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JUVENILE CHINOOK PRODUCTION IN THE NANAIMO RIVER, 2000 - 2002

by

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During 2000 – 2002, a study of juvenile chinook salmon (*Oncorhynchus tshawytscha*) productivity was continued by Fisheries and Oceans Canada, South Coast Salmon Stock Assessment, together with the Snuneymuxw First Nation. The three key elements of this yearly project are: i) enumeration of juvenile out-migrants, ii) monitoring growth of hatchery and naturally-reared fry, iii) monitoring hatchery releases and interaction between hatchery and naturally-reared fry in the river. A rotary screw trap was used to estimate fry production. Bismarck Brown dyed naturally-reared chinook and chum fry were released above the trap site and recapture results of these marked fry were used to expand trap catches to estimate total production.

In 2000, 87,817 naturally-reared chinook fry (range: 62,908 – 362,882) were estimated to have emigrated past the rotary screw trap between 08 March and 18 May. The Nanaimo River Hatchery released a total of 766,828 Nanaimo River chinook fry, 257,394 were released on 17 May into First Lake, 199,890 were released on 18 May into the Nanaimo River, 251,919 were released between 05 May and 23 May into the Nanaimo River, and 57,625 were released on 23 June at Jack Point. Egg to fry survival for naturally-reared chinook was estimated to be 2.50% (range: 1.79% – 10.32%). Most hatchery-reared chinook fry were enumerated in a single 12-hour period; trapping results maintain that most hatchery fry migrate to the estuary within a short period. Interaction between naturally-reared and hatchery-reared chinook juveniles is therefore believed to be limited in freshwater.

In 2001, 15,158 naturally-reared chinook fry (range: 6,274 – 167,957) were estimated to have emigrated past the rotary screw trap between 26 February and 17 May. The Nanaimo River Hatchery released a total of 576,388 Nanaimo River chinook fry, 207,955 were released on 23 and 24 May into First Lake, 317,363 released between 28 April and 29 May into the Nanaimo River, and 51,070 were released on 06 June at Jack Point. Egg to fry survival for naturally-reared chinook was estimated to be 1.12% (range: 0.46% – 12.43%). As only one hatchery-reared chinook fry was enumerated, interactions between hatchery and wild chinook could not be assessed.

In 2002, 110,667 naturally-reared chinook fry (range: 22,444 – 362,494) were estimated to have emigrated past the rotary screw trap between 27 February and 30 May. The Nanaimo River Hatchery released a total of 545,352 Nanaimo River chinook fry, 186,187 were released on 16 May into First Lake, 206,800 were released on 09 May into the Nanaimo River, 50,419 were released on 14 May into the Nanaimo River, 50,438 were released on 16 May into the Nanaimo River, and 51,508 were released on 17 June at Jack Point. Egg to fry survival for naturally-reared chinook was estimated to be 4.45% (range: 0.90% –14.59%). A majority of the hatchery-reared chinook fry were enumerated within a 36-hour period; trapping results maintain that most

hatchery fry migrate to the estuary within a short period. Interaction between naturally-reared and hatchery-reared chinook juveniles is therefore believed to be limited in freshwater.

RÉSUMÉ

Hop Wo, N.K., Carter, E.W., and Nagtegaal, D.A. 2005. Juvenile chinook production in the Nanaimo River, 2000 - 2002. Can. Manuscr. Rep. Fish. Aquat. Sci. 2725: 74 p.

Au cours de la période comprise entre 2000 et 2002, Pêches et Océans Canada (Recensement des stocks de saumon de la côte sud), en collaboration avec la Première nation Snuneymuxw, a effectué sa campagne annuelle d'étude de productivité portant sur les stocks de saumons quinnats juvéniles (*Oncorhynchus tshawytscha*). Cette campagne annuelle comporte trois grands volets : i) dénombrement des juvéniles en stade d'avalaison; ii) contrôle du taux de croissance des alevins issus d'écloserie et des alevins issus du milieu naturel; iii) contrôle des échappements d'écloserie et des interactions entre alevins d'élevage et alevins issus du milieu naturel dans le milieu fluviatile. Un piège rotatif a été employé pour évaluer la productivité d'alevinage. Des alevins de quinnats élevés dans le milieu naturel et marqués au Bismarck Brown et des alevins de kétas ont été libérés en amont du piège rotatif puis recapturés afin d'établir par extrapolation la productivité totale du stock.

En 2000, 87 817 alevins de quinnats élevés dans le milieu naturel (fourchette de productivité : 62,908 – 362,882) auraient descendu la rivière au-delà du piège rotatif entre le 8 mars et le 18 mai. L'écloserie de la rivière Nanaimo a libéré au total 766 828 alevins (stock de la rivière Nanaimo), dont 257 394 le 17 mai (First Lake), 199 890 le 18 mai (rivière Nanaimo), 251 919 entre le 5 et le 23 mai (rivière Nanaimo) et 57 625 le 23 juin (Jack Point). Le taux d'œufs parvenus au stade d'alevin, s'agissant des quinnats issus du milieu naturel, a été estimé à 2,50 % (fourchette de productivité : 1,79 % – 10,32 %). La plupart des alevins de quinnats issus d'écloserie ont été dénombrés à l'intérieur d'une période de douze heures; les résultats de piégeage indiquent que la plupart des alevins d'écloserie descendent jusqu'à l'estuaire à l'intérieur d'une période relativement courte. On peut en induire que dans le milieu dulcicole, les interactions entre juvéniles issus du milieu naturel et juvéniles issus d'écloserie sont relativement limitées.

En 2001, 15 158 alevins de quinnats issus du milieu naturel (fourchette de productivité : 6 274 – 167 957) auraient descendu la rivière au-delà du piège rotatif au cours de la période comprise entre le 26 février et le 17 mai. L'écloserie de la rivière Nanaimo a libéré au total 576 388 alevins (quinnats de la rivière Nanaimo), dont 207 955 les 23 et 24 mai (First Lake), 317 363 les 28 et 29 mai (rivière Nanaimo), et 51 070 le 6 juin (Jack Point). Le taux d'oeufs ayant atteint le stade d'alevin, s'agissant des quinnats issus du milieu naturel, serait de 1,12 % (fourchette de productivité : 0,46 % – 12,43 %). Comme un seul alevin d'élevage a été observé, les interactions entre individus d'élevage et individus sauvages n'ont pu être recensées.

En 2002, 110 667 alevins de quinnats issus du milieu naturel (fourchette de productivité : 22 444 – 362 494) auraient descendu la rivière au-delà du piège rotatif au cours de la période comprise entre le 27 février et le 30 mai. L'écloserie de la rivière Nanaimo a libéré au total 545 352 alevins de quinnats (stocks de la rivière Nanaimo), dont 186 187 le 16 mai (First Lake), 206 800 le 9 mai (rivière Nanaimo), 50 419 le 14 mai (rivière Nanaimo), 50 438 le 16 mai

(rivière Nanaimo) et 51 508 le 17 juin (Jack Point). Le taux d'œufs parvenus au stade d'alevin, s'agissant des quinnats issus du milieu naturel, serait de 4,45 % (fourchette de productivité : 0,90 % –14 59 %). La plupart des alevins quinnats issus d'écloserie ont été dénombrés à l'intérieur d'une période de 36 heures; les résultats de piégeage indiquent que la plupart des alevins issus d'écloserie migrent vers l'estuaire à l'intérieur d'une période relativement courte. On peut en induire que les interactions entre juvéniles issus du milieu naturel et juvéniles issus d'écloserie sont relativement limitées dans le milieu dulcicole.

INTRODUCTION

Chinook salmon (*Oncorhynchus tshawytscha*) have in the last several years shown a decline in stock size in the southern part of the Strait of Georgia and have been a focus of study since then because of their importance to the local fisheries (Nagtegaal et al. 1997). Along with the Cowichan River, the Nanaimo River was chosen as an escapement and exploitation indicator to monitor the status of Lower Strait of Georgia chinook stocks and the rebuilding of escapement into these systems (Nagtegaal and Carter 1998a). The accurate enumeration of chinook migrants can be used to assess freshwater survival, enhancement strategies, as well as investigate possible interactions between hatchery-reared chinook and naturally-reared chinook.

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 Lake, Second Lake or deep canyon pools until they spawn during late summer/early fall (Blackman 1981, Brähniuk 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 which rear for up to one year before out-migrating to the estuary (Healey 1980, Blackman 1981, Nagtegaal and Carter 2000).

The First Lake spring run spawns within the first 1.6 kilometres 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 out-migrate 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 out-migrate to sea upon emergence to rear in the estuary (Healey and Jordan 1982).

Prior to this study, research on Nanaimo River chinook stocks was limited to overflight information and standardized swim surveys carried out by the Nanaimo River Hatchery in conjunction with the Fishery Officers (Aro 1973). An opportunity arose in 1995 to implement an extensive adult chinook enumeration study in conjunction with Snuneymuxw (Nanaimo) First Nation on the Nanaimo River. A counting fence was constructed and in operation from the beginning of August to the end of October. In the spring of 1996, the juvenile portion of this study was initiated.

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 2002, 359,165 fall run and 186,187 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 2002, 49.1% of fall run chinook fry and 13.5% 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.).

Hatchery release of Nanaimo River chinook fry is generally done in three parts. First is an early release, where five gram pre-smolts are released in the beginning of May just downstream of the Island Highway bridge in the lower river. Second is the lake release, where six to seven gram pre-smolts are reared in the hatchery until they reach this point, then are moved to lake net pens situated at the mouth of First Lake. They are then released into the lake in late May. The third, which is the late release, consists of six gram pre-smolts also released downstream of the Island Highway bridge in late May.

The purpose of this report is to present the results obtained from the downstream fry trapping study conducted in the winter/spring of 2000, 2001, and 2002 as well as to estimate juvenile production based on these results. Hatchery-reared fish are referred to as those that were spawned and reared in a hatchery setting regardless of parental origin; alternatively, naturally-reared fish are those that were spawned and reared in the river setting.

This report presents the results of the study completed during 2000 – 2002. The objectives included:

1. Monitoring migration timing and providing an estimate for chinook salmon juveniles migrating downstream past the rotary screw trap.
2. Documenting CWT tag releases of chinook juveniles from the Nanaimo River Hatchery.
3. Monitoring the interaction between hatchery-reared and naturally-reared chinook juveniles in the river environment.
4. Providing an egg to fry survival estimate for fall run chinook juveniles.
5. Collecting biological information for both naturally-reared and hatchery-reared chinook juveniles.

METHODS

STUDY SITE DESCRIPTION

The Nanaimo River flows into the estuary on the east coast of Vancouver Island, British Columbia, just south of the city of Nanaimo and approximately 80 km north of Victoria (Figure 1). It flows for approximately 56 km, has a watershed of 830 km^2, includes four small lakes, and two storage reservoirs. Flow ranges from approximately 4 m^3/s in the summer to over 500 m^3/s during winter freshets and averaged 33.8 m^3/s during 2000 – 2002. The Nanaimo River system supports populations of chinook salmon, coho salmon (*O. kisutch*), pink salmon (*O. gorbuscha*), chum salmon (*O. keta*), steelhead trout (*O. mykiss*), cutthroat trout (*O. clarki*), and Dolly Varden (*Salvelinus malma*) (Aro 1973).

A Community Economic Development Program (CEDP) hatchery is situated alongside the Nanaimo River approximately eight kilometres upstream from the Nanaimo estuary. The hatchery is managed by the Community Futures Development Corporation of Central Island Society under the auspices of the Habitat and Enhancement Branch of Fisheries and Oceans Canada. The facility began chinook production with adults from the 1979 brood year.

FISH CAPTURE

During the period of late February to late May, a 2.4 m diameter rotary screw trap was used to trap salmonid juveniles migrating downstream to the estuary. The trap was placed approximately one kilometre upstream of the estuary (Figure 1) and held in place by galvanized steel cables suspended across the river. The trap was used to fish overnight on Monday, Wednesday, and Friday evenings. After each approximately 12-hour period, the trap was checked and the fish were sampled. On some occasions the trap was set to fish during the day or fished for 24-hour periods to observe diel movement. During diel tests, the trap was still checked every 12 hours to distinguish and observe the differences between day and night-time movement. When Bismarck Brown dyed fry were released above the trap for efficiency estimates, the trap was operated continuously for approximately 60 hours to record recapture data.

All fish collected were enumerated and recorded on data sheets according to species, time period, and capture date. Chinook juveniles were identified as being either hatchery or naturally-reared fry based on length and weight characteristics. As a general rule, the weight and length of hatchery fry at the time of release are substantially larger than that of a naturally-reared fry. No hatchery fish were assumed to be in the river prior to the first release. The number of adipose-clipped hatchery fish were also recorded. Coho were recorded as being fry, one year, or two year old smolts. Water temperature, flow rate, and weather conditions were also recorded at each sampling time. River discharge information was obtained from Water Survey Canada.

MIGRATION TIMING

Although considerable research has focused on understanding the physiological and genetic aspects of chinook emigration, much less information exists on the factors affecting the timing of these migrations. According to Seelbach (1985) and Roper and Scarnecchi (1996), key factors that affect hatchery fish migration timing are size and time of outplanting as well as water velocities. Roper and Scarnecchi (1998) compared magnitude and emigration timing of chinook juveniles in the South Umpqua River with adult escapement and four environmental factors. They determined that the magnitude of juvenile production, lunar cycle, photoperiod and stream temperature were key factors affecting the timing of fry emigration.

TRAP EFFICIENCIES

Chinook abundance estimates using the Bismarck Brown mark-recapture method to calculate trap efficiency may be biased high. The assumption that stained fish have the same capture rate as unmarked migrant chinook may be untrue. The stained fish have endured more handling and stress associated with the marking process; therefore, swimming ability and behavior of these fish may be affected and translate into lower recapture rates (Nagtegaal et al. 1997). According to Frith et al. (1995), not all released marked fish are available for recapture as some fish are lost to predation, disease or residualization. Efficiency tests from other studies (Thedinga et al. 1994, Roper and Scarnecchia 1996) indicate that there are considerable differences in trap efficiencies between species, flow rates and fish size.

ABUNDANCE ESTIMATES

Trap efficiency information, using the mark-recapture of Bismarck Brown stained juvenile fish (Ward and Verhoeven 1963), was used to expand the trap catch to estimate total numbers migrating past the trap site. Juvenile chinook and chum were stained, and then released approximately 500 m upstream from the trap site. The number of stained fish recaptured from continuous trapping over the next 60 hours was recorded.

The proportion of marked fish recaptured was used to expand unmarked fish catch and estimate the total number of fish. Mark-recapture estimates were conducted on a biweekly basis.

Trap efficiency was estimated using:

$$E_{ij} = \frac{m_{ij}}{M_{ij}}$$

where:

E is the estimated trap efficiency at site *i*, on day *j*.
m is the number of marked fish recaptured at site *i*, on day *j*.
M is the number of marked fish released at site *i*, on day *j*.

Inherent in these efficiency tests were the following assumptions:

i. marking of the fish does not affect short term survival of these fish,
ii. all marked fish released above the trap site migrate downstream past the trap,
iii. marked fish behave the same as unmarked fish, and
iv. all recaptured fish were counted.

24-hour fry enumeration was estimated by:

$$F = \frac{H}{h}$$

where:

F is the factor used to expand night estimates into 24-hour fry migration estimates.
H is the total number of fish caught during 24-hour trapping periods.
h is the total number of fish caught during the night portions of corresponding 24-hour trapping periods.

Diel migration testing periods were conducted throughout the course of the fry enumeration study. A diel migration expansion factor was calculated by using the ratio of fry counted over 24-hour periods over fry collected during night periods. Day portions were expanded by this factor if night portions were unavailable.

The total number of fish per day was estimated by:

$$N_{ij} = \frac{U_{ij}}{E_{ij}} * F$$

where:

N is the estimated number of fish that swam past site i, on day j.
U is the catch of unmarked fish in the trap, at site i, on day j.

The total abundance was then determined by summing the daily totals for the duration of trapping. For those nights when no trapping occurred (for example, Tuesday, Thursday, Saturday and Sunday) we assumed the number of migrants to be an average value obtained from the previous and post nights' sampling. The total abundance estimate was taken from the sum of the daily catch estimates for the duration of the study (Nagtegaal et al. 1997).

Naturally-reared chinook fry population ranges were calculated rather than confidence intervals because they incorporate the most influential fry enumeration variable, the trap efficiency expansion factor. The ranges calculated in this report reflect how the trap efficiency portions of this study can greatly influence fry population estimates. This enforces the reality that population estimates in this study are influenced heavily by the accuracy of trap efficiency results.

JUVENILE CHINOOK GROWTH

Observations on growth for naturally-reared chinook were obtained by collecting samples from each catch of the rotary trap. A target sample size of 30 chinook migrants were measured to the nearest millimeter (mm) fork length, and weight was recorded to the nearest one hundredth of a gram (g).

Growth information on hatchery fry was obtained from the Nanaimo River Hatchery. A sample size of approximately 50 – 250 fry were measured in length and weight periodically prior to release. Sample data were available for two hatchery release strategies, fall run chinook fry and First Lake spring run chinook fry.

PART 1: 2000

RESULTS

BIOPHYSICAL CONDITIONS

During the 2000 fry enumeration period the Nanaimo River had five main water discharge peaks, with the largest discharge of 68.4 m^3/s on 02 May and four lesser peaks of 63.9 m^3/s, 62.1 m^3/s, 61.7 m^3/s, and 55.1 m^3/s on 04 April, 19 March, 23 March, and 14 April, respectively. The lowest Nanaimo River discharge level, 22.2 m^3/s, was obtained near the completion of the study on 14 May. Flow rates averaged 0.83 m/s and decreased from a high of 1.19 m/s on 01 May to a low of 0.53 m/s on 12 May. Water temperatures averaged 8.0°C and increased from 5°C on 14 March to 14°C on 16 May. A graphical representation of river discharge and water temperature for the Nanaimo River during the course of the study is presented in Figure 2A. The mean discharge during the course of the study was 39.9 m^3/s, with March averaging 41.4 m^3/s, April averaging 39.0 m^3/s, and the May portion averaging 39.6 m^3/s (Figure 3A). All flow rates measured at the trapping site are presented in Figure 4A.

On a regular basis, there was a build up of small organic debris in the trap. However, when this occurred there was no noticeable difference in the fishing efficiency of the rotary trap. Water clarity at the trapping site was recorded daily as either clear or cloudy with all sampling days being recorded as having clear water clarity. During the study, there were seven sample periods when rain were recorded, 14 periods when overcast skies were noted, and 16 sampling periods when clear weather conditions were reported (Table 1A).

MIGRATION TIMING

The fry enumeration trap was run for 37, 12-hour intervals between 08 March and 18 May, 2000. At the trapping site, 3,622 naturally-reared and 1,953 hatchery-reared chinook juveniles were caught in the screw trap. In addition, 457,970 chum fry, 85 coho fry, 1,405 one year old coho, 19 Bismarck Brown dyed wild chinook fry, 11 Bismarck Brown dyed hatchery chinook fry, and 14 Bismarck Brown dyed wild chum fry were enumerated (Table 1A). Naturally-reared chinook migration had one major peak on 13 April and a lesser peak on 22 April (Figure 5A).

HATCHERY RELEASES

The Nanaimo River Hatchery has three major chinook fry release strategies, two fall run fry releases and a First Lake spring run fry release (Table 2, Figure 1). The only release which occurred during the enumeration period took place between 05 May and 23 May when 50,415 CWT and 201,504 untagged fall run chinook fry were released upstream of the enumeration site. More fall run chinook fry entered the Nanaimo River on 18 May when 100,652 CWT and 99,238 untagged were released. One fall run group, totaling 25,174 CWT and 32,450 untagged fry, was released at Jack point on 23 June. First Lake spring run chinook, totaling 25,185 CWT and 232,209 untagged fry, were released at First Lake on 17 June.

DIEL MIGRATION

This year's study included a continuous 24-hour trapping component to determine diel migration. The 24-hour fry enumeration periods were conducted on five days between 16 March and 14 April. A combined total of 1,842 naturally-reared chinook fry were counted with 1,189 fry obtained during night hours (~1900 – 0700 hours) and 653 fry collected during day hours (~0700 – 1900 hours) (Table 3A). The diel testing results from 14 April, of which 35 of 549 naturally-reared chinook fry were caught during day hours, was chosen for use in later expansion calculations. This provided an expansion value of 1.064 (Table 3A). No hatchery-reared chinook fry were caught during day hours; therefore, estimates provided from wild chinook were used to expand hatchery-reared chinook results.

TRAP EFFICIENCIES

Three separate Bismarck Brown mark-recapture studies were conducted on 15 March, 29 March, and 12 April in order to estimate trap efficiency (Table 4A). Fry recoveries were run for 60 hours after each mark-recapture fry release. The naturally-reared chinook expansion estimate of 12.74 was calculated from 19 of 242 fry recovered on 12 April. The hatchery-reared chinook expansion estimate of 58.36 was achieved by combining the results from 15 March and 29 March, where 8 of 482 fry and 3 of 160 fry were recovered, respectively. Chum fry were released on 29 March and 12 April, but these data were not utilized in expansion calculations. Trap efficiency and flow rates are compared in Figure 4A.

ABUNDANCE ESTIMATES

Abundance estimates were based on fry counts collected from the fry enumeration trap. When fry count data were not available, an estimate was calculated by using the average of adjacent fry trap enumeration days. If no day count was available, the night count was expanded by the 1.064 expansion factor obtained from the diel migration portion of the study (Table 3A). Daily naturally-reared chinook estimates were then expanded by the trap efficiency estimate of 12.74 obtained on 12 April (Table 4A). Hatchery-reared chinook fry were expanded by 58.36 obtained on 15 March and 29 March (Table 4A). The total Nanaimo River naturally-reared chinook migrating past the rotary screw trap between 08 March and 18 May is therefore estimated to be 87,818 fry (Table 5A). A point estimate of 113,576 hatchery-reared fry on 05 May is provided. Naturally-reared chinook daily abundance estimates are presented in Figure 5A.

Population estimate ranges were calculated by using the lowest and highest trap efficiency expansion factors. The lower population range used a trap efficiency expansion factor of 9.12 obtained from wild Nanaimo River chinook fry on 06 March, 1996 (n=73) (Nagtegaal and Carter, 1997). The upper population range was calculated using a trap efficiency expansion factor of 52.63 from hatchery-reared chinook fry obtained on 15 March and 29 March 20 (n =

642) (Table 4A). Population estimate ranges for naturally-reared chinook fry are 62,908 to 362,882. No ranges were calculated for hatchery-reared chinook fry.

EGG TO FRY SURVIVAL

To estimate the egg to fry survival rate, an accurate assessment of adult spawners, the percentage of females in the escapement, the average fecundity, and juvenile out-migration are needed. In 1999, the number of fall run chinook natural spawners was estimated to be 1,920 fish. The proportion of females obtained from a carcass mark-recapture was determined to be 40.82%, or 784 fish. The average fecundity from hatchery broodstock biosampling data was determined to be 4,485 eggs and the total egg production was estimated to be 3,514,776 eggs (Figure 6). The estimated abundance of naturally-reared chinook fry was 87,817; therefore, the egg to fry survival was calculated to be 2.50%. The egg to fry survival range was calculated using the lower and upper ranges from the estimated fry production yielding estimates of 1.79% and 10.32%. The number of naturally-reared chinook eggs deposited and subsequent fry production are compared in Figure 6.

JUVENILE CHINOOK GROWTH

During the study period, 532 naturally-reared chinook fry were biosampled for length and weight. Mean length was approximately 39 mm and mean weight varied from 0.260 to 0.617 g until 13 May. From 13 May to 18 May naturally-reared fry biosampling seemed to indicate a notable increase in mean length from 40.2 mm to 42.6 mm while mean weight increased from 0.603 to 0.891 g. A summary of fry biosampling information is available in Table 6A, while graphical representations of length and weight are presented in Figure 7A and Figure 8A, respectively.

Between 06 January and 22 June, 2,450 fall run chinook fry and 1,225 First Lake spring run chinook fry were biosampled for length and weight data (Table 6A). Mean length for both run types appeared to exhibit a steady growth rate throughout the sampling period (Figure 7A). Mean growth weight increased steadily until 07 March when accelerated growth was recorded for both run types, another spike in growth weight becomes apparent on 16 May for fall run hatchery fry (note: First Lake spring run fry were released by this time so a comparison was not possible) (Figure 8A).

Hatchery-reared chinook fry are generally longer and heavier set than naturally-reared chinook fry, length and weight ranges reflect these differences (Table 6A). Differences in size should have made most hatchery-reared fry easily distinguishable from naturally-reared chinook in the river. However, as the size of naturally-reared chinook increased during the study, the potential for misidentification at the trap site also increased. When naturally-reared and hatchery-reared chinook fry were compared, minimal overlapping in length ranges occurred on 02 May while overlapping of weight ranges occurred on 13 May (Figure 7A and Figure 8A).

DISCUSSION

BIOPHYSICAL CONDITIONS

Water turbidity or clarity would likely affect trap efficiency with decreased turbidity possibly resulting in more chinook fry being able to avoid the enumeration trap. Throughout the course of the study no sample periods were noted as having adverse water clarity conditions; therefore, decreased trap efficiency should be expected.

Conversely, low river flows may increase trap efficiency by decreasing the time a fry has in avoiding an oncoming trap in the river. Flow rates during recapture periods ranged from a high of 1.19 m/s on 01 May to a low of 0.53 m/s on 12 May. Low flow rates and other discharge dynamics, in combination with the cone rotation, may affect trap efficiency (Frith et al. 1995). Wetherall (1970) submitted that higher survival rates of larger migrants were observed with high flows (discharges), while fingerlings in stream discharges less than 20 m^3/s had lower survival rates.

MIGRATION TIMING

Naturally-reared chinook fry migration peaked on 13 April, between the 1998 peak on 09 April and the 1996 Peak on 19 April (Nagtegaal and Carter 1997, 1998b). Almost all hatchery-reared chinook fry enumerated (99.6%) were enumerated on a single day, 06 May. Although, the information from adjacent days was not available, this still supports the idea that most hatchery-reared chinook juveniles start migration towards the estuary almost immediately.

DIEL MIGRATION

Diel migration tests were performed to provide an estimate of the proportion of fry that migrate into the fry trap in daylight hours (~0700 – 1900 hours) compared to nighttime hours (~1900 – 0700 hours). Only the expansion factor from 14 April was used because the results from 13 April were very abnormal when compared with previous years (Nagtegaal and Carter 1997, 1998b, and 2000). It was necessary to use the efficiency test results from the naturally-reared fry to expand both chinook fry types as data obtained from hatchery-reared fry were too small to expand.

TRAP EFFICIENCIES

The two mark-recapture tests involving chum fry conducted on 29 March and 12 April were disregarded from efficiency calculations because of possible differences in behavior and/or physiology. Mark-recapture results from hatchery-reared chinook were not combined with efficiency estimates for naturally-reared chinook fry due a difference in physiology between the two fry types.

ABUNDANCE ESTIMATES

Approximately 87,818 naturally-reared chinook migrated from Nanaimo River in 2000 (range: 62,908 – 362,882). This estimate did not take into consideration the migration of chinook prior to the installation of the rotary trap or after the study ended. Previous studies suggest that fry emigration continues after trap removal on 18 May; and in 1996, 2.76% of total chinook fry were estimated to have emigrated between 18 May and 30 May (Nagtegaal and Carter 1997). Figure 5A also suggests fry continued to migrate past the screw trap after removal.

The Nanaimo River Hatchery documented that 251,919 hatchery fall run fry were released above the trapping site during the enumeration period. This estimate is approximately double the point value of 113,576 fry calculated from the rotary screw trap results. This discrepancy is most likely influenced by minimal trap enumeration surrounding the fry release, resulting in only a point estimate being calculable. Also, the trap estimate does not take into consideration fry lost to predation or natural mortality. Therefore, the hatchery-reared fry estimate provided by the Nanaimo River Hatchery is deemed more reliable than the rotary screw trap estimate.

EGG TO FRY SURVIVAL

The 1999 brood year egg to fry survival estimate of 2.50% (range: 1.79% - 10.32%) is higher than the 1998 brood average of 1.11% (range: 1.00% – 1.22%) and slightly lower than the 1997 brood year estimate of 2.74% (range: 1.52% – 8.21%); however, it is five fold smaller than the 1995 brood year estimate of 12.80% (range: 12.16% – 13.44%). Differences in survival rates between years may be attributed to many factors ranging from biophysical conditions, chum escapements, and spawner distribution (Nagtegaal et al. 1997). Because the fall run chinook natural spawner estimate is deemed fairly accurate and we are unsure of the exact out-migration timing of spring run fry, the egg to fry survival estimate was calculated assuming all fry were produced from fall run chinook.

Flow rates during the course of adult chinook spawning, egg development and fry growth were generally stable with the exception of November, when flows ranged from 30.8 m^3/s to 288 m^3/s within a four day period and December, when flows range between 24.4 m^3/s to 229 m^3/s (Figure 3A). Rapidly varying river flows can result in the scouring of spawning beds and possible damage to developing chinook eggs. Burt and Mundie (1986) note that rivers with rapidly fluctuating flow rates can negatively impact egg to fry survival rates by stranding juveniles, reducing insect abundance and scouring stream beds. Montgomery et al. (1995) determined that the depth of stream bed scouring due to discharge levels was directly related to egg survival.

JUVENILE CHINOOK GROWTH

Fry length and weight sampling during the study showed minimal increase in average size of naturally-reared chinook throughout the course of the 2000 study, with a small increase noted after 13 May. Biological sampling of both fry types resulted in some overlapping of size ranges and this suggests misidentification of hatchery-reared and naturally-reared chinook enumerated at the trapping site may have occurred after 02 May.

Variation in rearing environments between hatchery-reared and naturally-reared fry is likely the underlying factor in morphological differences such as mean weight and mean length. Hatchery-reared fry spend the winter months at the hatchery in various holding tanks and are fed fish pellets until being released during the spring months. Alternatively, naturally-reared fry are dependent on foraging for food within an environment with only limited resources. This difference in rearing environments results in naturally-reared fry growing at a slower rate than hatchery-reared fry.

PART 2: 2001

RESULTS

BIOPHYSICAL CONDITIONS

During the 2001 fry enumeration period the Nanaimo River had four main water discharge peaks, with the largest discharge of 120 m^3/s on 19 March and three lesser peaks of 80.3 m^3/s, 79.0 m^3/s, and 63.1 m^3/s on 25 April, 01 May, and 26 March, respectively. The lowest Nanaimo River discharge level of 9.65 m^3/s was obtained near the beginning of the study on 07 March. Flow rates averaged 0.80 m/s with peaks of 1.38 m/s and 1.42 m/s on 21 March and 27 April, respectively, and a low of 0.18 m/s on 07 March. Water temperatures averaged 7.8°C and increased from 4°C on 01 March to 12°C on 10 May and 14 May. A graphical representation of river discharge and water temperature for the Nanaimo River during the course of the study is presented in Figure 2B. The mean discharge during the course of the study was 34.2 m^3/s, with March averaging 34.1 m^3/s, April averaging 33.1 m^3/s, and the May portion averaging 36.2 m^3/s (Figure 3B). All flow rates measured at the trapping site are presented in Figure 4B.

On a regular basis, there was a build up of small organic debris in the trap. However, when this occurred there was no noticeable difference in the fishing efficiency of the rotary trap. Water clarity at the trapping site was recorded as clear for all sampling days, except set date 07 March which was recorded as having cloudy water clarity. During the study, there were two sample periods when rain were recorded, nine periods when overcast skies were noted, and 40 sampling periods when clear weather conditions were reported (Table 1B).

MIGRATION TIMING

The fry enumeration trap was run for 51, 12-hour intervals between 26 February and 17 May, 2001. At the trapping site, 660 naturally-reared and one hatchery-reared chinook juveniles were caught in the screw trap. In addition, 211,777 chum fry, 903 coho fry, 606 one year old coho, 11 two year old coho, and 123 Bismarck Brown dyed wild chum fry were enumerated (Table 1B). Naturally-reared chinook migration had two major peaks: an estimated 1,168 fry and 567 fry emigrated downstream on 03 April and 19 April, respectively (Figure 5B).

HATCHERY RELEASES

The Nanaimo River Hatchery has three major chinook fry release strategies, two fall run fry releases and a First Lake spring run fry release (Table 2, Figure 1). The only release which occurred during the enumeration period took place between 28 April and 29 May when 150,573 CWT and 166,790 untagged fall run chinook fry were released upstream of the enumeration site. One fall run group, totaling 25,091 CWT and 25,979 untagged fry, was released at Jack point on 06 June. First Lake spring run chinook, totaling 24,739 CWT and 183,216 untagged fry, were released at First Lake on 23 and 24 June.

DIEL MIGRATION

This year's study included a continuous 24-hour trapping component to determine diel migration. The 24-hour fry enumeration periods were conducted on seven days between 15 March and 11 May. A combined total of 47 naturally-reared chinook fry were counted with 45 fry obtained during night hours (~1900 – 0700 hours) and two fry collected during day hours (~0700 – 1900 hours) (Table 3B). The diel testing results were combined for all dates resulting in an expansion value of 1.044 (Table 3B).

TRAP EFFICIENCIES

Three separate Bismarck Brown mark-recapture studies were conducted on 14 March, 28 March, and 11 April in order to estimate trap efficiency (Table 4B). Fry recoveries were run for 60 hours after each mark-recapture fry release. Due to the lack of chinook fry recoveries, all Bismarck Brown studies were conducted using naturally-reared chum fry. The three Bismarck Brown results were as follows: 14 March, 329 chum fry were released with 41 recaptured, yielding an expansion factor of 8.02; 28 March, 305 chum fry were released with three recaptured, yielding an expansion factor of 101.67; and 11 April, 300 chum fry were released with 79 recaptured, yielding an expansion factor of 3.80. Trap efficiency and flow rates are compared in Figure 4B.

ABUNDANCE ESTIMATES

Abundance estimates were based on fry counts collected from the fry enumeration trap. When fry count data were not available, an estimate was calculated by using the average of adjacent fry trap enumeration days. If no day count was available, the night count was expanded by the 1.044 expansion factor obtained from the diel migration portion of the study (Table 3B). Daily naturally-reared chinook estimates were then expanded by trap efficiency estimates obtained from naturally-reared chum fry. Daily expansions were as follows: 27 February to 21 March were expanded by 8.02, 22 March to 04 April were expanded by 101.67, and 05 April to 17 May were expanded by 3.80 (Table 4B). Following this methodology, the total Nanaimo River naturally-reared chinook migrating past the rotary screw trap between 26 February and 17 May is estimated to be 15,158 fry (Table 5B). No estimate was calculated for hatchery-reared chinook fry. Naturally-reared chinook daily abundance estimates are presented in Figure 5B.

Population estimate ranges were calculated by using the lowest and highest trap efficiency expansion factors. The lower population range used a trap efficiency expansion factor of 3.80 obtained from naturally-reared chum fry on 11 April (Table 4B). The upper population range was calculated using a trap efficiency expansion factor of 101.67 from naturally-reared chum fry obtained on 28 March (Table 4B). Population estimate ranges for naturally-reared chinook fry are 6,274 to 167,957.

EGG TO FRY SURVIVAL

To estimate the egg to fry survival rate, an accurate assessment of adult spawners, the percentage of females in the escapement, the average fecundity, and juvenile out-migration are needed. In 2000, the number of fall run chinook natural spawners was estimated to be 596 fish. The proportion of females obtained from a carcass mark-recapture was determined to be 46.59%, or 278 fish. The average fecundity from hatchery broodstock biosampling data was determined to be 4,866 eggs and the total egg production was estimated to be 1,351,200 eggs (Figure 6). The estimated abundance of naturally-reared chinook was 15,158 fry; therefore, the egg to fry survival was calculated to be 1.12%. The egg to fry survival range was calculated using the lower and upper ranges from the estimated fry production yielding estimates of 0.46% and 12.43%. The number of naturally-reared chinook eggs deposited and subsequent fry production are compared in Figure 6.

JUVENILE CHINOOK GROWTH

During the study period, 231 naturally-reared chinook fry were biosampled for length and weight. Mean length was 40.0 mm and mean weight varied from 0.391 to 0.520 g until 17 April. From 17 April to 03 May naturally-reared fry biosampling seemed to indicate a notable increase in mean length from 41.3 mm to 62.3 mm while mean weight increased from 0.480 to 2.060 g. A summary of fry biosampling information is available in Table 6B, while graphical representations of length and weight are presented in Figure 7B and Figure 8B, respectively.

Between 23 January and 22 May, 950 fall run chinook fry and 800 First Lake spring run chinook fry were biosampled for length and weight data (Table 6B). Mean length and mean weight for both run types appeared to exhibit a steady growth rate throughout the sampling period (Figure 7B, Figure 8A, respectively).

Hatchery-reared chinook fry are generally longer and heavier set than naturally-reared chinook fry and length and weight ranges reflect these differences (Table 6B). Differences in size should have made most hatchery-reared fry easily distinguishable from naturally-reared chinook in the river. However, as the size of naturally-reared chinook increased during the study, the potential for misidentification at the trap site also increased. When naturally-reared and hatchery-reared chinook fry were compared, minimal overlapping in length ranges occurred until 13 April when the naturally-reared maximum values increases dramatically (Figure 7B and Figure 8B). This increase in maximum length and weight values is due to a few naturally-reared chinook outliers; it is possible that these chinook may be spring run stream-type juveniles.

DISCUSSION

BIOPHYSICAL CONDITIONS

Water turbidity or clarity would likely affect trap efficiency with decreased turbidity possibly resulting in more chinook fry being able to avoid the enumeration trap. Throughout the course of the study one sample period was noted as having adverse water clarity conditions; therefore, decreased trap efficiency should be expected.

Conversely low river flows may increase trap efficiency by decreasing the time a fry has in avoiding an oncoming trap in the river. Flow rates during recapture periods ranged from a high of 1.42 m/s on 27 April to a low of 0.18 m/s on 07 March. Low flow rates and other discharge dynamics, in combination with the cone rotation, may affect trap efficiency (Frith et al. 1995). Wetherall (1970) submitted that higher survival rates of larger migrants were observed with high flows (discharges), while fingerlings in stream discharges less than 20 m^3/s had lower survival rates.

MIGRATION TIMING

Naturally-reared chinook fry peaked on 03 April, the earliest since the rotary screw trap program was initiated in 1996 (Nagtegaal and Carter 1997); the next earliest chinook peak occurred a week later on 09 April, 1998 (Nagtegaal and Carter 1998b). Interactions between hatchery-reared and naturally-reared chinook juveniles could not be assessed as only one hatchery fry was enumerated in the rotary screw trap.

DIEL MIGRATION

Diel migration tests were performed to provide an estimate of the proportion of fry that migrate into the fry trap in daylight hours (~0700 – 1900 hours) compared to nighttime hours (~1900 – 0700 hours). Combining all 24-hour tests to obtain one diel migration expansion factor was necessary as sample sizes for each testing period were small.

TRAP EFFICIENCIES

Due to the low number of chinook fry obtained, naturally-reared chum fry were utilized in Bismarck Brown efficiency testing. It is hypothesised that chum fry may underestimate trap efficiency as they are larger and heavier than chinook fry; therefore, they may be able to avoid the trap more often than chinook fry. With this in mind, expansion factors may be larger than chinook fry alone would provide. The largest efficiency expansion factor obtained by using naturally-reared chinook fry on the Nanaimo River was 52.63 in 1999; however, these were derived under different river conditions (Nagtegaal and Carter 2000).

ABUNDANCE ESTIMATES

Approximately 15,158 naturally-reared chinook migrated from Nanaimo River in 2001 (range: 6,274 – 167,957). This estimate did not take into consideration the migration of chinook prior to the installation of the rotary trap or after the study ended. Previous studies suggest that fry emigration continues after trap removal on 17 May; and in 1996, 3.24% of total chinook fry were estimated to have emigrated between 17 May and 30 May (Nagtegaal and Carter 1997). Figure 5B also suggests fry continued to migrate past the screw trap after removal.

The Nanaimo River Hatchery documented that 317,363 hatchery fry being may have been released above the trapping site during the enumeration period. As only one hatchery-reared chinook was recorded during the fry enumeration, it is probable that the hatchery fry were released into the river after the removal of the rotary screw trap.

EGG TO FRY SURVIVAL

The 2000 brood year egg to fry survival estimate of 1.12% (range: 0.46% - 12.43%) is almost identical to the 1998 brood average of 1.11% (range: 1.00% – 1.22%) and is below the 1995 – 2000 brood year average of 4.05 %. Differences in survival rates between years may be attributed to many factors ranging from biophysical conditions, chum escapements, and spawner distribution (Nagtegaal et al. 1997). Because the fall run chinook natural spawner estimate is deemed fairly accurate and we are unsure of the exact out-migration timing of spring run fry, the egg to fry survival estimate was calculated assuming all fry were produced from fall run chinook.

Flow rates during the course of adult chinook spawning, egg development and fry growth were generally stable with the exception of January, where flows increased from 45.9 m^3/s to 283 m^3/s within two days (Figure 3B). Rapidly varying river flows can result in the scouring of spawning beds and possible damage to developing chinook eggs. Burt and Mundie (1986) note that rivers with rapidly fluctuating flow rates can negatively impact egg to fry survival rates by stranding juveniles, reducing insect abundance and scouring stream beds. Montgomery et al. (1995) determined that the depth of stream bed scouring due to discharge levels was directly related to egg survival.

JUVENILE CHINOOK GROWTH

Fry length and weight sampling during the study showed minimal increase in average size of naturally-reared chinook throughout the course of the 2001 study. Biological sampling of both fry types resulted in some overlapping of size ranges; however, these few larger naturally-reared chinook may be spring run stream type juveniles. It is doubtful that misidentification of hatchery-reared and naturally-reared chinook occurred at the trapping site as it appears no releases occurred during the enumeration.

Variation in rearing environments between hatchery-reared and naturally-reared fry is likely the underlying factor in morphological differences such as mean weight and mean length. Hatchery-reared fry spend the winter months at the hatchery in various holding tanks and are fed fish pellets until being released during the spring months. Alternatively, naturally-reared fry are dependent on foraging for food within an environment with only limited resources. This difference in rearing environments results in naturally-reared fry growing at a slower rate than hatchery-reared fry. Naturally-reared spring run stream type juveniles would be inherently larger when captured at the trapping site as they spend an additional year foraging in the freshwater environment before emigrating into the ocean.

PART 3: 2002

RESULTS

BIOPHYSICAL CONDITIONS

During the 2002 fry enumeration period the Nanaimo River had one main water discharge peak, 236 m^3/s on 14 April, and one minor peak, 90.9 m^3/s on 13 March. The lowest Nanaimo River discharge level of 17.7 m^3/s was obtained near the end of the study on 11 May. Flow rates averaged 0.81 m/s with the highest flow, 1.14 m/s, recorded on 03 May and the lowest flow, 0.23 m/s, recorded on 08 March. Water temperatures averaged 6.9°C and increased from 2°C on 09 March to 12°C on 23 to 30 May. A graphical representation of river discharge and water temperature for the Nanaimo River during the course of the study is presented in Figure 2C. The mean discharge during the course of the study was 42.5 m^3/s, with March averaging 34.3 m^3/s, April averaging 61.1 m^3/s, and the May portion averaging 32.7 m^3/s (Figure 3C). All flow rates measured at the trapping site are presented in Figure 4C.

On a regular basis, there was a build up of small organic debris in the trap. However, when this occurred there was no noticeable difference in the fishing efficiency of the rotary trap. Water clarity at the trapping site was recorded daily as either clear or cloudy with 54 sampling days noted as having clear water clarity and four days having cloudy water clarity. During the study, weather conditions were recorded on 50 sampling periods, with 23 days noted as being sunny, 18 days noted as being cloudy, seven days noted as being rainy, and two days noted as being snowy (Table 1C).

MIGRATION TIMING

The fry enumeration trap was run for 58, 12-hour intervals between 27 February and 30 May, 2002. At the trapping site, 1,838 naturally-reared, 7,384 adipose unclipped hatchery-reared, and 795 adipose clipped hatchery-reared chinook fry were caught in the screw trap. In addition, 149,509 chum fry, 588 coho fry, 2,891 one year old coho, five Bismarck Brown dyed wild chinook fry, and 141 Bismarck Brown dyed wild chum fry were enumerated (Table 1C). Peak movement for naturally-reared chinook occurred on 02 May when 7,774 fry were estimated to have migrated downstream (Figure 5C). Two major peaks were observed for hatchery-reared chinook fry, 10 May and 21 May when 65,910 fry and 39,404 fry, respectively, were estimated to have emigrated downstream (Figure 5D).

HATCHERY RELEASES

The Nanaimo River Hatchery has three major chinook fry release strategies, two fall run fry releases and a First Lake spring run fry release (Table 2, Figure 1). All releases occurred during the enumeration period. One release, the fall run chinook released at Jack Point, was not possible for capture; however, all other releases were available for enumeration. The remaining fall run chinook fry were released into the Nanaimo River above the trapping site on three separate dates, 09 May, 14 May, and 16 May; these releases totaled 151,331 CWT and 156,326 untagged chinook fry. First Lake spring run chinook, totaling 25,102 CWT and 161,085 untagged fry, were released at First Lake on 16 June.

DIEL MIGRATION

This year's study included a continuous 24-hour trapping component to determine diel migration for both naturally-reared and hatchery-reared chinook fry. The 24-hour fry enumeration periods were conducted on 12 days between 21 March and 24 May. A combined total of 445 naturally-reared chinook fry were counted with 371 fry obtained during night hours (~1900 – 0700 hours) and 74 fry collected during day hours (~0700 – 1900 hours) (Table 3C). The naturally-reared chinook fry diel results were combined for all dates resulting in an expansion value of 1.199 (Table 3C). The hatchery-reared chinook fry diel calculations were based on 3,814 fry obtained during night hours (~1900 – 0700 hours) and 284 fry collected during day hours (~0700 – 1900 hours), yielding an expansion value of 1.074 (Table 3D).

TRAP EFFICIENCIES

Six separate Bismarck Brown mark-recapture studies were conducted between 20 March and 22 May in order to estimate trap efficiency (Table 4C). Fry recoveries were run for 60 hours after each mark-recapture fry release. Due to the lack of chinook fry recoveries, the first four studies were conducted using naturally-reared chum fry, exclusively. The initial four Bismarck Brown results were as follows: 20 March, 301 chum fry were released with 30 recaptured, yielding an expansion factor of 10.03; 27 March, 317 chum fry were released with 20 recaptured, yielding an expansion factor of 15.85; 10 April, 288 chum fry were released with four recaptured, yielding an expansion factor of 72.00; and 24 April, 361 chum fry were released with 69 recaptured, yielding an expansion factor of 5.23. The final two studies used a combination of naturally-reared chinook and naturally-reared chum fry, but still relied heavily on the latter. Bismarck Brown results for the last two studies were as follows: 08 May, 24 chinook and 319 chum fry were released with four chinook and 15 chum recaptured, yielding a combined expansion factor of 18.05; and 22 May, eight chinook and 330 chum fry were released with one chinook and three chum recaptured, yielding a combined expansion factor of 84.50. Trap efficiency and flow rates are compared in Figure 4C.

ABUNDANCE ESTIMATES

Abundance estimates were based on fry counts collected from the fry enumeration trap. When fry count data were not available, an estimate was calculated by using the average of adjacent fry trap enumeration days. If no day count was available, the night count was expanded by the 1.199 expansion factor obtained from the diel migration portion of the study (Table 3C). Daily naturally-reared chinook estimates were then expanded by trap efficiency estimates obtained from either naturally-reared chum fry or a combination of naturally-reared chum and naturally-reared chinook fry. Daily expansions were as follows: 28 February to 23 March were expanded by 10.03, 24 March to 03 April were expanded by 15.85, 04 April to 17 April were expanded by 72.00, 18 April to 01 May were expanded by 5.23, 02 May to 15 May were expanded by 18.05, and 16 May to 30 May were expanded by 84.50 (Table 4C). Hatchery-reared chinook fry were expanded using the same methodology used to expand naturally-reared chinook fry except a diel expansion factor of 1.074 was used (Table 3D). Following these methodologies, the total Nanaimo River chinook migrating past the rotary screw trap between 27 February and 30 May are estimated to be 110,667 naturally-reared fry and 410,249 hatchery-reared fry (Table 5C, Table 5D, respectively). Naturally-reared and hatchery-reared chinook daily abundance estimates are presented in Figure 5C and Figure 5D, respectively.

Population estimate ranges were calculated by using the lowest and highest trap efficiency expansion factors. The lower population range used a trap efficiency expansion factor of 5.23 obtained from naturally-reared chum fry on 24 April (Table 4C). The upper population range was calculated using a trap efficiency expansion factor of 84.50 from combined naturally-reared chinook and chum fry obtained on 22 May (Table 4C). The population estimate range for naturally-reared chinook is 22,444 to 362,494 fry while the hatchery-reared chinook range is 69,729 to 1,126,185 fry.

EGG TO FRY SURVIVAL

To estimate the egg to fry survival rate, an accurate assessment of adult spawners, the percentage of females in the escapement, the average fecundity, and juvenile out-migration are needed. In 2001, the number of fall run chinook natural spawners was estimated to be 1,277 fish. The proportion of females obtained from a carcass mark-recapture was determined to be 41.35%, or 528 fish. The average fecundity from hatchery broodstock biosampling data was determined to be 4,705 eggs and the total egg production was estimated to be 2,484,439 eggs (Figure 6). The estimated abundance of naturally-reared chinook fry was 110,667 fry; therefore, the egg to fry survival was calculated to be 4.45%. The egg to fry survival range was calculated using the lower and upper ranges from the estimated fry production yielding estimates of 0.90% and 14.59%. The number of naturally-reared chinook eggs deposited and subsequent fry production are compared in Figure 6.

JUVENILE CHINOOK GROWTH

During the study period, 668 naturally-reared chinook fry were biosampled for length and weight. Mean length ranged from 36.0 to 42.4 mm and mean weight varied from 0.300 to 0.592 g until 14 May. From 14 May to 30 May naturally-reared fry biosampling seemed to indicate a notable increase in mean length from 40.7 mm to 52.1 mm while mean weight increased from 0.530 to 1.526 g. A summary of fry biosampling information is available in Table 6C, while graphical representations of length and weight are presented in Figure 7C and Figure 8C, respectively.

Between 08 January and 16 May, 1,700 fall run chinook fry and 850 First Lake spring run chinook fry were biosampled for length and weight data (Table 6C). Mean length and mean weight for both run types appeared to exhibit a steady growth rate throughout the sampling period (Figure 7C and Figure 8C, respectively).

Hatchery-reared chinook fry are generally longer and heavier set than naturally-reared chinook fry and length and weight ranges reflect these differences (Table 6C). Differences in size should have made most hatchery-reared fry easily distinguishable from naturally-reared chinook in the river. However, as the size of naturally-reared chinook increased during the study, the potential for misidentification at the trap site also increased. When naturally-reared and hatchery-reared chinook fry were compared, length ranges between the two fry types overlapped only briefly between 12 to 25 March; no overlapping in weight ranges was evident (Figure 7C and Figure 8C, respectively).

DISCUSSION

BIOPHYSICAL CONDITIONS

Water turbidity or clarity would likely affect trap efficiency with decreased turbidity possibly resulting in more chinook fry being able to avoid the enumeration trap. Throughout the course of the study four sample periods were noted as having adverse water clarity conditions; therefore, decreased trap efficiency should be expected.

Conversely low river flows may increase trap efficiency by decreasing the time a fry has in avoiding an oncoming trap in the river. Flow rates during recapture periods ranged from a high of 1.14 m/s on 03 May to a low of 0.23 m/s on 08 March. Low flow rates and other discharge dynamics, in combination with the cone rotation, may affect trap efficiency (Frith et al. 1995). Wetherall (1970) submitted that higher survival rates of larger migrants were observed with high flows (discharges), while fingerlings in stream discharges less than 20 m^3/s had lower survival rates.

MIGRATION TIMING

Naturally-reared chinook fry peaked on 02 May which is similar to the 1999 peak fry movement on 04 May (Nagtegaal and Carter 2000). Hatchery-reared chinook fry enumeration primarily (82.68%) occurred within a 36-hour time period, between sampling dates 10 May at 0655 hour and 11 May at 0650 hour (Table 1C). This supports the idea that most hatchery-reared chinook juveniles start migration towards the estuary almost immediately.

DIEL MIGRATION

Diel migration tests were performed to provide an estimate of the proportion of fry that migrate into the fry trap in daylight hours (~0700 – 1900 hours) compared to nighttime hours (~1900 – 0700 hours). Combining all 24-hour tests to obtain one diel migration expansion factor was necessary as sample sizes for each testing period were small. It was necessary to partition naturally-reared and hatchery-reared fry diel testing results due to differences in behavior as well as size.

TRAP EFFICIENCIES

Due to the low number of chinook fry obtained, naturally-reared chum fry were utilized, exclusively, in the initial four Bismarck Brown efficiency tests. Although the final two efficiency tests did include some naturally-reared chinook fry (n=24 and n=8), results were still heavily influence by the amount of chum released (n=319 and n=330) (Table 4C). It is hypothesised that chum fry may underestimate trap efficiency as they are larger and heavier than chinook fry; therefore, they may be able to avoid the trap more often than chinook fry. With this in mind, expansion factors may be larger than chinook fry alone would provide. The largest efficiency expansion factor obtained by using naturally-reared chinook fry on the Nanaimo River was 52.63 in 1999; however, these were derived under different river conditions (Nagtegaal and Carter 2000).

ABUNDANCE ESTIMATES

Approximately 110,667 naturally-reared chinook migrated from Nanaimo River in 2002 (range: 22,444 –362,494). This estimate did not take into consideration the migration of chinook prior to the installation of the rotary trap (27 February) or after the study ended (30 May). Although, no previous rotary screw trap enumeration study on the Nanaimo River has been conducted after 30 May, Figure 5C suggests fry continued to migrate past the screw trap after removal.

The Nanaimo River Hatchery documented that 307,657 fall run and 186,187 First Lake spring run hatchery fry were released above the trapping site during the enumeration period. The expanded trapping estimate of 410,249 fry underestimates the Nanaimo River Hatchery's recorded estimate of 493,844 fry by 20.4%. By dividing the number of hatchery-reared chinook enumerated, 8,179 fry, by the total number of fry released above the trapping site, 493,844 fry, a trap efficiency of 1.66% is yielded. This low efficiency may be due to several factors. Firstly, it may be partially reflective of the low efficiency rates obtained on 22 May (Table 4C). Secondly, the enumeration period is most likely not long enough to record all hatchery fry emigrating from the Nanaimo River Watershed; Figure 5D supports this hypothesis. Finally, this efficiency estimate does not take into consideration fry lost to predation or natural mortality while emigrating downstream towards the trapping site.

EGG TO FRY SURVIVAL

The 2001 brood year egg to fry survival estimate of 4.45% (range: 0.90% – 14.59%) is very close to the 1995 – 2001 brood year average of 4.12%. Differences in survival rates between years may be attributed to many factors ranging from biophysical conditions, chum escapements, and spawner distribution (Nagtegaal et al. 1997). Because the fall run chinook natural spawner estimate is deemed fairly accurate and we are unsure of the exact out-migration timing of spring run fry, the egg to fry survival estimate was calculated assuming all fry were produced from fall run chinook.

Flow rates during the course of adult chinook spawning, egg development and fry growth were varied, especially between November to February, (Figure 3C). Rapidly varying river flows can result in the scouring of spawning beds and possible damage to developing chinook eggs. Burt and Mundie (1986) note that rivers with rapidly fluctuating flow rates can negatively impact egg to fry survival rates by stranding juveniles, reducing insect abundance and scouring stream beds. Montgomery et al. (1995) determined that the depth of stream bed scouring due to discharge levels was directly related to egg survival.

JUVENILE CHINOOK GROWTH

Naturally-reared chinook fry mean length and mean weight showed minimal increases during the initial portion of the study; however, on 13 May both mean length and mean weight exhibited sharp increases which continued until the study concluded. Biological sampling of both wild and hatchery fry types resulted in the brief overlap of length ranges between 12 March to 25 March. This suggests very minimal misidentification between naturally-reared and hatchery-reared chinook fry occurred during the enumeration period.

Variation in rearing environments between hatchery-reared and naturally-reared fry is likely the underlying factor in morphological differences such as mean weight and mean length. Hatchery-reared fry spend the winter months at the hatchery in various holding tanks and are fed fish pellets until being released during the spring months. Alternatively, naturally-reared fry are dependent on foraging for food within an environment with only limited resources. This difference in rearing environments results in naturally-reared fry growing at a slower rate than hatchery-reared fry.

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Table 1A. Rotary screw trap catch data, Nanaimo River, 2000.

Set Date	Weather[1]	Water Temp. (°C)	Water Clarity[2]	Sample Date	Start Time	Wild Chinook	Hatchery Chinook	Adipose-Clipped Chinook	Chum	Coho Fry	Coho 1 year	Coho 2 year	Dye Marked Wild Chinook	Dye Marked Hatchery Chinook	Dye Marked Chum
08-Mar	3	6	1	09-Mar	7:00	0	0	0	11	0	0	0	0	0	0
13-Mar	2	5	1	14-Mar	7:00	0	0	0	97	0	0	0	0	0	0
15-Mar	3	6	1	16-Mar	7:00	0	0	0	55	0	0	0	0	8	0
15-Mar	3	6	1	16-Mar	19:00	0	0	0	798	0	0	0	0	0	0
15-Mar	3	6	1	17-Mar	7:00	0	0	0	21	0	0	0	0	0	0
15-Mar	3	6	1	17-Mar	19:00	0	0	0	123	0	0	0	0	0	0
15-Mar	3	6	1	18-Mar	7:00	0	0	0	49	0	0	0	0	0	0
20-Mar	2	6	1	21-Mar	7:00	0	0	0	1,906	1	0	0	0	0	0
22-Mar	1	7	1	23-Mar	7:00	2	0	0	1,753	0	3	0	0	0	0
24-Mar	1	6	1	25-Mar	7:00	0	0	0	2,812	0	0	0	0	0	0
27-Mar	2	6	1	28-Mar	7:00	4	0	0	5,874	0	2	0	0	0	0
29-Mar	1	7	1	30-Mar	7:00	1	0	0	524	0	0	0	0	2	0
29-Mar	1	7	1	30-Mar	19:00	0	0	0	4,432	0	0	0	0	1	0
29-Mar	1	7	1	31-Mar	7:00	2	0	0	12,619	1	0	0	0	0	1
29-Mar	1	7	1	31-Mar	19:00	0	0	0	1,039	0	0	0	0	0	0
29-Mar	1	7	1	01-Apr	7:00	4	0	0	15,297	0	0	0	0	0	0
03-Apr	2	8	1	04-Apr	7:00	64	0	0	9,605	2	3	0	0	0	0
05-Apr	1	7	1	06-Apr	7:00	33	0	0	4,167	4	6	0	0	0	0
07-Apr	1	7	1	08-Apr	7:00	82	0	0	21,957	2	6	0	0	0	0
10-Apr	1	8	1	11-Apr	7:00	272	0	0	47,499	6	8	0	0	0	0
12-Apr	2	9	1	13-Apr	7:00	638	0	0	44,524	6	38	0	19	0	13
12-Apr	2	9	1	13-Apr	19:00	618	0	0	15,705	2	32	0	0	0	0
12-Apr	2	9	1	14-Apr	7:00	549	0	0	33,121	0	0	0	0	0	0
12-Apr	2	9	1	14-Apr	19:00	35	0	0	3,102	0	0	0	0	0	0
12-Apr	2	9	1	15-Apr	7:00	26	0	0	8,852	0	0	0	0	0	0
17-Apr	1	9	1	18-Apr	7:00	69	0	0	43,125	0	56	0	0	0	0
19-Apr	1	9	1	20-Apr	7:00	237	0	0	54,000	0	0	0	0	0	0
21-Apr	2	8	1	22-Apr	7:00	427	0	0	57,475	5	21	0	0	0	0
24-Apr	3	9	1	25-Apr	7:00	72	0	0	33,760	16	28	0	0	0	0
26-Apr	2	9	1	27-Apr	7:00	129	0	0	26,181	12	15	0	0	0	0

Table 1A. (continued)

Set Date	Weather[1]	Water Temp. (°C)	Water Clarity[2]	Sample Date	Start Time	Wild Chinook	Hatchery Chinook	Adipose-Clipped Chinook	Chum	Coho Fry	Coho 1 year	Coho 2 year	Dye Marked Wild Chinook	Dye Marked Hatchery Chinook	Dye Marked Chum
01-May	1	8	1	02-May	7:00	47	0	0	1,343	8	250	0	0	0	0
05-May	2	9	1	06-May	7:00	29	1,946	0	426	8	702	0	0	0	0
08-May	1	9	1	09-May	7:00	25	0	0	1,540	1	62	0	0	0	0
10-May	2	9	1	11-May	7:00	6	7	0	743	0	22	0	0	0	0
12-May	2	12	1	13-May	7:00	10	0	0	1,517	0	36	0	0	0	0
15-May	1	14	1	16-May	7:00	15	0	0	1,027	3	49	0	0	0	0
17-May	1	.12	1	18-May	7:00	226	0	0	891	8	66	0	0	0	0
Total						3,622	1,953	0	457,970	85	1,405	0	19	11	14

[1] Weather code: 1 = clear; 2 = cloudy; 3 = raining. [2] Clarity code: 1 = clear; 2 = cloudy.

Table 1B. Rotary screw trap catch data, Nanaimo River, 2001.

Set Date	Weather[1]	Water Temp. (°C)	Water Clarity[2]	Sample Date	Start Time	Wild Chinook	Hatchery Chinook	Adipose-Clipped Chinook	Chum	Coho Fry	Coho 1 year	Coho 2 year	Dye Marked Wild Chinook	Dye Marked Hatchery Chinook	Dye Marked Chum
26-Feb	1	-	1	27-Feb	7:00	0	0	0	457	0	0	0	0	0	0
28-Feb	1	4	1	01-Mar	7:00	0	0	0	261	0	0	0	0	0	0
02-Mar	1	-	1	03-Mar	7:02	0	0	0	792	0	0	0	0	0	0
05-Mar	1	5	1	06-Mar	7:00	0	0	0	1,142	0	1	0	0	0	0
07-Mar	3	6	2	08-Mar	7:00	0	0	0	55	0	0	0	0	0	0
09-Mar	1	6	1	10-Mar	7:00	2	0	0	353	0	1	0	0	0	0
12-Mar	2	-	1	13-Mar	7:00	1	0	0	791	0	0	0	0	0	0
14-Mar	2	6	1	15-Mar	7:10	3	0	0	895	0	0	0	0	0	40
14-Mar	2	-	1	15-Mar	19:00	1	0	0	193	0	0	0	0	0	1
14-Mar	2	-	1	16-Mar	7:00	0	0	0	1,572	0	2	0	0	0	0
14-Mar	2	-	1	16-Mar	19:20	0	0	0	236	0	5	0	0	0	0
14-Mar	2	-	1	17-Mar	7:00	0	0	0	373	0	1	0	0	0	0
21-Mar	2	6	1	22-Mar	7:00	0	0	0	174	0	17	11	0	0	0
23-Mar	1	6	1	24-Mar	7:00	2	0	0	2,007	0	11	0	0	0	0
26-Mar	1	6	1	27-Mar	7:00	6	0	0	884	0	7	0	0	0	0
28-Mar	1	7	1	29-Mar	7:00	5	0	0	1,351	0	7	0	0	0	3
28-Mar	1	-	1	29-Mar	19:00	0	0	0	328	0	0	0	0	0	0
28-Mar	1	-	1	30-Mar	7:00	10	0	0	3,196	0	13	0	0	0	0
28-Mar	1	-	1	30-Mar	19:00	0	0	0	509	0	0	0	0	0	0
02-Apr	1	6	1	03-Apr	7:00	11	0	0	4,116	0	9	0	0	0	0
04-Apr	1	8	1	05-Apr	7:00	3	0	0	4,553	0	7	0	0	0	0
06-Apr	3	6	1	07-Apr	7:00	65	0	0	13,775	0	11	0	0	0	0
09-Apr	1	7	1	10-Apr	7:00	56	0	0	7,639	6	7	0	0	0	0
11-Apr	1	9	1	12-Apr	7:00	24	0	0	13,487	25	0	0	0	0	58
11-Apr	1	-	1	12-Apr	19:00	1	0	0	545	3	0	0	0	0	4
11-Apr	1	-	1	13-Apr	7:00	3	0	0	11,398	47	0	0	0	0	12
11-Apr	1	-	1	13-Apr	19:00	0	0	0	1,278	17	0	0	0	0	5
11-Apr	1	-	1	14-Apr	7:00	57	0	0	21,481	63	4	0	0	0	0
16-Apr	2	8	1	17-Apr	7:00	70	0	0	21,635	45	3	0	0	0	0
18-Apr	2	9	1	19-Apr	7:00	143	0	0	28,656	104	0	0	0	0	0

Table 1B. (continued)

Set Date	Weather[1]	Water Temp. (°C)	Water Clarity[2]	Sample Date	Start Time	Wild Chinook	Hatchery Chinook	Adipose-Clipped Chinook	Chum	Coho Fry	Coho 1 year	Coho 2 year	Dye Marked Wild Chinook	Dye Marked Hatchery Chinook	Dye Marked Chum
20-Apr	1	9	1	21-Apr	7:00	75	0	0	33,084	90	0	0	0	0	0
23-Apr	1	9	1	23-Apr	19:00	0	0	0	0	0	0	0	0	0	0
23-Apr	1	9	1	24-Apr	7:00	78	0	0	33,455	390	0	0	0	0	0
27-Apr	1	9	1	27-Apr	19:00	0	0	0	0	0	0	0	0	0	0
27-Apr	1	-	1	28-Apr	7:00	4	0	0	237	0	37	0	0	0	0
30-Apr	1	9	1	30-Apr	19:00	0	0	0	0	0	0	0	0	0	0
30-Apr	1	-	1	01-May	7:00	3	0	0	143	0	43	0	0	0	0
02-May	1	9	1	02-May	19:00	0	0	0	0	0	0	0	0	0	0
02-May	1	-	1	03-May	7:00	19	0	0	234	0	49	0	0	0	0
04-May	1	9	1	04-May	19:00	0	0	0	0	0	0	0	0	0	0
04-May	1	-	1	05-May	7:00	7	0	0	259	0	123	0	0	0	0
07-May	1	9	1	07-May	19:00	0	0	0	0	0	0	0	0	0	0
07-May	1	-	1	08-May	7:00	9	0	0	178	0	134	0	0	0	0
10-May	1	12	1	10-May	19:00	0	0	0	0	0	0	0	0	0	0
10-May	1	-	1	11-May	7:00	0	0	0	17	3	27	0	0	0	0
10-May	1	-	1	11-May	19:00	0	0	0	5	2	11	0	0	0	0
10-May	1	-	1	12-May	7:00	0	0	0	29	6	33	0	0	0	0
14-May	1	12	1	14-May	19:00	0	0	0	0	0	0	0	0	0	0
14-May	1	-	1	15-May	7:00	1	0	0	3	2	8	0	0	0	0
16-May	1	10	1	16-May	19:00	0	0	0	0	0	0	0	0	0	0
16-May	1	-	1	17-May	7:00	1	1	0	1	100	35	0	0	0	0
						660	1	0	211,777	903	606	11	0	0	123

[1] Weather code: 1 = clear; 2 = cloudy; 3 = raining. [2] Clarity code: 1 = clear; 2 = cloudy.

Table 1C. Rotary screw trap catch data, Nanaimo River, 2002.

Set Date	Weather[1]	Water Temp. (°C)	Water Clarity[2]	Sample Date	Start Time	Wild Chinook	Hatchery Chinook	Adipose-Clipped Chinook	Chum	Coho Fry	Coho 1 year	Coho 2 year	Dye Marked Wild Chinook	Dye Marked Hatchery Chinook	Dye Marked Chum
27-Feb	1	3	1	28-Feb	7:05	0	0	0	51	0	6	0	0	0	0
01-Mar	1	4	1	02-Mar	6:58	0	0	0	118	0	6	0	0	0	0
04-Mar	1	4	1	05-Mar	6:57	0	0	0	6	0	0	0	0	0	0
06-Mar	4	3	1	07-Mar	7:15	0	0	0	138	0	3	0	0	0	0
08-Mar	4	2	1	09-Mar	6:55	0	0	0	84	0	4	0	0	0	0
11-Mar	3	4	2	12-Mar	7:09	5	0	0	154	0	3	0	0	0	0
13-Mar	1	4	2	14-Mar	6:55	1	0	0	60	0	10	0	0	0	0
15-Mar	2	3	2	16-Mar	6:55	3	0	0	212	1	0	0	0	0	0
18-Mar	2	2	1	19-Mar	7:00	5	0	0	400	0	5	0	0	0	0
20-Mar	2	3	1	21-Mar	7:00	3	0	0	733	0	5	0	0	0	22
20-Mar	2	2	1	21-Mar	19:00	1	0	0	102	0	0	0	0	0	2
20-Mar	2	3	1	22-Mar	6:55	6	0	0	1,007	0	1	0	0	0	3
20-Mar	2	3	1	22-Mar	19:00	6	0	0	1,010	0	0	0	0	0	3
20-Mar	2	4	1	23-Mar	6:50	8	0	0	1,134	0	3	0	0	0	0
25-Mar	2	5	1	26-Mar	6:54	4	0	0	1,137	1	3	0	0	0	0
27-Mar	2	4	1	28-Mar	6:55	6	0	0	1,538	0	6	0	0	0	18
27-Mar	2	4	1	28-Mar	18:55	1	0	0	169	0	0	0	0	0	0
27-Mar	2	4	1	29-Mar	6:45	7	0	0	1,811	0	3	0	0	0	0
27-Mar	2	4	1	29-Mar	18:50	1	0	0	376	0	2	0	0	0	1
27-Mar	2	4	1	30-Mar	6:50	8	0	0	3,387	0	10	0	0	0	1
01-Apr	N/A		1	02-Apr	6:55	12	0	0	2,577	7	5	0	0	0	0
03-Apr	1	5	1	04-Apr	6:45	7	0	0	2,707	3	5	0	0	0	0
05-Apr	N/A		1	06-Apr	6:45	34	0	0	2,871	3	13	0	0	0	0
08-Apr	2	6	1	09-Apr	7:00	38	0	0	2,743	1	10	0	0	0	0
10-Apr	3	6	1	11-Apr	6:46	49	0	0	4,643	3	16	0	0	0	3
10-Apr	3	6	1	11-Apr	18:50	16	0	0	1,338	0	1	0	0	0	1
10-Apr	3	6	1	12-Apr	6:50	11	1	0	96	1	2	0	0	0	0
10-Apr	3	6	1	12-Apr	18:45	28	1	0	1,444	0	2	0	0	0	0
10-Apr	3	6	1	13-Apr	6:45	34	4	0	609	3	26	0	0	0	0
15-Apr	3	6	2	16-Apr	7:15	25	0	0	726	3	17	0	0	0	0
17-Apr	1	6	1	18-Apr	7:05	78	4	0	2,821	9	38	0	0	0	0

Table 1C. (continued).

Set Date	Weather[1]	Water Temp. (°C)	Water Clarity[2]	Sample Date	Start Time	Wild Chinook	Hatchery Chinook	Adipose-Clipped Chinook	Chum	Coho Fry	Coho 1 year	Coho 2 year	Dye Marked Wild Chinook	Dye Marked Hatchery Chinook	Dye Marked Chum
19-Apr	1	8	1	20-Apr	6:55	51	4	0	4,549	9	51	0	0	0	0
22-Apr	2	8	1	23-Apr	6:55	118	5	0	7,614	13	45	0	0	0	0
24-Apr	1	8	1	25-Apr	6:55	151	5	0	12,203	5	51	0	0	0	67
24-Apr	1	8	1	25-Apr	18:30	10	0	0	2,050	0	1	0	0	0	0
24-Apr	1	8	1	26-Apr	6:45	66	0	0	18,874	8	26	0	0	0	1
24-Apr	1	8	1	26-Apr	18:30	6	0	0	4,021	0	2	0	0	0	0
24-Apr	1	8	1	27-Apr	6:55	139	0	0	31,786	6	46	0	0	0	1
29-Apr	1	10	1	30-Apr	6:45	59	0	0	3,887	2	2	0	0	0	0
01-May	N/A		1	02-May	6:58	359	4	0	10,860	69	175	0	0	0	0
03-May	1	10	1	04-May	6:55	99	4	0	2,762	28	71	0	0	0	0
06-May	1	9	1	07-May	6:55	91	1	0	3,802	81	95	0	0	0	0
08-May	1	10	1	09-May	7:00	22	0	0	3,038	26	18	0	4	0	11
08-May	1	10	1	09-May	18:55	5	5	0	323	4	28	0	0	0	3
08-May	1	10	1	10-May	6:55	40	2,956	417	1,987	78	164	0	0	0	1
08-May	1	10	1	10-May	18:45	0	228	50	159	2	10	0	0	0	0
08-May	1	10	1	11-May	6:50	11	2,901	210	2,279	28	154	0	0	0	0
13-May	2	8	1	14-May	6:50	48	126	6	1,169	36	749	0	0	0	0
15-May	1	10	1	16-May	7:00	23	15	0	563	33	138	0	0	0	0
17-May	1	11	1	18-May	6:45	20	66	6	475	24	76	0	0	0	0
20-May	2	10	1	21-May	7:00	23	402	32	216	10	220	0	0	0	0
22-May	N/A	12	1	23-May	6:50	5	244	29	120	5	168	0	1	0	3
22-May	N/A	12	1	23-May	18:55	0	0	0	48	1	0	0	0	0	0
22-May	N/A	12	1	24-May	7:00	5	143	19	306	4	150	0	0	0	0
22-May	N/A	12	1	24-May	18:50	0	0	0	19	0	0	0	0	0	0
22-May	N/A	12	1	25-May	7:00	6	109	12	21	1	28	0	0	0	0
27-May	2	12	1	28-May	6:50	26	43	5	155	31	43	0	0	0	0
29-May	1	12	1	30-May	6:10	58	113	9	21	49	175	0	0	0	0
						1,838	7,384	795	149,509	588	2,891	0	5	0	141

[1] Weather code: 1 = clear; 2 = cloudy; 3 = raining; 4 = snow. [2] Clarity code: 1 = clear; 2 = cloudy.

Table 2. Nanaimo River Hatchery chinook release data for the brood years 1999 - 2001.

Tagcode	Brood Year	Number Tagged	Number Released	CWT % Marked	Weight (g)	Length (mm)	Start Release Date	End Release Date	Release Site	Run Type
184330	1999	25,185	257,394	9.78	4.03	73	05/17/2000	05/17/2000	First Lake	Spring*
184332	1999	25,071	25,071	100	5.1	82	05/18/2000	05/18/2000	Nanaimo	Fall
184331	1999	25,185	25,185	100	5.1	82	05/18/2000	05/18/2000	Nanaimo	Fall
184333	1999	25,165	25,165	100	5.1	82	05/18/2000	05/18/2000	Nanaimo	Fall
184334	1999	25,231	25,231	100	5.1	82	05/18/2000	05/18/2000	Nanaimo	Fall
-	1999	0	99,238	0	4.8	82	05/18/2000	05/18/2000	Nanaimo	Fall
184335	1999	25,300	126,422	20.01	5.0	82	05/05/2000	05/23/2000	Nanaimo	Fall
184336	1999	25,115	125,497	20.01	5.0	82	05/05/2000	05/23/2000	Nanaimo	Fall
		151,067	451,809	33.44						
184329	1999	25,175	57,625	43.69	10.34	97	06/23/2000	06/23/2000	Jack Point	Fall
184363	2000	24,739	207,955	11.9	6.56	84	05/23/2001	05/24/2001	First Lake	Spring*
184552	2000	50,060	105,512	47.44	4.9	79	04/28/2001	05/29/2001	Nanaimo	Fall
184554	2000	50,259	105,931	47.45	4.9	79	04/28/2001	05/29/2001	Nanaimo	Fall
184553	2000	50,254	105,920	47.45	4.9	79	04/28/2001	05/29/2001	Nanaimo	Fall
		150,573	317,363	47.45						
184362	2000	25,091	51,070	49.13	8.67	-	06/06/2001	06/06/2001	Jack Point	Fall
184337	2001	25,102	186,187	13.48	5.7	81	05/16/2002	05/16/2002	First Lake	Spring*
184717	2001	25,119	102,917	24.41	4.68	77	05/09/2002	05/09/2002	Nanaimo	Fall
184718	2001	25,355	103,883	24.41	4.68	77	05/09/2002	05/09/2002	Nanaimo	Fall
183205	2001	25,182	25,182	100	5.61	81	05/14/2002	05/14/2002	Nanaimo	Fall
183206	2001	25,237	25,237	100	5.61	81	05/14/2002	05/14/2002	Nanaimo	Fall
184715	2001	25,307	25,307	100	3.78	71	05/16/2002	05/16/2002	Nanaimo	Fall
184716	2001	25,131	25,131	100	3.78	71	05/16/2002	05/16/2002	Nanaimo	Fall
		151,331	307,657	49.19						
184628	2001	25,119	51,508	48.77	6.62	84	05/17/2002	05/17/2002	Jack Point	Fall

Note: * First Lake spring run

Table 3A. Daily summary of 24-hour trapping periods for naturally-reared chinook fry, Nanaimo River, 2000.

Sample Date	Naturally-Reared Chinook Fry Night	Day	24 Hour Period	Expansion Factor
16-Mar	0	0	0	N/A
17-Mar	0	0	0	N/A
31-Mar	2	0	2	1.000
13-Apr	638	618	1256	1.969
14-Apr	549	35	584	**1.064**
	1189	653	1842	1.549

Table 3B. Daily summary of 24-hour trapping periods for naturally-reared chinook fry, Nanaimo River, 2001.

Sample Date	Naturally-Reared Chinook Fry Night	Day	24 Hour Period	Expansion Factor
15-Mar	3	1	4	1.333
16-Mar	0	0	0	N/A
29-Mar	5	0	5	1.000
30-Mar	10	0	10	1.000
12-Apr	24	1	25	1.042
13-Apr	3	0	3	1.000
11-May	0	0	0	N/A
	45	2	47	**1.044**

Table 3C. Daily summary of 24-hour trapping periods for naturally-reared chinook fry, Nanaimo River, 2002.

Sample Date	Naturally-Reared Chinook Fry Night	Day	24 Hour Period	Expansion Factor
21-Mar	3	1	4	1.333
22-Mar	6	6	12	2.000
28-Mar	6	1	7	1.167
29-Mar	7	1	8	1.143
11-Apr	49	16	65	1.327
12-Apr	11	28	39	3.545
25-Apr	151	10	161	1.066
26-Apr	66	6	72	1.091
09-May	22	5	27	1.227
10-May	40	0	40	1.000
23-May	5	0	5	1.000
24-May	5	0	5	1.000
Totals	371	74	445	**1.199**

Table 3D. Daily summary of 24-hour trapping periods for hatchery-reared chinook fry, Nanaimo River, 2002.

Sample Date	Hatchery-Reared Chinook Fry Night	Day	24 Hour Period	Expansion Factor
21-Mar	0	0	0	N/A
22-Mar	0	0	0	N/A
28-Mar	0	0	0	N/A
29-Mar	0	0	0	N/A
11-Apr	0	0	0	N/A
12-Apr	1	1	2	2.000
25-Apr	5	0	5	1.000
26-Apr	0	0	0	N/A
09-May	0	5	5	N/A
10-May	3,373	278	3,651	1.082
23-May	273	0	273	1.000
24-May	162	0	162	1.000
Totals	3,814	284	4,098	**1.074**

Table 4A. Rotary screw trap efficiency data by release date, Nanaimo River, 2000.

Release	Flow	Released			Recovered			Recovered (%)			Expansion Factor		
		Wild	Hatch	Wild	Wild	Hatch	Wild	Wild	Hatch	Wild	Wild	Hatch	Wild
Date	(m/s)	Chin	Chin	Chum	Chin	Chin	Chum	Chin	Chin	Chum	Chin	Chin	Chum
15-Mar	0.866		482			8			1.66			60.25	
29-Mar	0.776		160	300		3	1		1.88	0.33		53.33	300.00
12-Apr	0.528	242		58	19		13	7.85		22.41	12.74		4.46
		242	642	358	19	11	14	7.85	1.71	3.91	**12.74**	**58.36**	25.57

Table 4B. Rotary screw trap efficiency data by release date, Nanaimo River, 2001.

Release Date	Flow (m/s)	Released Wild Chum	Recovered Wild Chum	Recovered (%) Wild Chum	Expansion Factor Wild Chum
14-Mar	0.522	329	41	12.46%	**8.02**
28-Mar	1.212	305	3	0.98%	**101.67**
11-Apr	0.521	300	79	26.33%	**3.80**
		934	123	13.17%	7.59

Table 4C. Rotary screw trap efficiency data by release date, Nanaimo River, 2002.

Release	Flow	Released			Recovered			Recovered (%)			Expansion Factor		
		Wild	Wild		Wild	Wild		Wild	Wild		Wild	Wild	
Date	(m/s)	Chin	Chum	Total	Chin	Chum	Total	Chin	Chum	Total	Chinook	Chum	Total
20-Mar	0.753		301			30			9.97			**10.03**	
27-Mar	0.743		317			20			6.31			**15.85**	
10-Apr	1.025		288			4			1.39			**72.00**	
24-Apr	N/A		361			69			19.11			**5.23**	
08-May	0.424	24	319	343	4	15	19	16.67	4.70	5.54	6.00	21.27	**18.05**
22-May	0.659	8	330	338	1	3	4	12.50	0.91	1.18	8.00	110.00	**84.50**
		32	1916	1948	5	141	146	15.63	7.36	7.49	6.40	13.59	13.34

Table 5A. Expanded daily trap catch estimates of naturally-reared chinook fry, Nanaimo River, 2000

Sample Date	Observed[1] PM	AM	Missing cells Interpolated	24-hour Estimates	Extrapolated Estimates	Cumulative Total
09-Mar	0			0	0	0
10-Mar				0	0	0
11-Mar				0	0	0
12-Mar				0	0	0
13-Mar				0	0	0
14-Mar	0			0	0	0
15-Mar				0	0	0
16-Mar	0	0		0	0	0
17-Mar	0	0		0	0	0
18-Mar	0			0	0	0
19-Mar				0	0	0
20-Mar				0	0	0
21-Mar	0			0	0	0
22-Mar			1	1	14	14
23-Mar	2			2	28	42
24-Mar			3	3	42	84
25-Mar	0			0	0	84
26-Mar			2	2	28	113
27-Mar			2	2	28	141
28-Mar	4			4	56	197
29-Mar			3	3	35	232
30-Mar	1	0		1	13	245
31-Mar	2	0		2	25	271
01-Apr	4			4	56	327
02-Apr			34	38	479	806
03-Apr			34	38	479	1,284
04-Apr	64			71	901	2,186
05-Apr			49	54	683	2,869
06-Apr	33			36	465	3,333
07-Apr			58	64	810	4,143
08-Apr	82			91	1,155	5,298
09-Apr			177	196	2,492	7,790
10-Apr			177	196	2,492	10,283
11-Apr	272			301	3,830	14,113
12-Apr			455	503	6,407	20,520
13-Apr	638	618		1,256	15,997	36,517
14-Apr	549	35		584	7,438	43,956
15-Apr	26			29	366	44,322
16-Apr			48	53	669	44,991
17-Apr			48	53	669	45,660
18-Apr	69			76	972	46,631
19-Apr			153	169	2,154	48,786
20-Apr	237			262	3,337	52,123
21-Apr			332	367	4,675	56,798
22-Apr	427			472	6,013	62,811
23-Apr			250	276	3,513	66,324

Table 5A. (continued)

Sample Date	Observed[1] PM	AM	Missing cells Interpolated	24-hour Estimates	Extrapolated Estimates	Cumulative Total
24-Apr			250	276	3,513	69,838
25-Apr	72			80	1,014	70,852
26-Apr			101	111	1,415	72,267
27-Apr	129			143	1,817	74,083
28-Apr			88	97	1,239	75,323
29-Apr			88	97	1,239	76,562
30-Apr			88	97	1,239	77,801
01-May			88	97	1,239	79,040
02-May	47			52	662	79,702
03-May			38	42	535	80,237
04-May			38	42	535	80,772
05-May			38	42	535	81,307
06-May	29			32	408	81,716
07-May			27	30	380	82,096
08-May			27	30	380	82,476
09-May	25			28	352	82,828
10-May			16	17	218	83,046
11-May	6			7	84	83,131
12-May			8	9	113	83,244
13-May	10			11	141	83,384
14-May			13	14	176	83,560
15-May	15			17	211	83,772
16-May			121	133	1,697	85,468
17-May			121	133	1,697	87,165
18-May	226			250	3,182	90,348

[1] PM = fry captured during previous day's night time trapping period; AM = fry captured during daylight trapping. See Table 1 for clarification.

Table 5B. Expanded daily trap catch estimates of naturally-reared chinook fry, Nanaimo River, 2001.

Sample Date	Observed[1] PM	AM	Missing cells Interpolated	24-hour Estimates	Extrapolated Estimates	Cumulative Total
27-Feb	0			0	0	0
28-Feb			0	0	0	0
01-Mar	0			0	0	0
02-Mar			0	0	0	0
03-Mar	0			0	0	0
04-Mar			0	0	0	0
05-Mar			0	0	0	0
06-Mar	0			0	0	0
07-Mar			0	0	0	0
08-Mar	0			0	0	0
09-Mar			1	1	8	8
10-Mar	2			2	17	25
11-Mar			2	2	13	38
12-Mar			2	2	13	50
13-Mar	1			1	8	59
14-Mar			2	2	17	75
15-Mar	3	1		4	32	108
16-Mar	0	0		0	0	108
17-Mar	0			0	0	108
18-Mar			0	0	0	108
19-Mar			0	0	0	108
20-Mar			0	0	0	108
21-Mar			0	0	0	108
22-Mar	0			0	0	108
23-Mar			1	1	106	214
24-Mar	2			2	212	426
25-Mar			4	4	425	851
26-Mar			4	4	425	1,276
27-Mar	6			6	637	1,913
28-Mar			6	6	584	2,497
29-Mar	5	0		5	508	3,005
30-Mar	10	0		10	1,017	4,022
31-Mar			11	11	1,115	5,137
01-Apr			11	11	1,115	6,252
02-Apr			11	11	1,115	7,367
03-Apr	11			11	1,168	8,535
04-Apr			7	7	743	9,278
05-Apr	3			3	12	9,290
06-Apr			34	36	135	9,425
07-Apr	65			68	258	9,682
08-Apr			61	63	240	9,922
09-Apr			61	63	240	10,162
10-Apr	56			58	222	10,384
11-Apr			40	42	159	10,543
12-Apr	24	1		25	95	10,638

Table 5B. (continued)

Sample Date	Observed[1] PM	AM	Missing cells Interpolated	24-hour Estimates	Extrapolated Estimates	Cumulative Total
13-Apr	3	0		3	11	10,649
14-Apr	57			60	226	10,875
15-Apr			64	66	252	11,127
16-Apr			64	66	252	11,379
17-Apr	70			73	278	11,657
18-Apr			107	111	422	12,079
19-Apr	143			149	567	12,646
20-Apr			109	114	432	13,079
21-Apr	75			78	297	13,376
22-Apr			77	80	303	13,680
23-Apr		0	77	77	291	13,970
24-Apr	78			81	309	14,280
25-Apr			41	43	163	14,442
26-Apr			41	43	163	14,605
27-Apr		0	41	41	156	14,760
28-Apr	4			4	16	14,776
29-Apr			4	4	14	14,790
30-Apr		0	4	4	13	14,803
01-May	3			3	12	14,815
02-May		0	11	11	42	14,857
03-May	19			20	75	14,933
04-May		0	13	13	49	14,982
05-May	7			7	28	15,010
06-May			8	8	32	15,041
07-May		0	8	8	30	15,072
08-May	9			9	36	15,107
09-May			5	5	18	15,125
10-May		0	5	5	17	15,142
11-May	0	0		0	0	15,142
12-May	0			0	0	15,142
13-May			1	1	2	15,144
14-May		0	1	1	2	15,146
15-May	1			1	4	15,150
16-May		0	1	1	4	15,154
17-May	1			1	4	15,158

[1] PM = fry captured during previous day's night time trapping period; AM = fry captured during daylight trapping. See Table 1 for clarification.

Table 5C. Expanded daily trap catch estimates of naturally-reared chinook fry, Nanaimo River, 2002.

Sample Date	Observed[1] PM	AM	Missing cells Interpolated	24-hour Estimates	Extrapolated Estimates	Cumulative Total
28-Feb	0			0	0	0
01-Mar			0	0	0	0
02-Mar	0			0	0	0
03-Mar			0	0	0	0
04-Mar			0	0	0	0
05-Mar	0			0	0	0
06-Mar			0	0	0	0
07-Mar	0			0	0	0
08-Mar			0	0	0	0
09-Mar	0			0	0	0
10-Mar			3	3	30	30
11-Mar			3	3	30	60
12-Mar	5			6	60	120
13-Mar			3	4	36	156
14-Mar	1			1	12	168
15-Mar			2	2	24	193
16-Mar	3			4	36	229
17-Mar			4	5	48	277
18-Mar			4	5	48	325
19-Mar	5			6	60	385
20-Mar			4	5	48	433
21-Mar	3	1		4	40	473
22-Mar	6	6		12	120	594
23-Mar	8			10	96	690
24-Mar			6	7	114	804
25-Mar			6	7	114	918
26-Mar	4			5	76	994
27-Mar			5	6	95	1,089
28-Mar	6	1		7	111	1,200
29-Mar	7	1		8	127	1,327
30-Mar	8			10	152	1,479
31-Mar			10	12	190	1,669
01-Apr			10	12	190	1,859
02-Apr	12			14	228	2,088
03-Apr			10	11	181	2,268
04-Apr	7			8	605	2,873
05-Apr			21	25	1,770	4,643
06-Apr	34			41	2,936	7,579
07-Apr			36	43	3,109	10,688
08-Apr			36	43	3,109	13,797
09-Apr	38			46	3,282	17,079
10-Apr			44	52	3,757	20,836
11-Apr	49	16		65	4,680	25,516
12-Apr	11	28		39	2,808	28,324
13-Apr	34			41	2,936	31,260

Table 5C. (continued)

Sample Date	Observed[1] PM	AM	Missing cells Interpolated	24-hour Estimates	Extrapolated Estimates	Cumulative Total
14-Apr			30	35	2,548	33,808
15-Apr			30	35	2,548	36,355
16-Apr	25			30	2,159	38,514
17-Apr			52	62	4,448	42,962
18-Apr	78			94	489	43,451
19-Apr			65	77	405	43,856
20-Apr	51			61	320	44,176
21-Apr			85	101	530	44,707
22-Apr			85	101	530	45,237
23-Apr	118			142	741	45,977
24-Apr			135	161	844	46,821
25-Apr	151	10		161	842	47,664
26-Apr	66	6		72	377	48,040
27-Apr	139			167	872	48,913
28-Apr			99	119	621	49,534
29-Apr			99	119	621	50,155
30-Apr	59			71	370	50,525
01-May			209	251	1,312	51,837
02-May	359			431	7,774	59,611
03-May			229	275	4,959	64,569
04-May	99			119	2,144	66,713
05-May			95	114	2,057	68,770
06-May			95	114	2,057	70,827
07-May	91			109	1,970	72,798
08-May			57	68	1,223	74,021
09-May	22	5		27	487	74,508
10-May	40	0		40	722	75,231
11-May	11			13	238	75,469
12-May			30	35	639	76,107
13-May			30	35	639	76,746
14-May	48			58	1,039	77,786
15-May			36	43	769	78,554
16-May	23			28	2,331	80,885
17-May			22	26	2,179	83,065
18-May	20			24	2,027	85,092
19-May			22	26	2,179	87,271
20-May			22	26	2,179	89,450
21-May	23			28	2,331	91,781
22-May			14	17	1,419	93,200
23-May	5	0		5	423	93,623
24-May	5	0		5	423	94,045
25-May	6			7	608	94,653
26-May			16	19	1,622	96,275
27-May			16	19	1,622	97,897

Table 5C. (continued)

Sample Date	Observed[1] PM	AM	Missing cells Interpolated	24-hour Estimates	Extrapolated Estimates	Cumulative Total
28-May	26			31	2,635	100,532
29-May			42	50	4,257	104,789
30-May	58			70	5,879	110,667

[1] PM = fry captured during previous day's night time trapping period; AM = fry captured during daylight trapping. See Table 1 for clarification.

Table 5D. Expanded daily trap catch estimates of hatchery-reared chinook fry, Nanaimo River, 2002.

Sample Date	Observed[1] PM	AM	Missing cells Interpolated	24-hour Estimates	Extrapolated Estimates	Cumulative Total
11-Apr	0	0		0	0	0
12-Apr	1	1		2	144	144
13-Apr	4			4	309	453
14-Apr			2	2	155	608
15-Apr			2	2	155	763
16-Apr	0			0	0	763
17-Apr			2	2	155	918
18-Apr	4			4	22	940
19-Apr			4	4	22	963
20-Apr	4			4	22	985
21-Apr			5	5	25	1,010
22-Apr			5	5	25	1,036
23-Apr	5			5	28	1,064
24-Apr			5	5	28	1,092
25-Apr	5	0		5	26	1,118
26-Apr	0	0		0	0	1,118
27-Apr	0			0	0	1,118
28-Apr			0	0	0	1,118
29-Apr			0	0	0	1,118
30-Apr	0			0	0	1,118
01-May			2	2	11	1,129
02-May	4			4	78	1,207
03-May			4	4	78	1,284
04-May	4			4	78	1,362
05-May			3	3	48	1,411
06-May			3	3	48	1,459
07-May	1			1	19	1,478
08-May			1	1	10	1,488
09-May	0	5		5	90	1,578
10-May	3373	278		3,651	65,910	67,489

Table 5D. (continued)

Sample Date	Observed[1] PM	AM	Missing cells Interpolated	24-hour Estimates	Extrapolated Estimates	Cumulative Total
11-May	3111			3,343	60,344	127,832
12-May			1,622	1,742	31,452	159,284
13-May			1,622	1,742	31,452	190,736
14-May	132			142	2,560	193,297
15-May			74	79	1,426	194,722
16-May	15			16	1,362	196,084
17-May			44	47	3,949	200,034
18-May	72			77	6,537	206,571
19-May			253	272	22,970	229,541
20-May			253	272	22,970	252,512
21-May	434			466	39,404	291,915
22-May			354	380	32,095	324,010
23-May	273	0		273	23,069	347,079
24-May	162	0		162	13,689	360,768
25-May	121			130	10,986	371,754
26-May			85	91	7,672	379,426
27-May			85	91	7,672	387,097
28-May	48			52	4,358	391,455
29-May			85	91	7,717	399,173
30-May	122			131	11,077	410,249

[1] PM = fry captured during previous day's night time trapping period; AM = fry captured during daylight trapping. See Table 1 for clarification.

Table 6A. Daily summary of chinook fry sampling length (mm) and weight (g) data, Nanaimo River, 2000.

Sampling	Naturally-Reared							Fall Run Hatchery-Reared							First Lake Spring Run Hatchery-Reared						
		Length (mm)			Weight (g)				Length (mm)			Weight (g)				Length (mm)			Weight (g)		
Date	n	Mean	Min	Max	Mean	Min	Max	n	Mean	Min	Max	Mean	Min	Max	n	Mean	Min	Max	Mean	Min	Max
06-Jan															25	37.9	37	40	0.440	0.30	0.60
25-Jan								150	42.2	32	48	0.634	0.20	1.00	50	42.8	32	51	0.610	0.40	1.10
08-Feb								200	45.8	39	55	0.877	0.50	1.30	50	45.0	37	53	0.866	0.50	1.40
22-Feb								250	48.7	38	59	0.976	0.40	1.80	50	49.3	40	57	1.028	0.50	1.80
07-Mar								200	52.3	40	61	1.284	0.10	2.20	50	51.2	42	58	1.146	0.60	1.80
21-Mar								200	58.5	44	70	1.893	0.60	3.60	300	56.0	40	71	1.648	0.50	3.70
28-Mar	4	38.0	38	38	0.363	0.32	0.41														
30-Mar	1	37.0	37	37	0.260	0.26	0.26														
01-Apr	4	41.0	40	43	0.325	0.29	0.37														
04-Apr	30	38.3	34	40	0.397	0.21	0.53	200	64.2	47	81	2.643	1.20	5.40	300	61.6	45	75	2.403	1.00	5.80
06-Apr	30	39.3	34	42	0.442	0.25	0.58														
08-Apr	29	39.6	37	42	0.431	0.32	0.60														
11-Apr	25	38.6	34	43	0.482	0.30	0.69														
12-Apr	30	40.1	34	44	0.484	0.25	0.62														
13-Apr	29	39.0	35	44	0.452	0.34	0.63														
14-Apr	48	39.5	37	44	0.463	0.28	0.68														
15-Apr	26	40.3	37	43	0.435	0.30	0.55														
18-Apr	21	39.6	36	44	0.475	0.33	0.70	100	67.9	53	76	3.361	1.40	5.10	150	64.3	50	82	2.594	1.20	6.30
20-Apr	30	38.1	34	41	0.444	0.24	0.61														
22-Apr	30	39.3	36	44	0.499	0.36	0.69														
25-Apr	18	39.7	38	41	0.528	0.43	0.58	250	71.2	60	85	3.774	1.90	6.40							
26-Apr	30	38.1	35	40	0.378	0.27	0.46														
02-May	30	40.2	37	45	0.539	0.37	0.80	100	72.4	57	86	4.165	1.60	8.00	100	66.9	40	84	3.010	1.20	7.30
04-May	5	38.2	33	45	0.436	0.23	0.76	250	73.7	60	88	4.283	1.90	7.50							
06-May	27	39.4	36	45	0.490	0.35	0.89														
09-May	25	38.8	34	46	0.524	0.34	1.07														
10-May								100	76.1	59	92	4.675	2.10	9.90							
11-May	6	39.7	38	41	0.617	0.50	0.74														
13-May	9	40.2	37	47	0.603	0.39	1.03														
16-May	15	42.2	35	61	0.856	0.34	2.79	150	76.7	63	92	4.888	2.10	8.90	150	72.8	53	102	3.940	1.03	11.40
18-May	30	42.6	36	60	0.891	0.41	2.68														

Table 6A. (continued)

Sampling	Naturally-Reared							Fall Run Hatchery-Reared							First Lake Spring Run Hatchery-Reared						
		Length (mm)			Weight (g)				Length (mm)			Weight (g)				Length (mm)			Weight (g)		
Date	n	Mean	Min	Max	Mean	Min	Max	n	Mean	Min	Max	Mean	Min	Max	n	Mean	Min	Max	Mean	Min	Max
30-May								100	83.4	60	100	6.693	2.00	12.10							
13-Jun								100	89.3	66	106	7.625	1.03	13.00							
22-Jun								100	96.7	64	116	10.471	2.30	22.40							
	532							2,450							1,225						

Table 6B. Daily summary of chinook fry sampling length (mm) and weight (g) data, Nanaimo River, 2001.

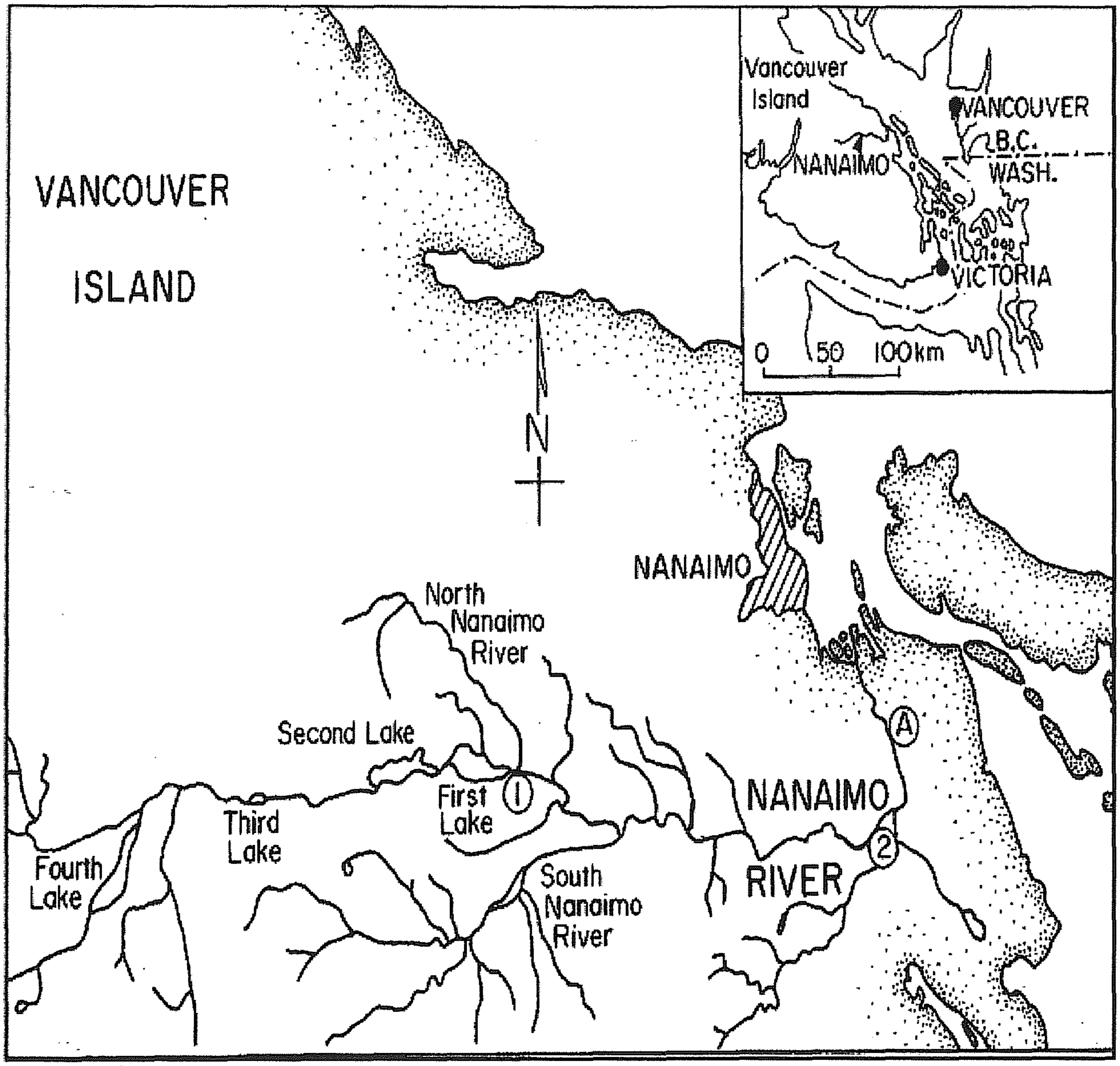
Sampling	Naturally-Reared							Fall Run Hatchery-Reared							First Lake Spring Run Hatchery-Reared						
		Length (mm)			Weight (g)				Length (mm)			Weight (g)				Length (mm)			Weight (g)		
Date	n	Mean	Min	Max	Mean	Min	Max	n	Mean	Min	Max	Mean	Min	Max	n	Mean	Min	Max	Mean	Min	Max
23-Jan								50	41.6	37	47	0.678	0.50	1.60	50	41.3	36	45	0.630	0.40	0.80
06-Feb								100	41.7	38	51	0.670	0.50	1.20	50	45.9	30	51	0.924	0.30	1.30
20-Feb								100	45.2	36	54	0.899	0.30	1.60	50	48.3	30	56	1.096	0.30	1.80
06-Mar								100	50.2	37	60	1.316	0.40	2.30	100	53.5	30	63	1.579	0.30	2.70
15-Mar	3	42.3	42	43	0.463	0.42	0.51														
20-Mar								100	55.4	44	64	1.766	0.80	2.70	100	59.2	37	74	2.263	0.40	4.60
24-Mar	2	40.5	40	41	0.455	0.40	0.51														
27-Mar	6	40.3	38	41	0.438	0.38	0.55														
29-Mar	5	40.2	39	41	0.421	0.39	0.47														
30-Mar	10	41.9	41	43	0.456	0.41	0.56														
03-Apr	11	40.6	38	42	0.422	0.34	0.52														
05-Apr	3	41.7	40	43	0.453	0.40	0.53														
07-Apr	31	40.9	38	44	0.444	0.29	0.61														
10-Apr	31	39.8	37	43	0.391	0.32	0.51														
12-Apr	11	40.9	38	45	0.415	0.30	0.54														
13-Apr	7	41.7	38	54	0.509	0.35	1.53														
14-Apr	30	42.4	37	63	0.520	0.37	2.57														
17-Apr	22	41.3	36	68	0.480	0.31	2.77	200	62.9	53	74	2.607	1.30	4.30	100	67.1	50	84	3.150	1.20	6.70
19-Apr	25	45.9	37	93	0.830	0.34	8.25														
24-Apr	15	40.1	37	44	0.420	0.34	0.61														
25-Apr															50	69.5	60	80	3.488	2.10	5.40
03-May	19	62.3	33	95	2.060	0.21	9.16														
07-May															150	74.4	58	95	4.011	1.90	7.40
09-May								200	73.2	61	97	3.767	1.90	9.20							
16-May								100	76.1	63	91	4.597	2.40	8.00							
22-May															150	84.3	68	102	6.567	3.60	12.10
	231							950							800						

Table 6C. Daily summary of chinook fry sampling length (mm) and weight (g) data, Nanaimo River, 2002.

Sampling	Naturally-Reared							Fall Run Hatchery-Reared							First Lake Spring Run Hatchery-Reared						
		Length (mm)			Weight (g)				Length (mm)			Weight (g)				Length (mm)			Weight (g)		
Date	n	Mean	Min	Max	Mean	Min	Max	n	Mean	Min	Max	Mean	Min	Max	n	Mean	Min	Max	Mean	Min	Max
08-Jan															50	41.0	37	45	0.642	0.50	0.90
15-Jan								50	40.3	37	45	0.560	0.40	0.80							
22-Jan															50	44.5	39	48	0.808	0.50	1.10
29-Jan								150	42.8	37	54	0.781	0.40	1.80							
05-Feb															50	47.4	41	53	0.996	0.60	1.40
12-Feb								200	46.5	36	53	0.901	0.20	1.30							
19-Feb															50	49.9	45	55	1.168	0.80	1.70
26-Feb								200	50.5	37	64	1.292	0.40	2.90							
05-Mar															50	55.2	45	63	1.634	0.90	2.60
12-Mar	5	40.2	37	42	0.476	0.32	0.60	200	57.0	42	72	1.959	0.70	4.00							
14-Mar	1	36.0	36	36	0.300	0.30	0.30														
16-Mar	3	41.3	40	43	0.490	0.47	0.53														
19-Mar	5	40.4	39	43	0.430	0.35	0.54								100	61.2	49	78	2.365	1.20	4.90
21-Mar	2	42.0	42	42	0.515	0.51	0.52														
23-Mar	7	40.1	38	43	0.431	0.35	0.53														
25-Mar	4	39.3	38	41	0.403	0.35	0.48														
26-Mar								250	61.8	42	78	2.532	0.70	5.60							
28-Mar	6	39.8	39	41	0.412	0.35	0.44														
30-Mar	8	38.3	34	41	0.364	0.25	0.44														
03-Apr															100	64.9	51	82	2.927	1.20	5.70
04-Apr	7	42.4	39	45	0.517	0.41	0.64														
06-Apr	28	39.3	35	45	0.407	0.28	0.59														
07-Apr	12	40.7	39	42	0.467	0.39	0.53														
09-Apr	28	39.9	37	44	0.436	0.32	0.63	250	69.0	49	85	3.645	1.20	7.10							
11-Apr	31	40.5	36	44	0.465	0.33	0.66														
13-Apr	32	40.2	36	44	0.512	0.31	0.65														
16-Apr	23	41.8	38	47	0.540	0.36	0.83								100	68.9	57	87	3.424	1.70	6.90
18-Apr	30	41.5	38	48	0.528	0.40	0.69														
20-Apr	30	40.5	36	44	0.475	0.31	0.60														
23-Apr	30	39.7	31	45	0.466	0.23	0.69														
24-Apr								100	72.4	49	81	4.231	1.20	5.90							

Table 6C. (continued)

Sampling	Naturally-Reared							Fall Run Hatchery-Reared							First Lake Spring Run Hatchery-Reared						
		Length (mm)			Weight (g)				Length (mm)			Weight (g)				Length (mm)			Weight (g)		
Date	n	Mean	Min	Max	Mean	Min	Max	n	Mean	Min	Max	Mean	Min	Max	n	Mean	Min	Max	Mean	Min	Max
25-Apr	30	40.7	38	44	0.474	0.33	0.68														
27-Apr	31	40.8	35	45	0.477	0.31	0.66														
30-Apr	29	41.0	38	45	0.503	0.34	0.74														
02-May	28	41.0	38	49	0.573	0.38	1.29														
04-May	31	40.7	38	48	0.523	0.34	1.27														
07-May	30	40.7	36	44	0.504	0.32	0.68	250	76.7	57	94	4.846	1.90	8.20							
08-May															150	78.2	62	103	4.807	2.10	11.90
09-May	22	41.5	38	47	0.545	0.40	0.83														
11-May	11	41.8	38	47	0.592	0.39	0.91														
14-May	29	40.7	35	48	0.530	0.29	1.06														
15-May								50	84.4	72	93	6.620	3.70	8.90							
16-May	25	42.7	37	57	0.641	0.36	1.66								150	82.5	70	95	5.695	3.00	9.00
18-May	20	47.1	35	64	0.958	0.30	2.22														
21-May	23	48.1	34	60	1.091	0.26	2.02														
23-May	5	50.4	37	60	1.308	0.41	2.12														
25-May	6	57.2	53	66	1.900	1.54	2.88														
28-May	26	54.2	43	70	1.615	0.67	3.75														
30-May	30	52.1	42	64	1.526	0.63	2.42														
	668							1,700							850						



Legend:

1 Hatchery release site for First Lake spring run chinook fry
2 Hatchery release site for fall run fry
A Downstream fry trapping site and Enumeration fence site

Figure 1. Location of rotary screw trap and Nanaimo River Hatchery release sites.

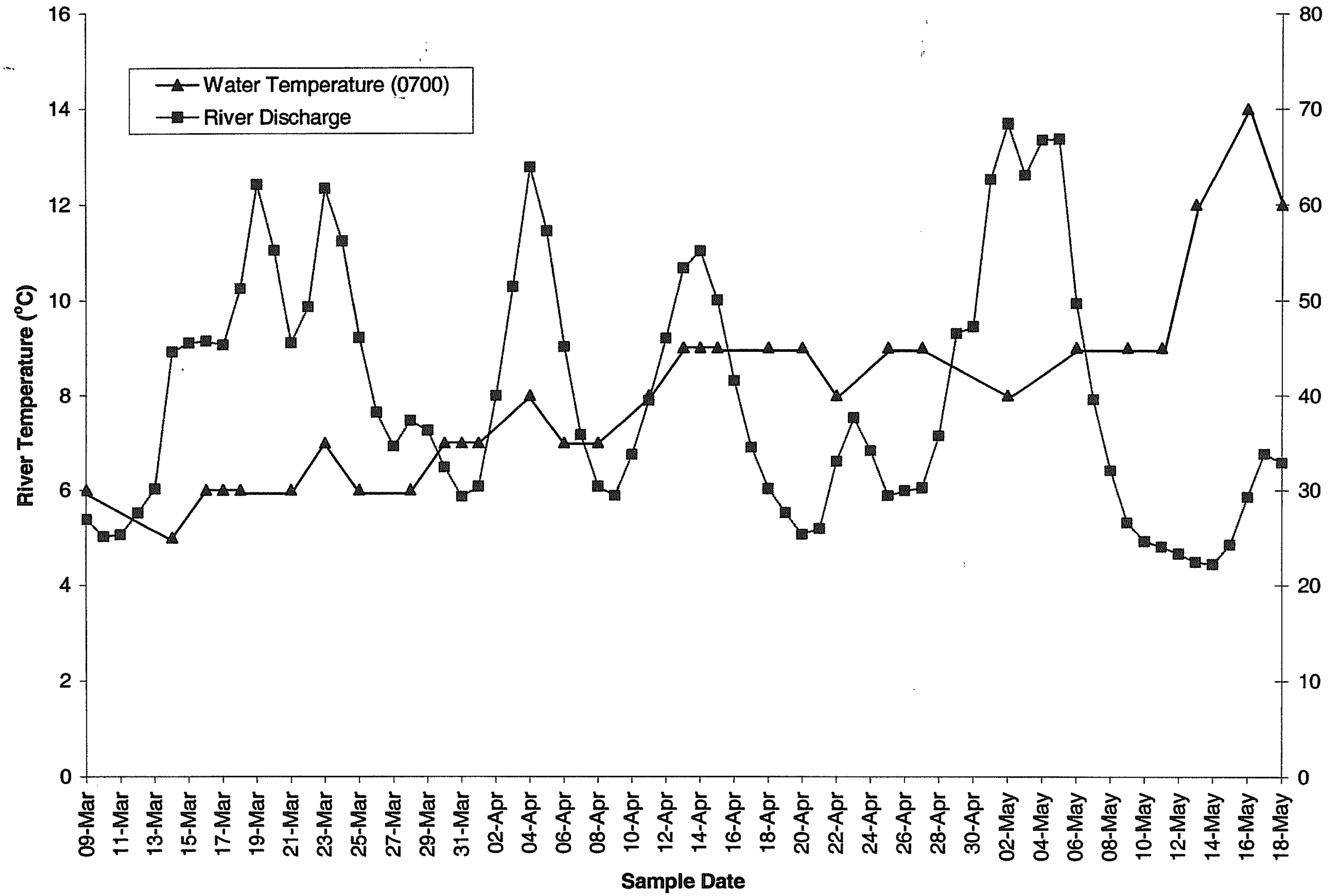


Figure 2A. River discharge and water temperature, Nanaimo River, 2000.

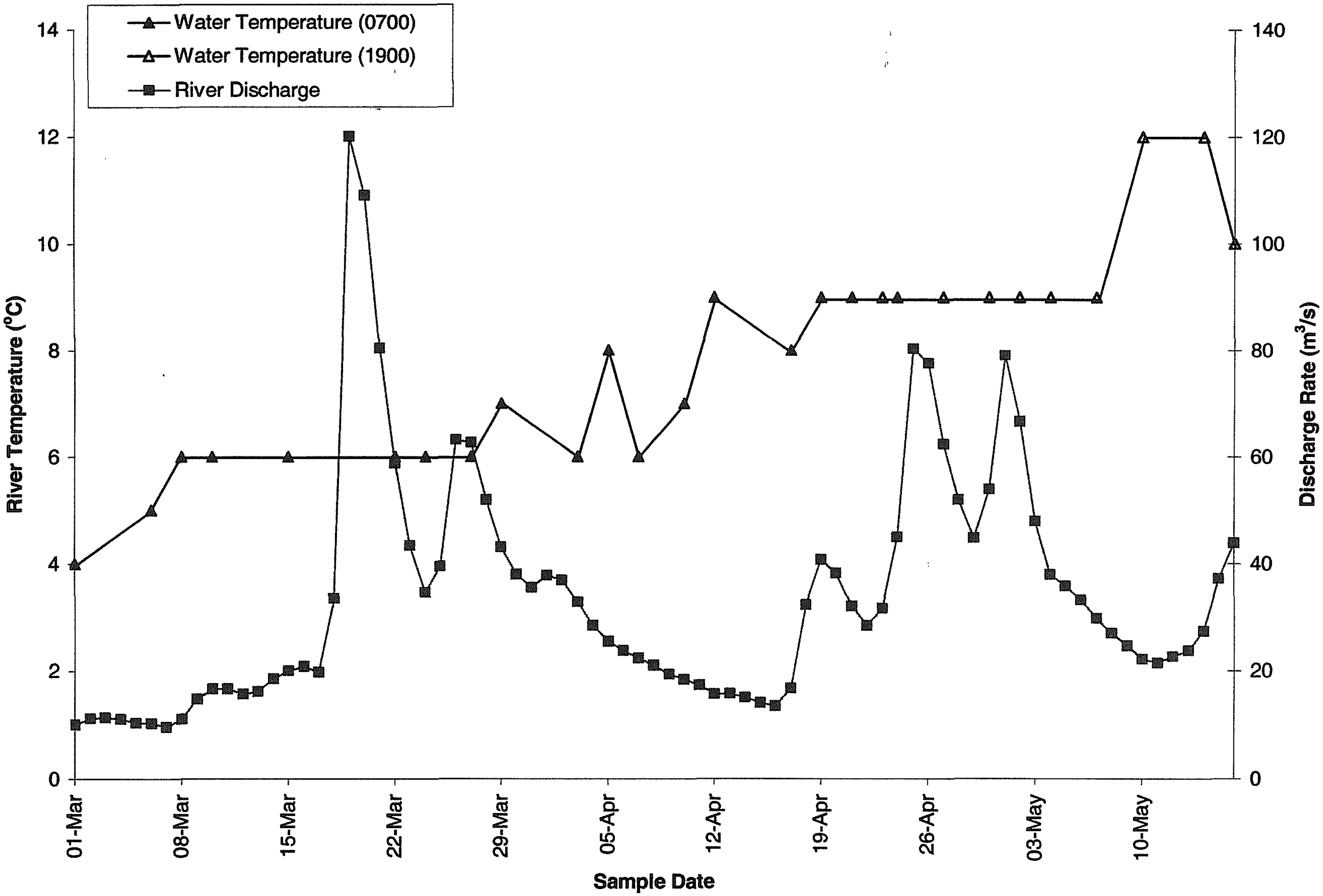


Figure 2B. River Discharge and water temperature, Nanaimo River, 2001.

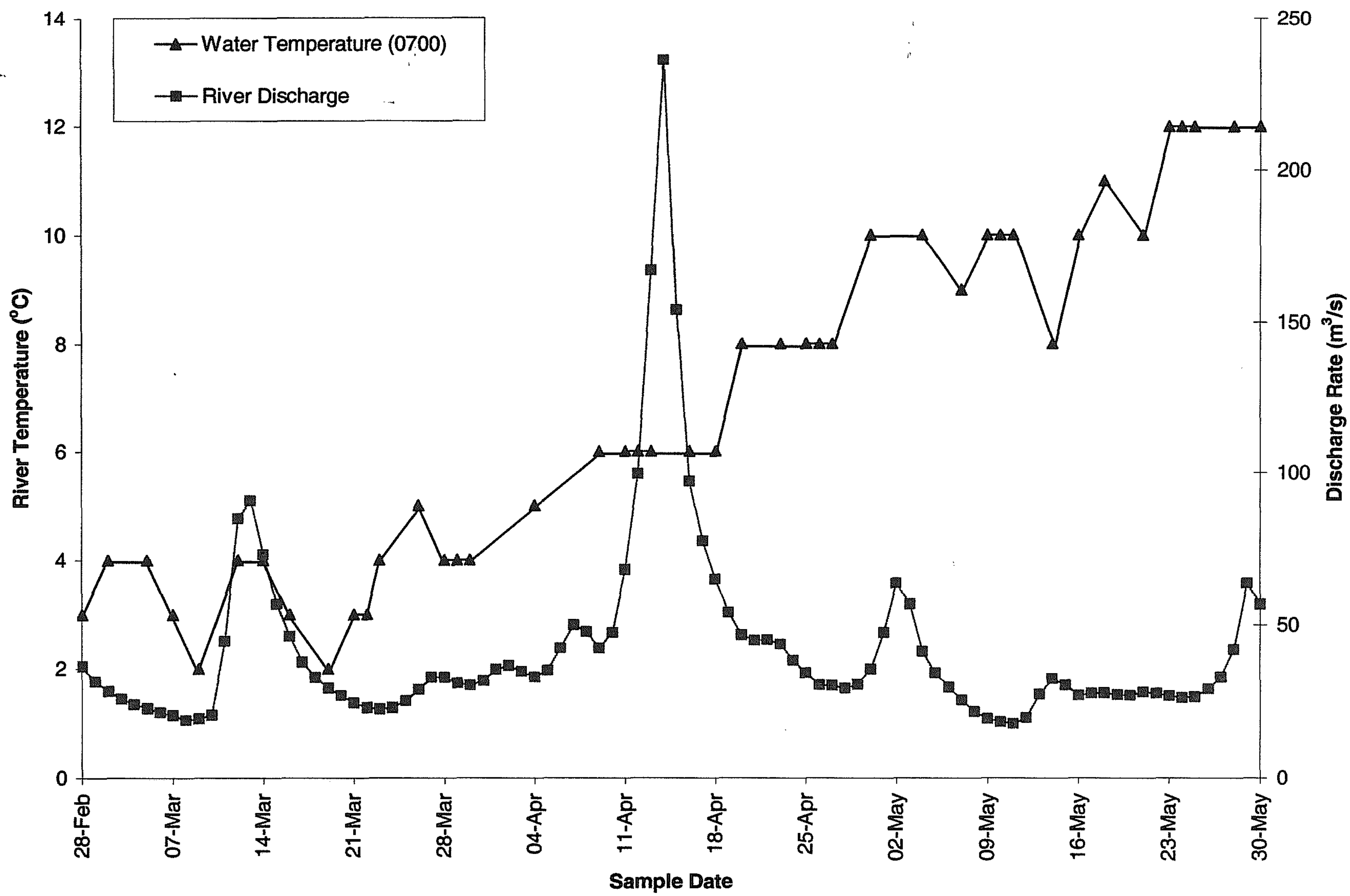


Figure 2C. River Discharge and water temperature, Nanaimo River, 2002.

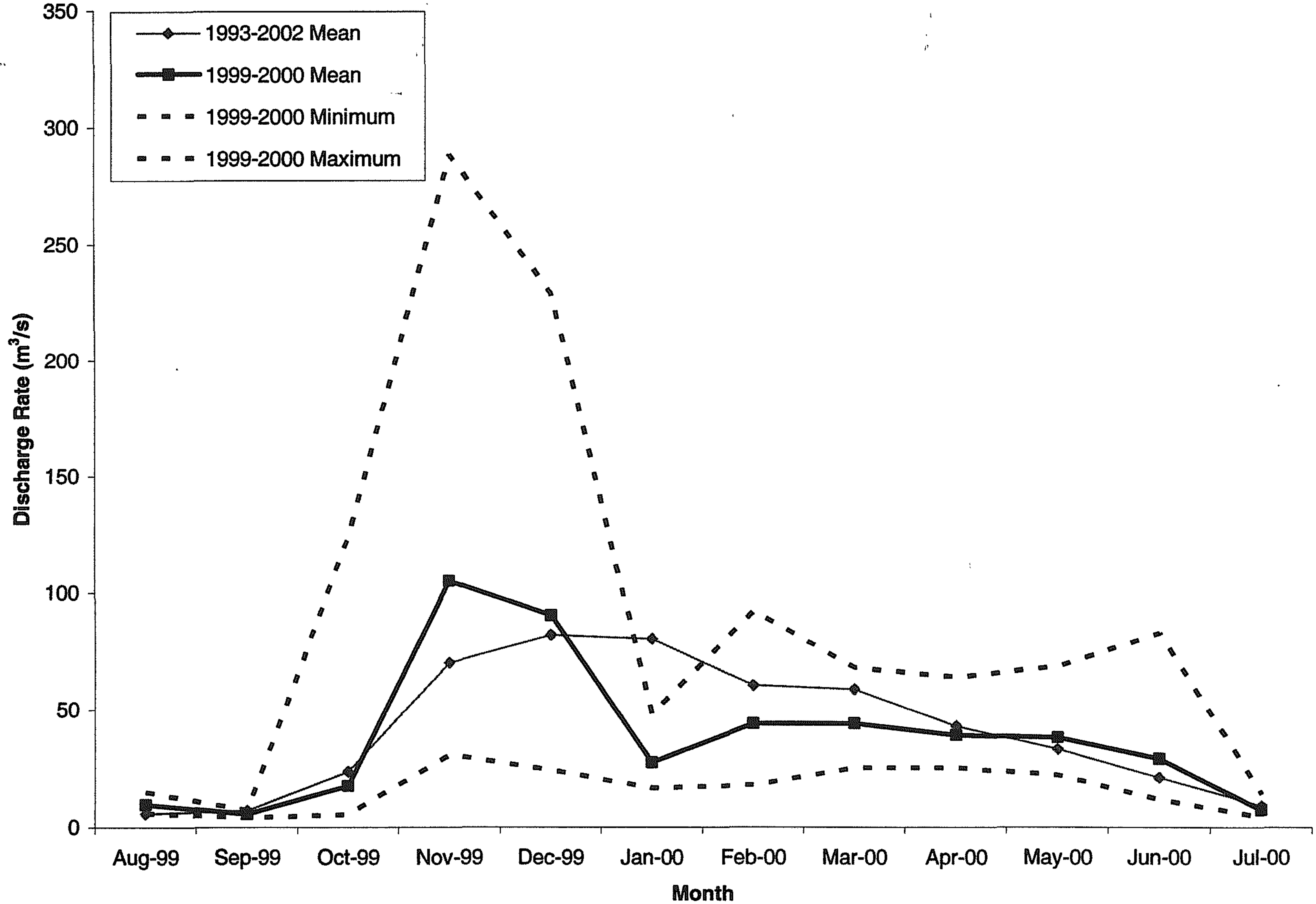


Figure 3A. Monthly Nanaimo River discharge (m^3/s) from August 1999 to July 2000 along with 10 year mean.

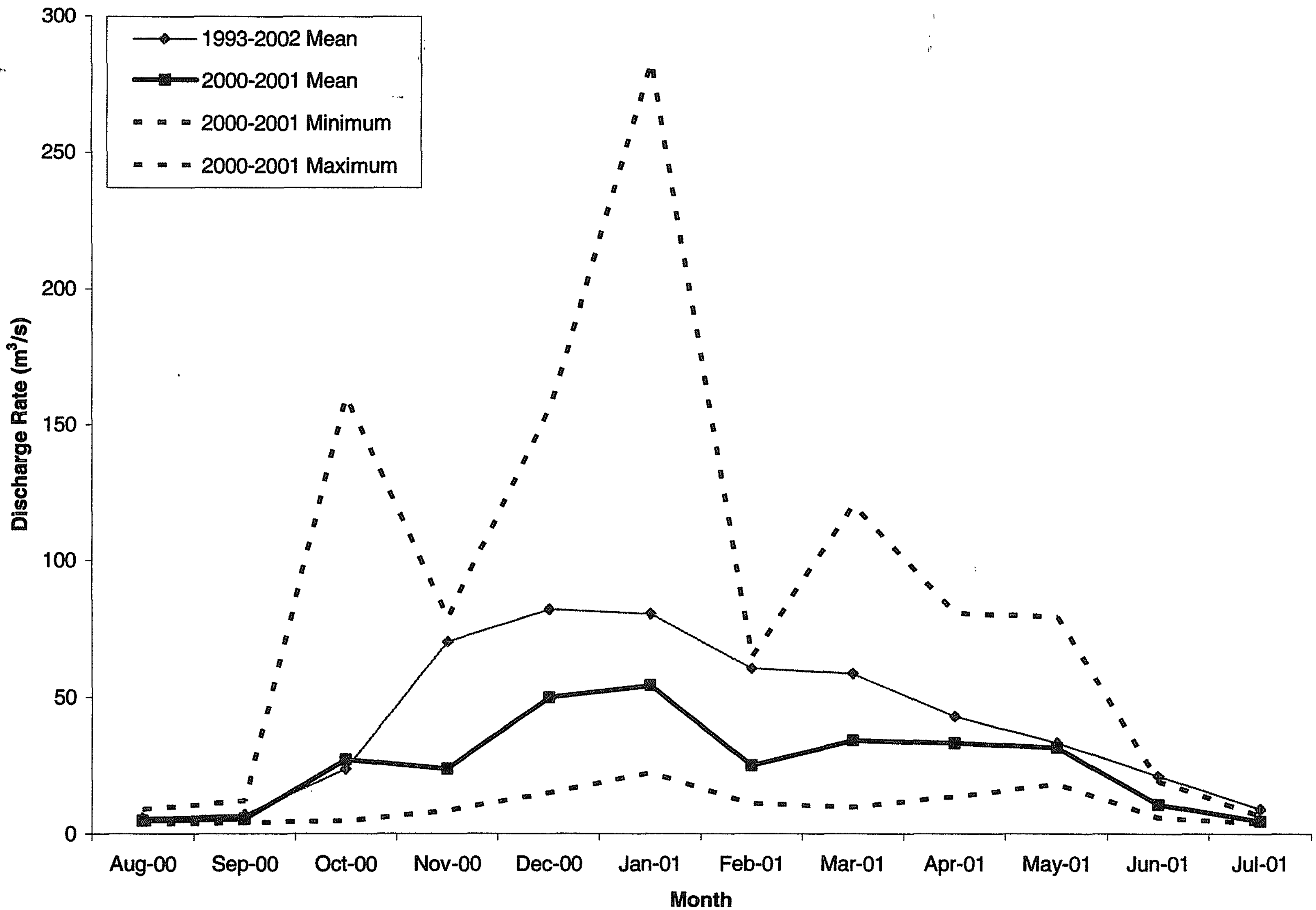


Figure 3B. Monthly Nanaimo River discharge (m^3/s) from August 2000 to July 2001 along with 10 year mean.

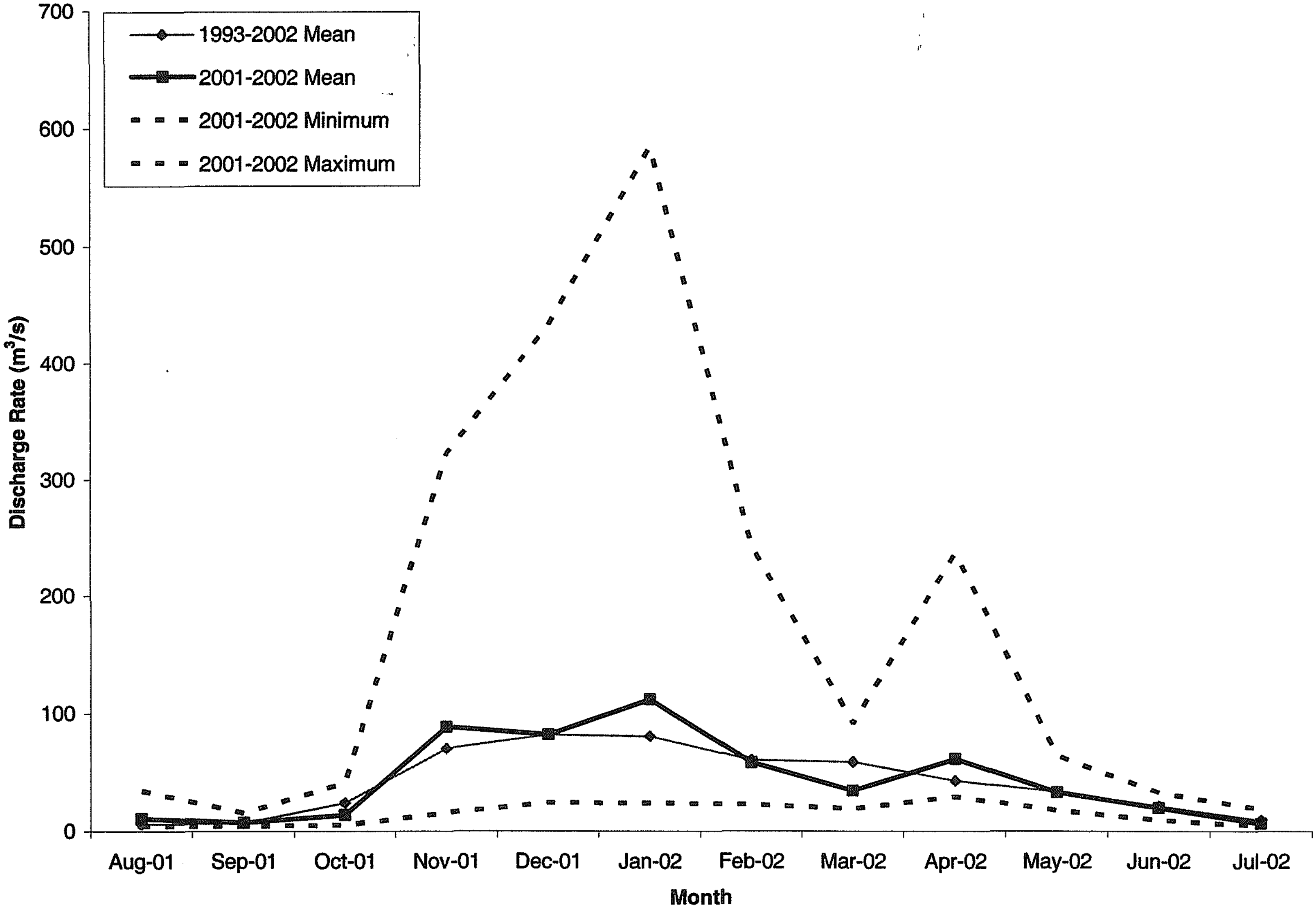


Figure 3C. Monthly Nanaimo River discharge (m^3/s) from August 2001 to July 2002 along with 10 year mean.

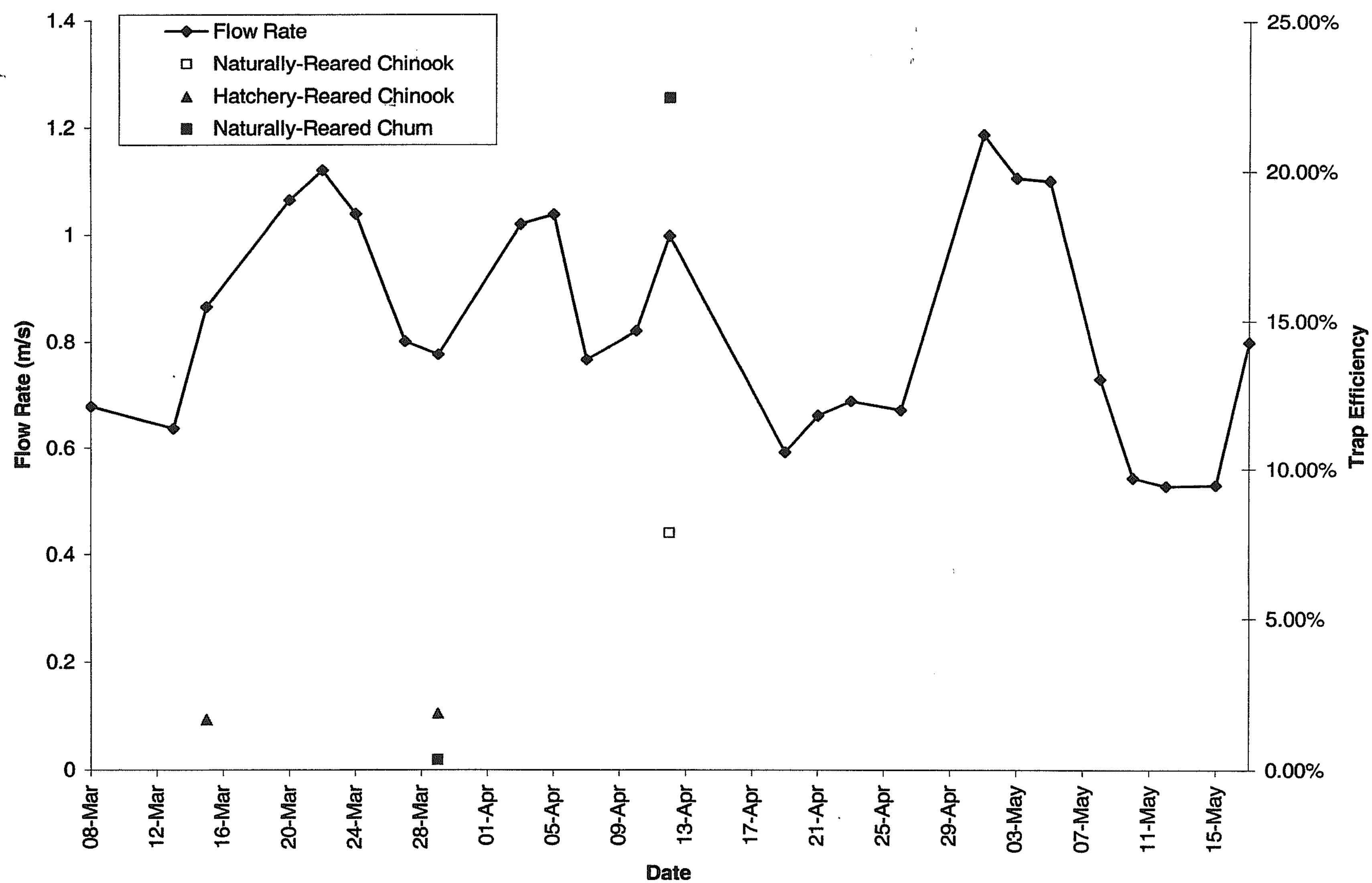


Figure 4A. Rotary screw trap efficiency compared with water flow, Nanaimo River, 2000.

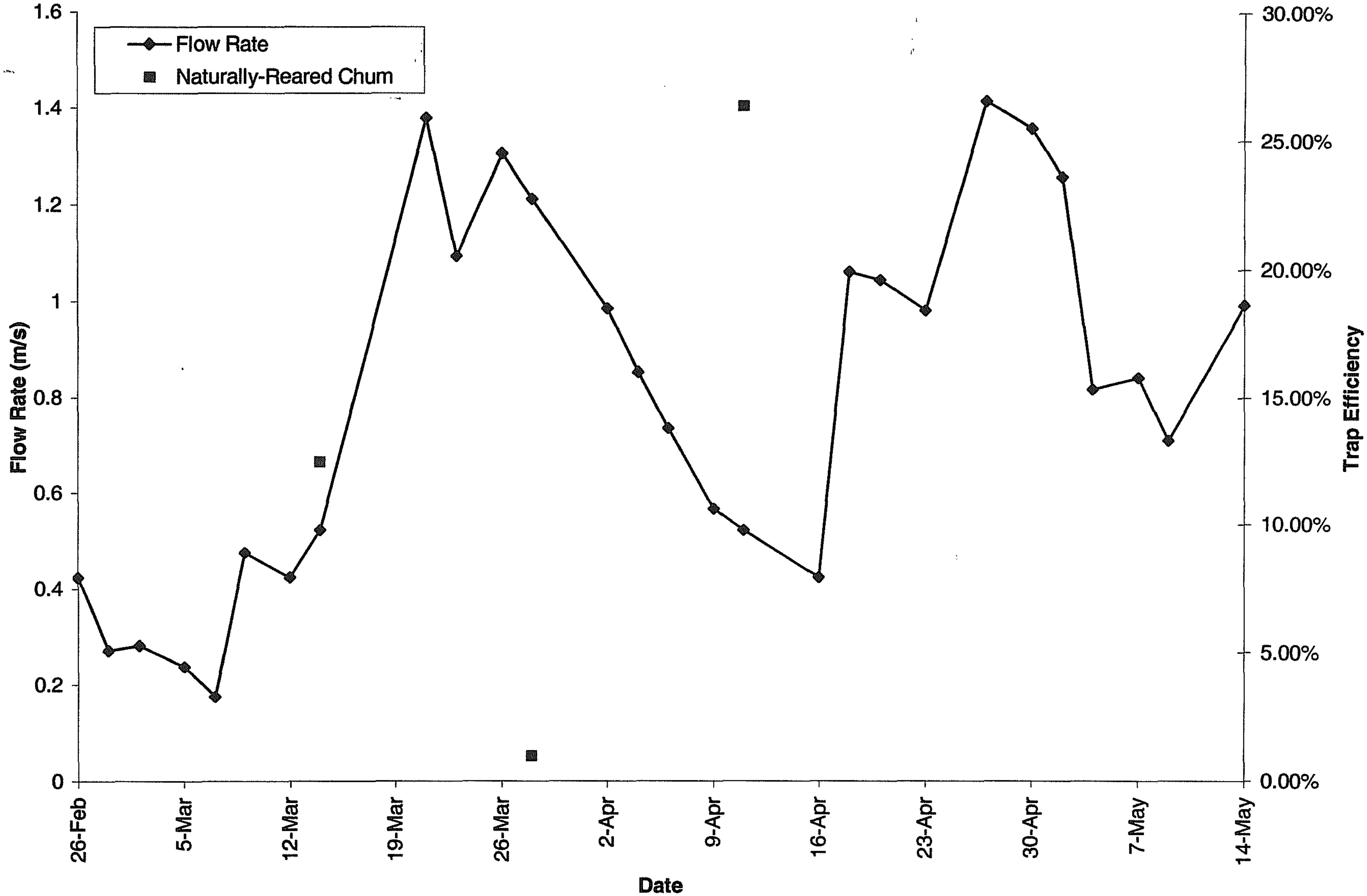


Figure 4B. Rotary screw trap efficiency compared with water flow, Nanaimo River, 2001.

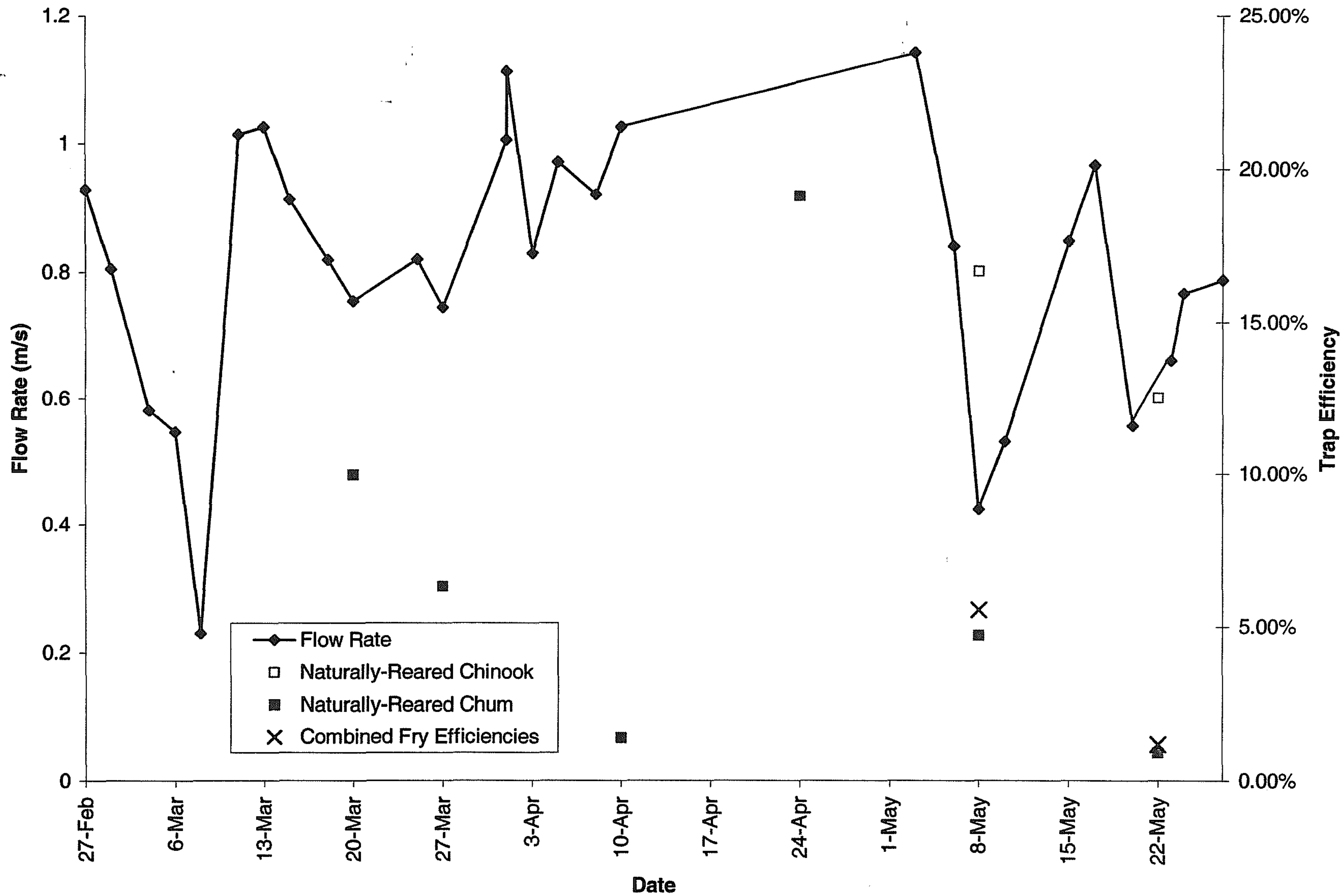


Figure 4C. Rotary screw trap efficiency compared with water flow, Nanaimo River, 2002.

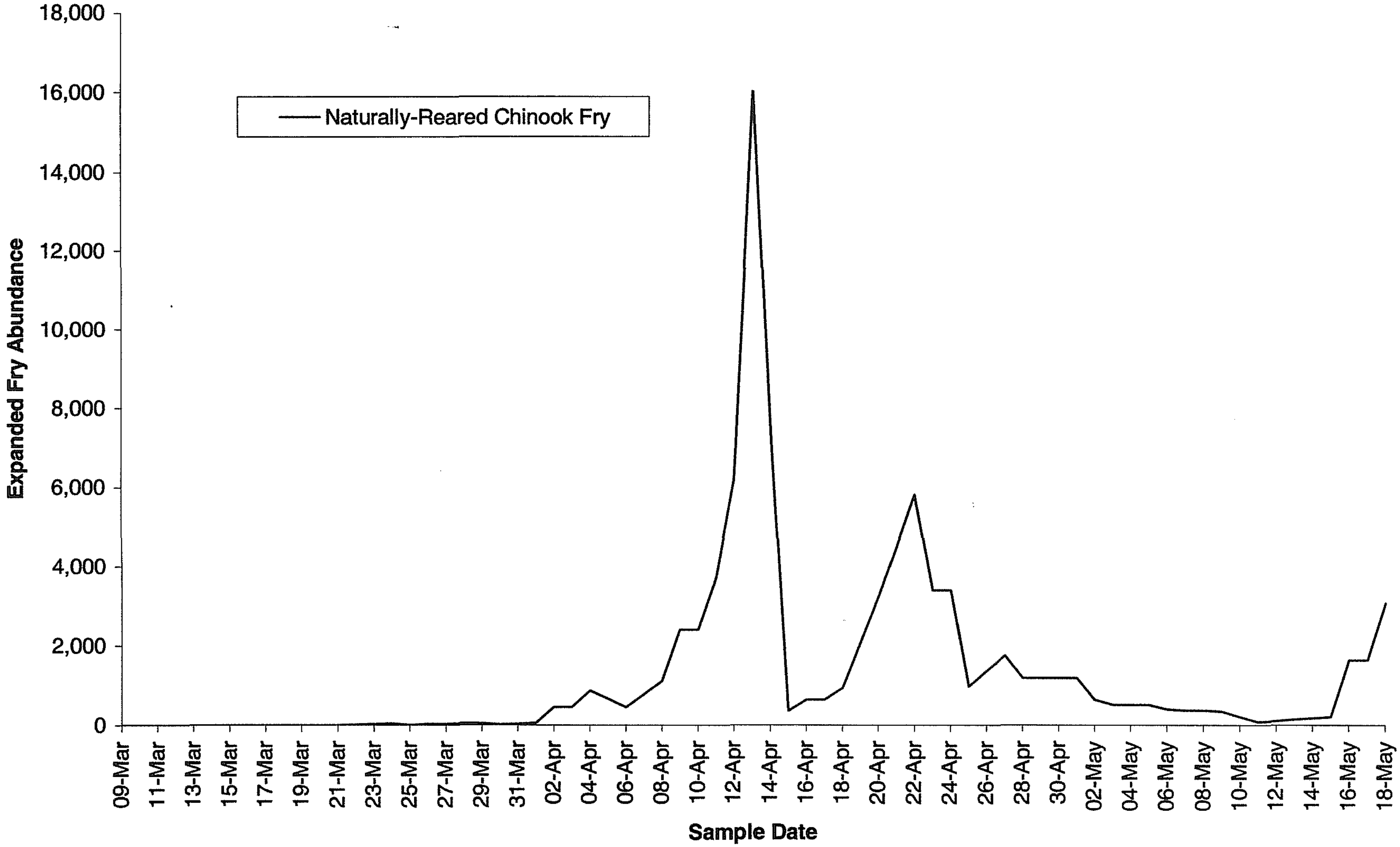


Figure 5A. Daily abundance estimates of naturally-reared chinook fry downstream migration, Nanaimo River, 2000.

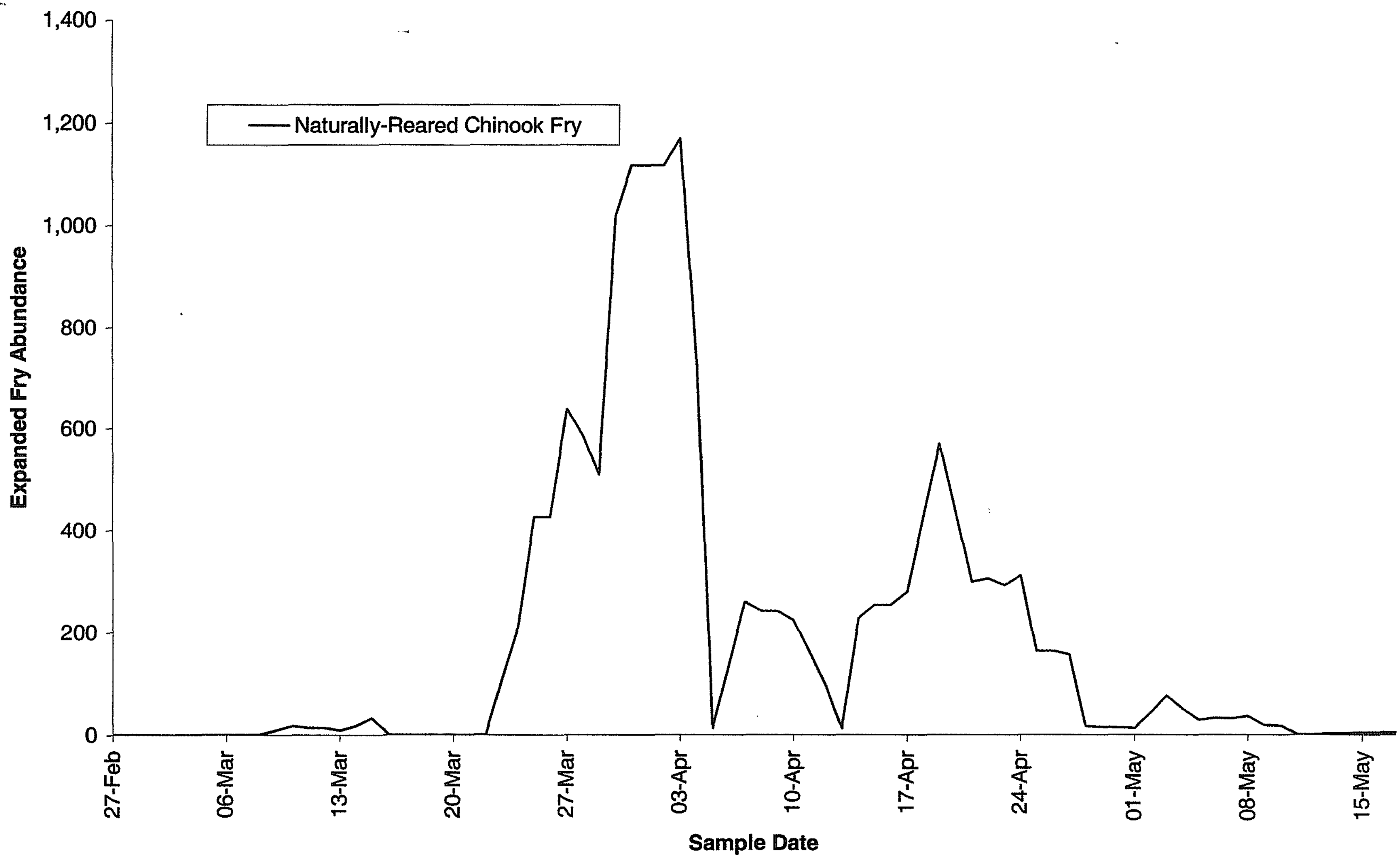


Figure 5B. Daily abundance estimates of naturally-reared chinook fry downstream migration, Nanaimo River, 2001.

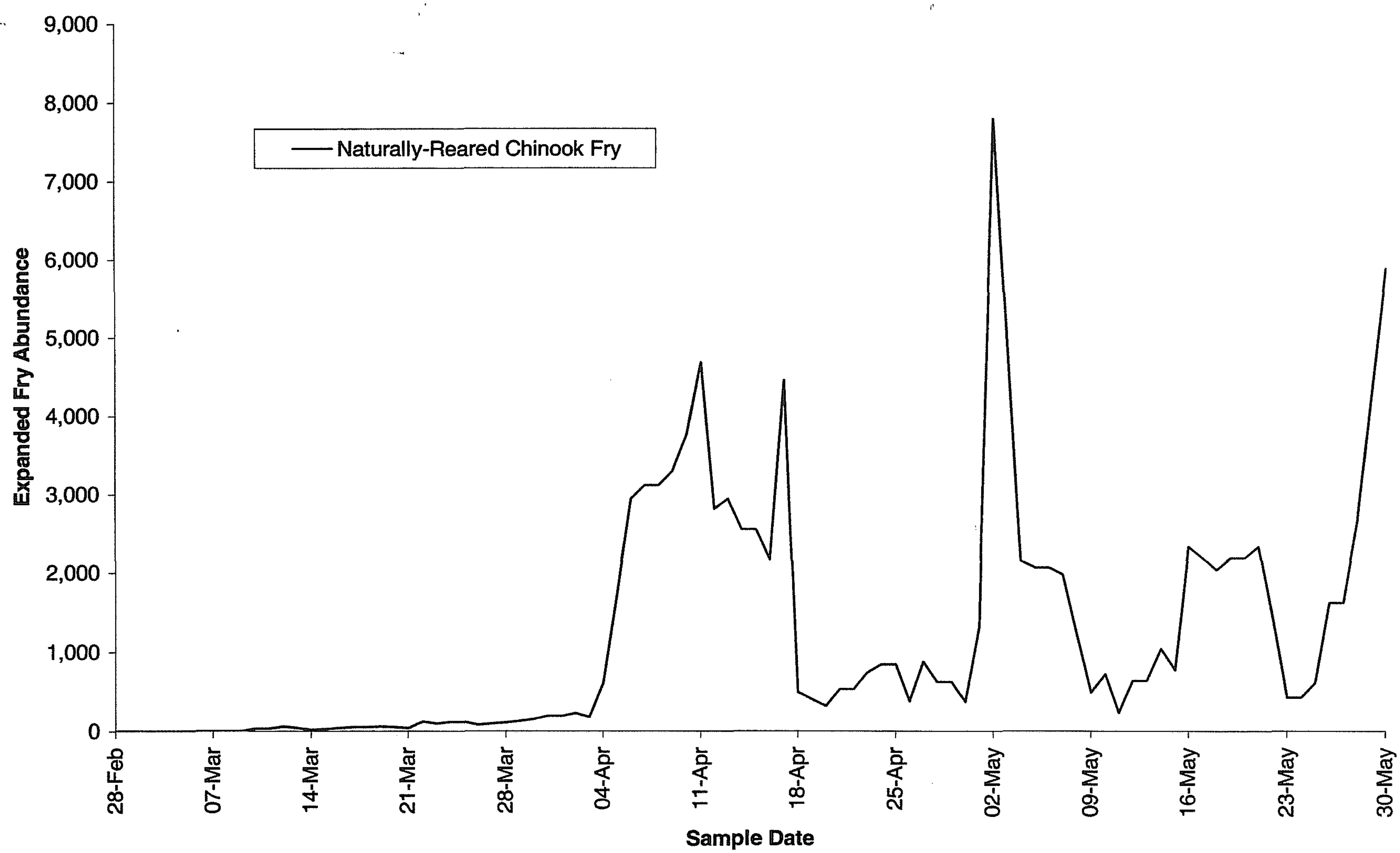


Figure 5C. Daily abundance estimates of naturally-reared chinook fry downstream migration, Nanaimo River, 2002.

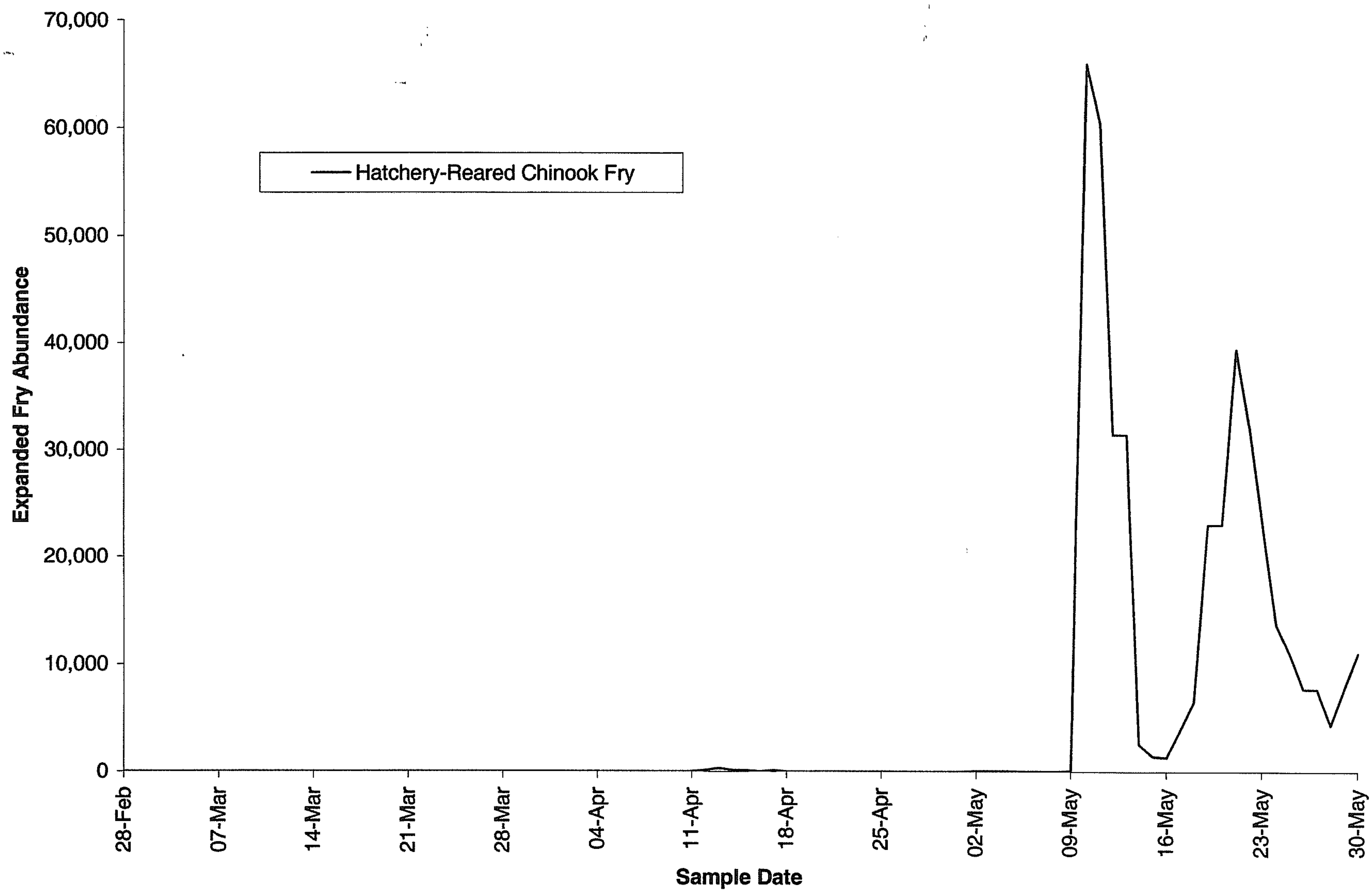


Figure 5D. Daily abundance estimates of hatchery-reared chinook fry downstream migration, Nanaimo River, 2002.

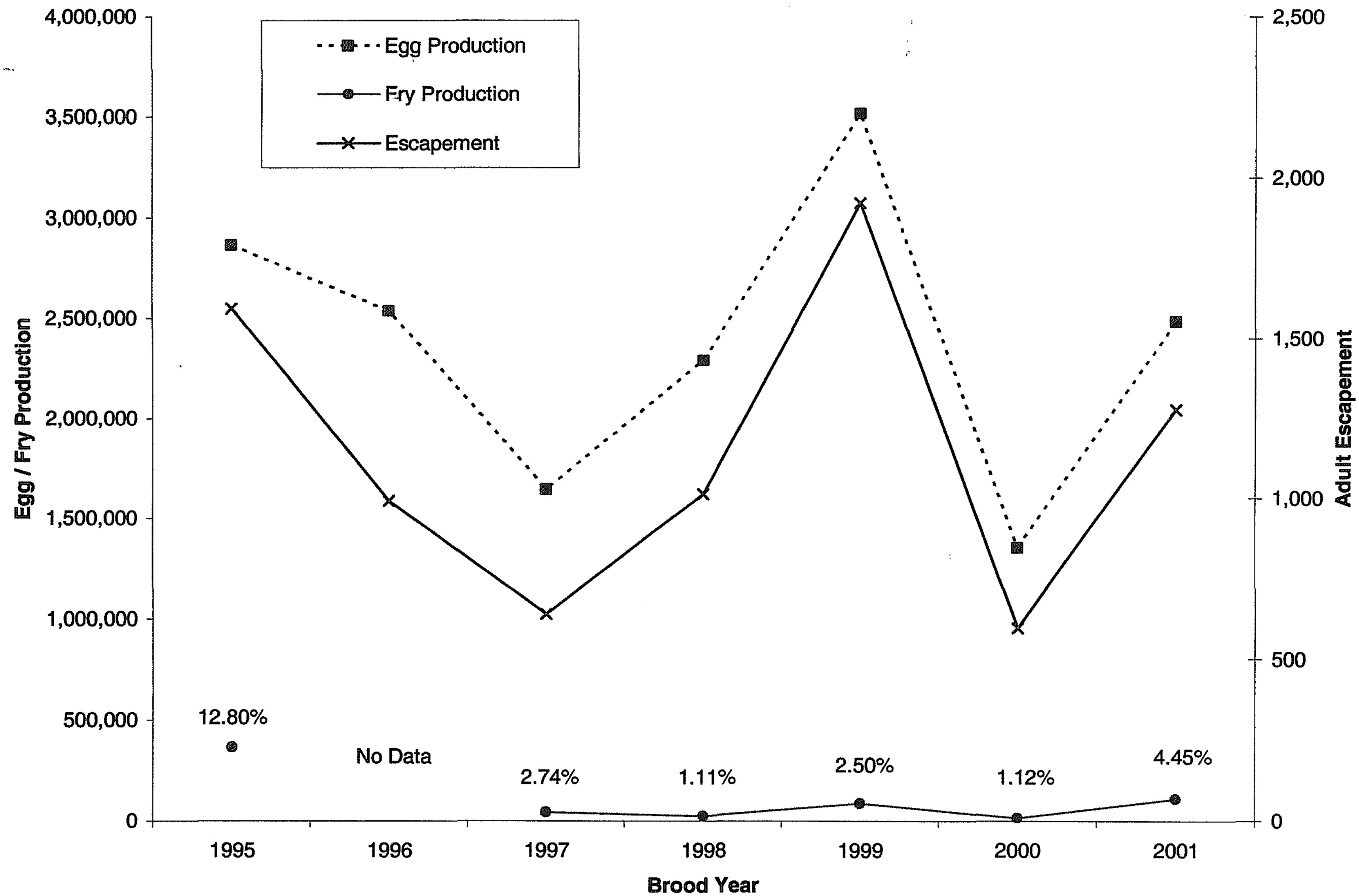


Figure 6. Egg to fry survival estimates compared to adult escapement and fry production, Nanaimo River, brood years 1995 – 2001.

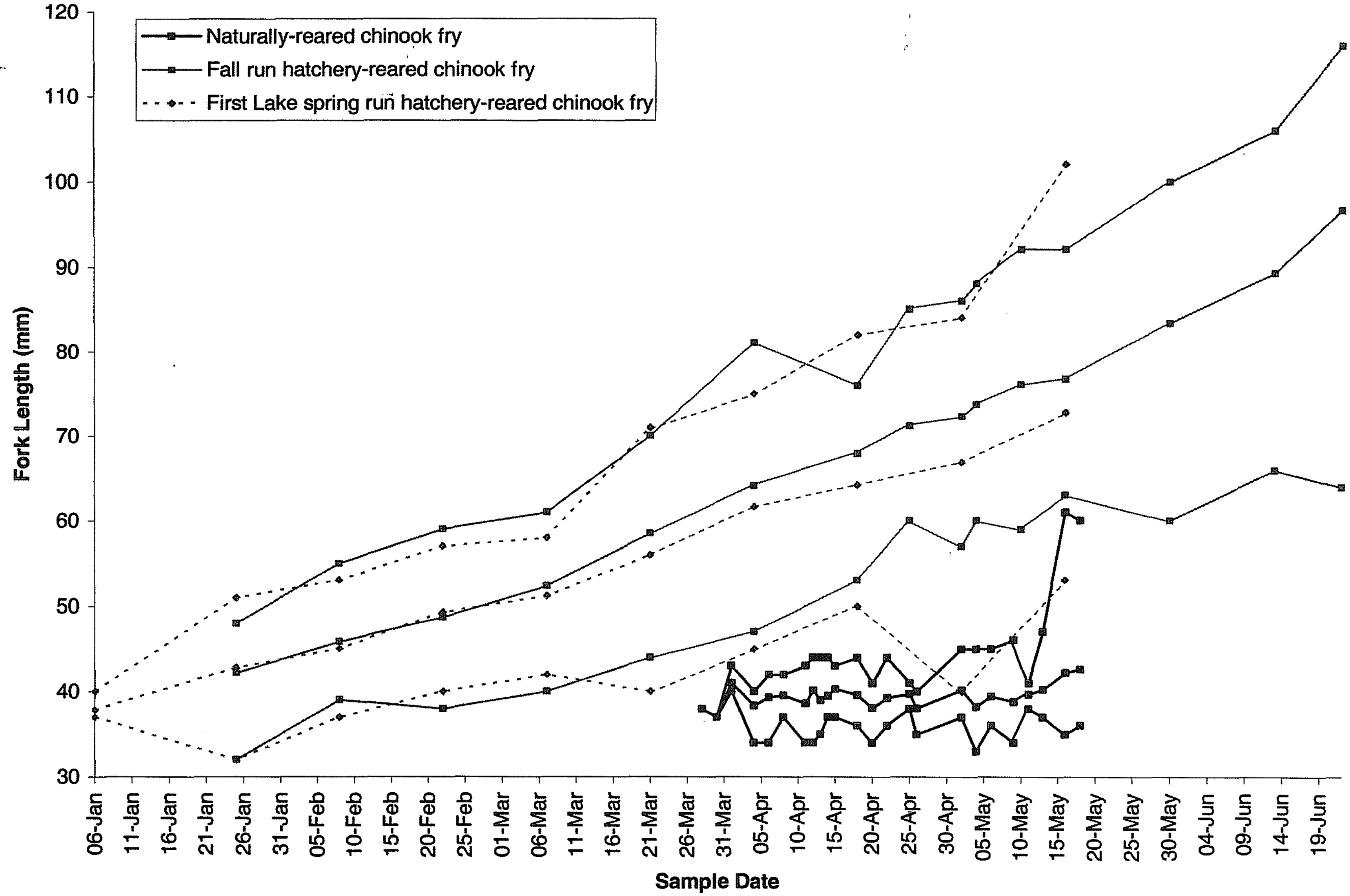


Figure 7A. Mean, minimum, and maximum lengths, by sampling date, of naturally-reared and hatchery-reared chinook fry, Nanaimo River, 2000.

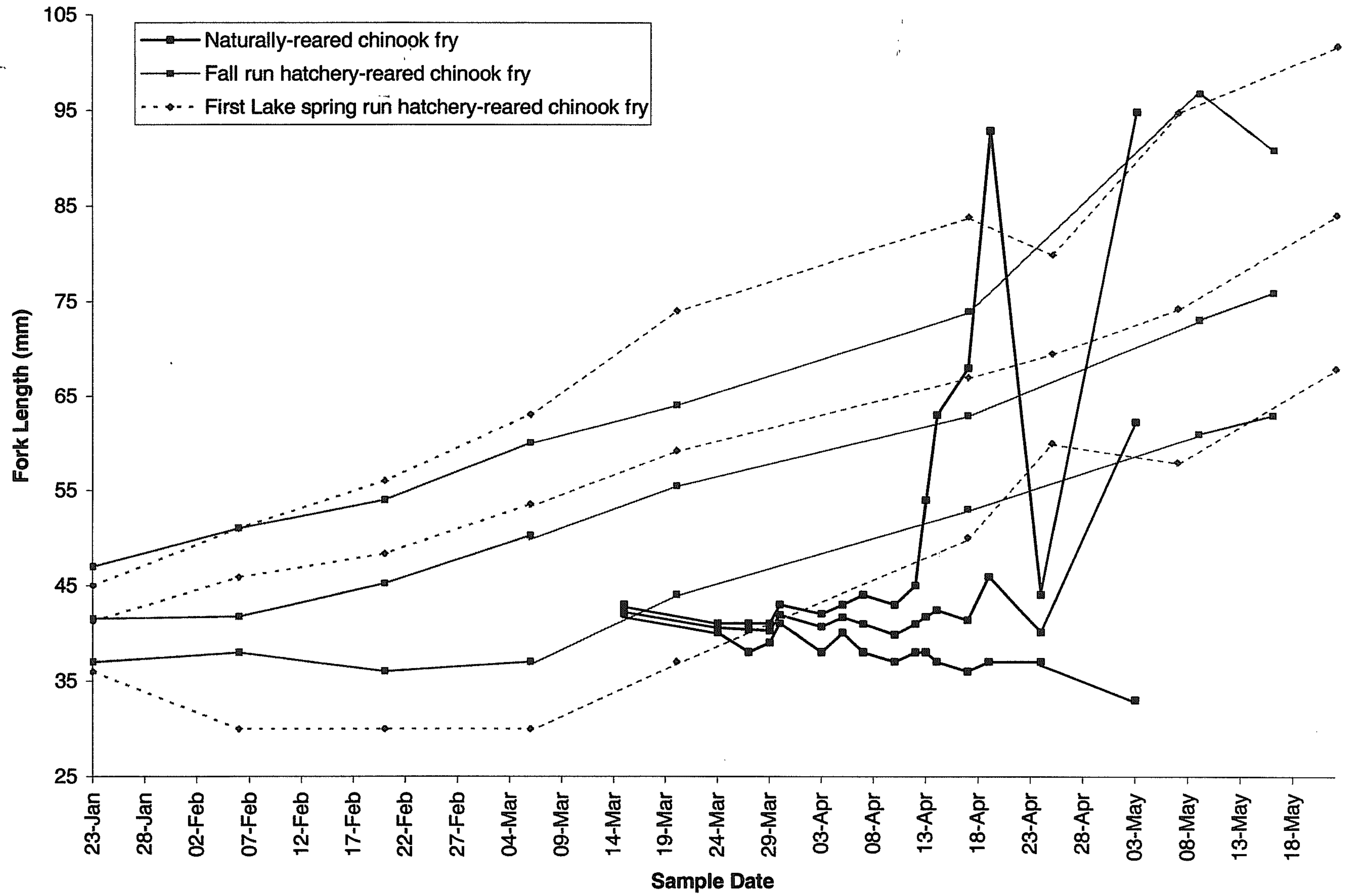


Figure 7B. Mean, minimum, and maximum lengths, by sampling date, of naturally-reared and hatchery-reared chinook fry, Nanaimo River, 2001.

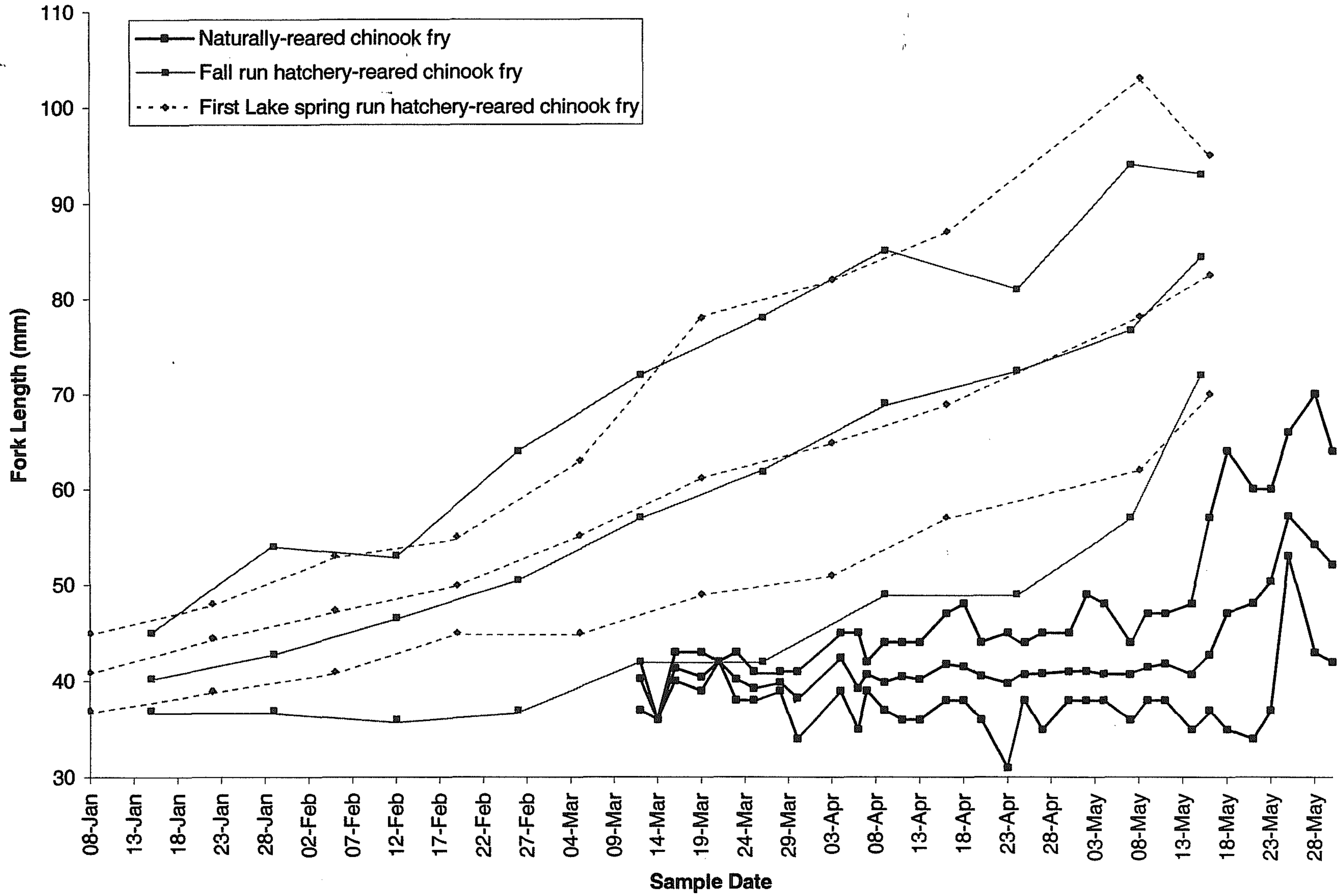


Figure 7C. Mean, minimum, and maximum lengths, by sampling date, of naturally-reared and hatchery-reared chinook fry, Nanaimo River, 2002.

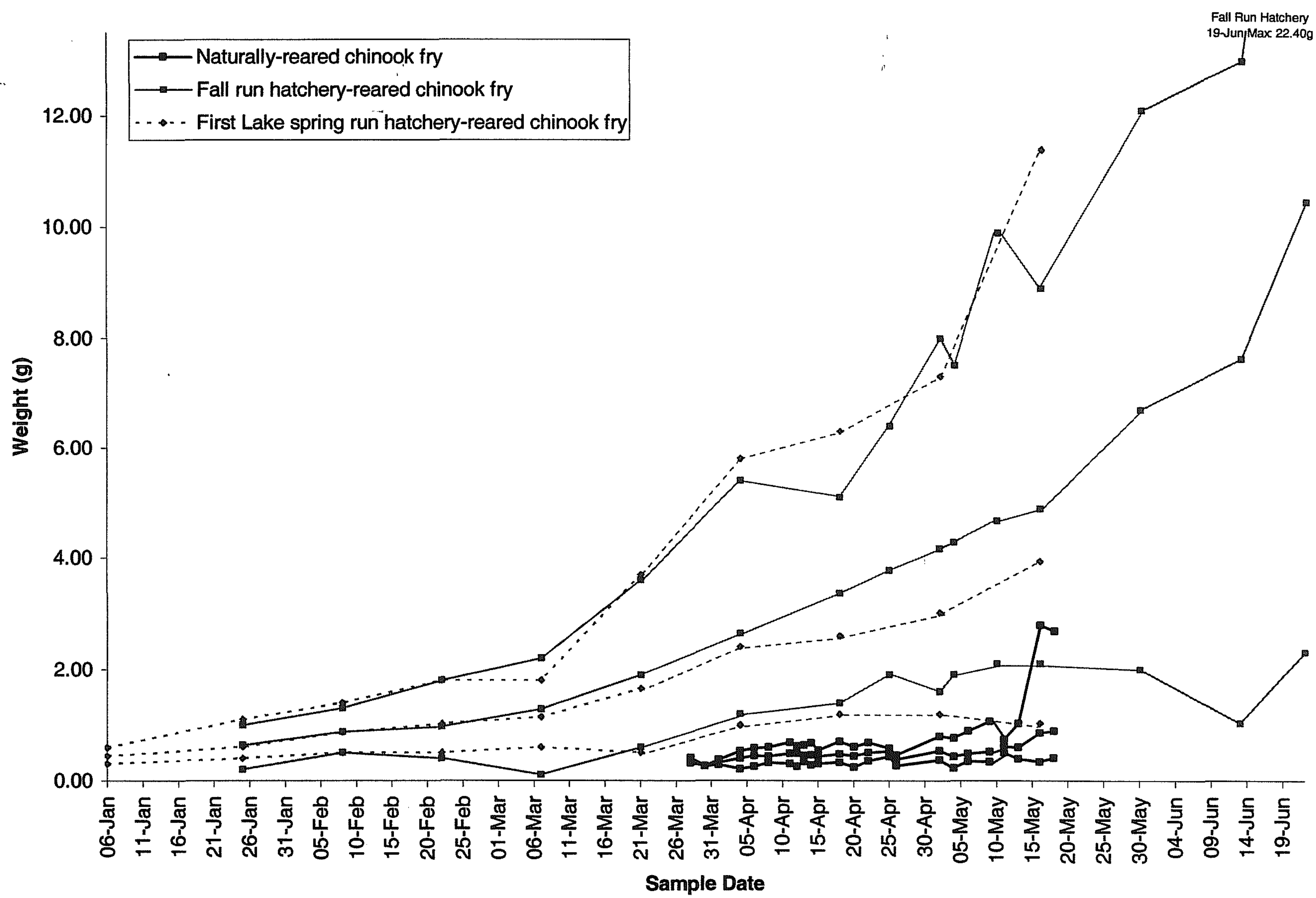


Figure 8A. Mean, minimum, and maximum weights, by sampling date, of naturally-reared and hatchery-reared chinook fry, Nanaimo River, 2000.

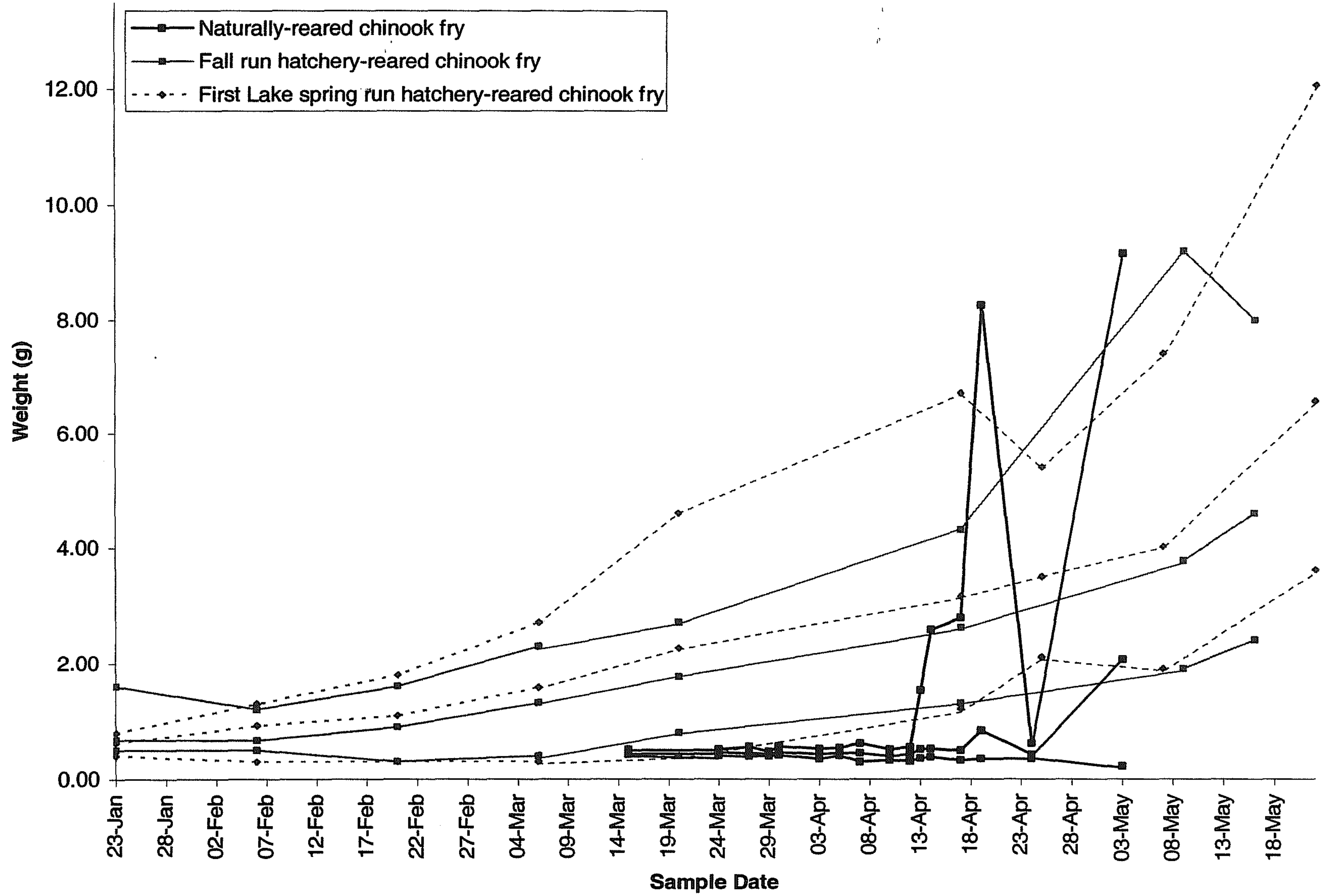


Figure 8B. Mean, minimum, and maximum weights, by sampling date, of naturally-reared and hatchery-reared chinook fry, Nanaimo River, 2001.

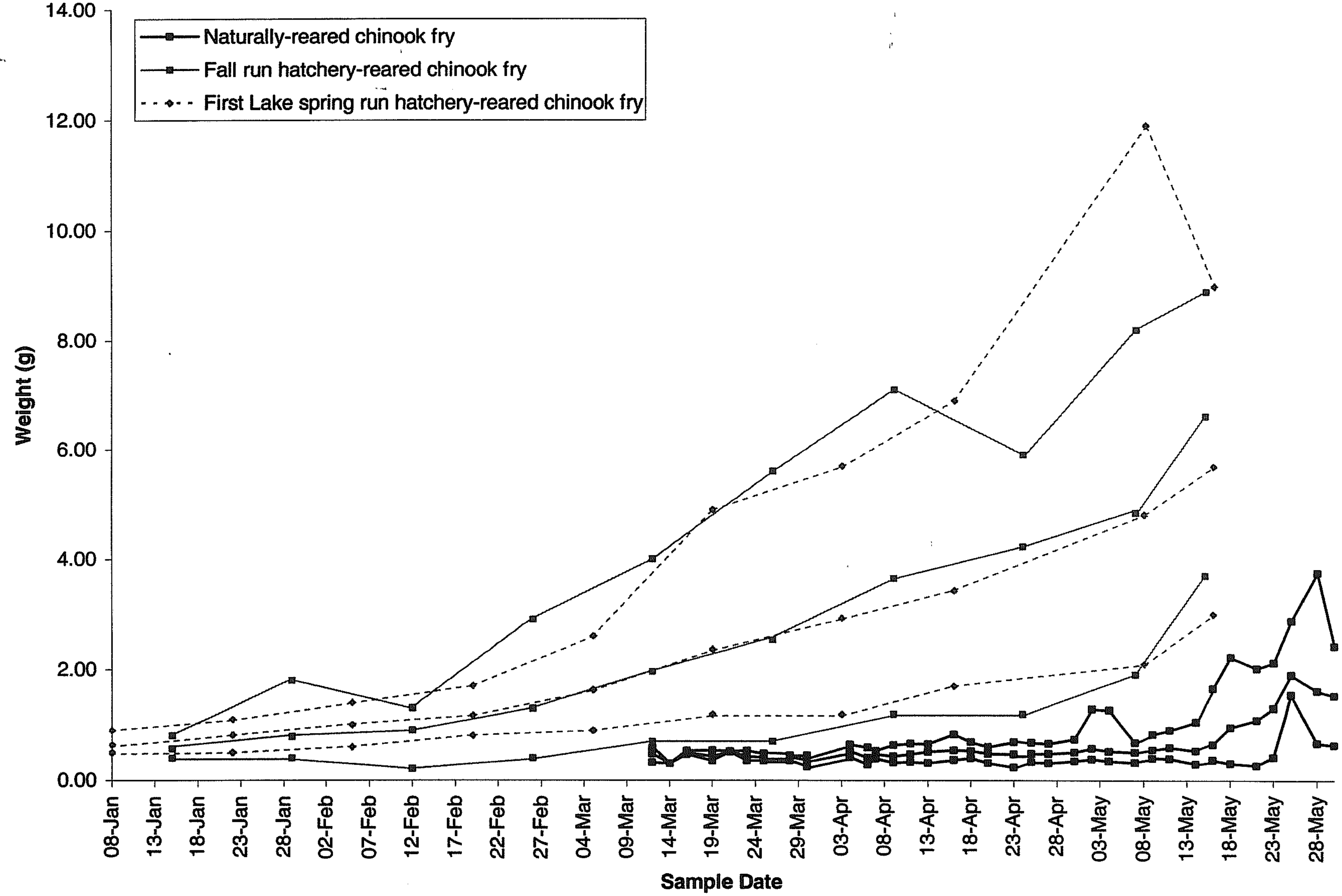


Figure 8C. Mean, minimum, and maximum weights, by sampling date, of naturally-reared and hatchery-reared chinook fry, Nanaimo River, 2002.