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Abundance, Age, Size, Sex and Coded Wire Tag Recoveries for Chinook Salmon Escapements of Kitsumkalum River, 1984-1986

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ABUNDANCE, AGE, SIZE, SEX AND CODED WIRE TAG RECOVERIES FOR CHINOOK SALMON ESCAPEMENTS OF KITSUMKALUM RIVER, 1984 - 1986

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ABSTRACT

Andrew, J.H. and T.M. Webb. 1988. Abundance, age, size, sex and coded wire tag recoveries for chinook salmon escapements of Kitsumkalum River, 1984-1986. Can. MS Rep. Fish. Aquat. Sci. 2004:62p.

The purpose of this study was to estimate the chinook salmon (Oncorhynchus tshawytscha) escapements to Kitsumkalum River from 1984 to 1986, to estimate the escapement of coded wire tags, and to estimate the contribution of hatchery production to the total escapement. The Kitsumkalum river is a major tributary of the Skeena River located near Terrace, British columbia and one of the most important chinook spawning streams on the northern coast.

Escapements were enumerated using the adjusted Petersen method, by tagging live returning adults on the spawning grounds and recovering tags from carcasses following spawning. Escapement estimates were 11,825 fish in 1984, 8,308 fish in 1985, and 10,151 fish in 1986. Tag loss was 5.9% to 45.7%. Spawners ranged in age from 3_2 to 7_3. Age classes 5 and 6 predominated.

One adipose fin clipped fish was observed in 1984, 35 fish in 1985, and 38 fish in 1986. In 1985, hatchery returns (136 fish) comprised 1.6% of the escapement and in 1986, 219 hatchery returns comprised 2.4% of the escapement.

Key words: Kitsumkalum, chinook, key stream, escapement, coded wire tags, age composition, hatchery, live tagging

RÉSUMÉ

Andrew, J.H. and T.M. Webb. 1988. Abundance, age, size, sex and coded wire tag recoveries for chinook salmon escapements of Kitsumkalum River, 1984-1986. Can. MS Rep. Fish. Aquat. Sci. 2004:62p.

La présente étude avait pour objectif d'estimer les échappées de saumon quinnat (Oncorhynchus tshawytscha) vers la rivière Kitsumkalum, de 1984 à 1986, les remontées de poissons marqués par fils codés et l'apport de la production pisilcole aux remontées totales. La rivière Kitsumkalum est un important tributaire de la rivière Skeena, à proximité de Terrace (Colombie-Britannique), et l'un des plus importants cours d'eau pour le trai du saumon quinnat dans la partie nord de la côte.

Les échappées ont été déterminées à l'aide de la méthode Petersen corrigée; les adultes revenant aux frayères etaient marqués et l'on récupérait ensuite les étiquettes sur les carcasses, après le frai. Les échappées ont été estimées a 11,825 poissons en 1984, 8,308 poissons en 1985, et à 10,151 poissons en 1986. Le nombre d'étiquettes perdues variait de 5.9% à 45.7%. L'âge des géniteurs se situait dans la gamme de 3_2 à 7_3. Les classes d'âge 5 et 6 étaient celles qui dominaient.

Le nombre de poissons à nageoire adipeuse coupée a été de un en 1984, de 35 en 1985 et de 38 en 1986. En 1985, les remontées de poissons d'élevage 136 poissons) représentaient 1.6% de l'échappée; en 1986, ces valeurs étaient de 219 poissons pour 2.4% de l'échappée.

Mots-clès: Kitsumkalum, quinnat, cours d'eau principal, échappée, étiquettes en fils codés, composition par âges, pisciculture, marquage de poissons vivants.

INTRODUCTION

Chinook salmon (<u>Oncorhynchus tshawytscha</u>), the largest of the Pacific salmon, are highly prized by both sport and commercial fishermen. Overfishing has reduced many British Columbia chinook stocks to dangerously low levels. In an effort to rebuild them, special measures have been taken to protect these stocks through management and enhancement actions. A key streams program was initiated in 1984 by the Department of Fisheries and Oceans to monitor the success of management actions in several important chinook producing streams throughout British Columbia. The objectives of the key streams program are:

1) to accurately estimate wild escapement on key streams;

2) to estimate harvest rates, and contributions to fisheries and escapement, based on an analysis of coded wire tagged (CWT) and adipose clipped returns, including estimates of the total escapement of CWTs to the key stream system; and

3) to estimate the contribution of hatchery production to the total key stream escapement.

Streams for the program were chosen based on criteria of existence of a relatively large chinook escapement, the presence of a hatchery, accessibility for field sampling, feasibility of fence operations, and geographic distribution with respect to other key streams such that different areas of the coast would be represented in the program.

One of the key streams selected is the Kitsumkalum River, a major tributary of the Skeena River located near Terrace, British Columbia. It is one of the most important chinook spawning streams on the northern coast (Ginetz 1976).

Petersen enumeration studies of the chinook escapement have been conducted since 1984 by staff of the Deep Creek Hatchery, which is operated by the Terrace Kitsumkalum Salmonid Enhancement Society under contract to the Department of Fisheries and Oceans. These studies have involved tagging live adults on the spawning grounds and recovering the tags from carcasses following spawning.

Each year since 1979, coded wire tagged fry have been released to assess the contribution of hatchery stocks to the river escapement and to provide a basis for determining harvest rates. Initial releases of coded wire tagged fry were conducted on wild fry in 1979, and of fry reared at the Kalum Pilot Hatchery at Dry Creek in 1980, 1981, and 1982 (MacKinlay and Fielden 1987). A small hatchery was constructed at Deep Creek in 1983 to increase the size of chinook escapement to the Kitsumkalum River.

The purpose of this report is to review Kitsumkalum River chinook escapement enumeration and CWT programs from 1984 to 1986. The escapement was enumerated by the adjusted Petersen method (Ricker 1975, p.78) to produce separate estimates for sexes and geographic stream areas and then summing these to form a total. Potential biases in the Petersen method and the method of stratification are discussed. Assumptions for the Petersen method and tests for biases caused by violations of assumptions are described in the methods section. The results section presents the escapement numbers, tests for bias in tagging and recovery, and the results of coded wire tagging studies. The results are then discussed on their own merits and with respect to other studies, and conclusions are made regarding their incorporation into future studies.

To avoid confusion in terminology relating to tagging and marking, the word "tagging" as used in this report refers to either Petersen disk or spaghetti tagging, "punching" refers to marking of chinook by opercular punch holes, and "marking" refers to marking of chinook juveniles with coded wire tags and clipped adipose fins.

STUDY AREA

Kitsumkalum River originates in the Kitimat and Nass Ranges of the Coast Mountains and flows in a southerly direction to its confluence with the Skeena River near Terrace, British Columbia (Fig. 1). The upper portion of the river drains into Treston Lake via Kitsumkalum Lake. Below Treston Lake (known locally as Mud Lake), the river flows through the Skeena Forest and the Kitsumkaylum Indian Reserve. Glacial till in runoff from tributary streams during spring to late fall creates high turbidity and reduces visibility to 5 - 10 cm. Observations of spawning salmon in the deeper areas of the mainstem is extremely difficult during this period (Morgan 1985).

Five species of Pacific salmon spawn in the Kitsumkalum River system (Hancock et al. 1983); in order of abundance these are pink, chinook, coho, sockeye, and chum salmon. Chinook, sockeye and coho spawn in the river upstream of Kitsumkalum Lake, sockeye spawn in the north end of Kitsumkalum Lake, and all five species spawn in scattered areas downstream of the lake to the mouth of the Skeena River (Hancock et al. 1983). Steelhead and anadromous Dolly Varden and cutthroat trout are also present. There are two spawning stocks of chinook in the Kitsumkalum system. The early run spawns upstream of Kitsumkalum Lake in late July to early August (G. Hazelwood, Manager, Deep Creek Hatchery, Terrace, B.C., pers. comm., 1988) and was not considered in this study; the study population spawns from late August to October downstream of Treston Lake.

Two waterfalls 86 km and 94 km upstream from the river mouth are barriers to salmonid migrations (Department of Fisheries and Oceans and Ministry of Environment and Parks 1987). About 10 km upstream of the Skeena River confluence, there is a 3 km section of canyon rapids (Fig. 1). The canyon is generally not navigable by boat but is not a barrier to fish migration. In this report, the portion of the study area upstream of the canyon is referred to as the "upper river" and the downstream portion is referred to as the "lower river".

The study area included the mainstem Kitsumkalum River from the confluence with the Skeena River to Treston Lake (Figure 1), a distance of approximately 22 km. Major tributaries of the Kitsumkalum River in the study area include Star, Alice, Glacier, Luncheon, Lean-to, Deep, and Spring creeks.

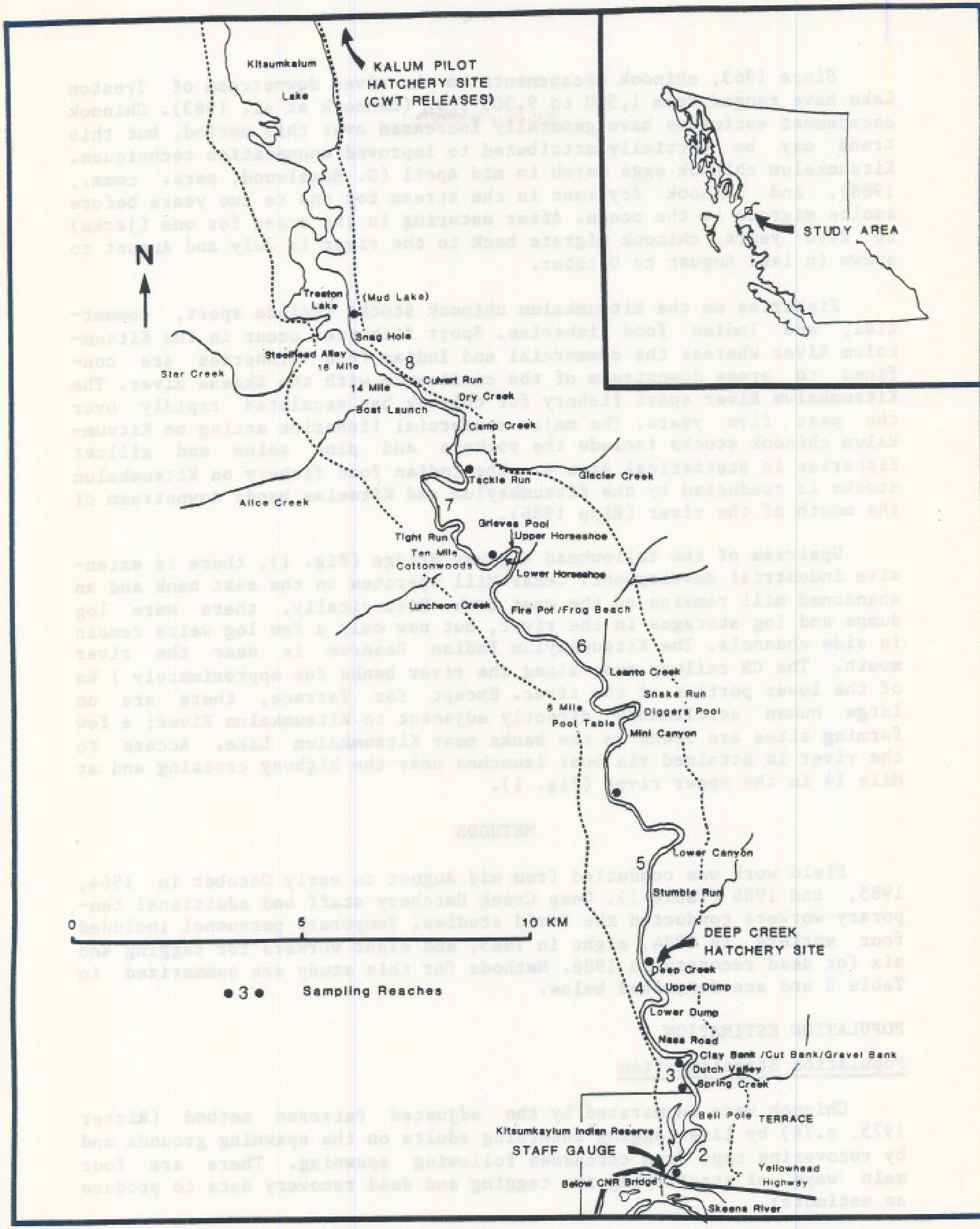

Figure 1. Map of Kitsumkalum River study area showing sampling reaches.

Since 1963, chinook escapements to the river downstream of Treston Lake have ranged from 1,500 to 9,300 fish (Hancock et al. 1983). Chinook escapement estimates have generally increased over this period, but this trend may be partially attributed to improved enumeration techniques. Kitsumkalum chinook eggs hatch in mid April (G. Hazelwood, pers. comm., 1988), and chinook fry rear in the stream for one to two years before smolts migrate to the ocean. After maturing in the ocean for one (jacks) to five years, chinook migrate back to the river in July and August to spawn in late August to October.

Fisheries on the Kitsumkalum chinook stocks include sport, commercial, and Indian food fisheries. Sport fisheries occur in the Kitsumkalum River whereas the commercial and Indian food fisheries are confined to areas downstream of the confluence with the Skeena River. The Kitsumkalum River sport fishery for chinook has escalated rapidly over the past five years. The major commercial fisheries acting on Kitsumkalum chinook stocks include the sockeye and pink seine and gillnet fisheries in Statistical Area 4. The Indian food fishery on Kitsumkalum stocks is conducted by the Kitsumkaylum and Kitselas bands downstream of the mouth of the river (Hipp 1986).

Upstream of the Yellowhead Highway Bridge (Fig. 1), there is extensive industrial development. Cedar Mill operates on the east bank and an abandoned mill remains on the west bank. Historically, there were log dumps and log storages in the river, but now only a few log weirs remain in side channels. The Kitsumkaylum Indian Reserve is near the river mouth. The CN railway runs along the river banks for approximately 1 km of the lower portion of the river. Except for Terrace, there are no large human settlements directly adjacent to Kitsumkalum River; a few farming sites are found on the banks near Kitsumkalum Lake. Access to the river is attained via boat launches near the highway crossing and at Mile 14 in the upper river (Fig. 1).

METHODS

Field work was conducted from mid August to early October in 1984, 1985, and 1986 (Table 1). Deep Creek Hatchery staff and additional temporary workers conducted the field studies. Temporary personnel included four workers in 1984, eight in 1985, and eight workers for tagging and six for dead recovery in 1986. Methods for this study are summarized in Table 2 and are described below.

POPULATION ESTIMATION

Population Stratification

Chinook were enumerated by the adjusted Petersen method (Ricker 1975, p.78) by live tagging returning adults on the spawning grounds and by recovering tags from carcasses following spawning. There are four main ways of stratifying the tagging and dead recovery data to produce an estimate:

1) sexes and areas (upper and lower river areas) pooled;

Table 1. Schedule of live tagging and dead recovery effort for chinook salmon, Kitsumkalum River, 1984-1986.

Year and Location[a]	Tagging	Dead recovery
1984		
Upper	August 16 - September 6	August 30 - September 30
Lower	August 16 - September 6	August 30 - September 30
1985		
Upper	August 22 - September 9	September 13 - October 4
Lower	August 21 - September 9	September 12 - October 7
1986		
Upper	August 21 - September 10	August 30 - October 6
Lower	August 20 - September 9	September 8 - October 2

[a] Upper river = Kitsumkalum River upstream of the canyon located 10 km upstream of the Skeena-Kitsumkalum confluence; lower river = the area downstream of the canyon to the confluence (see Fig.1).

Table 2. Summary of methods for Kitsumkalum River chinook salmon enumeration programs, 1984 - 1986.

Item	Method or materials
Population enumeration	Petersen estimate, sum separate estimates for sexes (1984) and upper and lower rivers (1985 and 1986)
Tagging of fish	1984 - Petersen discs, live tagging 1985 - Spaghetti tags, live tagging 1986 - Spaghetti tags, live tagging
Secondary marking	1984 - Tag scars 1985 - Opercular punches 1986 - Opercular punches
Recovery of fish	Daily foot surveys, dead pitch
CWT tagging[a]	Releases in 1979 (wild), 1980, 1981 and 1982 from Kalum Pilot Hatchery at Dry Creek; adipose clipped
CWT recovery	Collection of heads from live and dead adipose clipped fish
Biological and physical sampling	Ages from scales Sex ratios from sexes separate population estimates Post-orbital hypural length (mm) Success of spawning (females) Water level

[a]CWT = coded wire tagging.

2) sexes separate with areas pooled;

4) sexes pooled with areas separate; and

3) sexes separate and areas separate.

Separate Petersen estimates may be calculated for each stratum and then summed to obtain an estimate of the whole population. By segregating the data into separate population strata, biases caused by factors which affect the strata at different rates may be circumvented. The main factors of concern for accurate estimation of escapement numbers are rates of tag application, recovery of carcasses, and tag loss.

These factors may affect males, females and jacks at different rates so sexes can be subject to differential catchability for tagging, differential washout rates following spawning (affecting recovery rate), and different behavioural interactions that affect tag loss.

The canyon in the Kitsumkalum River study area poses a problem for unstratified enumeration of the spawning population. If the spawners in the upper and lower rivers do not mix following tagging and form two distinct groups then there is a potential for substantial bias if tagging or dead recovery rates and effort are not identical.

Due to the likelihood of factors affecting sexes and areas at different rates, Petersen estimates are stratified by sex and area in this study.

Potential Biases

Petersen estimates are potentially biased by violation of a number of assumptions. Seven of these assumptions, as modified from Ricker (1975, p. 81-82) are presented below along with the consequences of violating them.

Tests used to determine whether biases were acting in this study are also presented and discussed below with respect to sex and area stratification of the Petersen estimate. Other biases caused by methods of tagging, recovery, age determination, etc. are discussed in subsequent sections.

1) Tags are consistently applied in proportion to the available population and/or the distribution of recovery effort is proportional to the number of fish present in different river reaches and/or tagged fish become randomly mixed with untagged fish.

To obtain an accurate Petersen estimate, it is important to apply and/or recover tags in proportion to the available population. It is not possible to test whether tagging and dead recovery were conducted on a consistent proportion of the population because there is no independent measure of the numbers of fish available for tagging and dead recovery, or of the timing of the migration or of the termination of spawning apart from the tagging and recovery data. However, this is a fairly important problem as it affects the representativeness of sampling.

A related but untested problem associated with areas-separate estimates is that some tagged fish stray between areas; however, the assumption that tagged and untagged fish stray to the same degree circumvents this potential problem. It is not possible to test this assumption using the data from this study. Neither is it not possible to statistically test the extent of mixing of marked and unmarked fish using the data from this study, but movements of tagged fish are indicated by the location of recovery relative to the location of tagging. Tagging and recovery locations were grouped into river reaches to facilitate this comparison.

2) There is a negligible influx of spawners after the conclusion of tagging.

An influx of spawners following tagging could cause the Petersen calculations to overestimate or underestimate the true population depending on how they mixed with tagged fish. It is not possible to test this assumption with the data from this study.

3) Tagged fish suffer the same natural mortality as untagged fish.

Mortality due to tagging procedures cause Petersen calculations to overestimate the number of effective spawners. Mortality due to tagging may be indicated by reduced spawning success among tagged fish in the dead recovery. Tests for this bias are described in the recovery methods section.

4) There is no tag loss.

A high incidence of tag loss will cause Petersen calculations to overestimate the true population. Tag loss was determined by comparing tag and punch recoveries. The test for potential bias due to differential tag loss by sex are described in the tagging methods section. Petersen estimates were made using opercular punches to circumvent the potential bias due to spaghetti tag loss in 1985 and 1986. In 1984, no secondary marks were made to evaluate Petersen disk tag loss, therefore tag recovery plus tag scar recovery were used in the Petersen calculations.

5) All tags are recognized and reported on recovery after the conclusion of tagging.

In this study, no repitches were conducted to reexamine carcasses for missed tags and secondary marks, therefore it was not possible to evaluate tag recognition.

6) Recovery efforts are made on the same population as was tagged.

Dead recovery from a population other than the tagged population will cause Petersen calculations to overestimate the true population. Indications that tagging and recovery were conducted on different populations would be different age frequency and length frequency distributions among the two samples. Tests for this potential source of bias are described in the recovery methods section.

7) There is adequate sampling to obtain a tag recovery rate which provides an accurate and precise population estimate.

A small number of tag recoveries in a stratum will cause Petersen estimates to have low precision. Petersen estimates are generally more reliable if a high proportion of the tagged fish are recovered in each stratum. In the absence of other sources of bias, approximately 25 to 75 recaptures will produce population estimates with 25% accuracy, with 95% confidence, for populations of 10^2 to 10^9 (Ricker 1975). Confidence intervals for the estimates were calculated as described below.

Calculations

The Petersen estimate of each stratum was calculated by Chapman´s formula, cited in Ricker (1975, p.78):

$$\text{Petersen estimate} = (\text{total fish in dead pitch} + 1) \times \frac{(\text{total fish punched} + 1)}{(\text{total punched fish recovered} + 1)}$$

In 1985 and 1986, separate estimates were made for sexes and areas. In 1984, there were insufficient data to justify the same stratification system, and areas were pooled. Males, females and jacks were enumerated separately, but there were insufficient data to estimate the escapements of jacks in 1984 and 1985. Population estimates for each stratum were summed to obtain a total population estimate for each year.

Confidence intervals for the total population estimates were calculated by first calculating the variance of the estimate of each stratum as follows:

$$VAR_m = \frac{(PE_m)^2 \, (TA_m - TR_m)}{(TA_m + 1) \, (TR_m + 2)} \quad \text{(Ricker 1975, p.78)}$$

determining the total variance by summing the variances of strata as follows:

$$VAR_t = VAR_m + VAR_f + VAR_j$$

and applying this figure in the calculation of the 95% confidence interval for the total population estimate as follows:

$$\text{Upper and lower 95\% confidence limits of } PE_t = PE_t \pm 1.96\sqrt{VAR_t}$$

where VAR = variance of the population estimate

PE = Petersen estimate

DR = dead recovery

TA = tags (and punches) applied

TR = tags (and punches or tag scars) recovered

m = male stratum

f = female stratum

j = jack stratum.

t = total males, females, and jacks.

Strays

In this study, tagged fish movements through the canyon (Fig. 1) were considered to be strays from either the upper or lower rivers. "Straying" of tagged fish from the upper to the lower river was probably due largely to passive drift of moribund fish. Ideally, tagged strays could be recognized by their tag numbers. Unfortunately, this was frequently not the case due to tag loss. Although fish were punched on either the right or left operculum depending on the location of tagging (upper or lower rivers), these data were not consistently recorded in the dead pitch.

For purposes of the Petersen calculation, a calculation of punched strays was made using the number of tagged strays increased by the dead recovery rate and the tag loss rate. For purposes of this calculation, the dead recovery rate was calculated using areas pooled and sexes separate data. The tag loss rate was calculated for river areas separately because tagging in the two areas was performed by two separate crews. The number of punched fish available in each of the upper and lower river dead recovery programs was calculated by taking the number of punched fish in each location and subtracting the number of punched strays that moved <u>to</u> the opposite portion of the river and adding the number of punched strays that arrived <u>from</u> the opposite location. The calculations were performed as follows:

$$\text{Punched strays from lower river} = \text{Number tagged strays from lower river in dead pitch} \times \frac{1}{\text{Dead recovery rate}} \times \frac{1}{\text{Tag loss rate}}$$

where

$$\text{Dead recovery rate} = \frac{\text{Total recovered}}{\text{Total population}}$$

$$\text{Tag loss rate} = \frac{\text{Total tagged recovered}}{\text{Total punched recovered}}$$

and

$$\text{Punched available in the lower river} = \text{Punches applied in lower river} + \text{Punched strays from upper to lower river} - \text{Punched strays from lower to upper river}$$

The Petersen calculation was then performed using the calculated punched available in the Petersen equation given above.

TAGGING

In each year, there were two tagging crews composed of four workers each. Chinook were captured for tagging using floating gillnets (22.9 m long by 3.7 m deep) which were used to corral the fish, as in beach seining. Multifilament twine with a 28 or 38 gauge filament was normally used with a 15.2 cm mesh size; when smaller fish species were present and being gilled, a net with a 38 gauge filament was used with a 23.5 cm mesh size. This was an efficient method for tangling chinook salmon yet allowed smaller fish to escape. One end of the gillnet was tended on the shore to keep the net drifting at a right angle to the current. Fish were tagged on the spawning grounds prior to spawning. Once spawning had commenced, gillnets were only set in non-spawning areas to avoid disturbing redds and to direct netting effort to areas where unspent fish were holding prior to spawning.

When gillnets were beached, fish species other than chinook were released to the river, then chinook were "tailed" (tied with a slip knot around the caudal peduncle with a braided rope) to facilitate handling of the fish and to prevent damage to the gillnet and injury to the fish. During tagging the fish were held in shallow water (approximately 0.5 m) with their tail above and their head below the water surface for 20 seconds to 10 minutes until tagging and other procedures were completed. Once tailed in shallow water, fish were usually inactive and did not strain against their tailers. The fish were measured for postorbital-hypural length (± 0.5 cm) with a fabric measuring tape, sexed, tagged, and released back to the river. Males were considered to be jacks if their length was less than or equal to 50 cm. Tags were applied to virtually all chinook that were captured. However, bleeding or injured fish with damaged gills were not tagged.

In 1984, Petersen disk tags (22 mm diameter) were used for tagging but in 1985 and 1986, spaghetti tags were used (30.5 cm orange tags in 1985 and yellow tags in 1986). Petersen tags were inserted through the musculature at the base of the posterior end of the dorsal fin. Spaghetti tags were knotted at the base of the posterior end of the dorsal fin such that the two ends were approximately 14 cm in length. In 1985 and 1986, a secondary mark was administered by punching a hole (6 mm diameter) in the opercular flap to evaluate tag loss. Punch holes were applied with a standard paper punch to the right or left opercular flap (depending on whether the fish was captured above or below the canyon (Fig. 1). In 1984, no secondary "mark" was applied to test for tag loss but because some tag scars were noted, 1985 and 1986 study designs included secondary marks.

Tagging was conducted during August and September in the eight river reaches numbered below shown in Figure 1:

1) Mouth up to and including CN Bridge;

2) CN Bridge up to and including Spring Creek;

3) Spring Creek up to and including Clay Bank;

4) Clay Bank up to and including Deep Creek;

5) Deep Creek to the canyon;

6) Canyon up to and including Horseshoe areas;

7) Horseshoe up to and including Tackle Run; and

8) Tackle Run to Treston Lake.

Fish in up to seven river reaches were tagged each day in areas where they were holding prior to spawning. Tagging was discontinued when most of the chinook were ripe and eggs and milt were lost during handling.

Potential bias in the Petersen estimates created by tag loss was tested by χ^2 tests to compare the observed tag recovery and the expected tag recovery (i.e. punch recovery) for 1985 and 1986 data (years when punches were applied) and males and females separately. There were insufficient data to perform this test on jacks.

Differential tag loss by sex was tested by χ^2 tests to compare the observed tag recovery and the expected tag recovery (i.e. punch recovery) of males and females for 1985 and 1986 data (years when punches were applied).

Tag loss rate was calculated as the difference between the numbers of punched and tagged fish recovered divided by punched fish recovered.

RECOVERY

Personnel that conducted the dead (carcass) recovery consisted of eight workers in each of 1984 and 1985, and six in 1986. In each year, the workers were divided into two crews. River bars and side channels were searched daily for tagged, punched, marked, and unmarked carcasses.

Due to high turbidity and poor visibility, carcasses were recovered by wading shallow areas and prodding the stream bottom with fish pews. A fish pew is a long handled instrument with a pointed end, similar to a single prong pitch fork. Each carcass was examined for the presence of a Petersen disk or spaghetti tag, tag scar (1984), opercular punch (1985 and 1986), and missing adipose fin. Heads were removed from all adipose clipped fish to recover and decode coded wire nose tags. Material collected from the carcasses is described in the biological and physical sampling methods section. Recovered carcasses were cut in two with a machette near the caudal peduncle and were pitched onto the river banks to eliminate them from further enumeration.

Calculations relating to dead recovery were as follows:

$$\text{Punch or tag scar rate} = \frac{\text{Total punches or tag scars recovered}}{\text{Total dead recovered}}$$

$$\text{Punch or tag scar recovery rate} = \frac{\text{Total punched or tag scarred fish recovered}}{\text{Total tagged (and punched or tag scarred)}}$$

$$\text{Tag rate} = \frac{\text{Total tags recovered}}{\text{Total dead recovered}}$$

$$\text{Tag recovery rate} = \frac{\text{Total tags recovered}}{\text{Total tagged}}$$

The potential bias in the Petersen estimate from tagging mortality was examined with a χ^2 test to compare the number of unspent females among the tagged and untagged fish.

As noted earlier, a biased Petersen estimate may also result if fish are recovered from a different population than was tagged. This potential bias was examined by a Kolmogorov-Smirnov test (Sokal and Rohlf 1969) to compare the age frequency distributions of tagged and recovered fish for each sex separately. A similar test was done to compare the length frequency distributions of tagged and recovered fish for each sex separately.

CODED WIRE TAGGING AND RECOVERY

Juvenile chinook from the 1979 brood year were marked with a single tag code applied to wild Kitsumkalum fish; those from the 1980 brood year were marked with a single tag code applied to production releases from the Kalum Pilot Hatchery using Kitsumkalum brood stock; and those from the 1981 releases were marked with two tag codes representing a heated and unheated water experiment at the Kalum Pilot Hatchery. In 1981, the Kalum Pilot Hatchery also released coded wire tagged juveniles produced from Cedar and Clear creeks brood stock but none of these fish were recaptured in this study. Standard methods (Armstrong and Argue 1977) of coded wire tagging were used. Adipose fins were clipped off the fish when coded wire tags (CWT) were applied to flag the presence of a CWT in harvest and escapement fish. Binary coded wire nose tags have been described fully by Jefferts et al. (1963). Numbers and locations of coded wire tag releases are presented in Table 3. Further information on rearing of juveniles for this release program are given by MacKinlay and Fielden (1987).

In the tagging and dead recovery programs, chinooks were examined for the presence or absence of an adipose fin. All adipose clipped fish recovered in the dead pitch and a portion of those from the live tagging were decapitated and the heads were sent to the Vancouver laboratory for CWT extraction and decoding.

Estimating the total number of CWT returns from each of the brood years, and for each tag code is a three step process:

1) determining the appropriate samples and population strata to use for estimating the overall adipose clip rate (using either the samples taken in the tagging or the dead pitch or some combination of the two based on what is the most representative sample);

2) determining the proportion of the population examined to produce the observed number of adipose clips. This is then used to calculate the total number of adipose clips estimated to be in the escapement; and

3) allocating the total number of adipose clips estimated to be in the escapement among the tag codes in proportion to those successfully decoded.

In the 1985 and 1986 programs, adipose clipped fish were enumerated separately in the upper and lower rivers in both the tagging and dead pitch sampling to correspond with the stratified Petersen estimates.

The tagging and dead recovery samples were used independently to estimate the total number of adipose clipped fish in the escapement. These two estimates of adipose clip escapement to the whole river are equally valid if tagging and dead recovery both represent unbiased samples of the population (see recovery results section, Kolmogorov-Smirnov

Table 3. Summary of chinook coded wire tag releases from the Kalum Pilot Hatchery, 1979 - 1981.[a]

Brood year	Stock	Code used	Total released	Released unmarked	Released marked	Release date	Release location
1979	Kitsumkalum	021852	51,890	3,799	48,091	July, 1980	Upper Kitsumkalum River
1980	Kitsumkalum	021951	63,115	18,842	44,273	May 25-June 6, 1981	1.5 km downstream of Treston Lake
1981	Kitsumkalum (unheated)	022312	30,250	7,016	23,234	May 5-6, 1982	5 km downstream of Treston Lake
1981	Kitsumkalum (heated)	022313	70,400	40,941	29,459	May 5-6, 1982	5 km downstream of Treston Lake

[a] From MacKinlay and Fielden (1987) and Johnson and Longwill (1988).

tests comparing age and length frequency distributions of tagging and dead recovery samples). If both samples are unbiased then the "best estimate" can be calculated as the average of the tagging and dead recovery estimates weighted by their sample sizes.

The Petersen estimation procedures described earlier produce estimates of the total number of carcasses in the upper and lower rivers. The proportion of these populations sampled in the dead recovery is thus simply the number of carcasses pitched divided by the population estimates for the two areas. However, there was a net movement of fish from the upper to the lower river after tagging. This means that the Petersen estimates must be adjusted to reflect the populations of live fish that were available for sampling in the two areas. To estimate the population available for live sampling in the upper river tagging, carcasses straying to the lower river after live tagging were added to the Petersen estimate as follows:

$$\text{Estimate of male upper river population during tagging} = \text{Petersen estimate of upper river males} + \frac{\text{(Punched male strays from upper to lower river)} - \text{(Punched male strays from lower to upper river)}}{\text{Mean tag rate (sexes pooled)}}$$

The estimate of the male lower river population during tagging was calculated by subtracting the third term in the above equation (i.e. number of strays from the upper to lower river) from the Petersen estimate of lower river males. Similar calculations were made for the female populations. The estimated number of clips escaping to an area was then calculated as the observed number divided by the proportion of the population sampled.

Given an estimate of the number of adipose clips escaping to the river, the escapement of each tag code can be estimated by allocation to tag codes based on their relative frequency in the sample of decoded tags. This scheme of first estimating adipose clipped fish and then allocating these among the successfully decoded CWTs assumes that the lost pin/no pin fish in the sample represent fish that were once marked and have lost their CWT for some reason. If this assumption is incorrect, the calculated number of hatchery release fish would be biased upwards. It is possible, especially in the dead pitch, that some fish identified as hatchery releases by missing adipose fins may be natural fish that have lost their adipose fins through some other means, e.g. carcass decomposition. If decomposition of adipose fins is occurring then the adipose clip rate in the dead pitch should be higher than that observed in the live tagging. This was examined by a χ^2 test to compare the adipose clip rate in the dead pitch with that in tagging for each year separately (males and females pooled).

The hatchery contribution to the escapement was calculated by comparing the escapement of each tag code with the total escapement broken down by age class.

Due to the different ages at maturity of males and females, it is important that allocation of adipose clipped fish to tag codes is done separately by sex whenever possible. In the 1985 program, the sex of the fish providing the CWTs was not recorded, therefore the sexes were pooled for the allocation to tag codes. In 1986, the sex of the fish sampled for coded wire tags was recorded so that it was possible to estimate the total escapement of tag codes by sex. Due to small sample sizes, the recoveries of jacks have largely been excluded from this analysis.

BIOLOGICAL AND PHYSICAL SAMPLING

Biological sampling of fish during tagging included the sampling of scales for age determination (with the exception of 1985), sex, post-orbital hypural length, tag number of tag applied, and presence of an adipose clip. During recovery, biological sampling included scales for age determination, length, sex, spawning condition (success of spawning), tag number if a tag was present, and presence of a tag scar (1984) or opercular punch (1985 and 1986), and presence of an adipose clip.

In 1984 and 1986, five scales from each fish were examined for age, and in 1985, ten scales from each fish were sampled. Ages were read only when a portion of the previous annulus was present and scales were not regenerated. In this report, these scales are referred to as readable. Scales were classified as unreadable if the scales had regenerate centres, the scales were resorbed, or the scales were mounted too wet or upside down and it was not possible to determine the age of the fish. Ages were recorded for fish for which there were at least two scales which could be read for both marine and freshwater ages. In this report, the first numeral of the age recorded indicates the year of total life and second numeral (subscript) indicates the year of life in which the fish migrated to the ocean.

The age and length analysis of the available samples is valid only if the scales from tagging and dead pitch was random and there was no bias in readability of scales with age. Ages of older and hence larger fish are usually more difficult to determine than those of younger individuals because scales of older fish have more resorption and regeneration. To test for this bias, the Kolmogorov-Smirnov test was used to compare the length frequency distributions of fish that were successfully aged with those that were not. The tests were performed for each year and sex separately.

The population in each age class was determined by allocating portions of the Petersen estimate to age classes according to the age composition determined from scale samples.

The sex ratio in each year was determined by sexes and areas separate Petersen estimates (areas pooled in 1984), and summing male and female populations from upper and lower rivers to calculate the total for each sex. This method provides a valid sex ratio assuming that tag loss and tag recognition were not seriously biased by sex. The tests for potential differences in tag loss was described in the tagging methods section. As described earlier, the potential problem of tag loss was prevented by the use of tag scars or opercular punches in Petersen estimates. Tag recognition is not likely to be biased by sex; it is not possible to test for this bias with the data in this study.

Spawning condition of recovered female carcasses was recorded as spent, partially spent, or unspent. Condition was recorded as spent if the gonads were completely void of eggs or milt, partially spent if some eggs or milt remained, and unspent if gonads were intact and all eggs or milt appeared to be retained.

Water levels were measured using a staff gauge which was mounted on the highway bridge crossing of Kitsumkalum River on 16 August 1984 (Fig. 1).

RESULTS

TAGGING

Tagging was conducted in a maximum of five subreaches of the river in 1984, 17 in 1985, and 23 in 1986 (Appendix 1 to 3). In 1984, tagging effort was concentrated in the lower river in terms of number of days of tagging as well as number of river locations sampled (Appendix 1). In 1985 and 1986, tagging effort was similar in the upper and lower rivers in terms of numbers of days of tagging, but was concentrated on the lower river in terms of the number of river locations sampled within reaches where tagging was conducted (Appendix 1 and 2).

In 1984, the punch or tag scar rate (proportion of the total carcasses recovered bearing tag scars or opercular punches) was nearly 4% compared with over 15% in 1985 and 1986 (Table 4). Actual tag recovery rates ranged from 6.0% to 12.2%.

In each tagging program, more males were captured than females, and fewer jacks were captured than either large males or females. During tagging programs, the incidence of recapture of tagged fish in gillnets and of tag loss among these fish was relatively high. For example, in 1984, 50 tagged chinook were recaptured in gillnets, 14 of which had lost their tags and were tagged a second time.

Loss of spaghetti tags in 1985 and 1986 was 29.8% and 45.7%, respectively (sexes pooled). Loss of Petersen disk tags in 1984 was only 5.9% (32 tagged fish recovered and 2 tag scarred fish recovered); however, opercular punch holes were not used as secondary marks in 1984, hence this figure may be low because tag scars may have faded or been overlooked during carcass recovery. In 1986, yellow spaghetti tags were stiffer and did not tie as securely as the orange spaghetti tags used in 1985. Despite extra care taken in knotting in 1985, tag loss increased in 1986.

In 1985 and 1986, tag loss was biased by sex (1985: χ^2=34.02, df=1, p<.001; 1986: χ^2=68.75, df=1, p<.001). Male tag loss (1985: 51.7%; 1986: 74.4%) was greater than tag loss of females (1985: 12.8%; 1986: 23.1%; Table 4). There were insufficient data to perform the same test on 1984 males and females.

Table 4. Summary of tagging and dead recovery of chinook salmon in the Kitsumkalum River, 1984 - 1986.

Item	1984	1985	1986
A. Tagging programs			
Males tagged and punched or tag scarred	324	896	935
Females tagged and punched or tag scarred	184	557	590
Jacks tagged and punched or tag scarred	21	69	71
Total tagged and punched or tag scarred	529	1522	1596
B. Dead recovery programs			
Males recovered	264	540	623
Females recovered	602	1090	975
Jacks recovered	25	22	98
Total recovered	891	1652	1696
Punched or tag scarred males[a]	11	116	117
Punched or tag scarred females	23	149	143
Punched or tag scarred jacks	0	0	5
Total punched or tag scarred fish	34	265	265
Tagged males	11	56	30
Tagged females	21	130	110
Tagged jacks	0	0	4
Total tagged fish	32	186	144
C. Other[b]			
Tag rate	3.6%	11.3%	8.5%
Punched or tag scar rate	3.8%	16.0%	15.6%
Tag recovery rate	6.0%	12.2%	9.0%
Punch or tag scar recovery rate	6.4%	17.4%	16.6%
Tag loss[c]	5.9%	29.8%	45.7%
Male tag loss	0.0%	51.7%	74.4%
Female tag loss	8.7%	12.8%	23.1%

[a] Punched means marked with a punched hole in operculum; in 1984, tag scars were used instead of opercular punches.

[b] See methods section for method of calculation.

[c] In 1984, loss of Petersen discs was evaluated by the presence or absence of tag scars; in 1985 and 1986, loss of spaghetti tags was evaluated by the presence or absence of a punch hole in the operculum.

RECOVERY

Recovery of carcasses was conducted in a maximum of six specific locations per day in 1984, 14 in 1985, and 23 in 1986 within the eight river reaches examined (Appendix 4 to 6). In 1984, recovery effort was concentrated in the lower river in terms of number of days that recovery sampling was performed as well as number of river locations sampled (Appendix 4). In 1985 and 1986, recovery effort was similar between the upper and lower rivers in terms of number of days when recovery was conducted, as well as number of river locations sampled within reaches where recovery was conducted (Appendix 5 and 6). Most recaptures were in the same river area (i.e. upper or lower rivers) where they were originally tagged and released (1984: 94.1%; 1985: 88.4%; 1986: 54.1%; Appendix 7 to 9). However, there was a certain degree of straying of tagged and punched fish between the upper and lower rivers (see population estimate results section).

In each dead recovery program from 1984 to 1986, more females were recovered (pitched) than males, and fewer jacks were pitched than either females or males (Table 4). In 1984, 264 males, 602 females, and 25 jacks were recovered (Table 5). Similar dead recovery sex ratios occurred in 1985 and 1986 (Tables 6 and 7).

Tag recovery rates (tags only) varied between 6.0% and 12.2% and recovery rates of secondary marks based on opercular punches or tag scars varied between 6.4% and 17.4% in 1984 (tag scars) through 1985 and 1986 (punches) (Table 4). The total recovery of punched or tag scarred fish observed in the dead pitch was 34 in 1984 (scarred) and 265 fish in both 1985 and 1986 (punched).

Among the dead recoveries river in 1984, there were no tagged strays between the upper and lower rivers. In 1985, only one tagged female from the lower river was found in the upper river, but among the dead recoveries in the lower river, 12 tagged males and 8 tagged females from the upper river were found (Table 6). There were therefore a greater number of strays, particularly males, from the upper river to the lower river. Among the dead recoveries in the upper river in 1986, only 5 tagged female strays from the lower river were found, and in the lower river, 1 male and 1 female tagged strays from the upper river were found (Table 7).

Female chinook captured in gillnets and then tagged and subsequently recovered in the dead pitch had a high rate of spawning success and apparently low rate of mortality (87.5% spent in 1984; 99.2% in 1985; 99.3% in 1986). Virtually all fish recovered in the dead pitch were spawned out, and there was no significant difference in the numbers of unspent females between those tagged and untagged (1984: 21 spent out of 24 tagged recovered and 565 spent out of 577 untagged recovered, χ^2=0.26, df=1, p>0.05; 1985: 128 spent out of 129 tagged and 936 spent out of 961 untagged, χ^2=0.65, df=1, p>0.05; 1986: 142 spent out of 143 tagged and 812 spent out of 832 untagged, χ^2=0.04, df=1, p>0.05).

There was no significant difference in the age frequency distributions of live tagged versus dead recovered fish (tagged and untagged) in 1984 (Kolmogorov-Smirnov tests; 1984 females: Dmax=0.177856, n=36 tagged

Table 5. Upper and lower Kitsumkalum River chinook salmon Petersen estimates and enumeration data, 1984.

Location[a] and item	Male	Female	Jack	Total
Upper river				
Tagged	65	31	0	96
Dead recovery	36	71	7	114
Tag recovery	0	0	0	0
Tagged strays from lower river	0	0	0	0
Tag and tag scar recovery	0	0	0	0
Lower river				
Tagged	259	153	21	433
Dead recovery	228	531	18	777
Tag recovery	11	21	0	32
Tagged strays from upper river	0	0	0	0
Tag and tag scar recovery	11	23	0	34
Petersen estimate, areas pooled, males and jacks pooled	7,177	4,648	-[b]	11,825

[a] See Figure 1 for the location of the canyon which is the point of reference for the upper and lower river areas.

[b] No recaptures of tagged or tag scarred jacks; insufficient data to estimate escapement.

Table 6. Upper and lower Kitsumkalum River chinook salmon Petersen estimates and enumeration data, 1985.

Location[a] and item	Male	Female	Jack	Total
Upper river				
Tagged and punched	452	244	33	729
Dead recovery	139	330	2	471
Tag recovery	15	31	0	46
Tagged strays from lower river	0	1	0	1
Tag and punch recovery	32	37	0	69
Punched strays from lower river[b]	0	4	0	4
Punched available for Petersen estimate[b]	263	214	33	510
Petersen estimate, sexes separate[b]	1,120	1,873	–[c]	2,993
Lower river				
Tagged and punched	444	313	36	793
Dead recovery	401	760	20	1,181
Tag recovery	41	99	0	140
Tagged strays from upper river	12	8	0	20
Tag and punch recovery	84	112	0	196
Punched strays from upper river[b]	189	34	0	223
Punched available for Petersen estimate[b]	633	343	36	1,012
Petersen estimate, sexes separate[b]	2,998	2,317	–[c]	5,315

[a] See Figure 1 for the location of the canyon which is the point of reference for the upper and lower river areas.

[b] See methods section for method of calculation.

[c] No recaptures of tagged or punched jacks; insufficient data to estimate escapement.

Table 7. Upper and lower Kitsumkalum River chinook salmon Petersen estimates and enumeration data, 1986.

Location[a] and item	Male	Female	Jack	Total
Upper river				
Tagged and punched	449	297	31	777
Dead recovery	322	480	83	885
Tag recovery[a]	10	48	1	59
Tagged strays from lower river	0	5	0	5
Tag and punched recovery	53	58	2	113
Punched strays from lower river[b]	0	25	0	25
Punched available for Petersen estimate[b]	424	316	31	771
Petersen estimate, sexes separate[b]	2,542	2,584	896	6,022
Lower river				
Tagged and punched	486	293	40	819
Dead recovery	301	495	15	811
Tag recovery	20	62	3	85
Tagged strays from upper river	1	1	0	2
Tag and punched recovery	64	85	3	152
Punched strays from upper river[b]	25	6	0	31
Punched available for Petersen estimate[b]	511	274	40	825
Petersen estimate, sexes separate[b]	2,379	1,586	164	4,129

[a] See Figure 1 for the location of the canyon which is the point of reference for the upper and lower river areas.

[b] See text for method of calculation.

and 221 recovered, 6 groups, $p>0.05$) nor 1986 (1986 males: Dmax=0.0814356, n=76 tagged and 74 recovered, 8 groups, $p>0.05$; 1986 females: Dmax=0.0382977, n=37 tagged and 235 recovered, 8 groups, $p>0.05$). There was a significant difference in the length frequency distributions of tagged and recovered females in 1984 (Kolmogorov-Smirnov test; 1984 females: Dmax=0.48205, n=44 tagged and 357 recovered, 20 groups, $p<0.001$), but no significant differences in other groups (1986 males: Dmax=0.198224, n=107 tagged and 119 recovered, 20 groups, $p>0.05$; 1986 females: Dmax=0.243075, n=58 tagged and 306 recovered, 17 groups, $p>0.05$). There were insufficient data to perform the same tests on other strata (i.e. 1984 males, 1985 males, and 1985 females).

POPULATION ESTIMATES

The escapement estimates for 1984 to 1986 were, respectively: 11,825 fish, 8,308 fish, and 10,151 fish (Tables 5 to 7). A summary of these estimates, their confidence limits, and their composition by sex are presented in Table 8.

In 1985, the escapement to the upper river was 2,993 fish, and the lower river escapement was 5,315 fish (Table 6). In 1986, the escapement to the upper river was 6,022 fish, and the lower river escapement was 4,129 fish (Table 7).

AGE, LENGTH AND SEX COMPOSITION

Scales from a total of 1,737 fish (all years combined) were examined for age. Of these, ages determined for only 1,205 (69%) fish since many scales were unreadable due to a high degree of resorption. The sex ratios in the estimated escapements were 60.7% males to 39.3% females in 1984, 49.6% males to 50.4% females in 1985, and 54.1% males (excluding jacks) to 45.9% females in 1986 (Table 8).

Age and Length Composition

Ages of Kitsumkalum River chinook salmon ranged from 3_2 to 7_3 (Tables 9 to 11). Females were generally older than males; the maximum age of males was 6_2 and of females was 7_3. Most fish (nearly 96%) were sub-2s, indicating that they spent one full year in freshwater.

The predominant age class for both males and females in 1984 was age 6_2. In both 1985 and 1986, the predominant year classes (age 5 and 6, respectively) were from the 1980 brood year, with the possible exception of 1986 males.

The population in each age class is shown in Tables 12 to 14 for 1984 to 1986, respectively.

The spawning population in 1984 was composed of relatively small fish (mean postorbital-hypural length of age 6_2 males = 891.8 mm and females = 865.1 mm), whereas the mean postorbital-hypural lengths of age 6_2 males and females in 1985 and 1986 were 13.7 mm to 48.4 mm greater in length (Tables 9 to 11).

Table 8. Summary of Petersen escapement estimates for Kitsumkalum River chinook salmon, 1984-1986.

Year	Item	Male	Female	Jack	Total
1984[a]	Escapement estimate	7,177	4,648	-[b]	11,825
	Lower 95% CL[c]	3,348	2,948	-	7,636
	Upper 95% CL	11,006	6,348	-	16,014
1985[d]	Escapement estimate	4,118	4,190	-[b]	8,308
	Lower 95% CL	3,183	3,535	-	7,166
	Upper 95% CL	5,053	4,845	-	9,450
1986[d]	Escapement estimate	4,921	4,170	1,060	10,151
	Lower 95% CL	3,200	3,428	213	8,094
	Upper 95% CL	6,642	4,912	1,907	12,208

[a] Population estimate by Petersen method, areas pooled, sexes separate.

[b] No recaptures of tagged, tag scarred or punched jacks; insufficient data to estimate escapement.

[c] See methods section for method of calculating confidence intervals.

[d] Population estimate by sum of Petersen estimates for upper and lower rivers for separate sexes (see Tables 6 and 7). Confidence intervals by sum of separate confidence intervals for upper and lower rivers.

Table 9. Age composition of Kitsumkalum River chinook salmon, 1984. (Includes live tagging and dead recovery data.)

Age	Number of age determinations	Percent	Postorbital-hypural length (mm) Mean	Standard deviation	95% CL Lower	Upper
Males						
3_2	5	5.9	334.0	30.1	307.6	360.4
4_2	18	21.2	575.6	66.0	545.1	606.1
5_1	1	1.2	860.0	0.0	860.0	860.0
5_2	17	20.0	759.4	95.3	714.1	804.7
6_2	44	51.7	891.8	51.1	876.7	906.9
Total=	85	100.0	Mean=815.5	114.2	791.2	839.8
Females						
4_2	1	0.4	620.0	0.0	620.0	620.0
5_1	9	3.5	821.1	36.6	797.2	845.0
5_2	65	25.3	782.0	52.4	769.3	794.7
6_2	164	63.8	865.1	50.2	857.4	872.8
7_2	16	6.2	875.0	47.6	851.7	898.3
7_3	2	0.8	932.5	42.5	873.6	991.4
Total=	257[a]	100.0	Mean=823.7	67.7	815.4	832.0

[a] Two females included here were not included in Table 15 or in Kolmogorov-Smirnov tests presented in text.

Table 10. Age composition of Kitsumkalum River chinook salmon, 1985. (Includes dead recovery data; no age samples were collected during live tagging.)

Age	Number of age determinations	Percent	Postorbital-hypural length (mm) Mean	Standard deviation	95% CL Lower	Upper
Males						
3_2	6	4.5	339.7	159.6	212.0	467.4
4_2	22	16.4	597.7	55.3	574.6	620.8
5_2	64	47.8	786.0	73.4	768.0	804.0
6_2	42	31.3	922.6	36.4	911.6	933.6
Total=	134[a]	100.0	Mean=849.8	102.4	832.5	867.1
Females						
4_2	4	1.4	735.0	104.3	632.8	837.2
5_1	6	2.1	820.0	11.5	810.8	829.2
5_2	197	69.4	805.2	41.9	799.3	811.1
6_2	77	27.1	878.8	46.7	868.4	889.2
Total=	284	100.0	Mean=861.1	58.7	854.3	867.9

[a] One male included here was not included in Table 15 or in Kolmogorov-Smirnov tests presented in text.

Table 11. Age composition of Kitsumkalum River chinook salmon, 1986. (Includes live tagging and dead recovery data.)

Age	Number of age determinations	Percent	Postorbital-hypural length (mm)			
			Mean	Standard deviation	95% CL Lower	95% CL Upper
Males						
3_2	6	3.7	340.0	57.7	293.8	386.2
4_1	2	1.2	655.0	15.0	634.2	675.8
4_2	21	13.0	588.5	67.3	559.7	617.3
5_1	13	8.0	870.8	69.1	833.2	908.4
5_2	56	34.6	800.9	68.4	783.0	818.8
6_2	64	39.5	940.2	117.9	911.3	969.1
Total=	162[a]	100.0	Mean=863.7	140.4	842.1	885.3
Females						
3_2	1	0.4	340.0	0.0	340.0	340.0
5_1	17	6.0	846.5	42.7	826.2	866.8
5_2	103	36.4	820.1	85.5	803.6	836.6
6_2	161	56.8	898.2	49.9	890.5	905.0
7_2	1	0.4	990.0	0.0	990.0	990.0
Total=	283[a]	100.0	Mean=883.9	56.9	827.3	940.5

[a] Two males and three females included here were not included in Table 15 or in Kolmogorov-Smirnov tests presented in text.

Table 12. Petersen estimates allocated by age composition, 1984.

Age	Males		Females	
	Number[a]	Percent[b]	Number[a]	Percent[b]
3_2	423	5.9	0	0.0
4_2	1,522	21.2	19	0.4
5_1	86	1.2	163	3.5
5_2	1,435	20.0	1,176	25.3
6_2	3,711	51.7	2,965	63.8
7_2	0	0.0	288	6.2
7_3	0	0.0	37	0.8
Total	7,177[a]	100.0	4,648[a]	100.0

[a] From Table 8; male number does not include jacks.

[b] From Table 9.

Table 13. Petersen estimates allocated by age composition, 1985. (Dead recovery data; no age samples were collected during tagging.)

Age	Males		Females	
	Number[a]	Percent[b]	Number[a]	Percent[b]
3_2	185	4.5	0	0.0
4_2	675	16.4	59	1.4
5_1	0	0.0	88	2.1
5_2	1,968	47.8	2,909	69.4
6_2	1,289	31.3	1,136	27.1
Total	4,118[a]	100.0	4,190[a]	100.0

[a] Total population from upper and lower rivers (Table 8); male number does not include jacks.

[b] From Table 10.

Table 14. Petersen estimates allocated by age composition, 1986. (Includes live tagging, dead recovery, and coded wire tagged fish data.)

Age	Males		Females	
	Number[a]	Percent[b]	Number[a]	Percent[b]
3_2	182	3.7	17	0.4
4_1	59	1.2	0	0.0
4_2	640	13.0	0	0.0
5_1	394	8.0	250	6.0
5_2	1,703	34.6	1,518	36.4
6_2	1,944	39.5	2,369	56.8
7_2	0	0.0	17	0.4
Total	4,921[a]	100.0	4,170[a]	100.0

[a] Total population from upper and lower rivers (Table 8); male number does not include jacks.

[b] From Table 11.

Biases in Age-Length Composition

Kolmogorov-Smirnov tests showed that there were no significant differences between the length frequency distributions of fish with ages determined and fish without ages determined due to unreadable scales (1984 males: Dmax=0.20872, n=85 aged and 58 not aged, 18 groups, $p>0.05$; 1984 females: Dmax=0.139321, n=255 aged and 146 not aged, 20 groups, $p>0.05$; 1985 males: Dmax=0.272991, n=133 aged and 52 not aged, 18 groups, $p>0.05$; 1985 females: Dmax=0.331414, n=284 aged and 99 not aged, 11 groups, $p>0.05$; 1986 males: Dmax=0.150603, n=160 aged and 83 not aged, 20 groups, $p>0.05$; 1986 females: Dmax=0.106794, n=280 aged and 102 not aged, 17 groups, $p>0.05$). These results indicate that there was no bias in readability of scales with age. The mean post-orbital hypural length and scale condition are presented in Table 15.

CODED WIRE TAGGING AND RECOVERY

Coded wire tagged juvenile chinook released into the Kitsumkalum River from the 1979, 1980 and 1981 brood years were recovered in the tagging and dead recovery programs in 1985, and from the 1980 and 1981 brood years in 1986.

Decomposition of adipose fins did not appear to be a problem in either 1985 or 1986 in the Kitsumkalum River, since there was no significant difference between the adipose clip rate in the live tagging and dead recovery (1985 upper and lower rivers: $\chi^2=3.40$, df=1, $p>.05$; 1986 upper river: $\chi^2=0.31$, df=1, $p>.05$). There were insufficient data to perform the same test on lower river data. As noted earlier in the recovery results section, there was no significant difference in the age or length frequency distributions of tagged and dead recovered fish (Kolmogorov-Smirnov tests, males and females separate, 1985 and 1986 separate, $p>0.05$). Therefore, for purposes of coded wire tag analyses, the tagging and dead recovery samples are considered to be unbiased samples of the same population and estimates of the total number of adipose clips in the two samples were combined for a weighted average value.

In both 1985 and 1986, most of the adipose clipped fish were found in the upper river in both the tagging and dead pitch sampling.

The results of coded wire tag returns follow separately for 1985 and 1986. The results from each year are summarized in five tables which contain the following items:

1) the raw data and mark (adipose clip) rates for the calculations (Tables 16 and 21);

2) the total estimated escapement of adipose clips by two methods (i.e. in the population at the time of tagging and dead recovery) (Tables 17 and 22);

3) the weighted average of the total estimated adipose clips from the two methods (Tables 18 and 23);

4) the weighted average of the total number of adipose clips partitioned between tag codes, and the hatchery contribution to

Table 15. Mean length and scale condition of Kitsumkalum River chinook salmon, 1984-1986.[a]

Scale condition	Number	Postorbital-hypural length (mm) Mean	Standard deviation	95% CL Lower	95% CL Upper
1984 Males					
Readable	85	765.2	177.4	417.4	1,112.9
Unreadable	58	815.5	115.2	590.0	1,041.2
1984 Females					
Readable	255	842.9	64.1	717.3	968.4
Unreadable	146	823.7	67.9	690.5	956.8
1985 Males					
Readable	133	780.5	150.1	486.2	1,074.7
Unreadable	52	849.8	103.4	647.2	1,052.4
1985 Females					
Readable	284	824.5	56.1	714.6	934.4
Unreadable	99	861.1	59.0	745.5	976.7
1986 Males					
Readable	160	821.4	164.4	499.2	1,143.6
Unreadable	83	863.7	141.3	586.8	1,140.6
1986 Females					
Readable	280	867.8	66.9	736.7	998.9
Unreadable	102	875.2	104.4	670.6	1,079.8

[a] Two 1984 females, one 1985 male, two 1986 males and three 1986 females not included here were included in Tables 9 - 11.

the escapement for each tag code (Tables 19 and 24); and

5) the estimated hatchery contribution to the escapement by age class (Tables 20 and 25).

1985 Recoveries

Sample sizes and numbers of adipose clips observed in the different strata are summarized in Table 16. Only one adipose clipped fish was found in the tagging in the lower river and so this stratum (tagging/lower river) was not included in the calculations of recovery rates. The adipose clip rate in the upper river was very similar for the tagging and dead pitch samples for males but there was a slightly higher rate in the tagging sample of females. It should be noted that the adipose clip rates of females in the upper river tagging and dead pitch are based on low sample sizes (10 and 4 fish, respectively). The low numbers of adipose clips encountered in both the tagging and dead recovery in the lower river can be explained by the homing of the marked fish to their release location in the upper river.

Total adipose clips were estimated to be 60 males and 84 females from the upper river tagging sample, 32 males and 23 females from the upper river dead recovery, and 15 males and 9 females from the lower river dead recovery (Table 17). For the tagging estimate it has been assumed that all adipose clipped fish occurred in the upper river, while for the dead pitch estimates both the upper and lower river were considered. The total escapement of adipose clips (99 fish), calculated as the weighted average of escapements of adipose clips in tagging and dead recovery samples, is summarized in Table 18.

The allocation of the total escapement of adipose clips to tag codes in brood years 1979 to 1981 is given in Table 19. The hatchery contribution to escapement based on the marked to unmarked ratios at release of coded wire tag codes was a total of 136 fish (Table 19). The estimated hatchery contribution by age class was 1.6% of the 1985 escapement (Table 20).

1986 Recoveries

Sample sizes, numbers of adipose clips, and adipose clip rates from both the tagging and dead recovery are shown in Table 21. No adipose clipped jacks were found in tagging or dead recovery sampling. In 1986, mark rates were very low in the lower river tagging and lower river dead recovery, sexes pooled rates ranging from 0.4% to 2.5%.

Sample sizes, Petersen population estimates for relevant strata, and the proportion of the population of each stratum sampled to estimate adipose clips are summarized in Table 22. The total escapement of adipose clips calculated as the weighted average of escapement of adipose clips in tagging and dead recovery samples was 124 fish (Table 23).

Total numbers of adipose clips allocated to the different tag codes that were recovered and the hatchery contribution to the escapement by each tag code are summarized in Table 24. The total hatchery contribution was estimated to be 219 fish (Table 24) or 2.8% of the estimated

Table 16. Sample sizes and adipose clip rates for live tagging and dead recovery samples from chinook salmon in the Kitsumkalum River, 1985.

	Sample size[a]			Number adipose clips observed					Mark rate (%)		
	Upper river	Dead recovery		Upper river tagging			Dead recovery		Upper river	Dead recovery	
	tagging	Upper river	Lower river	Kept head	Tagged and released	Total	Upper river	Lower river	tagging	Upper river	Lower river
	A	B	C	D	E	F	G	H	I=F/A	J=G/B	K=H/C
Male	458	139	401	6	6	12	4	2	2.6	2.9	0.5
Female[b]	246	330	760	2	8	10	4	3	4.1	1.2	0.4
Jack	35	2	20	2	1	3	0	0	8.6	0	0
Total excluding jacks	704	469	1161	8	14	22	8	5	3.1	1.7	0.4

[a] From Table 6; sample size for upper river tagging includes heads that were kept, e.g., males 452 (from Table 6) + 6 (from column D) = 458.

[b] One female adipose clip was released in lower Kitsumkalum and is not included here.

Table 17. Estimates of the total escapement of adipose clips to the Kitsumkalum River by two methods, 1985.

Tagging location and sex	Sample size	Adipose clips observed	Peterson estimate of population size[a]	Percentage of population sampled	Total estimated adipose clips
	A	B	C	D=(A/C)x100	E=(B/A)xC
Upper river tagging					
Male	458	12	2,301	19.9	60
Female	246	10	2,061	11.9	84
Total	704	22			
Upper river dead recovery					
Male	139	4	1,120	12.4	32
Female	330	4	1,873	17.6	23
Total	469	8			
Lower river dead recovery					
Male	401	2	2,998	13.4	15
Female	760	3	2,317	32.8	9
Total	1,161	5			

a Dead recovery population sizes from Table 6. See text for method of calculation of upper river tagging population sizes.

Table 18. Estimation of total escapement of adipose clips to the Kitsumkalum River, 1985.

	Total estimated adipose clips[a]		
	Using tagging sample[b] A	Using dead recovery sample[c] B	Weighted average[d] C
Males	60	47	51
Females	84	32	48
Total	144	79	99
Total sample size[c]	704	1,630	

[a] From Table 17.

[b] Upper and lower rivers pooled.

[c] From Table 17.

[d] $C = \frac{(704 \times A) + (1,630 \times B)}{704 + 1,630}$; average weighted by sample size.

Table 19. Estimates of total escapement of coded wire tags to the Kitsumkalum River by tag code, 1985.

Brood year	Tag code	Observed adipose clips[a] A	Estimated adipose clips[b] B	Release numbers Marked C	Release numbers Unmarked D	Hatchery contribution[c] E
79	021852	5	31	48,091	3,799	33
80	021951	9	56	44,273	18,842	80
81	022313	2	12	29,459	40,941	23[d]
81	022312	0	0	23,234	7,016	
Total		16	99[e]			136
No pin/lost pin		6				
Total		22				

[a] Observed in upper river tagging; no CWT decoding data were available from dead recovery.

[b] $B = \text{Total estimated adipose clips (Table 18)} \times \frac{A}{\text{16 decoded tags}}$

[c] $E = B \cdot \frac{(C+D)}{C}$

[d] 1981 tag codes pooled.

[e] Total estimated adipose clips = weighted mean of upper river tagging and dead recovery (upper and lower rivers pooled) = $\frac{\Sigma(A \times E)}{\Sigma A}$ from Tables 17 and 18.

Table 20. Estimated hatchery contribution to the 1985 Kitsumkalum chinook escapement.

Age	Estimated escapement[a] A	Hatchery contribution[b] B	% Hatchery contribution C=(B/A)x100
3	185	0	0.0
4	734	23	3.1
5	4,965	80	1.6
6	2,425	33	1.4
Total	8,308	136	1.6

[a] From Table 13.

[b] From Table 19.

Table 21. Sample sizes and adipose clip rates for live tagging and dead recovery samples from chinook salmon in the Kitsumkalum River, 1986.

	Sample size[a]			Number adipose clips observed							Mark rate		
	Tagging		Upper river dead recovery	Tagging						Upper river dead recovery	Tagging		Upper river dead recovery (%)
	Upper river	Lower river		Upper river			Lower river				Upper river (%)	Lower river (%)	
				Kept head	Tagged and released	Total	Kept head	Tagged and released	Total				
	A	B	C	D	E	F	G	H	I	J	K=F/A	L=I/B	M=J/C
Male	464	486	322	15	1	16	0	0	0	6	3.4	0.0	1.9
Female	300	294	480	3	0	3	1	2	3	10	1.0	1.0	2.1
Jacks	31	40	83	0	0	0	0	0	0	0	0.0	0.0	0.0
Total excluding jack	764	780	802	18	1	19	1	2	3	16	2.5	0.4	2.0

[a] From Table 7; sample size for tagging includes heads that were kept, e.g., upper river males 449 (from Table 7) + 15 (from column D) = 464.

Table 22. Estimates of the total escapement of adipose clips to the Kitsumkalum River by two methods, 1986.

Tagging location and sex	Sample size A	Adipose clips observed B	Petersen estimate of population size[a] C	Percentage of population sampled D=(A/C)x100	Total estimated adipose clips E=(B/A)xC
Upper river tagging					
Male	464	16	2,702	17.2	93
Female	300	3	2,622	11.4	26
Total	764	19			
Lower river tagging					
Male	486	0	2,379	20.4	0
Female	294	3	1,746	16.8	18
Total	780	3			
Upper river dead recovery					
Male	322	6	2,542	12.7	47
Female	480	10	2,584	18.6	54
Total	802	16			

[a] Dead recovery population sizes from Table 7. See text for method of calculation of upper and lower river tagging population sizes.

Table 23. Estimation of total escapement of adipose clips to the Kitsumkalum River, 1986.

	Total estimated adipose clips[a]		
	Using tagging sample[b]	Using dead recovery sample	Weighted average[c]
	A	B	C
Males	93	47	77
Females	44	54	47
Total	137	101	124
Total sample size	1,544	802	

[a] From Table 22.

[b] Upper and lower rivers pooled.

[c] $C = \frac{(1,544 \times A) + (802 \times B)}{(1,544 + 802)}$; average weighted by sample size.

Table 24. Estimates of total escapement of coded wire tags to the Kitsumkalum River by tag code, 1986.

Brood year	Tag code	Observed adipose clips[a]		Estimated adipose clips[b]		Released		Hatchery contribution[c]
		Male A	Female B	Male C	Female D	Marked E	Unmarked F	G
79	021852	0	0	0	0	48,091	3,799	0
80	021951	4	7	19	17	44,273	18,842	51
81	022313	7	6	34	15	29,459	40,941	117
81	022312	5	6	24	15	23,234	7,016	51
Total		16	19	77[d]	47[d]			219
No pin/lost pin		0	0					

[a] Observed in upper river tagging and dead pitch.

[b] $C = \text{Total estimated male adipose clips (Table 23)} \times \frac{A}{\text{16 decoded male tags}}$

[c] $G = (C+D).\frac{(E+F)}{E}$

[d] Total estimated adipose clips = weighted mean of tagging (upper and lower river pooled) and upper river dead recovery = $\frac{\Sigma(A \times E)}{\Sigma A}$ from Tables 21 to 23.

escapement of males and 1.9% of the estimated escapement of females (Table 25).

DISCUSSION AND CONCLUSIONS

POPULATION ESTIMATION

The Petersen escapement estimates of chinook salmon to the Kitsumkalum River were 11,825 spawners in 1984, 8,308 spawners in 1985, and 10,151 spawners in 1986 (Table 8). These estimates were calculated within the limitations of the data as follows:

1984 by sum of Petersen estimates with upper and lower river areas pooled, males and jacks pooled, and females separate; and

1985 and 1986 by sum of Petersen estimates for upper and lower river areas for separate sexes.

Several potentially important sources of bias in Petersen estimates were circumvented by stratifying the populations by sex. Results from this study indicated that there were factors which affected sexes differentially. Differential catchability of males and females and/or differential washout rates caused a reversal in sex ratio from the number tagged and the number dead recovered. There was a higher proportion of males tagged and a higher proportion of females recovered. The gillnets used to capture fish for tagging may have selected for males due to a greater tangling rate of males caused by their numerous sharp protrusions, particularly in the head area (Wilson and Andrew 1987). Female salmon normally hold over their redds after spawning and tend to move into quiet water as they weaken. This behaviour makes them more recoverable than males, which do not hold their position in the stream and are washed out by the water current. A higher recoverability of females in spawning ground dead pitches has been noted for sockeye (Petersen 1954), pinks (Ward 1959), and coho (Eames and Himo 1981 and Eames et al. 1981). It is probable that a similar bias exists in spawning ground samples of chinook (Shardlow et al. 1986). Another factor affecting males and females differentially was tag loss. Tag loss was significantly higher in males ($p<0.001$), and may have been partly due to their aggressive behaviour on the spawning grounds. In future studies, Petersen estimates conducted on the Kitsumkalum chinook escapement should be calculated by stratifying the population by sex.

Potentially important sources of bias in Petersen estimates were also circumvented by stratifying the populations by upper and lower river areas where data were sufficient. Locations of tag recoveries relative to locations of tagging for individual tags indicated that there were movements of tagged fish between reaches within river areas (e.g. within the lower river area), but only a minor degree of movement between river areas (i.e. straying). If the upper and lower river spawners are separate sub-populations, they may still be enumerated by a single Petersen estimate on pooled tagging and dead recovery if the number of fish tagged and dead recovered in the upper and lower populations are both equal proportions of the populations in the respective areas. In the tagging and dead recovery programs in 1985 and 1986, this was not

Table 25. Estimated hatchery contribution to the 1986 Kitsumkalum chinook escapement.

Age	Estimated escapement[a] A	Hatchery contribution[b] B	% Hatchery contribution C=(B/A)x100
Males			
3	182	0	0.0
4	699	0	0.0
5	2,097	112	5.3
6	1,944	27	1.4
7	0	0	0.0
Total	4,921	139	2.8
Females			
3	17	0	0.0
4	0	0	0.0
5	1,768	56	3.2
6	2,369	24	1.0
7	17	0	0.0
Total	4,170	80	1.9

[a] From Table 14.

[b] From Table 24 (males: C x (E+F)/E).

the case, therefore population estimates are more accurately estimated by summing separate population estimates for each area. Moreover, the movement patterns of tagged fish indicate that in future, Petersen estimates conducted on the Kitsumkalum chinook escapement should be calculated by stratifying the population by river areas.

Another potential source of bias in Petersen estimates is movement of spawners into and/or out of the study area after tagging is completed. As already discussed, tagging was continued until the population commenced spawning, as indicated by the loss of eggs or milt as fish were handled for tagging, therefore it is likely that there was a negligible influx of spawners after the conclusion of tagging. However, there may have been some loss of tagged fish to the Skeena River following tagging operations near the mouth of the Kitsumkalum River. It is unlikely that many tagged fish moved into the Skeena River as there was a higher rate of tag recovery from the fish tagged downstream of the CN bridge than from the fish tagged upstream of the bridge (e.g. 1984: 7.7% downstream and 5.7% upstream).

A potentially important source of bias in Petersen estimates is mortality due to tagging. An alternative to capturing fish for tagging with gillnets would be seining, which might provide a less stressful method of capturing fish with a lower risk of handling mortality. However, there do not appear to be any suitable locations on the river for seining. If there were mortalities resulting from handling during tagging operations, these fish could have been washed out of the river prior to dead recovery effort and would not have been recovered. If this were the case, Petersen calculations would overestimate the populations due to a decrease in the number of recoveries. It is not possible to test for this bias using present data; an unsuccessful attempt was made in 1985 to operate a carcass weir which would have provided data for this test.

An ongoing problem in the enumeration of Kitsumkalum chinook has been significant tag loss, particularly among males (males: $p<0.001$; females: $p<0.01$). The use of opercular punch holes as secondary marks to evaluate tag loss and for purposes of Petersen calculations should be continued. The 1984 estimate would probably have been lower had a tag loss factor been available and applied to the tags recovered in the Petersen calculation. As presented, the 1984 escapement is probably an overestimate of the population, especially for males.

Kitsumkalum chinook salmon escapement may have been reduced by the commercial fisheries for sockeye and pink salmon, since the timing of the Kitsumkalum chinook spawning run coincides with the peak of the fisheries. In 1985, a record commercial fishery for sockeye salmon, many chinook were taken directly at the mouth of the Skeena River, whereas in 1986 there was a light bycatch of chinook in Area 4 due to a poor sockeye run and reduced fishing pressure. The Department of Fisheries and Oceans recorded only 7,148 chinook in the bycatch in 1986 compared to 29,769 chinook in 1985.

Important considerations in the evaluation of enumeration programs and the accuracy of population estimates are water and weather conditions. In August 1984, there was a low dead pitch and tag recovery due to constant rain and fluctuating high, turbid waters which buried or washed out carcasses (Fig. 2). In September 1984, heavy rains caused river levels to rise much higher than in previous years, and several large slides from the clay banks created highly turbid water conditions hindering tagging and recovery operations (G. Hazelwood, pers. comm., 1988). Low or dropping water levels could bias results if fish death is hastened by tagging, and tagged carcasses were more vulnerable to recovery due to stranding on bars or in shallow water. In 1985 and 1986, low rainfall, along with exceptionally low and clear waters and continually dropping water levels, provided optimal carcass recovery conditions (Fig. 2). In the 1985 program, there was a drop in water levels from 0.7 m to 0.25 m. In 1986, water levels declined steadily from 0.8 m on the staff gauge until the water levels fell below the lowest mark on the gauge. The Provincial Water Branch records indicated that the Skeena River had not been this low during August and September since 1965.

In future escapement enumeration of chinook salmon in the Kitsumkalum River, programs should be designed in a similar way to the 1985 and 1986 programs. Programs should include tag and recovery rates with equal effort in the upper and lower rivers and Petersen estimates should be stratified by sex and area. Such procedures should result in estimates with reasonable levels of precision.

AGE, LENGTH AND SEX COMPOSITION

Possible biases in age-length analyses from tagging were not a concern because the age frequency distribution of tagged versus dead recovered fish was not significantly different in any case tested (Kolmogorov-Smirnov tests, $p>0.05$). It was not possible to test possible biases arising from how dead recovery or scale sampling field procedures were conducted. However, testing for bias in scale readability with age was possible by comparing the length of fish with unreadable scales for age determination with those of readable scale condition, and assuming that longer fish are older. There were no significant differences in the length frequency distributions of fish for which ages were determined and those for which scales were unreadable for age in any group tested (Kolmogorov-Smirnov test, $p>0.05$). Scales from older fish are generally more difficult to read due to concentration of annuli near the outer edge of the scale and are more likely to be in poor condition (e.g. edges broken off) or regenerated.

The Kitsumkalum River chinook escapement was composed mainly of males (49.6% to 60.7% of the male and female escapement; Table 8). The escapement was composed mainly of 5 and 6 year old fish which spent at least one full year in freshwater. Dorsal fin rays, vertebrae, or scales from the caudal area are currently being studied for their reliability for aging of chinook (Y. Yole, Biological Services Division, Fisheries Branch, Department of Fisheries and Oceans, Vancouver, B.C., pers. comm., 1988) and could be used for more accurate age determinations in future programs.

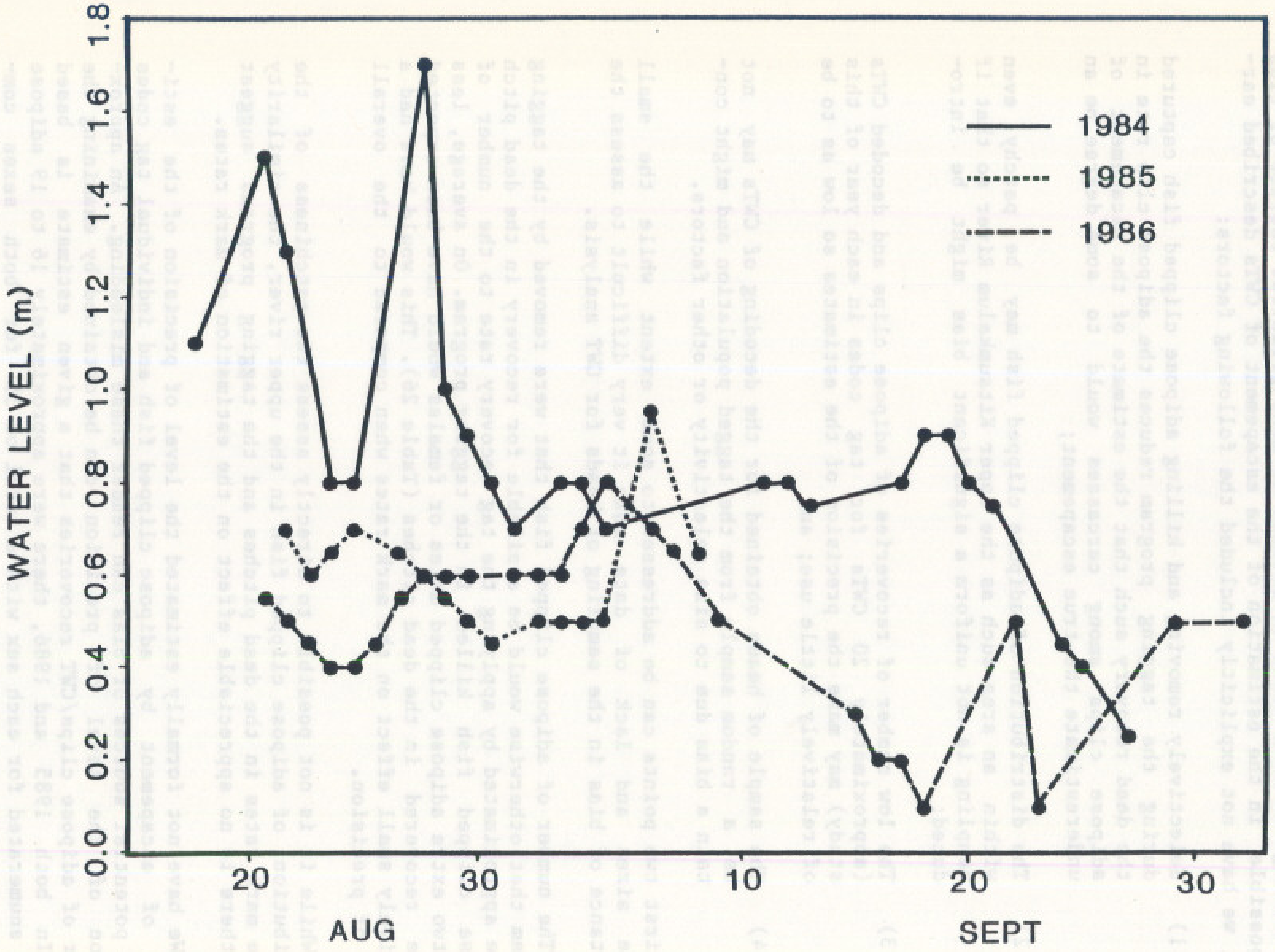

Figure 2. Water levels of Kitsumkalum River, 1984-1986. (Measured by staff gauge at CN Bridge near the mouth.)

CODED WIRE TAGGING AND RECOVERY

Although we have tried to address as many potential sources of bias as possible in the estimation of the escapement of CWTs described earlier, we have not explicitly included the following factors:

1) Selectively removing and killing adipose clipped fish captured during the tagging program reduces the adipose clip rate in the dead recovery such that the estimate of the escapement of adipose clips among carcasses would to some degree be an underestimate the true escapement;

2) The distribution of adipose clipped fish may be patchy even within an area such as the upper Kitsumkalum River so that if sampling is not uniform a significant bias might be introduced;

3) The low number of recoveries of adipose clips and decoded CWTs (approximately 20 CWTs for tag codes in each year of this study) may make the precision of the estimates so low as to be of relatively little use; and

4) The sample of heads obtained for the decoding of CWTs may not be a random sample from the tagged population and might contain a bias due to size selectivity or other factors.

The first two points can be addressed to some extent while the small sample sizes and lack of data make it very difficult to assess the importance of bias in the sampling of heads for CWT analysis.

The number of adipose clipped fish that were removed by the tagging program that otherwise would be available for recovery in the dead pitch can be approximated by applying the tag recovery rate to the number of adipose clipped fish killed in the tagging program. On average, less than two extra adipose clipped males or females would have been expected to be recovered in the dead pitches (Table 26). This would have had a relatively small effect on the mark rates when compared to the overall level of precision.

While it is not possible to directly assess the patchiness of the distribution of adipose clipped fish in the upper river, the similarity of the mark rates in the dead pitches and the tagging programs suggest that there is no appreciable effect on the estimation of mark rates.

We have not formally estimated the level of precision of the estimates of escapement by adipose clipped fish and individual tag codes since potential sources of bias can render these misleading. An approximation of the level of precision can be obtained by examining the number of adipose clips/CWT recoveries that a given estimate is based on. In both 1985 and 1986, there were approximately 16 to 19 adipose clips enumerated for each sex with a total of 35 for both sexes combined. The 95% confidence limits for 19 recoveries (based on a Poisson frequency distribution) range from 11 to 30 fish; thus we could expect any estimate based on this number of recoveries to have 95% confidence limits as narrow as ± 50%. For 35 recoveries the 95% limits would be as

Table 26. Effect of removal of adipose clipped fish during live tagging on mark rate in dead recovery for upper area of Kitsumkalum River, 1985-1986.

Item	1985		1986	
	Male	Female	Male	Female
% Tags recovered (A)[a]	19.9	11.9	17.2	11.4
Number of clipped fish removed in tagging (B)[b]	6	2	15	3
Estimated number of clipped fish missing from dead pitch (C)[c]	1.2	0.2	2.6	0.3

[a] Assuming random sampling, equal to the percentage of the population sampled. (From Table 17, column D and Table 22, column D.)

[b] From Table 16, column D and Table 21, column D.

[c] C=(A/100)xB

narrow as ± 37%. These estimates of precision are conservative since the expansion factors used to estimate the total number of adipose clips/marks in the escapement are also estimated with error.

In 1985 and 1986, hatchery released fish comprised 1.6% and 4.3% of the 5 year olds and 1.4% and 1.2% of the 6 year olds in the escapements, respectively. To simplify analyses of hatchery stocks, sampling for coded wire tags should be conducted in a consistent manner in the tagging and dead pitch programs. In addition, sampling of adipose clipped fish should not be selective in any way, for example in the tagging program releasing large females but sampling small females for coded wire tags.

Because the Kitsumkalum River has one of the highest escapements among streams in the north and central British Columbia coast, it is recommended that the Kitsumkalum programs be continued even though large numbers of CWT returns are not expected until 1988.

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APPENDICES

Appendix 1. Tagging effort (sampling times per day) on chinook salmon in the Kitsumkalum River, 1984.

Reach and location	Date																	Reach total
	August												September					
	16	17	20	21	22	23	24	27	28	29	30	31	2	3	4	5	6	
Reach 1																		11
Below CN Bridge	1	1	1	1	1	1	1		1	1				1	1			
Reach 2																		4
Spring Creek							1				1	1		1				
Reach 3																		9
Upper Spring Creek		1	1															
Lower Clay Bank									1									
Clay Bank					1	1	1	1		1	1							
Reach 4																		22
Upper Clay Bank									1									
Nass Road			1	1	1	1	1	1	2	1	1	1	1					
Lower Dump								1							1	1		
Upper Dump								1					1	1	1			
Lower Deep Creek								1										
Deep Creek													1					
Reach 5																		1
Upper Deep Creek											1							
Reach 6																		4
Lower Horseshoe																1	1	
Upper Horseshoe																1	1	
Reach 7																		
Reach 8																		2
14 Mile																1	1	
Total	1	2	3	2	3	3	4	5	5	3	4	2	3	3	3	4	3	53

Appendix 2. Tagging effort (sampling times per day) on chinook salmon in the Kitsumkalum River, 1985.

Reach and location	August										September									Reach total
	21	22	23	24	26	27	28	29	30	31	1	2	3	4	5	6	7	8	9	
Reach 1																				9
CN Bridge	1	1	1	1	1	2	2													
Reach 2																				9
Lower Spring Creek									1		1		1	2	1	1		1	1	
Reach 3																				55
Upper Spring Creek								1	2		1		1							
Lower Dutch Valley								1	2		2	3			1	1		1	1	
Dutch Valley		1	1									1	1	1		1		1		
Lower Clay Bank		1	2	2	1	1	1	1	2		2	2	1	2	2	1		1	1	
Clay Bank		1	1			1	1	1	1			1	1							
Reach 4																				56
Nass Road	1	1	2	1	1	1	1	1	1		1			1	2	1		1	1	
Lower Dump		1	1		1	1	1	1			1	1	1		1	1		1		
Middle Dump																1				
Upper Dump				1	1	1	1	1	1		1	1	1	2	1	1		1	1	
Deep Creek	1			1	1	1		1	1		1		1	1	1	1				
Reach 5																				
Reach 6																				32
Lower Horseshoe		1	1	1			1	1	1	1		1	1	1					1	
Grieves Pool		1				1	1		1	1		2	2	2	1	1	1		1	
Upper Horseshoe		1	1	1		1			1										1	
Reach 7																				4
Lower Tackle Run															1	1	1		1	
Reach 8																				37
Lower Glacier											1	1								
Dry Creek						1														
Boat Launch		1	1				1								1	1	1		1	
Lower Culvert Run		1		1		1			1											
Upper Culvert Run		2	2	1	2	2	2	2	2	1		1	2	1	1	1	1			
Total	3	13	13	10	8	14	12	11	17	3	11	14	13	13	13	13	4	7	10	202

Appendix 3. Tagging effort (sampling times per day) on chinook salmon in the Kitsumkalum River, 1986.

Reach and location	Date																					Reach total
	August												September									
	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5	6	7	8	9	10	
Reach 1																							
Reach 2																							16
Lower Spring Creek																2	1						
Spring Creek									1	2		2	1	2			1	1	2	1			
Reach 3																							67
Upper Spring Creek				1			1												1				
Lower Dutch Valley		1				1	1	2	1	1		2	1	1		2			1	1			
Dutch Valley						1	2	1	2	2		2	2	2		1		1	1	1			
Lower Clay Bank		1			1	1	1	1	2	1		1	3	4		1		2	1	2	1		
Clay Bank				1		1			1				1	1				1		1	1		
Reach 4																							62
Nass Road	1	1	1		1	1		1	1	2		2	1				1	1		1	1		
Lower Dump		1		1		1		1	1	2			1										
Middle Dump										1							1	1					
Upper Dump		2	1	1	1	1	1	1	1	2		1	1	1				2		1	1		
Lower Deep Creek				1													1	1					
Deep Creek			1		1	1	2	1	1	2			1	1				1		1	1		
Reach 5																							1
Upper Deep Creek				1																			
Reach 6																							50
Snake Run							1																
Lower Horseshoe		1	1			2	1	2	1	1	1			1	1			1		1			
Lower Grieves														1	1								
Grieves Pool		1	1			2	2	2	1	1	1		1	1	1			1		1	1	1	
Upper Horseshoe		1				2	1	2	1	1	1		1	1	1			1		1	1		
Reach 7																							12
Lower Tackle						1		1	1	1	1		1	1	1			1		1	1		
Tackle Run															1								
Reach 8																							39
Lower Glacier		1					1																
Glacier Creek								1		1													
Upper Glacier										1													
Boat Launch		2	1			1	1	2	1	1	1		2	1	1			1		1			
Culvert Run		2	2			2	1	1	1	1	1		1		1			1		1			
Upper Culvert																					1		
Site 11															1								
Lower Treston Lake																						1	
Total	1	14	8	6	4	18	16	19	17	23	6	10	18	18	9	6	5	17	6	15	9	2	247

Appendix 4. Recovery effort (sampling times per day) on chinook salmon in the Kitsumkalum River, 1984.

Reach and location	Date																						Reach total
	August				September																		
	23	27	30	31	2	4	5	7	10	11	12	13	14	17	18	19	20	21	24	25	27	28	
Reach 1																							17
Below CN Bridge						1		1															
Mouth to CN Bridge	1					1			1	1	1	1	1	1	1	1	1	1	1	1	1		
Reach 2																							19
Above CN Bridge			1	1																			
CN Bridge to Spring Creek								1	1	1	1	1	1	1	1	1	1	1	1	2	1		
Spring Creek		1			1																		
Reach 3																							16
Spring Creek to Clay Bank									1	2	1	1	1	1	1	1	1	1	1	1	1		
Clay Bank				1				1															
Reach 4																							11
Clay Bank to Deep Creek									1	1	1	1	1	1	1	1	1		1		1		
Reach 5																							
Reach 6																							6
Above Canyon														2		1			1			1	
Lower Horseshoe							1																
Reach 7																							
Reach 8																							
Total	1	1	1	2	1	2	1	3	4	5	4	4	4	6	4	5	4	3	5	4	4	1	69

Appendix 5. Recovery effort (sampling times per day) on chinook salmon in the Kitsumkalum River, 1985.

Reach and location	Date: September 12	13	16	17	18	19	20	21	22	23	24	25	26	27	29	30	October 1	2	3	4	6	7	Reach total
Reach 1																							
Below CN Bridge				1	1			1															21
Mouth to CN Bridge	1	1	1			1			1	1	1	1	1		2	1	1	1					
CN Bridge	1								1	1				1									
Reach 2																							
CN Bridge to Spring Creek		1	1													1							9
Lower Spring Creek										1													
Spring Creek											1				1								
CN Bridge to Dutch Valley																			1	1		1	
Reach 3																							
Upper Spring Creek													1					1					34
Spring Creek to Dutch Valley		1	1																				
Lower Dutch Valley	1			1	1			1	1	2		1		1									
Dutch Valley				1	1		1	1	1	1	1	1	1	1	1	1							
Clay Bank				1	1		1		1	1	1	1	1		1								
Reach 4																							
Lower Clay Bank to Nass Road	1																						22
Clay Bank to Nass Road			1															1					
Clay Bank to Deep Creek				1																			
Nass Road to Upper Dump	1																						
Nass Road to Deep Creek					1																		
Nass Road to Upper Deep Creek																		1					
Lower Dump									1	1									1				
Lower Dump to Deep Creek			1								1												
Lower Dump to Upper Deep Creek																					1		
Upper Dump											1	1											
Upper Dump to Deep Creek	1																						
Deep Creek									1		1	1	1		1								
Upper Deep Creek																			1				
Reach 5																							
Deep Creek to Canyon																		1					2
Upper Deep Creek and Side Channel																			1				
Reach 6																							
Upper Lean-to Creek																		1	1				17
Lower Luncheon Creek																		1					
Luncheon Creek																			1				
Lower Horseshoe		1					1					1						1					
Grieves Pool		1	1			1	1				1	1	1			1		1					
Reach 7																							
Ten-Mile						1					1	1				1		1	1				19
Lower Tackle Run			1			2	2				1	1	2			1	1	1	1				
Reach 8																							
Lower Glacier		1																					32
Glacier Creek			1			1	1				1		1			2			1				
Upper Glacier																	1	1		1			
Dry Creek																	1	1					
Boat Launch			1			2	1				2		1			1	1		1	1			
Upper Culvert						1					1	1	1			1	1			1			
[a] Lower Kalum	1			1	1			1		1				1									6
Total	7	6	9	6	6	9	8	4	7	9	14	11	11	4	6	10	6	13	10	4	1	1	162

[a] Recovered in Lower Kalum, specific reach unknown.

Appendix 6. Recovery effort (sampling times per day) on chinook salmon in the Kitsumkalum River, 1986.

Reach and location	Date																												
	Aug.	September																							October				Reach total
	30	1	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	1	2	3	6	
Reach 1																														14
Below CN Bridge					1				1	1	1		1			1		1						1	1		1			
CK Bridge											1	1				1		1												
Reach 2																														22
Bell Pole												1	1			1	1	1		1					1					
Lower Spring Creek									1																					
Spring Creek					1					4	1	2	1			1	1	1		1			1							
Reach 3																														46
Upper Spring Creek																1	1						1		1					
Lower Dutch Valley				1	1					2	2	1	1				2	1		1			1		1		1			
Dutch Valley										1	2	1	1				1			1			1							
Lower Clay Bank										1		1					1			1							1			
Clay Bank			1							1	2	1	1				1	2		1			1	1	1		1			
Reach 4																														30
Upper Clay Bank											1						1			1										
Nass Road											2	2					2						1							
Lower Dump											1	1	1				1			1				1			1			
Middle Dump											1																			
Upper Dump											1						1	1							1		1			
Deep Creek												1	1							1			1	1	1		1			
Reach 5																														
Reach 6																														49
Mini-Canyon Mouth																		1												
Digger's Pool											1							1												
Lower Lean-to						1												1												
Lean-to Creek												1						1												
Upper Lean-to						1						1						1								1				
Below Lower Horseshoe																					1									
Lower Horseshoe	1	1	1		1	1	1					1		1					1		1				1	1		1		
Grieves Pool			1	1	1	1		1				1		1					2		1					2				
Upper Horseshoe					2	1		1			1	1		1					1	1	1					1		1		
Reach 7																														28
Cottonwoods																		1												
Lower Tight Run																									1					
Tight Run								1			1	1		1											1					
Upper Tight Run																			1											
Lower Tackle Run			1				1	1			1	1		1					1	1	1	1				1		1		
Tackle Run				1		1		1			1			1							1							1	1	
Reach 8																														74
Upper Tackle Run													1						1											
Lower Glacier			1				1											1		1	1				1					
Glacier Creek								1			1		1					1		1		1				1				
Upper Glacier			1	1								1	1		1			1		1	1	1			1					
Lower Boat Launch					1	1	1						1		1			1	1	1	1	1			1	1		1		
Boat Launch			1	1	1	1		1			1		1	1	1			1	1	2	1	1			1	1		1		
Upper Boat Launch												1													1	1				
Culvert Run			1				1				1		1		1			1	1						1					
Upper Culvert Run								1					1		2			1	1	1										
Total	1	1	8	5	9	8	5	8	2	10	23	21	15	7	6	5	13	21	11	18	10	5	7	4	16	10	7	6	1	263

Appendix 7. Tagging and recapture locations of Kitsumkalum River chinook salmon, 1984.

Tagging reach[a]	Recapture reach[a] 1	2	3	4	5	6	7	8
Males and Jacks								
1	3			1				
2				1				
3			1					
4	4	1						
5								
6								
7								
8								
9[b]								
Females								
1	6	2						
2		1		1				
3	1							
4	3	2	4					
5		1						
6								
7								
8								
9[b]		1		1				

[a] Reaches 1 to 5 are in the lower river, reaches 6 to 8 are in the upper river (Fig. 1).

[b] Lost tag, location of tagging unknown.

Appendix 8. Tagging and recapture locations of Kitsumkalum River chinook salmon, 1985.

Tagging reach[a]	Recapture reach[a]								
	1	2	3	4	5	6	7	8	9[b]
<u>Males and Jacks</u>									
1			2						
2		1							
3	4	2	4	1					6
4		3	2	3					2
5									
6				1		2	1		1
7				2		1	2		
8	2	1	2	1	1	3	3	3	
9[c]	6	7	15	10	3	4	6	7	2
<u>Females</u>									
1	2								3
2	3		2	1					1
3	11	3	13	2					7
4	4	6	22	7	1			1	2
5									
6	1		3	2		6	3		
7						1	2		
8			2			1	3	14	1
9[c]	2	2	4	2		4	1	1	3

[a] Reaches 1 to 5 are in the lower river, reaches 6 to 8 are in the upper river (Fig. 1).

[b] Location of recovery was Lower Kalum, specific reach unknown.

[c] Lost tag, location of tagging unknown.

Appendix 9. Tagging and recapture locations of Kitsumkalum River chinook salmon, 1986.

Tagging reach[a]	Recapture reach[a]							
	1	2	3	4	5	6	7	8
Males and Jacks								
1								
2	1		1					
3	1	4	1					
4		4	6					
5								
6			2			1		
7						2	2	
8						1	3	1
9[b]	9	7	23	5		13	14	16
Females								
1								
2	1	4		1				
3	6	7	14	3			1	1
4		5	7	12		2		1
5				1				
6		1				12	5	4
7						1	4	1
8							1	15
9[b]	3	6	9	5		2	1	7

[a] Reaches 1 to 5 are in the lower river, reaches 6 to 8 are in the upper river (Fig. 1).

[b] Lost tag, location of tagging unknown.