99 | 640 | | 1 | | | | | 08/24/99 | 50 | 20 | 1 | 690 |
| 07/21/01 | 2448 | 2856 | **3** | 07/21/01 | 3533 | 1038 | 1 | 07/21/01 | 3220 | 1744 | 1 | 9,201 |
| 07/15/03 | 2315 | 272 | 2 | 07/15/03 | 750 | 701 | 1 | 07/15/03 | 3200 | 1014 | 2 | 6,265 |
| 07/14/04 | 173 | **277900** | 1 | 07/14/04 | 55 | **135000** | 1 | 07/14/04 | 621 | **404430** | 1 | 849 |
| Average of good surveys | | | | | | | | | | | | |
| 1974–1983 | 7,259 | | | | 1,789 | | | | 15,842 | | | |
| 1984–1993 | 13,122 | | | | 2,698 | | | | 16,157 | | | |
| 1994–2003 | 11,216 | | | | 3,148 | | | | 7,884 | | | |
| Total - years surveyed | | | 38 | | | | 34 | | | | 37 | |
| - rating 3 or none | | | 4 | | | | 1 | | | | 5 | |
| - chums masked by pinks | | | 10 | | | | 7 | | | | 12 | |
| - good or useable surveys | | | 24 | | | | 26 | | | | 22 | |

*Note*: Bold pink salmon counts are greater than 3 times (masking) chum salmon count, and bold survey rating of 3 are poor, not useable.