Population Characteristics of Spawning Inconnu (sheefish) in the Selawik River, Alaska, 1993-1996, Final Report

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Abstract

Inconnu *Stenodus leucichthys* from the Selawik River in northwest Alaska were sampled during the 1993-1996 spawning migrations. Inconnu were studied to provide basic population information in order to satisfy federal statutory requirements for protection and to provide management information in cooperation with the State of Alaska. Data collected by beach seine and hook and line methods were used to employ a modified Petersen model and to gather other population information. Estimates of spawning inconnu were 5,190 (95% confidence interval 3,690-7,272) and 5,157 (95% confidence interval 3,038-12,983) during 1995 and 1996, respectively. Wider confidence intervals in 1996 resulted from reduced sampling due to inclement weather. Fork lengths of migrating fish ranged from 52 to 120 cm. Mean lengths in the various samples were approximately 90 cm. Minor differences in length frequency distributions were observed among the years 1994 to 1996. Ages present during migration and prior to spawning ranged from 7 to 23. Inconnu of ages 13 and 14 were most numerous.

Migrating inconnu reached holding areas 25 km below the spawning area in the first week of July, one month earlier than previously recorded. In three years more than 389 radio locations were recorded during mobile tracking. Radiotelemetry indicated some inconnu stay in summer holding areas for up to one month prior to completing their migration. Precipitation appeared to trigger further travel upstream in late August and September. Inconnu spawned in a 12 km section of river in late September and early October. Post spawning migrations occurred rapidly after spawning, beginning as early as September 27 and ending by October 19 in radio tagged fish. Winter dispersal, measured by tag returns from fishermen, was throughout the Selawik Lake — Hotham Inlet complex. No inter-drainage migration was documented despite concurrent tagging of spawning inconnu in the adjacent Kobuk River. Some inconnu tagged with anchor tags in one year returned with migrating fish the next year. Management action should be taken to protect the Selawik stock similar to that afforded to the Kobuk River inconnu, that is, reduced bag limits. It may also be beneficial to protect the spawning habitat by purchasing private allotments in the spawning area and reviewing any special use permits for refuge compatibility.

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Introduction

The inconnu (sheefish, *Stenodus leucichthys*) are predatory whitefish found in specific Arctic and sub-Arctic waters of Asia and North America (Alt 1969, 1987; Scott and Crossman 1973; Morrow 1980). In the United States they are especially well known in northwest Alaska where they grow particularly large because of estuarine feeding areas (Alt 1969, 1973). Inconnu are near the top of the aquatic food chain and they are an important part of the ecosystem (Alt 1965). Because they can live in excess of 20 years (Alt 1969, 1973,1987) and are high level predators, inconnu may be a sensitive indicator species vulnerable to over harvest and environmental change. In 1980, Congress recognized the importance of inconnu by naming the species specifically for conservation in the Alaska National Interest Lands Conservation Act (ANILCA). Congress, through ANILCA, mandated that inconnu be maintained in their natural diversity in the Selawik National Wildlife Refuge (Selawik Refuge) and that opportunities for subsistence use be maintained as consistent with other refuge purposes. Inconnu use the Kobuk and Selawik rivers on and adjacent to Selawik Refuge for feeding, migration, and spawning.

Besides their ecological and aesthetic importance, inconnu hold economic value to the residents of northwest Alaska. The economic importance of inconnu stems from its role as a subsistence resource, its value to the commercial fishery, and the stature and reputation as a trophy sport fish (Alt 1969, 1987). As a subsistence resource, the inconnu is captured and used year round for human consumption and to feed sled dogs. A spring net fishery provides fresh fish for immediate use and dried fish for other times of the year. In summer fresh fish is provide by people using nets or hook and line. Fall and winter fisheries include an under the ice net fishery and through the ice jig fishery.

Subsistence inconnu harvest has been monitored to varying levels of intensity over the years by the Alaska Department of Fish and Game (ADFG). Estimates of subsistence harvest have ranged drastically with the thoroughness of the survey procedure. People from Kotzebue, Noorvik, Kiana, Ambler, Kobuk, Selawik and other villages along the Kobuk and Selawik rivers participate in these fisheries. A 1996 estimate of subsistence harvest in the Kobuk River was 9,465 inconnu (Lean et al. 1996). Fishery data for the winter of 1995 from Hotham Inlet and Selawik Lake estimates harvest from 11,925 to 18,396 inconnu (Taube 1997).

Commercial harvest in the Kotzebue District winter commercial inconnu fishery also has varied widely (26 to 4,000 fish) between 1967 and 1991. The most recent estimate available was a catch of 226 fish in 1995 (Lean et al. 1996). A recent request for a commercial fishing permit for the village of Selawik was granted, but the additional quota granted for whitefish were included in the total harvest quota for the Kotzebue District. No data are available to determine the effect of this new permit on inconnu of the Selawik River.

Sport fishermen caught approximately 3,270 inconnu and harvested 1,142 in 1995 from the northwest Alaska area, although most of the harvest comes from the Kobuk River (Howe et al. 1996). Sportfishing on the Selawik River is thought to be much less than on the Kobuk

River. In addition, it is difficult to separate sport caught inconnu from those caught for subsistence because angling is a common method of harvest for both.

Inconnu life history in Alaska is generally understood in the Kobuk and Selawik area (Alt 1969, 1987). At ice-out the juvenile and adult inconnu are found feeding in the river deltas, large lakes, and inlets of the region. While some inconnu remain in the lower lakes and sloughs, some juveniles and non-spawning adults join spawners that gradually move up either the Kobuk or Selawik rivers. By July spawners are thought to have moved farther up the drainage than the other life stages and move into deep holes and runs below spawning areas. By mid-September spawning inconnu are located on the spawning grounds. Spawning occurs before or during ice-up. Eggs are broadcast over gravel and cobble substrates. Spawning is thought to be a biannual event based on egg diameters found in adult fish. At the completion of spawning, inconnu travel downstream to feed in the large water bodies where overwintering occurs. Eggs are thought to hatch near the time of ice-out. It is believed that age 0 inconnu wash downstream with the high waters of spring. Fish younger than age 2 have not been sampled and their distribution remains unknown.

The overall picture of the population dynamics remains incomplete. Population estimates for the entire population are impractical because of variable distribution, mobility, and the large geographic area in which the population is found. Index estimates of the spawning population have been attempted intermittently. Aerial counts of spawners on the Kobuk River ranged from 1,025 to 8,166 between 1966 and 1971. On the Selawik River in 1968 and 1971 aerial counts were 1,243 and 1,105, respectively. No recent index numbers have been gathered. Alt's review (1987) recommended a four-year study of population dynamics to determine the level of sustainable harvest. Few resources have been available to address the question of sustainable yield since recommendations were compiled in 1987.

In the fall of 1993, ADFG proposed a major study of Kobuk River inconnu for 1994 and 1995 and suggested the Service undertake similar work on the Selawik River. The work was to provide a repeatable measure of abundance for spawning inconnu as well as other population indices to evaluate their status. Currently, managers have little information to make decisions on harvest allocation. The population indices collected in this project provide information necessary to estimate yield as suggested by Alt (1987).

OBJECTIVES:

1. To estimate the abundance of spawning inconnu in the Selawik River during two consecutive years such that the estimate is within 25% of the true abundance 90% of the time;

2. To estimate the length and age composition of spawning inconnu in the Selawik River such that estimates are within 5% of the population 95% of the time;

3. To describe migration and habitat use of spawn inconnu using radiotelemetry and to map those locations to determine the extent of spawning habitat in the Selawik River.

Study Area

The Selawik River is located in the Selawik Refuge in northwestern Alaska (Figure 1 top). The refuge extends east from the shores of Hotham Inlet and Selawik Lake straddling the Arctic Circle. The Selawik River has two major tributaries the Kugarak and Tagagawik rivers (Figure 1 bottom). Selawik River above the Kugarak River originates in the Percell Mountains within a wide tundra valley. The Selawik Refuge extends eastward upstream of the Tagagawik River to include the majority of the river corridor and minor tributaries. The Selawik River is a designated National Wild and Scenic River. Land adjacent to Selawik Refuge is administered by the Bureau of Land Management. Some tracts have been selected for conveyance to the State of Alaska including the headwaters of Ingruksukruk Creek which hold potentially viable mineral deposits.

Sampling for the study was conducted on the Selawik River upstream of the Tagagawik River (Figure 1 bottom). Inconnu were captured in deeper pools and runs. The river is characterized by meandering pools and runs with sand riffles between them. River banks are mud cut banks, sand beaches, and occasional wasting bluffs. The river has an abundance of woody debris from vegetation undercut during flooding and ice scouring. Vegetation consists of willow-alder thickets, grass, spruce forest, and pockets of cottonwood. In July and August tagging was conducted in an area where the substrate consisted of mud and sand. In September sampling was conducted approximately 25 km upstream of tagging where the substrate was predominately gravel and cobble. Large amounts of woody debris were present in the stream channel in both areas.

Methods

Some of the following methodology is adapted from ADFG Kobuk River Investigation Plan dated April 1993 and is used with permission of ADFG (Fred Deccico, ADFG, Sport Fish Division, Fairbanks, Alaska, personal communication). Adopting the methods used by ADFG on the Kobuk River facilitated comparisons between the Kobuk and Selawik rivers.

Abundance of Spawning Inconnu

Field sampling.— A two-sample mark and recapture experiment using Petersen's model with Bailey's modification (Bernard and Hansen 1992) was used to estimate the abundance of spawning inconnu in the upper Selawik River. The experiment was attempted in 1994 through 1996. Based on a pre-project assumption of approximately 3,000 spawning inconnu, we planned to tag 400 fish during the marking event and examine an equal number of fish during the recapture event (Robson and Regier 1964). The marking event occurred below the spawning grounds, but above the Tagagawik River as fish migrated to pre-spawn holding areas. The recapture event occurred during September in the spawning area ≈ 25 km upstream of the marking event.

Beach seine (3-m by 61-m, 3.8-cm stretch mesh) and hook and line techniques were used to capture fish. A crew of five to seven people sampled inconnu at locations holding fish, a ≈6 km section of river during marking and 12-17 km section during recapture sampling. Holding locations were visited multiple times per week often more than once in a day. Large spoons of assorted colors 14 to 60 g in weight (such as those with the trade names “Daredevils”, “Krocodile”, and “Cop-e-cat”) were used to collect fish.

Date, location, scale sample number, length, weight, tag number, fin clips, sex, and crew observation data were recorded. All fish were examined for prior Floy ® tags, visual implant tags, and fin clips. Lengths were recorded to the nearest cm using a hinged fish cradle to restrain the fish. Weights were found by hanging inconnu in a mesh net attached to a spring scale. Weights were measured to the nearest 0.1 kg or 0.25 kg depending on the spring scale being used. Untagged inconnu in healthy condition were marked with Floy ® internal anchor tags that were sequentially numbered. Anchor tags were inserted near the base of the dorsal fin so as to lock between posterior interneural bones. A secondary mark, visual implant tags, were inserted on the right side of the fish in the clear tissue of the preopercule bones and posterior to the eye. Sex and maturity of each live fish was determined by the presence of sex products. Fish for which sex could not be determined were recorded as unknown. Locations were recorded as latitude and longitude readings from a Global Positioning System (GPS) receiver.

Radiotelemetry was used (1) to further define the spawning area(s) to be sampled in the upper river during the recapture event; (2) to examine mixing of tagged and untagged fish; and (3) to monitor emigration from the study area. Radio transmitters were implanted in 22 inconnu in 1994, 32 inconnu in 1995, and 14 inconnu in 1996. Surgical and oral insertion of transmitters were used (Appendix A and Appendix B). Automated data logging receivers were used to minimize radio tracking time. Receivers were placed at sites above and below the study area to detect emigration. Each receiver was attached to two four-element yagi antennas, one aimed upstream and the second aimed downstream. Receivers recorded the date, time, channel number (frequency), relative power, and individual tag code. Scan times were set so that each frequency was scanned at least every 30 seconds. By graphing relative power of each antenna versus time, the direction of a travel of each fish could be determined.

Radio tracking by boat supplemented information from stationary receivers. Boat tracking was done with data logging receiver and a single three element yagi antenna. The boat was stopped to verify the detection of a valid signal and locations were then recorded.

Data analysis.— The estimator used is Bailey 's modification of the Peterson estimator

(Seber 1982). This estimator is unbiased for sampling with replacement given standard assumptions are met. The estimator is as follows:

$$\hat{N} = \frac{M(C+1)}{(R+1)} \text{; and,} \tag{1}$$

$$V[\hat{N}] = \frac{M^2 (C+1)(C-R)}{(R+1)^2 (R+2)} \text{;} \tag{2}$$

where:

M = the number marked during the first sampling event;

C = the number examined during the second sampling event; and,

R = the number captured during the second sampling event with marks from the first sampling event.

Two event mark-recapture experiments on a closed fish population are unbiased if the following conditions are met (Seber 1982; Bernard and Hansen 1992):

1. Marking does not effect catchability of the fish.

2. Fish do not lose marks between sampling events.

3. Recruitment and mortality do not occur together between sampling events.

4. Fish must have an equal probability of being marked and released alive during the first sampling event; **or** every fish must have an equal probability of being captured during the second sampling event; **or** marked fish mix completely with unmarked fish between sampling events.

Assumptions were tested and estimator corrections made based on Bernard and Hansen (1992) suggested options (Case 1-4). The analysis included a definition of the sample area based on radiotelemetry and hook and line sampling, a definition of the sample population, an analysis of bias (i.e., size selectivity), an explanation of the appropriate stratification of the data, and calculation of the estimate and confidence intervals. Kolmogorov-Smirnov two-sample tests (KS) on lengths and chi square tests of length intervals were used to evaluate size-selectivity. Size intervals used by the chi square test, selected in an arbitrary manner, were ≤90 cm, 91-100 cm, and ≥101. Size intervals for stratified estimates were selected by an iterative chi square

procedure described by the computer program "MRTest" (Dave Bernard, ADFG, Anchorage, personal
communication). Confidence intervals for stratified estimates were estimated using boot strap methods (Buckland et al. 1991).

Several actions were taken to increase the chance of meeting the assumptions listed above. Only inconnu judged to be healthy were marked and released. We selected a tagging area where we anticipated no mortality of marked fish or that the minor mortality of a small subsistence fishery would equally affect marked and unmarked fish. Also, at the tagging area selected, recruitment to the population was not thought to be a problem as long as marking was conducted as the entire spawning population migrated past the tagging area. To ensure this was the case we began sampling earlier each year until 1996 when we felt that sampling began before the inconnu arrived in the tagging area. Second, we test fished upstream in July when we first arrived to determine the distribution of fish in and above the tagging area. We also radio tracked transmitter implanted fish in the tagging area to determine when fish traveled to the spawning area. Finally, data logging receivers and mobile tracking were used to identify emigration out of the study area by recording the departure of transmitter implanted inconnu from that area.

Length and Age Composition

Field sampling.— Data from fish captured during the mark and recapture effort, as described above, were used for length and age composition analysis. Three to five scales were removed and stored. Scales were taken from all fish. Scale samples were removed from the side of the body midway between the lateral line and the base of the dorsal fin (Alt 1969).

Preparation and data analysis.— Samples selected for length and age composition analysis were based on recommendations of Bernard and Hansen (1992) after analyses regarding size selectivity. Scales were used to age the fish using standard techniques (Ambrose 1983). Scale impressions were made on acetate slides 20 mm thick using a Carver press at six metric tons and heated to 100 degrees C for 15 seconds. Scale impressions were read on a Micron 770 microfiche reader. Annulus determination was made using criteria described by Alt (1969). Scale samples were read by two readers. Disagreements on the age from a particular sample were either reconciled or the sample was discarded.

Length composition calculations were different for each year depending on whether size-selectivity was detected and the estimator stratified or not. Calculations for estimating length composition when no size selectivity was detected can be found in Appendix C. Calculations for estimating length composition when size selectivity indicated the need for stratification can be found in Appendix D.

Spawning Habitat and Migration

Field sampling.— Prior to the study it was determined that the spawning grounds were located above the Tagagawik River. This was based on aerial surveys (Ken Alt, ADFG retired, Fairbanks, Alaska, personal communication) and discussions with Service personnel (Rich

Johnson, Dave Daum, and Ken Troyer, U.S. Fish and Wildlife Service, Fairbanks, Alaska, personal communication). A preliminary survey was conducted in September 1993 and some fish were tagged and released when a concentration of inconnu were located. In 1994 -1996, the study area was surveyed to locate inconnu using two sampling techniques, hook and line and radiotelemetry (discussed above). Early in each season as fish migrated upstream, a new occurrence, where no fish had been caught previously, was interpreted as a sign of migration into an area. To investigate post-spawning migration, in 1995 a stationary receiver with automated data logging capabilities was installed on the lower Selawik River upstream from the entrance to Inland Lake. The purpose of the station was to record adult downstream migrants previously located on the spawning grounds. The station ran from September 27 until December 12, 1995 when power reserves were exhausted.

Results

Abundance of Spawning Inconnu

Results describing a two-event mark and recapture estimate should include a definition of the sample area, a definition of the sample population, an analysis of bias (i.e., size selectivity), an explanation of the appropriate stratification of the data, and calculations of the estimate and confidence intervals. The results below describe each of these in the order given. Additionally, readers need to distinguish between the marking event, often described as "event I", and the recapture event, "event II". The marking event occurs when primary and secondary marks are applied to the fish ("M" of equation 1). In contrast, the recapture event occurs after the marking event and describes two groups of fish, the total number of fish examined ("C" of equation 1), and of those examined, the total found to have marks ("R" of equation 1). Distinguishing between the "events" and groups of fish within each event is key to understanding the findings presented and the implications for each.

Abundance estimates were attempted in 1994, 1995, and 1996, but only completed for the latter two years because flooding halted work in 1994. The timing of mark and recapture events varied slightly by year. The marking events ran from July 17 to August 31, 1995 and July 12 to August 23, 1996. Recapture events ran from September 5 to 22, 1995 and August 31 to September 14, 1996.

Recapture sampling area.— The recapture sampling area is the area in which sampling for "event II" occurs and is important to describe to confirm that the marked population is the same population sampled for recapture. The sampling area was defined based on 226 radio locations collected in 1994, 1995, and 1996. These radio locations were the primary factor in determining where to sample during the recapture event each year. Radio locations provided a bracketed area which shrank in length as the inconnu completed their migration and arrived at their final destination, the spawning habitat. Hook and line sampling above and below the range of radio tagged fish verified the presence or absence of additional inconnu and thus, crews were able to direct effort efficiently. In 1995 the year of greatest telemetry coverage, no fish were collected outside the geographic limits of the distribution set by radio tagged fish. The geographic distribution was only 12 km in length by September 15. Prior to that date some fish were found below the 12 km section and sampling effort was extended to those areas. In years with fewer radio tags deployed, inconnu were collected outside the range of radio tagged fish, but were still within the 12 km geographic distribution established in 1995.

No new spawning areas were located despite extensive mobile and stationary monitoring. All radio tags in each year were accounted for with the exception of one tag. Movement by fish within the spawning area was documented during the second event in the later two years. Most radio tagged fish moved among the pools and runs found within the spawning area indicating some mixing of the population.

Sample population.— In 1995, crews successfully marked 570 inconnu during the marking event and examined 372 fish for marks during the recapture event finding 33 recaptured fish. In 1996 crews marked 263 inconnu in the marking event and examined 279 fish in the recapture event of which 18 were recaptured. In each year few fish (<5%) were caught by beach seine during tagging and none were captured during the recapture event.

The sample population is the population represented by the estimate. If the range of lengths of recaptured fish in “event II” is the same as that of marked fish during “event I”, then the sample population includes fish of all sizes represented in the catch. In most cases, however, the range of lengths represented by the recaptured fish of “event II” is much smaller than that of the marked population “event I” and the sample population must be restricted to fish represented by those recaptured during “event II”. The latter case is that observed in both 1995 and 1996. The range of lengths in 1995 of recaptured fish during “event II” (Figure 2B) was more restricted than the range of the marked population (Figure 2A). In 1996 the range of lengths from recaptured fish from event “event II” was even more restricted than in 1995 (Figure 2C, 3D). The range of lengths from recaptured fish was different in both years requiring separate adjustments to be made to accurately reflect the sample populations. Strictly interpreted, length ranges of the sampled populations for 1995 and 1996 would differ, 68-107 vs. 78-111 cm, respectively. However, to provide a comparable estimate for the two years the sample population was defined for the estimate as fish ≥ 75 and ≤ 111 cm. This means that only fish ≥ 75 to ≤ 111 cm are represented by the estimate. In 1995 only 31 fish met the length range criteria and composed the total number of recaptured fish (“R” equation 1). The number of recaptured fish (R=18) during 1996 did not change because of restrictions to the sample population.

Size selectivity.— Size selectivity is a common sampling phenomena that can introduce bias into a population estimate by over representation of one size of fish over others in the data. Line graphs of cumulative frequency and hypothesis testing were used to examine the data for size selectivity. In 1995, cumulative frequency plots (Figure 3, top) indicated small differences among the marked, examined, and recaptured fish. Results from KS and chi square tests on fish tagged during “event I” versus recaptured during “event II” indicated no difference between the two groups (D_{max}=0.12, n = (573/33), P = 0.77; and X^2 = 4.481, d.f. = 4, P = 0.34, respectively).

A second test, a KS test of fish tagged during “event I” versus those examined “event II” indicated the two groups differed (D_{max}=0.11, n = 618;349, *P* = 0.008). In combination the tests showed size selectivity was present in the marking event, but not in the recapture event. These statistical tests indicate that a single unstratified estimator was appropriate for 1995 (Bernard and Hansen 1992).

In 1996, line graphs of cumulative frequencies (Figure 5, bottom) indicated a large difference in sampling selectivity between some groups. Hypothesis testing indicated size selectivity in both sampling events. Results from KS and chi square tests on fish tagged during “event I” versus recaptured during “event II” indicated significant differences between the groups (D_{max}=0.48, n = 305, *P* = 0.0009; and X^2 =15.31, d.f.=2, *P* = 0.001, respectively). The second test, a KS test on fish captured during “event I” versus those examined during “event II” showed the two groups did not differ (D_{max}=0.06, n =567, *P*=0.71). These results indicated that a stratified estimator should be used (Bernard and Hansen 1992). An iterative process of chi square tests was used to determine the optimal stratum for the estimator. The stratum selected were ≤99 cm and ≥100 cm.

Population estimate.— Based on the above information population estimates of 5,190 and 5,157 were calculated for 1995 and 1996, respectively (Table 1). Confidence intervals were wider in 1996. An unstratified estimate for 1996 indicated that bias was significant and should not be ignored for length composition.

Length and Age Composition

Length composition.— Fork length mean, median, and range of spawning inconnu were similar in the three years sampled, 1994-1996 (Table 2). In 1994, only fish sampled prior to flooding were included in the distribution and may not be representative of the population (Figure 4, A; Table 3). In 1995, only fish from “event II” were used for length composition because size selectivity was indicated in “event I”. Multiple peaks were visible on the length frequency distribution (Figure 4, B; Table 4). In 1996, size selectivity was evident and as a result the data from both sample events were used to estimate the proportion in each size interval incorporating a correction (Bernard and Hansen 1992). Again, multiple peaks were evident in 1996 (Figure 4, C; Table 5). A comparison of length frequencies for the three years indicated minor differences (Figure 4). For example, in 1996 more fish below 74 cm were evident. A 3×5 chi square of year by size interval (≤79 cm,>80-89 cm,>90-99 cm,>100-109, ≥110) indicated differences among the years (X^2 = 28.3, df = 776, *P* = 0.001). An examination of individual cell chi square values indicated large values in the 90-99 cm interval in 1994 as well as the >110 cm interval in 1996 (Table 6).

Age composition.— In 1995, age composition was based on fish from the second sampling event because no size selectivity was indicated for that sample (see above). Inconnu ranged from age 8 to 21 years (Table 7). Age 13 inconnu were most prevalent although two secondary modes occurred at age 9 and 18. Considerable overlap of the range of lengths were indicated in a plot of length on age (Figure 5). In 1996, age composition was based on fish from both sampling events (Table 8). Inconnu ranged from age 7 to 23. Age 13 and 14 fish were most numerous. A secondary mode at age 9 was evident.

Spawning Habitat and Migration

Radiotelemetry 1994.— In 1994, radio transmitters were surgically implanted into 22 inconnu prior to when the project was halted due to flooding. Thirteen fish were recorded traveling downstream out of the study area by the lower stationary receivers. Five fish traveled downstream in times of gradually increasing discharge between August 7 and 13. The remaining eight fish traveled downstream between August 17-19, a time of quickly increasing discharge at the beginning of the flood. After the flood, crews recovering equipment September 15-17 found eight radio tagged fish. Six fish were found in the suspected spawning area and other untagged fish were collected in those areas. One fish was found approximately 4 km downstream of the others and one fish was located just above the Tagagawik River. The fish located near the Tagagawik River moved upstream while being tracked over a 30 minute time period.

Radiotelemetry 1995.— In 1995, radio transmitters were applied to 32 inconnu from July 20 to August 20. Surgical implanted transmitters with internal helical antennas comprised 29 of the total and 3 transmitters with whip antennas were inserted orally into the stomach. Radio locations recorded from a boat exceeded 141 in the tagging area and 198 in the spawning area. Thirty fish were tracked upstream out of the tagging area and into the area previously identified as the likely spawning area. Two fish with surgically implanted transmitters proceeded downstream out of the study area within hours of release after surgery. The disposition of these two fish is unknown, but it is likely that they died from the effects of the surgery. The remaining 30 fish were accounted for in the upstream spawning area until crews stopped radio tracking on September 22.

In the marking area fish receiving radio tags prior to August 3 did not move far from where they were released until rain caused significant increases in discharge around August 8 and 9. At that time rainfall raised Selawik River water levels by about 0.6 m. From August 9 to 15, the majority of those tagged fish began moving upstream. The movement of fish radio tagged after August 3 varied much more than those tagged early. Of the fish tagged late, a few moved upstream within two days of surgery while others held in place until later. Rainfall again caused the river to rise August 21 and additional upstream movement was observed.

In the spawning area during 1995 half the tracked fish were within the 12 km area by September 5 and the remainder arrived by September 15. Once in the 12 km area radio tagged fish mixed so that no pattern based on time of release, location of release, and relative location during the recapture event could be detected. Most fish were observed in different locations every few days, generally moving upstream although a few fish seemed to wander both up and downstream. Some individuals were observed to move upstream to their furthest upstream position by September 15 and hold position within a specific segment until tracking was stopped September 22. A few fish were observed to migrate to the furthest upstream end of the 12 km segment and were subsequently observed holding back downstream. This last behavior gave the impression that habitat at the furthest upstream point was not suitable for spawning and the fish moved back downstream towards the main body of holding inconnu to better habitat. It was not thought that these fish had spawned and started their downstream migration because no females had been observed to extrude eggs while being handled. In contrast, nearly all males were observed to have flowing milt.

In 1995, we monitored the post-spawn migration downstream at a receiver that was stationed approximately 15 km above the channel providing access to Inland Lake, the first opportunity that inconnu would have to disperse from the Selawik River after spawning. The data-logging receiver operated from September 27 to December 13, 1995. Post-spawning downstream migrants were recorded moving past the receiver from September 27 to October 19 (Figure 6). We detected all 30 potential migrants traveling downstream. Travel times past the receiver ranged from 8 to 52 minutes and averaged 16.8 minutes excluding one exception which stayed within range of the receiver for approximately 18 h.

Radiotelemetry 1996.— In 1996, 11 of 14 deployed transmitters were located on the spawning grounds by September 7. All detected radio tagged inconnu were within the geographic limits identified in 1995. One fish was unaccounted for in the telemetry surveys. Two fish passed the fixed receiver site below the lower sampling area; one passed within an hour after insertion of the transmitter and the second, three days after the transmitter application. Radio locations totaled 42 in the spawning area. Approximately half of the fish located in the spawning area moved to a new upstream or downstream location between September 4 and 7.

Conventional tagging.— Anchor tags were deployed as the primary mark from September 1993 until the fall of 1996. Visual implant tags were used as a secondary mark after 1993. Visual implant tags were also evaluated as a potential long term mark. Tags were captured in subsequent years of sampling and from fishers in the winter fishery. Some fish recaptured during our sampling showed consecutive year spawning (Table 9). Tag loss data based on recaptured fish (Table 10) indicated that anchor tag retention was better than retention of visual implant tags for short term, <1 to 3 years, study. However, sample sizes were too small to make strong statements about tag retention. Tags recovered by fishers (n=15) indicate that fish dispersed from the southern portion of Selawik Lake to the northern edge of Hotham Inlet during the winters of 1995 and 1996. No fish tagged in the Selawik River were recaptured in the Kobuk River in the three years of sampling by the ADFG or by residents along the river as far as we know (Taube, Alaska Department of Fish and Game, personal communication). The opposite was also true: No fish tagged during a concurrent study in the Kobuk River (Taube 1996, 1997) were recaptured in the Selawik River.

Discussion

In 1995 and 1996 statistically defensible population estimates for inconnu were made for the first time for the Selawik River. The estimates are higher than first predicted indicating that the spawning populations are large enough to be genetically stable and less vulnerable to over harvest than previously thought. However, these findings are not grounds for complacency because the harvest rate is unknown and more important than population size when determining population trends. A comprehensive evaluation of harvest would complement the population estimates and should be the next step in evaluating the population dynamics.

The extremely similar estimates, 5,190 and 5,157 respectively, could well be an artifact of chance and hold less importance than the range given by the confidence intervals. Confidence intervals for 1995 are much narrower than in 1996. This reflects the larger sample size in 1995 and a better estimate as a result. Sample size was lower in 1996 because of a flood lasting approximately 12 days during July as well as colder temperatures during September that lowered catch rates and reduced sampling by 7 days. Fish ≥ 75 to ≤ 111 cm were represented by the index, or approximately 90% of spawners based on 1995 length frequency data.

Length and age data were similar to past studies and comparison of length distributions and harvest patterns provide insight into the effect of some fisheries on the population. Alt's sampling of Selawik inconnu primarily occurred in lake and slough habitat during the summer and not with spawning fish (Alt 1969, 1987). For this reason his sample included smaller fish and younger age classes than our sample. A comparison of length frequency distributions of 1995 spawners (Figure 7, A), fish harvested in the spring gill net fishery (Figure 7, B) at Selawik in 1993 (unpublished data), and fish harvested in the Hotham Inlet gill net fishery (Figure 7, C) in November (Taube 1996, 1997) showed that a small proportion of spawners were harvested in the spring fishery (Figure 7, B). In contrast, the winter fishery harvested a larger proportion of that group (Figure 7, C); however, harvest of inconnu over 100 cm appears to be infrequent (Taube 1996, 1997). In addition, there is some evidence that spring subsistence fishing effort is declining. The number of fish camps occupied by residents of Selawik Village counted in surveys were 27 in 1986, 14 in 1993 (unpublished data), and 3 in 1996. In 1996, six additional nets were run daily from the village (Ken Alt, ADFG retired, personal communication). These observations indicate that harvest in the spring is probably lower now than in past years.

The age most frequently occurring in Alt's data for the Selawik area (Alt 1969) was age 13, similar to our data. The youngest fish captured in the spawning migration was age 7 and the oldest was age 23. The maximum age is slightly higher than that reported by Alt (1987) perhaps because of extremely high subsistence harvest in the late 1960s (Lean et al. 1996; Taube 1996). Our ages were similar to those reported by Taube (1996, 1997) for the Kobuk River. The degree overlap in lengths at age is extreme and may reflect inaccuracies in aging. Aging by scales has yet to be validated for inconnu, but some consistency between earlier reports was provided by Ken Alt who assisted in training some of the scale readers.

Verification of the spawning area is also an important finding of this study. Two results are significant. The first is that only one spawning aggregate was found. Prior to this study it was not known if more than one spawning aggregate used the many kilometers of habitat above the Tagagawik River. Our data indicates this is not the case. Second, the aggregate was found in a significantly shorter segment of river than previously described, which was based on aerial observations (Alt 1987). While inconnu do hold in deeper parts of the lower river during July and August, radiotelemetry confirmed that a relatively short section of approximately 12 km was used in September. It was unclear why this area was selected for spawning. Potential hypotheses include selection based on substrate, gradient, or ground water intrusion. The habitat used in September was different from that used in July and August. The area used earlier in the year has a lower gradient with sand and mud substrate. The Selawik River spawning area has substrates of gravel and cobble with only occasional areas of sand or mud. In both areas fish were often found adjacent to or in water deeper than 3 m. However, in September fish were also found in shallower water with no adjacent deep water.

Catch during sampling, radiotelemetry, and conventional tag returns provided insight into the behavior and migration of inconnu. For example, the arrival of fish in the upstream area is now more fully understood. Previously it was believed that upstream movement of spawning inconnu was slow and constant resulting in the arrival of fish in the vicinity summer holding areas in early August. Based on sampling catches, fish appear to arrive in summer holding areas as early as the first week of July. Radiotelemetry indicated that inconnu may hold in the lower river for up to a month before resuming their migration. Summer rains and increased discharge were associated with additional movement upstream to the spawning area in the middle and latter part of August.

Between July and September the behavior of the inconnu varied among years. In mid-August of 1994, heavy rains caused a 40 year flood. Radio tagged inconnu moved downstream with the rise in water levels. Subsequent to the flood, approximately one third of the fish were located in the spawning area. In 1995, the lack of rain caused a marked drop in water levels on the Selawik River. Radio tagged inconnu for the most part stayed in deeper pools near where the radio tags were deployed. Some fish were located in the same pool for more than one month; while others moved often. Little net upstream movement of radio tagged fish occurred until rain increased discharge around August 12 and August 22. By September 5, 1995 approximately one half of the radio tagged fish had traveled to the 12 km section described as the spawning grounds, ~25 km upstream of their previous holding area.

Previous knowledge of post spawning migration was based on anecdotal information of residents and Kobuk River tag returns (Alt 1977, 1987). Telemetry data verified these earlier observations as true for the Selawik River and indicated a spawning time of late September to early October in 1995. Downstream migration occurred in a relatively short time period (Figure 6), being completed by the third week of October. Resources did not allow confirmation of the result for a second year in 1996 so it is not known if spawning dates and downstream migration remain consistent from year to year.

Conventional tags provided information on dispersal, repeat spawning, and inter-river movement. Tag returns from fishermen indicated wide spread dispersal of post-spawners. Dispersal of spawners during the winter proved to be complete within the Selawik Lake —

Hotham Inlet complex. Selawik spawners were collected in the same nets as spawners tagged in the Kobuk River. Alt (1977) reported tag returns, from Selawik area and Kobuk River inconnu, as far away as the town of Kotzebue, Alaska. Clearly, the fish tagged in the two rivers mix in the winter habitat. This data clarifies and confirms earlier conjecture on the distribution (Alt 1977).

Recapture on the spawning areas of inconnu tagged in previous years show that some fish do not skip years prior to returning to the spawning grounds. Berg (1948) as reported by Alt (1987) suggested nonconsecutive was the rule for inconnu. Alt (1969) reported females during the same time period with eggs (1.2 - 1.5 mm diameter) and other females with some eggs less than 1 mm and many eggs less than 0.5 mm. Two egg sizes during the same time period may indicate that some fish may not be spawning every year. In addition Alt (1987) reported inconnu, in early summer feeding areas, with small eggs and eggs retained from the previous years spawning. Alt associated this condition with nonconsecutive spawning. Small developing eggs occurring with retained eggs have been associated with alternate spawning in two anadromous coregonids by Lambert and Dodson (1990) who also demonstrated that the energetic cost of the spawning migration precluded yearly spawning. Considering Alt's observations and tag returns from this study, the number of years between repeat spawning remain unclear. It is clear that some inconnu do migrate to spawn in consecutive years, but we cannot conclude that all inconnu spawn every year. The "decision" to spawn may be gender specific and may depend on the abundance of food in the winter habitat or body condition (Craig 1989). The question of consecutive versus nonconsecutive spawning is an important management consideration. The spawning population is essentially half the size if consecutive year spawning is normal rather than alternate year spawning. Further work by the ADFG on the Kobuk River during 1997 may clarify the picture; however, a more focused study may be needed. This could be accomplished by using programmable radio-tags that extend their operational life by turning on and off on a predetermined schedule over several years.

Tagging data provides no evidence of inter-drainage movement of inconnu between the Kobuk and Selawik rivers. The hypothesis about inter-drainage movement stems from a June tagging operations in Selawik and Inland lakes, and in the Tuklomarak River between the two lakes (Alt 1977). Alt (1977) reported that 26% of the tag recoveries of these fish were in the Kobuk River and suggested the possibility that inconnu may choose either river in which to spawn. In addition, similar growth patterns were given as evidence of a single stock with multiple spawning locations. An alternate explanation is that the inconnu tagged by Alt (1977) were Kobuk River fish that had dispersed to summer feeding areas and not Selawik River fish that later selected the Kobuk River for spawning in subsequent years. Similar growth patterns would stem from similar primary feeding areas. Genetic analysis indicates a degree of isolation between the populations, but cannot conclusively say the spawning populations represent separate stocks (Miller et al. 1998).

Conclusions

This study provides data that allows the evaluation of spawning inconnu of the Selawik River as a separate stock. Viewed in conjunction with the concurrent study completed by Taube (1996, 1997) knowledge of inconnu populations of the Kobuk and Selawik drainages is more complete. Some biological questions remain unanswered, particularly life history and habitat needs of young-of-the-year inconnu, validation of aging techniques, the question of how often inconnu spawn, reasons behind the selection of spawning habitat, and harvest rates. Priority should be given to monitoring the harvest of the numerous components of the fishery and identifying the size and age composition of the catch in each. Any increase or decrease in population size is a function of the mortality rate independent from the size of the population. Therefore, despite the fact that the spawning population was higher than expected, the harvest rate, suspected as the major contributor to mortality, will likely determine the rate of change.

Monitoring of the spawning population on the Selawik River and repeating the population estimate, is recommended at 7 to 10 year intervals. Future monitoring is needed to measure the effect of current harvest rates on the population. A resistence board weir may improve the cost effectiveness of a population evaluation because flood events, which halted the project one year and severely affected sampling in a second year, may not affect the outcome of the project. These risks would have to be weighed against the cost of the weir, transportation to the site, the debris load, and inconnu behavior that indicate downstream movement with major flood events.

Some consideration should be given to the protection of the spawning area because the selected habitat is so restricted (12 km in length). Three actions are recommended: sport harvest regulation changes, acquisition of selected land in the spawning area, and review of special use permits in light of the new data. First, changing sport harvest regulation to limit the harvest of inconnu above the Tagagawik River should be recommended to the Alaska Board of Fisheries. Currently, bag and possession limits are 10 inconnu in the Selawik River. In contrast, sport harvest is restricted on the Kobuk River inconnu spawning grounds to a two fish bag and possession limits. The Selawik River should be afforded the same protection. Second, there is one private allotment within the spawning area which could be developed once it is conveyed. Development as a commercial site to exploit the fish and wildlife in the upper Selawik River could have detrimental effects on the spawning inconnu. Finally, the new information should be reflected in the review of special use permits on Selawik Refuge lands. The limited nature of the spawning habitat may make some activities not compatible to Selawik Refuge purposes.

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APPENDIX A: Surgical Insertion of Transmitters

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Surgical Procedures

Inconnu from 71 to 120 cm (fork length) were caught by hook and line and held in a live car prior to surgery. Initially, weights, lengths, and scales were taken from all fish undergoing surgery, but later only fork lengths were measured to reduce handling stress. Fish undergoing surgery were tagged with either a Flay anchor tag or a visible implant (VI) tag. Initially, some were tagged with both. Lotek transmitters (model CFRT-3C) with internal helical or external whip antennae were surgically implanted in the peritoneal cavity. Air weights and dimensions for the two antennae type transmitters were 13.0 g, 69 x 16 mm; and 10.0 g, 41 x 14.5 mm, respectively. Transmitters had unique digital codes on one of six frequencies that ranged from 150.10 to 151.10 megahertz so that individual fish could be recognized.

Fish were placed in a Bonar Multi-Tote III (112 x 66 x 46 cm) containing 68 l of water with Tricane Methanesulfonate (MS-222) at concentrations of 50-100 mg/L. Three 19 l collapsible jugs were used to increase the water depth without increasing water volume and reduce the amount of MS-222 required for each fish. Sodium Bicarbonate (Baking Soda) at concentrations of 200-250 mg per 100 mg of MS-222 was used to buffer the solution. Water was changed for each fish. In 1995 litmus paper was used to measure pH prior to placement of the fish into the anesthetic solution and after removal. No changes in pH (usually pH 7) were documented. Fish lost equilibrium in 3.75 minutes on average and loss of equilibrium ranged from one to six minutes. After fish were anaesthetized, they were placed ventral side up in a foam lined cradle. Wet towels were placed over the head and tail to retain moisture. Fresh water or anesthetic solution was applied to the gills throughout surgery to maintain level of anesthesia necessary to maintain some gill movement, but avoid response to stimuli.

Prior to surgery all instruments were sterilized in Control III, a cold sterilant, and rinsed using a sterile saline solution. Two to four rows of scales were removed from the belly posterior of the distal end of the pectoral fin when pressed flat along the midline. A scalpel with a No. 12 stainless steel blade was used to begin the incision through the body wall. The midline incision resulted in reduced bleeding because the body wall was thinnest there and connective tissue was cut instead of more vascularized muscle. Rat-toothed forceps were used to pull away skin and muscle so that surgical scissors could be used to complete the incision. Finishing with scissors reduced the chance of damage to internal organs. The incision was just large enough to insert the transmitter approximately 1.5 cm into the body cavity. Radio transmitters with helical antennas were inserted directly into the body cavity, but transmitters with whip antennas required that the antennae be threaded through the body wall. To thread the antennae a 10 cm stainless steel hollow needle was inserted posterior to the incision and anterior to the pelvic girdle. A stainless steel speculum was used to spread the incision and lift the body wall to facilitate insertion of the surgical needle without damaging internal organs. After removing the speculum the antenna was threaded through the surgical needle which was removed prior to insertion of the transmitter. After the transmitter was inserted, the antibiotic Liquamycin (Oxytetracycline HCL) was injected into the peritoneal cavity at 55mg/kg of weight. The incision was sutured using 3-O CP-1 suture with a ½ circle cutting needle. Four to six three-knot sutures were tied using a pair of stainless steel hemostats and rat-toothed forceps. The body wall and peritoneum were sutured together rather than separately and then dried with cotton swabs. A thin layer of Vetbond (Animal Care Products-3M Company) was applied, to seal the incision, and allowed to dry. Surgeries initially took from 15 to 26 minutes, but times were quickly reduced to 9 to 11 minutes. Upon completion the fish was returned to the live car to regain equilibrium which generally took from one to four minutes. Initially, fish were held overnight after surgery, but in our judgement stress was reduced by reducing the holding time so active fish were later held for as little as ten minutes.

Problems and Modifications

Surgeries the first two days of 1994 resulted in 40 and 50 percent mortality (n=5). Internal and external examinations of mortalities showed little or no internal damage which suggests that stress or anaesthetic may have caused the high mortality. Handling was reduced and the anaesthetic concentration was reduced to 50-80 mg/l. Subsequently, we experienced one mortality during surgeries.

Stressed fish showed distinct symptoms. Some fish held in livecars for surgery and tagging developed what the crew termed "red fin syndrome" characterized by a retraction of blood into the base of the pelvic, pectoral, and caudal fins and lots of subcutaneous bleeding. In addition, the trailing 2 cm of all fins became markedly pale. Fish that developed "red-fin syndrome" during or after surgery often died. Therefore, if fish showed signs of "red-fin syndrome" prior to surgery, we released them without implanting a receiver. A second symptom was noticeable on sunny days; the corneas of some fish turned cloudy. Setting the livecar in the shade and covering the head and tail with a wet towel during surgery appeared to reduce this problem.

APPENDIX B: Procedures for Oral Insertion of Transmitters

APPENDIX B: Procedures for Oral Insertion of Transmitters

Anaesthetic was applied in the same manner as fish undergoing surgery. Fish were placed in a Bonar Multi-Tote III (112 x 66 x 46 cm) containing 68 l of water with Tricane Methanesulfonate (MS-222) at concentrations of 50-100 mg/l. Three 19 l collapsible jugs were used to increase the water depth without increasing water volume and reducing the amount of MS-222 required for each fish. Sodium Bicarbonate (Baking Soda) at concentrations of 200-250 mg per 100 mg of MS-222 was used to buffer the solution. Water was changed for each fish. Each fish was held in the anaesthetic solution until it showed signs of loss of equilibrium.

Transmitter insertion was usually completed within one minute of loss of equilibrium. The transmitters were placed in a 1.5 cm (inside diameter) thin-wall plastic pipe fitted with a wooden push rod. The outside edge of the pipe that contacted the fish was smoothed of all sharp and rough edges. The push rod was slotted so the whip antennae could run within the slot and not bind with the pipe inhibiting movement. When the fish had lost equilibrium, the person tagging would grasp the lower jaw with one hand and insert as a unit the pipe, transmitter, and push rod. With steady gentle pressure the rod was pushed through the esophagus and into the stomach. The push rod was then slowly pushed forcing the transmitter out of the pipe. The pipe and push rod were removed leaving the transmitter. The antennae passed through the esophagus and into mouth.

APPENDIX C: Formulae for Length Composition When the Estimate is Unstratified

APPENDIX C: Formulae for Length Composition When the Estimate is Unstratified

If abundance estimates are not stratified due to size-selectivity in the sampling gear, estimates of length and age composition will be calculated as follows (Cochrane 1977):

$$\hat{P}_j = \frac{N_J}{n}; \text{ and,} \tag{3}$$

$$V[\hat{P}_j] = \frac{\hat{P}_j (1-\hat{p}_j)}{n - 1}; \tag{4}$$

where:

N_J = the number in the sample from group j;

n = the sample size; and,

P_j = the estimated fraction of the population that is made up of group j.

The estimated abundance of each group j in the population ($_{NJ}$) is:

$$\hat{N}_j = \hat{p}_j N \tag{5}$$

where:

$\hat{N}_J$ = the estimated number of fish in the population in group j.

P_j = the estimated fraction of the population in group j.

$\hat{N}$ = the estimated population.

The variance of $_{NJ}$ is the exact variance of a product (Goodman 1960):

$$V[\hat{N}_j] = V[\hat{P}_j]N^2 + V[\hat{N}]p_j^2 - V[p_j]V[\hat{N}] \tag{6}$$

APPENDIX D: Formulae for Length Composition When the Estimate is Stratified

APPENDIX D: Formulae for Length Composition When the Estimate is Stratified

If abundance estimates are stratified due to size-selectivity in the sampling gear estimates of length composition will be calculated as follows:

$$\hat{p}_{ij} = n_{ij} / n_i$$

where:

n_i = the number sampled from stratum i in the mark-recapture experiment;

n_{ij} = the number sampled from stratum i that belong to group j; and,

p_{ij} = the estimated fraction of the fish in group j in stratum i

Note that $\sum_j p_{ij} = 1$. The variance for $\hat{p}_{ij}$ is:

$$V[\hat{p}_{ij}] = \frac{\hat{P}_{ij}(1 - \hat{p}_{ij})}{n_i - 1} \quad (8)$$

The estimated abundance of inconnu in group j in the population ($\hat{N}_J$) is:

$$\hat{N}_J = \sum_i \hat{p}_{ij} \hat{N}_i \quad (9)$$

where: $\hat{N}_i$ = the estimated abundance in stratum i of the mark-recapture

experiment. The variance for $\hat{N}_J$ is a sum of the exact variance of a product from Goodman (1960):

$$V[\hat{N}_j] = \sum_i \left(V[\hat{p}_{ij}]\, \hat{N}_i^2 + V[\hat{N}_i]\, \hat{p}_{ij}^2 - V[\hat{p}_{ij}]\, V[\hat{N}_i] \right) \tag{10}$$

The estimated fraction of the population that belongs to group j (pj) is:

$$\hat{p}_j = \hat{N}_j / \hat{N} \tag{11}$$

where: $N = \sum N_i$. The variance of the estimated fraction can be approximated with the delta method (see Seber 1982):

$$V[\hat{p}_j] = \sum_i V[\hat{p}_{ij}] \frac{\hat{N}_i^2}{\hat{N}} + \frac{\sum_i \left(V[\hat{N}_i]\, (\hat{p}_{ij} - \hat{p}_j)^2 \right)}{\hat{N}^2} \tag{12}$$

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Table 1.— Population estimate of spawning inconnu in the Selawik River for 1995 and 1996. The population estimate includes fish from 75 to 111 cm. The 1995 estimate is from an unstratified Chapman estimator. For data from 1996 a stratified estimator was used because of size selectivity in sampling. The stratum used were fish ≤ 100 cm and those from 101 to 111 cm. Confidence intervals are for a 95% Poisson distribution. The unstratified estimate for 1996 is presented for comparison only and shows the benefit of stratifying the estimate.

	Marked	Examined	Recapture	Estimate	Confidence interval	
			1995			
Unstratified	511	324	31	5,190	3,690	7,274
			1996			
≤99 cm	170	142	4	4,862		
≥100 to 111cm	65	67	14	295		
Total				5,157		
Boot strap estimate					3,038	12,983
Unstratified estimate	235	209	18	2,597		

Table 2.— Length data for spawning inconnu from the Selawik River for three years 1994, 1995, and 1996 by sampling period including average, median, and ranges of fork length in cm.

	N	Mean	Median	Minimum	Maximum
			1994		
Marking, event I	146	88.8	89	67	120
			1995		
Marking, event I	618	91.5	91	64	117
Examined, event II	349	89.2	88	65	116
Recaptured, event II	31	94.3	96	67	107
			1996		
Marking, event I	287	91	91	52	117
Examined, event II	281	91	91	63	119
Recaptured, event II	18	101.4	103	78	111

Table 3.— Inconnu length frequency data for 1994 from the Selawik River was collected above the Tagagawik River during August.

Lengths	Frequency	p	V(p)	SE
61	0	0.00	.	.
63	0	0.00	.	.
65	0	0.00	.	.
67	1	0.01	4.69E-05	5.67E-04
69	0	0.00	0.00E+00	0.00E+00
71	1	0.01	4.69E-05	5.67E-04
73	2	0.01	9.32E-05	7.99E-04
75	6	0.04	2.72E-04	1.36E-03
77	7	0.05	3.15E-04	1.47E-03
79	11	0.08	4.80E-04	1.81E-03
81	12	0.08	5.20E-04	1.89E-03
83	7	0.05	3.15E-04	1.47E-03
85	8	0.05	3.57E-04	1.56E-03
87	11	0.08	4.80E-04	1.81E-03
89	8	0.05	3.57E-04	1.56E-03
91	17	0.12	7.10E-04	2.20E-03
93	11	0.08	4.80E-04	1.81E-03
95	12	0.08	5.20E-04	1.89E-03
97	9	0.06	3.99E-04	1.65E-03
99	1	0.01	4.69E-05	5.67E-04
101	7	0.05	3.15E-04	1.47E-03
103	3	0.02	1.39E-04	9.75E-04
105	5	0.03	2.28E-04	1.25E-03
107	3	0.02	1.39E-04	9.75E-04
109	1	0.01	4.69E-05	5.67E-04
111	1	0.01	4.69E-05	5.67E-04
113	1	0.01	4.69E-05	5.67E-04
115	0	0.00	0.00E+00	0.00E+00
117	0	0.00	0.00E+00	0.00E+00
119	0	0.00	0.00E+00	0.00E+00
121	1	0.01	4.69E-05	5.67E-04

Table 4.— Inconnu length frequency data for 1995 from the Selawik River was collected above the Tagagawik River in September.

Lengths	Frequency	p	V(p)	SE
61	0	0.000	0.00E+00	0.00E+00
63	0	0.000	0.00E+00	0.00E+00
65	1	0.003	.	.
67	4	0.011	3.78E-03	3.07E-02
69	3	0.009	4.26E-03	3.77E-02
71	9	0.026	3.14E-03	1.87E-02
73	11	0.032	3.05E-03	1.67E-02
75	15	0.043	2.94E-03	1.40E-02
77	11	0.032	3.05E-03	1.67E-02
79	19	0.054	2.86E-03	1.23E-02
81	30	0.086	2.71E-03	9.50E-03
83	24	0.069	2.78E-03	1.08E-02
85	22	0.063	2.81E-03	1.13E-02
87	16	0.046	2.92E-03	1.35E-02
89	25	0.072	2.77E-03	1.05E-02
91	21	0.060	2.83E-03	1.16E-02
93	22	0.063	2.81E-03	1.13E-02
95	8	0.023	3.20E-03	2.00E-02
97	17	0.049	2.90E-03	1.31E-02
99	11	0.032	3.05E-03	1.67E-02
101	18	0.052	2.88E-03	1.26E-02
103	9	0.026	3.14E-03	1.87E-02
105	16	0.046	2.92E-03	1.35E-02
107	14	0.040	2.96E-03	1.45E-02
109	11	0.032	3.05E-03	1.67E-02
111	8	0.023	3.20E-03	2.00E-02
113	3	0.009	4.26E-03	3.77E-02
115	0	0.000	0.00E+00	0.00E+00
117	1	0.003	.	.
119	0	0.000	0.00E+00	0.00E+00
121	0	0.000	0.00E+00	0.00E+00

Table 5.— Spawning inconnu length composition for 1996 was collected above the Tagagawik River from September 1 to 14, 1996 and is adjusted by the stratified population estimate. The count and probability (p_{ji}) are the sample data. The adjusted count (N_j) and frequency p_j in size interval j are by the stratified estimate. The variance of p_j [$V(p_j)$] and the standard error of p_j [$SE(p_j)$] make up the final columns.

Lengths	Frequency	(p) j i	(N) j	(p) j	V[p j]	SE(j)
61	2	0.000	2.000	0.004	1.39E-06	8.34E-04
63	3	0.001	3.000	0.005	3.13E-06	1.02E-03
65	2	0.000	2.000	0.004	1.39E-06	8.34E-04
67	6	0.001	6.000	0.011	1.25E-05	1.44E-03
69	12	0.002	12.000	0.021	5.00E-05	2.04E-03
71	19	0.004	19.000	0.034	1.25E-04	2.57E-03
73	15	0.003	15.000	0.026	7.81E-05	2.28E-03
75	10	0.002	10.000	0.018	3.47E-05	1.86E-03
77	18	0.004	18.000	0.032	1.12E-04	2.50E-03
79	34	0.007	34.000	0.060	4.01E-04	3.44E-03
81	39	0.008	39.000	0.069	5.28E-04	3.68E-03
83	29	0.006	29.000	0.051	2.92E-04	3.17E-03
85	28	0.006	28.000	0.049	2.72E-04	3.12E-03
87	28	0.006	28.000	0.049	2.72E-04	3.12E-03
89	25	0.005	25.000	0.044	2.17E-04	2.95E-03
91	21	0.004	21.000	0.037	1.53E-04	2.70E-03
93	22	0.005	22.000	0.039	1.68E-04	2.76E-03
95	23	0.005	23.000	0.041	1.84E-04	2.83E-03
97	32	0.007	32.000	0.056	3.55E-04	3.33E-03
99	22	0.005	22.000	0.039	1.68E-04	2.76E-03
101	21	0.071	21.000	0.037	1.88E-07	9.47E-05
103	23	0.078	23.000	0.041	2.25E-07	9.90E-05
105	29	0.098	29.000	0.051	3.57E-07	1.11E-04
107	28	0.095	28.000	0.049	3.33E-07	1.09E-04
109	28	0.095	28.000	0.049	3.33E-07	1.09E-04
111	22	0.075	22.000	0.039	2.06E-07	9.69E-05
113	13	0.044	13.000	0.023	7.34E-08	7.51E-05
115	10	0.034	10.000	0.018	4.42E-08	6.65E-05
117	1	0.003	1.000	0.002	2.35E-09	4.85E-05
119	2	0.007	2.000	0.004	3.62E-09	4.26E-05
121	0	0.000	0.000	0.000	1.93E-09	.

Table 6.— Results of a 3×5 chi-square comparing the ratio of inconnu placed in size intervals among three years. Difference among the years (X^2 = 28.3, df = 776, *P* = 0.001) were indicated. Cell chi-square values are an indication of where differences may be present.

	Length (cm)					
	79	80-89	90-99	100-110	110	n
			1994			
Frequency	28	46	50	19	3	146
Expected	29.73	44.96	34.81	29.16	7.34	
Chi-square	0.10	0.02	6.6	3.54	2.56	
			1995			
Frequency	73	117	79	69	12	349
Expected	71.1	107.5	83.2	69.7	17.5	
Chi-square	0.05	0.84	0.21	0.04	1.75	
			1996			
Frequency	57	76	56	68	24	281
Expected	57.2	86.5	67.0	56.1	14.1	
Chi-square	<0.01	1.28	1.80	2.51	6.9	
Total	158	239	185	155	39	776

Table 7.— Age composition of inconnu collected in 1995. Age data presented are from September of that year.

Age	Frequency	p	V(p)	SE
7	0	0.000	0.000	.
8	2	0.007	0.007	0.057
9	14	0.046	0.003	0.016
10	9	0.030	0.004	0.020
11	16	0.053	0.003	0.014
12	44	0.145	0.003	0.008
13	67	0.221	0.003	0.006
14	46	0.152	0.003	0.008
15	24	0.079	0.003	0.011
16	19	0.063	0.003	0.013
17	20	0.066	0.003	0.013
18	22	0.073	0.003	0.012
19	11	0.036	0.003	0.018
20	5	0.017	0.004	0.028
21	4	0.013	0.004	0.033
22	0	0.000	0.000	.

Table 8.—Age composition of inconnu collected in 1996. Age data presented are from September of that year.

Age	Frequency	p	V(p)	SE
7	1	0.002	.	.
8	13	0.026	0.0021	0.013
9	17	0.034	0.0021	0.011
10	9	0.018	0.0022	0.016
11	20	0.040	0.0020	0.010
12	40	0.080	0.0019	0.007
13	60	0.120	0.0018	0.005
14	65	0.130	0.0018	0.005
15	48	0.096	0.0018	0.006
16	44	0.088	0.0019	0.007
17	46	0.092	0.0019	0.006
18	41	0.082	0.0019	0.007
19	42	0.084	0.0019	0.007
20	26	0.052	0.0020	0.009
21	22	0.044	0.0020	0.010
22	5	0.010	0.0025	0.022
23	1	0.002	.	.

Table 9.— Year of catch, total catch, number of inconnu tagged and released each year, and the number of inconnu recaptured from each year of tagging. Recaptures listed include those from both the marking and recapture events of each year.

Year of catch	Total catch	Tags released	Number of inconnu caught from year			
			1993	1994	1995	1996
1993	76	70	0			
1994	171	143	1	0		
1995	995	596	2	16	85	
1996	568	505	1	8	7	39

Table 10.— Proportion of tags lost after three time periods at large. Each category includes fish from the mark and recapture event during the year. Sample sizes are those of the recaptured fish in Table 9 which should be recognized as small especially for the longer time period.

Year Released	Probability of tag loss		
	Same year	1 year	2 years
		Visual Implant Tag	
1995	0.08	0.33	0.5
1996	0.15	0.43	0.5
		Floy Anchor Tag	
1995	0.01	0.07	0
1996	0.11	0	0.12

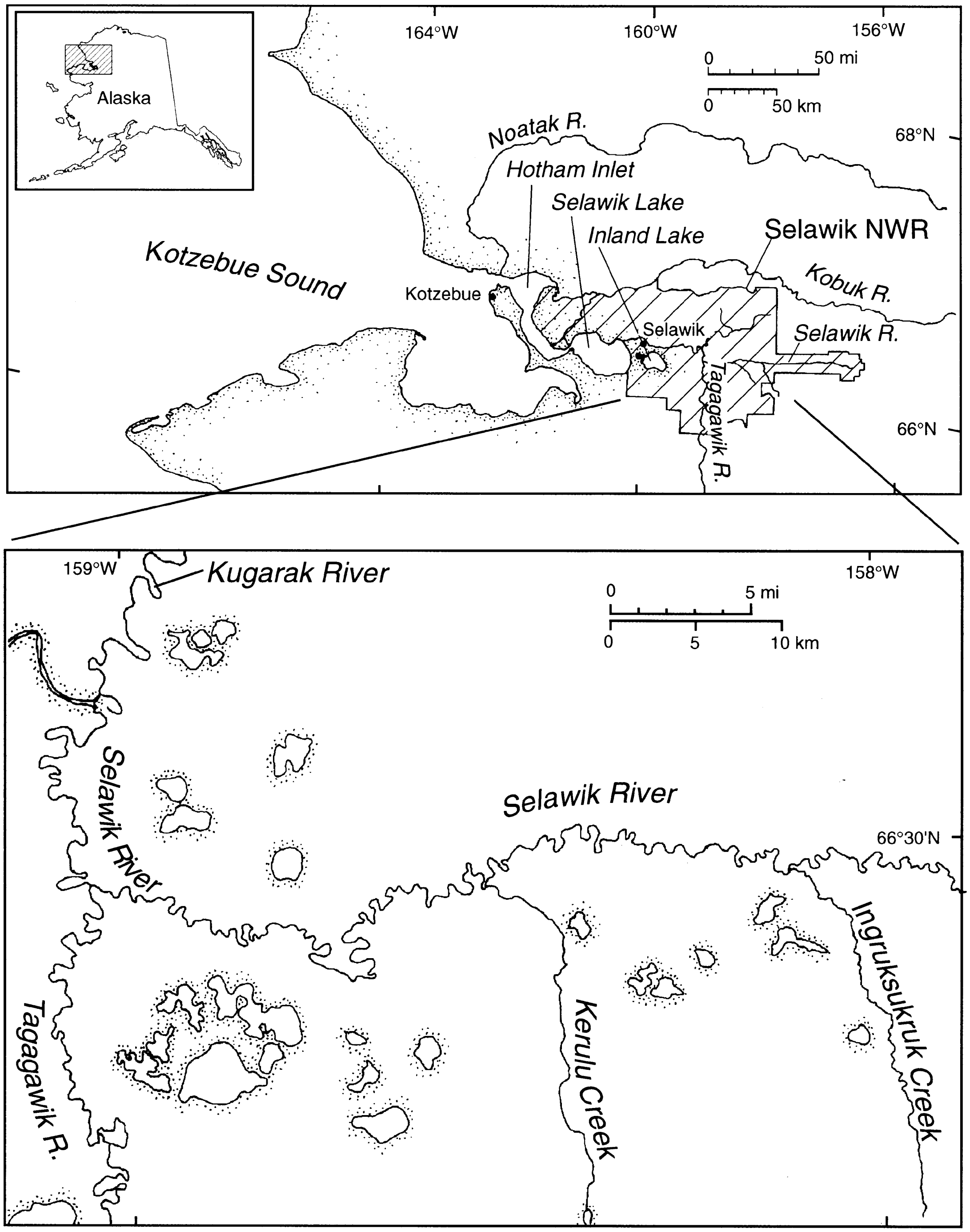

Figure 1.— The Selawik National Wildlife Refuge Selawik River is located located in northwest Alaska east of the City of Kotzebue. The Selawik River study area (bottom) was above the confluence of theTagagawik and flows generally from east to west into Selawik Lake.

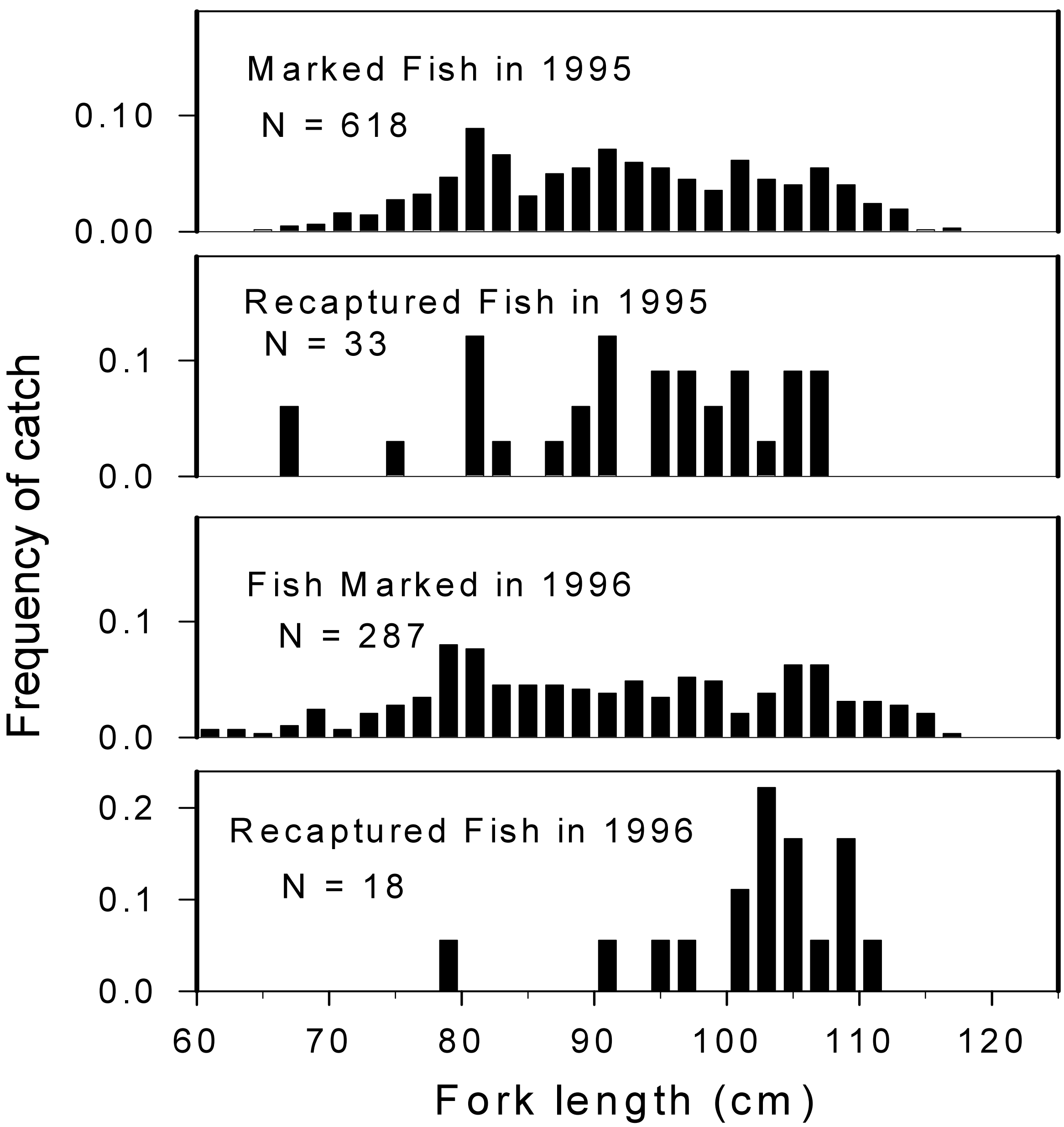

Figure 2.— Length frequencies for marked (A, C) and recaptured (B, D) inconnu collected during 1995 and 1996 on the Selawik River. The sample population for each year is normally set by the range of lengths of recaptured fish. Because the range of lengths of recaptured fish was different for each year, the sample population was limited to fish from 75 to 111 cm.

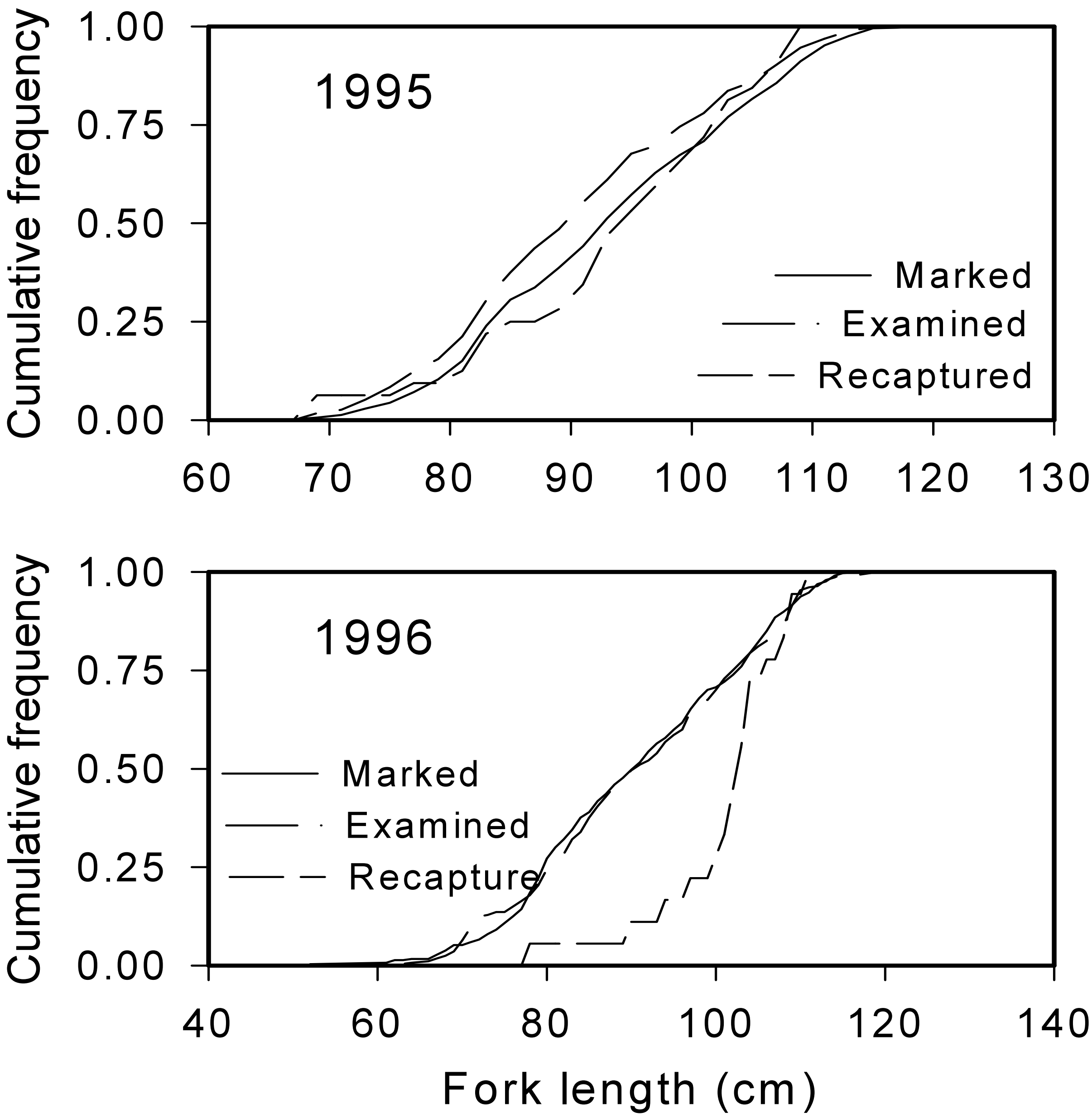

Figure 3.— Cumulative length frequencies for 1995 (top) and 1996 (bottom) of marked fish during the first event as well as fish examined and fish recaptured during the recapture event.

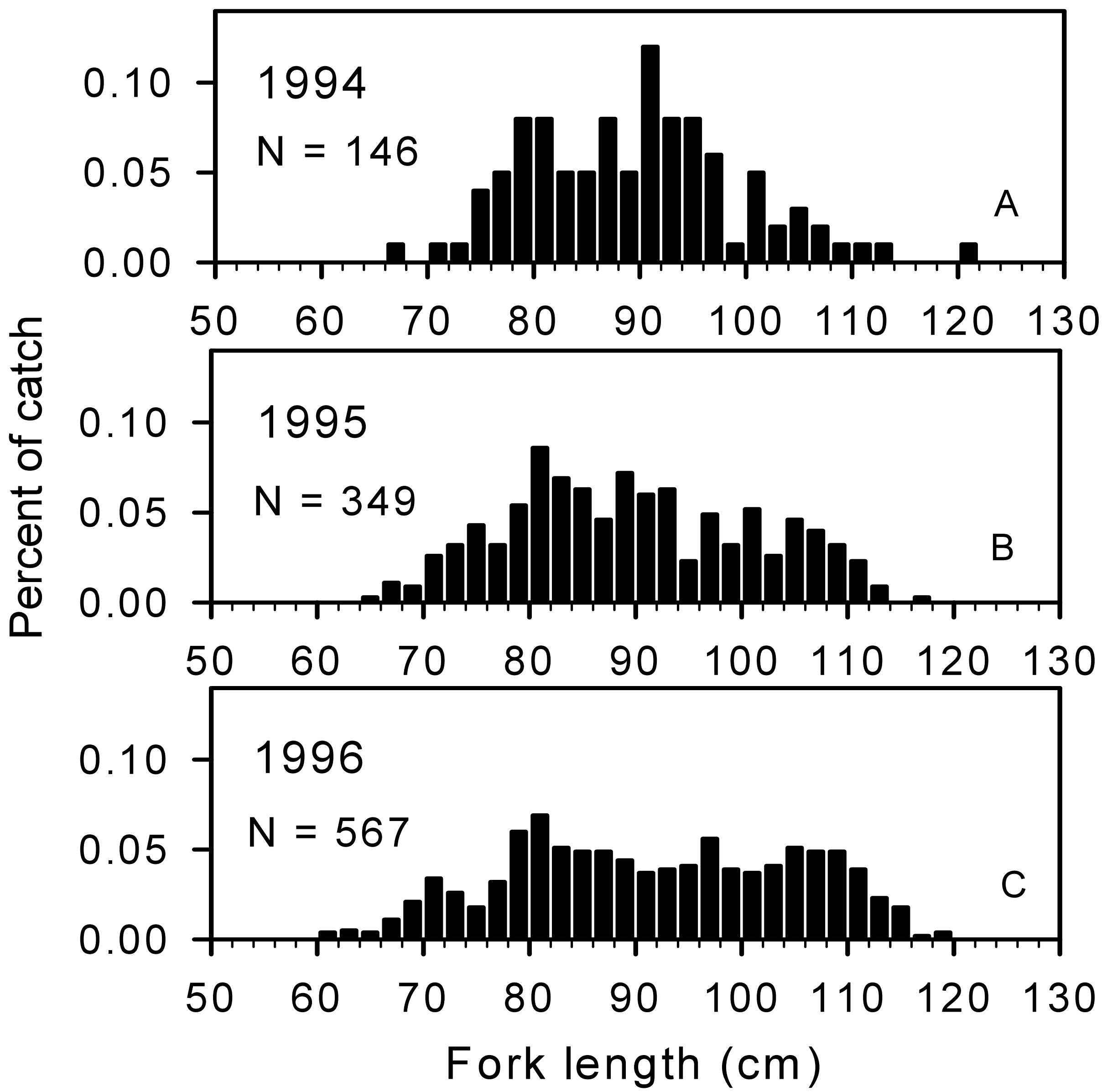

Figure 4.— Length composition for 1994-1996 of the spawning stock from the Selawik River on the Selawik National Wildlife Refuge. Minor differences in the length frequencies are distinguishable.

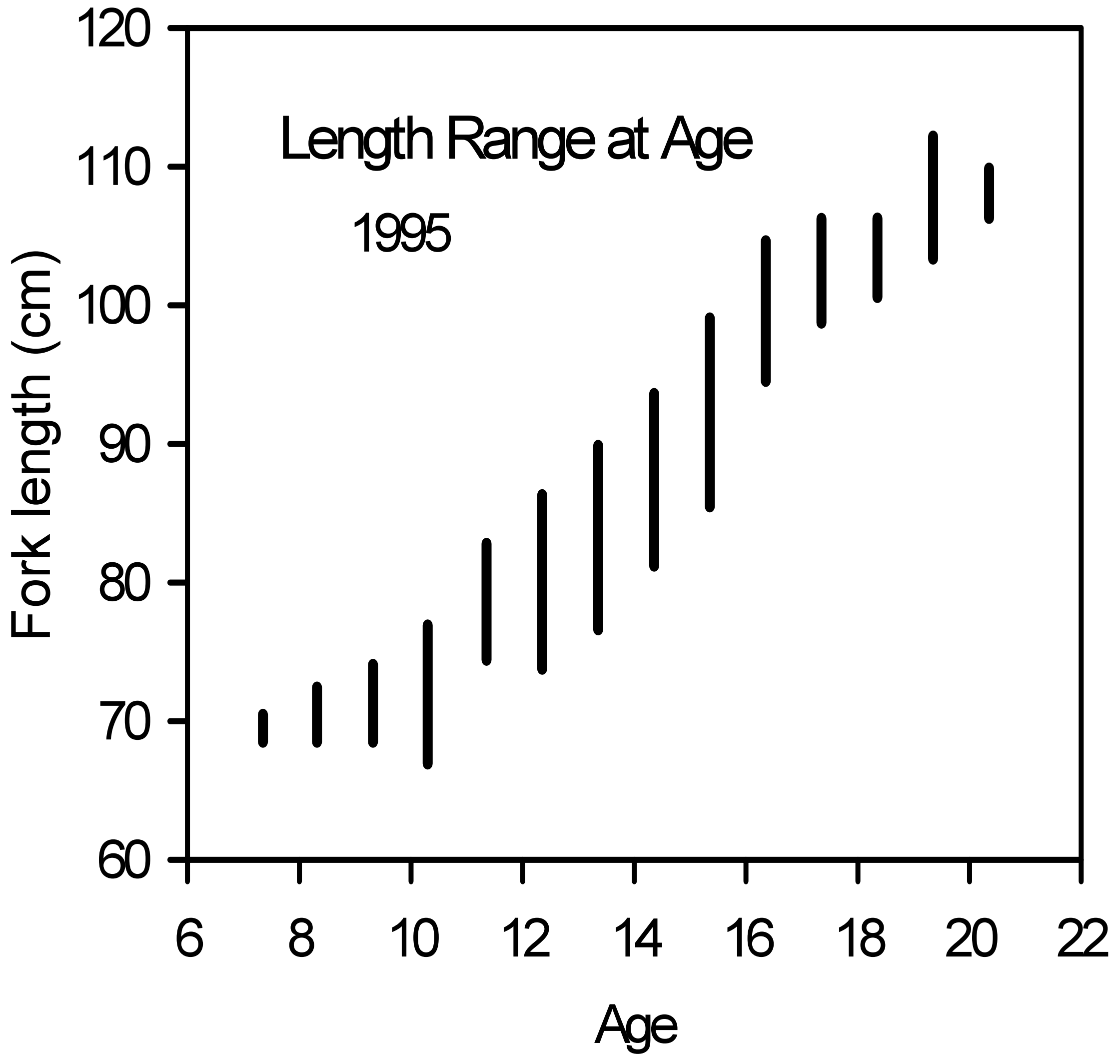

Figure 5.— Range of inconnu lengths at age in 1995. The data demonstrates the wide range of lengths observed at a given age.

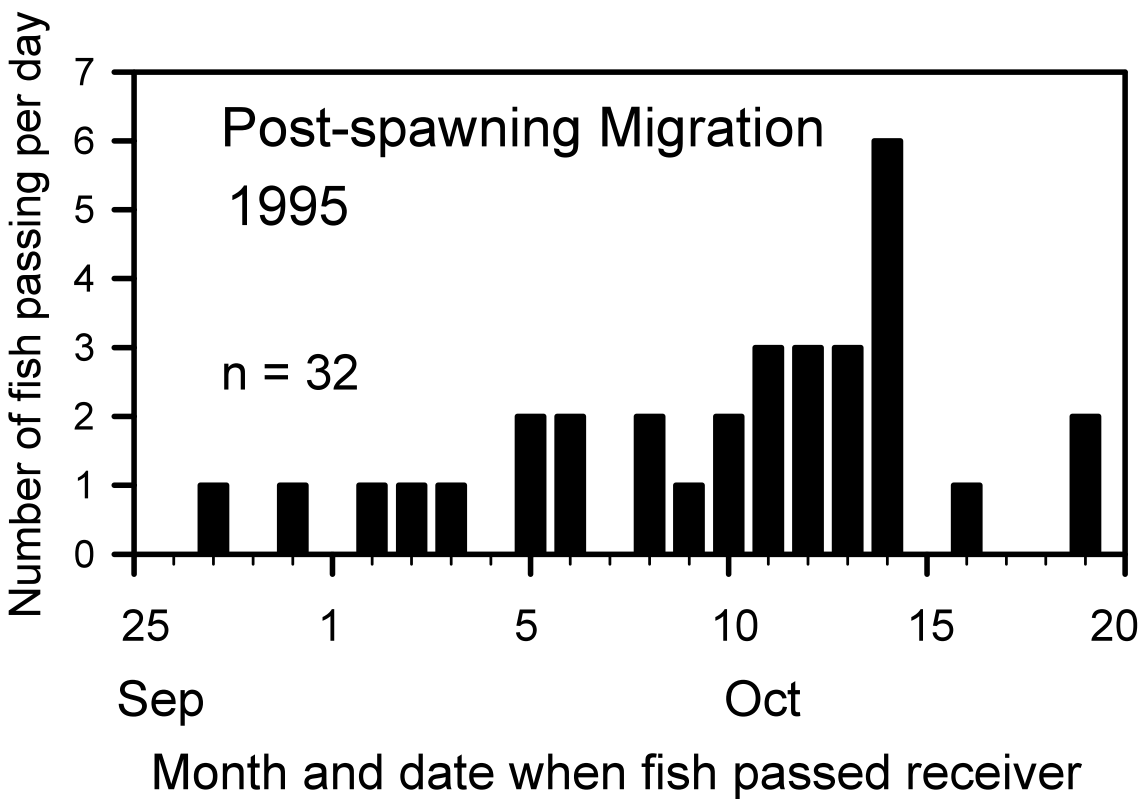

Figure 6. — Date and number of inconnu that passed the receiver site on the Selawik River approximately 15 km above the entrance to Inland Lake, Selawik National Wildlife Refuge. The receiver was operated from September 27, 1996 to December 13, 1996 when the battery power was depleted.

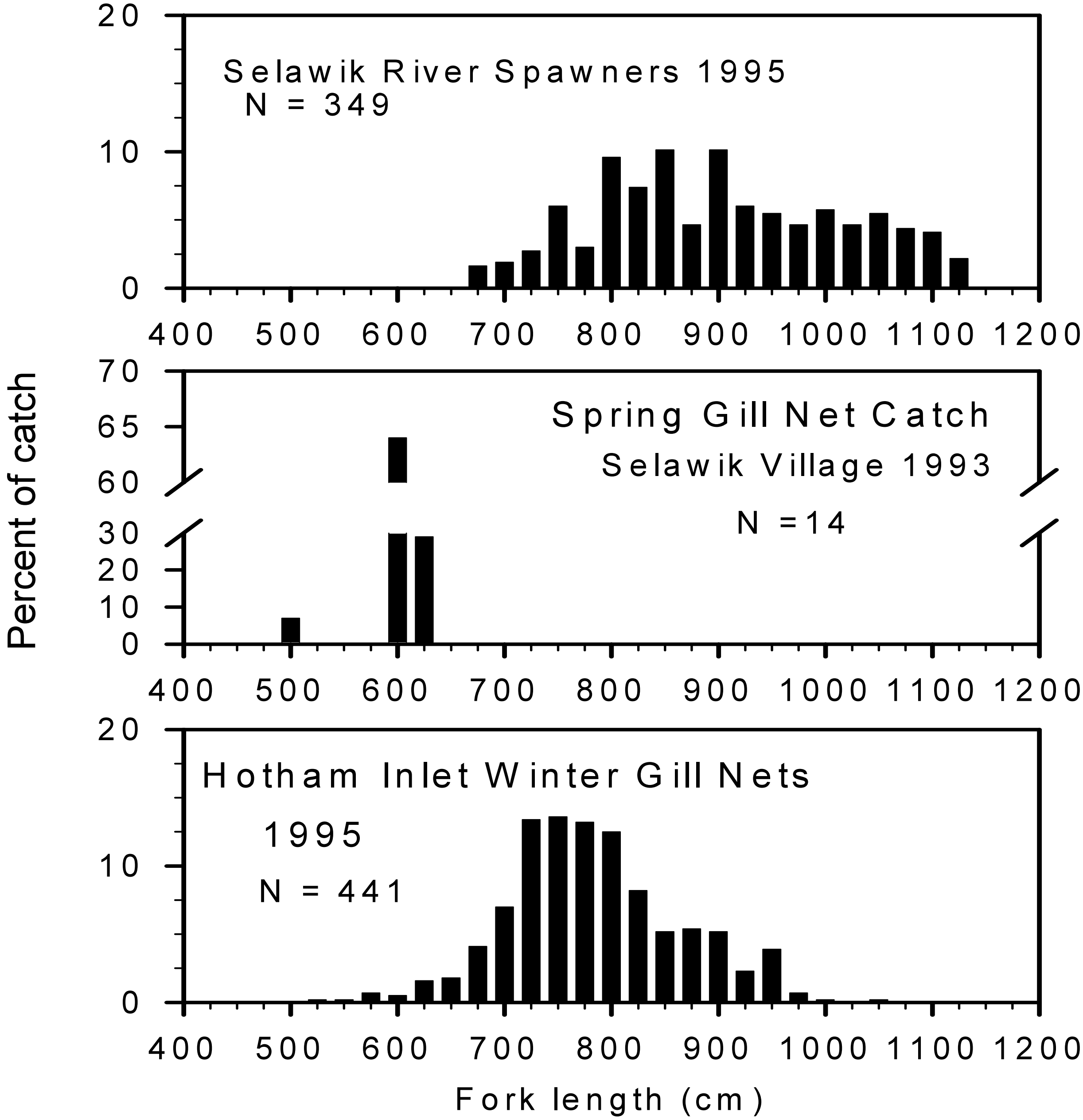

Figure 7.— Length frequency distributions of Selawik River spawners from 1995 (A) and from two inconnu fisheries. The Selawik Village net fishery occurs annually in late May and June (B). The Hotham Inlet gill net fishery data (C) from Taube (1996) which occurs from October until ice-out in April or May.