Juvenile Chinook Production in the Cowichan River, 2002

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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, 2002. Can. Manuscr. Rep. Fish. Aquat. Sci. 2679: 35 p.

In 1991, Fisheries and Oceans Canada (DFO) began a study of juvenile chinook salmon (*Oncorhynchus tshawytscha*) productivity in the Cowichan River. The 2002 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 2001 brood year was 895,180 (range: 480,505 – 1,340,148). The release of juvenile chinook from the Cowichan River Hatchery totaled 3,228,287. Of these, 2,572,674 hatchery-reared chinook were released above the trapping site. Egg to fry survival for naturally-reared chinook was estimated to be 12.73% (range: 6.83% – 19.05%). 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, 2002. Can. Manuscr. Rep. Fish. Aquat. Sci. 2679: 35 p.

En 1991, Pêches et Océans Canada a entrepris une étude sur la productivité du saumon quinnat (*Oncorhynchus tshawytscha*) juvénile de la rivière Cowichan. L'étude de 2002 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 2001 a été estimée à 895 180 (étendue : 480 505 – 1 340 148). Au total, 3 228 287 saumons quinnats juvéniles élevés dans l'écloserie de la rivière Cowichan ont été libérés, dont 2 572 674 en amont du site de piégeage. La survie des oeufs d'origine naturelle jusqu'au stade d'alevin a été estimée à 12,73 % (étendue : 6,83 % - 19,05 %). 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 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. 1994-2004).

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 3,228,287 chinook smolts in 2002 (Candy et al. 1996; D. Elliott, 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. 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 2002, the number of hatchery produced chinook which were coded-wire tagged was 225,908 fry (7.0%).

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 49.0 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 (Figure 1). It was assumed that virtually all chinook spawning occurred above this point. 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 13 to May 25, 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 the day and night movement.

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.

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

ABUNDANCE ESTIMATES

Trap efficiency information, using the mark-recapture of Bismark 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 three to four 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 release strategies.

RESULTS

BIOPHYSICAL CONDITIONS

During the fry enumeration period the Cowichan River had three main water discharge peaks, with the largest discharge of 174.0 m^3/s on February 22 and two lesser peaks of 99.7 m^3/s on March 13 and 103.5 m^3/s on April 15. The lowest Cowichan River discharge level of 23.5 m^3/s was obtained on the last day of the study. The mean discharge during the course of the study was 60.8 m^3/s with the February portion averaging 93.1 m^3/s; March yielding a 68.3 m^3/s average; April a 60.2 m^3/s average; and the May portion a 31.7 m^3/s average water discharge (Figure 2). Flow rates averaged 1.05 m/s and decreased from a high of 1.55 m/s on February 13 to a low of 0.65 m/s on May 24. Water temperatures averaged 7.4°C and increased from 4°C on February 8 to 14°C on May 22 and May 24. 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. Exactly half of the days were recorded as cloudy water clarity with the other days recorded as clear water clarity. During the study there were only two sample periods when rain was recorded (Table 1). In order to ensure sufficient flows and maintain optimal gear efficiency during periods of decreased water levels, the rotary screw trap was moved upstream from site 7A to site 7F on April 3 (Figure 1).

MIGRATION TIMING

The fry enumeration trap was run for 57, 12-hour intervals between February 13 and May 25, 2002. At the Pumphouse, 6,815 naturally-reared and 810 hatchery-reared chinook juveniles were caught in the screw trap. The number of hatchery-reared chinook fry enumerated also included 29 adipose-clipped fish. In addition, 30,177 chum fry, 11,206 coho fry, 1,602 one year old coho, 20 Bismark Brown dyed chinook fry and six Bismark Brown dyed chum fry were enumerated (Table 1). The downstream movement of hatchery-reared chinook was observed from April 13 (287 fry) to May 25 (one 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 and Carter, 1998). Naturally-reared chinook migration had two major peaks on April 2 and on April 13 and hatchery-reared fry enumeration peaks on April 13 and May 14 (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 April 11 with 998,044 fry being released of which 100,399 fry carried CWT's. The second release was also in the upper Cowichan River where 50,130 CWT fry of 1,574,630 total fry were released approximately on May 15. Two releases occurred below the fry enumeration site. The first, on April 30 from the Hatchery site released 558,827 fry of which 50,216 fry had CWT's. The final chinook fry release of the year was from the Seapen site in Cowichan Bay on May 21 where 25,163 CWT fry of 96,786 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 ten days between March 7 and May 3. A combined total of 1,616 naturally-reared chinook fry were counted with 1,468 fry obtained during night hours (~1900 – 0700 hours) and 148 fry collected during day hours (~0700 – 1900 hours) (Table 3). An expansion factor of 1.101 was obtained from the combined totals of the 24-hour trapping periods. The sample size of hatchery-reared chinook fry was too small to calculate a separate diel migration expansion factor as only one fry was captured during daylight hours (Table 1). As a result, the hatchery-reared fry enumerated during this study were also expanded by the diel migration results obtained from naturally-reared chinook fry.

TRAP EFFICIENCIES

Efficiency tests were divided into two sampling locations. Flow rate at the fry enumeration trap was recorded during each efficiency test (Figure 5). The enumeration trap was located at site 7A from February 13 to April 2 where three efficiency tests were conducted. During this period a total of 493 Bismark Brown dyed chinook fry and ten dyed chum fry were released on February 20, March 6 and March 20 (Table 4). Fry recoveries were run for 60 hours after each release date and yielded a total of seven Bismark Brown dyed chinook fry. An expansion factor of 70.43 was calculated from these results and used to expand February 13 to April 2 daily fry counts.

The second set of efficiency tests were conducted on April 3, April 24 and May 1 when the trap was located at site 7F. The April 3 efficiency test released 383 chinook fry of which 12 fry were recovered, while the April 24 and May 1 releases were primarily chum fry (Table 4). The April 3 expansion factor of 31.92 was chosen to expand the April 3 to May 25 fry enumeration count data.

ABUNDANCE ESTIMATES

Abundance estimates are 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 1.101 expansion factor obtained from the diel migration portion of the study. Daily estimates were then expanded by the trap efficiency estimates with February 13 to April 2 estimates expanded by 70.43 and April 3 to May 25 estimates expanded by 31.92. Total Cowichan River naturally-reared chinook is estimated to be 895,180 fry (Table 5) while the hatchery-reared chinook estimate is 65,052 fry (Table 6).

Population estimate ranges were calculated by using the lowest and highest diel and trap efficiency expansion factors. The lower population range used a diel expansion factor of 1.000 obtained from May 3 (n = 48) and a trap efficiency expansion factor of 31.92 obtained from site 7F on April 3 (n = 383). The upper population range was calculated using a diel expansion factor of 1.302 from March 21 (n = 168) and a trap efficiency expansion factor of 70.43 obtained from combined site 7A samples on February 20, March 6 and March 20 (n = 493). Population estimate ranges for naturally-reared chinook fry are 480,505 to 1,340,148 while ranges for hatchery-reared chinook fry are 59,100 to 169,779.

A coho mark-recapture study in Lake Cowichan provided supplementary data about chinook fry in the upper Cowichan water system. Two floating net traps were in Lake Cowichan from April 15 to June 14, 2002 of which only the trap located on the north shore counted chinook fry. During this time, 115 chinook fry were enumerated with one being adipose-clipped. Daily results from the north shore floating lake trap are summarized in Table 7.

Cowichan River Hatchery documented 2,572,674 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 0.031%. 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 2001, the number of chinook natural spawners was estimated to be 3,282. The proportion of females obtained from a carcass mark-recapture was determined to be 53.3%, or 1,748. The average fecundity from broodstock biosample data was determined to be 4,024 eggs and the total egg production was estimated to be 7,033,952 (Figure 6). The estimated abundance of naturally-reared chinook fry was extrapolated to 895,180 and the egg to fry survival was therefore estimated to be 12.73%. The egg to fry survival range was calculated using the lower and upper ranges from the estimated fry production and the estimated number of eggs produced. Lower and upper egg to fry survival ranges were 6.83% and 19.05%, 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, 1,088 naturally-reared chinook fry were biosampled for length and weight. Mean length was approximately 40 mm and mean weight varied from 0.44 - 0.69 g until the end of April (Table 8; Table 9; Figure 8; Figure 9). From April 25 to May 23 naturally-reared fry increased in mean length from 41.82 to 61.67 mm and mean weight increased from 0.54 to 2.42 g (Table 8; Table 9; Figure 8; Figure 9).

Between February 19 and May 14, three hatchery release strategies totaling 945 juvenile chinook were biosampled for length and weight data. Hatchery-reared chinook fry are generally longer and heavier set than naturally-reared chinook fry and the length and weight ranges reflect these differences (Table 8; Table 9;). 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 8; Table 9). 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. The month of March and the last portion of April had poor clarity which may have resulted in relatively higher trap efficiency. Conversely low river flows may increase trap efficiency decreasing the time a fry has in avoiding an oncoming trap in the river. Flow rates during recapture periods ranged from a high of 1.55 m/s on February 13 to a low of 0.65 m/s on May 24. 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

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 extinction 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 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.

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 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 early April, approximately the same time as the first hatchery release on April 11. Figure 4 indicates the early Roadpool hatchery release occurred during the peak migration of naturally-reared chinook on April 13. Thus interaction between hatchery and naturally-reared chinook migrants was highly probable.

The late Roadpool hatchery release took place over a couple of days and occurred approximately on May 15. By this time 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). It was necessary to use the efficiency test results from the naturally-reared fry to expand both fry types as data obtained from hatchery-reared fry were too small to expand.

TRAP EFFICIENCIES

Chinook abundance estimates using the Bismark 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. Due to the trap being located at different enumeration sites in the Cowichan River stratifying the trap expansion results into two categories was necessary. The first three trap efficiency results were combined and represented the February 13 to April 2 fry enumeration period. When the trap location was moved upstream on April 3 only the April 3 efficiency result was expanded to the April 3 to May 25 fry enumeration period. The two mark-recapture tests conducted on April 24 and May 1 were disregarded from efficiency calculations because they primarily consisted of chum fry. Possible differences in chum fry behavior and/or physiology between the two species could 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 sites 7A and 7F were used for this study, the difference in trap avoidance from a low velocity riffle area and the head of a pool was not applicable to this study.

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 895,180 naturally-reared chinook migrated from Cowichan River in 2002 (range: 480,505 – 1,340,148). 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 2,572,674 hatchery fry being released above the fry enumeration trap site. This estimate is considerably more than the value of 65,052 fry calculated from the rotary screw trap results. This discrepancy is most likely influenced by minimal trap enumeration following the three days after both hatchery fry releases. In the two previous years, the greatest number of hatchery-reared fry were enumerated within three days of being released (Nagtegaal et al. 2003, 2004). During the current study, only 12-hours of the initial 72-hours were monitored after each hatchery fry release most likely resulting in both migration peaks not being enumerated. 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. Furthermore, 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. 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 Floating lake trap used in the coho mark-recapture study suggest some hatchery fry may be stragglers from the late hatchery release on May 15. These fry may have swum upstream into Cowichan Lake before migrating downstream towards the estuary. Alternatively, fry enumerated in Cowichan Lake during May and June may be part of the later migration of juveniles reported by Lister et al. (1971). The 115 chinook fry enumerated in the floating lake trap indicate that the current 2002 population estimate is incomplete. Unfortunately no population estimate could be derived from data collected during this later study in May and 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 895,180 (range: 480,505 – 1,340,148) pertains only to the February 13 to May 25 enumeration period. The hatchery-reared chinook estimate of 3,228,287 fry supplied by the Cowichan River Hatchery is considered to be complete.

EGG TO FRY SURVIVAL

The egg to fry survival estimate of 12.73% is higher than the 1990 - 2001 brood year average of 6.54% and is within ranges reported by Healey (1991) who had chinook fry survival ranges from 8% to 16% (Figure 6). The 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). Flow rates during the course of adult chinook spawning, egg development and fry growth were generally stable with the exception of December and January with ranges between 79.2 m^3/s to 288.6 m^3/s (Figure 2). 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. In previous Cowichan River studies, high flows have result in scouring of spawning beds and therefore loss of developing chinook fry (Nagtegaal and Carter, 2000). 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 a steady increase in average size of naturally-reared chinook throughout the course of the 2002 study. 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, 2002.

Set Date	Weather[1]	Temperature (°C)	Clarity[2]	Sample Date	Start Time	Natural Chinook	Total Hatchery Chinook	Adipose-Clipped Chinook	Chum Fry	Coho Fry	Coho 1 year	Dye Marked Chinook	Dye Marked Chum
13-Feb	2	4	1	14-Feb-02	6:58	103	0	0	1	0	50	0	0
15-Feb	2	4	1	16-Feb-02	6:58	135	0	0	0	0	74	0	0
18-Feb	2	6	1	19-Feb-02	6:58	234	0	0	10	0	44	0	0
20-Feb	2	6	2	21-Feb-02	6:58	162	0	0	8	1	29	3	0
27-Feb	1	5	2	28-Feb-02	7:00	134	0	0	1	0	28	0	0
01-Mar	1	6	2	02-Mar-02	7:00	131	0	0	1	0	25	0	0
04-Mar	1	5	2	05-Mar-02	7:00	148	0	0	3	0	29	0	0
06-Mar	2	5	2	07-Mar-02	7:00	157	0	0	2	0	23	3	0
06-Mar	2	5	2	07-Mar-02	19:00	32	0	0	1	0	1	0	0
06-Mar	2	5	2	08-Mar-02	7:00	154	0	0	3	0	25	0	0
06-Mar	2	5	2	08-Mar-02	19:30	39	0	0	8	0	2	0	0
06-Mar	2	5	2	09-Mar-02	7:04	138	0	0	8	0	33	0	0
11-Mar	3	5	2	12-Mar-02	7:00	192	0	0	5	1	13	0	0
13-Mar	3	6	2	14-Mar-02	7:00	240	0	0	3	1	34	0	0
15-Mar	2	5	2	16-Mar-02	7:00	242	0	0	4	0	19	0	0
18-Mar	2	5	2	19-Mar-02	7:00	225	0	0	7	2	16	0	0
20-Mar	2	5	2	21-Mar-02	7:00	129	0	0	9	0	15	1	0
20-Mar	2	5	2	21-Mar-02	19:00	39	0	0	14	0	0	0	0
20-Mar	2	5	2	22-Mar-02	7:00	153	0	0	22	0	20	0	0
20-Mar	2	5	2	22-Mar-02	19:00	19	0	0	7	0	0	0	0
20-Mar	2	5	2	23-Mar-02	7:08	139	0	0	18	2	18	0	0
25-Mar	1	7	1	26-Mar-02	7:00	40	0	0	29	1	10	0	0
27-Mar	1	8	1	28-Mar-02	7:00	43	0	0	44	0	6	0	0
29-Mar	1	6	1	30-Mar-02	7:00	121	0	0	331	0	4	0	0
01-Apr	1	7	1	02-Apr-02	7:00	792	0	0	66	13	15	0	0
03-Apr	1	6	1	04-Apr-02	7:00	498	0	0	177	41	18	11	0
03-Apr	1	6	1	04-Apr-02	19:00	8	0	0	76	0	0	0	0
03-Apr	1	6	1	05-Apr-02	7:00	283	0	0	522	36	9	1	0
03-Apr	1	6	1	05-Apr-02	19:00	6	0	0	8	0	0	0	0
03-Apr	1	6	1	06-Apr-02	7:00	221	0	0	247	25	23	0	0

Table 1. (continued)

Set Date	Weather[1]	Temperature (°C)	Clarity[2]	Sample Date	Start Time	Natural Chinook	Total Hatchery Chinook	Adipose-Clipped Chinook	Chum Fry	Coho Fry	Coho 1 year	Dye Marked Chinook	Dye Marked Chum
08-Apr	1	8	1	09-Apr-02	7:00	121	0	0	503	33	18	0	0
10-Apr	2	8	N/A	11-Apr-02	7:00	200	0	0	611	42	16	0	0
12-Apr	2	8	2	13-Apr-02	7:00	793	287	24	84	651	38	0	0
15-Apr	2	7	2	16-Apr-02	7:00	112	4	0	45	245	58	0	0
17-Apr	1	7	2	18-Apr-02	7:00	142	6	0	5050	471	45	0	0
19-Apr	1	8	2	20-Apr-02	7:00	86	1	0	5835	281	59	0	0
22-Apr	1	8	2	23-Apr-02	7:00	39	1	0	4732	100	66	0	0
24-Apr	1	8	2	25-Apr-02	7:10	17	1	0	2320	45	36	1	0
24-Apr	1	8	2	25-Apr-02	19:00	1	0	0	125	1	0	0	0
24-Apr	1	8	2	26-Apr-02	7:00	4	0	0	1686	38	16	0	0
24-Apr	1	8	2	26-Apr-02	19:00	3	1	0	101	1	2	0	0
24-Apr	1	8	2	27-Apr-02	7:00	7	1	0	1467	41	17	0	0
29-Apr	1	10	1	30-Apr-02	7:00	21	0	0	1740	382	18	0	0
01-May	1	10	1	02-May-02	7:00	25	0	0	1355	1038	72	0	6
01-May	1	10	1	02-May-02	19:00	1	0	0	39	12	2	0	0
01-May	1	10	1	03-May-02	7:00	48	0	0	1085	2419	54	0	0
01-May	1	10	1	03-May-02	19:00	0	0	0	15	16	0	0	0
01-May	1	10	1	04-May-02	7:00	33	1	0	476	1076	56	0	0
06-May	1	9	1	07-May-02	7:00	48	2	0	428	1015	53	0	0
08-May	1	10	1	09-May-02	7:00	22	0	0	230	524	25	0	0
10-May	1	10	1	11-May-02	7:00	13	0	0	136	526	43	0	0
13-May	1	10	1	14-May-02	7:00	18	339	0	140	382	67	0	0
15-May	1	10	1	16-May-02	7:00	27	37	0	118	732	46	0	0
17-May	1	10	1	18-May-02	7:00	31	54	2	118	648	45	0	0
20-May	1	10	1	21-May-02	7:00	34	66	2	58	188	121	0	0
22-May	1	12	1	23-May-02	7:00	12	8	1	39	132	42	0	0
24-May	2	12	1	25-May-02	7:00	0	1	0	6	44	4	0	0
Total						6815	810	29	30177	11206	1602	20	6

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

Table 2. Cowichan River Hatchery chinook release data, 2002.

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	**998044**		**100399**			9-Apr	67.83	57	77	3.27	1.81	4.72
		184639	25140	10.06	11-Apr							
		184640	25047	10.06	11-Apr							
		184641	25255	10.06	11-Apr							
		184642	24957	10.06	11-Apr							
Late	**1574630**		**50130**			14-May	83.70	75	92	6.00	3.61	7.89
		184643	25068	3.18	15-May[1]							
		184644	25062	3.18	15-May[1]							
Hatchery	**558827**		**50216**			23-Apr	74.27	64	88	4.24	2.66	6.56
		184645	25019	8.99	30-Apr							
		184646	25197	8.99	30-Apr							
Seapen	**96786**		**25163**			21-May				5.68		
		184448	25163	26.00	21-May							
Total	**3228287**		**225908**	**7.0%**								

Total released above trap site: 2572674

Release Sites:

Early- upper Cowichan R. (Road Pool)[2]
Late- upper Cowichan R. (below weir)[2]
Hatchery- released directly from Hatchery
Seapen- released from seapens in Cowichan Bay

[1] This is only an approximate release date with the entire release occurring over a couple of days
[2] Indicates that these fish are released above the trapping site

Table 3. Daily summary of 24-hour trapping periods for naturally-reared chinook fry, Pumphouse site, Cowichan River, 2002.

Sample Date	Naturally-Reared Chinook Fry Night	Day	24-Hour Period	Expansion Factor
07-Mar	157	32	189	1.204
08-Mar	154	39	193	1.253
21-Mar	129	39	168	1.302
22-Mar	153	19	172	1.124
04-Apr	498	8	506	1.016
05-Apr	283	6	289	1.021
25-Apr	17	1	18	1.059
26-Apr	4	3	7	1.750
02-May	25	1	26	1.040
03-May	48	0	48	1.000
Totals	1468	148	1616	1.101

Table 4. Trap efficiency data by release date, Pumphouse site, Cowichan River, 2002.

Release Date	Flow (m/s)	Released		Recovered		Recovered		Expansion Factor	
		Chinook	Chum	Chinook	Chum	Chinook	Chum	Chinook	Chum
20-Feb[1]	1.370	192	7	3	0	1.56%	0.00%	64.00	
6-Mar	1.194	115	3	3	0	2.61%	0.00%	38.33	
20-Mar	1.163	186	0	1	0	0.54%	0.00%	186.00	
Total		493	10	7	0	1.42%	0.00%	**70.43**	
3-Apr	0.888	383	0	12	0	3.13%	0.00%	**31.92**	
24-Apr	1.089	9	302	1	0	11.11%	0.00%	9.00	
1-May	1.072	0	302	0	6	0.00%	1.99%		50.33

[1] Trap count incomplete.

Table 5. Expanded daily trap catch estimates of naturally-reared chinook fry, Pumphouse site, Cowichan River, 2002.

	Observed[1]		Missing cells	24-hour	Extrapolated	Cumulative
Date	PM	AM	Interpolated	Estimates	Estimates	Total
14-Feb	103			113	7985	7985
15-Feb			119	131	9226	17211
16-Feb	135			149	10466	27678
17-Feb			185	203	14304	41982
18-Feb			185	203	14304	56286
19-Feb	234			258	18142	74428
20-Feb			198	218	15351	89779
21-Feb	162	134		296	20847	110625
22-Feb			147	161	11358	121983
23-Feb			147	161	11358	133341
24-Feb			147	161	11358	144699
25-Feb			147	161	11358	156057
26-Feb			147	161	11358	167415
27-Feb			147	161	11358	178773
28-Feb			147	161	11358	190131
01-Mar			147	161	11358	201489
02-Mar	131			144	10156	211646
03-Mar			140	154	10815	222461
04-Mar			140	154	10815	233276
05-Mar	148			163	11474	244751
06-Mar			153	168	11823	256574
07-Mar	157	32		189	13311	269885
08-Mar	154	39		193	13593	283477
09-Mar	138			152	10699	294176
10-Mar			165	182	12792	306969
11-Mar			165	182	12792	319761
12-Mar	192			211	14886	334647
13-Mar			216	238	16746	351393
14-Mar	240			264	18607	370000
15-Mar			241	265	18684	388684
16-Mar	242			266	18762	407446
17-Mar			234	257	18103	425549
18-Mar			234	257	18103	443652
19-Mar	225			248	17444	461096
20-Mar			177	195	13723	474819
21-Mar	129	39		168	11832	486651
22-Mar	153	19		172	12114	498765
23-Mar	139			153	10777	509541
24-Mar			90	99	6939	516480
25-Mar			90	99	6939	523419
26-Mar	40			44	3101	526520
27-Mar			42	46	3217	529738
28-Mar	43			47	3334	533071
29-Mar			82	90	6357	539429
30-Mar	121			133	9381	548810

Table 5. (continued)

Date	Observed[1] PM	AM	Missing cells Interpolated	24-hour Estimates	Extrapolated Estimates	Cumulative Total
31-Mar			457	503	35392	584202
01-Apr			457	503	35392	619594
02-Apr	792			872	61403	680997
03-Apr			645	710	22662	703658
04-Apr	498	8		506	16150	719808
05-Apr	283	6		289	9224	729032
06-Apr	221			243	7765	736797
07-Apr			171	188	6008	742805
08-Apr			171	188	6008	748813
09-Apr	121			133	4251	753064
10-Apr			161	177	5639	758703
11-Apr	200			220	7027	765730
12-Apr			497	547	17444	783174
13-Apr	793			873	27862	811036
14-Apr			453	498	15898	826934
15-Apr			453	498	15898	842833
16-Apr	112			123	3935	846768
17-Apr			127	140	4462	851230
18-Apr	142			156	4989	856219
19-Apr			114	125	4005	860224
20-Apr	86			95	3022	863246
21-Apr			63	69	2196	865442
22-Apr			63	69	2196	867637
23-Apr	39			43	1370	869008
24-Apr			28	31	984	869991
25-Apr	17	1		18	575	870566
26-Apr	4	3		7	223	870789
27-Apr	7			8	246	871035
28-Apr			14	15	492	871527
29-Apr			14	15	492	872019
30-Apr	21			23	738	872757
01-May			23	25	808	873565
02-May	25	1		26	830	874395
03-May	48	0		48	1532	875927
04-May	33			36	1159	877086
05-May			41	45	1423	878509
06-May			41	45	1423	879932
07-May	48			53	1686	881619
08-May			35	39	1230	882848
09-May	22			24	773	883621
10-May			18	19	615	884236
11-May	13			14	457	884693
12-May			16	17	545	885237
13-May			16	17	545	885782
14-May	18			20	632	886414
15-May			23	25	791	887205

Table 5. (continued)

Date	Observed[1] PM	AM	Missing cells Interpolated	24-hour Estimates	Extrapolated Estimates	Cumulative Total
16-May	27			30	949	888154
17-May			29	32	1019	889172
18-May	31			34	1089	890262
19-May			33	36	1142	891404
20-May			33	36	1142	892545
21-May	34			37	1195	893740
22-May			23	25	808	894548
23-May	12			13	422	894970
24-May			6	7	211	895180
25-May	0			0	0	895180

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

Table 6. Expanded daily trap catch estimates of hatchery-reared chinook fry, Pumphouse site, Cowichan River, 2002.

	Observed[1]		Missing cells	24-hour	Extrapolated	Cumulative
Sample Date	PM	AM	Interpolated	Estimates	Estimates	Total
13-Apr	287			316	10085	10085
14-Apr			146	160	5113	15197
15-Apr			146	160	5113	20310
16-Apr	4			4	141	20450
17-Apr			5	6	176	20626
18-Apr	6			7	211	20837
19-Apr			4	4	123	20960
20-Apr	1			1	35	20995
21-Apr			1	1	35	21030
22-Apr			1	1	35	21065
23-Apr	1			1	35	21100
24-Apr			1	1	35	21136
25-Apr	1	0		1	32	21167
26-Apr	1	0		1	32	21199
27-Apr	1			1	35	21235
28-Apr			1	1	18	21252
29-Apr			1	1	18	21270
30-Apr	0			0	0	21270
01-May			0	0	0	21270
02-May	0	0		0	0	21270
03-May	0	0		0	0	21270
04-May	1			1	35	21305
05-May			2	2	53	21358
06-May			2	2	53	21410
07-May	2			2	70	21481
08-May			1	1	35	21516
09-May	0			0	0	21516
10-May				0	0	21516
11-May	0			0	0	21516
12-May			170	187	5956	27472
13-May			170	187	5956	33427
14-May	339			373	11912	45339
15-May			188	207	6606	51945
16-May	37			41	1300	53245
17-May			46	50	1599	54844
18-May	54			59	1897	56742
19-May			60	66	2108	58850
20-May			60	66	2108	60958
21-May	66			73	2319	63277
22-May			37	41	1300	64577
23-May	8			9	281	64858
24-May			5	5	158	65017
25-May	1			1	35	65052

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

Table 7. Floating lake trap data, northern shore of Cowichan Lake, 2002.

Set Date	Temperature (°C)	Total Chinook Fry	Adipose-Clipped Chinook	Coho	Kokanee	Rainbow Trout	Cutthroat Trout	Brown Trout
15-Apr	9.00	0	0	0	3	0	1	0
16-Apr	7.00	0	0	0	0	0	0	0
17-Apr	7.00	0	0	0	1	0	0	0
18-Apr	8.00	0	0	0	0	0	0	0
19-Apr	8.25	0	0	0	0	0	0	0
20-Apr	9.00	0	0	0	0	0	0	0
21-Apr	-	0	0	3	2	1	0	0
22-Apr	9.00	0	0	1	0	0	1	0
23-Apr	9.00	0	0	1	0	0	0	0
24-Apr	9.00	0	0	0	0	0	0	0
25-Apr	9.00	0	0	0	0	0	0	0
26-Apr	9.00	0	0	1	0	0	0	0
27-Apr	9.00	0	0	0	0	0	0	0
28-Apr	9.00	0	0	6	0	0	0	0
29-Apr	10.00	0	0	15	0	0	0	0
30-Apr	11.00	0	0	8	2	172	0	0
01-May	11.00	0	0	32	0	0	0	0
02-May	11.00	0	0	5	0	0	1	0
03-May	12.00	0	0	7	0	0	0	0
04-May	11.00	0	0	0	1	0	0	0
05-May	11.00	0	0	8	10	0	0	0
06-May	-	0	0	5	0	0	0	0
07-May	11.00	0	0	5	3	2	0	0
08-May	11.00	0	0	7	7	0	1	0
09-May	10.50	0	0	24	10	1	2	0
10-May	11.00	0	0	54	7	0	2	0
11-May	11.50	0	0	0	0	0	1	0
12-May	-	0	0	2	0	0	0	0
13-May	10.50	0	0	17	3	0	0	0
14-May	-	0	0	0	0	0	0	0
15-May	11.00	0	0	8	2	0	0	0
16-May	12.50	6	0	61	69	1	4	0
17-May	12.00	2	1	89	67	0	1	0
18-May	12.00	0	0	0	0	0	0	0
19-May	11.00	0	0	12	1	1	1	0
20-May	11.00	0	0	1	0	0	0	0
21-May	11.25	2	0	99	16	0	4	0
22-May	12.00	2	0	12	11	0	4	0
23-May	12.00	85	0	162	18	5	0	0
24-May	12.00	0	0	0	0	0	0	0
25-May	12.00	0	0	6	0	1	3	0
26-May	12.50	0	0	2	0	1	0	0
27-May	13.50	0	0	3	0	0	0	0
28-May	13.00	0	0	12	4	0	0	0
29-May	12.50	0	0	0	0	0	0	0

Table 7. (continued)

Set Date	Temperature (°C)	Total Chinook Fry	Adipose-Clipped Chinook	Coho	Kokanee	Rainbow Trout	Cutthroat Trout	Brown Trout
30-May	13.00	1	0	0	0	0	0	0
31-May	13.00	5	0	5	1	0	0	0
01-Jun	13.00	0	0	0	0	0	0	0
02-Jun	14.00	2	0	63	23	4	3	0
03-Jun	15.00	0	0	31	20	1	1	1
04-Jun	15.00	0	0	16	1	1	0	0
05-Jun	15.00	0	0	49	2	2	3	1
06-Jun	15.00	0	0	28	12	4	0	0
07-Jun	15.00	1	0	17	15	8	0	0
08-Jun	15.00	0	0	11	1	2	3	1
09-Jun	15.00	0	0	30	8	3	7	0
10-Jun	16.00	0	0	16	3	3	3	0
11-Jun	16.00	0	0	2	1	0	6	0
12-Jun	16.00	0	0	27	6	6	5	0
13-Jun	16.00	4	0	64	23	12	2	0
14-Jun	16.50	5	0	28	6	7	0	0
Total		115	1	1055	359	238	59	3

Table 8. Daily summary of chinook fry sampling length (mm) data, Cowichan River , 2002.

Sampling	Naturally-Reared				Hatchery Release				Late Release				Early Release			
Date	n	Mean	Min	Max	n	Mean	Min	Max	n	Mean	Min	Max	n	Mean	Min	Max
14-Feb	30	40.13	36	43												
16-Feb	30	40.57	35	44												
19-Feb	30	40.07	35	45					60	43.35	38	48	30	46.67	42	51
21-Feb	30	40.27	37	44												
26-Feb					30	46.83	40	51	30	46.57	38	53	30	48.63	41	54
28-Feb	30	41.20	36	50												
02-Mar	30	41.17	37	44												
05-Mar	30	40.57	39	43	30	48.40	42	53	30	49.20	43	55	30	51.60	42	57
07-Mar	30	40.83	39	43												
09-Mar	30	41.80	40	47												
12-Mar	30	40.67	38	43	30	52.00	44	58	30	53.20	48	56	30	54.90	50	63
14-Mar	30	40.97	37	43												
16-Mar	30	41.27	38	50												
19-Mar	30	40.90	36	45	30	55.73	47	62	30	55.87	46	63	30	56.10	47	62
21-Mar	30	40.77	38	44												
23-Mar	30	40.87	38	45												
26-Mar	30	40.37	35	43	30	58.23	51	66	30	58.23	50	63	30	59.43	50	65
30-Mar	30	40.17	37	43												
02-Apr	30	40.87	37	46	30	62.43	56	71	30	63.20	56	75	30	63.20	54	68
04-Apr	30	40.80	37	44												
06-Apr	27	41.04	37	44												
09-Apr	30	40.70	38	44	30	64.90	54	72	30	69.63	58	77	30	67.83	57	77
11-Apr	30	40.50	37	45												
13-Apr	30	41.00	38	46									15	66.80	60	72
16-Apr	30	42.77	39	54	30	70.53	56	80	30	71.70	65	80				
18-Apr	29	41.69	38	48												
20-Apr	30	41.07	35	52												
23-Apr	30	40.87	37	47	30	74.27	64	88	30	77.57	70	90				
25-Apr	17	41.82	37	54												
27-Apr	7	41.86	36	52												
30-Apr	21	42.10	39	51					30	80.87	70	90				
02-May	25	42.92	35	59												
04-May	30	43.37	37	64												
07-May	30	43.87	38	64					30	79.67	62	86				
09-May	22	46.00	39	61												
11-May	13	46.85	42	53												
14-May	18	49.33	38	61					30	83.70	75	92				
16-May	27	52.59	40	67												
18-May	30	53.17	40	65												
21-May	30	58.83	39	70												
23-May	12	61.67	50	72												

Table 9. Daily summary of chinook fry sampling weight (g) data, Cowichan River , 2002.

Sampling	Naturally-Reared				Hatchery Release				Late Release				Early Release			
Date	n	Mean	Min	Max	n	Mean	Min	Max	n	Mean	Min	Max	n	Mean	Min	Max
14-Feb	30	0.44	0.30	0.57												
16-Feb	30	0.49	0.31	0.62												
19-Feb	30	0.45	0.31	0.61					60	0.71	0.42	1.01	30	0.92	0.68	1.25
21-Feb	30	0.47	0.33	0.62												
26-Feb					30	0.91	0.57	1.26	30	0.91	0.48	1.31	30	1.05	0.64	1.41
28-Feb	30	0.56	0.38	1.06												
02-Mar	30	0.51	0.39	0.67												
05-Mar	30	0.47	0.39	0.61	30	1.10	0.77	1.43	30	1.13	0.66	1.68	30	1.37	0.74	1.85
07-Mar	30	0.48	0.37	0.62												
09-Mar	30	0.53	0.40	0.85												
12-Mar	30	0.58	0.42	0.70	30	1.37	0.74	1.92	30	1.45	1.09	1.76	30	1.65	1.20	2.66
14-Mar	30	0.59	0.41	0.72												
16-Mar	30	0.52	0.41	0.80												
19-Mar	30	0.50	0.42	0.76	30	1.75	0.99	2.45	30	1.81	0.85	2.78	30	1.73	1.06	2.47
21-Mar	30	0.49	0.38	0.65												
23-Mar	30	0.50	0.39	0.67												
26-Mar	30	0.48	0.37	0.62	30	2.02	1.23	3.19	30	2.06	1.18	2.74	30	2.15	1.40	2.87
30-Mar	30	0.45	0.33	0.60												
02-Apr	30	0.48	0.36	0.70	30	2.51	1.67	3.72	30	2.65	1.85	4.80	30	2.62	1.62	3.40
04-Apr	30	0.49	0.36	0.61												
06-Apr	27	0.48	0.32	0.61												
09-Apr	30	0.49	0.38	0.62	30	2.89	1.57	3.70	30	3.63	1.93	5.30	30	3.27	1.81	4.72
11-Apr	30	0.48	0.36	0.70												
13-Apr	30	0.51	0.38	0.81									15	2.91	2.17	3.71
16-Apr	30	0.69	0.51	1.43	30	3.66	1.86	5.31	30	3.80	2.48	5.48				
18-Apr	29	0.59	0.40	0.97												
20-Apr	30	0.52	0.28	1.19												
23-Apr	30	0.49	0.40	0.82	30	4.24	2.66	6.56	30	5.01	3.68	7.60				
25-Apr	17	0.54	0.37	1.41												
27-Apr	7	0.54	0.30	1.30												
30-Apr	21	0.58	0.36	1.21					30	5.56	3.42	8.29				
02-May	25	0.63	0.30	1.94												
04-May	30	0.69	0.34	2.63												
07-May	30	0.71	0.37	2.52					30	5.16	2.30	7.03				
09-May	22	0.88	0.40	2.25												
11-May	13	0.92	0.57	1.49												
14-May	18	1.12	0.39	2.40					30	6.00	3.61	7.89				
16-May	27	1.47	0.43	2.91												
18-May	30	1.49	0.51	2.76												
21-May	30	2.14	0.42	3.26												
23-May	12	2.42	1.10	3.67												

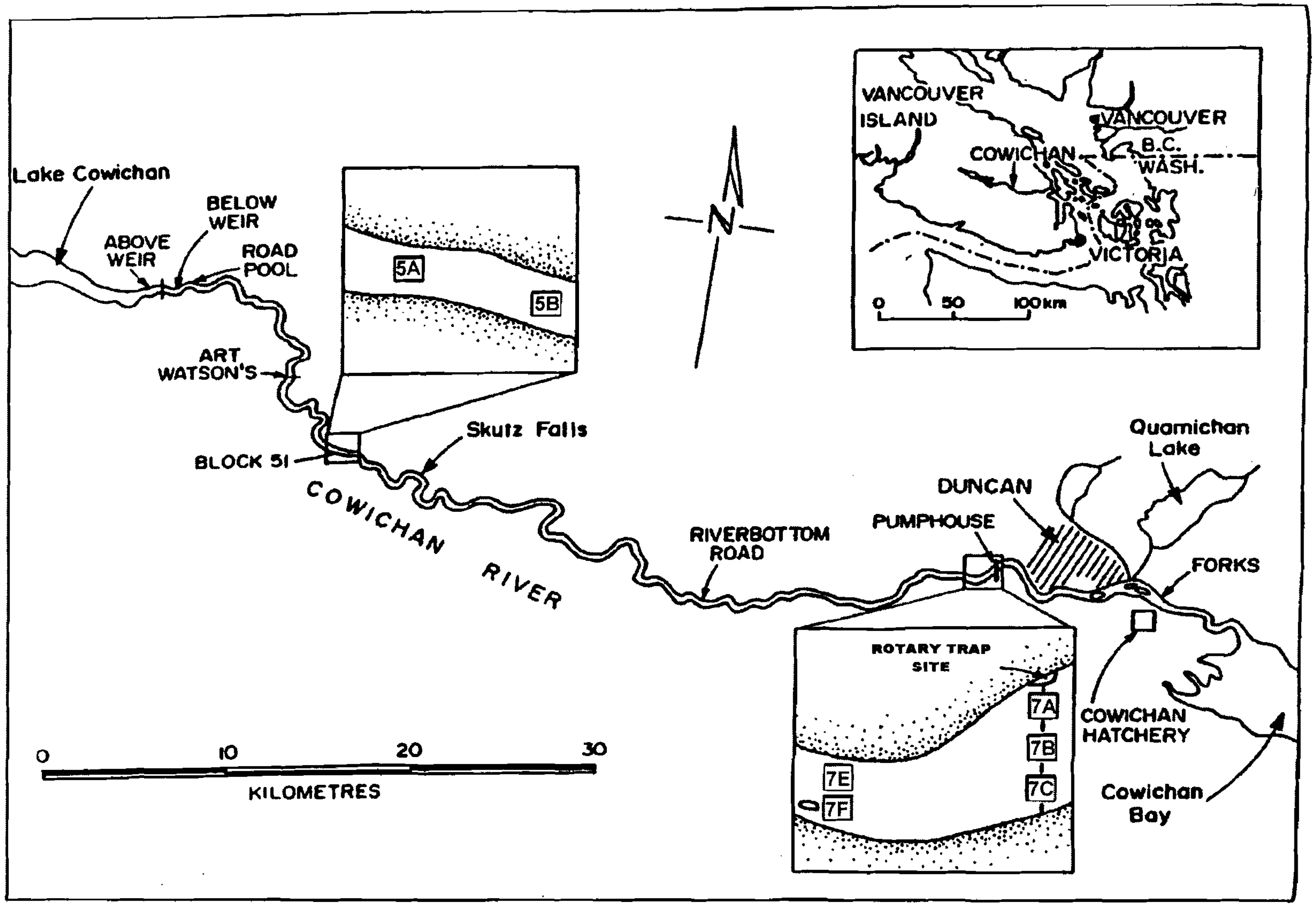

Figure 1. Cowichan River downstream fry trap locations.

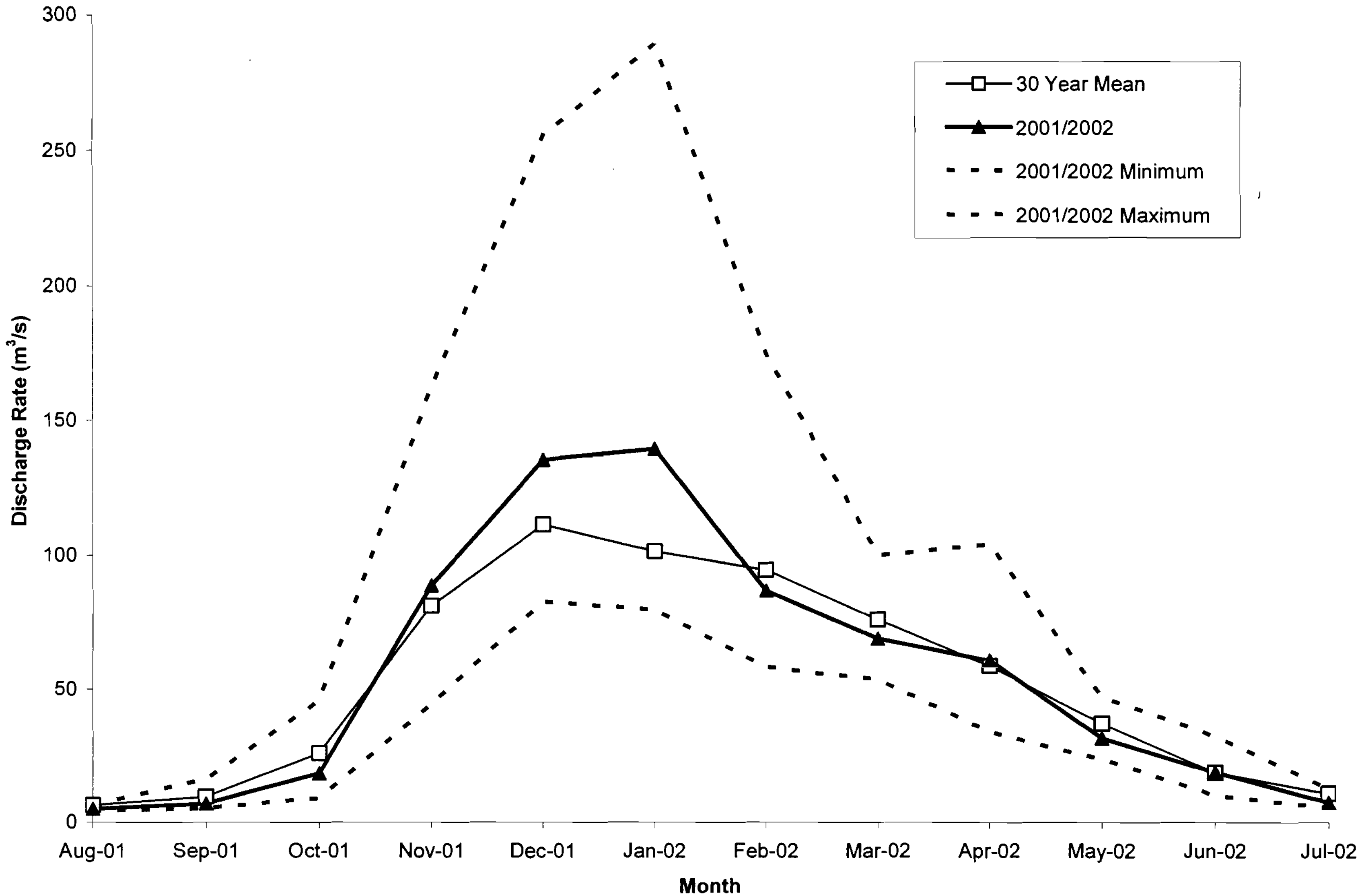

Figure 2. Monthly Cowichan River discharge[1] (m^3/s) from August 2001 to July 2002 along with 30 year mean.
[1] Water Survey of Canada data recorded in Duncan, B.C., data subject to revision.

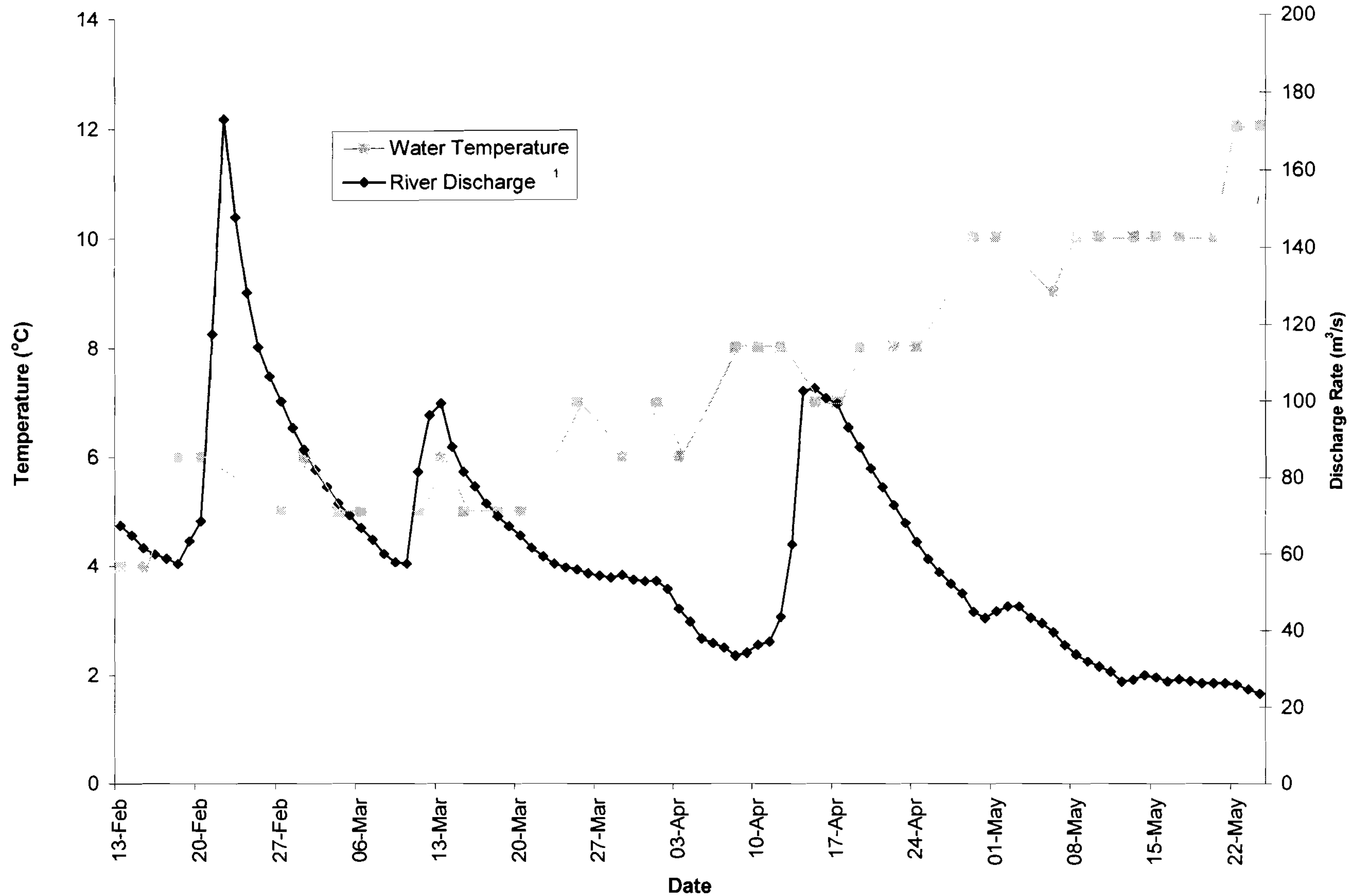

Figure 3. Biophysical conditions recorded at the Pumphouse site, Cowichan River, 2002
[1] River discharge measured at the Island Highway Bridge in Duncan, B.C.

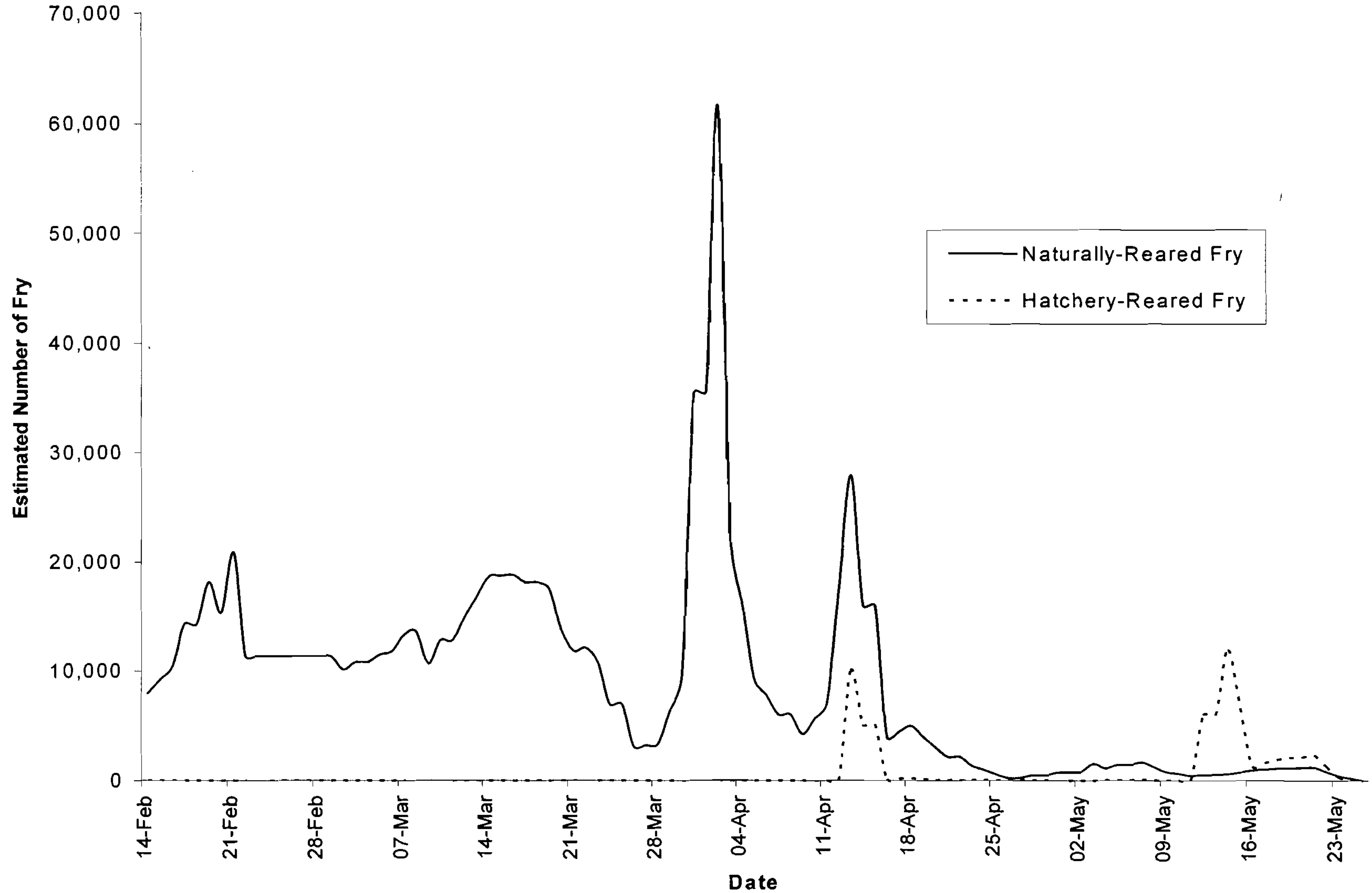

Figure 4. Daily abundance estimates of naturally-reared and hatchery-reared chinook fry downstream migration, Pumphouse site, Cowichan River, 2002.

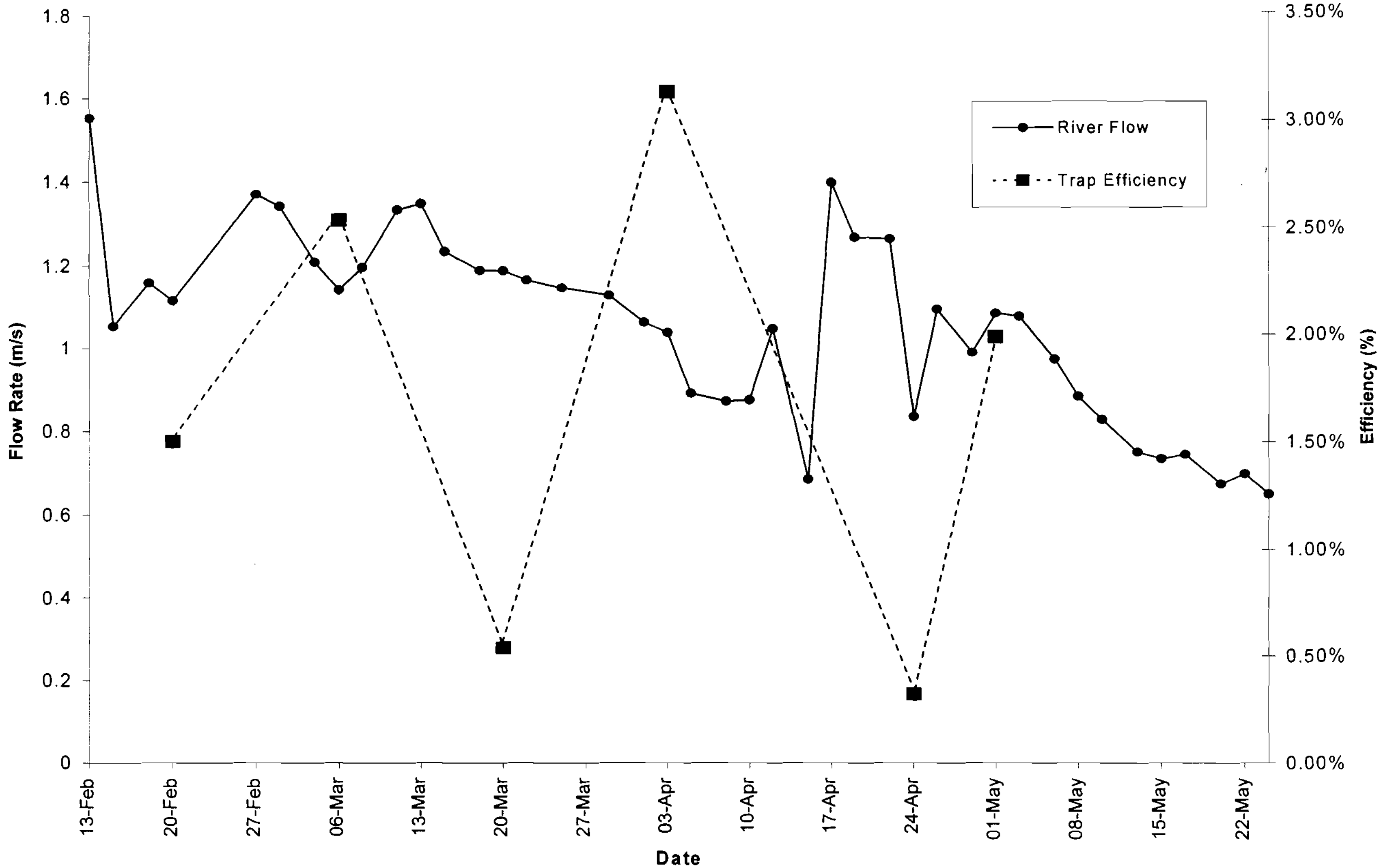

Figure 5. Rotary screw trap efficiency compared with water flow at the Pumphouse site, Cowichan River, 2002.

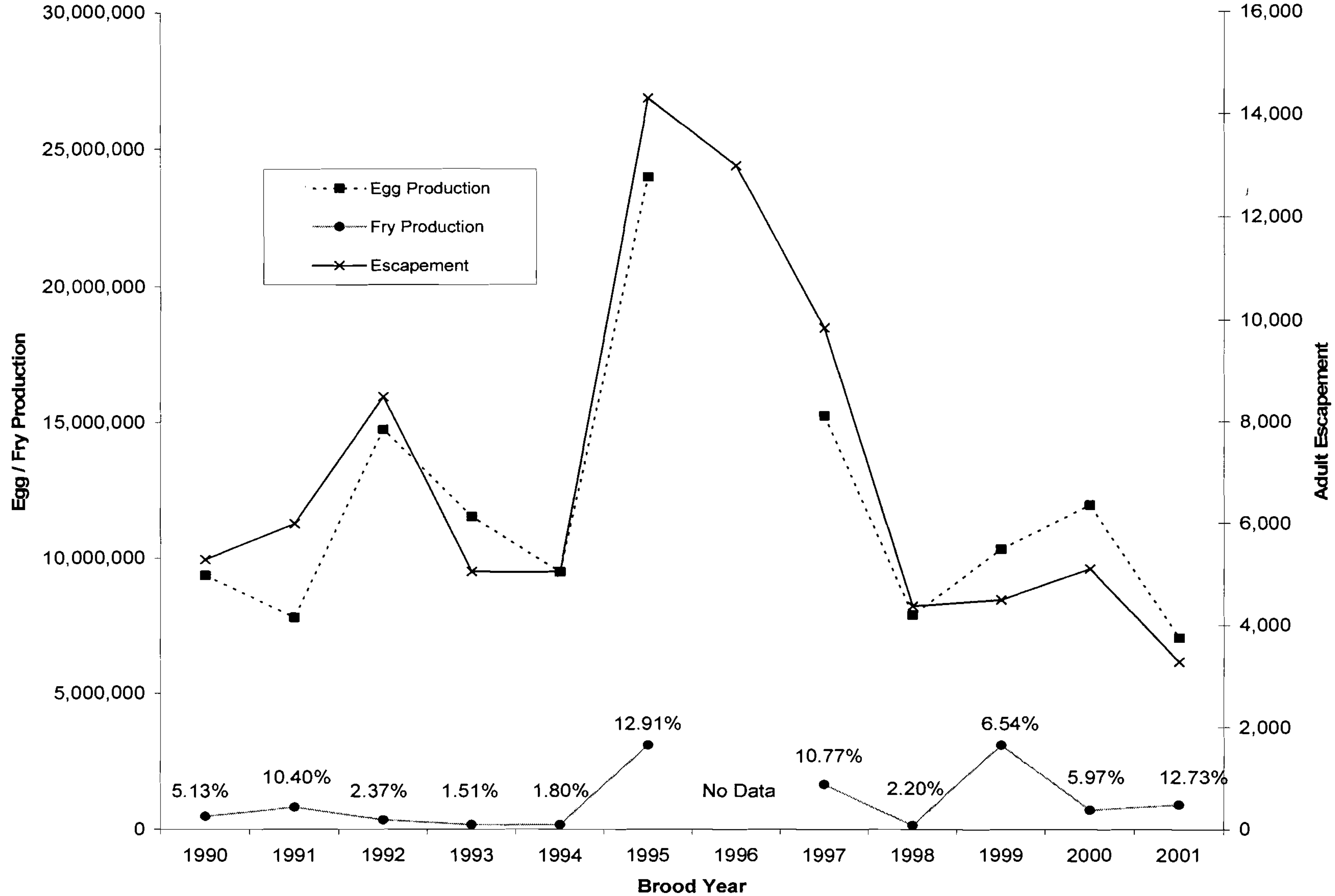

Figure 6. Egg to fry survival estimates compared to adult escapement and fry production, Cowichan River.

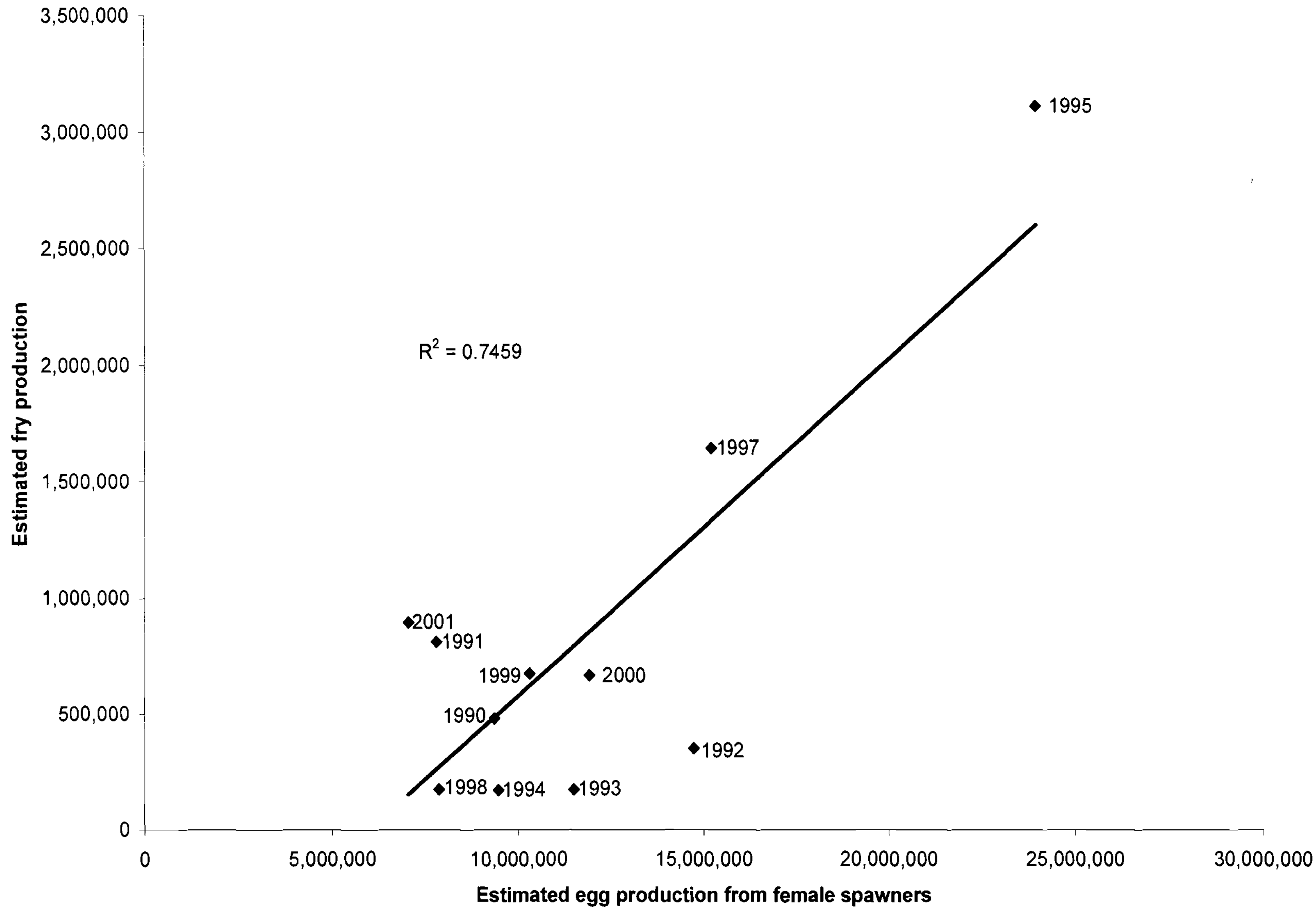

Figure 7. Chinook eggs deposited compared with subsequent fry production, Cowichan River.

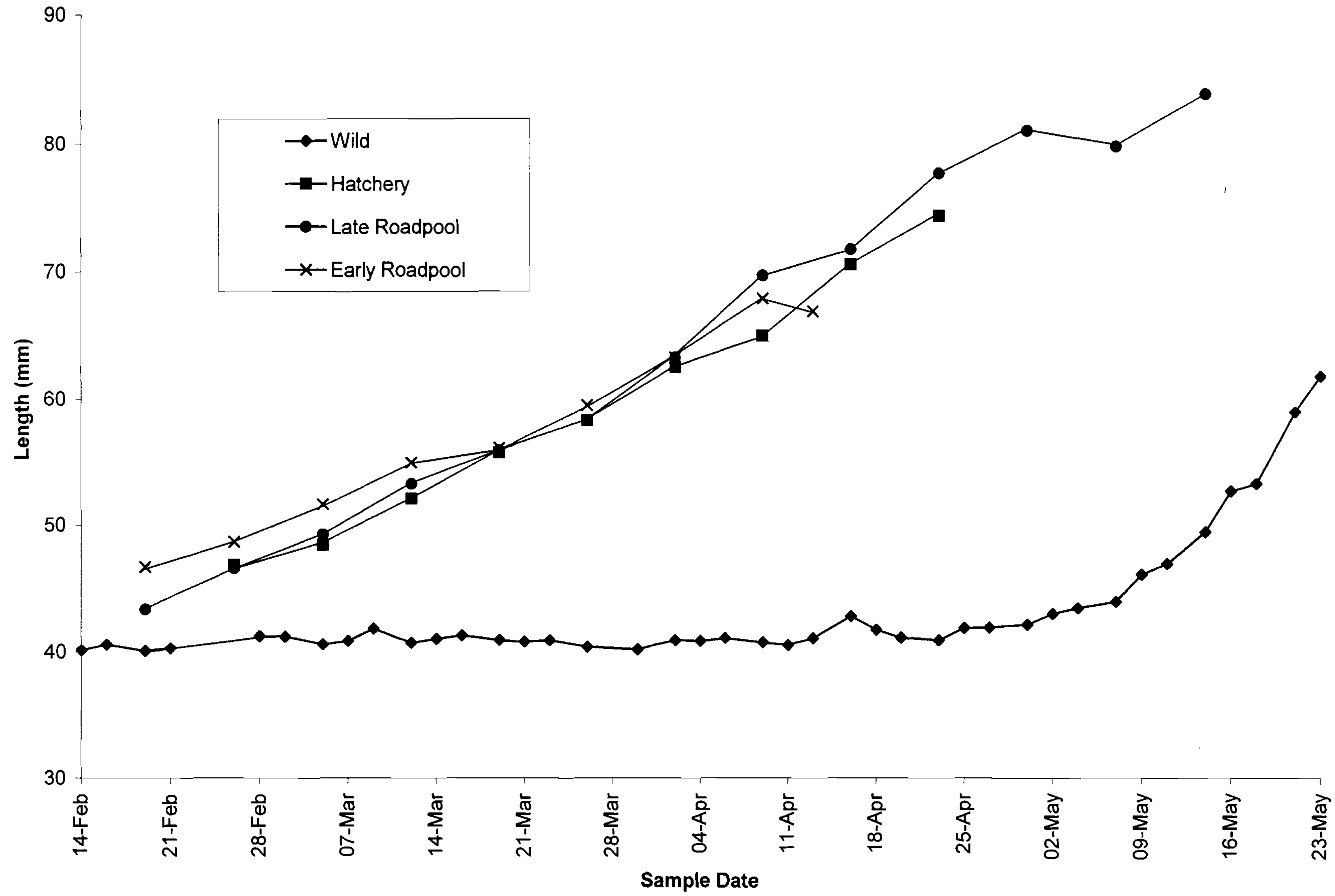

Figure 8. Mean lengths of hatchery-reared and naturally-reared chinook fry, Cowichan River, 2002.

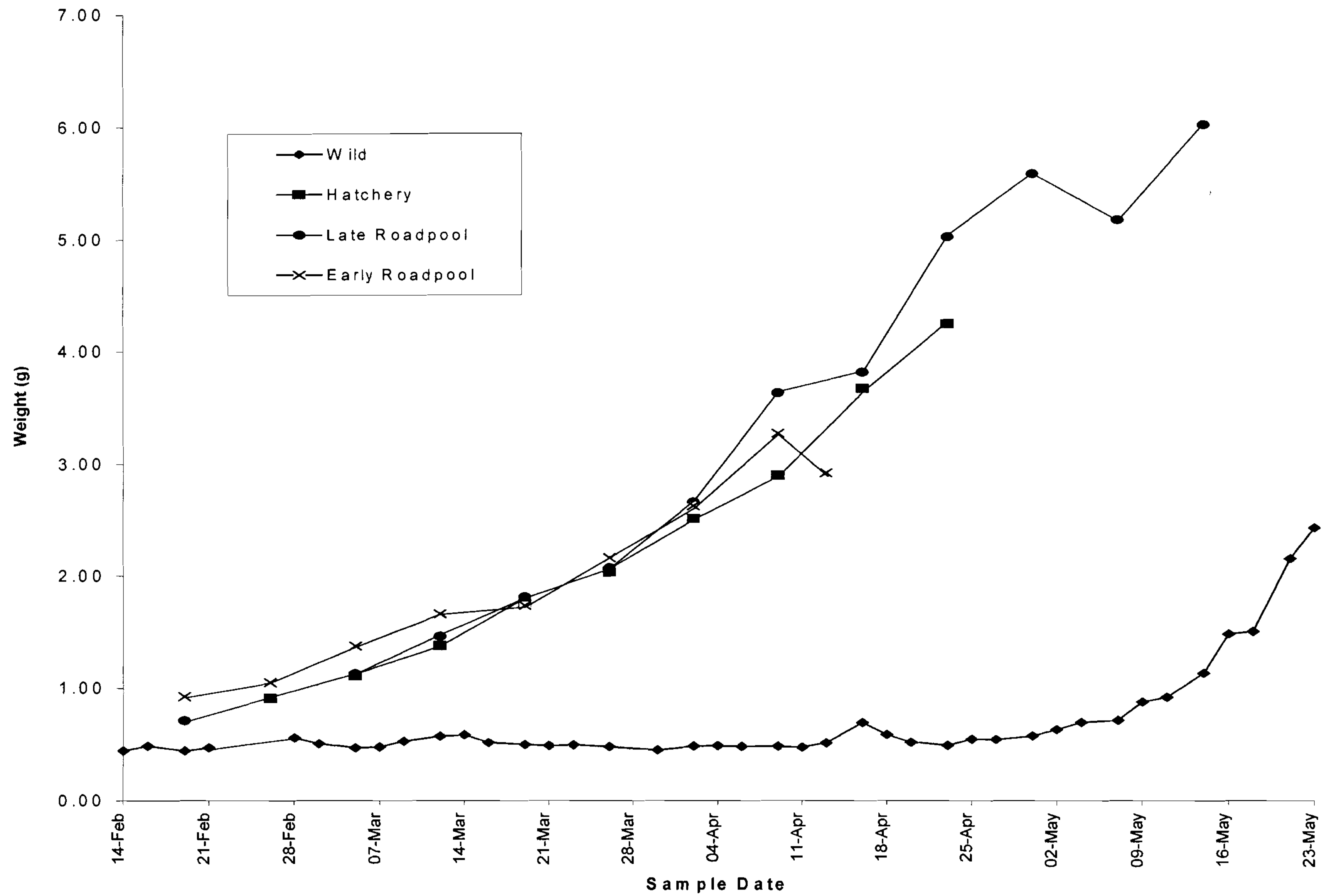

Figure 9. Mean weights of hatchery-reared and naturally-reared chinook fry, Cowichan River, 2002.