Juvenile Chinook Production in the Cowichan River, 2001

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ABSTRACT

Nagtegaal, D.A., E.W. Carter, N.K. Hop Wo, and K.E. Jones. 2004. Juvenile chinook production in the Cowichan River, 2001. Can. Manuscr. Rep. Fish. Aquat. Sci. 2669: 35 p.

In 1991, Fisheries and Oceans Canada (DFO), Pacific Biological Station began a study of juvenile chinook salmon (*Oncorhynchus tshawytscha*) productivity in the Cowichan River. The 2001 study is concerned primarily with the enumeration and out-migration timing of naturally-reared chinook juveniles. The estimated production of naturally-reared chinook juveniles from the 2000 brood year was 664,715 (range: 385,911 – 757,678). The release of juvenile chinook from the Cowichan River Hatchery totaled 2,409,720. Of these, 1,971,251 hatchery-reared chinook were released above the trapping site. Egg to fry survival for naturally-reared chinook was estimated to be 5.58% (range: 3.24% - 6.36%). Trapping results maintain that most hatchery-reared chinook migrate to the Cowichan estuary within one week of release. Interaction between naturally-reared and hatchery-reared chinook juveniles is therefore believed to be limited in freshwater.

RÉSUMÉ

Nagtegaal, D.A., E.W. Carter, N.K. Hop Wo, and K.E. Jones. 2004. Juvenile chinook production in the Cowichan River, 2001. Can. Manuscr. Rep. Fish. Aquat. Sci. 2669: 35 p.

En 1991, la Station biologique du Pacifique de Pêches et Océans Canada a entrepris une étude sur la productivité du saumon quinnat (*Oncorhynchus tshawytscha*) juvénile de la rivière Cowichan. L'étude de 2001 a consisté principalement à dénombrer les saumons quinnats juvéniles d'origine naturelle et à déterminer le moment de leur dévalaison. La production de saumons quinnats juvéniles d'origine naturelle de l'année d'éclosion 2000 a été estimée à 664 715 (étendue : 385 911 – 757 678). Au total, 2 409 720 saumons quinnats juvéniles élevés dans l'écloserie de la rivière Cowichan ont été libérés, dont 1 971 251 en amont du site de piégeage. La survie des oeufs d'origine naturelle jusqu'au stade d'alevin a été estimée à 5,58 % (étendue : 3,24 % - 6,36 %). Les résultats de piégeage indiquent que la plupart des saumons quinnats élevés en écloserie migrent vers l'estuaire de la Cowichan dans la semaine qui suit leur libération dans la rivière. Les interactions entre les saumons quinnats juvéniles d'origine naturelle et ceux provenant de l'écloserie sont donc considérées comme limitées en eau douce.

INTRODUCTION

Situated in southeastern Vancouver Island, the Cowichan watershed is one of the most important salmonid producing systems draining into the Strait of Georgia (Candy et al. 1995). Chinook (*Oncorhynchus tshawytscha*), coho (*O. kisutch*), chum (*O. keta*), steelhead (*O. mykiss*), cutthroat (*O. clarki*), as well as brown trout (*Salmo trutta*) and dolly varden (*Salmo malma*) spend periods of their life cycle or reside in this system. Historically, the chinook in this system have played an important role in the recreational, aboriginal, and commercial fisheries (Neave, 1949). Since 1958, the discharge of the Cowichan River has been controlled by a weir located at the outlet of Lake Cowichan, approximately 50 km upstream from the mouth of the Cowichan River (Burns et al. 1988). There have been periods of perceived salmonid population decline that have led to numerous studies (Lister et al. 1971; Candy et al. 1995; Nagtegaal et al. 1994-2003).

Recent years have shown a dramatic decrease in the abundance of chinook throughout BC waters. The late 1970's were characterized by peak harvest rates of approximately 750,000 pieces. In the 1980's these rates dropped to numbers less than 25% of their former abundance (Argue et al. 1983). For this reason, many stock rebuilding initiatives were implemented. In 1979, the Cowichan River Hatchery initiated a chinook enhancement program. Production began with a modest output of less than 70,000 chinook fry and grew to 2,409,720 chinook smolts in 2001 (Candy et al. 1996; D. Millerd, Cowichan River community economic development hatchery manager, P.O. Box 880, Duncan, B.C., pers. comm.).

As in previous years, a portion of hatchery produced chinook were coded-wire tagged (CWT). Fisheries managers rely heavily on information provided by tagged salmonids to evaluate the strategies for each hatchery program. The data from tag recoveries also provide key information regarding stock migration, harvest rates, and a measure of enhanced contribution to the stock (Nagtegaal et al. 1998). In 2001, the portion of hatchery produced chinook which were coded-wire tagged was 225,352 fry (9.4%).

In 1985, a chinook rebuilding strategy in conjunction with the Pacific Salmon Treaty, led to the Cowichan River's inclusion into a naturally spawning chinook study. Along with the Nanaimo and Squamish River stocks, the Cowichan 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 et al. 1998). The accurate enumeration of chinook migrants is also an important resource management tool. For this reason the results of this ongoing study can be used to assess enhancement strategies and harvest management practices, as well as investigate possible interactions between hatchery-reared chinook and naturally-reared chinook. In 2000, the Squamish River and in 2002, the Nanaimo River were both dropped as chinook indicator streams.

For the purposes of this study, we refer to hatchery-reared fish as those that were spawned and reared in the hatchery environment regardless of parental origin, and naturally-reared fish as those that spawned and reared in the river environment. The naturally-reared juvenile chinook of Cowichan River are considered to be the "ocean-type". This means that they usually migrate to sea within three months of emergence (Healey 1991). Lister et al. (1971) subdivided the Cowichan chinook migrants into two distinct groups. The 'early group' comprises the majority of the migrants and consists mainly of newly emerged fry with an average length of approximately 42 mm. The 'early group' migrates to the estuary in March and April. The 'late group' as described by Lister are larger with lengths averaging over 55 mm. This group may rear in the river system for up to 90 days before migrating to the estuary in May and June. This 'late group' may account for approximately 15% of the total juvenile chinook population.

METHODS

STUDY SITE DESCRIPTION

The Cowichan River begins at the Lake Cowichan weir and drains the mountainous slopes of the Vancouver Island range with a watershed area of 840 km^2 (Candy et al. 1995). Approximately 40 km north of Victoria, the Cowichan River flows eastward through the City of Duncan, and carries a mean annual discharge of 42.0 m^3/s. Skutz Falls, located 18 km downstream of Lake Cowichan, is a partial obstruction to the upstream migration of chinook spawners (Figure 1). In 1956, a fishway was built to help alleviate this problem (Lister et al. 1971). The Cowichan chinook spawn primarily in the mainstem, above Skutz Falls.

The rotary trap was placed at the City of Duncan old Pumphouse site as it is assumed that virtually all chinook spawning occurred above this point (Figure 1). Enumeration first started at site 7A and as water levels dropped the trap was moved upstream to site 7F to ensure sufficient river flows and optimal operation (Figure 1).

FISH CAPTURE

A rotary screw trap[1], 2.4 m in diameter was used to trap juveniles migrating downstream to the Cowichan Estuary. Fish passing through the cone were collected in a live box. In operation from February 5 to May 24, the trap was held in place by a galvanized steel cable which secured the trap at site 7 (the lower Pumphouse site). The trap was set for fishing and then sampled on alternating days. The trap was set at approximately 1900 h and fished continuously until 0700 h the following morning at which time the trapped fish were removed and sampled. The trap was then set again on the following evening after sampling had occurred. During efficiency tests, trapping occurred continuously over 24-hour periods and the trap was checked at both 0700 and 1900 h to monitor day and night fry migration.

All fish captured were enumerated by species and recorded by time period and capture date. Chinook migrants were identified as hatchery-reared or naturally-reared, based on identifiable physical characteristics (size, absence or presence of an adipose fin). Coho were recorded as either fry or one year old smolts. Biophysical conditions (water temperature, flow rates, water clarity, and weather conditions) were also noted.

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[1] Manaufactured by E.G. Solutions, Corvallis, Oregon, U.S.A.

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 two to three days 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 periods were non-sequential sampling days conducted through-out 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).

JUVENILE CHINOOK GROWTH

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

At the Cowichan River Hatchery 30 juvenile chinook were sampled weekly for each rearing strategy prior to release. Sample data were available for three hatchery releases strategies.

RESULTS

BIOPHYSICAL CONDITIONS

During the fry enumeration period the Cowichan River had three main water discharge peaks, with the largest discharge of 69.8 m^3/s on May 2 and two lesser peaks of 67.8 m^3/s on February 5 and 49.5 m^3/s on April 2. The lowest Cowichan River discharge level was on the March 12 at 15.8 m^3/s. The mean discharge during the course of the study was 37.8 m^3/s with the February portion averaging 47.4 m^3/s; March yielding a 24.6 m^3/s average; April a 38.2 m^3/s average; and the May portion a 44.7 m^3/s average water discharge (Figure 2). Flow rates were generally steady throughout the course of the study with a high of 1.79 m/s on February 7 and a low of 0.61 m/s on May 14. Water temperatures averaged 8.3°C and increased from lows of 5°C in early February to a high of 19°C on May 18. A graphical representation of river discharge and water temperature for the Cowichan River during the course of the study is presented in Figure 3.

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. Twenty sample periods (34.5%) were recorded as cloudy water clarity while the other 38 days (65.5%) were recorded as clear water clarity (Table 1). During the time of the study there were only two sample periods when rain was recorded (Table 1).

Due to water levels dropping in the river the rotary screw trap was moved upstream from site 7A to 7F on March 12 (Figure 1). High river discharge rates resulted in the inability to set the screw trap between April 25 and May 4 (Figure 3).

MIGRATION TIMING

The fry enumeration trap was run for 58, 12-hour intervals between February 5 and May 24, 2001. At the Pumphouse, 14,636 naturally-reared and 28,790 hatchery-reared chinook juveniles were caught in the screw trap. The number of hatchery-reared chinook fry enumerated also included 3,086 adipose-clipped fish. In addition, 169,060 chum fry, 11,035 coho fry, 2,685 one year old coho, 64 Bismarck Brown dyed chinook fry and four Bismarck Brown dyed chum fry were enumerated (Table 1). The downstream movement of hatchery chinook was observed from March 20 (4,408 fry) to May 24 (297 fry). It was understood that the hatchery fish released in the upper river would have reached the trapping site within approximately one week of their release date (Nagtegaal et al. 1998). Naturally-reared chinook migration had two major peaks on March 3 and March 20 with hatchery-reared enumeration peaks on March 21 and May 5 (Figure 4).

HATCHERY RELEASES

Cowichan River Hatchery had four chinook fry release strategies with two releases 30 km above the trapping site (Table 2). The first release occurred in the upper Cowichan River at the Roadpool site on March 20 with 963,499 fry being released of which 100,026 fry carried CWT's. The second release was also in the upper Cowichan River where 49,985 CWT fry of 1,007,752 total fry were released on May 1. Two releases occurred below the fry enumeration site. A release on May 3 from the Hatchery site released 338,640 fry of which 50,166 fry had CWT's. The final chinook fry release of the year was from the Seapen site in Cowichan Bay on May 23 where 25,175 CWT fry of 99,829 total fry were released into the ocean.

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 12 days between February 15 and April 20. The diel migration tests were stratified into naturally-reared fry and hatchery-reared fry components. A combined total of 7,565 naturally-reared chinook fry were counted with 6,920 fry obtained during night hours (~1900 – 0700 hours) and 645 fry collected during day hours (~0700 – 1900 hours) (Table 3). An expansion factor of 1.093 for naturally-reared chinook fry was obtained from the combined totals of the 24-hour trapping periods. Diel migration testing with hatchery-reared chinook yielded 20,115 fry of which 19,189 were caught during night hours and 926 were caught during daylight hours (Table 4). An expansion factor of 1.048 was obtained for hatchery-reared fry.

TRAP EFFICIENCIES

Five efficiency tests were conducted on February 14, February 28, March 7, March 21 and April 18 during the 2001 fry enumeration study (Table 5). In previous years, the efficiency tests have been stratified into categories corresponding to trap location. In 2001, the trap was moved upstream from location 7A to 7F on March 12; however, due to low sample sizes in trap efficiency tests conducted at site 7F, stratifying results by location was not feasible. Combining all five efficiency tests conducted during the 2001 study produced 52 Bismarck Brown dyed chinook recovered from 1,144 dyed chinook released above the trapping site. This yielded a trap efficiency of 4.55% and an expansion factor of 22.00 (Table 5). This factor was used to expand naturally-reared fry counts through the duration of the 2001 study. Hatchery-reared fry were also expanded by the same factor as there was no separate efficiency test conducted for hatchery fry. Rotary screw trap efficiencies by species and river flow rates are presented in Figure 5.

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 1.093 for naturally-reared fry and 1.048 for hatchery-reared fry obtained from diel migration results. Daily estimates were then expanded by the trap efficiency estimates of 22.00. Total Cowichan River naturally-reared chinook is estimated to be 664,715 fry (Table 6) while the hatchery-reared chinook estimate is 900,632 fry (Table 7).

Population estimate ranges were calculated by using the lowest and highest diel and trap efficiency expansion factors. The lower naturally-reared chinook fry population range used a diel expansion factor of 1.030 obtained from April 19 (n = 137) and a trap efficiency expansion factor of 13.35 obtained from the March 7 result (n = 307) (Table 3; Table 5). The corresponding upper population range was calculated using a diel expansion factor of 1.298 from February 15 (n = 331) and a trap efficiency expansion factor of 22.00 obtained from combining all efficiency results (n = 1,144) (Table 3; Table 5). Population estimate ranges for naturally-reared chinook fry are 385,911 to 757,678. Similarly, hatchery-reared fry ranges were calculating using the lower (1.017; March 22; n = 4,233) and upper (1.060; March 23; n = 369) results of the hatchery-reared diel migration tests (Table 4; Table 5). Using the same upper and lower trap efficiency factors as naturally-reared fry yielded hatchery-reared chinook fry ranges of 539,913 to 904,795.

During a separate study, a rotary screw trap was placed approximately 2 km downstream of Cowichan Lake from June 1 to June 28, 2001. This trap was used to recapture juvenile coho which were marked and released into Cowichan Lake. During this time, 126 naturally-reared chinook fry and 880 hatchery-reared chinook fry were enumerated. Results from this study are summarized by day in Table 8.

Cowichan River Hatchery documented 1,971,251 hatchery fry being released above the fry enumeration trap site. Calculating trap efficiency using documented hatchery release numbers and hatchery-reared chinook counts at the enumeration site yielded 1.46%. This efficiency estimate does not consider fry lost to predation or natural mortality during a 30 km migration downstream towards the fry trapping site.

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 outmigration are needed. In 2000, the number of chinook natural spawners was estimated to be 5,109 fish. The proportion of females obtained from a carcass mark-recapture was determined to be 56.9%, or 2,907. The average fecundity from broodstock biosample data was determined to be 4,098 eggs and the total egg production was estimated to be 11,912,972 (Figure 6). The estimated abundance of naturally-reared chinook fry was extrapolated to 664,715 and the egg to fry survival was therefore estimated to be 5.58%. The egg to fry survival range was calculated using the lower and upper ranges of estimated fry production and the estimated number of eggs produced. Lower and upper egg to fry survival ranges were 3.24% and 6.36%, respectively. The number of naturally-reared chinook eggs deposited and subsequent fry production are compared in Figure 7.

JUVENILE CHINOOK GROWTH

During the study period, 1,085 naturally-reared chinook fry were biosampled for length and weight. Mean length was approximately 39.5 – 43.4 mm and mean weight varied from 0.44 – 0.75 g until April 19 (Table 9; Table 10; Figure 8; Figure 9). From April 19 to May 24 naturally-reared fry increased in mean length from 44.27 to 65.87 mm and mean weight increased from 0.79 to 2.83 g (Table 9; Table 10; Figure 8; Figure 9).

Between February 13 and April 24, three hatchery release strategies totaling 522 juvenile chinook were biosampled for length and weight data. Hatchery-reared chinook fry were generally longer and heavier set than naturally-reared chinook fry and the length and weight ranges reflect these differences (Table 9; Table 10). This size difference 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 (Figure 8; Figure 9).

There was minimal overlapping in size and weight ranges between naturally-reared and hatchery-reared chinook fry sampled (Table 9; Table 10). Length and weight averages of hatchery-reared and naturally-reared chinook fry were compared and analyzed by a Student's t-test ($p<0.05$). Both the mean lengths and mean weights obtained from hatchery-reared fry were found to be statistically different than those obtained from naturally-reared fry.

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. Twenty days of poor clarity may have resulted in relatively higher trap efficiency as 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 1.79 m/s on February 7 to a low of 0.61 m/s on May 14. 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 migrants were observed with larger fish and flows (discharges), while fingerlings in stream discharges less than 20 m^3/s had lower survival rates.

MIGRATION TIMING

In his report on the Cowichan River, Neave (1949) discusses a spring run of chinook that spawned primarily around the Cowichan Lake tributaries. He postulated that these spring run fish were near extinct in his time. Whether current populations of Cowichan Lake tributary chinook are remnants of a spring run or directly related to the lake pen release strategy is unknown.

Although considerable research has focussed 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 and 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 adult escapement was closely related to the magnitude of juvenile production, lunar cycle, photoperiod and stream temperature were key factors affecting the timing of emigration.

HATCHERY RELEASES

Hatchery release data are provided by the Cowichan River Hatchery and fry are released into the river approximately 30 km upstream of the fry enumeration site. Hatchery fry mortality for this 30 km stretch of river is unknown and it is assumed not all fry swim past the enumeration trap. Therefore, the estimates provided from the Cowichan River Hatchery are assumed to be the most reliable source of hatchery-reared fry data.

Some level of interaction between the early naturally-reared chinook and hatchery-reared chinook in Cowichan River seems likely (Lister et al. 1971). A large proportion of naturally-reared chinook head to the estuary upon emergence and the peak migration of these chinook occurred in late March, approximately the same time as the first hatchery release March 20. Figure 4 indicates the early Roadpool hatchery release occurred during the peak migration of naturally-reared chinook on March 20. Thus some interaction between hatchery and naturally-reared chinook migrants was highly probable.

The late Roadpool hatchery release occurred on May 1. Migration peaks between naturally-reared and hatchery-reared fry cannot be compared due to high river discharge rates hindering the use of the rotary screw trap during this time. It is assumed the majority of 'early' chinook migrants had already passed the trapping site, and capture rates of these naturally-reared chinook had decreased substantially. Possible interactions between hatchery released chinook and the 'late' larger migrants could occur even if the hatchery fish move quickly to the estuary upon release, as Candy et al. (1996) indicated. The relatively large numbers of hatchery fish released and the assumed small population of 'late' migrants would suggest a very limited amount of interaction.

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). Diel migration testing was stratified into naturally-reared and hatchery-reared fry categories to account for potential biases arising from variations in behavior between the two juvenile types.

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 recapture 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. The trap efficiency release on April 18 consisted of primarily chum fry and that portion of the test was not utilized in calculating expansion factors. Possible differences in behavior and/or physiology between the two species of fry may result in different trapping efficiencies than chinook fry alone provide.

Trap efficiencies may be affected by the stream characteristics in which the trap is placed. Site 7A is located in a riffle or run section of the Pumphouse site, while site 7F is at the outlet of a short chute at the end of an upstream pool. Roper and Scarnecchi (1996) stated that hatchery-reared fish were often able to avoid a trap in a low velocity riffle area, however, when the trap was positioned at the head of a pool they were often caught. Since only sites 7A and 7F were used in this study, the difference in trap avoidance from a low velocity riffle area and the head of a pool was not applicable. During the 2001 study, a low recovery of Bismarck brown dyed chinook fry at site 7F made a comparison between the two sites not possible. For this reason, all efficiency tests, regardless of trap location were combined and used to expand fry counts throughout the entire study. During the 2000 study, trap efficiency increased by 1% when relocated upstream (Nagtegaal et al. 2003) and it is assumed a similar outcome may have occurred in 2001. If site 7F efficiencies were underestimated, the result would be an overestimation of fry abundance estimates.

For this study it was assumed that trap efficiencies for naturally-reared and hatchery-reared chinook were different due to size and behavioral differences. However, because only naturally-reared trap efficiency results were obtained, these results were also used to expand hatchery-reared fry caught in the rotary screw trap. Therefore the hatchery-reared fry estimate obtained from the fry enumeration trap is thought to be imprecise.

ABUNDANCE ESTIMATES

Approximately 664,715 naturally-reared chinook migrated from Cowichan River in 2001 (range: 385,911 – 757,678). This estimate did not take into consideration the migration of chinook prior to the installation of the rotary trap or after the study ended. Lister et al. (1971) reported that there is a later migration of juveniles that peaks in June.

Naturally-reared chinook fry population ranges were calculated rather than confidence intervals because they incorporate the two most influential fry enumeration variables; the diel migration expansion factor and the trap efficiency expansion factor. The ranges calculated in this report reflect how the diel migration and trap efficiency portions of this study can greatly influence fry population estimates. Therefore the accuracy of population estimates in this study rely primarily on the accuracy of diel and trap efficiency results.

Cowichan River Hatchery documented 1,971,251 hatchery fry being released above the fry enumeration trap site. This estimate is more than double the value calculated from fry enumeration trap results, however, the rotary screw trap estimate does not account for fry lost to predation or natural mortality during a 30 km migration downstream towards the fry trapping site. All rotary screw trap estimates are calculated using efficiency results from only naturally-reared chinook fry which are assumed to be less accurate in estimating hatchery-reared fry. Therefore the hatchery-reared fry estimate provided by the Cowichan River Hatchery is deemed more reliable than the rotary screw trap estimate.

Results from the rotary screw trap used in the coho mark-recapture study suggest some hatchery fry may be stragglers from the late hatchery release on May 1. These fry may have swum upstream into the Cowichan Lake before migrating downstream towards the estuary. Fry enumerated in the upper portion of the Cowichan River during June may also be part of the late migration of juveniles reported by Lister et al. (1971). The 126 naturally-reared and 880 hatchery-reared chinook fry enumerated in the coho mark-recapture screw trap indicate that the current 2001 population estimate is incomplete. Unfortunately no population estimate could be derived from data collected during this later study in June. Providing chinook fry estimates prior to installation or after removal of the rotary screw trap at the Pumphouse site is not within the scope of this study. Therefore the naturally-reared chinook fry estimate of 664,715 (range: 385,911 – 757,678) pertains only to the 05-Feb to 24-May enumeration period. The hatchery-reared chinook estimate of 2,409,720 fry supplied by the Cowichan River Hatchery is considered to be complete.

EGG TO FRY SURVIVAL

The egg to fry survival estimate of 5.58% is slightly below the 1990 - 2000 brood year average of 5.92% (Figure 6). The 2001 estimate is also below ranges reported by Healey (1991) who had chinook fry survival ranges from 8% to 16%. The differences in survival rates among years may be attributed to many factors ranging from biophysical conditions, chum escapements and spawner distribution (Nagtegaal et al. 1997). River discharge rates that mirrored the historical rates throughout the summer and early fall months along with lower than average rates in January to April probably attributed to survival rates that approximated the 1990 – 2000 brood year averages (Figure 2). In previous studies, high flows resulted in scouring of spawning beds and therefore loss of developing chinook fry. Montgomery et al. (1995) determined that the depth of stream bed scouring due to discharge levels was directly related to egg survival.

When comparing naturally-reared chinook eggs deposited and subsequent fry production, there appears to be no reduction in fry abundance as egg production peaked in 1995 (Figure 7). This suggests the maximum number of chinook eggs the Cowichan River can support has not yet been reached.

JUVENILE CHINOOK GROWTH

Fry length and weight sampling during the study showed little increase in average size of naturally-reared chinook until after April 17. According to one participant at the trapping site, the identification of naturally-reared versus hatchery chinook became more difficult after the late hatchery release since the length of naturally-reared fish had increased. 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.

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 1. Rotary screw trap catch data at the Pumphouse site, Cowichan River, 2001.

Set Date	Weather[1]	Temperature (°C)	Clarity[2]	Sample Date	Start Time	Wild Chinook	Total Hatchery Chinook	Adipose-Clipped Chinook	Chum Fry	Coho Fry	Coho 1 year	Dye Marked Chinook	Dye Marked Chum
05-Feb	2	7	2	06-Feb	7:00	50	0	0	8	1	6	0	0
07-Feb	3	5	2	08-Feb	7:22	30	0	0	6	4	1	0	0
09-Feb	3	6	2	10-Feb	6:58	76	0	0	7	3	8	0	0
12-Feb	1	5	2	13-Feb	7:52	218	0	0	23	1	17	0	0
14-Feb	2	7	1	15-Feb	7:18	255	0	0	31	1	7	13	0
14-Feb	2	7	1	15-Feb	18:45	76	0	0	5	0	1	0	0
15-Feb	2	5	1	16-Feb	7:04	269	0	0	57	1	13	1	0
15-Feb	2	5	1	16-Feb	18:56	66	0	0	12	0	0	0	0
19-Feb	1	6	1	20-Feb	7:15	423	0	0	177	1	20	0	0
21-Feb	2	7	1	22-Feb	7:15	250	0	0	404	0	13	0	0
23-Feb	1	6	1	24-Feb	7:00	365	0	0	436	5	9	0	0
26-Feb	1	6	1	27-Feb	7:15	619	0	0	510	6	5	0	0
28-Feb	2	6	1	01-Mar	7:00	520	0	0	767	6	6	14	0
28-Feb	2	6	2	01-Mar	19:00	45	0	0	11	0	2	0	0
28-Feb	2	6	2	02-Mar	6:52	1086	0	0	1177	10	8	1	0
28-Feb	2	6	2	02-Mar	18:54	167	0	0	23	1	1	0	0
28-Feb	2	6	2	03-Mar	7:00	1910	0	0	942	17	8	0	0
05-Mar	1	7	1	06-Mar	7:00	405	0	0	4094	2	7	0	0
07-Mar	2	8	1	08-Mar	7:05	17	0	0	651	0	0	22	0
07-Mar	2	8	1	08-Mar	19:00	3	0	0	8	0	0	1	0
07-Mar	2	8	1	09-Mar	7:00	13	0	0	1327	0	2	0	0
07-Mar	2	8	1	09-Mar	19:00	0	0	0	47	0	0	0	0
07-Mar	2	8	1	10-Mar	7:00	36	0	0	3091	3	0	0	0
12-Mar	2	N/A	1	13-Mar	7:00	117	0	0	5771	2	3	0	0
14-Mar	2	N/A	1	15-Mar	7:05	266	0	0	6073	8	5	0	0
16-Mar	2	8	1	17-Mar	7:05	394	0	0	7399	14	15	0	0
19-Mar	1	8	2	20-Mar	7:15	2557	0	0	9450	213	58	0	0
19-Mar	1	8	2	20-Mar	19:00	120	4408	900	30	5	0	0	0
19-Mar	1	8	2	21-Mar	7:00	1014	14671	1734	12395	568	85	0	0
19-Mar	1	8	2	21-Mar	19:00	126	833	75	885	3	5	0	0
19-Mar	1	8	2	22-Mar	7:00	574	4162	330	8935	400	100	11	0

Table 1. (continued)

Set Date	Weather[1]	Temperature (°C)	Clarity[2]	Sample Date	Start Time	Wild Chinook	Total Hatchery Chinook	Adipose-Clipped Chinook	Chum Fry	Coho Fry	Coho 1 year	Dye Marked Chinook	Dye Marked Chum
19-Mar	1	8	2	22-Mar	19:00	21	71	9	159	3	2	0	0
19-Mar	1	8	2	23-Mar	7:00	482	348	20	9221	67	20	1	0
19-Mar	1	8	2	23-Mar	19:00	17	21	2	140	1	0	0	0
19-Mar	1	8	2	24-Mar	7:00	361	239	16	15449	114	19	0	0
26-Mar	1	8	1	27-Mar	7:30	538	18	0	18807	186	40	0	0
30-Mar	2	8	2	31-Mar	7:00	206	27	0	13295	56	27	0	0
04-Apr	2	9	1	05-Apr	7:00	26	4	0	9642	39	20	0	0
06-Apr	1	8	1	07-Apr	7:00	54	1	0	8328	63	12	0	0
09-Apr	2	9	1	10-Apr	7:00	43	1	0	10129	354	20	0	0
11-Apr	2	8	1	12-Apr	7:00	67	4	0	6280	676	17	0	0
13-Apr	2	7	1	14-Apr	7:00	155	7	0	3185	1265	20	0	0
16-Apr	2	9	1	17-Apr	7:00	63	1	0	3388	556	14	0	0
18-Apr	2	11	1	19-Apr	7:00	133	8	0	1424	1177	52	0	4
18-Apr	1	10	1	19-Apr	19:00	4	1	0	137	26	1	0	0
18-Apr	1	10	1	20-Apr	7:00	92	5	0	2182	1941	45	0	0
18-Apr	1	10	1	20-Apr	19:00	5	2	0	172	63	0	0	0
18-Apr	1	10	1	21-Apr	7:00	53	4	0	1523	1173	0	0	0
23-Apr	2	9	1	24-Apr	7:00	37	0	0	547	689	88	0	0
04-May	1	9	2	05-May	7:00	5	1249	0	61	36	60	0	0
07-May	2	9	2	08-May	7:15	1	1191	0	49	26	85	0	0
09-May	1	11	1	10-May	7:00	7	186	0	36	82	99	0	0
11-May	1	11	1	12-May	7:00	12	137	0	38	112	106	0	0
14-May	2	11	1	15-May	7:00	48	298	0	52	252	608	0	0
16-May	2	13	1	17-May	7:00	34	198	0	36	279	354	0	0
18-May	1	19	1	19-May	6:54	18	126	0	2	98	118	0	0
22-May	1	12	1	23-May	7:00	49	272	0	13	170	231	0	0
23-May	1	12	1	24-May	7:00	38	297	0	13	256	222	0	0
Total						14636	28790	3086	169060	11035	2685	64	4

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

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

Table 2. Cowichan River Hatchery chinook release data, 2001.

Release Code	Total Released	Tag Code	CWT Tagged	Percent Tagged	Release Date	Sample Date	Length (mm) Mean	Length (mm) Min	Length (mm) Max	Weight (g) Mean	Weight (g) Min	Weight (g) Max
Early	**963499**		**100026**		20-Mar	20-Mar	68.0	56	78	3.08	1.49	4.53
		18-45-46	49972	10.38%								
		18-45-47	50054	10.38%								
Late	**1007752**		**49985**		01-May	24-Apr	82.7	67	92	6.32	3.26	8.79
		18-32-16	25152	4.98%								
		18-32-17	24833	4.94%								
Hatchery	**338640**		**50166**		03-May	13-Feb	42.4	37	45	0.71	0.45	0.88
		18-45-39	50166	14.81%								
Seapen	**99829**		**25175**		23-May					7.98		
		18-28-11	25175	25.22%								
Total	**2409720**		**225352**	**9.4%**								

Total released above trap site: 1971251

Release Sites:
Early- upper Cowichan R. (Road Pool)*
Late- upper Cowichan R. (below weir)*
Hatchery- released directly from Hatchery
Seapen- released from seapens in Cowichan Bay

* indicates that these fish are released above trapping site

Table 3. Daily summary of 24-hour trapping periods for naturally-reared chinook fry, Pumphouse site, Cowichan River, 2001.

Sample Date	Naturally-Reared Chinook Night	Day	24-Hour Period	Expansion Factor
15-Feb	255	76	331	1.298
16-Feb	269	66	335	1.245
01-Mar	520	45	565	1.087
02-Mar	1086	167	1253	1.154
08-Mar	17	3	20	1.176
09-Mar	13	0	13	1.000
20-Mar	2557	120	2677	1.047
21-Mar	1014	126	1140	1.124
22-Mar	574	21	595	1.037
23-Mar	482	17	499	1.035
19-Apr	133	4	137	1.030
20-Apr	92	5	97	1.054
Total	6920	645	7565	1.093

Table 4. Daily summary of 24-hour trapping periods for hatchery-reared chinook fry, Pumphouse site, Cowichan River, 2001.

Sample Date	Hatchery-Reared Chinook Night	Day	24-Hour Period	Expansion Factor
21-Mar	14671	833	15504	1.057
22-Mar	4162	71	4233	1.017
23-Mar	348	21	369	1.060
19-Apr	8	1	9	1.125
20-Apr	5	2	7	1.400
Total	19189	926	20115	1.048

Table 5. Trap efficiency data by release date, Pumphouse site, Cowichan River, 2001.

Release	Flow	Released		Recovered		Percent Recovered		Expansion Factor	
Date	(m/s)	Chinook	Chum	Chinook	Chum	Chinook	Chum	Chinook	Chum
14-Feb	1.619	197		13		6.60%		15.15	
28-Feb	0.815	306		15		4.90%		20.40	
07-Mar	0.877	307		23		7.49%		13.35	
21-Mar	1.366	304		1		0.33%		304.00	
18-Apr	1.215	30	308	0	4	0.00%	1.30%		77.00
Total		1144	308	52	4	4.55%	1.30%	22.00	77.00

Table 6. Expanded daily trap catch estimates of naturally-reared chinook fry, Pumphouse site, Cowichan River, 2001

Sample Date	Observed[1] PM	Observed[1] AM	Missing cells Interpolated	24-hour Estimates	Extrapolated Estimates	Cumulative Total
06-Feb	50			55	1203	1203
07-Feb			40	44	962	2165
08-Feb	30			33	722	2886
09-Feb			53	58	1275	4161
10-Feb	76			83	1828	5989
11-Feb			147	161	3535	9524
12-Feb			147	161	3535	13059
13-Feb	218			238	5243	18302
14-Feb			237	259	5688	23990
15-Feb	255	76		331	7282	31272
16-Feb	269	66		335	7370	38642
17-Feb			346	378	8322	46964
18-Feb			346	378	8322	55285
19-Feb			346	378	8322	63607
20-Feb	423			462	10173	73780
21-Feb			337	368	8093	81873
22-Feb	250			273	6013	87886
23-Feb			308	336	7396	95282
24-Feb	365			399	8778	104060
25-Feb			492	538	11833	115893
26-Feb			492	538	11833	127726
27-Feb	619			677	14887	142613
28-Feb			570	623	13697	156310
01-Mar	520	45		565	12430	168740
02-Mar	1086	167		1253	27566	196306
03-Mar	1910			2088	45937	242243
04-Mar			1158	1265	27839	270081
05-Mar			1158	1265	27839	297920
06-Mar	405			443	9740	307660

Table 6. (continued)

Sample Date	Observed[1] PM	AM	Missing cells Interpolated	24-hour Estimates	Extrapolated Estimates	Cumulative Total
07-Mar			211	231	5075	312735
08-Mar	17	3		20	440	313175
09-Mar	13	0		13	286	313461
10-Mar	36			39	866	314327
11-Mar			77	84	1840	316166
12-Mar			77	84	1840	318006
13-Mar	117			128	2814	320820
14-Mar			192	209	4606	325426
15-Mar	266			291	6397	331823
16-Mar			330	361	7937	339760
17-Mar	394			431	9476	349236
18-Mar			1476	1613	35487	384723
19-Mar			1476	1613	35487	420209
20-Mar	2557	120		2677	58894	479103
21-Mar	1014	126		1140	25080	504183
22-Mar	574	21		595	13090	517273
23-Mar	482	17		499	10978	528251
24-Mar	361			395	8682	536934
25-Mar			450	491	10811	547744
26-Mar			450	491	10811	558555
27-Mar	538			588	12939	571494
28-Mar			372	407	8947	580441
29-Mar			372	407	8947	589388
30-Mar			372	407	8947	598335
31-Mar	206			225	4954	603289
01-Apr			116	127	2790	606079
02-Apr			116	127	2790	608869
03-Apr			116	127	2790	611659
04-Apr			116	127	2790	614449
05-Apr	26			28	625	615074
06-Apr			40	44	962	616036
07-Apr	54			59	1299	617335
08-Apr			49	53	1166	618501
09-Apr			49	53	1166	619667
10-Apr	43			47	1034	620702
11-Apr			55	60	1323	622024
12-Apr	67			73	1611	623636
13-Apr			111	121	2670	626305
14-Apr	155			169	3728	630033
15-Apr			109	119	2622	632655
16-Apr			109	119	2622	635276
17-Apr	63			69	1515	636792
18-Apr			98	107	2357	639148
19-Apr	133	4		137	3014	642162
20-Apr	92	5		97	2134	644296
21-Apr	53			58	1275	645571

Table 6. (continued)

Sample Date	Observed[1] PM	AM	Missing cells Interpolated	24-hour Estimates	Extrapolated Estimates	Cumulative Total
22-Apr			45	49	1082	646653
23-Apr			45	49	1082	647736
24-Apr	37			40	890	648626
25-Apr			21	23	505	649131
26-Apr			21	23	505	649636
27-Apr			21	23	505	650141
28-Apr			21	23	505	650646
29-Apr			21	23	505	651151
30-Apr			21	23	505	651656
01-May			21	23	505	652161
02-May			21	23	505	652666
03-May			21	23	505	653171
04-May			21	23	505	653676
05-May	5			5	120	653796
06-May			3	3	72	653869
07-May			3	3	72	653941
08-May	1			1	24	653965
09-May			4	4	96	654061
10-May	7			8	168	654229
11-May			10	10	228	654458
12-May	12			13	289	654746
13-May			30	33	722	655468
14-May			30	33	722	656189
15-May	48			52	1154	657344
16-May			41	45	986	658330
17-May	34			37	818	659148
18-May			26	28	625	659773
19-May	18			20	433	660206
20-May			34	37	806	661012
21-May			34	37	806	661817
22-May			34	37	806	662623
23-May	49			54	1178	663801
24-May	38			42	914	664715

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

Table 7. Expanded daily trap catch estimates of hatchery-reared chinook fry, Pumphouse site, Cowichan River, 2001

Sample Date	Observed[1] PM	AM	Missing cells Interpolated	24-hour Estimates	Extrapolated Estimates	Cumulative Total
20-Mar[2]		4408		4408	96976	96976
21-Mar	14671	833		15504	341088	438064
22-Mar	4162	71		4233	93126	531190
23-Mar	348	21		369	8118	539308
24-Mar	239			251	5512	544820
25-Mar			129	135	2963	547783
26-Mar			129	135	2963	550747
27-Mar	18			19	415	551162
28-Mar			23	24	519	551681
29-Mar			23	24	519	552199
30-Mar			23	24	519	552718
31-Mar	27			28	623	553341
01-Apr			16	16	357	553698
02-Apr			16	16	357	554056
03-Apr			16	16	357	554413
04-Apr			16	16	357	554771
05-Apr	4			4	92	554863
06-Apr			3	3	58	554921
07-Apr	1			1	23	554944
08-Apr			1	1	23	554967
09-Apr			1	1	23	554990
10-Apr	1			1	23	555013
11-Apr			3	3	58	555071
12-Apr	4			4	92	555163
13-Apr			6	6	127	555290
14-Apr	7			7	161	555451
15-Apr			4	4	92	555543
16-Apr			4	4	92	555636
17-Apr	1			1	23	555659
18-Apr			5	5	104	555762
19-Apr	8	1		9	198	555960
20-Apr	5	2		7	154	556114
21-Apr	4			4	92	556207
22-Apr			2	2	46	556253
23-Apr			2	2	46	556299
24-Apr	0			0	0	556299
25-Apr			625	655	14402	570701
26-Apr			625	655	14402	585103
27-Apr			625	655	14402	599505
28-Apr			625	655	14402	613907
29-Apr			625	655	14402	628309
30-Apr			625	655	14402	642711
01-May			625	655	14402	657113
02-May			625	655	14402	671515
03-May			625	655	14402	685917

Table 7. (continued)

Sample Date	Observed[1] PM	AM	Missing cells Interpolated	24-hour Estimates	Extrapolated Estimates	Cumulative Total
04-May			625	655	14402	700319
05-May	1249			1309	28804	729123
06-May			1220	1279	28135	757258
07-May			1220	1279	28135	785393
08-May	1191			1248	27466	812860
09-May			689	722	15878	828738
10-May	186			195	4289	833027
11-May			162	169	3724	836752
12-May	137			144	3159	839911
13-May			218	228	5016	844927
14-May			218	228	5016	849943
15-May	298			312	6872	856815
16-May			248	260	5719	862535
17-May	198			208	4566	867101
18-May			162	170	3736	870837
19-May	126			132	2906	873743
20-May			199	209	4589	878332
21-May			199	209	4589	882921
22-May			199	209	4589	887510
23-May	272			285	6273	893783
24-May	297			311	6849	900632

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

[2] No expanded estimates were made prior to and during 20-Mar due to no hatchery releases before this date, see Table 2.

Table 8. Rotary screw trap catch data from the Cowichan Lake coho mark-recapture program, Cowichan River, 2001.

Set Date	Temperature (°C)	Wild Chinook	Hatchery Chinook	Coho 1 year	Coho fry	Chum fry	Trout fry	Lamprey
01-Jun	14	4	69	32	64	2	1	0
02-Jun	15	6	84	67	61	0	4	0
03-Jun	15	5	68	57	34	0	39	0
04-Jun	15	8	70	43	32	3	34	2
05-Jun	15	5	60	16	9	9	14	0
06-Jun	14.5	1	83	29	20	3	3	0
07-Jun	15	6	90	21	50	7	23	0
08-Jun	15	8	75	47	85	1	24	0
09-Jun	15	10	28	24	67	1	39	1
10-Jun	15	10	50	42	105	0	39	2
11-Jun	15	7	64	31	148	0	37	1
12-Jun	14	10	37	26	145	1	20	2
13-Jun	13	2	12	4	72	2	12	1
14-Jun	16	1	13	5	76	0	20	1
15-Jun	15.5	2	7	4	80	0	12	0
16-Jun	16	7	17	9	57	0	2	2
17-Jun	16	6	8	10	41	0	15	2
18-Jun	16	1	10	3	39	0	8	1
19-Jun	16.5	6	10	8	49	0	8	1
20-Jun	16.5	4	4	6	58	0	5	1
21-Jun	17	1	3	3	55	0	6	1
22-Jun	17	2	2	0	35	0	4	1
23-Jun	18	3	2	1	30	0	5	0
24-Jun	17.5	2	1	0	18	0	13	1
25-Jun	17	5	2	6	32	0	5	1
26-Jun	17	0	1	1	9	0	7	3
27-Jun	16.5	2	5	0	19	0	8	4
28-Jun	16.5	2	5	1	20	2	6	2
Total		126	880	496	1510	31	413	30

Table 9. Daily summary of chinook fry sampling length (mm) data, Cowichan River, 2001.

Sampling	Naturally Reared				Hatchery Release				Early Release				Late Release			
Date	n	Mean	Min	Max	n	Mean	Min	Max	n	Mean	Min	Max	n	Mean	Min	Max
06-Feb	30	40.33	37	44												
08-Feb	30	40.60	34	46												
10-Feb	30	39.53	36	44												
13-Feb	30	41.13	38	44	30	42.37	37	45	30	51.33	47	57	30	45.63	38	52
15-Feb	30	40.80	36	44												
16-Feb	30	40.87	38	44												
20-Feb	30	41.03	38	44					30	54.47	50	60	30	50.07	43	56
22-Feb	30	40.63	36	43												
24-Feb	30	41.30	35	46												
27-Feb	30	41.60	38	44					30	57.60	49	65	30	55.30	48	62
01-Mar	30	40.33	35	43												
02-Mar	30	41.20	36	44												
06-Mar	30	41.40	37	45					30	59.80	51	68	30	57.23	50	64
08-Mar	30	41.60	37	45												
10-Mar	30	40.93	36	44												
13-Mar	30	40.43	36	44					30	68.20	63	76	30	59.30	51	65
15-Mar	30	41.50	37	45												
17-Mar	29	40.90	35	44												
20-Mar	30	42.60	38	47					42	68.02	56	78	30	63.97	56	70
22-Mar	29	42.03	36	51												
24-Mar	30	40.70	37	46												
27-Mar	30	41.73	39	48									30	67.57	60	76
31-Mar	30	41.93	39	48												
03-Apr													30	70.63	62	78
05-Apr	26	43.42	39	54												
07-Apr	30	43.10	33	52												
10-Apr	30	42.30	39	53									30	74.90	63	85
12-Apr	30	42.10	38	56												
14-Apr	30	41.37	38	50												
17-Apr	30	42.40	38	63									30	77.47	62	86
19-Apr	30	44.27	37	62												
21-Apr	30	46.67	37	61												
24-Apr	30	49.90	38	64									30	82.67	67	92
05-May	6	59.33	49	69												
10-May	7	64.43	48	74												
12-May	10	66.30	54	75												
15-May	30	62.40	51	73												
17-May	30	60.43	48	70												
19-May	18	61.89	53	74												
24-May	30	65.87	57	76												

Table 10. Daily summary of chinook fry sampling weight (g) data, Cowichan River, 2001.

Sampling	Naturally Reared				Hatchery Release				Early Release				Late Release			
Date	n	Mean	Min	Max	n	Mean	Min	Max	n	Mean	Min	Max	n	Mean	Min	Max
06-Feb	30	0.48	0.33	0.60												
08-Feb	30	0.47	0.30	0.90												
10-Feb	30	0.44	0.32	0.56												
13-Feb	30	0.49	0.36	0.57	30	0.71	0.45	0.88	30	1.28	0.88	1.75	30	0.93	0.48	1.36
15-Feb	30	0.49	0.32	0.65												
16-Feb	30	0.49	0.36	0.61												
20-Feb	30	0.50	0.36	0.60					30	1.56	1.20	1.98	30	1.17	0.73	1.61
22-Feb	30	0.47	0.33	0.61												
24-Feb	30	0.51	0.26	0.76												
27-Feb	30	0.49	0.33	0.62					30	1.89	1.09	2.59	30	1.62	1.03	2.15
01-Mar	30	0.47	0.30	0.62												
02-Mar	30	0.49	0.31	0.70												
06-Mar	30	0.49	0.31	0.66					30	2.28	1.56	3.41	30	1.89	1.32	2.51
08-Mar	30	0.51	0.35	0.72												
10-Mar	30	0.50	0.38	0.61												
13-Mar	30	0.46	0.34	0.61					30	3.36	2.38	4.64	30	2.21	1.33	2.98
15-Mar	30	0.54	0.38	0.75												
17-Mar	29	0.48	0.28	0.63												
20-Mar	30	0.56	0.37	0.74					42	3.08	1.49	4.53	30	2.67	1.47	3.29
22-Mar	29	0.54	0.33	1.03												
24-Mar	30	0.49	0.31	0.81												
27-Mar	30	0.52	0.35	0.86									30	3.32	2.29	4.71
31-Mar	30	0.57	0.38	0.83												
03-Apr													30	3.83	2.46	5.24
05-Apr	26	0.67	0.49	1.38												
07-Apr	30	0.75	0.45	1.61												
10-Apr	30	0.62	0.34	1.63									30	4.56	2.59	6.46
12-Apr	30	0.69	0.37	4.52												
14-Apr	30	0.53	0.40	1.09												
17-Apr	30	0.67	0.38	2.47									30	5.14	2.72	7.63
19-Apr	30	0.79	0.33	2.18												
21-Apr	30	0.99	0.33	2.27												
24-Apr	30	1.40	0.43	2.66									30	6.32	3.26	8.79
05-May	6	2.10	1.26	3.16												
10-May	7	2.78	1.19	3.77												
12-May	10	3.03	1.58	4.12												
15-May	30	2.33	1.24	3.55												
17-May	30	2.06	0.98	3.38												
19-May	18	2.32	1.30	3.99												
24-May	30	2.83	1.68	4.48												

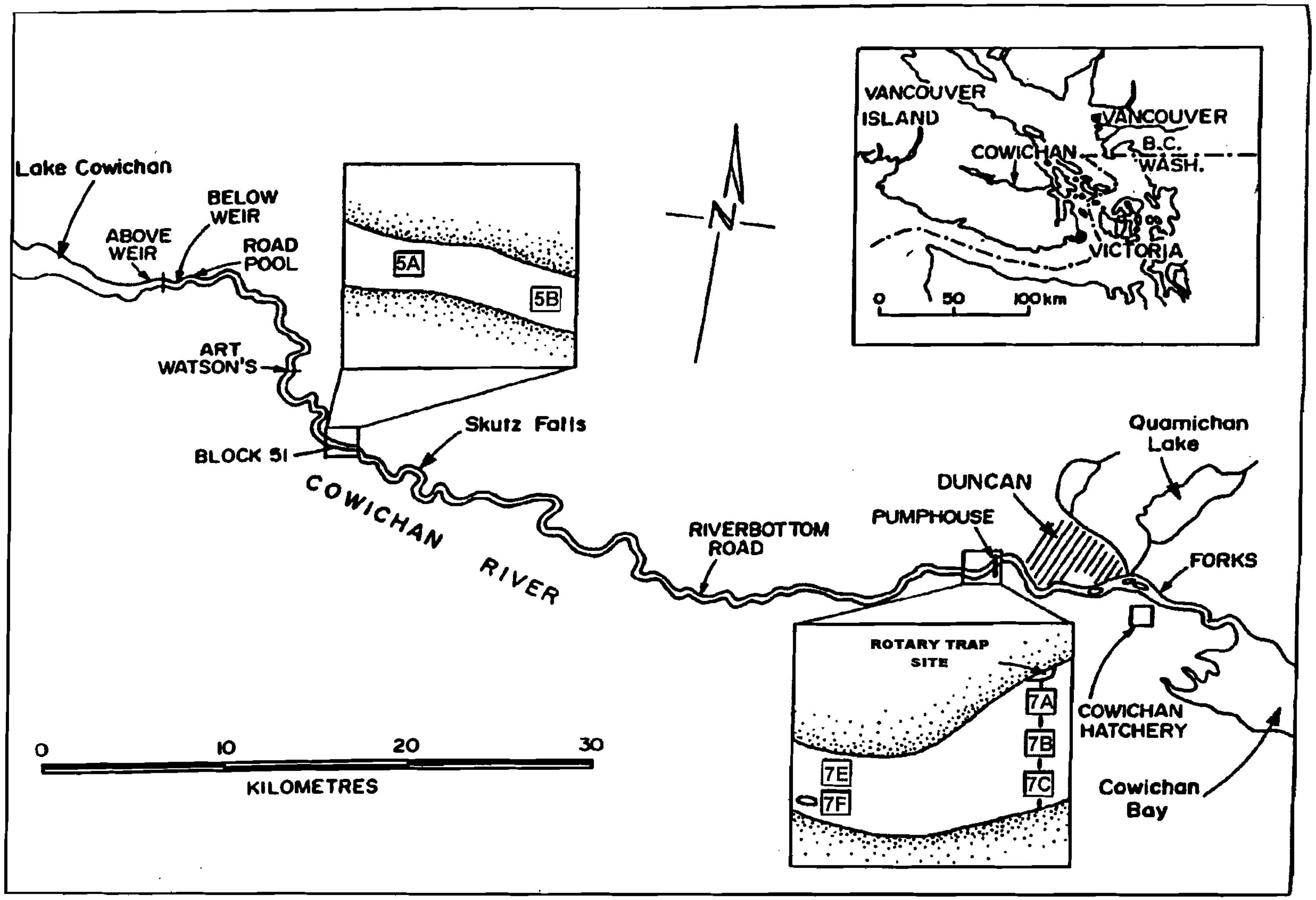

Figure 1. Cowichan River downstream fry trap locations.

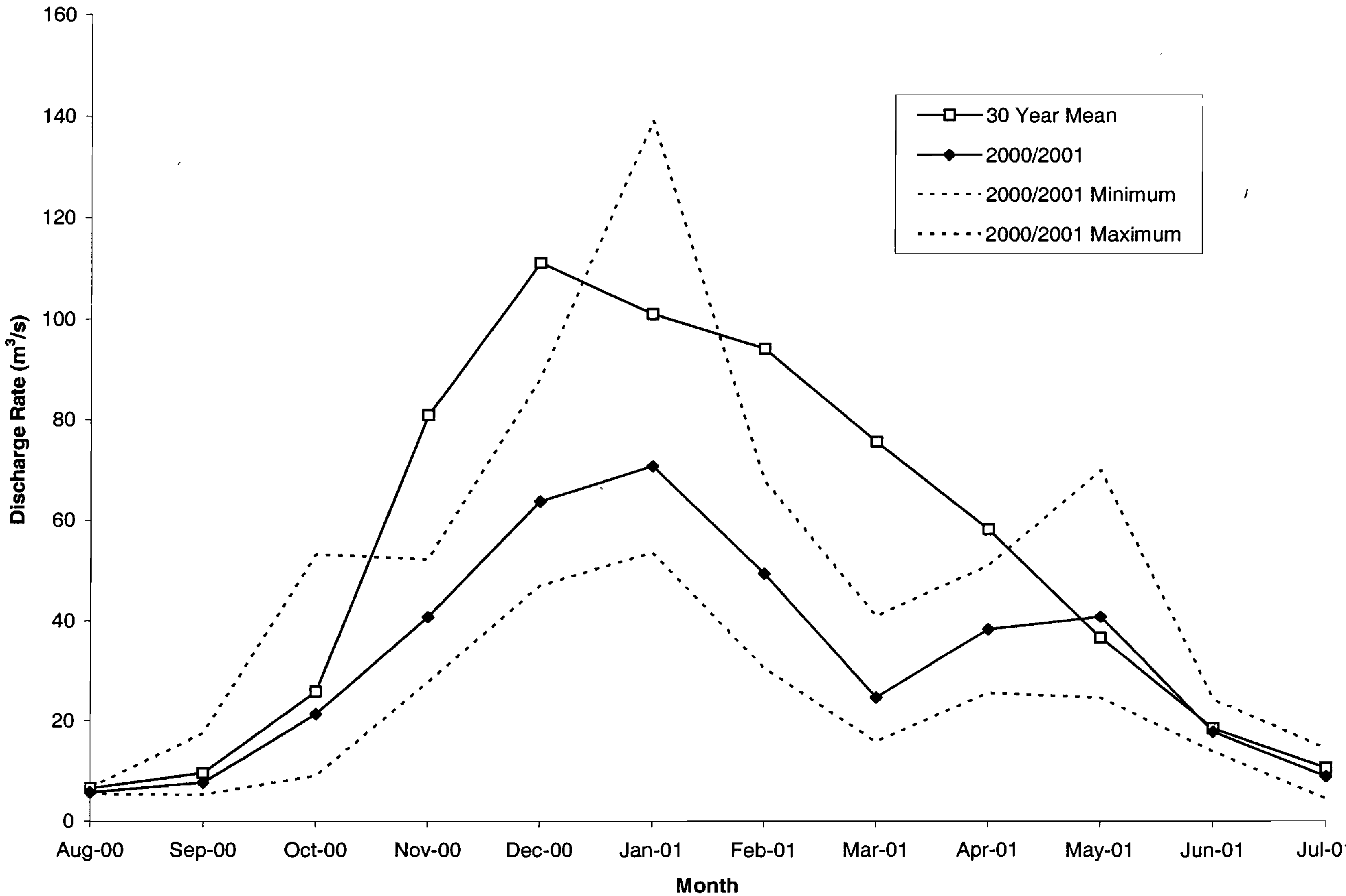

Figure 2. Monthly Cowichan River discharge[1] (m^3/s) from August 2000 to July 2001 with 30 year mean.

[1] Water Survey of Canada data recorded in Duncan, B.C., data subject to revision.

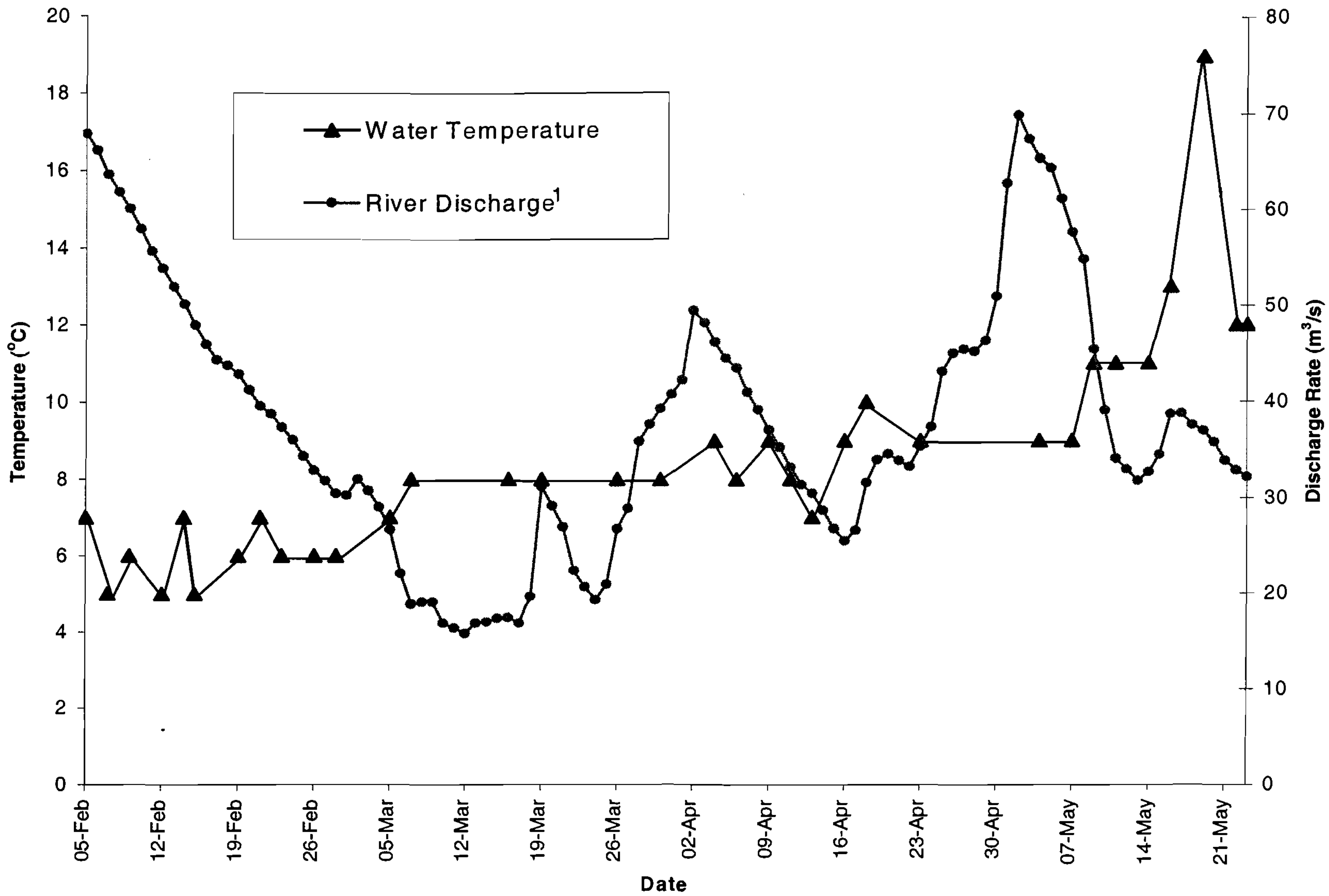

Figure 3. Biophysical conditions recorded at the Pumphouse site, Cowichan River, 2001
[1] River discharge measured at the Island Highway Bridge in Duncan, B.C.

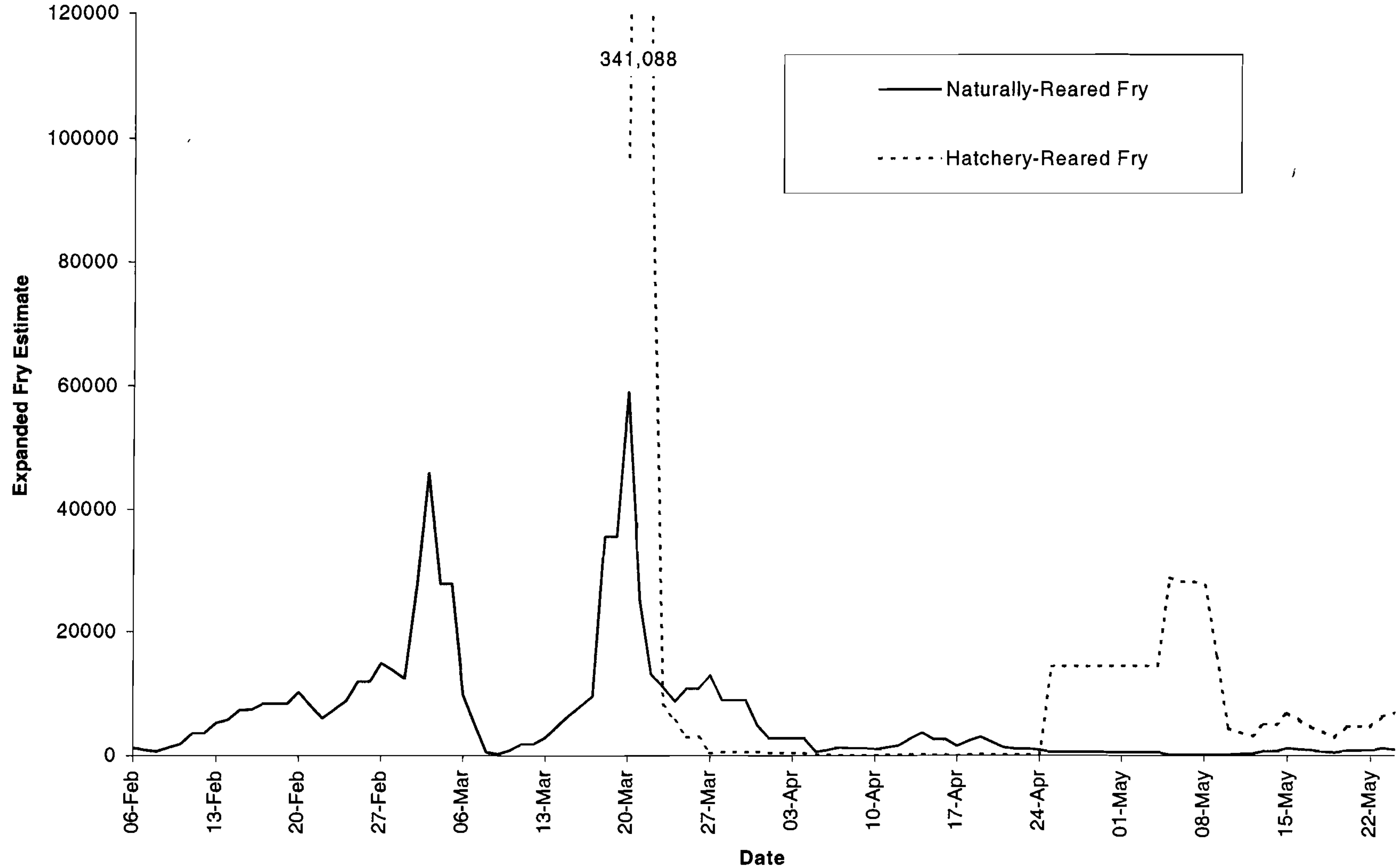

Figure 4. Daily abundance estimates of naturally-reared and hatchery-reared chinook fry downstream migration, Pumphouse site, Cowichan River, 2001.

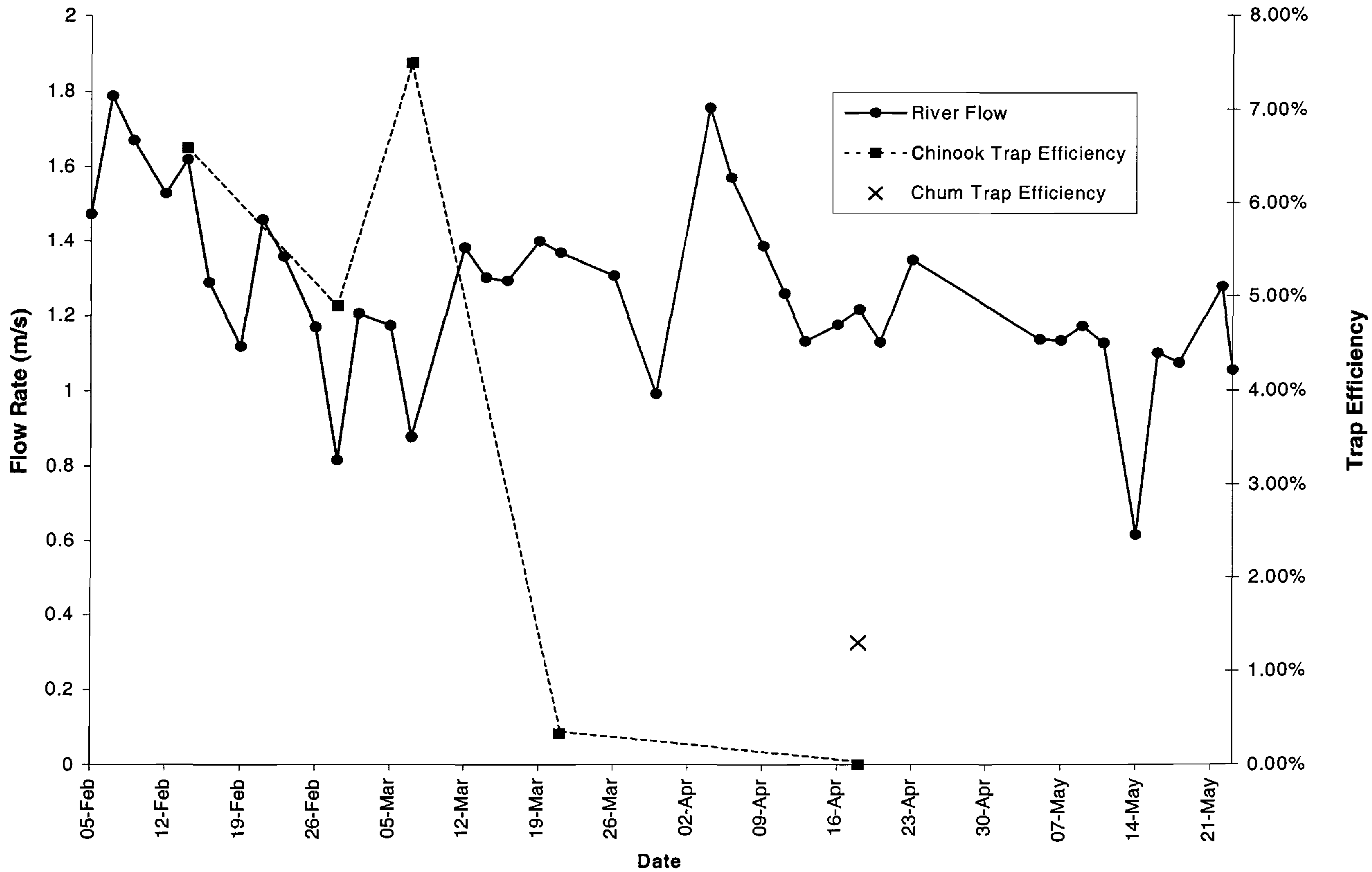

Figure 5. Rotary screw trap efficiency compared with water flow at the Pumphouse site, Cowichan River, 2001.

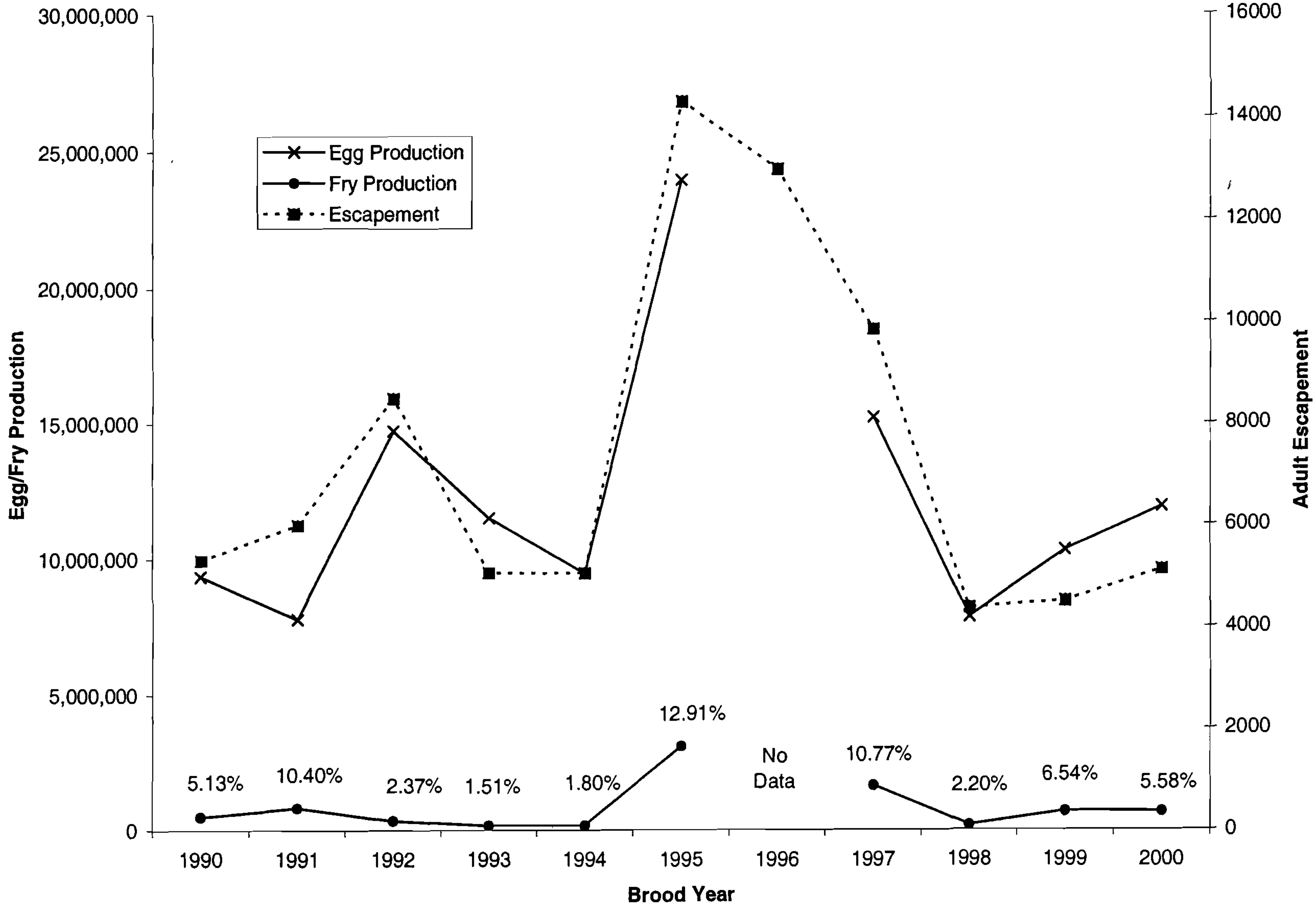

Figure 6. Egg to fry survival estimates compared to adult escapement and fry production, Cowichan River.

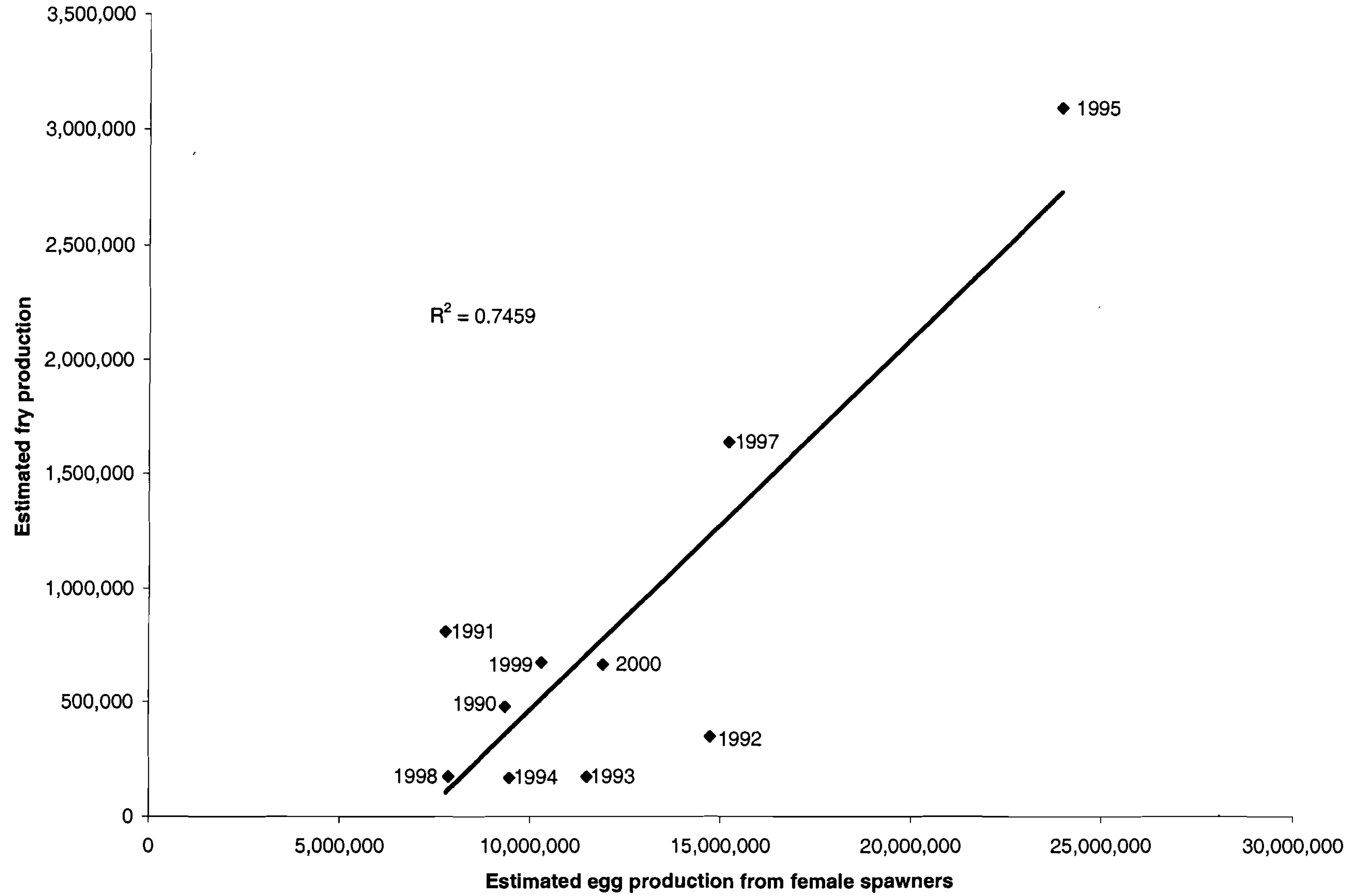

Figure 7. Chinook eggs deposited compared with subsequent fry production, by brood year, Cowichan River.

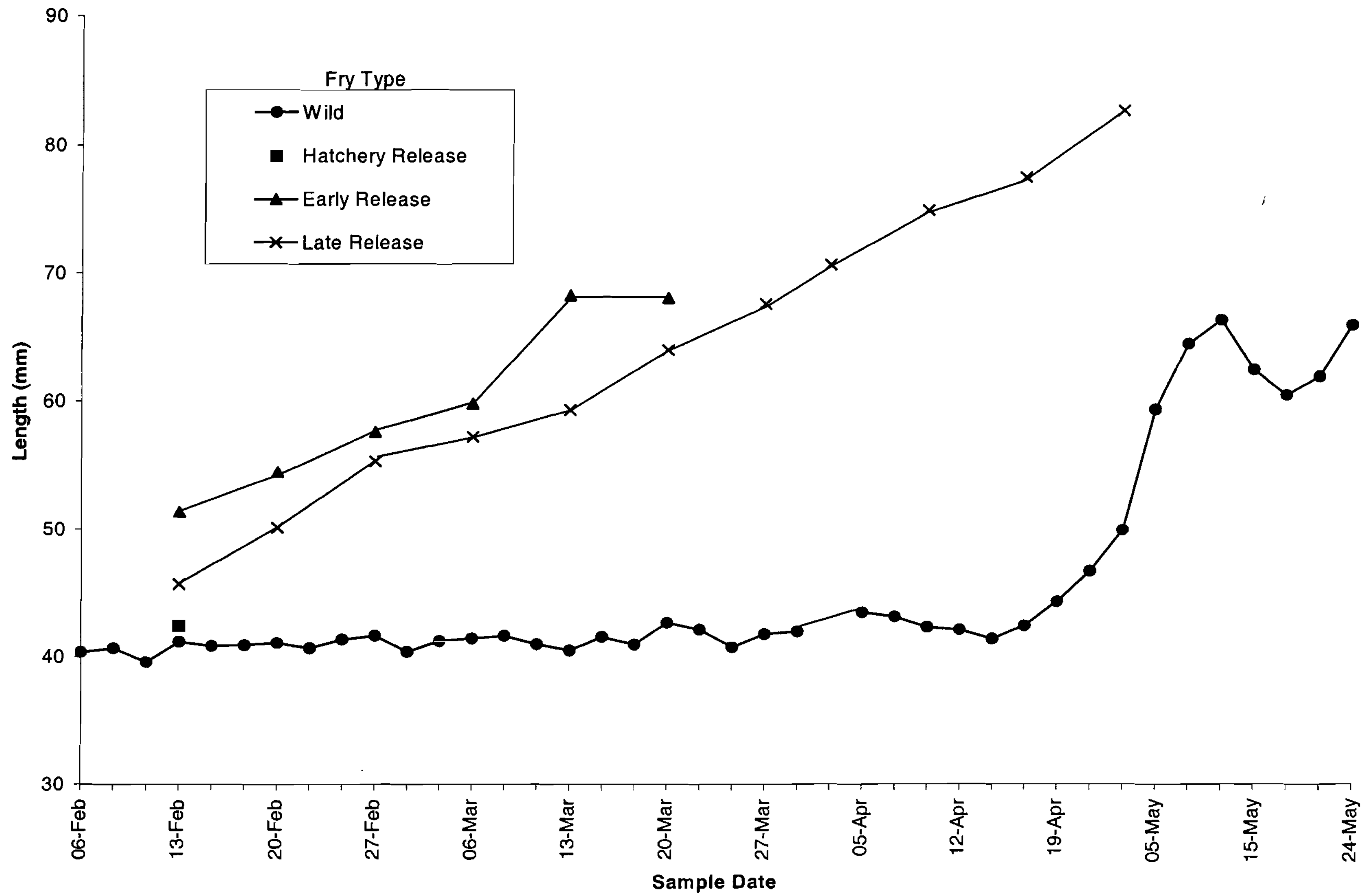

Figure 8. Mean lengths of hatchery-reared and naturally-reared chinook fry, Cowichan River, 2001.

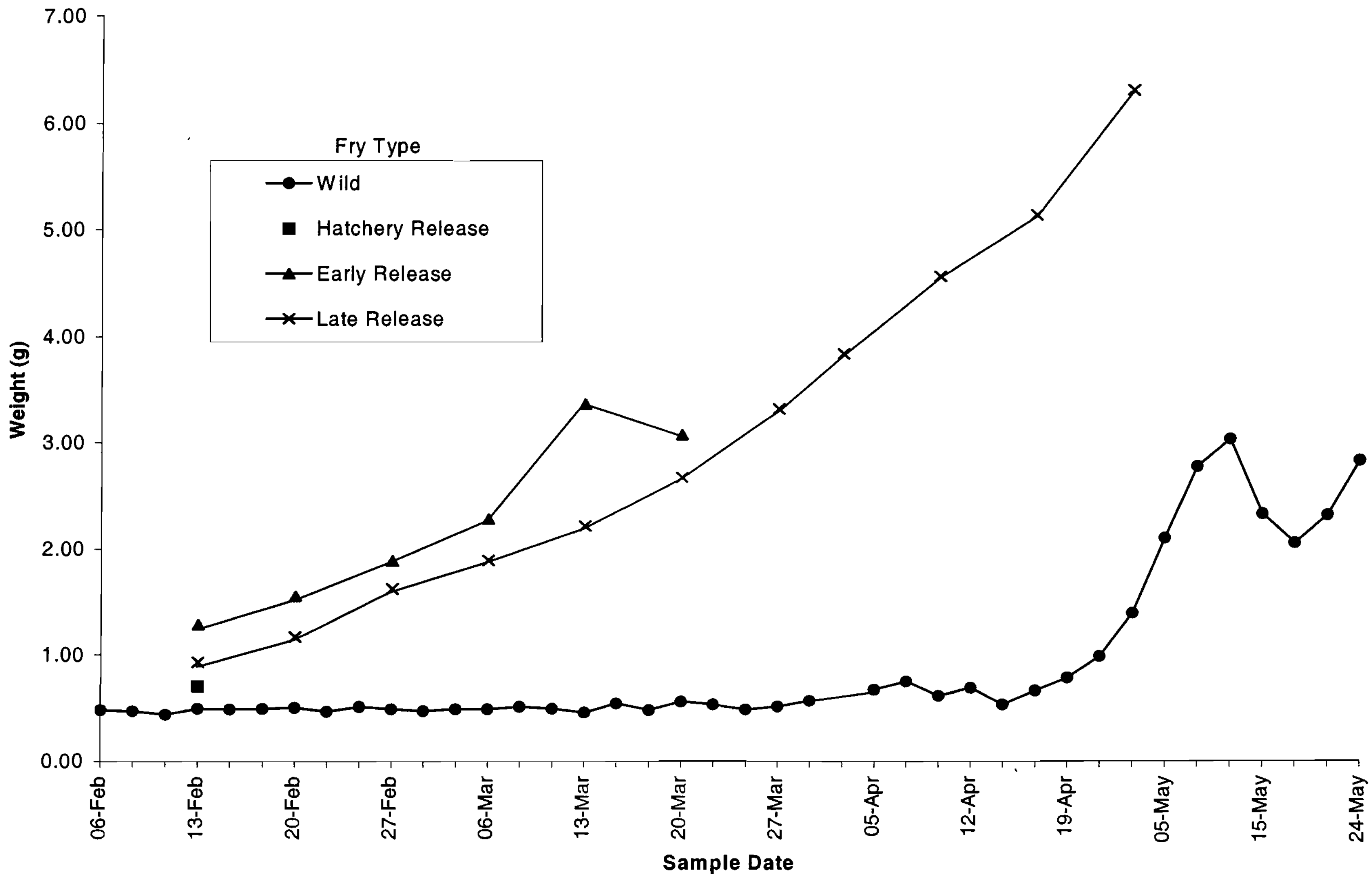

Figure 9. Mean weights of hatchery-reared and naturally-reared chinook fry, Cowichan River, 2001.