Adult Chinook Escapement Assessment Conducted on the Nanaimo River During 2001

N.K. Hop Wo, E.W. Carter, D.A. Nagtegaal, and K.E. Jones

Fisheries and Oceans Canada
Science Branch, Pacific Region
Pacific Biological Station
Nanaimo, British Columbia
V9T 6N7

2003

Canadian Manuscript Report of Fisheries and Aquatic Sciences 2654

Fisheries and Oceans Canada | Pêches et Océans Canada

Canada

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 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 ques 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 annual 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 a 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.

Canadian Manuscript Report of

Fisheries and Aquatic Sciences 2654

2003

ADULT CHINOOK ESCAPEMENT ASSESSMENT CONDUCTED ON THE NANAIMO RIVER DURING 2001

by

N.K. Hop Wo, E.W. Carter, D.A. Nagtegaal, and K.E. Jones

Fisheries and Oceans Canada

Science Branch, Pacific Region

Pacific Biological Station

Nanaimo, British Columbia

V9T 6N7

Cat. No. Fs 97-4/2654E ISSN 0706-6473

Correct citation for this publication:

Hop Wo, N.K., E.W. Carter, D.A. Nagtegaal, and K.E. Jones. 2003. Adult chinook escapement assessment conducted on the Nanaimo River during 2001. Can. Manuscr. Rep. Fish. Aquat. Sci. 2654: 38 p.

LIST OF TABLES

LIST OF TABLES (continued)

LIST OF FIGURES

ABSTRACT

Hop Wo, N.K., E.W. Carter, D.A. Nagtegaal, and K.E. Jones. 2003. Adult chinook escapement assessment conducted on the Nanaimo River during 2001. Can. Manuscr. Rep. Fish. Aquat. Sci. 2654: 38 p.

In 2001, Fisheries and Oceans Canada in co-operation with Snuneymuxw First Nation continued a productivity study of chinook salmon (*Oncorhynchus tshawytscha*) in the Nanaimo River. Areas of concentration for this study included: i) enumeration of returning chinook; ii) collection of biological and coded-wire tag (CWT) data; and iii) estimation of returning chinook using a carcass mark-recapture project as a comparison. The estimated total return of fall run adult chinook to the Nanaimo River was 1,630 of which 1,277 spawned naturally. We used observations at First Lake and information compiled during broodstock collection to estimate the total return of the First Lake spring chinook stock at 419 adult chinook. Total return of both fall run and spring run adult chinook to the Nanaimo River in 2001 was 2,049. We also examined the effects of a water management plan implemented in 1989 to aid the upstream movement of fall chinook.

RÉSUMÉ

Hop Wo, N.K., E.W. Carter, D.A. Nagtegaal, and K.E. Jones. 2003. Adult chinook escapement assessment conducted on the Nanaimo River during 2001. Can. Manuscr. Rep. Fish. Aquat. Sci. 2654: 38 p.

En 2001, Pêches et Océans Canada, en coopération avec la Première nation Snuneymuxw, a poursuivi une étude de la productivité du saumon quinnat (*Oncorhynchus tshawytscha*) dans la rivière Nanaimo, dont les principaux éléments étaient les suivants : i) dénombrement des quinnats amontants; ii) collecte de données biologiques et de marques métalliques codées et iii) estimation des remontes de quinnat par le biais d'un projet de récupération des carcasses de saumons étiquetés à titre de comparaison. Selon nos estimations, la remonte totale de quinnats adultes d'automne dans la Nanaimo se chiffrait à 1 630, dont 1 277 ont frayé dans la rivière. Nous avons utilisé des observations faites dans le lac First et de l'information recueillie lors de la récolte de géniteurs pour estimer la remonte totale de quinnats de printemps dans ce lac, qui se chiffrait à 419 adultes. D'après nos calculs, la remonte totale de quinnats adultes d'automne et de quinnats adultes de printemps dans la rivière Nanaimo en 2001 atteignait 2 049 individus. Nous examinons aussi les effets d'un plan de gestion des eaux mis en œuvre en 1989 en vue de faciliter la montaison du quinnat d'automne.

INTRODUCTION

Since 1988, considerable interest has been focused on the status of chinook salmon (*Oncorhynchus tshawytscha*) stocks in the lower Strait of Georgia. Along with the Cowichan River, the Nanaimo River is one of the lower Strait of Georgia exploitation and escapement indicator rivers where chinook spawning escapement information is intensively collected. Escapement information is used to evaluate rebuilding strategies and harvest management policies for lower Strait of Georgia chinook (Farlinger et al. 1990). In 2001, DFO, Science Branch, in conjunction with the Snuneymuxw First Nation continued to operate a counting fence and collect information on chinook escapements in the Nanaimo River.

The Nanaimo River chinook exhibit a variety of life history strategies, with at least three genetically distinct runs produced (Carl and Healey 1984). Unique to only a few systems on the east coast of Vancouver Island, there are two distinct spring chinook stocks in additional to a fall run stock returning to the Nanaimo River.

The two spring run stocks enter the river from between December and February and hold in First or Second Lakes or deep canyon pools until they spawn during late summer/early fall (Blackman 1981, Brahniuk et al. 1993, Nagtegaal and Carter 2000). The Upper Nanaimo River spring chinook stock spawns upstream of Second Lake to Sadie Creek at the outlet of Fourth Lake (Hardie 2002) during October and the majority of fry are stream-type and rear for up to one year before outmigrating to the estuary (Healey 1980, Blackman 1981, Nagtegaal and Carter 2000).

The First Lake spring run spawns within the first 1.6 kilometers downstream of the First Lake outlet to the Wolfe Creek junction pool (Healey and Jordan 1982, Hardie 2002), with the peak of spawning typically during the first two weeks of October (Nagtegaal and Carter 2000, Brahniuk et al., 1993). Chinook fry produced from the late spring run are mostly ocean-type and rear for 90 days in freshwater before migrating to sea. Stream type fry will be more vulnerable to changes in freshwater productivity and habitat conditions than ocean type fry that outmigrate upon emergence. Once in the estuary, First Lake fry exhibit greater agonistic behavior than fry produced by the lower Nanaimo stocks due to their longer period of territorial stream residence prior to migration into the estuary (Taylor 1990).

The larger fall chinook stock enters the Nanaimo River during August and a portion of the run spawns in the lower river downstream of the Borehole/lower canyon area down to the Cedar Road bridge (Healey and Jordan 1982, Hardie 2002). Some of the fall chinook run ascend the falls to spawn in the upper river downstream of First Lake. The majority (99%) of fry incubated in the lower river exhibit ocean-type life history strategy and outmigrate to sea upon emergence to rear in the estuary (Healey and Jordan 1982).

Hatchery production of chinook on the Nanaimo River began in 1979 (Cross et al. 1991). In that first year, eggs were incubated at the Pacific Biological Station and later released into the river. The first year of production at the hatchery facility was 1980 (1979 brood) when 100,000 chinook fry were released. Over the years fry production has increased, and in 2001, 368,433 fall run and 207,955 First Lake spring run chinook fry were released. There is no hatchery enhancement for the Upper Nanaimo River spring run chinook stock. Coded-wire tagging of chinook began in 1979 and by 2001, 47.7% of fall run chinook fry and 11.9% of spring run chinook fry carried coded-wire tags (P. McKay, Nanaimo River Salmonid Enhancement Project Co-Manager, Community Futures Development Corporation of Central Island, 271 Pine Street, Nanaimo, B.C., V9R 2B7. pers. comm.).

In addition to chinook, the Nanaimo River also supports stocks of coho salmon (*O. kisutch*), chum salmon (*O. keta*), pink salmon (*O. gorbuscha*), steelhead trout (*O. mykiss*), cutthroat trout (*O. clarki*), and Dolly Varden (*Salvelinus malma*).

In consultation with various user groups, the B.C. Ministry of Environment, Lands and Parks initiated a Nanaimo River Water Management Plan in June 1989. The primary goal of the plan was to improve salmon escapement by increasing flows during typically low water levels in the fall while at the same time maintaining adequate flows to satisfy industrial and domestic water use (Ministry of Environment, Lands and Parks 1993).

This report presents the results of the study completed during 2001. The objectives included:

1. enumerating chinook, coho and chum salmon migrating past the counting fence,
2. estimating the First Nations food fishery catch,
3. recording hatchery broodstock removals of fall and spring run chinook,
4. implementing a carcass mark-recapture study for both fall run adult and jack chinook, and
5. collecting biological data and sampling coded-wire tag (CWT) recoveries.

METHODS

Three methods were employed to estimate chinook spawning escapement in the Nanaimo River. These included fence counts, carcass mark-recapture techniques, and swim surveys. Both fence counts and mark-recapture methods were used to estimate escapement of fall run chinook. Spring run chinook enter the river prior to fence installation, therefore estimates of escapement for this stock were dependent on swims and visual observations at known holding locations and from broodstock capture data at First Lake. Swim surveys were conducted to observe and record spawning distribution of the fall run chinook stock that was enumerated passing the fence. Biological data including length, sex, scales and presence/absence of an adipose fin were collected from carcasses during the mark-recapture program.

Carter and Nagtegaal (1997) have previously described fence construction and data collection methods in detail. A brief description along with modifications made to the project in 2001 are explained below.

FENCE OPERATION

In previous years attempts to improve the fishway by creating holding pools or diverting water to increase flow and encourage fish movement through the trap box had little success (Carter and Nagtegaal 1998). In 1998, the fence was moved upstream about two km to a site known as San Salvadore at the Nanaimo River campground (Figure 1, Figure 2). In 2000, an excavator operator completed extensive in-river work to properly secure the rail in the substrate and to excavate an approach channel to the trap box and another leading from the trap box upstream. In addition, the rail was further re-enforced by attaching cable and anchors that are buried about two metres into the substrate upstream.

Fish counts were recorded by 15-minute intervals for adult and jack chinook, adult and jack coho and chum salmon. When identification was in doubt, fish were recorded in the unknown category. Other information including water depth, water temperature, water clarity, and weather was recorded three times daily. Staff were responsible for keeping the fence clear of leaves and other debris as well as general maintenance to ensure optimal operating capability.

MARK-RECAPTURE AND BIOLOGICAL DATA COLLECTION

In addition to the fence counts, adult chinook escapement estimates for the fall stock were also generated from the carcass mark-recapture data using a pooled Petersen model (Chapman modification; Ricker 1975). Although the fence counts were considered the most accurate, the mark-recapture data enabled us to estimate the sex composition and enhanced (hatchery) contribution in the population using the CWT data.

The carcass mark-recapture estimate is based on recoveries of chinook carcasses tagged on the Nanaimo River spawning grounds. This population estimate compliments the fence enumeration count and is implemented for several reasons. Firstly, the handling and tagging of chinook as they passed through the counting fence would cause additional undue stress and delay migration. Therefore the tagging of chinook carcasses is preferred because it provides valuable population information while minimizing the physical contact to spawning chinook salmon. Secondly, the carcasses provide the primary source of CWT recoveries and biological information.

The carcass recovery operation involved a two or three-person crew in an inflatable boat searching the river daily for spawned out chinook carcasses. Recovery effort was concentrated on the fall run chinook stock in the area of highest spawning activity between the Island Highway Bridge and the Cedar Bridge. Each carcass was tagged with a numbered Ketchum[1] aluminum sheep ear tag on the left operculum and released into the river. For all recaptures, the tag number and location were recorded. Once recaptured, the carcass was cut up and removed from the river to avoid multiple recaptures.

[1] Ketchum Manufacturing Ltd., Ottawa, Canada

In previous years, excursions were made to a two to three km section of river below First Lake to locate spring run chinook carcasses in an attempt to estimate the escapement of this population (Carter and Nagtegaal 1997; 1998; 1999). Due to an inability to recover sufficient numbers of carcasses, this was discontinued in 1998. Population estimates for the First Lake spring stock were based on visual observations in the vicinity of First and Second Lakes.

Biological data were collected primarily from spawned out chinook carcasses which were recovered and tagged during a carcass mark-recapture program on the spawning grounds. Additional biological data were collected from carcasses that washed up onto the fence. Staff at the Nanaimo River Hatchery collected and contributed biological data from the First Lake spring run chinook broodstock. Information and biological samples taken for each chinook carcass included capture location, post orbital-hypural (POH) length, sex, scale sample, and presence or absence of adipose fin. If the adipose fin was absent, indicating a coded-wire tagged fish, the head was removed and placed in a bag with a numbered label. Heads were later catalogued and CWT's were decoded.

Mark-recapture estimates were calculated using a pooled Petersen estimator. Since the true population size was not known, a direct measure of the accuracy of the estimates was not possible. However, an assessment of the underlying assumptions of equal probability of capture, simple random recovery sampling and complete mixing can usually be made by testing recovery and application samples for temporal, sex and size related biases (Schubert 2000). To carry out most of the bias assessments, different gear types must be utilized for capturing the tag application and the recovery samples. In the current study, the spawning ground carcass recovery was used to attain both samples thus limiting the ability to assess sample biases.

Finding sampling biases usually results in the use of a stratified estimator; however, Schubert (2000) compared the performance of several mark-recapture population estimators for a sockeye salmon population of known abundance and concluded that the pooled Petersen estimator was less biased and preferred over stratified estimators. In that study, the Schaeffer estimator would not improve accuracy and it was recommended that the method be abandoned for use in population estimation. Also, it was determined that while the maximum likelihood Darroch estimator could potentially improve accuracy there was no obvious way of selecting between accurate and highly biased estimates. Parken and Atagi (2000) found that pooled and stratified estimators of Nass River summer steelhead produced similar escapement estimates but that the pooled estimator was more precise and had less statistical bias than the stratified estimator. These findings indicate the robust nature of the pooled Petersen estimator and suggest that its use to determine population abundance from mark-recapture data is generally appropriate under a wide range of circumstances.

SWIM SURVEYS

Swim surveys were conducted in conjunction with the Nanaimo River Hatchery staff to estimate the number of spawning chinook. To reduce bias, surveys were carried out independently and without knowledge of counts from previous surveys. Swim surveys were normally carried out using three to five swimmers. Swimmers attempted to stay abreast of each other while moving downstream and counts were made independently. Swimmers combined their counts, which were recorded by pre-defined localities in the river (Figure 2).

Swim surveys in the lower river between the Island highway bridge and the Forks were conducted between 13 September and 07 November to estimate the number of fall chinook as well as to observe their distribution. Visual surveys in the vicinity of First Lake were conducted during broodstock collection and were used to estimate the number of First Lake spring run chinook. These swim surveys were completed on 07 June, 21 September and 04 October in the upper Nanaimo River and First Lakes area. Five swim surveys were also conducted above Second Lake to enumerate Upper Nanaimo River spring run chinook between 07 June and 13 October.

WATER MANAGEMENT PLAN

The low flow and water levels likely result in delayed fish movement and higher water temperatures which may potentially increase levels of disease and parasites. This is particularly true for the parasite Ich (*ichthyophthirius*) which matures more rapidly with higher temperature (Ministry of Environment, Lands and Parks 1993). During particularly low water levels the river flow can be increased with a controlled water release.

Three man-made reservoirs in the Nanaimo River system have been utilised to increase flows during periods of low flow between late summer and early fall. Prior to 1989, water releases were conducted based on an informal arrangement between local Fisheries Officers and Harmac Pacific. Fisheries Officers would request a water release when, in their opinion, fish holding in the lower river became threatened due to low water. These requests would be granted by Harmac dependent upon the availability of water in reserve.

With the increase in population in the Nanaimo area and in an effort to satisfy domestic, industrial, agricultural, fishery, wildlife, and recreational needs, a Nanaimo River Water Management Plan was initiated by the B.C. Ministry of Environment (BCMOE) in June 1989. A team comprised of members from the BCMOE, Greater Nanaimo Water District, MacMillan Bloedel Limited, Snuneymuxw First Nation, and Fisheries and Oceans Canada (DFO) negotiated a water flow management plan (Ministry of Environments, Lands and Parks 1993). The primary water management issue has been to enhance flows to meet fisheries requirements while maintaining flows to satisfy industrial and municipal needs. This is particularly important during periods of lowest flow (September and October) and in the 10-km section of river below the Harmac Pulp Operations water intake area. Increases in the fall water releases from the reservoirs since 1989 have encouraged spawning migration.

RESULTS

ENUMERATION FENCE

Since 1998, the enumeration fence has been located at a site known as San Salvadore (Figure 1, Figure 2) and was in operation from 10 September until 30 October, 2001. Water conditions were clear for most of the study with seven days having moderate visibility and three days with low visibility (Table 1). As a result, conditions were good for enumerating and identifying fish past the fence and all counts were deemed to be reliable. A total of 1,945 adult chinook, 852 jack chinook, 1,057 adult coho, 333 jack coho, and 34,025 chum were enumerated. In addition, 14 fish were unable to be accurately identified and were recorded as unknown. Since there were no breaches in the fence during the course study it was assumed all fish migrating past the fence were enumerated.

At the fence location, the fish swam through the trap box voluntarily allowing an opportunity to observe preferred times of natural movement. The period between 0800 h and 1200 h showed the highest percentage of adult chinook movement with 37.3% travelling through the fence during this time interval (Table 2). During periods of high chum abundance downstream of the fence, staff removed fence panels to encourage large numbers of fish to swim upstream. Fence panels were removed due to a build up of chum downstream of the fence from 11 October to 12 October allowing 1,558 chum to be counted and from 16 October to 18 October where 5,339 chum were enumerated.

Environmental data collected at the enumeration fence included water temperature and river depth (Table 1). Water temperature was highest at the start of the study and decreased steadily until the end of the study. Temperature over this period ranged from a high of 19°C on 12 September to a low of 8°C on 29 October and 30 October with an average of 12.6°C (Figure 3). Water depth was inconsistent, partially due to tidal influence, with a low of 18.0 cm on 22 September, 6 October, and 8 October, a high of 99 cm on 27 October and an average of 38.0 cm (Figure 3).

SWIM SURVEYS

Since the counting fence was put into place on 10 September, the intention was to enumerate fall run chinook. Swim surveys are conducted in addition to fence enumeration in order to get an idea of the spawning distribution of chinook as well as fish still holding in the river downstream of the fence. Fourteen swim surveys were conducted in the lower Nanaimo River between 13 September and 07 November (Table 3, Figure 2). The survey showing the highest abundance was conducted on 13 September between Pumphouse Pool and Cedar Bridge where 497 adult chinook were enumerated.

In addition, three swim surveys conducted on 07 June, 21 September and 04 October in the vicinity of the upper Nanaimo River and First Lake were used to estimate First Lake spring run chinook (Table 3). The natural spawning estimate for First Lake spring run chinook in 2001 was 250 adults (H. Bob, Nanaimo River Salmonid Enhancement Project Co-Manager, Community Futures Development Corporation of Central Island, 271 Pine Street, Nanaimo, B.C., V9R 2B7. pers. comm.). Five swim surveys conducted above Second Lake resulted in a combined total of 19 Upper Nanaimo River spring run adult chinook being enumerated (Table 3). No estimate of Upper Nanaimo River spring run chinook was calculated.

HATCHERY COMPONENT

On 02 October and 11 October, the Nanaimo River Hatchery staff collected 29 male, 15 female and five jack fall run chinook downstream of the enumeration fence. In addition, 47 male, 74 female and 14 jack fall run chinook were collected between 09 October and 26 October upstream of the fence. On 02 October and 04 October, 114 male, 55 female and 27 jack First Lake spring run chinook were captured in the First Lake area. No Upper Nanaimo River spring run chinook were removed for hatchery broodstock. A summary of all hatchery broodstock collected is presented in Table 4.

NATIVE FOOD FISHERY

Historically, an in-river chum gillnet fishery has taken place, usually in October, to provide food fish for the Snuneymuxw First Nation (SFN). This fishery is held in a one-km area downstream of the counting fence and monitored by the Snuneymuxw Fisheries Guardians. Catch estimates are acquired through interviews with fishers and provided to the Aboriginal Fisheries Strategy co-ordinator with DFO. In 2001, the catch was determined to be 188 adult chinook.

CARCASS MARK-RECAPTURE

The carcass mark-recapture program began on 02 November and was discontinued on 30 November, 2001. During this period 139 male, 98 female, 71 jack and three unknown chinook carcasses were tagged and released in the Nanaimo River (Table 5). Of the 95 carcasses recaptured with tags, 39 (41.1%) were male, 39 (41.1%) were female and 17 (17.9%) were jack chinook. Using the Petersen estimator, the total adult fall run chinook population estimate was 952 (95% CI: 771 - 1133), while the jack fall run chinook population estimate was 356 (95% CI: 213 - 499) (Table 6).

Potential Biases

The assessment of sampling selectivity had several potential biases in the carcass mark-recapture study.

1. Temporal bias: Temporal bias in the tagging sample was examined by stratifying the

mark incident rate into four recovery periods (Table 7). There was a significant temporal bias in the application sample for male adult chinook when the data were stratified into four equal recovery periods (Chi-square = 15.08; $p<0.01$). There was no detectable temporal bias for female chinook when stratified into identical recovery periods (Chi-square = 9.19; $p<0.01$).

Temporal bias in the recovery sample was analysed by stratifying the recovery rates into four application periods (Table 8). A statistical difference in the recovery sample for both male and female adult chinook was observed (Chi-square = 34.18; $p<0.01$ and Chi-square = 30.79; $p<0.01$, males and females, respectively).

2. Fish Sex: Sex related bias was examined by comparing the sex ratio of the marked and unmarked spawning ground recoveries by application sample and by recovery sample. No sex related bias was evident when comparing male and female chinook populations (Chi-square = 3.59; $p<0.01$ and Chi-square = 1.69; $p<0.01$, application sample and recovery sample, respectively) (Table 9). When jack chinook were included into the application and recovery samples no significant bias was apparent (Chi-square = 5.77; $p<0.01$, and Chi-square = 2.95; $p<0.01$, application sample and recovery sample, respectively) (Table 10).

3. Size bias: Size related bias was examined by comparing the POH mean lengths of unrecovered marked chinook and recaptured chinook by sex. No size bias was evident in the recovery sample of adult male, adult female and jack chinook (Student's t-test: $t = 0.390$; $p<0.01$, $t = 0.641$; $p<0.01$, and $t = 0.358$; $p<0.01$, for males, females and jacks respectively).

BIOLOGICAL DATA

During the spawning ground carcass recovery 139 male, 96 female and 71 jack chinook carcasses were recovered and measured for post orbital-hypural length (Table 11). The lengths of adult male chinook carcasses ranged from 34 cm to 91 cm and averaged 61.9 cm, while adult female carcasses ranged from 45 cm to 84 cm and averaged 66.3 cm. Jack chinook carcasses ranged in lengths from 29 cm to 45 cm and averaged 40.7 cm. A total of seven male, three female and 15 jack chinook were missing adipose fins (5.0%, 3.1% and 21.1%, respectively) (Table 11). Age analysis reveals 49.5% of fish classified as adult male chinook were three years old, 65.2% of female chinook were three years old, and 98.2% of carcasses identified as jack chinook were two years old (Table 12).

A total of 28 male, 69 female and 12 jack fall run chinook were randomly collected from hatchery broodstock, measured for post orbital-hypural lengths and monitored for adipose-clipped fins (Table 13). Adult male chinook ranged from 45.7 cm to 74.1 cm and averaged 58.5 cm while female chinook lengths ranged from 44.1 cm to 81.8 cm and averaged 66.4 cm. Jack chinook lengths ranged from 36.5 cm to 44.5 cm and averaged 41.0 cm. Three males (10.7%), six females (8.7%) and eight jacks (66.7%) were found to be missing adipose fins (Table 13). Fish identified as adult male chinook were predominately three years old (52.4%), while 46.6 % of female chinook were three years old and 100.0% of jack chinook were two years old (Table 14).

When comparing the mean lengths of chinook recovered from the spawning grounds and fall run chinook sampled from hatchery broodstock, no statistical difference was apparent for male, female and jack chinook (Student's t-test: $t = 1.632$; $p<0.01$, $t = 0.140$; $p<0.01$ and $t = 0.288$; $p<0.01$ for males, females and jacks respectively).

A total of four male and 39 female First Lake spring run chinook were randomly collected from hatchery broodstock to be measured for POH lengths and monitored for the absence of adipose fins (Table 15). Male chinook ranged from 45.3 cm to 71.0 cm and averaged 60.6 cm while female chinook ranged from 51.7 cm to 74.5 cm and averaged 66.3 cm. There were no male chinook missing adipose fins and only two female chinook were adipose-clipped representing 5.1%. Three male and 17 female chinook had scales removed for age analysis, 64.7% of females were three years old (Table 16).

Coded-wire tags were recovered from 13 chinook carcasses sampled on the spawning grounds. All chinook identified as having a CWT were released from the Nanaimo River hatchery, with 11 chinook (84.6%) released during the 1999 brood year and two chinook (15.4%) released during the 1997 brood year (Table 17). A summary of the Nanaimo River Hatchery CWT and fry release data for 1996 to 2000 brood years is presented in Table 18.

WATER MANAGEMENT PLAN

Nanaimo River water releases occurred between 24 September and 27 September, 2001. The initial water release occurred at Fourth Lake at a discharge rate of 525 ft^3/s (~14.9 m^3/s) on 24 September and continually decreased to 375 ft^3/s (~10.6 m^3/s) on 26 September and 250 ft^3/s (~7.1 m^3/s) on 27 September. During this period 100 $ft/^3s$ (~2.8 m^3/s) was released from Jump Lake. The water release in 2001 was important in encouraging about 341 fish to pass through the fence during a 24-hour time period (Figure 4). A summary of monthly Nanaimo River discharge and ten year average is presented in Figure 5.

POPULATION ESTIMATE

Escapement and total return estimates for 2001 were determined using fence count data since these are considered to be the most accurate enumeration method. However, after reviewing both spawning ground carcass recovery and hatchery broodstock collection data, it became evident that the chinook fence count did not accurately reflect the true jack to adult ratio. Comparing the lengths of jack and adult chinook with the traditionally accepted jack designated length of 450 mm revealed an overlapping of age groups (Figure 6). As a result, the spawning ground carcass recovery data were utilised to apportion the total chinook fence count with a more reflective ratio of jack and adult chinook populations. This was accomplished by comparing age data with length data to calculate the proportion of 2-year old jack chinook with lengths greater then 450 mm (28.8%) and the proportion of 3-year old or greater adult chinook with lengths of 450 mm or less (1.4%). The fence count data were then adjusted by these proportions yielding total chinook fence counts of 1,398 adults and 1,399 jacks.

The number of naturally spawning fall run adult chinook in the Nanaimo River during 2001 was determined to be the adjusted fence count minus any fall run broodstock removals from areas above the fence. Following this methodology, the total number of adult fall run chinook spawning in the Nanaimo River was estimated to be 1,277 fish (Table 19). The total return of adult fall run chinook to the Nanaimo River was determined to be the sum of the adjusted fence count with the addition of broodstock removals below the fence and First Nation fishery catch, yielding 1,630 fish. The natural spawning population of First Lake spring run chinook estimated from swim surveys was 250 adult chinook and with the addition of First Lake broodstock removals yields a total spring run adult estimate of 419. Upper Nanaimo River spring run chinook swim survey counts were low and no adjustments were made to total spring run chinook estimates. Therefore, the total return of fall run and spring run adult chinook to the Nanaimo River was estimated to be 2,049 fish (Table 19).

DISCUSSION

ENUMERATION FENCE

The floating fence design worked well provided that debris was removed regularly. Water levels were similar to historical data and allowed fish to move through the trap box with little hesitation. Typically, fish hold beneath the fence as they search for a path through.

The possibility of the relocation of the fence inhibiting the upstream movement of chum above the fence has been noted in a previous report (Carter and Nagtegaal 2000). Staff indicated that while chinook and coho made every effort to pass through the fence and continue their migration, many chum were observed spawning below the counting fence. In order to encourage chum to spawn upstream of the enumeration fence, staff would open one or two fence panels during high chum abundance. This encouraged thousands of chum to pass the fence site and continue their migration upstream.

Water levels along with river discharge influenced on fish movement past the counting fence (Figure 4). This is particularly evident between 24 - 28 September 2001 during a scheduled water release resulting in peak chinook migration. The highest peak of chinook migration occurred on 16 October with an one day increase of 341 adult chinook after a rise in water levels.

SWIM SURVEY

Swim surveys conducted in the lower portion of the Nanaimo River provide supplemental information to the fence enumeration as well as spawning distribution of fall run chinook in the Nanaimo River. The natural spawning estimate for First Lake spring run chinook is based on hatchery swim surveys completed in the upper Nanaimo River and First Lake area. No Upper Nanaimo River spring run chinook estimate was calculated and because of the extremely low swim survey counts no adjustments were made to the total Nanaimo River chinook run.

NATIVE FOOD FISHERY

Catch estimation procedures developed by the Snuneymuxw First Nation have not been assessed by stock assessment staff. As a result, no comments can be made regarding the methodologies used. The 2001 estimate of 188 adult chinook was an increase over 1999, and 2000 years (Table 19). Since no observers were employed during 2001, SFN catch estimates could not be independently verified.

CARCASS MARK-RECAPTURE

Significant temporal biases for male chinook in the recovery sample as well as male and female chinook in the application samples were evident. This is likely due to the nature of the carcass recovery study, since tagging and recovery were concurrent activities. As a result, there were very few tagged carcasses available for recovery in the early period and as the number of tags in the population accumulated tag incidence in the later periods was higher. Conversely, no temporal bias was detected in female chinook from the recovery sample.

No sex related bias was evident in the application or recovery samples when male and female chinook were compared or when all chinook were compared. This suggests sex was not a contributing factor in recovering tagged carcasses.

Size bias testing did not provide an assessment of the size selectivity of the sampling method since both application and recovery samples were attained using the same method. Rather, the size bias assessment provided an evaluation of the recoverability, based on size, of tagged carcasses that were redistributed back into the river after tagging. Testing revealed that there were no size biases for male, female, or jack chinook.

BIOLOGICAL DATA

A comparison of male, female and jack fall run chinook mean lengths obtained from the spawning grounds and from the hatchery broodstock revealed no statistical difference. This may be due to the relatively non-selective collection methods used in both the carcass recovery and the hatchery broodstock collection. Furthermore, because both samples were collected from the fall run chinook stock, negligible variation in lengths was to be expected.

Coded-wire tag recoveries were mostly 1999 brood year (84.6%) which would be 2-year old jack chinook returning to spawn. Total fall run chinook hatchery releases for 1999 brood year were 410,196 with 176,242 carrying CWT's (Table 18). The lack of 1998 brood year recoveries is due to no CWT chinook being released from Nanaimo River Hatchery for that year.

WATER MANAGEMENT PLAN

The scheduled water release during 24 September to 27 September was gradually decreased in order to minimise the effects associated with a sudden rise in river levels. This release resulted in a migration peak as fish holding below the enumeration fence swam upstream during this brief period of increased river discharge.

POPULATION ESTIMATE

The 2001 Nanaimo River fall run chinook population estimate was based on the enumeration fence count. Clear water conditions for most of the study and no breaches in the fence allowed for a complete and accurate fish count. The fall run chinook spawning estimate of 1,277 was slightly higher than the 771 - 1133, 95% confidence interval obtained from the mark-recapture Petersen estimate. An underestimation by the Petersen estimate is consistent with 2000 results (Carter et al. 2003) and may be due to the mark-recapture study area which concentrates on the main spawning channel and does not include chinook that spawn outside of the surveyed area. The First Lake spring run population estimate was based on three swim surveys and broodstock collection conducted in the First Lake area. The 2001 estimate of 250 naturally spawning spring run adult chinook is below the 1995 – 2001 average of 386 adult chinook. The 2001 total return estimate for both fall run and spring run chinook of 2,049 is above the period average of 1,622 fish.

ACKNOWLEDGEMENTS

We would like to thank Ron Zenner, Clifford Thomas Jr., Nick Wyse, Less Thomas, Robin Good, Dave Key, Richard Seward, Glen Seward, Juan Moreno, Artie White, Wayne Jones, Rob Peters, Tina Wesley, Jamie Thomas, Dean Lulu and Garnet White for their assistance in the construction, installation, and monitoring of the enumeration fence as well as the collection of biological data. We gratefully acknowledge the Snuneymuxw First Nation for providing funding for labour throughout the project, and particularly the involvement of Jason Wyse. We thank Henry Bob, Patti McKay and the staff of the Nanaimo River Fish Hatchery for their support, guidance and assistance throughout the project. We thank John Baldwin from Ministry of Environment, Lands and Parks as well as Weyerhaeuser Canada and the Greater Nanaimo Water District. We also thank Randy Brahniuk, Gordon Curry, and local Fisheries Officers of Fisheries and Oceans Canada for their continued support in the project.

REFERENCES

Blackman, B. 1981. Nanaimo River Stock Assessment and enhancement proposals. 35+ p. (only chinook section available for Nanaimo River Library).

Brahniuk, R., B. Hurst and B. Tutty. 1993. Nanaimo River Salmon Management contingency plan: An overview. Discussion paper. Edited by Dr. B. Riddell, Pacific Biological Station. 20 p.

Carl, L.M. and M.C. Healey. 1984. Differences in enzyme frequency and body morphology among three juvenile life history types of chinook salmon (*Oncohynchus tshawytscha*) in Nanaimo River, British Columbia. Can J. Fish. Aquat. Sci 41: 1070–1077.

Carter, E.W. and D.A. Nagtegaal. 1997. A preliminary report on the adult chinook productivity study conducted on the Nanaimo River during 1995. Can. Manuscr. Rep. Fish. Aquat. Sci. 2414: 31 p.

Carter, E.W. and D.A. Nagtegaal. 1998. A preliminary report on the adult chinook productivity study conducted on the Nanaimo River during 1996. Can. Manuscr. Rep. Fish. Aquat. Sci. 2450: 29 p.

Carter, E.W. and D.A. Nagtegaal. 1999. Adult Chinook Escapement Assessment conducted on the Nanaimo River during 1997. Can. Manuscr. Rep. Fish. Aquat. Sci. 2482: 27 p.

Carter, E.W. and D.A. Nagtegaal. 2000. Adult Chinook Escapement Assessment conducted on the Nanaimo River during 1998. Can. Manuscr. Rep. Fish. Aquat. Sci. 2527: 29 p.

Carter E.W., D.A. Nagtegaal, N.K. Hop Wo and K.E. Jones. 2003. Adult Chinook Escapement Assessment Conducted on the Nanaimo River During 1999 and 2000. Can. Manuscr. Rep. Fish Aquat. Sci. 2653: 58 p.

Cross, C.L., L. Lapi, and E.A. Perry. 1991. Production of chinook and coho salmon from British Columbia hatcheries, 1971 through 1989. Can. Tech. Tech. Rep. Fish. Aquat. Sci. No. 1816.

Farlinger, S., N. Bourne, B. Riddell, D. Chalmers, and A. Tyler (Eds.). 1990. Pacific stock assessment review committee (PSARC) annual report for 1989. Can. Manuscr. Rep. Fish. Aquat. Sci. 2064: 236 p.

Hardie, D.C. 2002. Chinook salmon spawning habitat survey for the Nanaimo River, 2001. Prepared for Fisheries and Oceans Canada, Science Branch, Pacific Region, Pacific Biological Station, Nanaimo, British Columbia. 13 p + maps and appendices.

Healey, M.C. and F.P. Jordan. 1982. Observations on juvenile chum and chinook and spawning chinook in the Nanaimo River, British Columbia, during 1975-1981. Can. Manuscr. Rep. Fish. Aquat. Sci. 1659: iv + 31 p.

Healey, M.C. 1980. Utilization of the Nanaimo River estuary by juvenile chinook salmon, *Oncorhynchus tshawytscha*. Fish. Bull. 77: 654-668.

Koo, T.S.Y. 1962. Age designation in salmon, p. 41-48. In T.S.Y. Koo [ed.] Studies of Alaska red salmon. University of Washington Press, Seattle, Wash.

Ministry of Environment, Lands and Parks. 1993. Nanaimo River Water Management Plan. Water Management, Vancouver Island Regional Headquarters, Nanaimo, B.C.

Nagtegaal, D.A. and E.W. Carter. 2000. Results of rotary auger trap sampling in the Nanaimo River, 1999. Can. Manuscr. Rep. Fish. Aquat. Sci. 2502: 24 p.

Parken, C.K., and D.Y. Atagi. 2000. Preliminary estimate of the escapement of summer steelhead to the Nass River, 1998. British Columbia Ministry of Environment, Lands and Parks, Smithers, BC, Skeena Fisheries Report SK-124.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Can. 191: 382 p.

Schubert, N.D. 2000. The 1994 Stellako River sockeye (*Oncorhynchus nerka*) escapement: evaluation of pooled Petersen and stratified mark-recapture estimates of a known population. Can. Tech. Rep. Fish. Aquat. Sci. 2303: 56 p.

Taylor, E.B. 1990. Variability in agonistic behaviour and salinity tolerance between and within two populations of juvenile chinook salmon, *Oncorhynchus tshawytscha*, with contrasting life histories. Can. J. Fish. Aquat. Sci., vol. 47: 2172-2180.

Table 1. Daily counts at the Nanaimo River enumeration fence, 2001.

Date	Visibility[1]	Depth (cm)	Temp (°C)	Chinook Adult	Chinook Jack	Coho Adult	Coho Jack	Chum	Unknown
10-Sep	1	-	-	0	0	0	0	0	0
11-Sep	1	-	-	0	2	0	0	0	0
12-Sep	1	19.0	19.0	0	6	0	0	0	0
13-Sep	1	24.7	16.7	3	11	3	0	0	0
14-Sep	1	24.3	16.7	6	13	4	0	0	0
15-Sep	1	36.0	18.0	7	10	0	0	0	0
16-Sep	1	23.0	16.0	9	6	0	0	0	0
17-Sep	1	21.0	15.3	6	40	3	8	0	0
18-Sep	1	27.3	16.0	7	21	1	2	0	0
19-Sep	1	27.3	15.0	15	23	3	2	0	0
20-Sep	1	27.3	15.0	3	16	1	0	0	0
21-Sep	1	23.0	16.0	2	3	0	0	0	0
22-Sep	1	18.0	16.0	24	28	1	0	0	0
23-Sep	1	20.3	15.3	1	9	2	0	0	0
24-Sep	1	20.7	15.7	11	36	0	2	0	0
25-Sep	1-2	27.3	14.0	29	38	0	1	3	0
26-Sep	1-2	39.0	16.0	124	27	1	3	0	2
27-Sep	1-2	44.0	15.0	124	111	3	1	0	1
28-Sep	1-2	47.3	14.0	62	65	6	0	7	1
29-Sep	1	39.7	14.0	37	29	0	0	0	0
30-Sep	1	36.7	14.0	22	28	4	0	0	0
1-Oct	1	37.0	14.7	12	22	3	1	0	1
2-Oct	1	34.3	13.0	24	8	6	3	2	2
3-Oct	1	31.0	13.0	40	28	4	0	0	0
4-Oct	1	27.0	13.0	11	23	2	0	4	0
5-Oct	1	23.0	11.7	12	11	3	0	2	0
6-Oct	1	18.0	11.5	4	6	0	0	4	0
7-Oct	1	18.3	12.0	13	9	0	0	3	0
8-Oct	1	18.0	11.7	21	8	0	1	49	0
9-Oct	1	20.0	11.3	49	4	0	0	38	1
10-Oct	1	27.3	10.7	79	16	1	1	93	1
11-Oct	1	28.0	10.7	79	22	55	12	941	1
12-Oct	1	40.3	11.0	33	10	9	1	617	2
13-Oct	1	45.0	10.0	13	6	7	1	442	0
14-Oct	1	50.0	11.0	19	14	10	2	436	1
15-Oct	1	39.3	10.3	269	9	12	13	365	0
16-Oct	1-2	38.7	10.3	341	14	38	2	3087	0
17-Oct	1	38.0	10.0	84	5	11	5	2279	0
18-Oct	1	43.3	10.0	86	6	7	0	1243	0

Table 1. (continued)

Date	Visibility[1]	Depth (cm)	Temp (°C)	Chinook Adult	Chinook Jack	Coho Adult	Coho Jack	Chum	Unknown
19-Oct	1	42.7	10.7	24	12	21	9	1133	0
20-Oct	1-2	39.3	10.0	11	10	2	9	800	0
21-Oct	1	30.7	10.0	19	7	14	10	867	0
22-Oct	1	33.0	9.7	12	12	5	5	1312	0
23-Oct	1-2	67.0	9.3	88	21	260	99	6967	0
24-Oct	2	78.3	9.3	12	5	112	20	3139	0
25-Oct	2	68.3	9.7	0	1	102	12	1548	0
26-Oct	1	63.7	10.0	3	5	51	14	2789	1
27-Oct	2	94.7	9.7	5	14	49	19	3660	0
28-Oct	1	87.3	8.7	5	2	35	5	1371	0
29-Oct	1	72.7	8.0	62	20	154	67	700	0
30-Oct[2]	1	62.0	8.0	23	0	52	3	124	0
Total				1945	852	1057	333	34025	14

[1] Visibility Code: 1 = clear; 2 = cloudy.
[2] Partial enumeration from 0000-0800 hours.

Table 2. Total counts by time interval at the Nanaimo River enumeration fence, 2001.

Time Period	Chinook				Coho				Chum	
	Adult		Jack		Adult		Jack			
	Count	%	Count	%	Count	%	Count	%	Count	%
0000 - 0100	49	2.5	40	4.7	49	4.6	20	6.0	1216	3.6
0100 - 0200	65	3.3	70	8.2	54	5.1	23	6.9	730	2.1
0200 - 0300	50	2.6	101	11.9	37	3.5	1	0.3	645	1.9
0300 - 0400	48	2.5	43	5.0	37	3.5	9	2.7	700	2.1
0400 - 0500	50	2.6	33	3.9	58	5.5	21	6.3	795	2.3
0500 - 0600	33	1.7	32	3.8	42	4.0	17	5.1	881	2.6
0600 - 0700	23	1.2	12	1.4	27	2.6	8	2.4	886	2.6
0700 - 0800	33	1.7	18	2.1	18	1.7	5	1.5	1315	3.9
0800 - 0900	194	10.0	25	2.9	84	7.9	13	3.9	2470	7.3
0900 - 1000	179	9.2	30	3.5	23	2.2	3	0.9	1853	5.4
1000 - 1100	198	10.2	47	5.5	61	5.8	19	5.7	2577	7.6
1100 - 1200	155	8.0	49	5.8	37	3.5	11	3.3	1470	4.3
1200 - 1300	113	5.8	32	3.8	71	6.7	19	5.7	1485	4.4
1300 - 1400	94	4.8	27	3.2	74	7.0	16	4.8	2369	7.0
1400 - 1500	104	5.3	27	3.2	47	4.4	17	5.1	2152	6.3
1500 - 1600	112	5.8	31	3.6	41	3.9	20	6.0	2077	6.1
1600 - 1700	87	4.5	39	4.6	35	3.3	13	3.9	1616	4.7
1700 - 1800	97	5.0	38	4.5	48	4.5	11	3.3	1833	5.4
1800 - 1900	89	4.6	27	3.2	51	4.8	15	4.5	2006	5.9
1900 - 2000	57	2.9	25	2.9	32	3.0	13	3.9	1133	3.3
2000 - 2100	38	2.0	21	2.5	39	3.7	26	7.8	869	2.6
2100 - 2200	30	1.5	23	2.7	28	2.6	18	5.4	1043	3.1
2200 - 2300	27	1.4	33	3.9	37	3.5	7	2.1	949	2.8
2300 - 2400	20	1.0	29	3.4	27	2.6	8	2.4	955	2.8
Total	1945	100	852	100	1057	100	333	100	34025	100

Table 3. Swim surveys conducted on the Nanaimo River, 2001.

Fall Run Chinook

Date	Area [1]	Adult Chinook
13-Sep	Pumphouse Pool to Cedar Bridge	497
01-Oct	Dyke Pool to San Salvadore	130
02-Oct	San Salvadore	103
09-Oct	Bridge Pool / Dyke Pool / Swimming Hole	64
10-Oct	Bridge Pool to Log Jam	62
12-Oct	Log Jam to Dyke Pool	188 [2]
17-Oct	Log Jam / San Salvadore	64
22-Oct	Log Jam / San Salvadore	13
23-Oct	Log Jam / San Salvadore	7
26-Oct	Bridge Pool to Log Jam	14
05-Nov	Log Jam / San Salvadore	9
06-Nov	Log Jam	1
07-Nov	Bridge Pool	0

First Lake Spring Run Chinook

Date	Area	Adult Chinook
07-Jun	First Lake Area	40
21-Sep	First Lake Area	64
04-Oct	First Lake Area	435 [2]

Upper Nanaimo River Spring Run Chinook

Date	Area	Adult Chinook
07-Jun	Above Second Lake	1
18-Jul	Above Second Lake	0
21-Sep	Above Second Lake	2
28-Sep	Above Second Lake	15
13-Oct	Above Second Lake	1

[1] See Figure 2.
[2] Includes adult and jack chinook.

Table 4. Summary by day and location, of chinook collected for Nanaimo River Hatchery broodstock, 2001.

Fall Run Chinook

Date	Location Code[1]	Below Fence			Above Fence		
		Male	Jack	Female	Male	Jack	Female
02-Oct	6	5	0	0	-	-	-
09-Oct	22	-	-	-	6	0	6
10-Oct	22	-	-	-	6	0	5
11-Oct	6	24	5	15	-	-	-
12-Oct	31	-	-	-	0	0	10
15-Oct	31	-	-	-	10	3	10
16-Oct	31	-	-	-	10	4	20
17-Oct	31	-	-	-	2	0	6
18-Oct	22	-	-	-	0	6	2
19-Oct	31	-	-	-	6	0	4
22-Oct	31	-	-	-	0	0	2
23-Oct	31	-	-	-	2	0	1
24-Oct	31	-	-	-	2	1	3
26-Oct	31	-	-	-	3	0	5
Total		29	5	15	47	14	74

First Lake Spring Run Chinook

Date	Location	Below Fence			Above Fence		
		Male	Jack	Female	Male	Jack	Female
02-Oct	First Lake	-	-	-	65	11	28
04-Oct	First Lake	-	-	-	49	16	27
Total		-	-	-	114	27	55

[1] See Figure 2.

Table 5. Daily summary of chinook sampled during the carcass mark-recapture program, Nanaimo River, 2001.

	Carcasses Examined				Tags Applied				Recaptured Carcasses			
Date	Unkn	Male	Female	Jack	Unkn	Male	Female	Jack	Unkn	Male	Female	Jack
2-Nov	0	24	17	3	0	24	17	3	0	0	0	0
5-Nov	0	31	23	16	0	27	21	16	0	4	2	0
6-Nov	0	22	11	19	0	18	10	16	0	4	1	3
7-Nov	0	12	6	9	0	12	4	9	0	0	2	0
8-Nov	0	35	29	17	0	25	17	12	0	10	12	5
9-Nov	0	17	20	13	0	6	11	9	0	11	9	4
13-Nov	1	13	11	5	1	10	7	2	0	3	4	3
14-Nov	0	1	1	0	0	1	1	0	0	0	0	0
19-Nov	2	16	4	4	2	12	1	3	0	4	3	1
22-Nov	0	2	4	0	0	1	4	0	0	1	0	0
23-Nov	0	0	4	1	0	0	1	1	0	0	2	0
26-Nov	0	4	1	2	0	2	1	0	0	2	0	1
27-Nov	0	1	3	0	0	1	3	0	0	0	0	0
29-Nov	0	0	1	0	0	0	0	0	0	0	1	0
30-Nov	0	0	3	0	0	0	0	0	0	0	3	0
Total	3	178	138	89	3	139	98	71	0	39	39	17

Table 6. Petersen chinook escapement estimates by sex, Nanaimo River, 2001

Sex	Population Estimate	95% Confidence Limits	
		Lower	Upper
Male [1]	627	457	796
Female	342	253	430
Total Adult	**952**	**771**	**1133**
Jack	356	213	499
Total Population	1323	1092	1553

[1] Adult males only, jacks not included.

Table 7. Incidence of tagged adult chinook carcasses recovered on the spawning grounds by recovery period and sex, Nanaimo River, 2001.

Recovery Period	Days of Recovery	Tagged Recoveries			Total Recoveries			Tag Incidence (%)		
		Male	Female	Total	Male	Female	Total	Male	Female	Total
Nov 2 - Nov 8	7	18	17	35	124	86	210	14.52	19.77	16.67
Nov 9 - Nov 15	7	14	13	27	31	32	63	45.16	40.63	42.86
Nov 16 - Nov 23	8	5	5	10	18	12	30	27.78	41.67	33.33
Nov 24 - Nov 30	7	2	6	8	5	12	17	40.00	50.00	47.06
Total	29	39	41	80	178	142	320	21.91	28.87	25.00
Chi-Square Test Result:								15.08	9.19	
Critical Chi-Square (df = 3; p<0.01)								11.35	11.35	

Table 8. Percentage of the tag application sample recovered on the spawning grounds, by application period and sex, Nanaimo River, 2001.

Application Period	Days of Application	Tags Applied Male	Tags Applied Female	Tags Applied Total	Tagged Recoveries Male	Tagged Recoveries Female	Tagged Recoveries Total	Percent Recovered Male	Percent Recovered Female	Percent Recovered Total
Nov 2 - Nov 8	7	106	69	175	18	17	35	16.98	24.64	20.00
Nov 9 - Nov 15	7	17	19	36	14	13	27	82.35	68.42	75.00
Nov 16 - Nov 23	8	13	6	19	5	5	10	38.46	83.33	52.63
Nov 24 - Nov 30	7	3	5	8	2	6	8	66.67	120.00	100.00
Total		139	99	238	39	41	80	28.06	41.41	33.61
Chi-Square test result:								34.18	30.79	
Critical Chi-Square (df = 3; p<0.01)								11.35	11.35	

Table 9. Sex composition of chinook in the tag application and recovery samples, Nanaimo River, 2001.

Sex	Application sample by recovery status: Sample Size	Recovered	Not Recovered	Total	Recovery sample by mark status: Sample Size	Marked	Not Marked	Total
Male	139	50.0%	62.9%	58.6%	178	50.0%	58.4%	56.3%
Female	98	50.0%	37.1%	41.4%	138	50.0%	41.6%	43.7%
Chi-Square test result:				3.59				1.69
Critical Chi-Square (df = 1; p<0.01)				6.64				6.64

Table 10. Sex composition of chinook in the tag application and recovery samples, Nanaimo River, 2001 (jacks included).

Sex	Application sample by recovery status: Sample Size	Recovered	Not Recovered	Total	Recovery sample by mark status: Sample Size	Marked	Not Marked	Total
Male	139	41.1%	46.9%	45.1%	178	41.1%	44.8%	44.0%
Female	98	41.1%	27.7%	31.8%	138	41.1%	31.9%	34.1%
Jack	71	17.9%	25.4%	23.1%	89	17.9%	23.2%	22.0%
Chi-Square test result:				5.77				2.95
Critical Chi-Square (df = 2; p<0.01)				9.21				9.21

Table 11. Length-frequency of chinook sampled during the carcass mark-recapture program, Nanaimo River, 2001.

Length (cm)	Males	Jacks	Females
29	0	1	0
30	0	1	0
31	0	1	0
32	0	0	0
33	0	1	0
34	1	2	0
35	0	0	0
36	0	3	0
37	0	7	0
38	1	5	0
39	0	3	0
40	0	4	0
41	0	8	0
42	1	6	0
43	0	7	0
44	0	7	0
45	0	15	1
46	16	0	1
47	3	0	0
48	3	0	0
49	3	0	0
50	2	0	1
51	0	0	1
52	1	0	0
53	2	0	1
54	1	0	0
55	1	0	1
56	1	0	0
57	2	0	1
58	4	0	2
59	3	0	7
60	7	0	3
61	7	0	4
62	3	0	5
63	3	0	7
64	9	0	5
65	9	0	5
66	7	0	6

Table 11. (continued)

Length (cm)	Males	Jacks	Females
67	8	0	4
68	6	0	3
69	5	0	9
70	1	0	2
71	4	0	5
72	7	0	2
73	0	0	5
74	7	0	2
75	1	0	0
76	5	0	5
77	1	0	3
78	0	0	1
79	2	0	1
80	1	0	1
81	0	0	0
82	0	0	1
83	0	0	0
84	0	0	1
85	0	0	0
86	0	0	0
87	0	0	0
88	0	0	0
89	0	0	0
90	0	0	0
91	1	0	0
Total	139	71	96
Mean Length (cm)	61.9	40.7	66.3
Std. Deviation	10.3	4.0	7.4
Adipose Clips	7	15	3
Mark Rate	5.0%	21.1%	3.1%

Table 12. Summary of age data from chinook sampled during the carcass mark-recapture program, Nanaimo River, 2001.

European Age[1]	Brood Year	Total Age	Males #	Males %	Females #	Females %	Total adult #	Total adult %	Jacks #	Jacks %
0.1	1999	2	25	25.8	0	0.0	25	15.1	55	98.2
0.2	1998	3	48	49.5	43	62.3	91	54.8	1	1.8
1.1	1998	3	0	0.0	2	2.9	2	1.2	0	0.0
0.3	1997	4	24	24.7	24	34.8	48	28.9	0	0.0
Total			97	100.0	69	100.0	166	100.0	56	100.0

[1] The first number indicates the number of annuli formed in freshwater, the second number indicates the number of annuli formed in the ocean (Koo 1962).

Total number of unreadable scales: 86

Table 13. Length-frequency of fall run chinook sampled during broodstock collection, Nanaimo River, 2001

Length (cm)	Males	Jacks	Females
36	0	1	0
37	0	0	0
38	0	2	0
39	0	1	0
40	0	1	0
41	0	1	0
42	0	1	0
43	0	2	0
44	0	3	1
45	0	0	1
46	3	0	0
47	3	0	0
48	1	0	0
49	1	0	0
50	0	0	0
51	0	0	0
52	0	0	0
53	0	0	0
54	0	0	1
55	0	0	0
56	2	0	2
57	1	0	1
58	0	0	0
59	0	0	1
60	2	0	6
61	3	0	5
62	2	0	2
63	3	0	3
64	3	0	4
65	0	0	3
66	0	0	3
67	0	0	3
68	2	0	6
69	0	0	6
70	0	0	1
71	0	0	3
72	0	0	5
73	1	0	2
74	1	0	3

Table 13. (continued)

Length (cm)	Males	Jacks	Females
75	0	0	1
76	0	0	2
77	0	0	1
78	0	0	1
79	0	0	0
80	0	0	1
81	0	0	0
82	0	0	1
Total	28	12	69
Mean Length (cm)	58.5	41.0	66.4
Std. Deviation	8.5	2.7	7.1
Adipose Clips	3	8	6
Mark Rate	10.7%	66.7%	8.7%

Table 14. Summary of age data from fall run chinook broodstock collection, Nanaimo River, 2001

European Age [1]	Brood Year	Total Age	Males #	Males %	Females #	Females %	Total #	Total %	Jacks #	Jacks %
0.1	1999	2	8	38.1	7	12.1	15	19.0	9	100.0
0.2	1998	3	11	52.4	27	46.6	38	48.1	0	0.0
0.3	1997	4	2	9.5	24	41.4	26	32.9	0	0.0
Total			21	100.0	58	100.0	79	100.0	9	100.0

[1] The first number indicates the number of annuli formed in freshwater, the second number indicates the number of annuli formed in the ocean (Koo 1962).

Total number of unreadable scales: 14

Table 15. Length-frequency of First Lake spring run chinook sampled during broodstock collection, Nanaimo River, 2001.

Length (cm)	Males	Jacks	Females
45	1	0	0
46	0	0	0
47	0	0	0
48	0	0	0
49	0	0	0
50	0	0	0
51	0	0	0
52	0	0	1
53	0	0	0
54	0	0	0
55	0	0	0
56	0	0	1
57	0	0	0
58	1	0	1
59	0	0	1
60	0	0	0
61	0	0	2
62	0	0	2
63	0	0	2
64	0	0	1
65	0	0	4
66	0	0	4
67	1	0	1
68	0	0	5
69	0	0	4
70	0	0	5
71	1	0	1
72	0	0	0
73	0	0	2
74	0	0	2
Total	4	0	39
Mean Length (cm)	60.6	-	66.3
Std. Deviation	11.5	-	4.9
Adipose Clips	0	0	2
Mark Rate	0	-	5.1%

Table 16. Summary of age data from First Lake spring run chinook broodstock collection, Nanaimo River, 2001

European Age [1]	Brood Year	Total Age	Males #	Males %	Females #	Females %	Total #	Total %	Jacks #	Jacks %
0.1	1999	2	1	33.3	0	0.0	1	5.0	0	0.0
0.2	1998	3	2	66.7	10	58.8	12	60.0	0	0.0
1.1	1998	3	0	0.0	1	5.9	1	5.0	0	0.0
0.3	1997	4	0	0.0	5	29.4	5	25.0	0	0.0
1.2	1997	4	0	0.0	1	5.9	1	5.0	0	0.0
Total			3	100.0	17	100.0	20	100.0	0	0.0

[1] The first number indicates the number of annuli formed in freshwater, the second number indicates the number of annuli formed in the ocean (Koo 1962).

Total number of unreadable scales: 0

Table 17. Coded-wire tag code data from chinook sampled on the spawning grounds, Nanaimo River, 2001.

Recovery Data				Release Data			
Date (dd/mm/yy)	Location	POH Length (mm)	Sex	Brood Year	Tag Code	Location	Date (dd/mm/yy)
02/11/01	20	470	M		No Data		
02/11/01	20	460	M		No Data		
02/11/01	19	300	J		No Data		
05/11/01	17	710	F		No Data		
05/11/01	17	490	M	1999	184333	Nanaimo River	18/05/00
05/11/01	17	390	J	1999	184332	Nanaimo River	18/05/00
05/11/01	17	450	J	1997	182408	Nanaimo River	26/05/98
05/11/01	15	440	J		No Pin		
06/11/01	13	370	J	1999	184333	Nanaimo River	18/05/00
06/11/01	14	460	M	1999	184333	Nanaimo River	18/05/00
06/11/01	12	440	J	1999	184331	Nanaimo River	18/05/00
06/11/01	12	410	J	1999	184332	Nanaimo River	18/05/00
07/11/01	9	430	J		No Pin		
07/11/01	10	460	M	1999	184334	Nanaimo River	18/05/00
08/11/01	20	820	F	1997	183223	Nanaimo River	05/26/98
08/11/01	20	800	F		No Pin		
08/11/01	18	420	J	1999	184334	Nanaimo River	18/05/00
08/11/01	18	450	J	1999	184336	Nanaimo River	23/05/00
08/11/01	15	450	J	1999	184332	Nanaimo River	18/05/00
08/11/01	19	440	J		No Data		
09/11/01	17	410	J	1999	184331	Nanaimo River	18/05/00
09/11/01	16	450	J		No Pin		
19/11/01	15	620	M		No Data		
23/11/01	18	410	J		No Pin		
27/11/01	12	490	M		No Pin		

Table 18. Nanaimo River Hatchery chinook release data for brood years 1996 - 2000.

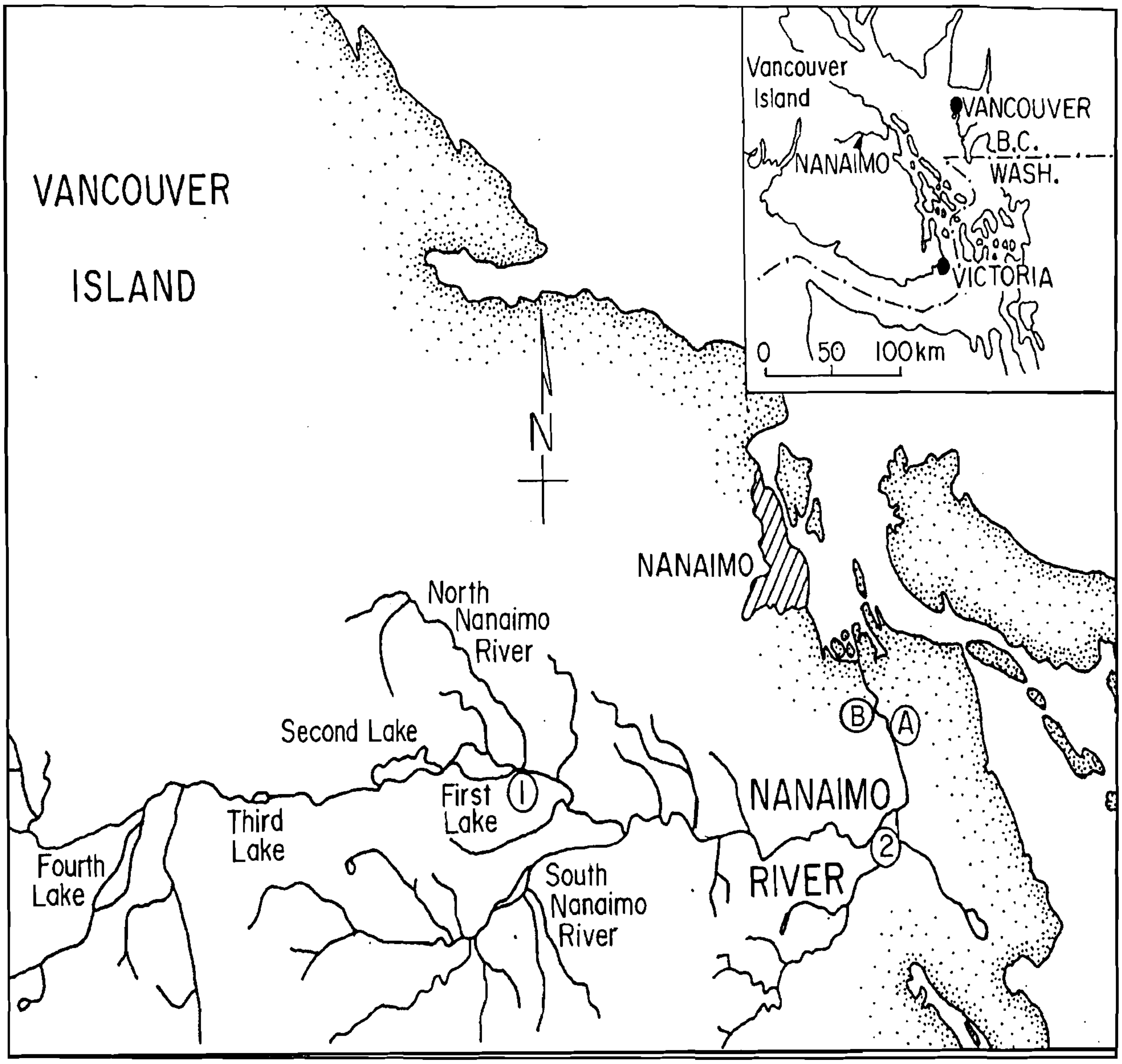
Tagcode	Brood Year	Number Tagged	Number Released	CWT % Marked	Weight (g)	Start Release Date	End Release Date	Release Site	Run Type
182747	1996	28525	115033	24.8	5.44	05/05/97	05/05/97	Nanaimo R.	Fall
182306	1996	9132	36827	24.8	5.44	05/05/97	05/05/97	Nanaimo R.	Fall
183454	1996	10095	42937	23.51	6.22	20/05/97	20/05/97	First Lake	Spring[1]
183453	1996	10077	42861	23.51	6.22	20/05/97	20/05/97	First Lake	Spring[1]
183452	1996	10052	42755	23.51	6.22	20/05/97	20/05/97	First Lake	Spring[1]
183455	1996	10050	42746	23.51	6.22	20/05/97	20/05/97	First Lake	Spring[1]
181716	1996	10025	83484	12.01	4.94	20/05/97	21/05/97	Nanaimo R.	Fall
182746	1996	27690	230592	12.01	4.94	20/05/97	21/05/97	Nanaimo R.	Fall
183220	1997	25240	70000	36.06	6.67	07/05/98	07/05/98	First Lake	Spring[1]
183221	1997	25173	99098	25.4	6	15/05/98	15/05/98	First Lake	Spring[1]
183223	1997	28252	43881	64.38	6.01	26/05/98	26/05/98	Nanaimo R.	Fall
182408	1997	10050	15610	64.38	6.01	26/05/98	26/05/98	Nanaimo R.	Fall
183222	1997	24824	24824	100	15.5	23/07/98	23/07/98	Jack Point	Fall
184330	1999	25185	257394	9.78	4.03	17/05/00	17/05/00	First Lake	Spring[1]
184332	1999	25071	25071	100	5.1	18/05/00	18/05/00	Nanaimo R.	Fall
184331	1999	25185	25185	100	5.1	18/05/00	18/05/00	Nanaimo R.	Fall
184333	1999	25165	25165	100	5.1	18/05/00	18/05/00	Nanaimo R.	Fall
184334	1999	25231	25231	100	5.1	18/05/00	18/05/00	Nanaimo R.	Fall
184335	1999	25300	126422	20.01	5	05/05/00	23/05/00	Nanaimo R.	Fall
184336	1999	25115	125497	20.01	5	05/05/00	23/05/00	Nanaimo R.	Fall
184329	1999	25175	57625	43.69	10.34	23/06/00	23/06/00	Jack Point	Fall
184363	2000	24739	207955	11.9	6.56	23/05/01	24/05/01	First Lake	Spring[1]
184552	2000	50060	105512	47.44	4.9	28/04/01	29/05/01	Nanaimo R.	Fall
184554	2000	50259	105931	47.45	4.9	28/04/01	29/05/01	Nanaimo R.	Fall
184553	2000	50254	105920	47.45	4.9	28/04/01	29/05/01	Nanaimo R.	Fall
184362	2000	25091	51070	49.13	8.67	06/06/01	06/06/01	Jack Point	Fall

[1] First Lake spring run chinook only.

Table 19. Total adult chinook returns to the Nanaimo River, 1975-2001.

	Natural Spawners		Hatchery Broodstock		Native Food	Total
Year	Fall	Spring [1]	Fall	Spring [1]	Fish Catch	Returns
1975	475	-	-		15	490
1976	880	-	-		50	930
1977	2380	-	-		60	2420
1978	2125	-	-		40	2165
1979	2700	-	41		23	2764
1980	2900	-	82		200	3182
1981	210	-	15		100	325
1982	1090	-	62		21	1173
1983	1600	-	240		30	1870
1984	3000	-	178		50	3228
1985	650	-	264		185	1099
1986	700	-	258		190	1148
1987	400	-	357		50	807
1988	650	-	429		0	1079
1989	1150	-	402		0	1552
1990	1275	-	122		0	1397
1991	800	-	135		0	935
1992	800	-	377		0	1177
1993	850	-	528		0	1378
1994	400	-	280		0	742
1995	1592 [2]	100	311	75	0	2078 [3]
1996	990 [2]	600	257	167	0	2014 [3]
1997	638 [2]	600	52	129	0	1419 [3]
1998	1011 [2]	200	251	89	0	1551 [3]
1999	1920 [4]	500	242	179	70	2911 [5]
2000	596 [6]	450	184	162	126	1518 [3]
2001	1277 [6]	250	165	169	188	2049 [3]

[1] First Lake spring run chinook only.
[2] Count at enumeration fence minus fall broodstock removal above the fence.
[3] Fall natural spawners plus fall broodstock removal below the fence, Native food fish catch and spring run estimate.
[4] Mark recapture Peterson estimate.
[5] Mark recapture estimate plus fall broodstock removal, Native food fish catch and spring run estimate.
[6] Adjusted fence count minus fall broodstock removal above the fence.



LEGEND:

1	Hatchery Release Site
2	Hatchery Release Site
A	Enumeration Fence Site
B	Downstream Fry Trapping Site

Figure 1. Nanaimo River study area.

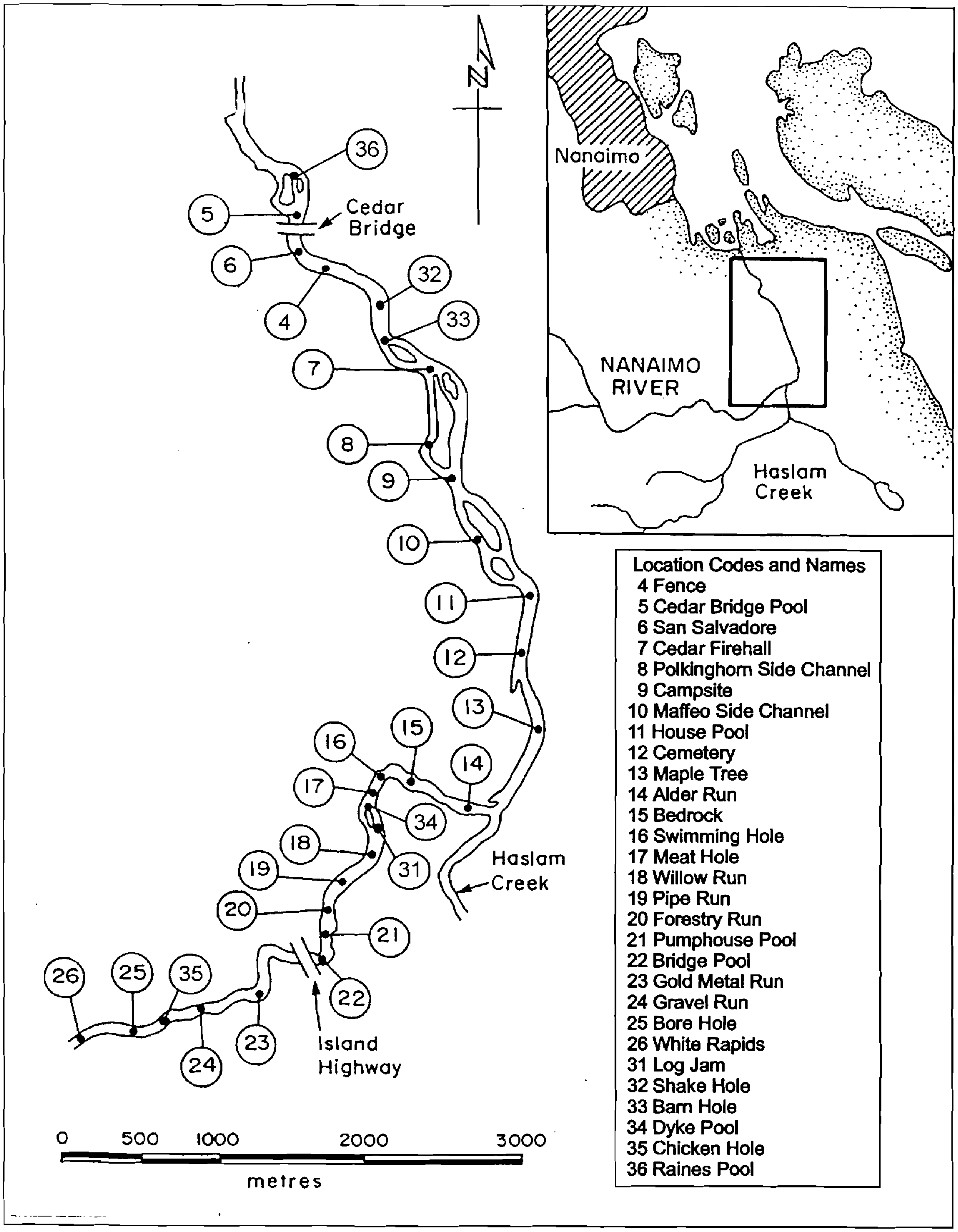


Figure 2. Swim survey and mark-recapture sites on the Nanaimo River.

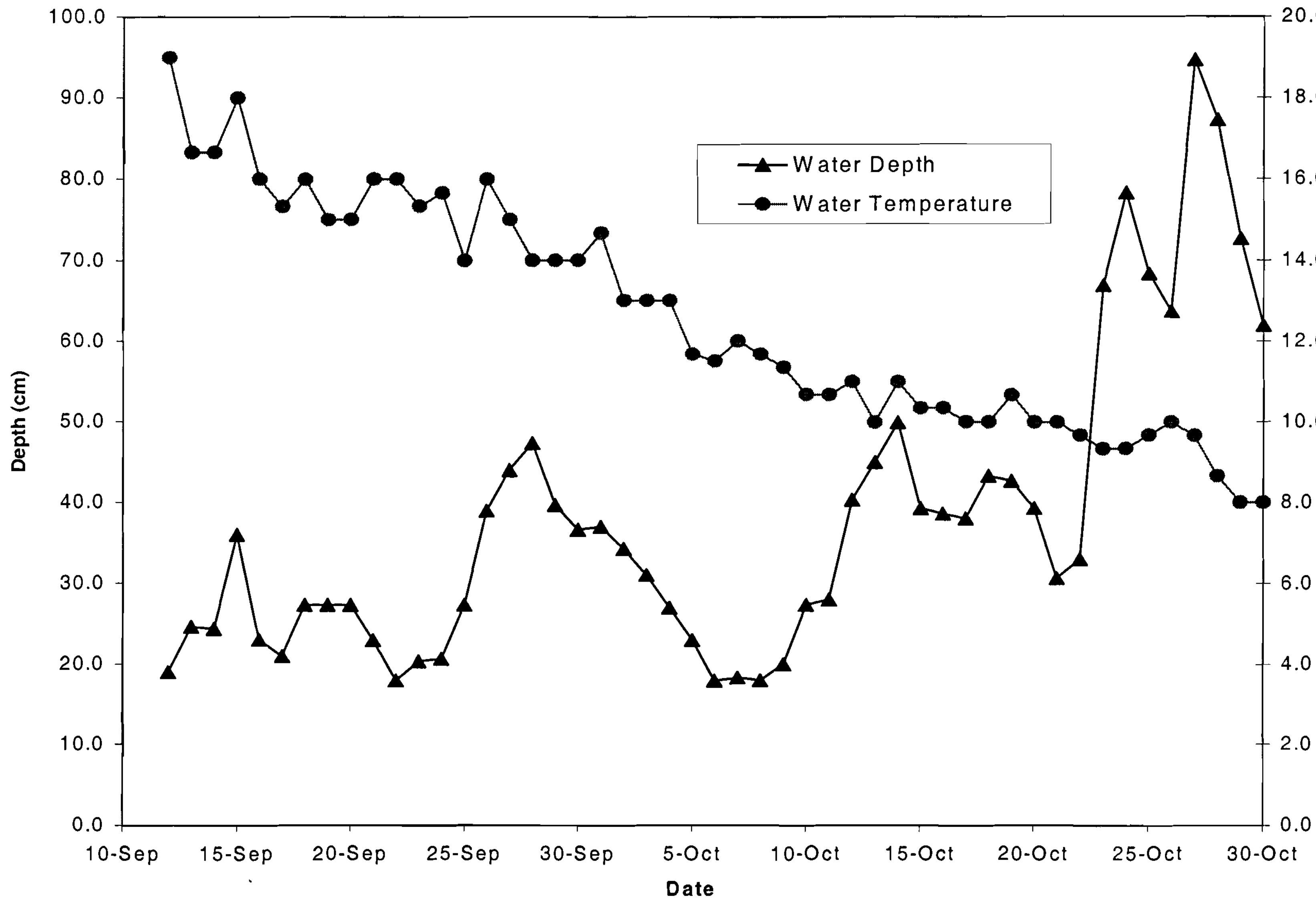


Figure 3. Average water depth and water temperature at the Nanaimo River enumeration fence, 2001.

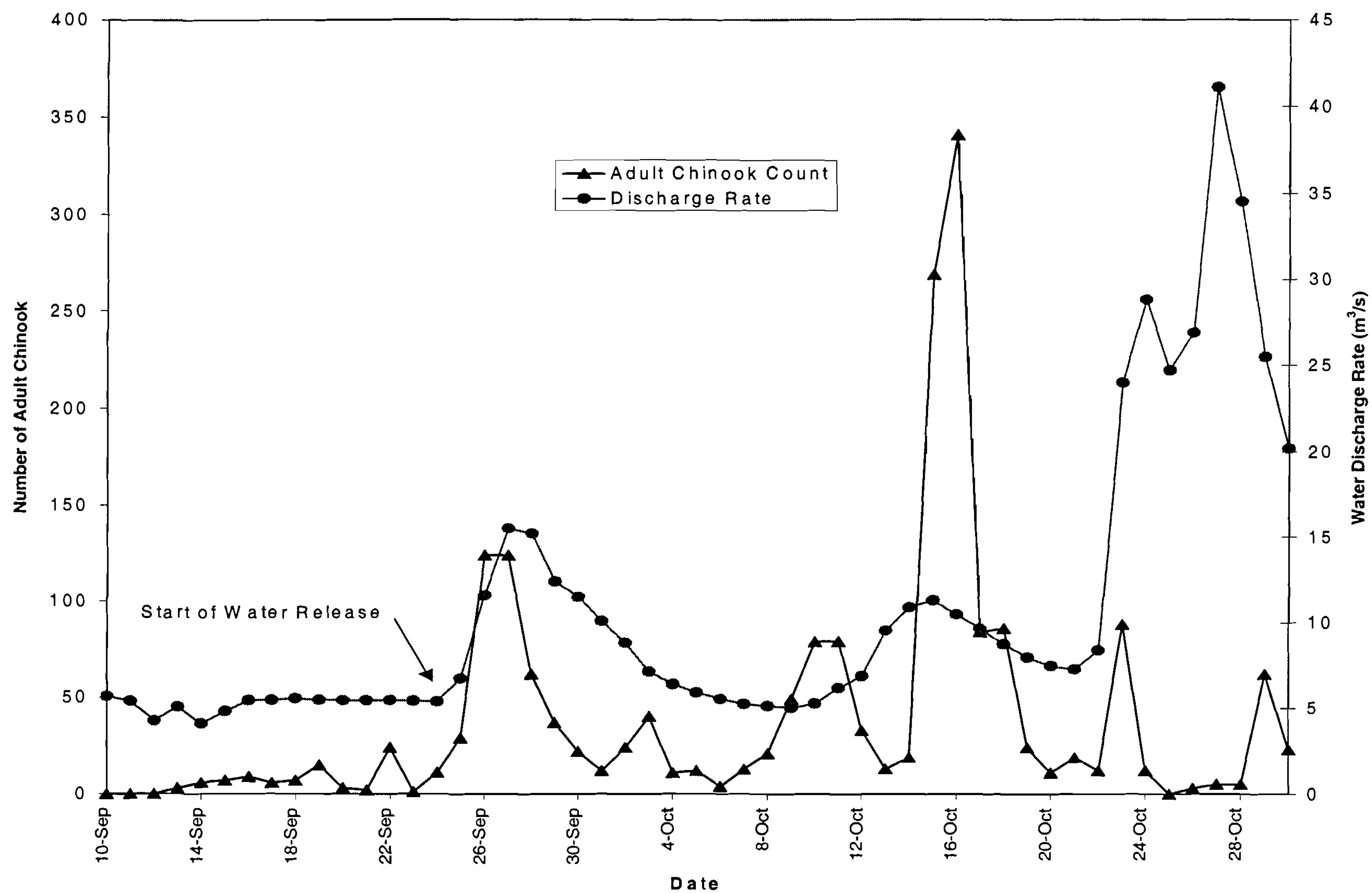


Figure 4. Discharge rate and adult chinook count for the Nanaimo River, 2001.

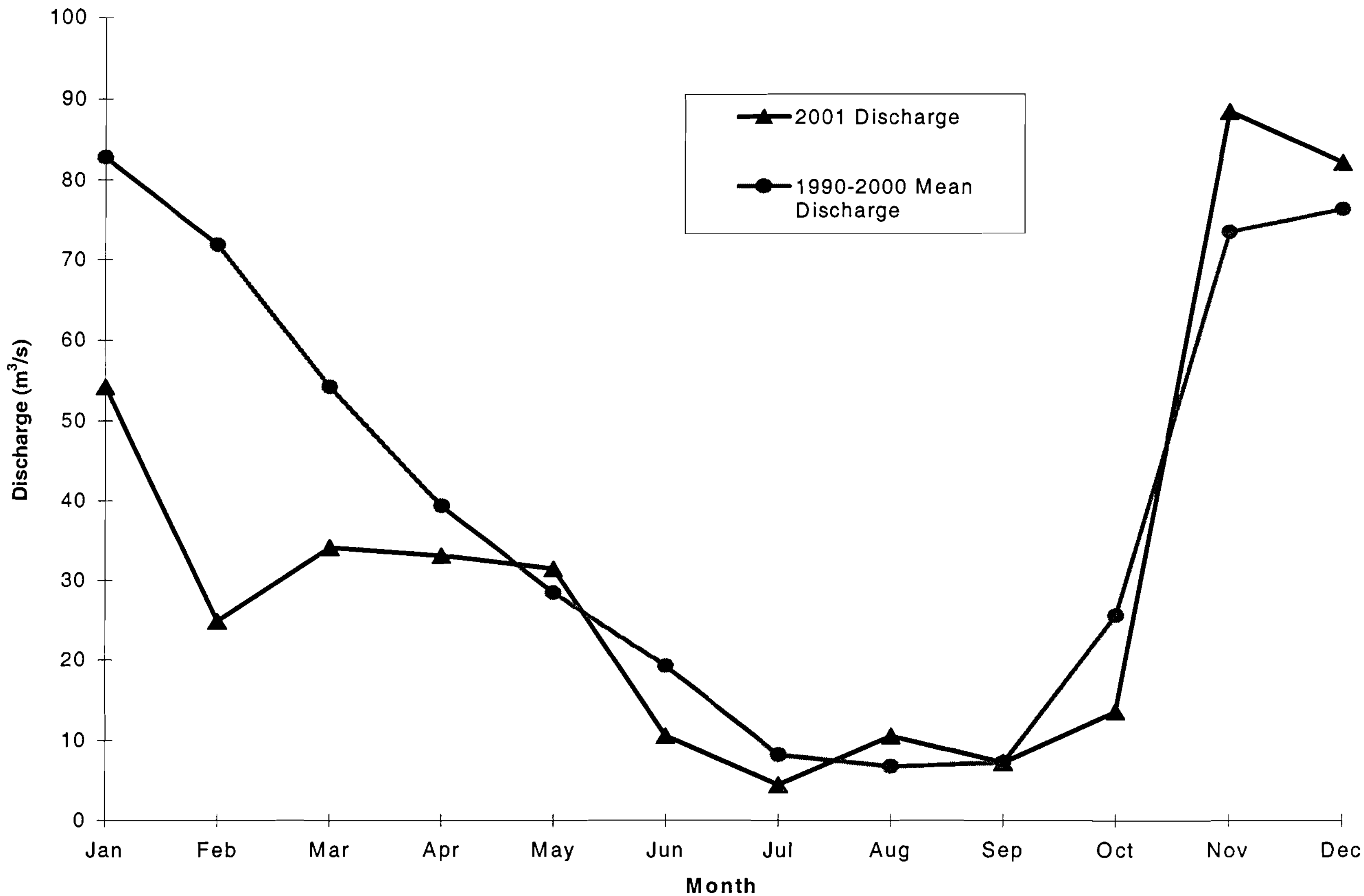


Figure 5. Monthly Nanaimo River discharge (m^3/s) in 2001 along with historical values.

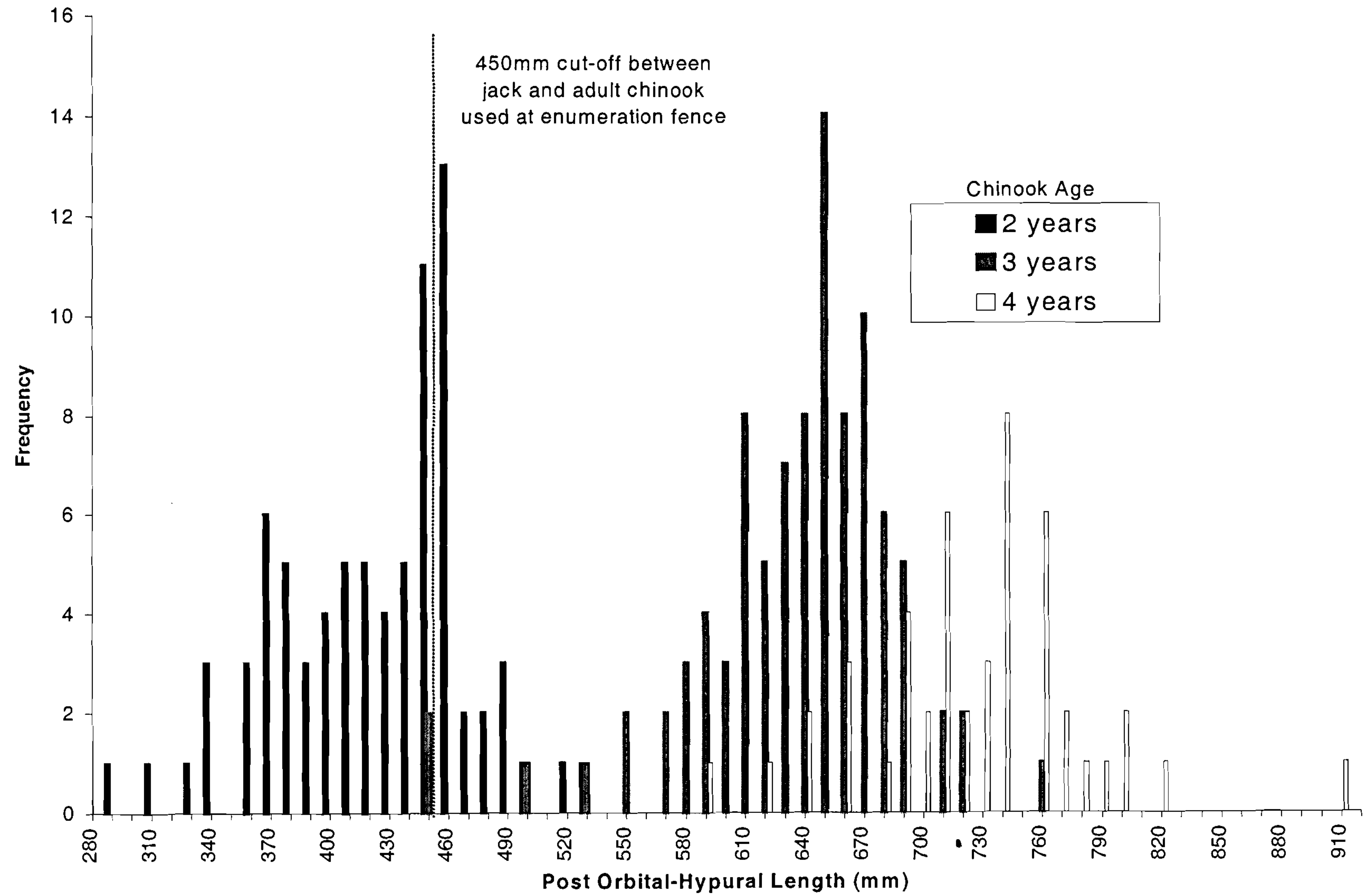


Figure 6. Adult and jack chinook length-frequencies collected from the Nanaimo River spawning grounds, 2001.