

DFO - Library / MPO - Bibliothèque



12022675

Abundance, Age, Size, Sex and Coded Wire Tag Recoveries for Chinook Salmon Escapements of Campbell and Quinsam Rivers, 1993

H.R. Frith and T.C. Nelson

Department of Fisheries and Oceans
Biological Sciences Branch
#416, Suite 400-555 West Hastings Street
Vancouver, British Columbia V6B 5G3

September 1994

Canadian Manuscript Report of
Fisheries and Aquatic Sciences No. 2251

Canadian Manuscript Report of Fisheries and Aquatic Sciences

Manuscript reports contain scientific and technical information that contributes to existing knowledge but which deals with national or regional problems. Distribution is restricted to institutions or individuals located in particular regions of Canada. However, no restriction is placed on subject matter, and the series reflects the broad interests and policies of the Department of Fisheries and Oceans, namely, fisheries and aquatic sciences.

Manuscript reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report is abstracted in *Aquatic Sciences and Fisheries Abstracts* and indexed in the Department's annual index to scientific and technical publications.

Numbers 1-900 in this series were issued as Manuscript Reports (Biological Series) of the Biological Board of Canada, and subsequent to 1937 when the name of the Board was changed by Act of Parliament, as Manuscript Reports (Biological Series) of the Fisheries Research Board of Canada. Numbers 901-1425 were issued as Manuscript Reports of the Fisheries Research Board of Canada. Numbers 1426-1550 were issued as Department of Fisheries and the Environment, Fisheries and Marine Service Manuscript Reports. The current series name was changed with report number 1551.

Manuscript reports are produced regionally but are numbered nationally. Requests for individual reports will be filled by the issuing establishment listed on the front cover and title page. Out-of-stock reports will be supplied for a fee by commercial agents.

Rapport manuscrit canadien des sciences halieutiques et aquatiques

Les rapports manuscrits contiennent des renseignements scientifiques et techniques qui constituent une contribution aux connaissances actuelles, mais qui traitent de problèmes nationaux ou régionaux. La distribution en est limitée aux organismes et aux personnes de régions particulières du Canada. Il n'y a aucune restriction quant au sujet; de fait, la série reflète la vaste gamme des intérêts et des politiques du ministère des Pêches et des Océans, c'est-à-dire les sciences halieutiques et aquatiques.

Les rapports manuscrits peuvent être cités comme des publications complètes. Le titre exact paraît au-dessus du résumé de chaque rapport. Les rapports manuscrits sont résumés dans la revue *Résumés des sciences aquatiques et halieutiques*, et ils sont classés dans l'index annuel des publications scientifiques et techniques du Ministère.

Les numéros 1 à 900 de cette série ont été publiés à titre de manuscrits (série biologique) de l'Office de biologie du Canada, et après le changement de la désignation de cet organisme par décret du Parlement, en 1937, ont été classés comme manuscrits (série biologique) de l'Office des recherches sur les pêcheries du Canada. Les numéros 901 à 1425 ont été publiés à titre de rapports manuscrits de l'Office des recherches sur les pêcheries du Canada. Les numéros 1426 à 1550 sont parus à titre de rapports manuscrits du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom actuel de la série a été établi lors de la parution du numéro 1551.

Les rapports manuscrits sont produits à l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur dont le nom figure sur la couverture et la page du titre. Les rapports épuisés seront fournis contre rétribution par des agents commerciaux.

Department of Fisheries
& Oceans

OCT 31 1994

Ministère des Pêches et des
Océans
OTTAWA

Canadian Manuscript Report of
Fisheries and Aquatic Sciences 2251

September 1994

ABUNDANCE, AGE, SIZE, SEX AND CODED WIRE TAG
RECOVERIES FOR CHINOOK SALMON ESCAPEMENTS OF
CAMPBELL AND QUINSAM RIVERS, 1993

by

H. R. Frith and T. C. Nelson¹

for

Department of Fisheries and Oceans
Biological Sciences Branch
#416, Suite 400 - 555 West Hastings Street
Vancouver, B.C.
V6B 5G3

¹LGL Limited environmental research associates, 9768 Second Street, Sidney, B.C. V8L 3Y8

(c) Minister of Supply and Services Canada 1994

Cat. No.Fs 97-4/ 2251E ISSN 0706-6473

Correct citation for this publication:

Frith, H. R. and T. C. Nelson. 1994. Abundance, age, size, sex and coded wire tag recoveries for chinook salmon escapements of Campbell and Quinsam rivers, 1993. Can. Manusc. Rep. Fish. Aquat. Sci. 2251: ix + 59 p.

TABLE OF CONTENTS

	Page
LIST OF TABLES	v
LIST OF FIGURES	vi
LIST OF APPENDICES	vii
ABSTRACT	viii
RÉSUMÉ	ix
INTRODUCTION	1
STUDY AREA	2
METHODS	3
POPULATION ESTIMATION	5
Population Stratification	5
Potential Biases	6
Calculations	8
Strays	8
TAGGING	9
RECOVERY	9
BIOLOGICAL AND PHYSICAL SAMPLING	10
CODED WIRE TAGGING AND RECOVERY	11
Method A	11
Method B	13
RESULTS	15
TAGGING	15
Carcass Tagging	15
RECOVERY	15
POPULATION ESTIMATES	16
Carcass Tagging	16
AGE, LENGTH AND SEX COMPOSITION	16
CODED WIRE TAGGING AND RECOVERY	17
Hatchery Contributions - Method A	19
Hatchery Contributions - Method B	19

TABLE OF CONTENTS - Cont'd

DISCUSSION AND CONCLUSIONS	20
POPULATION ESTIMATION	20
AGE, LENGTH AND SEX COMPOSITION	21
CODED WIRE TAGGING AND RECOVERY	21
SUMMARY	22
ACKNOWLEDGEMENTS	23
REFERENCES	23
TABLES	25
APPENDICES	51

LIST OF TABLES

TABLE	Page
1. Summary of methods for the Campbell and Quinsam rivers chinook salmon enumeration programs, 1993	26
2. Summary of tagging and recovery effort for chinook salmon carcasses in Campbell and Quinsam rivers, 1993	27
3. Summary of in situ carcass tagging and dead recovery of chinook salmon in Campbell and Quinsam rivers, 1993	28
4. Petersen population estimates, confidence limits and enumeration data for chinook salmon escapement in the Campbell River, Quinsam River and Quinsam Hatchery based on in situ chinook carcass tagging and recovery of carcasses, 1993	29
5. Age composition of Campbell River chinook salmon, 1993	30
6. Age composition of Quinsam River chinook salmon, 1993	31
7. Age composition of Quinsam Hatchery chinook salmon, 1993	32
8. Age-length distribution of Campbell River, Quinsam River and Quinsam Hatchery chinook salmon, 1993	33
9. Petersen estimates, by age, of chinook salmon escapement to the Campbell River, Quinsam River, and Quinsam Hatchery, 1993	35
10. Estimates of the total escapement of adipose clipped chinook salmon to the Campbell River and Quinsam River, and Quinsam Hatchery, 1993	36
11. Estimates of total escapement of adipose clipped chinook salmon to the Campbell River, Quinsam River, and Quinsam Hatchery, by tag code, 1993 (Method A)	37
12. CWT release data for hatchery-reared chinook salmon returning to the Campbell River, Quinsam River, and Quinsam Hatchery, by tag code, 1993	40
13. Estimates of total escapement of hatchery-reared chinook salmon to the Campbell River, Quinsam River, and Quinsam Hatchery, by tag code, 1993 (Method A)	41

LIST OF TABLES - Cont'd

TABLE		Page
14.	Estimated hatchery contributions to Campbell River, Quinsam River, and Quinsam Hatchery chinook salmon escapement, 1993 (Method A)	43
15.	Estimates of the adjusted number of CWT chinook salmon to the Campbell River, Quinsam River, and Quinsam Hatchery, by tag code, 1993 (Method B) . .	44
16.	Estimates of total escapement of CWT chinook salmon to the Campbell River, Quinsam River, and Quinsam Hatchery, by tag code, 1993 (Method B)	46
17.	Estimates of total escapement of hatchery-reared CWT chinook salmon to the Campbell River, Quinsam River, and Quinsam Hatchery, by tag code, 1993 (Method B)	48
18.	Estimated hatchery and stray contributions to Campbell River, Quinsam River, and Quinsam Hatchery chinook salmon escapement, 1993 (Method B)	50

LIST OF FIGURES

FIGURE		Page
1.	Map of the Campbell and Quinsam rivers study area.	4
2.	Chinook escapement estimates, stratified by river location, 1985-1993	18

LIST OF APPENDICES

APPENDIX	Page
1. Operculum tagging of chinook salmon carcasses in Campbell River, 1993	52
2. Operculum tagging of chinook salmon carcasses in Quinsam River, 1993	53
3. Dead recovery of tagged chinook salmon carcasses in Campbell River, 1993 . . .	54
4. Dead recovery of tagged chinook salmon carcasses in Quinsam River, 1993 . . .	55
5. Sequential mark-recapture data for chinook salmon carcasses in Campbell River, 1993	56
6. Sequential mark-recapture data for chinook salmon carcasses in Quinsam River, 1993	57
7. Total dead recovery and adipose clip recovery of chinook salmon in Campbell River, 1993	58
8. Total dead recovery and adipose clip recovery of chinook salmon in Quinsam River, 1993	59

ABSTRACT

Frith, H. R. and T.C. Nelson. 1994. Abundance, age, size, sex and coded wire tag recoveries for chinook salmon escapements of Campbell and Quinsam rivers, 1993. Can. Manusc. Rep. Fish. Aquat. Sci. 2251 : ix + 59 p.

Estimates of escapement were derived for the Campbell/Quinsam River system for 1993 using carcass tagging as part of the chinook key stream program. The Petersen estimate of chinook escapement was 2,486 in 1993 and includes hatchery removals (sales, broodstock, mortalities) and chinook passed over the hatchery fence. Males and females were mostly age 5, except in Quinsam Hatchery where males were mostly age 3. The female chinook age distribution was similar for the Campbell River, Quinsam River and the hatchery with age 5 fish contributing greater than 70%. Males were more variable in age distribution and ranged from 72.2% age 5 in Campbell River to 26.2% age 5 in Quinsam Hatchery.

Estimated escapement of adipose-clipped chinook to the entire system was 133 in 1993. This estimate was further stratified by age, sex, and tag code. The total hatchery contribution (marked and unmarked) to the escapement was estimated by expanding the number of observed adipose clips by the adipose-clip mark rate at release. In 1993, the hatchery contribution was 63.9% and 70.8% for male and female chinook escapements, respectively. These hatchery contribution estimates were compared with those estimated using the Mark Recovery Program (Kuhn 1988) method of coded wire tag expansions. Using the MRP method, the total 1993 hatchery contribution was 61.6% for adult males and 65.8% for adult females.

Key words: Campbell, Quinsam, chinook, key stream, escapement, coded wire tags, live tagging, carcass tagging

RÉSUMÉ

Frith, H. R. and T. C. Nelson. 1994. Abundance, age, size, sex and coded wire tag recoveries for chinook salmon escapements of Campbell and Quinsam rivers, 1993. Can. Manuscr. Rep. Fish. Aquat. Sci. 2251 : ix + 59 p.

Les estimations de l'échappée pour le réseau de la Campbell et de la Quinsam (1993) ont été calculées au moyen du marquage des carcasses de poisson dans le cadre du programme des rivières clés pour le quinnat. L'estimation de Petersen concernant l'échappée de quinnat s'établissait à 2 486 poissons en 1993 et comprenait les prélèvements à la pisciculture (ventes, géniteurs, mortalités) et les quinnats qui réussissaient à franchir la barrière de la pisciculture. Les mâles et les femelles appartenaient en grande partie à la classe d'âge 5, sauf à la pisciculture Quinsam où les mâles étaient en grande partie âgés de trois ans. La répartition des quinnats femelles était semblable pour la rivière Campbell, la rivière Quinsam et les poissons de la pisciculture, les poissons d'âge 5 contribuant pour plus de 70 %. La variabilité de la répartition selon l'âge était plus grande chez les mâles, s'établissant entre 72,2 % d'âge 5 dans la rivière Campbell et 26,2 % d'âge 5 à la pisciculture de Quinsam.

L'estimation de l'échappée de quinnat à nageoire adipeuse coupée pour tout le réseau était de 133 en 1993. Par la suite, cette estimation a été stratifiée selon l'âge, le sexe et la marque. La contribution totale de la pisciculture (poissons marqués et non marqués) à l'échappée a été évaluée en multipliant le nombre de poissons à nageoire adipeuse coupée observés par le nombre de poissons à nageoire adipeuse coupée au moment du lâcher. En 1993, respectivement 63,9 % et 70,8 % des échappées de quinnats mâles et femelles provenaient de la pisciculture. On a comparé ces estimations à celles de la méthode de l'extrapolation des micromarques utilisée dans le cadre du Programme de récupération des marques (Kuhn, 1988). Selon cette méthode, la pisciculture aurait fourni au total, pour 1993, 61.6 % des mâles adultes et 65.8 % des femelles adultes.

Mots clés: Campbell, Quinsam, quinnat, cours d'eau clé, échappée, fil codé, poissons marqués, carcasses marquées.

INTRODUCTION

The chinook salmon of the Campbell/Quinsam River system was selected as one of the indicator stocks for assessing the response of Pacific chinook salmon stocks to a new harvest management regime. The goal of the new management regime is to rebuild chinook stocks to historical levels. This "key stream" program began in 1984 in response to objectives set out in the Canada - U.S. Salmon treaty.

The major objectives of the key stream program are:

1. to accurately estimate chinook escapement on key streams;
2. to estimate harvest rates and contributions to fisheries and escapement based on coded wire tagged/adipose clip returns, including estimates of the total escapement of coded wire tags to the key streams system; and
3. to estimate the contribution of hatchery and natural production to the escapement.

Chinook escapements to the Campbell River have ranged from 750 to 8,000 since 1947 (Shardlow et al. 1986). Chinook escapement to the Quinsam River was negligible prior to the opening of Quinsam Hatchery in 1972, but has increased to 1,500 in 1985 and 5,311 in 1988 (Andrew et al. 1988, Bocking et al. 1990). Chinook returns to the Quinsam Hatchery have also increased from 1,885 in 1986 to 5,412 in 1990 (Bocking 1991*b*). In recent years, total system adult escapement has declined from a high of 15,538 in 1990 to 7,906 in 1991 and 4,782 in 1992 (Frith et al. 1992; Frith 1993).

This manuscript report is the seventh in a series describing the escapement monitoring and biological sampling of chinook salmon in the Campbell/Quinsam River system. The 1984 study results are presented in Shardlow et al. (1986), 1985 results are in Andrew et al. (1988), the 1986-88 study results are described by Bocking et al. (1990), the 1989-90 results are described in Bocking (1991*b*), the 1991 results are in Frith et al. (1993), and the 1992 results are presented in Frith (1993).

As in previous years, the 1993 escapements of chinook salmon were calculated using the adjusted Petersen method (Ricker 1975). Carcasses were tagged to produce escapement estimates for each sex and river and summed to form a total estimate for the in-river escapement of chinook. The total recovery of chinook salmon at the Quinsam Hatchery was then added to the in-river escapement estimates to produce an escapement figure for the Quinsam/Campbell River system.

In this report, potential biases in the Petersen method, carcass tagging method, and method of stratification are discussed. Assumptions for the methods used and the tests for biases caused by violations of assumptions are also described in the methods section. The

results section presents the population estimates, tests for bias in tagging and recovery, population composition (age, length, and sex), and the results of coded wire tagging studies.

To avoid confusion in terminology relating to tagging and marking, the word "tagging" in this report refers to operculum tagging of dead mature chinook in the river and "marking" refers to marking of chinook juveniles with coded wire tags (CWT) and adipose fin clips (AFC).

STUDY AREA

The physical attributes of the Quinsam/Campbell drainage area have been described in detail by Andrew et al. (1988). The Campbell River originates east of the Vancouver Island Ranges and flows in an easterly direction for 9 km into Discovery Passage immediately north of the city of Campbell River, British Columbia (Figure 1). The Quinsam River, a major tributary of Campbell River, flows for over 30 km in a northerly direction through a series of small lakes before joining Campbell River approximately 3.8 km upstream from its mouth.

The drainage area for the Campbell River system is 1,460 km² and for the Quinsam River system is 265 km² (Andrew et al. 1988). Fish passage in Campbell River is blocked by natural falls and a hydroelectric dam 5.5 km upstream of the mouth. Approximately 27 km of the Quinsam River is accessible to natural spawning but chinook spawning takes place primarily in the lower 4 km of the river (Shardlow et al. 1986). Chinook access to the upper Quinsam River above the counting fence near Quinsam Hatchery was improved in 1988.

Flows in the Campbell River are controlled by the John Hart Generating Station, located 5.5 km upstream of the mouth (Marshall et al. 1977) and vary from 1.2 m³s⁻¹ to 826.0 m³s⁻¹ (mean=96.0 m³s⁻¹). Flows on the Quinsam River are not controlled and vary from 0.9 m³s⁻¹ to 21.6 m³s⁻¹ (mean=9.0 m³s⁻¹) (Shardlow et al. 1986).

Commercial activity in the Campbell River estuary includes log booming, sawmill operations, shake mills, a seaplane base at Tyee Spit, and recreational boat moorages (Andrew et al. 1988). Man-made islands have been constructed in the estuary in an effort to improve fish habitat (Levings 1986). The lower reaches of the Campbell River have been modified due to expansion of the Campbell River community (population approximately 18,000) which surrounds the lower 2 km of the river. Access to the Campbell River is primarily by municipal roads and by Campbell River Road, which runs along the south bank of the river.

Mining for coal is conducted in the headwaters of the Quinsam River, and forest harvesting is conducted throughout the watershed (Andrew et al. 1988). The lower reaches of the Quinsam River are easily accessed via logging roads, whereas access is more difficult in upper reaches above the hatchery.

The Campbell/Quinsam river system supports five species of Pacific salmon as well as steelhead trout (*Oncorhynchus mykiss*) and cutthroat trout (*O. clarki*). The salmonids, in order of abundance, are pink, chinook, chum, coho and pink salmon (*O. gorbuscha*, *O. tshawytscha*, *O. keta*, *O. kisutch*, and *O. nerka*, respectively). Chinook spawn in Campbell River upstream of the confluence with the Quinsam River, and in the Quinsam River from the mouth to the counting fence (Andrew et al. 1988). Each year some chinook salmon swim through the counting fence to spawn in the upper Quinsam River or are passed over the fence by hatchery staff. Coho spawn in the Quinsam River, but not in the Campbell River, and chum and pink salmon that previously spawned in the lower reaches of the Campbell River now utilize the lower reaches of Quinsam River as well. Chinook begin migration into the Campbell River in late August and the majority of chinook enter the system in October. Peak spawning in Campbell River occurs from mid-October to mid-November (Andrew et al. 1988; M. VanTine, pers. comm.²). Migration of chinook into the Quinsam River occurs later from late September to late November and is strongly influenced by rainfall. Spawning is usually completed by late November or early December.

The Quinsam Hatchery is located approximately 3.7 km upstream of the Quinsam River confluence with the Campbell River. A fence is located immediately upstream of the hatchery for broodstock collection (Figure 1). Fish distribution and smolt production, as well as river flows and water quality in the watershed were studied by Blackmun et al. (1985).

METHODS

Carcass tagging and recovery was conducted from October 25 to November 18 by Quinsam Hatchery workers. A summary of methods for this study is presented in Table 1 and is described below.

²Manager of Quinsam Hatchery, P.O. Box 467, Campbell River, B.C. V9W 5C1

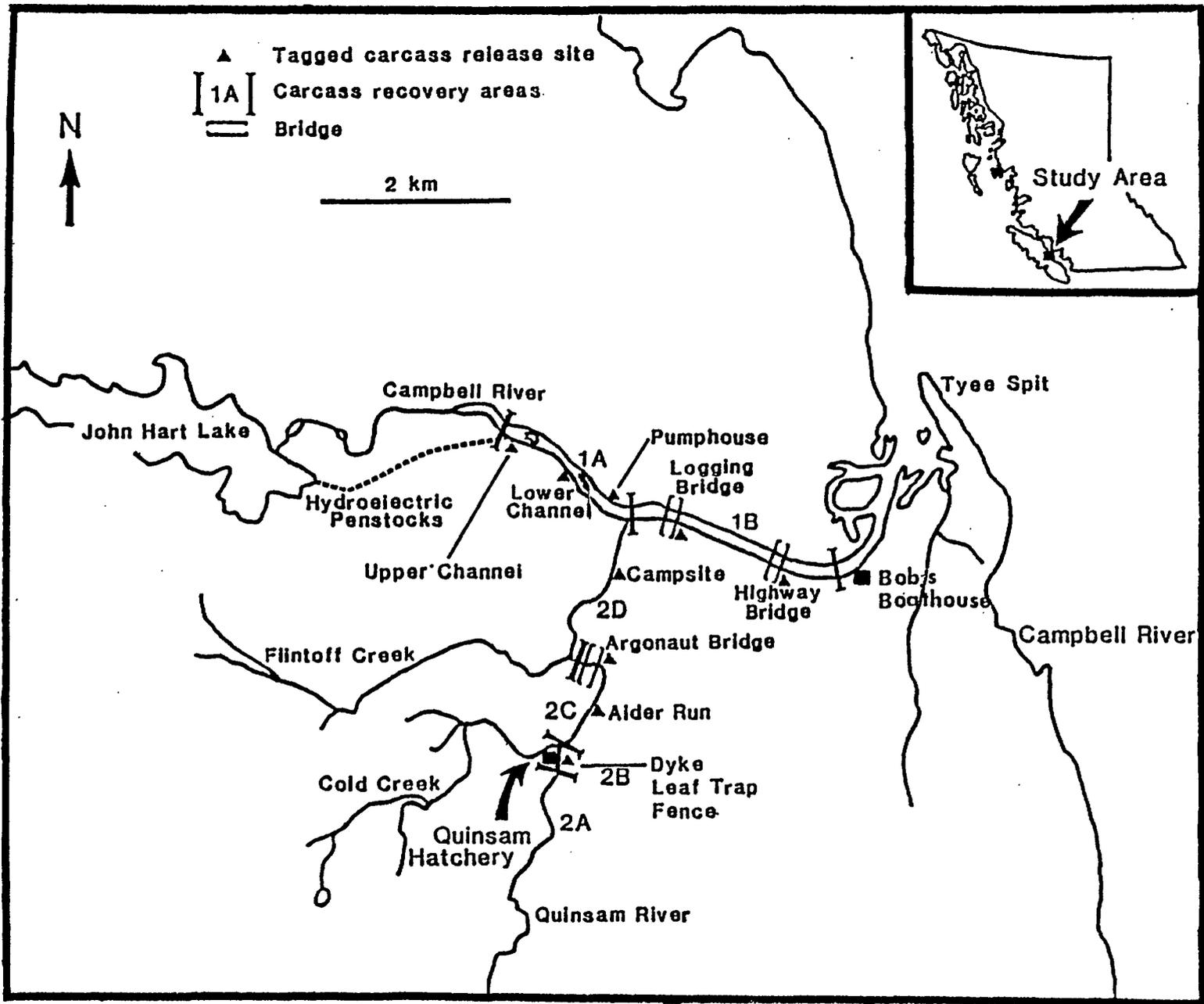


Figure 1. Map of the Campbell and Quinsam rivers study area.

POPULATION ESTIMATION

Chinook salmon were enumerated using the adjusted Petersen method (Ricker 1975, p. 78) by tagging spawned-out chinook carcasses and recovering tags from the carcasses. Carcasses were tagged and recovered *in situ*.

Population Stratification

Carcass Tagging:

There are four main ways of stratifying the carcass tagging and recovery data to produce a Petersen estimate of escapement:

1. sexes and rivers pooled;
2. sexes separate with rivers pooled;
3. sexes separate and rivers separate; and
4. sexes pooled with rivers 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, potential biases may be avoided. The potential sources of bias are differential rates of tag application, recovery of carcasses, and tag loss. If carcasses in the Campbell and Quinsam rivers do not mix following release of tagged carcasses and form two distinct groups, and tagging rates, dead recovery rates and recovery effort are different between the two rivers, then an unstratified population estimate could be biased. Similarly if the two sexes (and jacks) have different rates of tag application, recovery rates, or tag loss, then a non-sex stratified population estimate may also be biased.

Due to the likelihood of factors affecting sexes and rivers at different rates, as documented by Andrew et al. (1988), Petersen estimates were stratified by sex and river in this study. Petersen estimates were generated for the Campbell River and the Quinsam River (below the fence). Additional counts of chinook salmon returning to the hatchery rack and those fish passing upstream through the Quinsam River fence were added to the two Petersen estimates to give a total system escapement.

Potential Biases

Carcass Tagging:

Within a stratum, Petersen estimates using carcass tagging are subject to bias if a number of assumptions are violated. Seven of these assumptions were discussed in Andrew et al. (1988), Bocking et al. (1990), Bocking (1991*b*), Frith et al. (1993) and Frith (1993) and are repeated in this paper for the benefit of the reader.

Tests used to evaluate bias of the Petersen estimate in this study are also presented and discussed below. Certain biases caused by methods of tagging, recovery, and age determination are discussed in subsequent sections.

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

To obtain an accurate Petersen estimate, it is important to apply and recover tags in proportion to the available population. In 1993, carcasses were tagged sequentially and *in situ* during recovery. Hatchery workers attempted to tag a consistent proportion of the number of fish examined during each recovery survey by tagging every fifth carcass in 1993, but when the number of carcasses examined in a day was low, a higher tag rate was applied. The proportion of fish tagged ranged from about 20-60% over the study period.

A related problem associated with escapement estimates for separate rivers is that tagged carcasses may stray (washout) between rivers. Apart from passive movement due to water flow, tagged carcasses are not subject to movement or straying in the same way as live fish. In 1993 there was no straying between rivers of tagged carcasses.

Assumption 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. In 1993, tagging continued *in situ* in the rivers every 1 to 5 days throughout the spawning and die-off period.

Assumption 3. 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 a hole punch in the operculum of all tagged carcasses. A different number of opercular holes was used to distinguish carcasses tagged in the Campbell River from carcasses tagged in the Quinsam River. All secondary marks (opercular punches) were included in the tag recovery data and Petersen estimates.

Assumption 4. All tags are recognized and reported during recovery after the conclusion of tagging.

In this study, no duplicate pitches were conducted to re-examine carcasses for missed tags and secondary marks. Therefore, it was not possible to evaluate the validity of this assumption.

Assumption 5. Recovery efforts are made on the same population that 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. Since tagging occurred concurrently with recovery, this is an unlikely source of error.

Assumption 6. There is adequate sampling to provide 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 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, and 95% confidence, for population sizes of 10^2 to 10^9 (Ricker 1975).

Assumption 7. Tagged carcasses are representative of the population and behave in a similar manner to untagged carcasses with respect to buoyancy, visibility, and decomposition.

Tagged carcass recoveries will not be representative of the population if tagged carcasses do not mix completely with untagged carcasses (see assumption 1), in which case the Petersen method may overestimate or underestimate the population. The thoroughness of mixing depends on whether tagged carcasses behave in a similar manner to untagged carcasses. It is not possible to statistically test the assumption of mixing with the data from this study.

Buoyancy and decomposition may be important factors causing differential behaviour of tagged and untagged carcasses especially if tagged carcasses become bloated with air during handling. Differences in tag visibility could cause preferential sampling of tagged carcasses, and result in an underestimate of the population. An attempt was made to circumvent this problem by using neutral colours to prevent increased visibility of tagged carcasses. It is not possible to test the assumption of similar visibility between tagged and untagged carcasses with the data from this study. The assumption of similar buoyancy and decomposition of tagged and untagged carcasses could be tested by comparing the tag recovery rate during dead recovery with the recovery rate at carcass weirs if such data were available.

Calculations

The adjusted Petersen estimate of each river stratum and sex was calculated as follows (Chapman's formula, cited in Ricker 1975, p. 78):

$$P_{i,r} = \frac{(C_{i,r} + 1)(M_{i,r} + 1)}{(R_{i,r} + 1)} \quad (1)$$

where P is the population estimate, C is the total number of fish recovered, M is the total number of fish tagged, and R is the number of tagged fish recovered and includes fish with missing tags (secondary marks only). The subscript i is the sex stratum and the subscript r is the river stratum.

Population estimates for sex and river (carcass tagging only) strata were summed to obtain a total in-river population estimate:

$$P_t = \sum_{i=1}^n \sum_{r=1}^m P_{i,r} \quad (2)$$

where n is the total number of sex strata and m is the total number of river strata.

Confidence limits for each stratum population estimate were obtained using fiducial limits for the Poisson distribution as described by Ricker (1975, p79). The 95% confidence limits for the total escapement was then determined by assigning equal weights to all strata and summing the lower and upper confidence limits across strata.

Population estimates were not calculated for jack chinook because no marked jacks were recovered.

Strays

There were no carcass strays between rivers in 1993.

TAGGING

Tagging was conducted in tandem with the dead recovery effort. This enabled the tagging effort to be spread evenly throughout the recovery period (Appendix 1 and 2).

RECOVERY

Sampling crews that conducted the dead recovery were composed of two to six workers each day. Table 2 shows the number of person-days spent in dead recovery effort in each river. Recovery crews were instructed to dead pitch and count all available carcasses and record and keep all operculum tags. Crews attempted to distribute recovery effort evenly throughout the study period. Dead chinook were recovered from the Campbell and Quinsam rivers by two methods:

1. recovery crews searched the banks and shallow reaches of the rivers on foot and from a boat; and
2. a SCUBA diver recovered carcasses from deep pools in the lower reaches of the Campbell and Quinsam rivers.

Chinook were also recovered at the Quinsam Hatchery rack.

Each carcass was examined for the presence of an opercular tag and opercular punch hole(s), and the absence of an adipose fin. Heads were removed from adipose-clipped fish for sampling of coded wire tags (CWT). Data collected from carcasses are described in the biological and physical sampling methods section. All carcasses tagged during the recovery effort were released at the same location as they were tagged. All recaptured tagged carcasses were cut in half to prevent recounting in future dead pitches.

For Petersen mark-recapture estimates, only carcasses recovered after the first day of tagging were included in the values of C and R . It was assumed that 24 hours were required between tagging and recapture for sufficient mixing between tagged and untagged carcasses.

Other calculations relating to the dead recovery were as follows:

$$\text{tag rate} = R / C \quad (3)$$

where *tag rate* is an estimate of the proportion of the population that were tagged.

$$\text{tag recovery rate} = R / M \quad (4)$$

where *tag recovery rate* is an estimate of the proportion of tagged fish that were later recaptured.

BIOLOGICAL AND PHYSICAL SAMPLING

Biological sampling during dead recovery included the collection of scales for age determination, length measurements, sex determination, the recording of the presence of secondary marks (hole punches in the operculum), and presence of an adipose clip. Postorbital-hypural length was recorded for 69-70% of the carcasses (marked and unmarked fish) recovered in the Campbell River, 55-59% of the carcasses recovered in the Quinsam River, and 19-20% of the chinook recovered alive at the hatchery rack.

Scale samples were taken from the same unmarked fish as length samples. Some adipose-clipped fish (CWT) were also sampled for age (from CWT decoding) and lengths. A scraping of scales was placed in a labelled plastic envelope and the individual scales from each fish were mounted in scale books at the hatchery. Scales were aged at the Department of Fisheries and Oceans scale laboratory in Vancouver. Heads were removed from adipose-clipped fish and saved for CWT extraction and decoding at the coded wire tag dissection laboratory in Vancouver.

Ages were read only when a portion of the previous annulus was present and scales were not regenerated. Scales were classified as unreadable if the scales had regenerate centres, they were resorbed, or if they were mounted upside down. Ages were recorded for fish for which there were at least two scales that could be read for both marine and freshwater ages. In this report, only the total age was reported. The aging system follows that described by Gilbert and Rich (1927).

The age composition determined with the available samples is valid only if age sampling was random and there was no bias in readability of scales with age. Ages of older fish are usually more difficult to read than those of young fish because scales of older fish usually undergo more resorption and regeneration. The data were examined for this potential bias using a t-test to compare the mean lengths of known and unknown age males and females. The dead recovery sample was used to determine the age and length composition of the population. Because of problems in distinguishing jacks from adult males, age and length information for jacks was grouped with males.

The population of each age class was then determined by allocating portions of the Petersen estimate to age classes according to the age composition determined from scale samples and CWT decoding. The number of jacks was too small to estimate population size

with accuracy and therefore escapement by age was determined for adult males and females only.

A sex ratio was determined from Petersen estimates for each river. The test for potential differences in tag loss is described in the tagging methods section. Tag recognition is not likely to be biased by sex, although it was not possible to test this potential bias with the data in this study.

CODED WIRE TAGGING AND RECOVERY

Juvenile chinook from the 1986 - 1991 brood years were marked at Quinsam Hatchery with binary coded wire tags (CWT) described by Jefferts et al. (1963) using standard methods (Armstrong and Argue 1977). Adipose fins of coded wire tagged juveniles were clipped prior to the release of these fish.

Estimates of the contribution of hatchery-reared chinook to the total escapement were calculated following two approaches. The first approach (Method A) applies the AFC (adipose fin clip) mark rate in recovery (dead pitch) samples to estimate AFC escapement by tag code. The second approach (Method B) follows a similar approach where the percentage of CWT tags in escapement counts by tag code are used for expansion.

Method A

Adipose-clipped fish were enumerated separately for males and females in the Campbell River, Quinsam River, and Quinsam Hatchery. Quinsam Hatchery recoveries included fish examined and released upstream of the counting fence. The recovery of chinook jacks was not included with the adult male recoveries in this analysis. The first step was to estimate the number of adipose-clipped fish in each stratum (river and sex) from the observed number of adipose clips:

$$EAD_{i,r} = \frac{OAD_{i,r} \cdot P_{i,r}}{C_{i,r}} \quad (5)$$

where EAD is the estimated number of adipose clips, OAD is the number of adipose clips observed, C is the number of fish examined, P is the population estimate, and i and r are subscripts denoting sex and river location (stratum). The sex-specific population estimates used here were from the Petersen population estimates for the Campbell and Quinsam Rivers

and from direct counts for the hatchery. Estimates of the number of adipose clips for jack chinook were not possible because there was no population estimate.

Given an estimate of the total number of adipose clips for each sex escaping to each portion of the system, the number of adipose clips for each tag code can be estimated by the allocation of adipose clips to tag code groups based on their relative frequency in the sample of decoded tags:

$$EAD_{i,r,tc} = \frac{EAD_{i,r} \cdot NDT_{i,r,tc}}{\sum NDT_{i,r}} \quad (6)$$

where tc is a subscript denoted tag code, NDT is the number of successfully decoded tags for each tag code, and $\sum NDT$ is the total number of decoded tags for all tag codes, for each strata and sex.

This approach of first estimating adipose-clipped fish and then allocating these among the successfully decoded CWTs assumes that any adipose-clipped fish not decoded contained a coded wire tag at release. If this assumption is incorrect, the calculation of the number of hatchery-origin fish using this method would be positively biased. It is possible, especially in the dead pitch, that some fish identified as hatchery releases by missing adipose fins may be fish that have naturally lost their adipose fins through some other means, e.g. carcass decomposition, or were misidentified. Other potential sources of bias using Method A are discussed in Bocking (1991b).

The hatchery contribution to each year's escapement, stratified by river and sex, was calculated by expanding the estimated number of adipose clips from each tag code group in proportion to the percentage of juvenile fish possessing an adipose clip at time of release:

$$EHC_{i,r,tc} = \frac{EAD_{i,r,tc} \cdot (RC_{tc} + RUC_{tc})}{RC_{tc}} \quad (7)$$

where EHC is the estimated hatchery contribution, RC is the number of chinook released with an adipose fin clip for each tag code group (tc), and RUC is the number of chinook released without an adipose fin clip for each tag code group (tc).

These estimates of hatchery contributions, stratified by brood year (t), river (r), sex (i) and tag code (tc) can then be summed to give the hatchery contribution of all tag codes to the entire escapement:

$$EHC = \sum_{t=1}^j \sum_{r=1}^k \sum_{i=1}^m \sum_{tc=1}^n EHC_{i,r,i,tc} \quad (8)$$

where n is the number of tag codes for a given brood year t .

Due to the potentially different ages at maturity of males and females, it is important that the allocation of adipose-clipped fish to tag codes be carried out separately by sex whenever possible. In this study, the sex of all fish sampled for CWTs was recorded so that it was possible to estimate the total escapement of tag codes by sex (males do not include jacks). Final hatchery contribution estimates were made separately for fish of Quinsam Hatchery origin and for strays from other rivers.

Method B

In the second approach used to estimate the hatchery contribution, we estimated the number of successfully decoded CWT chinook in the escapement, stratified by river and sex using the methods described for the Mark Recovery Program (Kuhn 1988). The primary difference between this method and Method A is that Method B uses the number of actual CWTs present in the escapement from which to derive the hatchery contribution, whereas Method A uses the number of adipose clips present in the escapement. Method B is currently used by DFO to estimate hatchery contributions in commercial and sport chinook catches.

Estimating the total number of CWT returns from each of the brood years, and for each tag code, was done as follows.

First, the observed number of CWT recoveries was adjusted to account for "no pin" (no tag) recoveries:

$$ADJ_{i,r,tc} = OBS_{i,r,tc} \cdot \left[1 + \frac{LP}{K} + \frac{ND \cdot (K + LP)}{K \cdot (K + LP + NP)} \right] \quad (9)$$

where ADJ is the adjusted number of observed CWT fish, OBS is the observed number of CWT fish, K is the sum of all successfully decoded tags for all tag codes recovered, LP is the number of lost pin recoveries, ND is the number of no data recoveries, NP is the number of no pin recoveries, and i , r , and tc are subscripts denoting sex, river, and tag code.

This adjusted number of CWT recoveries was then used to estimate the total number of CWT returns for each tag code:

$$EST_{i,r,tc} = \frac{ADJ_{i,r,tc} \cdot P_{i,r}}{C_{i,r}} \quad (10)$$

where EST is the estimated number of CWT recoveries for a single tag code, C is the number of fish examined, P is the population estimate, and i , r , and tc are subscripts denoting sex, river, and tag code.

This approach of estimating the number of CWT chinook in the escapement assumes that any adipose-clipped chinook found without CWTs were never marked. This assumption is only valid if chinook tagged with a particular tag code did not lose the CWT after release from the hatchery (i.e. after accounting for tag loss during a retention test). Since 90% of tag loss occurs within four weeks of tagging (Blankenship 1990), any fish released within this four-week period are more susceptible to tag loss prior to being recovered in the fishery or escapement. Violation of the assumption of no tag loss will result in a negative bias in the hatchery contribution estimates. Other potential sources of bias using Method B are discussed in Bocking (1991b).

The hatchery contribution to each year's escapement, stratified by river location and sex, was calculated by expanding the estimated number of CWT fish of each tag code group in proportion to the percentage of juvenile fish having a CWT at time of release:

$$EHC_{i,r,tc} = \frac{EST_{i,r,tc} \cdot (RM_{tc} + RUM_{tc})}{RM_{tc}} \quad (11)$$

where EHC is the estimated hatchery contribution, RM is the number of chinook released with CWTs for each tag code group (tc), and RUM is the number of chinook released without CWTs for each tag code group (tc).

As for Method A, these estimates of hatchery contribution by tag code were then summed to give the hatchery contribution of all tag codes to the entire escapement, stratified by river, sex, and brood year:

$$EHC_{i,r,t} = \sum_{j=1}^j \sum_{r=1}^k \sum_{i=1}^m \sum_{tc=1}^n EHC_{t,r,i,tc} \quad (12)$$

where n is the number of tag codes for a given brood year t .

Percent hatchery contributions by sex and age were then calculated using the Petersen population estimates for adult males and females.

RESULTS

TAGGING

Carcass Tagging

In 1993, 65 chinook carcasses were tagged and released (returned to the river) between October 26 to November 5 in the Campbell River, and 86 carcasses were tagged and released from October 25 to November 15 in the Quinsam River (Table 3; Appendix 1 and 2).

RECOVERY

Surveys to recover carcasses in 1993 began on October 29 in the Campbell River and on October 28 in the Quinsam River and continued until November 10 and 18, respectively (Appendices 3 and 4; Figure 1). On some days, some reaches in each river were surveyed more frequently than others. The number of carcasses recovered in each area of the rivers for 1993 are summarized in Appendices 3 and 4.

Sequential daily totals of the number of carcasses recovered, the number of tags applied, and the number of tags recovered, stratified by river and sex are presented in Appendices 5 and 6. Note that the total number of fish examined is greater than the number of fish examined (C) in the Petersen formula because recoveries on or before the first day of tagging cannot be included.

In 1993, a total of 156 chinook carcasses were examined in the Campbell River (77 males, 77 females, and two jacks; Table 3). This number included 41 tag recoveries (21 males, 20 females and zero jacks). In the Quinsam River, a total of 382 chinook carcasses were examined (106 males, 269 females, and seven jacks; Table 3). This included 38 tag recoveries (four males, 34 females, and zero jacks). In both rivers, more tagged females than males were recovered and no tagged jacks were recovered.

The carcass tag recovery rates in the Campbell River (63.1%) and Quinsam River (44.2%) in 1993 differed by 18.9% ($P < 0.025$, χ^2 ; Zar 1984). The tag rates were similar

for males (61.8%) and females (64.5%) in Campbell River but were much lower for females (22.2%) than males (50.7%) in Quinsam River ($P < 0.05$, χ^2 ; Zar 1984).

POPULATION ESTIMATES

Carcass Tagging

Petersen escapement estimates, stratified by river and sex, are given in Table 4. In 1993, chinook escapement to the Campbell River and Quinsam River was estimated at 219 and 852 adults, respectively (Table 4). Sex-specific estimates and 95% confidence limits for both rivers are also shown in Table 4. The total escapement to the Campbell/Quinsam River system in 1993, including hatchery rack recoveries, was estimated at 2,486 adults with 95% confidence limits of 2,073 to 3,379 fish.

The proportion of fish amongst sampling location strata was 8.5: 33.2: 58.3 (Campbell:Quinsam:Hatchery). These proportions are similar to the 1992 proportions (16.1: 27.9: 56.0) but are a departure from previous years averaging 17.9: 42.2: 39.9 for 1989-1991 (Bocking 1991*b*; Frith et al. 1993) where the maximum range for any one system was 9.3%. In 1991 and 1992, the Quinsam River representation suggests a decline and the Quinsam Hatchery an increase compared to the previous three-year averages. The total returns also suggest a continued decrease from the high in 1990 for the Campbell River, Quinsam River and hatchery (Figure 2).

AGE, LENGTH AND SEX COMPOSITION

Age composition and mean lengths of chinook salmon are presented in Tables 5-7. All scale-aged fish in the Campbell and Quinsam rivers left the river to rear in the ocean during their first year of life (termed sub-one in this report). Total ages of Campbell and Quinsam river chinook ranged from 2 to 6 years. The dominant age-group for both sexes in the Campbell River, Quinsam River and hatchery was age 5 fish except for hatchery males where age-3 fish dominated. The proportion of females in the age-5 group was consistently greater than 70% where only Campbell River males showed a similar age distribution (72% age 5). In Quinsam River and hatchery, the number of age-3, age-4 and age-5 fish were each greater than 20% (Table 9).

Male and female chinook from Campbell River had larger mean lengths (postorbital-hypural) than male and female chinook from the Quinsam River (Campbell: male = 787 mm, female = 802 mm; Quinsam: male = 697 mm, female = 792 mm). T-tests were conducted

to compare the mean lengths among sexes and among rivers. Male chinook carcasses were significantly smaller than female carcasses in Campbell River only ($P < 0.001$). Female carcasses recovered in the Campbell River were significantly larger than those recovered in the Quinsam River ($P < 0.001$) whereas female carcass lengths were not significantly different. Carcasses recovered in the Quinsam River were larger than chinook recovered at the hatchery but the difference was only significant for females ($P < 0.002$).

There was no significant difference between the mean length of unaged and aged (all ages) chinook for any combination of sex and river stratum (t-test, $P > 0.05$) except for Campbell River females where the unknown aged chinook were significantly larger than aged chinook (t-test, $P < 0.05$). Age-length distributions for chinook returning to the Campbell River, Quinsam River, and Quinsam Hatchery in 1993 are shown in Table 8 and escapement stratified by age, class and sex is shown in Table 9. The sex ratio of males (not including jacks)/females was 1.03 in the Campbell River, 0.78 in the Quinsam River, and 1.79 at the Quinsam Hatchery (Table 9).

CODED WIRE TAGGING AND RECOVERY

Coded wire tagged (adipose-clipped) juvenile chinook released into the Campbell and Quinsam rivers from the 1987 to 1991 brood years were captured in the dead recovery programs in 1993 (Appendix 7 and 8). There was one recovery in Quinsam River and six recoveries in Quinsam hatchery of adipose-clipped chinook jacks (1990 and 1991 broods).

The results of coded wire tag returns are presented below for the Campbell and Quinsam rivers and the Quinsam Hatchery. Information includes the following:

1. the raw data and mark rates for the Petersen estimates (Appendices 7 and 8);
2. estimates of the total escapement of adipose clips (Table 10);
3. hatchery release information for recovered tag codes (Table 12).
4. the observed and estimated escapement of adipose clips by tag codes, and the hatchery contribution to the escapement for each tag code (Tables 11 and 13 and Tables 15 to 17); and
5. the estimated hatchery contribution to the escapement by age class (Tables 14 and 18).

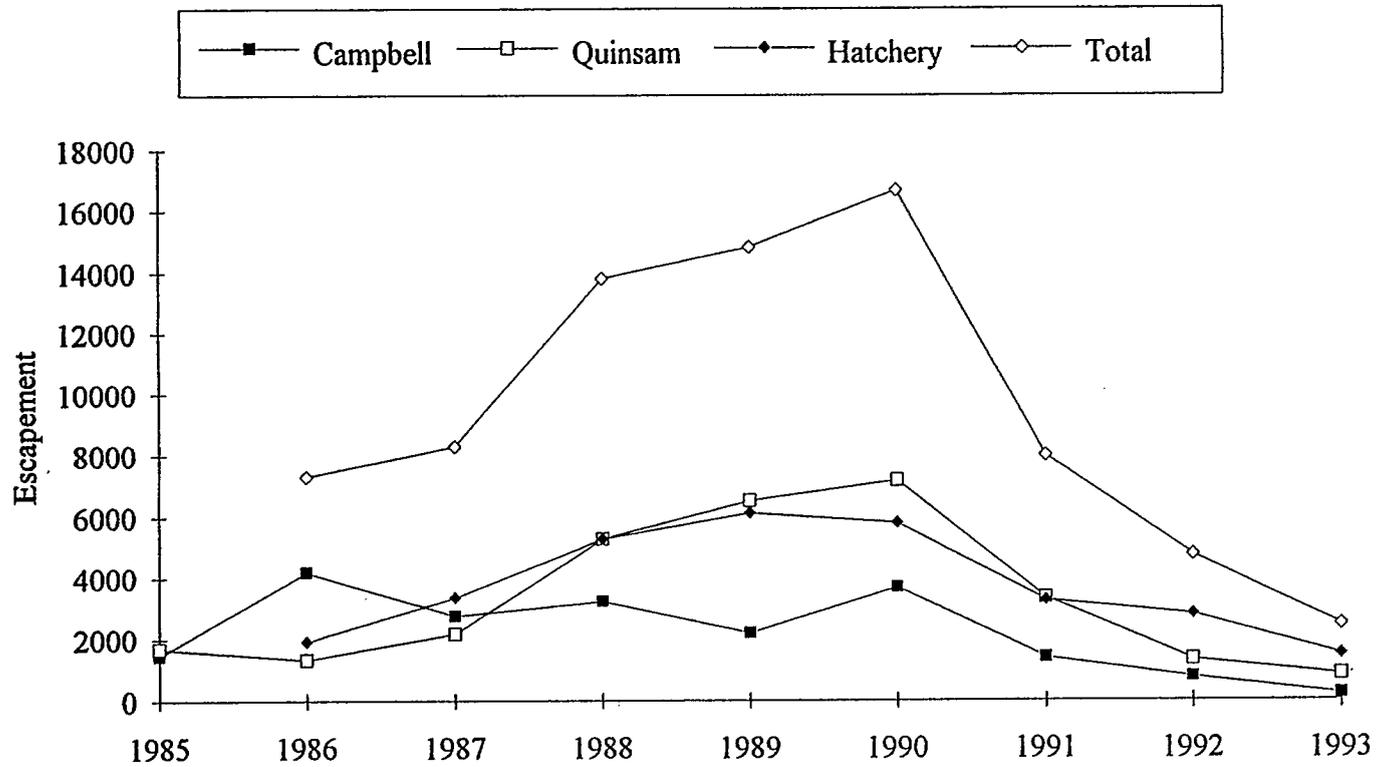


Figure 2. Chinook escapement estimates, stratified by river location, for 1985 (Andrew et al. 1988), 1986-88 (Bocking et al. 1990), 1989-90 (Bocking 1991), 1991 (Frith et al. 1993), 1992 (Frith 1993) and 1993 (this study).

In 1993, there were five adipose-clipped chinook recovered in the Campbell River dead pitch, 18 in the Quinsam River dead pitch and 86 at the hatchery rack not including jacks (Table 10). The adipose-clip mark rate was highest in the hatchery returns (6.1%) and lowest in the Campbell River returns (3.2%). The total estimated adipose clips to Campbell River, Quinsam River, and Quinsam Hatchery were seven, 41, and 86, respectively.

These mark rates at return were tested for significant differences between rivers using a chi-square test. The mark rates for the Campbell River, Quinsam River, and Quinsam Hatchery were not significantly different (χ^2 , $P > 0.10$).

Hatchery Contributions - Method A

Results from the decoding of adipose-clipped fish from the Campbell and Quinsam river dead pitch and returns to Quinsam Hatchery are shown in Table 11. Any CWT fish recovered in the system which were released from another enhancement facility were included in the analysis (only one stray was recovered in the Quinsam hatchery in 1993). A total of 109 fish were recovered in 1993 and of these 102 were successfully decoded.

The allocations of the total escapement of adipose clips to tag codes recovered in each portion of the river are shown in Tables 11 and 13. Table 12 lists the number of CWT fish and adipose-clipped fish released for each tag code (data from MRP database). The estimated hatchery contributions to the 1993 escapement of chinook to the Campbell River, Quinsam River, and Quinsam Hatchery were 93, 485, and 1087, respectively (Table 13).

The hatchery contributions to the total escapement of chinook in 1993, by age class is presented in Table 14. The hatchery contribution to the Campbell River population of chinook was estimated to be 21.6% for males and 63.9% for females. Contributions to the in-river Quinsam chinook escapement were 54.6% for males and 58.8% for females. This increased to 72.9% for males and 83.7% for females in the returns to the hatchery. Strays contributed 4.5% of the total CWT returns to the Quinsam Hatchery.

Hatchery Contributions - Method B

The allocations of the total escapement of CWTs to tag codes recovered in each portion of the river are shown in Tables 15-17. The estimated hatchery contributions to the 1993 escapement of chinook (both males and females) to the Campbell River, Quinsam River, and Quinsam Hatchery using Method B were 73, 424, and 1079, respectively (Table 17).

The hatchery contribution to the total escapement of chinook in 1993, by age class, is presented in Table 18. The 1993 hatchery contribution to the Campbell River population of chinook was estimated to be 21.6% for males and 45.4% for females. Contributions to the in-river Quinsam chinook escapement were 43.3% for males and 54.9% for females. These

were lower than the 74.0% for males and 80.3% for females in the returns to the hatchery. The estimated stray contribution was 7.4% of the escapement estimate in Quinsam Hatchery, whereas no strays were reported for Quinsam or Campbell Rivers. The large expansion factor (67.2) for the stray CWT release group (Table 17) magnifies the error associated with the stray estimate.

DISCUSSION AND CONCLUSIONS

POPULATION ESTIMATION

The separation of Petersen estimates by sex provides a more accurate estimate of the total population size. In this study, sex ratio differences occurred in hatchery broodstock, dead recovery, and Petersen estimates. A greater number of females than males were recovered in the dead pitch surveys for the Quinsam River, whereas the number of females and males were similar in the Campbell River. Andrew et al. (1988) found greater numbers of females than males in live and dead pitch recoveries in the Quinsam/Campbell system in 1986, as did Shardlow et al. (1986) in 1984-85. Higher numbers of females than males have also been observed in spawning ground dead pitches for sockeye salmon (Petersen 1954), pink salmon (Ward 1959), and coho salmon (Eames and Hino 1981; Eames et al. 1981). The stratification of escapement estimates by sex in the Quinsam/Campbell system should be continued to minimize error in population estimates.

Petersen estimates were also improved by stratifying estimates by river. No mixing of carcasses due to passive drift was observed between rivers. The tag recovery rate in the Quinsam river was lower than in Campbell River, mainly due to the low numbers of males recovered. The low numbers of chinook returns and fish available for tagging is a potential source of error.

Straying of live fish between rivers was not a source of error due to the use of carcasses for tagging. However, one factor which could have produced a serious bias in the carcass tagging Petersen estimate is the degree of mixing of tagged carcasses with the rest of the carcass population, particularly in deep pools, where many carcasses may have been immobilized. Bias due to incomplete mixing was reduced firstly by conducting tagging and recovery effort in proportion to the distribution of fish, secondly by frequently moving to different tagging and recovery sites throughout both operations, and thirdly by snorkelling or SCUBA diving in deeper areas.

AGE, LENGTH AND SEX COMPOSITION

In 1993, chinook escapements to the Campbell and Quinsam rivers were composed mainly of age-4 and age-5 year old fish. The ratio of adult males to females, as determined from the Petersen estimates, was 1.03 in Campbell River and 0.78 in Quinsam River in 1993. The adult male to female ratio of returns to the Quinsam Hatchery was 1.79 in 1993.

CODED WIRE TAGGING AND RECOVERY

In this study, we used the adipose clip rate in the dead recovery of chinook in the rivers and at the hatchery rack to estimate the number of adipose clips in the escapement (Method A). Sampling for adipose-clipped fish was non-selective and assumed random at each of these locations. The rate of recovery was 3.2% - 6.1% in 1993.

Estimates of the total hatchery contribution to the Quinsam/Campbell River system for adult males and females in 1993 were either approximately the same (within 2%) or higher (3.4% to 18.5%) using Method A (AFC rate) compared to Method B (CWT rate). Method A produced hatchery contribution estimates ranging from 21.6% to 83.7% (Table 14) and were similar in range to the 21.6% to 80.3% realised by Method B (Table 18). A comparison of the hatchery contribution estimates for Methods A and B in 1991 and 1992 returns to the Quinsam/Campbell River system showed similar ranges between the two methods and the maximum differences were 7.2% and 12.7% respectively. The greater maximum difference in total hatchery contribution between the two methods in 1993 (18.5%) may be the result of a lower sample size and the resultant greater error in estimating tag recovery rate.

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

1. Low number of recoveries of adipose clips and decoded CWTs (e.g. 20 CWTs in the 1989 brood year) may reduce the precision of the estimates; and
2. The sample of heads obtained for the decoding of CWTs may not be a random sample from the population and may be biased (e.g. size selectivity).

We have not formally estimated the level of precision of the estimates of escapement by adipose-clipped fish and individual tag codes, as 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 on which a given estimate is based. There were eight to 86 adipose clips enumerated for each river stratum (jacks not included) in 1993. The

95% confidence limits for eight recoveries (based on a Poisson frequency distribution) would be approximately $\pm 81\%$ and significantly smaller at 22% for 86 recoveries. These estimates of precision are conservative because the expansion factors used to estimate the total number of adipose clips/marks in the escapement are also estimated with error. Note that adipose clip numbers were lower in 1993 than in recent years.

There were differences between the hatchery contributions to each of the Campbell River, the Quinsam River, and the Quinsam Hatchery within 1993. In general, there was a higher proportion of hatchery-reared fish in the Quinsam River and at the hatchery than in the Campbell River. This pattern has been observed in previous years (Bocking et al. 1990; Bocking, 1991*b*; Frith et al. 1993; Frith 1993).

SUMMARY

1. The total escapement for chinook salmon in the Campbell/Quinsam River system using carcass tagging and hatchery returns was estimated at 2486 in 1993. Estimates were stratified by river and sex.
2. The age composition of chinook between the Campbell and Quinsam rivers and the Quinsam Hatchery were similar for females but variable for males. Male and female chinook were predominantly age 5 with the exception of Quinsam River males where the number of age-3 was greatest. The proportion of age-3, age-4 and age-5 fish were all greater than 20% for males in the Quinsam River and hatchery.
3. Based on the Petersen estimates and Quinsam Hatchery rack recoveries, females were more abundant in the Quinsam River population, less abundant than males in the rack recoveries and equally represented in the Campbell River population.
4. The mean length of chinook salmon was greatest in the Campbell River, and smallest in the Quinsam Hatchery returns. Females tended to be significantly larger than males.
5. The total estimated return of adipose-clipped chinook to the Campbell/Quinsam River system was 133 fish in 1993.
6. The total estimated hatchery contribution to the chinook escapement, based on adipose clips (Method A), was 1,664 (66.9%) in 1993. The contribution estimate derived using the adjusted CWTs recovered (Method B) was slightly lower at 1,576 (63.4%).

ACKNOWLEDGEMENTS

The authors sincerely thank Rick Semple and Bryan Nass for reviewing the manuscript and the Quinsam Hatchery field crews who collected data for this study.

REFERENCES

- Andrew, J.H., M. Lightly, and T.M. Webb. 1988. Abundance, age, size, sex and coded wire tag recoveries for chinook salmon escapements of Campbell and Quinsam rivers, 1985. *Can. Man. Rep. Fish. Aquat. Sci.* 2007: 46 p.
- Armstrong, R.W. and A.W. Argue. 1977. Trapping and coded wire tagging of wild coho and chinook juveniles from the Cowichan River system, 1975. *Fish. Mar. Serv., Tech. Rep. Ser. PAC/T-77-14*: 58 p.
- Blackmun, G.J. B.V. Lukyn, W.E. McLean and D. Ewart. 1985. Quinsam watershed study: 1983. *Can. MS Rep. Fish. Aquat. Sci.* 1832: ix + 65 p.
- Blankenship, H.L. 1990. Effects of time and fish size on coded wire tag loss from chinook and coho salmon. *Proceedings of the First International Symposium on Fish Marking Techniques*. Seattle, Washington. June 1988.
- Bocking, R.C. 1991. Abundance, age, size, sex and coded wire tag recoveries for chinook salmon escapements of Campbell and Quinsam rivers, 1989-90. *Can. MS. Rep. Fish. Aquat. Sci.* 2124: 109 p.
- Bocking, R.C., K.K. English and T.M. Webb. 1990. Abundance, age, size, sex and coded wire tag recoveries for chinook salmon escapements of Campbell and Quinsam rivers, 1986-1988. *Can. MS. Rep. Fish. Aquat. Sci.* 2065: 126 p.
- Eames, M. and M. Hino. 1981. A mark-recapture study of an enumerated coho spawning population. *Wash. Dep. Fish. Progr. Rep.* 148: 22 p.
- Eames, M., I. Quinn, K. Reidinger and D. Harling. 1981. Northern Puget Sound 1976 adult coho and chum tagging studies. *Wash. Dep. Fish. Tech. Rep.* 64: 217 p.

- Frith, H.R., B.L. Nass and T.C. Nelson. 1993. Abundance, age, size, sex and coded wire tag recoveries for chinook salmon escapements of Campbell and Quinsam rivers, 1991. *Can. MS. Rep. Fish. Aquat. Sci.* 2199: 57 p.
- Frith, H.R. 1993. Abundance, age, size, sex and coded wire tag recoveries for chinook salmon escapements of Campbell and Quinsam rivers, 1992. *Can. MS. Rep. Fish. Aquat. Sci.* 2207: 56p.
- Gilbert, C.H. and W.H. Rich. 1927. Investigations concerning the red salmon runs to the Karluk River, Alaska. *Bull. U.S. Bus. Fish.* 43(2): 1-69 (Doc. No 991).
- Jefferts, K.B., P.K. Bergman and H.F. Fiscus. 1963. A coded wire tag identification system for macro-organisms. *Nature (London)* 198: 460-462.
- Kuhn, B.R. 1988. The MRP-Reporter Program: A data extraction and reporting tool for the Mark Recovery Program Database. *Can. Tech. Rep. Fish. Aquat. Sci.* 1625: 145p.
- Levings, C. 1986. Fish and invertebrate utilization of Campbell River estuary islands. p. 16-19 In: J. Patterson (ed.) *Proceedings of the workshop on habitat improvements, Whistler, B.C., 8-10 May 1984.* *Can. Tech. Rep. Fish. Aquat. Sci.* 1483.
- Marshall, D.E., R.F. Brown, V.D. Chahley and D.G. Demontier. 1977. Preliminary catalogue of salmon streams and spawning escapements of Statistical Area 13 (Campbell River). Environment Canada. *Fish. Mar. Serv. PAC/D-77-1:* 176 p.
- Petersen, A.E. 1954. The selective action of gillnets on Fraser River sockeye salmon. *Int. Pac. Salmon Fish. Comm. Bull.* 5: 101 p.
- Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. *Bull. Fish. Res. Board Can.* 191: 382 p.
- Shardlow, T.F., T. Webb and D.T. Lightly. 1986. Chinook salmon escapement estimation of the Campbell and Quinsam rivers in 1984: accuracy and precision of mark/recapture techniques using tagged salmon carcasses. *Can. Tech. Rep. Fish. Aquat. Sci.* 1507: 52 p.
- Ward, F.J. 1959. Character of the migration of pink salmon to Fraser River spawning grounds in 1957. *Int. Pac. Salmon Fish. Comm. Bull.* 10: 70 p.
- Zar, J.H. 1984. *Biostatistical Analysis.* 2nd ed. Prentice-Hall, N.Y., USA. 718 p.

TABLES

Table 1. Summary of methods for the Campbell and Quinsam rivers chinook salmon enumeration programs, 1993.

Item	Method and Materials
Dead recovery population estimate	Petersen estimate, sum of separate estimates for sexes and rivers
Carcass tagging	Cattle ear tags (a) applied in situ to carcasses recovered in river
Secondary marking (dead)	Two-hole opercular punch for Campbell and single hole punch for Quinsam on left operculum
Recovery of fish	Foot, SCUBA surveys, rack
Coded wire tagging (CWT)	Collection of heads from adipose clipped fish in dead recovery and at hatchery rack
Biological and physical sampling	Ages from scales and CWT, sex ratios from sex-specific population estimates for each river and at hatchery rack, postorbital-hypural length

(a) Tags were supplied by:
 Ketchum Manufacturing Sales Ltd., 396 Berkely Ave., Ottawa, Ontario, K2A 2G6
 (Size No. 3, 1 1/8 " x 1/4")

Table 2. Summary of tagging and recovery effort (person-days) for chinook salmon carcasses in the Campbell and Quinsam rivers, 1993.

River	Stream walk	Diver	Total person days
Campbell	33	3	36
Quinsam	32	0	32

Table 3. Summary of in situ carcass tagging and dead recovery of chinook salmon in Campbell and Quinsam rivers, 1993.

Category	Campbell (a)	Quinsam (b)	Total
<u>Carcass tagging:</u>			
Males	34	18	52
Females	31	67	98
Jacks	0	1	1
Total	65	86	151
<u>Dead recovery:</u>			
Males	77	106	183
Females	77	269	346
Jacks	2	7	9
Total	156	382	538
Tagged males (c)	21	4	25
Tagged females (c)	20	34	54
Tagged jacks (c)	0	0	0
Total tagged (c)	41	38	79
Tag rate (%)	26.3	9.9	14.7
Tag recovery rate (%)	63.1	44.2	52.3
Tag loss (%)	0.0	13.2	6.6

(a) See Appendix 5 for number of carcasses recovered, number of carcasses tagged, and number of tagged recoveries, by date in Campbell River

(b) See Appendix 6 for number of carcasses recovered, number of carcasses tagged, and number of tagged recoveries, by date in Quinsam River

(c) Tagged recoveries include all carcasses with opercular punch holes (ie. secondary marks)

Table 4. Petersen population estimates, confidence limits and enumeration data for chinook salmon escapement in the Campbell River, Quinsam River, and Quinsam Hatchery based on in situ chinook carcass tagging and recovery of carcasses, 1993. Confidence limits are determined assuming R is Poisson distributed (Ricker 1975, p. 343).

River and Item	Male	Female	Jack (h)	Total
<u>Campbell River (a)</u>				
Number tags applied (d)	34	31	0	65
Number recovered (e)	69	70	2	141
Number of tagged recoveries (f)	21	20	0	41
Petersen estimate	111	108	NA	219 (i)
Lower 95 % CL	74	71	NA	146 (i)
Upper 95 % CL	175	172	NA	347 (i)
<u>Quinsam River (b, below fence)</u>				
Number tags applied (d)	18	67	1	86
Number recovered (e)	97	246	7	350
Number of tagged recoveries (f)	4	34	0	38
Petersen estimate	372	480	NA	852 (i)
Lower 95 % CL	166	346	NA	513 (i)
Upper 95 % CL	931	686	NA	1617 (i)
<u>Quinsam Hatchery (c)</u>				
Number of fish (g)	907	508	82	1497
<u>Total system</u>				
Escapement estimate	1390	1096	NA	2486 (i)
Lower 95 % CL	1147	926	NA	2073 (i)
Upper 95 % CL	2013	1366	NA	3379 (i)

(a) Appendix 5 for no. of carcasses recovered, no. of carcasses tagged, and no. of tagged recoveries, by date in Campbell River

(b) Appendix 6 for no. of carcasses recovered, no. of carcasses tagged, and no. of tagged recoveries, by date in Quinsam River

(c) Hatchery recoveries plus fish not available for carcass enumeration including brood stock, fish sold, fish released above the fence, and mortalities at the fence trap

(d) Total number of fish tagged and operculum hole punched

(e) Total number of fish examined (tagged and untagged recoveries) less number of fish observed on first day of tagging

(f) Total recoveries possessing an operculum punch (secondary mark)

(g) Confidence limits not applicable

(h) Peterson estimates were not calculated for jacks due to low sample size

(i) Totals not including jacks (see (h))

Table 5. Age composition of Campbell River chinook salmon, 1993 (determined from dead recovery).

Sex and age	Unmarked	AD/CWT	Total	Percent (b)	Postorbital-hypural length (mm)					
					N	Mean (mm)	SD	95% CL		
								Lower	Upper	
Males (a)										
2	2	0	2	3.6		2	435	170	195	675
3	2	1	3	5.4 (5.6)		3	610	99	496	724
4	8	0	8	14.3 (14.8)		8	698	76	644	752
5	38	1	39	69.6 (72.2)		39	830	61	810	850
6	4	0	4	7.1 (7.4)		4	846	48	798	894
Total aged	54	2	56	100.0 (100.0)		56	787	115	756	818
Total			56							
Females										
3	1	0	1	1.9		1	675	0	(c)	(c)
4	8	0	8	15.1		8	716	53	699	733
5	38	2	40	75.5		40	814	47	799	829
6	4	0	4	7.5		5	872	62	817	927
Total aged	51	2	53	100		54	802	65	790	814
Unknown age	3		3			3	895	84	798	992
Total			56							

(a) Jacks (age-2 fish) are included with males

(b) Figures in parentheses are age distributions in percent for adult males only (jacks are excluded)

(c) Confidence intervals can not be calculated for a sample size of 1

Table 6. Age composition of Quinsam River chinook salmon, 1993 (determined from dead recovery).

Sex and age	Unmarked	AD/CWT	Total	Percent (b)	Postorbital-hypural length (mm)					
					N	Mean (mm)	SD	95% CL		
								Lower	Upper	
Males (a)										
2	2	0	2	2.6	2	425	57	344	506	
3	19	3	22	28.2 (28.9)	22	564	60	538	590	
4	23	0	23	29.5 (30.3)	23	689	75	658	720	
5	29	2	31	39.7 (40.8)	31	816	47	799	833	
Total aged	73	5	78	100.0 (100.0)	78	697	127	668	726	
Unknown age	0	1	1		1	780	0	(c)	(c)	
Total			79							
Females										
3	3	0	3	1.9	3	670	22	645	695	
4	21	1	22	13.8	22	724	39	707	741	
5	120	9	129	80.5	129	806	39	799	813	
6	5	1	6	3.8	6	818	35	789	847	
Total aged	149	11	160	100.0	160	792	51	784	800	
Unknown age	42	2	44		44	791	64	772	810	
Total			204							

(a) Jacks (age-2 fish) are included with males

(b) Figures in parentheses are age distributions in percent for adult males only (jacks are excluded)

(c) Confidence intervals can not be calculated for a sample size of one

Table 7. Age composition of Quinsam Hatchery chinook salmon, 1993 (determined from rack recovery).

Sex and age	Unmarked	AD/CWT	Total	Percent (b)	Postorbital-hypural length (mm)					
					N	Mean (mm)	SD	95% CL		
								Lower	Upper	
Males (a)										
2	0	2	2	1.3	2	378	34	330	426	
3	34	34	68	43.9 (44.4)	68	578	60	563	593	
4	30	15	45	29.0 (29.4)	45	711	55	695	727	
5	29	11	40	25.8 (26.2)	40	787	50	771	803	
Total aged	93	62	155	100 (100.0)	155	668	109	650	686	
Unknown age	23		23		23	666	117	617	715	
Total			178							
Females										
3	5	3	8	4.6	8	660	38	633	687	
4	34	6	40	22.9	40	729	44	715	743	
5	104	20	124	70.8	124	792	50	783	801	
6	3	0	3	1.7	3	809	62	737	881	
Total aged	146	29	175	100.0	175	772	60	763	781	
Unknown age	7		7		7	776	78	717	835	
Total			182							

(a) Jacks (age-2 fish) are included with males

(b) Figures in parentheses are age distributions in percent for adult males only (jacks are excluded)

Table 8. Age-length distribution of Campbell River, Quinsam River, and Quinsam Hatchery chinook salmon, 1993.

Location	Length class (mm)	Age													
		Males						Females							
		2	3	4	5	6	Total	unk(a)	2	3	4	5	6	Total	unk(a)
<u>Campbell River</u>															
	250-299	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	300-349	1	0	0	0	0	1	0	0	0	0	0	0	0	0
	350-399	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	400-449	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	450-499	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	500-549	0	1	0	0	0	1	0	0	0	0	0	0	0	0
	550-599	1	0	1	0	0	2	0	0	0	0	0	0	0	0
	600-649	0	1	1	0	0	2	0	0	1	0	0	1	0	
	650-699	0	1	1	0	0	2	0	1	2	0	0	3	0	
	700-749	0	0	2	2	0	4	0	0	2	4	0	6	0	
	750-799	0	0	3	9	1	13	0	0	3	8	1	12	0	
	800-849	0	0	0	14	1	15	0	0	0	18	0	18	1	
	850-899	0	0	0	7	1	8	0	0	0	8	2	10	0	
	900-949	0	0	0	6	1	7	0	0	0	2	2	4	1	
	950-999	0	0	0	1	0	1	0	0	0	0	0	0	1	
	1000-1049	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Mean	435	610	698	830	846	787	0	0	675	716	814	872	802	895
	SD	170	99	76	61	48	115	0	0	0	53	47	62	65	84
	N	2	3	8	39	4	56	0	0	1	8	40	5	54	3
<u>Quinsam River</u>															
	250-299	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	300-349	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	350-399	1	0	0	0	0	1	0	0	0	0	0	0	0	0
	400-449	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	450-499	1	3	0	0	0	4	0	0	0	0	0	0	0	0
	500-549	0	5	1	0	0	6	0	0	0	0	0	0	0	0
	550-599	0	8	1	0	0	9	0	0	0	0	0	0	0	0
	600-649	0	3	5	0	0	8	0	0	1	2	0	3	3	
	650-699	0	3	7	0	0	10	0	0	2	1	0	3	1	
	700-749	0	0	4	3	0	7	0	0	0	12	12	24	4	
	750-799	0	0	3	5	0	8	1	0	0	7	47	56	12	
	800-849	0	0	1	16	0	17	0	0	0	0	50	53	18	
	850-899	0	0	1	6	0	7	0	0	0	0	20	21	5	
	900-949	0	0	0	1	0	1	0	0	0	0	0	0	1	
	950-999	0	0	0	0	0	0	0	0	0	0	0	0	0	
	1000-1049	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Mean	425	564	689	816	0	697	780	0	670	724	806	818	792	791
	SD	57	60	75	47	0	127	0	0	22	39	39	35	51	64
	N	2	22	23	31	0	78	1	0	3	22	129	6	160	44

(a) Unk = age unknown

Table 8 (cont). Age-length distribution of Campbell River, Quinsam River, and Quinsam Hatchery chinook salmon, 1993.

River	Length class (mm)	Age													
		Males						Females							
		2	3	4	5	6	Total	unk(a)	2	3	4	5	6	Total	unk(a)
<u>Quinsam Hatchery</u>															
	250-299	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	300-349	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	350-399	1	0	0	0	0	1	0	0	0	0	0	0	0	0
	400-449	1	1	0	0	0	2	1	0	0	0	0	0	0	0
	450-499	0	6	0	0	0	6	0	0	0	0	0	0	0	0
	500-549	0	15	0	0	0	15	2	0	0	0	0	0	0	0
	550-599	0	19	1	0	0	20	5	0	1	0	0	0	1	0
	600-649	0	22	5	0	0	27	4	0	1	1	3	0	5	1
	650-699	0	3	11	2	0	16	1	0	5	9	0	0	14	1
	700-749	0	2	18	8	0	28	3	0	1	18	20	0	39	0
	750-799	0	0	8	11	0	19	4	0	0	10	41	1	52	0
	800-849	0	0	2	16	0	18	1	0	0	2	48	1	51	5
	850-899	0	0	0	3	0	3	2	0	0	0	11	1	12	0
	900-949	0	0	0	0	0	0	0	0	0	0	1	0	1	0
	950-999	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1000-1049	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Mean	378	578	711	787	0	668	666	0	660	729	792	809	772	776
	SD	34	60	55	50	0	109	117	0	38	44	50	62	60	78
	N	2	68	45	40	0	155	23	0	8	40	124	3	175	7

(a) Unk = age unknown

Table 9. Petersen estimates, by age, of chinook salmon escapement to the Campbell River, Quinsam River, Quinsam Hatchery, 1993.

Location	Age	Males (a)		Females	
		Number (b)	Percent (c)	Number (b)	Percent (c)
<u>Campbell River</u>					
	3	6	5.6	2	1.9
	4	17	14.8	16	15.1
	5	80	72.2	82	75.5
	6	8	7.4	8	7.5
	Total	111 (d)	100.0	108 (d)	100.0
<u>Quinsam River</u>					
	3	107	28.9	9	1.9
	4	113	30.3	66	13.8
	5	152	40.8	386	80.5
	6	0	0.0	18	3.8
	Total	372 (d)	100.0	480 (d)	100.0
<u>Quinsam Hatchery</u>					
	3	402	44.4	23	4.6
	4	267	29.4	116	22.9
	5	238	26.2	360	70.8
	6	0	0.0	9	1.7
	Total	907 (d)	100.0	508 (d)	100.0

(a) Does not include jacks; see table 4, footnote (h)

(b) Number of fish by age are calculated from the product of the percent age (c) and total adult escapement (d)

(c) Percentage age distribution from tables 5, 6 and 7

(d) Petersen estimates or Quinsam Hatchery recoveries from Table 4

Table 10. Estimates of the total escapement of adipose clipped chinook salmon to the Campbell River, Quinsam River and Quinsam Hatchery, 1993. The Petersen estimates were derived using the in situ carcass-tagging method (Method A).

Location	Sex	Sample size (a) A	Observed adipose clips (a) B	Mark rate (%) $C=(B/A) \times 100$	Population estimate (b) D	Percentage of population sampled $E=(A/D) \times 100$	Total estimated adipose clips $F=(B/A) \times D$
<u>Campbell River</u>							
	Male (c)	77	2	2.6	111	69.4	3
	Female	77	3	3.9	108	71.3	4
	Total	154	5	3.2	219	70.3	7
<u>Quinsam River (below fence)</u>							
	Male (c)	106	5	4.7	372	28.5	18
	Female	269	13	4.8	480	56.0	23
	Total	375	18	4.8	852	44.0	41
<u>Quinsam Hatchery</u>							
	Male (c)	907	57	6.3	907	100.0	57
	Female	508	29	5.7	508	100.0	29
	Total	1415	86	6.1	1415	100.0	86

(a) Campbell River data from Appendix 7; Quinsam River data from Appendix 8; Quinsam Hatchery data from unsummarized rack recovery data base, six adipose-clipped jacks were observed

(b) From Table 4

(c) Does not include jacks, see Table 4, footnote (h)

Table 11. Estimates of total escapement of adipose-clipped chinook salmon to the Campbell River, Quinsam River, and Quinsam Hatchery, by tag code, 1993. The source of tags for the Petersen estimates was from in situ carcass tagging. One decimal place is carried for the estimated adipose clips for calculating the expanded hatchery contribution in Table 13 (Method A).

Brood year	CWT code	Campbell River (a,b)				Quinsam River (a,b)				Quinsam Hatchery (a,b)				Total (a,b)			
		Observed adipose clips		Estimated adipose clips		Observed adipose clips		Estimated adipose clips		Observed adipose clips		Estimated adipose clips		Observed adipose clips		Estimated adipose clips	
		M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
1990	20956	1	0	1.5	0.0	0	0	0.0	0.0	4	0	4.1	0.0	5	0	5.6	0.0
	20957	0	0	0.0	0.0	0	0	0.0	0.0	2	0	2.1	0.0	2	0	2.1	0.0
	20958	0	0	0.0	0.0	1	0	4.5	0.0	5	0	5.2	0.0	6	0	9.7	0.0
	20959	0	0	0.0	0.0	0	0	0.0	0.0	4	0	4.1	0.0	4	0	4.1	0.0
	21449	0	0	0.0	0.0	0	0	0.0	0.0	3	0	3.1	0.0	3	0	3.1	0.0
	21450	0	0	0.0	0.0	0	0	0.0	0.0	7	0	7.3	0.0	7	0	7.3	0.0
	21451	0	0	0.0	0.0	0	0	0.0	0.0	2	0	2.1	0.0	2	0	2.1	0.0
	26016	0	0	0.0	0.0	0	0	0.0	0.0	1	1	1.0	1.0	1	1	1.0	1.0
	26017	0	0	0.0	0.0	1	0	4.5	0.0	3	0	3.1	0.0	4	0	7.6	0.0
	26018	0	0	0.0	0.0	0	0	0.0	0.0	0	1	0.0	1.0	0	1	0.0	1.0
	26019	0	0	0.0	0.0	0	0	0.0	0.0	0	1	0.0	1.0	0	1	0.0	1.0
	Subtotal	1	0	1.5	0.0	2	0	9.0	0.0	31	3	32.1	3.1	34	3	42.6	3.1
1989	20354	0	0	0.0	0.0	0	1	0.0	2.1	2	0	2.1	0.0	2	1	2.1	2.1
	20355	0	0	0.0	0.0	0	0	0.0	0.0	0	2	0.0	2.1	0	2	0.0	2.1
	20359	0	0	0.0	0.0	0	0	0.0	0.0	3	0	3.1	0.0	3	0	3.1	0.0
	20360	0	0	0.0	0.0	0	0	0.0	0.0	1	0	1.0	0.0	1	0	1.0	0.0
	20361	0	0	0.0	0.0	0	0	0.0	0.0	0	1	0.0	1.0	0	1	0.0	1.0
	26062	0	0	0.0	0.0	0	0	0.0	0.0	4	0	4.1	0.0	4	0	4.1	0.0
	26063	0	0	0.0	0.0	0	0	0.0	0.0	1	1	1.0	1.0	1	1	1.0	1.0
	26101	0	0	0.0	0.0	0	0	0.0	0.0	0	2	0.0	2.1	0	2	0.0	2.1
	26102	0	0	0.0	0.0	0	0	0.0	0.0	2	0	2.1	0.0	2	0	2.1	0.0
	Subtotal	0	0	0.0	0.0	0	1	0.0	2.1	13	6	13.5	6.2	13	7	13.5	8.3

(continued)

Table 11 (cont). Estimates of total escapement of adipose-clipped chinook salmon to the Campbell River, Quinsam River, and Quinsam Hatchery, by tag code 1993. The source of tags for the Petersen estimates was from in situ carcass tagging. One decimal place is carried for the estimated adipose clips for calculating the expanded hatchery contribution in Table 13 (Method A).

Brood year	CWT code	Campbell River (a,b)				Quinsam River (a,b)				Quinsam Hatchery (a,b)				Total (a,b)			
		Observed		Estimated		Observed		Estimated		Observed		Estimated		Observed		Estimated	
		adipose clips		adipose clips		adipose clips		adipose clips		adipose clips		adipose clips		adipose clips		adipose clips	
		M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
1988	25526	1	0	1.5	0.0	0	1	0.0	2.1	0	0	0.0	0.0	1	1	1.5	2.1
	25527	0	0	0.0	0.0	0	1	0.0	2.1	0	0	0.0	0.0	0	1	0.0	2.1
	25814	0	0	0.0	0.0	1	0	4.5	0.0	2	3	2.1	3.1	3	3	6.6	3.1
	25816	0	0	0.0	0.0	1	0	4.5	0.0	0	0	0.0	0.0	1	0	4.5	0.0
	25817	0	0	0.0	0.0	0	2	0.0	4.2	0	3	0.0	3.1	0	5	0.0	7.3
	25818	0	0	0.0	0.0	0	1	0.0	2.1	1	2	1.0	2.1	1	3	1.0	4.2
	25819	0	0	0.0	0.0	0	2	0.0	4.2	2	1	2.1	1.0	2	3	2.1	5.2
	25820	0	0	0.0	0.0	0	2	0.0	4.2	2	4	2.1	4.1	2	6	2.1	8.3
	25821	0	0	0.0	0.0	0	0	0.0	0.0	3	2	3.1	2.1	3	2	3.1	2.1
	25822	0	2	0.0	4.0	0	0	0.0	0.0	0	4	0.0	4.1	0	6	0.0	8.1
	Subtotal	1	2	1.5	4.0	2	9	9.0	18.8	10	19	10.4	19.7	13	30	20.9	42.5
1987	24420	0	0	0.0	0.0	0	1	0.0	2.1	0	0	0.0	0.0	0	1	0.0	2.1
	Subtotal	0	0	0.0	0.0	0	1	0.0	2.1	0	0	0.0	0.0	0	1	0.0	2.1
	Total hatchery	2	2	3.0	4.0	4	11	18.0	23.0	54	28	56.0	29.0	60	41	77.0	56.0
<u>Strays: (d)</u>																	
1989	20949	0	0	0.0	0.0	0	0	0.0	0.0	1	0	1.0	0.0	1	0	1.0	0.0
	Total strays	0	0	0.0	0.0	0	0	0.0	0.0	1	0	1.0	0.0	1	0	1.0	0.0
	Total CWT (c)	2	2	3.0	4.0	4	11	18.0	23.0	55	28	57.0	29.0	61	41	78.0	56.0

(continued)

Table 11 (cont). Estimates of total escapement of adipose-clipped chinook salmon to the Campbell River, Quinsam River, and Quinsam Hatchery, by tag code 1993. The source of tags for the Petersen estimates was from in situ carcass tagging. One decimal place is carried for the estimated adipose clips for calculating the expanded hatchery contribution in Table 13 (Method A).

Brood year	CWT code	Campbell River (a,b)				Quinsam River (a,b)				Quinsam Hatchery (a,b)				Total (a,b)			
		Observed		Estimated		Observed		Estimated		Observed		Estimated		Observed		Estimated	
		adipose clips		adipose clips		adipose clips		adipose clips		adipose clips		adipose clips		adipose clips		adipose clips	
		M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
No data (5000)		0	0			0	1			0	0			0	1		
No pin (8000)		0	1			1	1			2	1			3	3		
Lost pin (9000)		0	0			0	0			0	0			0	0		
Observed adipose		2	3			5	13			57	29			64	45		

(a) Abbreviations are M = male, F = female

(b) Does not include jacks

(c) Total estimated adipose clips from Table 10

(d) Adipose-clipped fish that have strayed from other systems

Table 12. CWT release data for hatchery-reared chinook salmon returning to the Campbell River, Quinsam River, and Quinsam Hatchery, by tag code, 1993.

Brood year	CWT code	Release numbers		CWT loss (%)	Days held	Adipose release status	
		CWT	Untagged			Clipped	Unclipped
1990	20956	26953	189154	0.2	8	27007	189100
	20957	26752	430178	0.6	10	26913	430017
	20958	26658	205795	0.3	6	26738	205715
	20959	25870	203520	0.6	9	26026	203364
	21449	26602	332627	0.8	8	26817	332412
	21450	26384	331055	0.0	9	26384	331055
	21451	26502	320497	0.5	7	26635	320364
	26016	27211	588892	0.5	14	27348	588755
	26017	25911	284261	2.7	13	26630	283542
	26018	28265	183904	0.0	14	28265	183904
	26019	26817	502724	0.7	10	27006	502535
1989	20354	23306	174330	1.9	12	23757	173879
	20355	22574	263949	0.8	11	22756	263767
	20359	24396	300109	2.7	10	25073	299432
	20360	24499	291972	1.9	10	24973	291498
	20361	24669	291802	1.4	10	25019	303058
	26062	24929	291542	0.1	10	24954	194589
	26063	24904	291567	0.8	10	25105	196137
	26101	25007	291464	0.3	10	25082	417458
	26102	24739	291732	1.1	12	25014	190712
1988	25526	24624	182558	1.4	7	24974	182208
	25527	23937	244318	2.8	7	24627	243628
	25814	25246	289421	1.4	7	25604	289063
	25816	22344	256059	1.0	7	22570	255833
	25817	25029	268880	0.0	7	25029	268880
	25818	25096	269867	0.0	7	25096	269867
	25819	25037	270958	0.0	7	25037	270958
	25820	24810	406636	1.4	7	25162	406284
	25821	24609	403341	1.4	7	24958	402992
25822	24884	407850	1.4	7	25237	407497	
1987	24420	24386	332520	1.9	unk	24858	332048
Total hatchery		782950	9393482			790656	9230549
<u>Strays: (a)</u>							
1989	20949	26660	1763593	0.0	3	26660	1018290

(a) Stray came from Robertson Creek

Table 13. Estimates of total escapement of hatchery-reared chinook salmon to the Campbell River, Quinsam River, and Quinsam Hatchery, by tag code, 1993 (Method A). The expansion factor is used to expand the estimated number of adipose-clipped chinook in the escapement (from Table 11) to account for unclipped hatchery releases and, hence, derive hatchery contributions to escapement.
 Expansion factor = (adipose clipped + unclipped releases)/adipose-clipped releases.

Brood year	CWT release group	Release Numbers (c)		Expansion factor	Expanded hatchery contributions (a,b)							
		Clipped	Unclipped		Campbell River		Quinsam River		Quinsam Hatchery		Total	
					M	F	M	F	M	F	M	F
1990	20956	27007	189100	8.0	12.0	0.0	0.0	0.0	33.2	0.0	45.2	0.0
	20957	26913	430017	17.0	0.0	0.0	0.0	0.0	35.2	0.0	35.2	0.0
	20958	26738	205715	8.7	0.0	0.0	39.1	0.0	45.0	0.0	84.2	0.0
	20959	26026	203364	8.8	0.0	0.0	0.0	0.0	36.5	0.0	36.5	0.0
	21449	26817	332412	13.4	0.0	0.0	0.0	0.0	41.6	0.0	41.6	0.0
	21450	26384	331055	13.5	0.0	0.0	0.0	0.0	98.3	0.0	98.3	0.0
	21451	26635	320364	13.0	0.0	0.0	0.0	0.0	27.0	0.0	27.0	0.0
	26016	27348	588755	22.5	0.0	0.0	0.0	0.0	23.3	23.3	23.3	23.3
	26017	26630	283542	11.6	0.0	0.0	52.4	0.0	36.2	0.0	88.6	0.0
	26018	28265	183904	7.5	0.0	0.0	0.0	0.0	0.0	7.8	0.0	7.8
	26019	27006	502535	19.6	0.0	0.0	0.0	0.0	0.0	20.3	0.0	20.3
	Subtotal	295769	3570763		12.0	0.0	91.5	0.0	376.4	51.4	480.0	51.4
1989	20354	23757	173879	8.3	0.0	0.0	0.0	17.4	17.2	0.0	17.2	17.4
	20355	22756	263767	12.6	0.0	0.0	0.0	0.0	0.0	26.1	0.0	26.1
	20359	25073	299432	12.9	0.0	0.0	0.0	0.0	40.2	0.0	40.2	0.0
	20360	24973	291498	12.7	0.0	0.0	0.0	0.0	13.1	0.0	13.1	0.0
	20361	25019	303058	13.1	0.0	0.0	0.0	0.0	0.0	13.6	0.0	13.6
	26062	24954	194589	8.8	0.0	0.0	0.0	0.0	36.5	0.0	36.5	0.0
	26063	25105	196137	8.8	0.0	0.0	0.0	0.0	9.1	9.1	9.1	9.1
	26101	25082	417458	17.6	0.0	0.0	0.0	0.0	0.0	36.5	0.0	36.5
	26102	25014	190712	8.6	0.0	0.0	0.0	0.0	17.9	0.0	17.9	0.0
	Subtotal	221734	2330529		0.0	0.0	0.0	17.4	134.1	85.3	134.1	102.7

(continued)

Table 13 (cont.). Estimates of total escapement of hatchery-reared chinook salmon to the Campbell River, Quinsam River, and Quinsam Hatchery, by tag code 1993 (Method A). The expansion factor is used to expand the estimated number of adipose-clipped chinook in the escapement (from Table 11) to account for unclipped hatchery releases and, hence, derive hatchery contributions to escapement.
 Expansion factor = (adipose clipped + unclipped releases)/adipose-clipped releases.

Brood year	CWT release group	Release Numbers (c)		Expansion Factor	Expanded hatchery contributions (a,b)							
		Clipped	Unclipped		Campbell River		Quinsam River		Quinsam Hatchery		Total	
					M	F	M	F	M	F	M	F
1988	25526	24974	182208	8.3	12.4	0.0	0.0	17.3	0.0	0.0	12.4	17.3
	25527	24627	243628	10.9	0.0	0.0	0.0	22.8	0.0	0.0	0.0	22.8
	25814	25604	289063	12.3	0.0	0.0	55.3	0.0	25.5	38.2	80.8	38.2
	25816	22570	255833	12.3	0.0	0.0	55.5	0.0	0.0	0.0	55.5	0.0
	25817	25029	268880	11.7	0.0	0.0	0.0	49.1	0.0	36.5	0.0	85.6
	25818	25096	269867	11.8	0.0	0.0	0.0	24.6	12.2	24.3	12.2	48.9
	25819	25037	270958	11.8	0.0	0.0	0.0	49.4	24.5	12.2	24.5	61.7
	25820	25162	406284	17.1	0.0	0.0	0.0	71.7	35.5	71.0	35.5	142.7
	25821	24958	402992	17.1	0.0	0.0	0.0	0.0	53.3	35.5	53.3	35.5
	25822	25237	407497	17.1	0.0	68.6	0.0	0.0	0.0	71.0	0.0	139.6
	Subtotal	248294	2997210		12.4	68.6	110.8	234.9	151.0	288.9	274.3	592.4
1987	24420	24858	332048	14.4	0.0	0.0	0.0	30.0	0.0	0.0	0.0	30.0
	Total hatchery				24.4	68.6	202.3	282.4	661.5	425.6	888.3	776.6
<u>Strays (d)</u>												
1989	20949	26660	1018290	39.2	0.0	0.0	0.0	0.0	40.6	0.0	40.6	0.0

(a) Abbreviations are M = male, F = female
 (b) Does not include jacks
 (c) From Table 12
 (d) Adipose-clipped fish that have strayed from other systems

Table 14. Estimated hatchery contributions to Campbell River, Quinsam River, and Quinsam Hatchery chinook salmon escapement, 1993.
Contributions were calculated using expansion Method A for the estimated number of adipose clips (Table 13).

Location	Age	Estimated escapement (a)		Hatchery contribution (b)				Stray contribution (b)			
				Male (c)		Female		Male (c)		Female	
		Male (c)	Female	Number	%	Number	%	Number	%	Number	%
<u>Campbell River</u>											
	3	6	2	12	100 (e)	0	0.0	0	0.0	0	0.0
	4	17	16	0	0.0	0	0.0	0	0.0	0	0.0
	5	80	82	12	15.0	69	84.1	0	0.0	0	0.0
	6	8	8	0	0.0	0	0.0	0	0.0	0	0.0
	Total	111	108	24	21.6	69	63.9	0	0.0	0	0.0
<u>Quinsam River</u>											
	3	107	9	92	86.0	0	0.0	0	0.0	0	0.0
	4	113	66	0	0.0	17	25.8	0	0.0	0	0.0
	5	152	386	111	73.0	235	60.9	0	0.0	0	0.0
	6	0	18	0	0.0	30	100 (e)	0	0.0	0	0.0
	Total	372	480	203	54.6	282	58.8	0	0.0	0	0.0
<u>Quinsam Hatchery (d)</u>											
	3	402	23	376	93.5	51	100 (e)	0	0.0	0	0.0
	4	267	116	134	50.2	85	73.3	41	15.4	0	0.0
	5	238	360	151	63.4	289	80.3	0	0.0	0	0.0
	6	0	9	0	0.0	0	0.0	0	0.0	0	0.0
	Total	907	508	661	72.9	425	83.7	41	4.5	0	0.0

43

- (a) From Table 9; rounding errors cause apparent discrepancies between numbers at age and totals
(b) From Table 13
(c) Does not include jacks
(d) Population estimate includes chinook enumerated above the fence on the Quinsam River
(e) Estimated hatchery contribution greater than 100%

Table 15. Estimates of the adjusted number of CWT chinook salmon to the Campbell River, Quinsam River, and Quinsam Hatchery, by tag code, 1993. One decimal place is carried for the estimated adipose clips for calculating the expanded hatchery contribution in Table 17 (Method B).

Brood year	CWT code	Campbell River (a,b)				Quinsam River (a,b)				Quinsam Hatchery (a,b)				Total (a,b)			
		Observed		Adjusted		Observed		Adjusted		Observed		Adjusted		Observed		Adjusted	
		CWTs		CWTs		CWTs		CWTs		CWTs		CWTs		CWTs		CWTs	
		M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
1990	20956	1	0	1.0	0.0	0	0	0.0	0.0	4	0	4.0	0.0	5	0	5.0	0.0
	20957	0	0	0.0	0.0	0	0	0.0	0.0	2	0	2.0	0.0	2	0	2.0	0.0
	20958	0	0	0.0	0.0	1	0	1.0	0.0	5	0	5.0	0.0	6	0	6.0	0.0
	20959	0	0	0.0	0.0	0	0	0.0	0.0	4	0	4.0	0.0	4	0	4.0	0.0
	21449	0	0	0.0	0.0	0	0	0.0	0.0	3	0	3.0	0.0	3	0	3.0	0.0
	21450	0	0	0.0	0.0	0	0	0.0	0.0	7	0	7.0	0.0	7	0	7.0	0.0
	21451	0	0	0.0	0.0	0	0	0.0	0.0	2	0	2.0	0.0	2	0	2.0	0.0
	26016	0	0	0.0	0.0	0	0	0.0	0.0	1	1	1.0	1.0	1	1	1.0	1.0
	26017	0	0	0.0	0.0	1	0	1.0	0.0	3	0	3.0	0.0	4	0	4.0	0.0
	26018	0	0	0.0	0.0	0	0	0.0	0.0	0	1	0.0	1.0	0	1	0.0	1.0
	26019	0	0	0.0	0.0	0	0	0.0	0.0	0	1	0.0	1.0	0	1	0.0	1.0
	Subtotal	1	0	1.0	0.0	2	0	2.0	0.0	31	3	31.0	3.0	34	3	34.0	3.0
1989	20354	0	0	0.0	0.0	0	1	0.0	1.1	2	0	2.0	0.0	2	1	2.0	1.1
	20355	0	0	0.0	0.0	0	0	0.0	0.0	0	2	0.0	2.0	0	2	0.0	2.0
	20359	0	0	0.0	0.0	0	0	0.0	0.0	3	0	3.0	0.0	3	0	3.0	0.0
	20360	0	0	0.0	0.0	0	0	0.0	0.0	1	0	1.0	0.0	1	0	1.0	0.0
	20361	0	0	0.0	0.0	0	0	0.0	0.0	0	1	0.0	1.0	0	1	0.0	1.0
	26062	0	0	0.0	0.0	0	0	0.0	0.0	4	0	4.0	0.0	4	0	4.0	0.0
	26063	0	0	0.0	0.0	0	0	0.0	0.0	1	1	1.0	1.0	1	1	1.0	1.0
	26101	0	0	0.0	0.0	0	0	0.0	0.0	0	2	0.0	2.0	0	2	0.0	2.0
	26102	0	0	0.0	0.0	0	0	0.0	0.0	2	0	2.0	0.0	2	0	2.0	0.0
	Subtotal	0	0	0.0	0.0	0	1	0.0	1.1	13	6	13.0	6.0	13	7	13.0	7.1
1988	25526	1	0	1.0	0.0	0	1	0.0	1.1	0	0	0.0	0.0	1	1	1.0	1.1
	25527	0	0	0.0	0.0	0	1	0.0	1.1	0	0	0.0	0.0	0	1	0.0	1.1
	25814	0	0	0.0	0.0	1	0	1.0	0.0	2	3	2.0	3.0	3	3	3.0	3.0
	25816	0	0	0.0	0.0	1	0	1.0	0.0	0	0	0.0	0.0	1	0	1.0	0.0
	25817	0	0	0.0	0.0	0	2	0.0	2.2	0	3	0.0	3.0	0	5	0.0	5.2

(continued)

Table 15 (cont). Estimates of the adjusted number of CWT chinook salmon to the Campbell River, Quinsam River, and Quinsam Hatchery, by tag code, 1993. One decimal place is carried for the estimated adipose clips for calculating the expanded hatchery contribution in Table 17 (Method B).

Brood year	CWT code	Campbell River (a,b)				Quinsam River (a,b)				Quinsam Hatchery (a,b)				Total (a,b)			
		Observed CWTs		Adjusted CWTs		Observed CWTs		Adjusted CWTs		Observed CWTs		Adjusted CWTs		Observed CWTs		Adjusted CWTs	
		M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
	25818	0	0	0.0	0.0	0	1	0.0	1.1	1	2	1.0	2.0	1	3	1.0	3.1
	25819	0	0	0.0	0.0	0	2	0.0	2.2	2	1	2.0	1.0	2	3	2.0	3.2
	25820	0	0	0.0	0.0	0	2	0.0	2.2	2	4	2.0	4.0	2	6	2.0	6.2
	25821	0	0	0.0	0.0	0	0	0.0	0.0	3	2	3.0	2.0	3	2	3.0	2.0
	25822	0	2	0.0	2.0	0	0	0.0	0.0	0	4	0.0	4.0	0	6	0.0	6.0
	Subtotal	1	2	1.0	2.0	2	9	2.0	9.8	10	19	10.0	19.0	13	30	13.0	30.8
1987	24420	0	0	0.0	0.0	0	1	0.0	1.1	0	0	0.0	0.0	0	1	0.0	1.1
	Total hatchery	2	2	2.0	2.0	4	11	4.0	11.9	54	28	54.0	28.0	60	41	60.0	41.9
<u>Strays: (c)</u>																	
	1989 20949	0	0	0.0	0.0	0	0	0.0	0.0	1	0	1.0	0.0	1	0	1.0	0.0
	Total strays	0	0	0.0	0.0	0	0	0.0	0.0	1	0	0.0	0.0	1	0	0.0	0.0
	Total CWT	2	2	2.0	2.0	4	11	4.0	11.9	55	28	54.0	28.0	61	41	60.0	41.9
	No data (5000)	0	0			0	1			0	0			0	1		
	No pin (8000)	0	1			1	1			2	1			3	3		
	Lost pin (9000)	0	0			0	0			0	0			0	0		
	Observed adipose	2	3			5	13			57	29			64	45		

(a) Abbreviations are M = male, F = female

(b) Does not include jacks

(c) Adipose-clipped fish that have strayed from other systems

Table 16. Estimates of total escapement of CWT chinook salmon to the Campbell River, Quinsam River, and Quinsam Hatchery, by tag code, 1993. One decimal place is carried for the estimated adipose clips for calculating the expanded hatchery contribution in Table 13 (Method B).

Brood year	CWT code	Campbell River (a,b)				Quinsam River (a,b)				Quinsam Hatchery (a,b)				Total (a,b)			
		Adjusted CWTs		Estimated CWTs		Adjusted CWTs		Estimated CWTs		Adjusted CWTs		Estimated CWTs		Adjusted CWTs		Estimated CWTs	
		M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
1990	20956	1.0	0.0	1.4	0.0	0.0	0.0	0.0	0.0	4.0	0.0	4.0	0.0	5.0	0.0	5.4	0.0
	20957	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	2.0	0.0	2.0	0.0	2.0	0.0
	20958	0.0	0.0	0.0	0.0	1.0	0.0	3.5	0.0	5.0	0.0	5.0	0.0	6.0	0.0	8.5	0.0
	20959	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0	4.0	0.0	4.0	0.0	4.0	0.0
	21449	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	3.0	0.0	3.0	0.0	3.0	0.0
	21450	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.0	0.0	7.0	0.0	7.0	0.0	7.0	0.0
	21451	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	2.0	0.0	2.0	0.0	2.0	0.0
	26016	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	26017	0.0	0.0	0.0	0.0	1.0	0.0	3.5	0.0	3.0	0.0	3.0	0.0	4.0	0.0	6.5	0.0
	26018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0
	26019	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0
	Subtotal	1.0	0.0	1.4	0.0	2.0	0.0	7.0	0.0	31.0	3.0	31.0	3.0	34.0	3.0	39.5	3.0
1989	20354	0.0	0.0	0.0	0.0	0.0	1.1	0.0	1.9	2.0	0.0	2.0	0.0	2.0	1.1	2.0	1.9
	20355	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	2.0	0.0	2.0	0.0	2.0
	20359	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	3.0	0.0	3.0	0.0	3.0	0.0
	20360	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0
	20361	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0
	26062	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0	4.0	0.0	4.0	0.0	4.0	0.0
	26063	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	26101	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	2.0	0.0	2.0	0.0	2.0
	26102	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	2.0	0.0	2.0	0.0	2.0	0.0
	Subtotal	0.0	0.0	0.0	0.0	0.0	1.1	0.0	1.9	13.0	6.0	13.0	6.0	13.0	7.1	13.0	7.9
1988	25526	1.0	0.0	1.4	0.0	0.0	1.1	0.0	1.9	0.0	0.0	0.0	0.0	1.0	1.1	1.4	1.9
	25527	0.0	0.0	0.0	0.0	0.0	1.1	0.0	1.9	0.0	0.0	0.0	0.0	0.0	1.1	0.0	1.9
	25814	0.0	0.0	0.0	0.0	1.0	0.0	3.5	0.0	2.0	3.0	2.0	3.0	3.0	3.0	5.5	3.0

(continued)

Table 16 (cont.). Estimates of total escapement of CWT chinook salmon to the Campbell River, Quinsam River, and Quinsam Hatchery, by tag code, 1993. One decimal place is carried for the estimated adipose clips for calculating the expanded hatchery contribution in Table 13 (Method B).

Brood year	CWT code	Campbell River (a,b)				Quinsam River (a,b)				Quinsam Hatchery (a,b)				Total (a,b)			
		Adjusted CWTs		Estimated CWTs		Adjusted CWTs		Estimated CWTs		Adjusted CWTs		Estimated CWTs		Adjusted CWTs		Estimated CWTs	
		M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
	25816	0.0	0.0	0.0	0.0	1.0	0.0	3.5	0.0	0.0	0.0	0.0	0.0	1.0	0.0	3.5	0.0
	25817	0.0	0.0	0.0	0.0	0.0	2.2	0.0	3.9	0.0	3.0	0.0	3.0	0.0	5.2	0.0	6.9
	25818	0.0	0.0	0.0	0.0	0.0	1.1	0.0	1.9	1.0	2.0	1.0	2.0	1.0	3.1	1.0	3.9
	25819	0.0	0.0	0.0	0.0	0.0	2.2	0.0	3.9	2.0	1.0	2.0	1.0	2.0	3.2	2.0	4.9
	25820	0.0	0.0	0.0	0.0	0.0	2.2	0.0	3.9	2.0	4.0	2.0	4.0	2.0	6.2	2.0	7.9
	25821	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	2.0	3.0	2.0	3.0	2.0	3.0	2.0
	25822	0.0	2.0	0.0	2.8	0.0	0.0	0.0	0.0	0.0	4.0	0.0	4.0	0.0	6.0	0.0	6.8
	Subtotal	1.0	2.0	1.4	2.8	2.0	9.8	7.0	17.4	10.0	19.0	10.0	19.0	13.0	30.8	18.5	39.2
1987	24420	0.0	0.0	0.0	0.0	0.0	1.1	0.0	1.9	0.0	0.0	0.0	0.0	0.0	1.1	0.0	1.9
	Subtotal	0.0	0.0	0.0	0.0	0.0	1.1	0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total hatchery	2.0	2.0	2.9	2.8	4.0	11.9	14.0	21.3	54.0	28.0	54.0	28.0	60.0	40.8	70.9	50.1
<u>Strays: (c)</u>																	
1989	20949	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0
	Total strays	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0
	Petersen est. (d)	111	108			372	480			907	508						
	Sample size (d)	77	77			106	269			907	508						

(a) Abbreviations are M = male, F = female
 (b) Does not include jacks
 (c) CWT chinook that have strayed from other systems
 (d) From Table 10

Table 17. Estimates of total escapement of hatchery-reared CWT chinook salmon to the Campbell River, Quinsam River, and Quinsam Hatchery, by tag code, 1993 (Method B). The expansion factor is used to expand the estimated number of CWT chinook in the escapement (from Table 16) to account for unmarked hatchery releases and, hence, derive hatchery contributions to escapement.
Expansion factor = (CWT releases + untagged releases)/CWT releases.

Brood year	CWT release group	Release Numbers (c)		Expansion factor	Expanded hatchery contributions (a,b)							
		CWT	Untagged (d)		Campbell River		Quinsam River		Quinsam Hatchery		Total	
					M	F	M	F	M	F	M	F
1990	20956	26953	189154	8.0	11.6	0.0	0.0	0.0	32.1	0.0	43.6	0.0
	20957	26752	430178	17.1	0.0	0.0	0.0	0.0	34.2	0.0	34.2	0.0
	20958	26658	205795	8.7	0.0	0.0	30.6	0.0	43.6	0.0	74.2	0.0
	20959	26026	203364	8.8	0.0	0.0	0.0	0.0	35.3	0.0	35.3	0.0
	21449	26602	332627	13.5	0.0	0.0	0.0	0.0	40.5	0.0	40.5	0.0
	21450	26384	331055	13.5	0.0	0.0	0.0	0.0	94.8	0.0	94.8	0.0
	21451	26502	320497	13.1	0.0	0.0	0.0	0.0	26.2	0.0	26.2	0.0
	26016	27211	588892	22.6	0.0	0.0	0.0	0.0	22.6	22.6	22.6	22.6
	26017	25911	284261	12.0	0.0	0.0	42.0	0.0	35.9	0.0	77.9	0.0
	26018	28265	183904	7.5	0.0	0.0	0.0	0.0	0.0	7.5	0.0	7.5
	26019	26817	502724	19.7	0.0	0.0	0.0	0.0	0.0	19.7	0.0	19.7
	Subtotal	294081	3572451		11.6	0.0	72.6	0.0	365.2	49.9	449.3	49.9
1989	20354	23306	174330	8.5	0.0	0.0	0.0	16.4	17.0	0.0	17.0	16.4
	20355	22574	263949	12.7	0.0	0.0	0.0	0.0	0.0	25.4	0.0	25.4
	20359	24396	300109	13.3	0.0	0.0	0.0	0.0	39.9	0.0	39.9	0.0
	20360	24499	291972	12.9	0.0	0.0	0.0	0.0	12.9	0.0	12.9	0.0
	20361	24669	291802	12.8	0.0	0.0	0.0	0.0	0.0	12.8	0.0	12.8
	26062	24929	291542	12.7	0.0	0.0	0.0	0.0	50.8	0.0	50.8	0.0
	26063	24904	291567	12.7	0.0	0.0	0.0	0.0	12.7	12.7	12.7	12.7
	26101	25007	291464	12.7	0.0	0.0	0.0	0.0	0.0	25.3	0.0	25.3
	26102	24739	291732	12.8	0.0	0.0	0.0	0.0	25.6	0.0	25.6	0.0
	Subtotal	94775	1030360		0.0	0.0	0.0	16.4	158.9	76.2	158.9	92.6
1988	25526	24624	182558	8.4	12.1	0.0	0.0	16.3	0.0	0.0	12.1	16.3
	25527	23937	244318	11.2	0.0	0.0	0.0	21.7	0.0	0.0	0.0	21.7
	25814	25246	289421	12.5	0.0	0.0	43.7	0.0	24.9	37.4	68.7	37.4

(continued)

Table 17 (cont.). Estimates of total escapement of hatchery-reared CWT chinook salmon to the Campbell River, Quinsam River, and Quinsam Hatchery, by tag code, 1993 (Method B). The expansion factor is used to expand the estimated number of CWT chinook in the escapement (from Table 16) to account for unmarked hatchery releases and, hence, derive hatchery contributions to escapement.
Expansion factor = (CWT releases + untagged releases)/CWT releases.

Brood year	CWT release group	Release Numbers (c)		Expansion factor	Expanded hatchery contributions (a,b)							
		CWT	Untagged (d)		Campbell River		Quinsam River		Quinsam Hatchery		Total	
					M	F	M	F	M	F	M	F
	25816	22344	256059	12.5	0.0	0.0	43.7	0.0	0.0	0.0	43.7	0.0
	25817	25029	268880	11.7	0.0	0.0	0.0	45.4	0.0	35.2	0.0	80.6
	25818	25096	269867	11.8	0.0	0.0	0.0	22.7	11.8	23.5	11.8	46.2
	25819	25037	270958	11.8	0.0	0.0	0.0	45.7	23.6	11.8	23.6	57.5
	25820	24810	406636	17.4	0.0	0.0	0.0	67.2	34.8	69.6	34.8	136.8
	25821	24609	403341	17.4	0.0	0.0	0.0	0.0	52.2	34.8	52.2	34.8
	25822	24884	407850	17.4	0.0	48.8	0.0	0.0	0.0	69.6	0.0	118.3
	Subtotal	245616	2999888		12.1	48.8	87.5	219.0	147.3	281.8	246.9	549.6
1987	24420	24386	332520	14.6	0.0	0.0	0.0	28.3	0.0	0.0	0.0	28.3
	Subtotal	24386	332520		0.0	0.0	0.0	28.3	0.0	0.0	0.0	28.3
	Total hatchery				23.7	48.8	160.1	263.7	671.3	408.0	855.1	720.4
<u>Strays: (e)</u>												
1989	20949	26660	1763593	67.2	0.0	0.0	0.0	0.0	67.2	0.0	67.2	0.0
	Total strays				0.0	0.0	0.0	0.0	67.2	0.0	67.2	0.0

(a) Abbreviations are M = male, F = female

(b) Does not include jacks

(c) From Table 12

(d) Untagged = AD only (ie. tag lost) + unmarked (ie. no CWT/AFC applied)

(e) CWT chinook that have strayed from other systems

Table 18. Estimated hatchery and stray contributions to Campbell River, Quinsam River, and Quinsam Hatchery chinook salmon escapement, 1993. Contributions were calculated using expansion Method B for the estimated number of CWTs (Table 17).

Location	Age	Estimated escapement (a)		Hatchery contribution (b)				Stray contribution (b)			
				Male (c)		Female		Male (c)		Female	
		Male (c)	Female	Number	%	Number	%	Number	%	Number	%
<u>Campbell River</u>											
	3	6	2	12	100 (d)	0	0.0	0	0.0	0	0.0
	4	17	17	0	0.0	0	0.0	0	0.0	0	0.0
	5	80	81	12	15.0	49	60.5	0	0.0	0	0.0
	6	8	8	0	0.0	0	0.0	0	0.0	0	0.0
	Total	111	108	24	21.6	49	45.4	0	0.0	0	0.0
<u>Quinsam River</u>											
	3	107	9	73	68.2	0	0.0	0	0.0	0	0.0
	4	113	66	0	0.0	16	24.2	0	0.0	0	0.0
	5	152	386	88	57.9	219	56.7	0	0.0	0	0.0
	6	0	18	0	0.0	28	100 (d)	0	0.0	0	0.0
	Total	372	479	161	43.3	263	54.9	0	0.0	0	0.0
<u>Quinsam Hatchery</u>											
	3	402	23	365	90.8	50	100 (d)	0	0.0	0	0.0
	4	267	116	159	59.6	76	65.5	67	25.1	0	0.0
	5	238	360	147	61.8	282	78.3	0	0.0	0	0.0
	6	0	9	0	0.0	0	0.0	0	0.0	0	0.0
	Total	907	508	671	74.0	408	80.3	67	7.4	0	0.0

(a) From Table 9

(b) From Table 17

(c) Does not include jacks

(d) Estimated hatchery contribution greater than 100%

APPENDICES

Appendix 1. Operculum tagging of chinook salmon carcasses in Campbell River, 1993.

Date	Capture area (a)	Tagged			Total
		Male	Female	Jack	
26-Oct	1A	0	0	0	0
	1B	3	4	0	7
27-Oct	1A	3	2	0	5
	1B	3	3	0	6
29-Oct	1A	0	1	0	1
	1B	9	10	0	19
02-Nov	1A	2	1	0	3
	1B	4	3	0	7
03-Nov	1A	0	3	0	3
	1B	1	2	0	3
05-Nov	1A	0	0	0	0
	1B	9	2	0	11
Total		34	31	0	65

(a) See Figure 1 for location of capture areas

Appendix 2. Operculum tagging of chinook salmon carcasses in Quinsam River, 1993.

Date	Capture area (a)	Tagged			Total
		Male	Female	Jack	
25-Oct	2B	0	2	0	2
	2C	1	2	0	3
	2D	0	2	0	2
28-Oct	2B	0	2	0	2
	2C	1	5	0	6
	2D	1	7	1	9
01-Nov	2B	0	3	0	3
	2C	3	9	0	12
	2D	3	7	0	10
04-Nov	2B	0	1	0	1
	2C	1	4	0	5
	2D	3	3	0	6
08-Nov	2B	1	2	0	3
	2C	2	6	0	8
	2D	2	5	0	7
11-Nov	2B	0	1	0	1
	2C	0	2	0	2
	2D	0	0	0	0
15-Nov	2B	0	1	0	1
	2C	0	0	0	0
	2D	0	3	0	3
Total		18	67	1	86

(a) See Figure 1 for location of capture areas

Appendix 3. Dead recovery of tagged chinook salmon carcasses in Campbell River, 1993.

Date	Recovery area (a)	Recovered			Total
		Male	Female	Jack	
29-Oct	1A	0	0	0	0
	1B	3	5	0	8
02-Nov	1A	0	0	0	0
	1B	6	6	0	12
03-Nov	1A	1	1	0	2
	1B	2	2	0	4
05-Nov	1A	0	0	0	0
	1B	6	4	0	10
08-Nov	1A	0	0	0	0
	1B	2	1	0	3
10-Nov	1A	0	1 (b)	0	1
	1B	1	0	0	1
Total		21	20	0	41

(a) See Figure 1 for location of recovery areas

(b) This single female chinook possessed an opercular punch only (operculum tag missing)

Appendix 4. Dead recovery of tagged chinook salmon carcasses in Quinsam River, 1993.

Date	Capture area (a)	Tagged			Total
		Male	Female	Jack	
28-Oct	2B	0	1	0	1
	2C	0	1	0	1
	2D	0	1	0	1
01-Nov	2B	0	1	0	1
	2C	0	0	0	0
	2D	0	4	0	4
04-Nov	2B	0	0	0	0
	2C	0	2 (b)	0	2
	2D	1	6	0	7
08-Nov	2B	0	1	0	1
	2C	0	1	0	1
	2D	0	4 (b)	0	4
11-Nov	2B	0	2	0	2
	2C	1	3	0	4
	2D	1	2	0	3
15-Nov	2B	0	0	0	0
	2C	0	1	0	1
	2D	1	2	0	3
18-Nov	2B	0	0	0	0
	2C	0	0	0	0
	2D	0	2	0	2
Total		4	34	0	38

(a) See Figure 1 for location of capture areas

(b) Included in the number recovered is a chinook that possessed an opercular punch only (operculum tag missing)

Appendix 5. Sequential mark-recapture data for chinook salmon carcasses in Campbell River, 1993. Carcasses examined on or before the first date of tagging are not included for the mark-recapture estimate (MR).

Date	Male			Female			Jack			Total		
	No. examined	No. tags applied	No. tags recovered	No. examined	No. tags applied	No. tags recovered	No. examined	No. tags applied	No. tags recovered	No. examined	No. tags applied	No. tags recovered
26-Oct	8	3	0	7	4	0	0	0	0	15	7	0
27-Oct	11	6	0	10	5	0	1	0	0	22	11	0
29-Oct	16	9	3	25	11	5	0	0	0	41	20	8
2-Nov	12	6	6	11	4	6	0	0	0	23	10	12
3-Nov	7	1	3	8	5	3	1	0	0	16	6	6
5-Nov	13	9	6	9	2	4	0	0	0	22	11	10
8-Nov	2	0	2	1	0	1	0	0	0	3	0	3
10-Nov	4	0	1	3	0	1	0	0	0	7	0	2
12-Nov	4	0	0	3	0	0	0	0	0	7	0	0
Total	77	34	21	77	31	20	2	0	0	156	65	41
Totals for MR(a)	69	34	21	70	31	20	2	0	0	141	65	41

(a) To be used in the Peterson population estimation procedure for the carcass tagging and recovery method. Number of tags examined on the first day of tagging are not included

Appendix 6. Sequential mark-recapture data for chinook salmon carcasses in Quinsam River, 1993. Carcasses examined on or before the first date of tagging are not included in the number examined for the mark-recapture estimate (MR).

Date	Male			Female			Jack			Total		
	No. examined	No. tags applied	No. tags recovered	No. examined	No. tags applied	No. tags recovered	No. examined	No. tags applied	No. tags recovered	No. examined	No. tags applied	No. tags recovered
25-Oct	9	1	0	23	6	0	0	0	0	32	7	0
28-Oct	14	2	0	47	14	3	2	1	0	63	17	3
1-Nov	26	6	0	76	19	5	2	0	0	104	25	5
4-Nov	16	4	1	41	8	8	0	0	0	57	12	9
8-Nov	25	5	0	59	13	6	1	0	0	85	18	6
11-Nov	4	0	2	10	4	7	2	0	0	16	4	9
15-Nov	7	0	1	9	3	3	0	0	0	16	3	4
18-Nov	5	0	0	4	0	2	0	0	0	9	0	2
Total	106	18	4	269	67	34	7	1	0	382	86	38
Totals for MR(a)	97	18	4	246	67	34	7	1	0	350	86	38

(a) To be used in the Peterson population estimation procedure for the carcass tagging and recovery method. Number of tags examined on the first day of tagging are not included.

Appendix 7. Total dead recovery and adipose clip recovery of chinook salmon in Campbell River, 1993 (a).

Date	Area 1A								Area 1B							
	Total recovered (b)				Adipose clipped recovered				Total recovered (b)				Adipose clipped recovered			
	M	F	J	T	M	F	J	T	M	F	J	T	M	F	J	T
26-Oct	0	0	0	0	0	0	0	0	8	7	0	15	0	0	0	0
27-Oct	6	6	0	12	0	1	0	1	5	4	1	10	0	1	0	1
29-Oct	0	2	0	2	0	0	0	0	16	23	0	39	0	1	0	1
2-Nov	4	1	0	5	0	0	0	0	8	10	0	18	0	0	0	0
3-Nov	3	6	0	9	0	0	0	0	4	2	1	7	0	0	0	0
5-Nov	0	0	0	0	0	0	0	0	13	9	0	22	1	0	0	1
9-Nov	0	0	0	0	0	0	0	0	2	1	0	3	1	0	0	1
10-Nov	2	2	0	4	0	0	0	0	2	1	0	3	0	0	0	0
12-Nov	0	0	0	0	0	0	0	0	4	3	0	7	0	0	0	0
Total	15	17	0	32	0	1	0	1	62	60	2	124	2	2	0	4

(a) See Figure 1 for location of recovery areas

(b) Abbreviations are M=male, F=female, J=jack, T=total

Appendix 8. Total dead recovery and adipose clip recovery of chinook salmon in Quinsam River, 1993 (a).

Date	Area 2B								Area 2C								Area 2D							
	Total recovered (b)				Adipose clipped recovered				Total recovered (b)				Adipose clipped recovered				Total recovered (b)				Adipose clipped recovered			
	M	F	J	T	M	F	J	T	M	F	J	T	M	F	J	T	M	F	J	T	M	F	J	T
25-Oct	1	3	0	4	0	0	0	0	5	11	0	16	0	2	0	2	3	9	0	12	1	1	0	2
28-Oct	0	4	1	5	0	1	0	1	3	15	0	18	0	1	0	1	11	28	1	40	0	0	0	0
1-Nov	2	10	0	12	0	1	0	1	12	35	0	47	1	0	0	1	12	31	2	45	0	3	0	3
4-Nov	0	7	0	7	0	0	0	0	8	17	0	25	1	0	0	1	8	17	0	25	0	0	0	0
8-Nov	2	7	0	9	0	0	0	0	10	26	0	36	0	2	0	2	13	26	1	40	0	2	0	2
11-Nov	0	2	0	2	0	0	0	0	2	5	1	8	1	0	1	2	2	3	1	6	0	0	0	0
15-Nov	0	2	0	2	0	0	0	0	2	1	0	3	0	0	0	0	5	6	0	11	0	0	0	0
18-Nov	0	0	0	0	0	0	0	0	4	2	0	6	1	0	0	1	1	2	0	3	0	0	0	0
Total	5	35	1	41	0	2	0	2	46	112	1	159	4	5	1	10	55	122	5	182	1	6	0	7

(a) See Figure 1 for location of recovery areas

(b) Abbreviations are M= male, F= female, J=jack, T=total

