Juvenile Chinook Production in the Cowichan River, 2000

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Nagtegaal, D.A., E.W. Carter, N.K. Hop Wo, and K.E. Jones. 2000. Juvenile chinook production in the Cowichan River, 2000. Can. Manuscr. Rep. Fish. Aquat. Sci. 2658: 37 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 2000 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 1999 brood year was 673,726 (range: 546,060 – 915,723). The release of juvenile chinook from the Cowichan River hatchery totaled 2,580,655. Of these, 2,050,028 hatchery-reared chinook were released above the trapping site. Egg to fry survival for naturally-reared chinook was estimated to be 6.54% (range: 5.30% - 8.89%). 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.

RÉSUMÉ

Nagtegaal, D.A., E.W. Carter, N.K. Hop Wo, and K.E. Jones. 2000. Juvenile chinook production in the Cowichan River, 2000. Can. Manuscr. Rep. Fish. Aquat. Sci. 2658: 37 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 2000 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 1999 a été estimée à 673 726 (étendue : 546 060 – 915 723). Au total, 2 580 655 saumons quinnats juvéniles élevés dans l'écloserie de la rivière Cowichan ont été libérés, dont 2 050 028 en amont du site de piégeage. La survie des oeufs d'origine naturelle jusqu'au stade d'alevin a été estimée à 6,54 % (étendue : 5,30 % - 8,89 %). 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.

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. 1994-98).

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 2,580,655 chinook fry in 2000 (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 provides key information regarding stock migration, harvest rates, and a measure of enhanced contribution to the stock (Nagtegaal et al. 1998). In 2000, the portion of hatchery produced chinook which were coded-wire tagged were 224,579 fry.

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. Since then, the Nanaimo and Squamish Stocks are no longer used as indicators.

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 36.6 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. The rotary screw trap was located at site 7A for the entire duration of the study in 2000 (Figure 1).

FISH CAPTURE

A rotary screw trap, 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 21 to May 16, 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, one or two year old smolts. Biophysical conditions (water temperature, flow rates, water clarity, and weather conditions) were also noted.

ABUNDANCE ESTIMATES

Trap efficiency information, using the mark-recapture of Bismarck Brown[1] 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 throughout the course of the fry enumeration study. Twenty-four hour estimates were expanded for portions of the day when the trap was not in operation.

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

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 30 samples from each catch of the rotary trap. For two days after a hatchery fry release 15 hatchery-reared chinook fry were sampled. Chinook migrants were measured to the nearest millimeter (mm) fork length, and weight was recorded to the nearest one hundredth of a gram (g).

RESULTS

BIOPHYSICAL CONDITIONS

During the fry enumeration period the Cowichan River had three main water discharge peaks, with the largest discharge of 70.0 m^3/s on March 2 and two lesser peaks of 60.3 m^3/s on March 23 and 57.4 m^3/s on May 7. The lowest Cowichan River discharge level was of 35.9 m^3/s was recorded on April 21. The mean discharge during the course of the study was 49.1 m^3/s with the February portion averaging 48.8 m^3/s; March yielding a 55.3 m^3/s average; April a 43.0 m^3/s average; and the May portion a 48.9 m^3/s average water discharge (Figure 2). Flow rates decreased from a high of 1.85 m/s on March 24 to a low of 1.25 m/s on April 21. Water temperatures averaged 7.3°C and increased from 3°C on February 21 to 12°C on May 15. 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. Sixteen sample periods (28.1%) were recorded as cloudy water clarity with other days recorded as clear water clarity. During the time of the study there were only four sample periods when rain was recorded (Table 1).

MIGRATION TIMING

The fry enumeration trap was run for 57, 12-hour intervals between February 21 and May 16, 2000. At the Pumphouse site, 12,133 naturally-reared and 76,011 hatchery chinook juveniles were caught in the screw trap. The number of hatchery-reared chinook fry enumerated also included 683 adipose-clipped fish. In addition, 200,441 chum fry, 7,372 coho fry, 3,265 one year old coho, 47 Bismarck Brown dyed chinook fry and nine Bismarck Brown dyed chum fry (Table 1). The downstream movement of hatchery chinook was observed from March 7 (21,172 fry) to May 16 (31 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 peaked on March 28 and hatchery-reared enumeration peaked on March 7 and April 28 (Figure 4; Figure 5).

HATCHERY RELEASES

Cowichan River Hatchery had four chinook fry release strategies with two releases 30 km above the trapping site. The first release occurred in the upper Cowichan River at the Roadpool site on March 7 with 1,086,403 fry being released of which 99,729 fry carried CWT's. The second release was also in the upper Cowichan River where 49,615 CWT fry of 963,625 total fry were released on April 27. Two Cowichan River Hatchery releases occurred below the fry enumeration site. A release on May 5 from the Hatchery site released 430,691 fry of which 50,157 fry had CWT's. The final chinook fry release of the year was from the Seapen site in Cowichan Bay on May 17 where 25,078 CWT fry of 99,936 total fry were released into the ocean. A summary of all releases from the Cowichan River Hatchery is presented in Table 2.

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 11 days between March 2 and April 29. The diel migration tests were stratified into naturally-reared fry and hatchery-reared fry components. A combined total of 4,188 naturally-reared chinook fry were counted with 3,752 fry obtained during night hours (~1900 – 0700 hours) and 436 fry collected during day hours (~0700 – 1900 hours) (Table 3). An expansion factor of 1.116 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 27,182 fry of which 26,371 were caught during night hours and 811 were caught during daylight hours (Table 4). An expansion factor of 1.031 was obtained for hatchery-reared fry.

TRAP EFFICIENCIES

Four efficiency tests were conducted on March 1, March 15, March 29 and April 19 during the 2000 fry enumeration study (Figure 5). The results were stratified into two categories with March 1 and March 15 results combined and subsequent March 29 and April 19 results combined. This division allows for potential efficiency differences due to river flow, river hydraulics and variation in fry behavior over the course of the study (Figure 6).

During the first set of efficiency tests a total of 833 Bismark Brown dyed chinook were released on March 1 and March 15. Fry recoveries were run for 48 - 60 hours after each release date and yielded a total of 27 Bismark Brown dyed chinook fry. An expansion factor of 30.85 was calculated from these results and used to expand February 22 to March 22 daily fry counts (Table 5).

The second set of efficiency tests on March 29 and April 19 released 473 Bismark Brown dyed chinook and 250 dyed chum fry of which 20 chinook and nine chum were recovered. Excluding the chum fry data, an expansion factor of 23.65 was calculated to expand the March 23 to May 16 fry enumeration data (Table 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 1.116 for naturally-reared fry and 1.031 for hatchery-reared fry obtained from diel migration results. Daily estimates were then expanded by the trap efficiency estimates with February 22 to March 22 estimates expanded by 30.85 and March 23 to May 16 estimates expanded by 23.65. Total Cowichan River naturally-reared chinook is estimated to be 637,726 fry (Table 6) while the hatchery-reared chinook estimated is 2,182,557 fry (Table 7).

Population estimate ranges were calculated by using the lowest and highest diel and trap efficiency expansion factors. The lower population range for naturally-reared fry used a diel expansion factor of 1.000 obtained from April 29 (n = 183) and a trap efficiency expansion factor of 23.28 obtained on March 29 (n = 419). The upper population range for naturally-reared fry was calculated using a diel expansion factor of 1.343 from March 2 (n = 682) and a trap efficiency expansion factor of 42.13 obtained on March 1 (n = 337). Population estimate ranges for naturally-reared chinook fry are 546,060 to 915,723. Similarly, hatchery-reared fry ranges were calculating using the lower (1.000; April 29; n = 9,750) and upper (1.060; March 9; n = 13,357) results of the hatchery-reared diel migration tests. Using the same upper and lower trap efficiency factors as naturally-reared fry yielded hatchery-reared chinook fry ranges of 1,800,193 to 2,721,067.

A coho mark-recapture study in Cowichan Lake provides supplementary data about chinook fry in the upper Cowichan River. A fyke trap was in place just downstream of

Cowichan Lake from April 19 to May 19, 2000. During this time, 65 chinook fry were enumerated. From May 20 to June 28 a rotary screw trap replaced the fyke trap and 3,193 chinook fry were counted. A total of 3,258 chinook fry were enumerated during the coho mark-recapture study in the upper Cowichan River between April 19 and June 28. Results from the Cowichan Lake coho mark-recapture study are presented in Table 8.

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 1999, the number of chinook natural spawners was estimated to be 4,500 fish and the proportion of females obtained from a carcass mark-recapture was determined to be 61.7%, or 2,777 of total natural spawning chinook. The average fecundity from broodstock biosample data were determined to be 3,711 eggs and the total egg production was estimated to be 10,303,947 (Figure 7). The estimated abundance of naturally-reared chinook fry was extrapolated to 673,726 and the egg to fry survival was therefore estimated to be 6.54%. 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 5.30% and 8.89%, respectively. The number of naturally-reared chinook eggs deposited and subsequent fry production are compared in Figure 8.

JUVENILE CHINOOK GROWTH

During the study period, 1,082 naturally-reared chinook fry were biosampled for length and weight. Mean length was approximately 40 mm and mean weight varied from 0.45 - 0.52 g until the beginning of April (Table 9; Table 10; Figure 9; Figure 10). From April 6 to May 13 naturally-reared fry increased in mean length from 40.6 to 54.2 mm and mean weight increased from 0.499 g to 1.584 g (Table 9; Table 10; Figure 9; Figure 10).

Hatchery-reared chinook were sampled four times totaling 60 fry during the course of the study and were generally longer and heavier set than naturally-reared chinook fry with length and weight ranges reflecting these differences (Table 9; Table 10). Size differences 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 9; Figure 10).

During four hatchery-reared sampling periods, no overlapping of length and weight ranges occurred with hatchery-reared fry sampled at corresponding time periods (Figure 9; Figure 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 increase trap efficiency with decreased turbidity possibly resulting in more chinook fry being able to avoid the enumeration trap. The month of March had poor clarity which may have resulted in relatively higher trap efficiency. Conversely low river flows may increase trap efficiency decreasing the time fry have in avoiding an oncoming trap in the river. Flow rates during recapture periods ranged from a high of 1.85 m/s on March 7 to a low of 1.25 m/s on April 21. 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 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 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 assume not all fry swim past the enumeration trap. Therefore, the estimates provide 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 migration of these chinook primarily occurred between Feb 27 and April 10 (Figure 4). During this time the first hatchery release occurred on March 7 and some interaction between hatchery and naturally-reared chinook migrants was highly probable (Figure 4; Figure 5).

The late Roadpool hatchery release occurred on April 27. 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 (Figure 4; Figure 5). 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 behaviour between the two juvenile types.

TRAP EFFICIENCIES

Due to the length of the Cowichan River study and constantly changing water flow rates stratifying the trap expansion results into two categories was necessary. The first two trap efficiency results were combined and represented the February 22 to March 22 portion of the study while the subsequent two efficiency results represented the March 23 to May 16 fry enumeration period.

Chinook abundance estimates using the Bismarck Brown mark-recapture method to calculate trap efficiency may be biased low. The assumption that stained fish have identical recapture rates as unmarked migrant chinook may be untrue as dyed 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 19 consisted of primarily chum fry and that portion of the release was not utilized in calculating expansion factors. Possible differences in chum fry behavior and/or physiology between the two species could result in different trapping efficiencies than chinook fry 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. 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 site 7A was exclusively 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 used to expanded 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 673,726 naturally-reared chinook fry migrated past the Cowichan River enumeration trap in 2000 (range: 546,060 - 915,723). This estimate did not take into consideration the migration of chinook prior to the installation of the rotary trap or after the study ended. It has been reported (Lister et al. 1971) 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 in the accuracy of diel and trap efficiency results.

Cowichan River Hatchery documented 2,050,028 hatchery fry being released above the fry enumeration trap site. This estimate is slightly lower than the value obtained from the fry enumeration trap and this result is unfeasible because 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. However, the hatchery release estimate is well within the 1,800,193 – 2,721,067 range provided by the enumeration trap. The higher estimate provided by the enumeration trap may be due to using efficiency results obtained from naturally-reared fry to expand hatchery-reared fry counts. Therefore the hatchery-reared fry estimate provided by the Cowichan River Hatchery is deemed more reliable than the rotary screw trap estimate.

Combined results from the fyke trap and rotary screw trap used in the coho mark-recapture study suggest that some hatchery fry may not immediately migrate downstream upon being released. Some of these fry may be from the late hatchery release on April 27 (Table 2). It is possible hatchery fry may swim 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 3,258 fry enumerated in the coho mark-recapture study indicate that results obtained from the Pumphouse rotary screw trap may underestimate the true chinook fry population migrating from the Cowichan River.

EGG TO FRY SURVIVAL

The egg to fry survival estimate of 6.54% is higher than the 2.2% reported in the previous survey in 1999 (Nagtegaal and Carter 2000) but is above the 1990 – 1999 brood year average of 5.96%. The 2000, egg to fry estimate is also below the ranges reported by Healey (1991) who had chinook fry survival ranges from 8% to 16% (Figure 7). 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). However, the low egg to fry survival rate in 2000 (Figure 7), could be attributed to above average flow in both November and December of 1999. These high flows may have 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 8). This suggests the maximum number of chinook eggs the Cowichan River supports 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 6. Misidentification between the two fry types is most likely minimal, as sampling results show no overlapping size ranges during sampling periods (Figure 9; Figure 10). However, as the study progressed the difference between size ranges appeared to be decreasing making it harder to differentiate between the two fry types (Figure 9; Figure 10). According to one participant at the trapping site, the identification of naturally-reared versus hatchery-reared chinook became more difficult after the late hatchery release.

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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REFERENCES

Argue, A.W., R. Hilborn, R. Peterman, M. Staley, and C. Walters. 1983. Strait of Georgia chinook and coho fishery. Can. Bull. Fish. Aquat. Sci. 211: 91 p.

Burns, T., E.A. Harding, and B.D.Tutty. 1988. Cowichan River assessment (1987): the influence of river discharge on sidechannel fish habitats. Can. Manuscr. Rep. Fish. Aquat. Sci. 1999.

Candy, J.R., D.A. Nagtegaal, and B. Riddell. 1995. A preliminary report on juvenile chinook production in the Cowichan River during 1991 and 1992. Can. Manuscr. Rep. Fish. Aquat. Sci: 2329.

Candy, J.R., D.A. Nagtegaal, and B. Riddell. 1996. Preliminary report on juvenile chinook production in the Cowichan River during 1993 and 1994. Can. Manuscr. Rep. Fish. Aquat. Sci. 2354: 80 p.

Frith, H.R., T.C. Nelson, and C.J. Schwarz. 1995. Comparison of rotary trap mark-recapture outmigration estimates with fence counts for coho and steelhead smolts in the Keogh River, 1995. Report prepared for the British Columbia Ministry of Environment, Lands, and Parks, Watershed Restoration Program, by LGL Limited, Sidney, BC.

Healey, M.C. 1991. Life history of chinook salmon (*Oncorhynchus tshawytscha*), p. 313-393. In C. Groot and L. Margolis (eds.) Pacific Salmon Life Histories. UBC Press, Vancouver.

Lister, D.B., C.E. Walker, and M.A. Giles. 1971. Cowichan River chinook salmon escapements and juvenile production, 1965-1967. Department of Fisheries and Forestry, Tech. Rep. 1971-3.

Montgomery, D.R., J.M. Buffington, N.P. Peterson, D. Schuett-Hames, and T.P. Quinn. 1995. Stream-bed scour, egg burial depths, and the influence of salmonid spawning on bed surface mobility and embryo survival. Can. J. Fish. Aquat. Sci. 53: 1061-1070.

Nagtegaal, D.A., P. J. Starr, and B. Riddell. 1994. A preliminary report on the chinook productivity study conducted on the Cowichan River, 1988 and 1989. Can. Manuscr. Rep. Fish. Aquat. Sci. 2233: 53 p.

Nagtegaal, D.A., J. Candy, and B. Riddell. 1994. A preliminary report on the chinook productivity study conducted on the Cowichan River during 1990 and 1991. Can. Manuscr. Rep. Fish. Aquat. Sci. 2265: 71 p.

Nagtegaal, D.A., J. Candy, and B. Riddell. 1994. A preliminary report on the chinook productivity study conducted on the Cowichan River during 1992. Can. Manuscr. Rep. Fish. Aquat. Sci. 2268: 73 p.

Nagtegaal, D.A., J. Candy, and B. Riddell. 1995. A preliminary report on the chinook productivity study conducted on the Cowichan River during 1993. Can. Manuscr. Rep. Fish. Aquat. Sci. 2315: 84 p.

Nagtegaal, D.A., G. Graf, and E.W. Carter. 1997. A preliminary report on juvenile chinook production of the Cowichan River, 1996. Can. Manuscr. Rep. Fish. Aquat. Sci. 2415: 84 p.

Nagtegaal, D.A. and E. W. Carter. 1998. Adult chinook escapement assessment conducted on the Cowichan River during 1997. Can. Manuscr. Rep. Fish. Aquat. Sci. 2466: 53 p.

Nagtegaal, D.A. and E.W. Carter. 2000. A preliminary report of juvenile chinook production in the Cowichan River, 1999. Can. Manuscr. Rep. Fish. Aquat. Sci. 2504: 38 p.

Neave, F. 1949. Game fish populations of the Cowichan River. Fish. Res. Bd. Can. Bull. LXXXIV. 32 p.

Roper, B. and D. Scarnecchi. 1996. A comparison of trap efficiencies for wild and hatchery age 0+ chinook salmon. N. Am. J. Fish. Manage. 16:214-217.

Roper, B. and D. Scarnecchi. 1998. Emigration of age-0 chinook salmon (*Oncorhynchus tshawytscha*) smolts from the upper South Umpqua River basin, Oregon, U.S.A. Can. J. Fish. Aquat. Sci. 56: 939-946.

Seelbach, P.W. 1985. Smolt migration of wild and hatchery-raised coho and chinook salmon in a tributary of northern Lake Michigan. Michigan Department of Natural Resources, Fisheries Research Report 1935, Ann Arbor.

Thedinga, J.F., M.L. Murphy, S.W. Johnson, J.M. Lorenz, and K.V. Koski. 1994. Determination of salmonid yield with rotary screw traps in the Situk River, Alaska, to predict effects of glacial flooding. N. Am. J. Fish. Man. 14: 837-851.

Ward, F. J. and L.A. Verhoeven. 1963. Two biological stains as markers for sockeye salmon fry. Trans. Am. Fish. Soc. 92: 379-383.

Wetherall, J.A. 1970. Estimation if survival rates for chinook salmon during their downstream migration on the Green River, Washington. Ph.D. Dissertation, Univ. Washington, Seattle.

Table 1. Rotary screw trap catch data at the Pumphouse location, Cowichan River, 2000.

Set Date	Weather[1]	Temperature (°C)	Clarity[2]	Sampling Date	Start Time	Wild Chinook	Total Hatchery Chinook	Adipose-Clipped Chinook	Chum Fry	Coho Fry	Coho 1 year	Coho 2 year	Dye Marked Chinook	Dye Marked Chum
21-Feb	2	3	1	22-Feb	7:00	88	0	0	114	0	3	0	0	0
23-Feb	2	3	1	24-Feb	7:00	137	0	0	168	0	11	0	0	0
25-Feb	2	7	2	26-Feb	7:00	171	0	0	150	4	2	0	0	0
28-Feb	3	6	N/A	29-Feb	7:00	407	0	0	205	1	7	0	0	0
01-Mar	3	6	2	02-Mar	7:00	508	0	0	189	18	14	0	8	0
02-Mar	2	5	2	02-Mar	19:00	174	0	0	18	0	1	0	0	0
02-Mar	2	6	2	03-Mar	7:00	331	0	0	158	2	21	0	0	0
03-Mar	1	4	2	04-Mar	7:00	349	0	0	329	1	20	0	0	0
03-Mar	1	4	2	04-Mar	19:00	90	0	0	19	0	19	0	0	0
07-Mar	1	5	1	07-Mar	19:00	146	21172	298	470	0	12	0	0	0
07-Mar	2	6	1	08-Mar	15:00	14	7398	29	15	0	3	0	0	0
08-Mar	2	5	2	09-Mar	7:00	217	12605	169	498	0	6	0	0	0
08-Mar	1	5	1	09-Mar	19:00	23	752	8	27	0	2	0	0	0
09-Mar	1	5	1	10-Mar	7:00	481	3976	6	1003	0	13	0	0	0
09-Mar	1	5	1	10-Mar	19:00	9	37	0	19	0	0	0	0	0
10-Mar	1	4	2	11-Mar	7:00	403	664	7	1544	3	7	0	0	0
13-Mar	1	7	2	14-Mar	7:00	580	56	0	2560	18	11	0	0	0
15-Mar	2	6	2	16-Mar	7:00	277	13	0	2180	29	6	0	18	0
15-Mar	2	6	2	16-Mar	19:00	71	7	0	278	0	1	0	0	0
16-Mar	3	6	2	17-Mar	7:00	170	11	0	3087	20	7	0	1	0
16-Mar	3	6	2	17-Mar	19:00	38	2	0	273	2	3	0	0	0
17-Mar	2	5	2	18-Mar	7:00	122	6	0	1903	8	14	0	0	0
20-Mar	2	6	2	21-Mar	7:00	171	3	0	4018	32	5	0	0	0
22-Mar	1	4	2	23-Mar	7:00	548	2	0	5296	72	23	0	0	0
24-Mar	1	7	1	25-Mar	7:00	325	6	0	6812	71	28	0	0	0
27-Mar	1	7	1	28-Mar	7:00	1093	3	0	12798	292	16	0	0	0
29-Mar	1	8	1	30-Mar	7:00	737	3	0	13035	182	13	0	18	0
29-Mar	1	8	1	30-Mar	18:40	15	0	0	57	0	0	0	0	0
30-Mar	1	8	1	31-Mar	7:00	805	4	0	13292	185	18	0	0	0
30-Mar	1	8	1	31-Mar	18:45	13	1	0	11	5	1	0	0	0
31-Mar	1	7	1	01-Apr	7:00	579	1	0	11380	207	18	0	0	0

Table 1. (continued)

Set Date	Weather[1]	Temperature (°C)	Clarity[2]	Sampling Date	Start Time	Wild Chinook	Total Hatchery Chinook	Adipose-Clipped Chinook	Chum Fry	Coho Fry	Coho 1 year	Coho 2 year	Dye Marked Chinook	Dye Marked Chum
03-Apr	2	6	1	04-Apr	7:00	548	1	0	13323	273	52	0	0	0
05-Apr	1	6	1	06-Apr	7:00	631	0	0	19095	360	26	0	0	0
07-Apr	1	7	1	08-Apr	7:00	601	1	0	17847	630	18	0	0	0
10-Apr	1	9	1	11-Apr	7:00	216	0	0	12312	187	26	0	0	0
12-Apr	2	9	1	13-Apr	7:00	93	1	0	13440	72	15	0	0	0
14-Apr	1	10	1	15-Apr	7:00	58	0	0	9894	61	18	0	0	0
17-Apr	1	9	1	18-Apr	7:00	26	2	0	3327	19	18	0	0	0
18-Apr	1	8	1	19-Apr	7:00	33	5	1	6686	41	25	0	0	0
19-Apr	2	10	1	20-Apr	7:00	11	2	0	3327	37	9	0	2	8
19-Apr	2	10	1	20-Apr	19:00	1	0	0	42	0	0	0	0	0
20-Apr	2	11	1	21-Apr	7:00	20	1	0	6093	85	8	0	0	1
21-Apr	1	10	1	22-Apr	7:00	70	8	0	5469	522	38	0	0	0
24-Apr	2	10	1	25-Apr	7:00	21	5	0	1245	305	38	0	0	0
26-Apr	2	9	1	27-Apr	7:00	14	7	0	945	218	99	0	0	0
26-Apr	2	9	1	27-Apr	19:00	2	12	0	27	22	0	0	0	0
27-Apr	2	10	1	28-Apr	7:00	81	19158	15	1355	548	118	0	0	0
28-Apr	1	9	1	29-Apr	7:00	183	9750	150	1191	740	166	0	0	0
28-Apr	1	9	1	29-Apr	17:00	0	0	0	0	0	0	0	0	0
29-Apr	2	9	1	30-Apr	7:00	101	108	0	912	415	160	0	0	0
01-May	2	9	1	02-May	7:00	167	40	0	847	860	501	0	0	0
03-May	1	9	1	04-May	7:00	25	27	0	402	326	277	0	0	0
05-May	1	10	1	06-May	7:00	59	28	0	230	300	530	0	0	0
08-May	1	9	1	09-May	7:00	41	34	0	128	84	402	0	0	0
10-May	2	10	1	11-May	7:00	15	15	0	243	36	138	0	0	0
12-May	1	11	1	13-May	7:00	23	53	0	94	37	187	0	0	0
15-May	1	12	1	16-May	7:00	1	31	0	61	42	91	0	0	0
Total						12133	76011	683	200441	7372	3265	0	47	9

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

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

Table 2. Cowichan River Hatchery chinook release data, 2000.

Release Code	Total Released	Tag Code	CWT Tagged	Percent Tagged	Release Date	Length (mm)			Weight (g)		
						Mean	Min	Max	Mean	Min	Max
Early	**1086403**		**99729**			65.8	52	75	3.20	1.5	4.7
		183119	24855	9.18%	07-Mar						
		183121	24933	9.18%	07-Mar						
		183120	24917	9.18%	07-Mar						
		183122	25024	9.18%	07-Mar						
Late	**963625**		**49615**			84.9	67	96	6.58	2.8	9.72
		183124	24839	5.15%	27-Apr						
		183123	24776	5.15%	27-Apr						
Hatchery	**430691**		**50157**			85.2	73	94	6.99	3.44	8.56
		183126	25039	11.63%	05-May						
		183125	25118	11.66%	05-May						
Seapen	**99936**		**25078**						8.66		
		183127	25078	25.09%	17-May						
Total	**2580655**		**224579**	8.70%							

Total Released Above Trap Sites: 2050028

Release Sites:
Early: upper Cowichan R. (Road Pool)*
Lakepen: Lake Cowichan above the weir (Lakepen site)*
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, 2000.

Sample Date	Naturally-Reared Chinook Fry Night	Day	24-Hour Period	Expansion Factor
02-Mar	508	174	682	1.343
04-Mar	349	90	439	1.258
09-Mar	217	23	240	1.106
10-Mar	481	9	490	1.019
16-Mar	277	71	348	1.256
17-Mar	170	38	208	1.224
30-Mar	737	15	752	1.020
31-Mar	805	13	818	1.016
20-Apr	11	1	12	1.091
27-Apr	14	2	16	1.143
29-Apr	183	0	183	1.000
Total	3752	436	4188	1.116

Table 4. Daily summary of 24-hour trapping periods for hatchery-reared chinook fry, Pumphouse site, Cowichan River, 2000.

Sample Date	Hatchery-Reared Chinook Night	Day	24-Hour Period	Expansion Factor
02-Mar	0	0	0	-
04-Mar	0	0	0	-
09-Mar	12605	752	13357	1.060
10-Mar	3976	37	4013	1.009
16-Mar	13	7	20	1.538
17-Mar	11	2	13	1.182
30-Mar	3	0	3	1.000
31-Mar	4	1	5	1.250
20-Apr	2	0	2	1.000
27-Apr	7	12	19	2.714
29-Apr	9750	0	9750	1.000
Total	26371	811	27182	1.031

Table 5. Trap efficiency data by release date, Pumphouse site, Cowichan River, 2000.

Release Date	Flow (m/s)	Released Chinook	Released Chum	Recovered Chinook	Recovered Chum	Percent Recovered Chinook	Percent Recovered Chum	Expansion Factor Chinook	Expansion Factor Chum
01-Mar	1.837	337	0	8	0	2.37%	-	42.13	-
15-Mar	1.475	496	0	19	0	3.83%	-	26.11	-
Sub-Total		833	0	27	0	**3.24%**	-	**30.85**	
29-Mar	1.643	419	0	18	0	4.30%	-	23.28	-
19-Apr	1.461	54	250	2	9	3.70%	3.60%	27.00	27.78
Sub-Total		473	250	20	9	**4.23%**	3.60%	**23.65**	27.78
Total		1306	250	47	9	3.60%	3.60%	27.79	27.78

Table 6. Expanded daily trap catch estimates of naturally-reared chinook fry, Pumphouse site, Cowichan River, 2000.

Sample Date	Observed[1] PM	AM	Missing cells Interpolated	24-hour Estimates	Extrapolated Estimates	Cumulative Total
22-Feb	88			98	3030	3030
23-Feb			113	126	3874	6905
24-Feb	137			153	4718	11622
25-Feb			154	172	5303	16926
26-Feb	171			191	5889	22815
27-Feb			289	323	9952	32767
28-Feb			289	323	9952	42719
29-Feb	407			454	14016	56735
01-Mar			458	511	15755	72490
02-Mar	508	174		682	21041	93531
03-Mar	331			369	11399	104929
04-Mar	349	90		439	13544	118473
05-Mar			283	316	9746	128219
06-Mar			283	316	9746	137965
07-Mar		146	283	429	13235	151200
08-Mar		14	283	297	9163	160363
09-Mar	217	23		240	7404	167768
10-Mar			310	346	10675	178443
11-Mar	403			450	13878	192321
12-Mar			492	549	16926	209247
13-Mar			492	549	16926	226173
14-Mar	580			647	19973	246146
15-Mar			429	478	14756	260902
16-Mar	277	71		348	10736	271639
17-Mar	170	38		208	6417	278056
18-Mar	122			136	4201	282257
19-Mar			147	164	5045	287302
20-Mar			147	164	5045	292347
21-Mar	171			191	5889	298236
22-Mar			360	401	12380	310616
23-Mar	548			612	14466	325082
24-Mar			437	487	11523	336605
25-Mar	325			363	8579	345185
26-Mar			709	791	18716	363901
27-Mar			709	791	18716	382617
28-Mar	1093			1220	28853	411471
29-Mar			915	1021	24154	435625
30-Mar	737	15		752	17785	453410
31-Mar	805	13		818	19346	472756
01-Apr	579			646	15285	488040
02-Apr			564	629	14875	502916
03-Apr			564	629	14875	517791
04-Apr	548			612	14466	532257

Table 6. (continued)

Sample Date	Observed[1] PM	AM	Missing cells Interpolated	24-hour Estimates	Extrapolated Estimates	Cumulative Total
05-Apr			590	658	15562	547819
06-Apr	631			704	16657	564476
07-Apr			616	688	16261	580738
08-Apr	601			671	15865	596603
09-Apr			409	456	10784	607387
10-Apr			409	456	10784	618170
11-Apr	216			241	5702	623872
12-Apr			155	172	4079	627951
13-Apr	93			104	2455	630406
14-Apr			76	84	1993	632399
15-Apr	58			65	1531	633930
16-Apr			42	47	1109	635039
17-Apr			42	47	1109	636148
18-Apr	26			29	686	636834
19-Apr	33			37	871	637705
20-Apr	11	1		12	284	637989
21-Apr	20			22	528	638517
22-Apr	70			78	1848	640365
23-Apr			46	51	1201	641566
24-Apr			46	51	1201	642767
25-Apr	21			23	554	643321
26-Apr			18	20	462	643783
27-Apr	14	2		16	378	644162
28-Apr	81			90	2138	646300
29-Apr	183	0		183	4328	650628
30-Apr	101			113	2666	653294
01-May			134	150	3537	656831
02-May	167			186	4409	661240
03-May			96	107	2534	663774
04-May	25			28	660	664434
05-May			42	47	1109	665543
06-May	59			66	1557	667100
07-May			50	56	1320	668420
08-May			50	56	1320	669740
09-May	41			46	1082	670823
10-May			28	31	739	671562
11-May	15			17	396	671958
12-May			19	21	502	672459
13-May	23			26	607	673066
14-May			12	13	317	673383
15-May			12	13	317	673700
16-May	1			1	26	673726

[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, 2000.

Sample Date	Observed[1] PM	AM	Missing cells Interpolated	24-hour Estimates	Extrapolated Estimates	Cumulative Total
04-Mar	0	0		0	0	0
05-Mar			0	0	0	0
06-Mar			0	0	0	0
07-Mar[2]		21172	0	21172	653195	653195
08-Mar	N/A	7398		7398	228242	881437
09-Mar	12605	752		13357	412088	1293526
10-Mar	3976	37		4013	123808	1417334
11-Mar	664			684	21116	1438450
12-Mar			360	371	11448	1449898
13-Mar			360	371	11448	1461346
14-Mar	56			58	1781	1463127
15-Mar			35	36	1097	1464224
16-Mar	13	7		20	617	1464841
17-Mar	11	2		13	401	1465242
18-Mar	6			6	191	1465433
19-Mar			5	5	143	1465576
20-Mar			5	5	143	1465719
21-Mar	3			3	95	1465815
22-Mar			3	3	80	1465894
23-Mar	2			2	49	1465943
24-Mar			4	4	98	1466040
25-Mar	6			6	146	1466187
26-Mar			5	5	110	1466296
27-Mar			5	5	110	1466406
28-Mar	3			3	73	1466479
29-Mar			3	3	73	1466552
30-Mar	3	0		3	71	1466623
31-Mar	4	1		5	118	1466742
01-Apr	1			1	24	1466766
02-Apr			1	1	24	1466790
03-Apr			1	1	24	1466815
04-Apr	1			1	24	1466839
05-Apr			1	1	12	1466851
06-Apr	0			0	0	1466851
07-Apr			1	1	12	1466863
08-Apr	1			1	24	1466888
09-Apr			1	1	12	1466900
10-Apr			1	1	12	1466912
11-Apr	0			0	0	1466912
12-Apr			1	1	12	1466924
13-Apr	1			1	24	1466949
14-Apr			1	1	12	1466961
15-Apr	0			0	0	1466961

Table 7. (continued)

Sample Date	Observed[1] PM	AM	Missing cells Interpolated	24-hour Estimates	Extrapolated Estimates	Cumulative Total
16-Apr			1	1	24	1466985
17-Apr			1	1	24	1467010
18-Apr	2			2	49	1467058
19-Apr	5			5	122	1467180
20-Apr	2	0		2	47	1467228
21-Apr	1			1	24	1467252
22-Apr	8			8	195	1467447
23-Apr			7	7	158	1467605
24-Apr			7	7	158	1467764
25-Apr	5			5	122	1467886
26-Apr			6	6	146	1468032
27-Apr	7	12		19	449	1468481
28-Apr	19158			19747	467021	1935502
29-Apr	9750	0		9750	230588	2166090
30-Apr	108			111	2633	2168722
01-May			74	76	1804	2170526
02-May	40			41	975	2171501
03-May			34	35	817	2172318
04-May	27			28	658	2172976
05-May			28	28	670	2173647
06-May	28			29	683	2174329
07-May			31	32	756	2175085
08-May			31	32	756	2175841
09-May	34			35	829	2176669
10-May			25	25	597	2177267
11-May	15			15	366	2177632
12-May			34	35	829	2178461
13-May	53			55	1292	2179753
14-May			42	43	1024	2180777
15-May			42	43	1024	2181801
16-May	31			32	756	2182557

[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 07-Mar due to no hatchery releases before this date, see Table 2.

Table 8. Daily summary of fyke trap and rotary screw trap data from the coho mark-recapture study, Cowichan Lake, 2000.

Sampling Date	Trapping Method	Temperature (°C)	Chinook Fry	Coho Fry	Coho 1 Year	Chum Fry	Trout Fry
19-Apr	Fyke	10	0	2	0	0	0
20-Apr	Fyke	10	3	9	0	0	0
21-Apr	Fyke	10	7	4	0	0	0
22-Apr	Fyke	10	1	0	0	0	1
23-Apr	Fyke	10	1	2	0	0	0
24-Apr	Fyke	9.5	0	0	0	0	0
25-Apr	Fyke		1	1	0	0	0
26-Apr	Fyke	10	3	12	0	0	0
27-Apr	Fyke	8	9	9	0	0	1
28-Apr	Fyke	9	17	451	1	7	0
29-Apr	Fyke	10	0	453	0	3	0
30-Apr	Fyke	9	12	280	1	1	0
01-May	Fyke	9	3	175	0	0	0
02-May	Fyke	9	2	77	0	5	1
03-May	Fyke	9.5	0	26	0	0	2
04-May	Fyke	10	2	40	0	0	0
05-May	Fyke	9.5	1	41	0	0	1
06-May	Fyke	9.5	0	18	0	0	1
07-May	Fyke	10.5	0	17	0	0	0
08-May	Fyke	10	0	3	0	0	0
09-May	Fyke	10.5	0	4	0	0	1
10-May	Fyke	11	0	6	0	0	0
11-May	Fyke	11	0	8	3	1	0
12-May	Fyke		2	9	1	0	3
13-May	Fyke	10	1	5	1	0	4
14-May	Fyke	10.5	0	1	0	0	0
15-May	Fyke		0	23	1	0	3
16-May	Fyke	15	0	42	0	0	3
17-May	Fyke	10.5	0	44	0	0	0
18-May	Fyke		0	18	0	0	1
19-May	Fyke		0	15	0	0	0
20-May	RST	13	47	210	121	6	1
21-May	RST	13	94	1021	237	3	7
22-May	RST		161	1197	288	3	38
23-May	RST	12	162	983	280	6	20
24-May	RST		84	270	96	3	41
25-May	RST		63	135	141	0	35
26-May	RST		47	159	141	0	40
27-May	RST		69	73	109	0	27
28-May	RST	12.5	1	31	4	0	13
29-May	RST		130	228	206	0	42
30-May	RST		144	183	165	3	138
31-May	RST		143	260	105	1	64

Table 8. (continued)

Sampling Date	Trapping Method	Temperature (°C)	Chinook Fry	Coho Fry	Coho 1 Year	Chum Fry	Trout Fry
01-Jun	RST	13.5	160	265	130	4	67
02-Jun	RST	14	191	234	131	9	50
03-Jun	RST	13.5	161	265	80	6	120
04-Jun	RST	13	134	153	122	5	102
05-Jun	RST		117	152	65	2	164
06-Jun	RST		82	107	33	1	45
07-Jun	RST		211	313	105	7	166
08-Jun	RST	14.5	99	232	45	3	162
09-Jun	RST	14.5	101	182	49	6	128
10-Jun	RST		116	145	45	0	63
11-Jun	RST	14	70	81	22	1	47
12-Jun	RST		60	73	44	4	49
13-Jun	RST		170	225	47	6	92
14-Jun	RST		57	160	21	11	68
15-Jun	RST	13.5	59	157	15	10	78
16-Jun	RST		100	193	21	13	55
17-Jun	RST	13	25	70	10	0	20
18-Jun	RST		No Data	No Data	No Data	No Data	No Data
19-Jun	RST		37	142	14	6	66
20-Jun	RST	11	25	85	8	2	25
21-Jun	RST	13.5	14	78	4	1	20
22-Jun	RST	16.5	16	154	10	1	43
23-Jun	RST	15.5	12	80	5	1	30
24-Jun	RST	14	7	60	6	0	10
25-Jun	RST	16	3	40	7	1	20
26-Jun	RST		5	45	10	1	30
27-Jun	RST	16	7	54	13	0	15
28-Jun	RST		9	68	13	1	25
Total			3258	10358	2976	144	2248

RST: Rotary Screw Trap

Table 9. Daily summary of chinook fry sampling length (mm) data, Cowichan River, 2000.

Sampling	Naturally-Reared				Hatchery-Reared			
Date	n	Mean	Minimum	Maximum	n	Mean	Minimum	Maximum
22-Feb	30	40.4	37	46				
24-Feb	30	40.2	37	44				
26-Feb	30	40.5	37	42				
29-Feb	30	40.3	37	43				
02-Mar	30	40.6	36	45				
03-Mar	30	39.8	36	44				
04-Mar	30	39.9	36	43				
07-Mar	30	39.8	34	47	15	64.2	59	70
09-Mar	30	39.7	36	43	15	64.6	58	73
11-Mar	30	40.8	37	47				
14-Mar	30	40.3	37	44				
16-Mar	26	41.1	36	44				
17-Mar	30	39.6	36	47				
18-Mar	30	39.8	36	43				
21-Mar	30	40.9	37	45				
23-Mar	30	39.9	35	44				
25-Mar	30	40.5	36	44				
28-Mar	30	40.1	35	44				
30-Mar	60	39.9	33	44				
01-Apr	30	39.2	32	44				
04-Apr	30	40.4	34	53				
06-Apr	30	40.6	32	53				
11-Apr	30	41.1	33	54				
13-Apr	30	41.4	37	53				
15-Apr	30	41.3	34	53				
19-Apr	30	42.2	35	63				
20-Apr	11	41.3	38	45				
21-Apr	19	41.7	34	60				
22-Apr	30	41.8	34	60				
25-Apr	21	43.8	34	58				
27-Apr	14	44.7	35	62				
28-Apr					15	84.3	72	92
29-Apr	30	47.7	34	66	15	83.3	76	98
02-May	30	45.6	34	64				
04-May	25	47.2	38	55				
06-May	30	50.9	40	65				
09-May	30	55.7	43	70				
11-May	14	55.4	45	67				
13-May	22	54.2	43	64				

Table 10. Daily summary of chinook fry sampling weight (g) data, Cowichan River, 2000.

Sampling	Naturally-Reared				Hatchery-Reared			
Date	n	Mean	Minimum	Maximum	n	Mean	Minimum	Maximum
22-Feb	30	0.457	0.31	0.78				
24-Feb	30	0.445	0.32	0.59				
26-Feb	30	0.455	0.35	0.55				
29-Feb	30	0.449	0.34	0.59				
02-Mar	30	0.438	0.30	0.59				
03-Mar	30	0.433	0.32	0.55				
04-Mar	30	0.427	0.29	0.55				
07-Mar	30	0.449	0.32	0.77	15	3.029	2.22	4.28
09-Mar	30	0.438	0.29	0.62	15	2.649	1.80	4.02
11-Mar	30	0.461	0.30	0.65				
14-Mar	30	0.449	0.32	0.60				
16-Mar	26	0.460	0.30	0.60				
17-Mar	30	0.431	0.31	0.59				
18-Mar	30	0.520	0.36	0.73				
21-Mar	30	0.467	0.31	0.67				
23-Mar	30	0.413	0.27	0.58				
25-Mar	30	0.470	0.32	0.71				
28-Mar	30	0.491	0.33	0.62				
30-Mar	60	0.457	0.27	0.65				
01-Apr	30	0.427	0.24	0.61				
04-Apr	30	0.493	0.28	1.19				
06-Apr	30	0.499	0.18	1.21				
11-Apr	30	0.560	0.24	1.54				
13-Apr	30	0.570	0.36	1.50				
15-Apr	30	0.556	0.29	1.36				
19-Apr	30	0.675	0.39	2.22				
20-Apr	11	0.493	0.35	0.69				
21-Apr	19	0.579	0.25	1.85				
22-Apr	30	0.556	0.23	1.78				
25-Apr	21	0.704	0.22	2.04				
27-Apr	14	0.820	0.27	2.41				
28-Apr					15	6.637	3.43	8.13
29-Apr	30	1.021	0.30	2.60	15	6.257	4.53	9.41
02-May	30	0.838	0.29	2.36				
04-May	25	0.933	0.38	1.59				
06-May	30	1.314	0.50	2.70				
09-May	30	1.733	0.68	3.15				
11-May	14	1.662	0.81	2.69				
13-May	22	1.584	0.70	2.66				

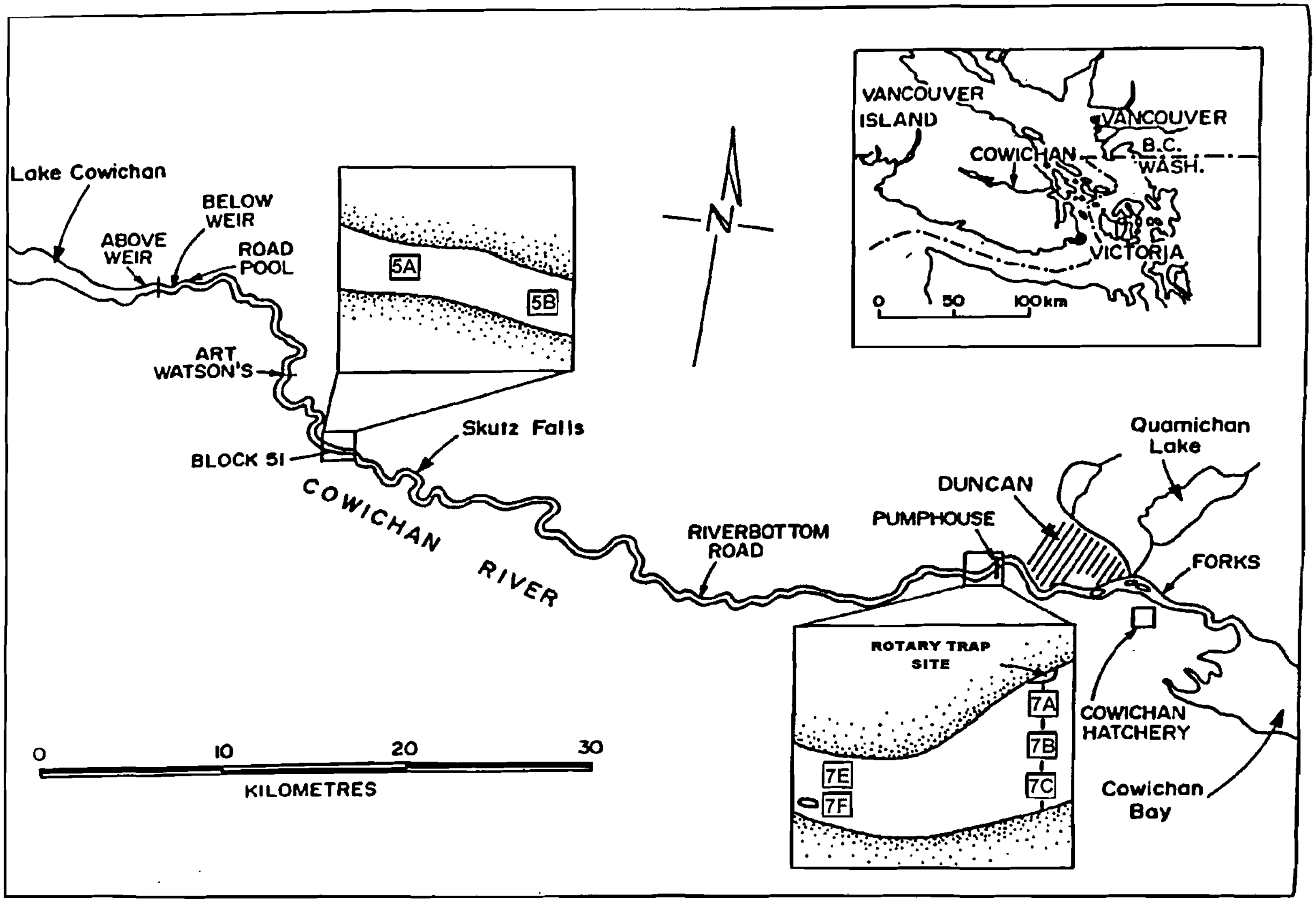

Figure 1. Cowichan River downstream fry trap locations.

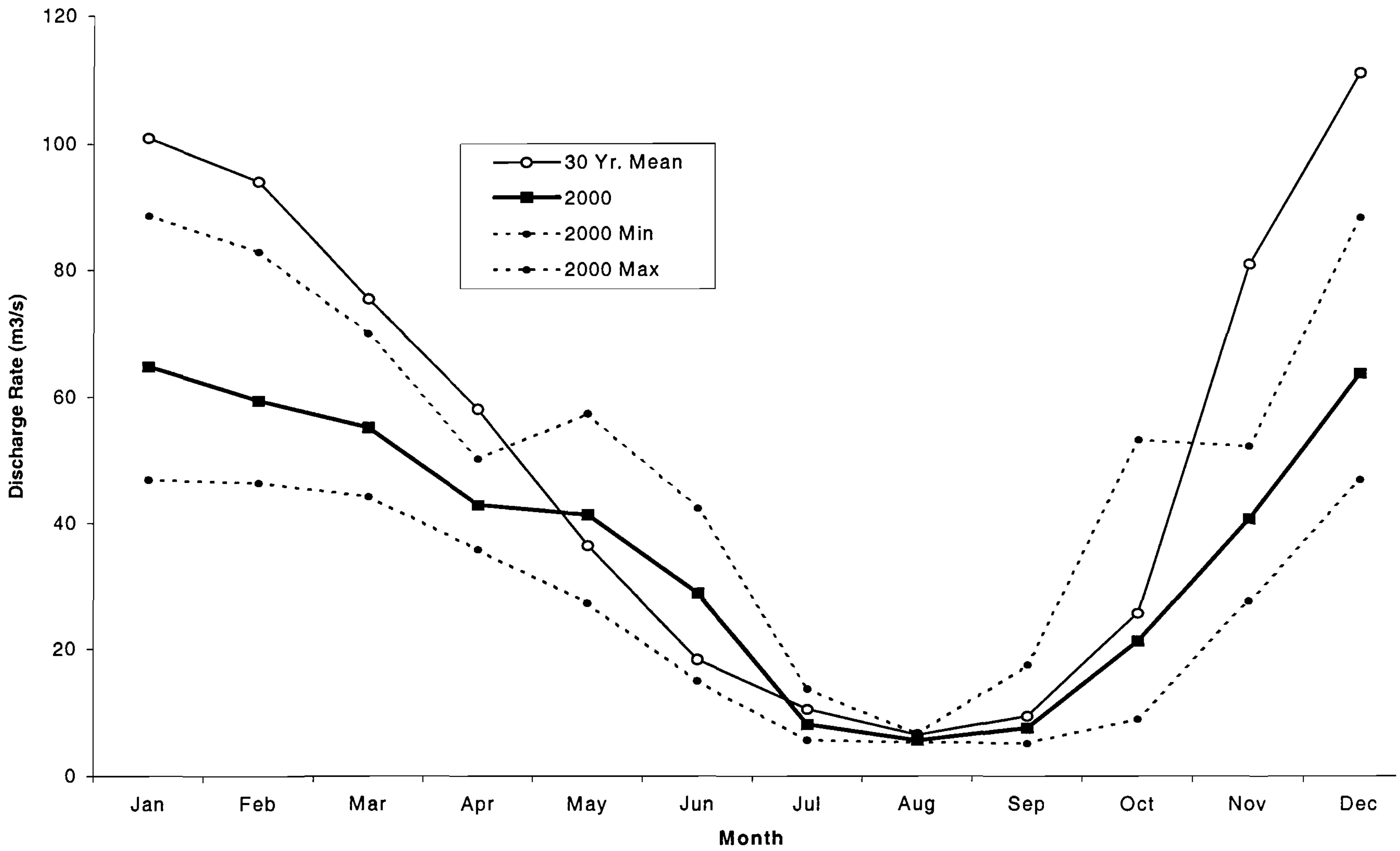

Figure 2. Monthly Cowichan River discharge[1] (m^3/s) in 2000 along with 30 year mean.

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

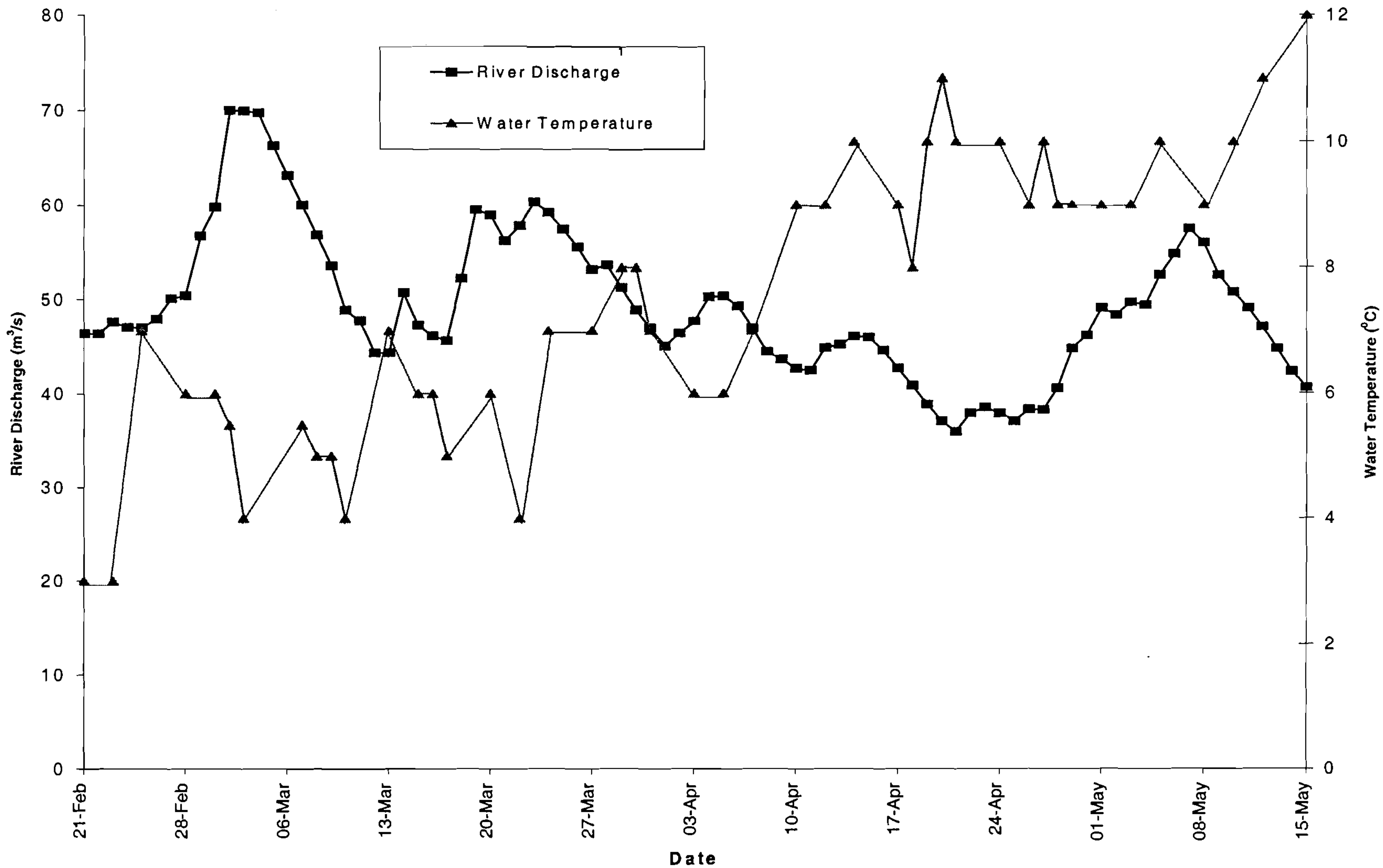

Figure 3. Biophysical conditions recorded at the Pumphouse site, Cowichan River, 2000.
[1] River discharge measured at the Island Highway Bridge in Duncan, B.C.

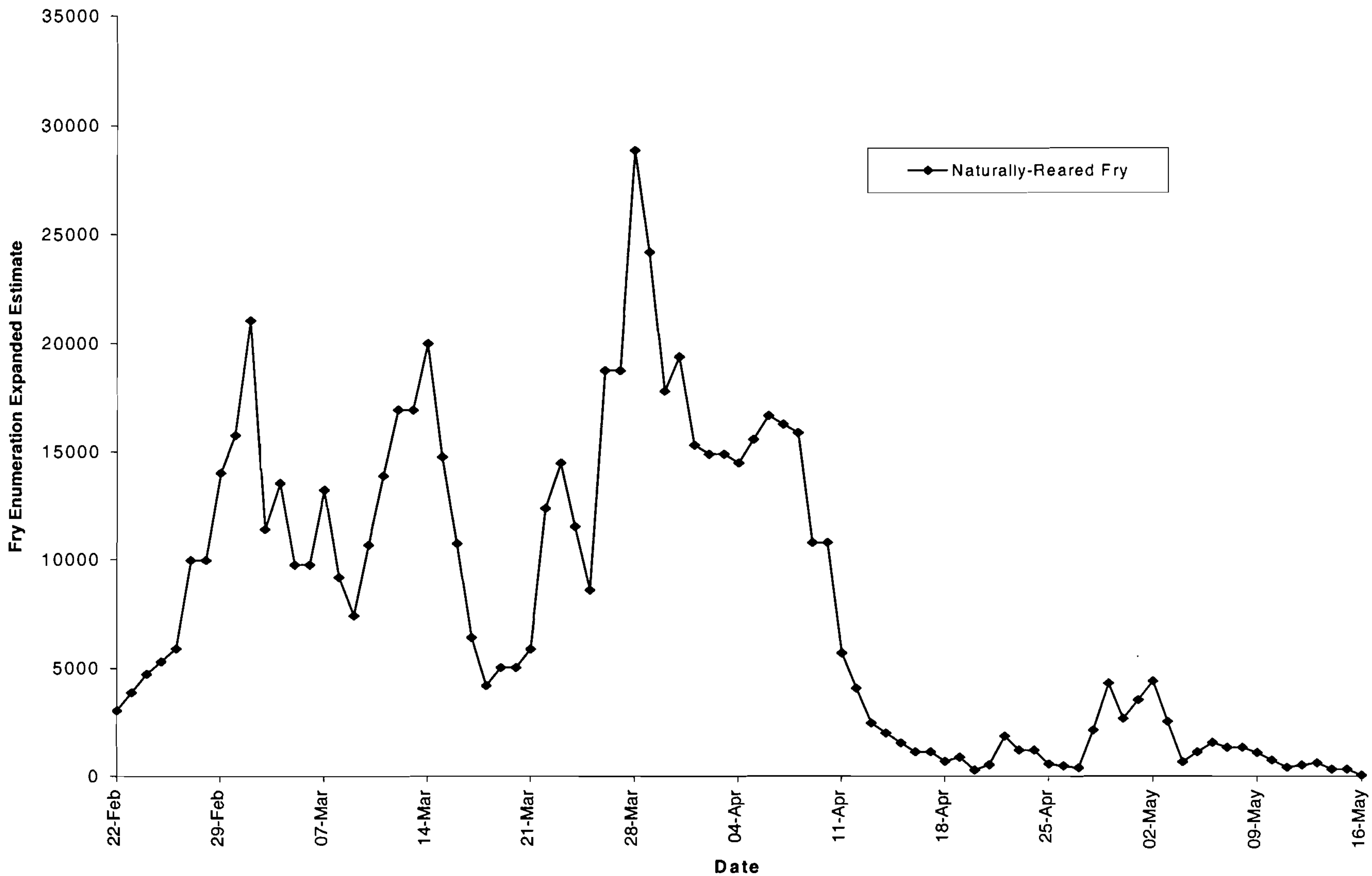

Figure 4. Daily abundance estimates of naturally-reared chinook fry downstream migration, Pumphouse site, Cowichan River, 2000.

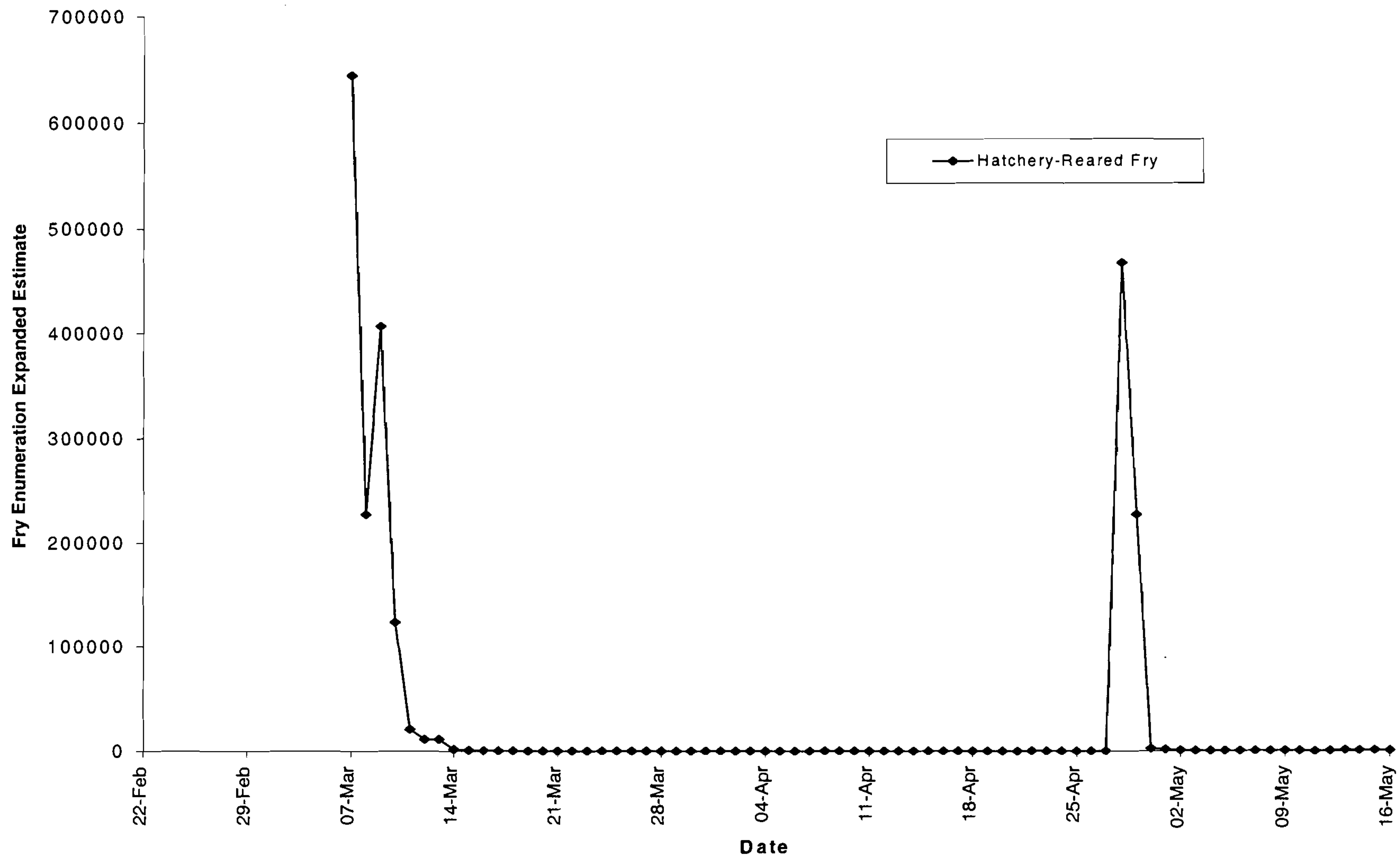

Figure 5. Daily abundance estimates of hatchery-reared chinook fry downstream migration, Pumphouse site, Cowichan River, 2000.

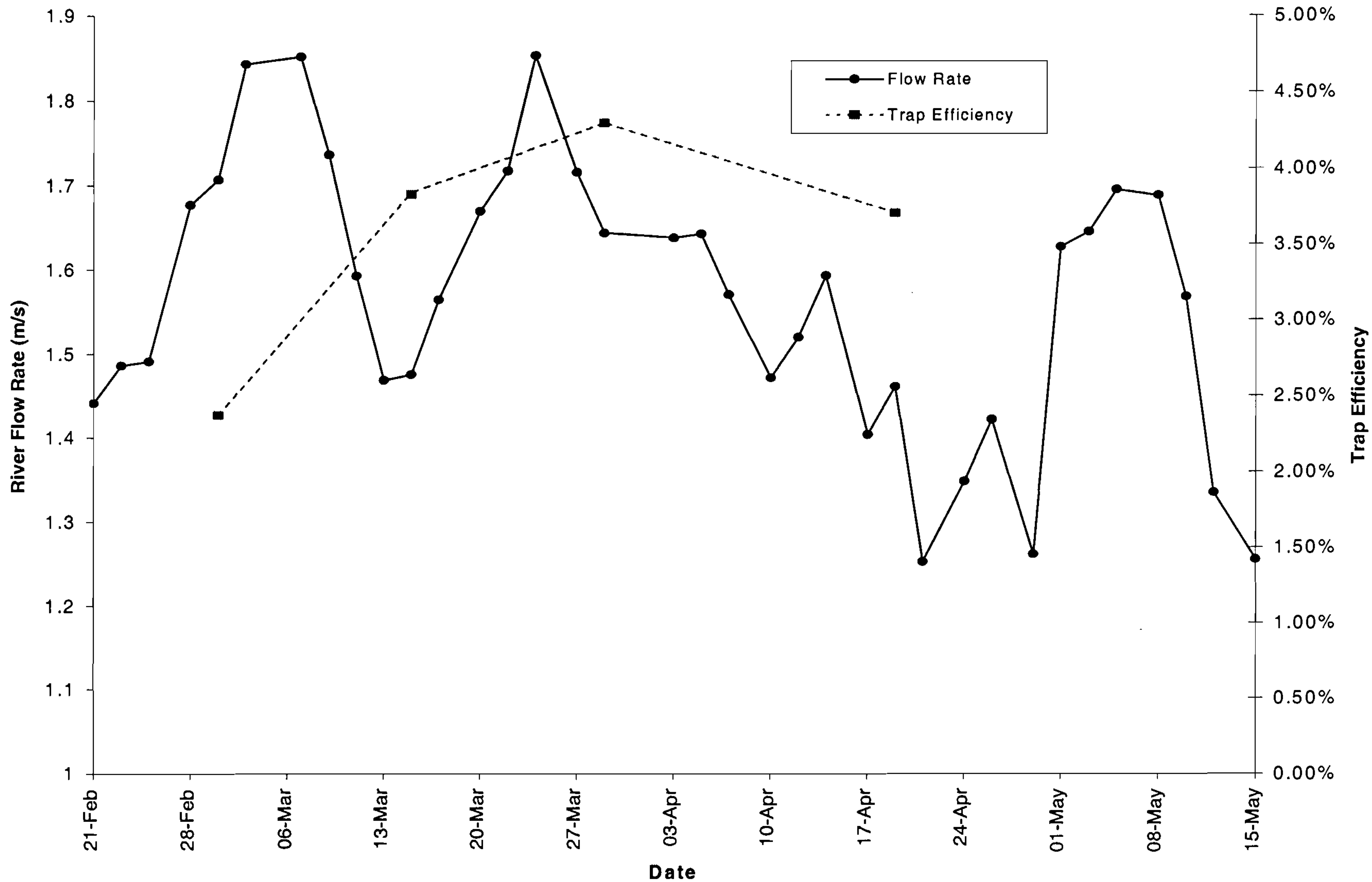

Figure 6. Rotary trap efficiency compared with water flow at the Pumphouse site, Cowichan River, 2000.

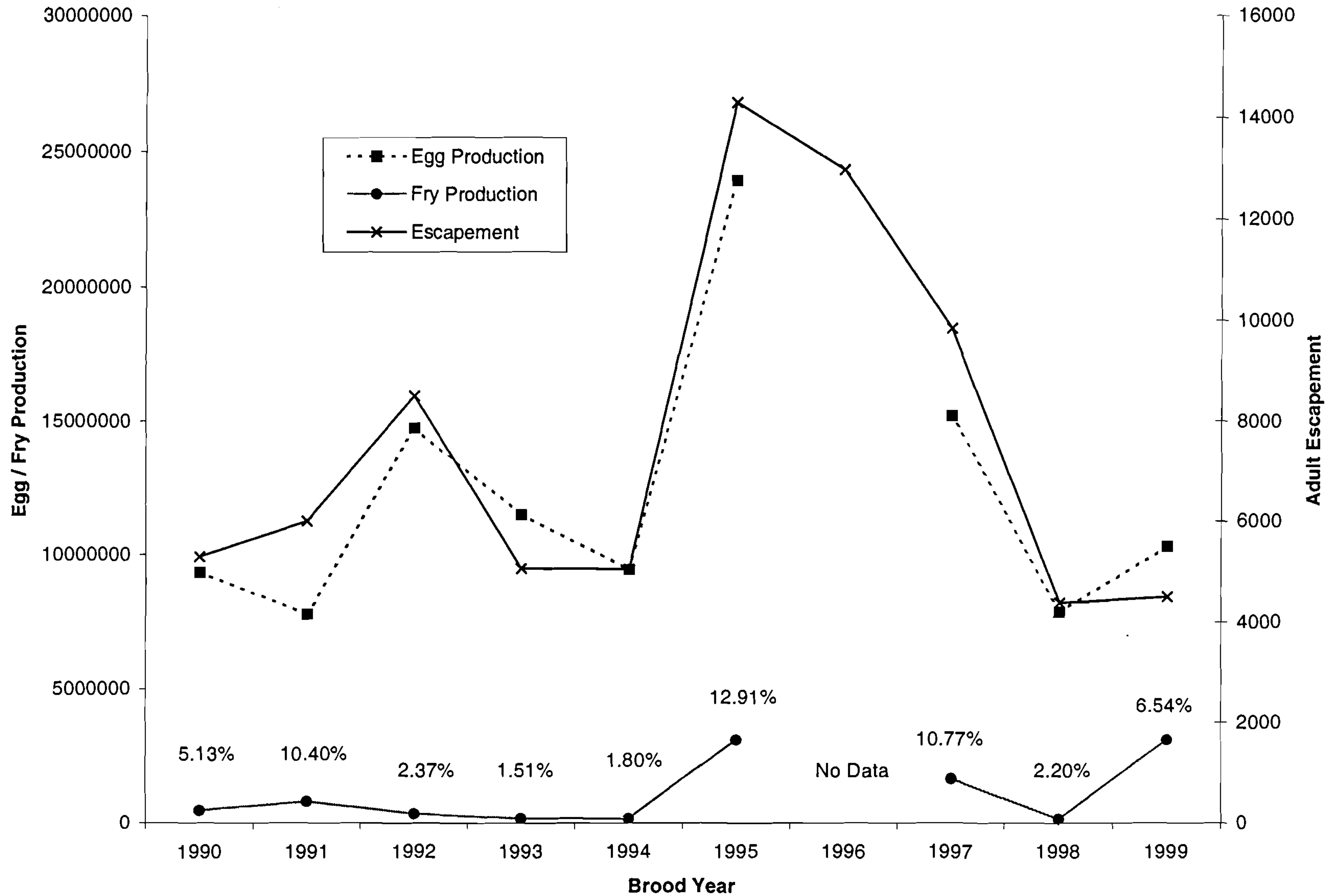

Figure 7. Egg to fry survival estimates compared to adult escapement and fry production, Cowichan River.

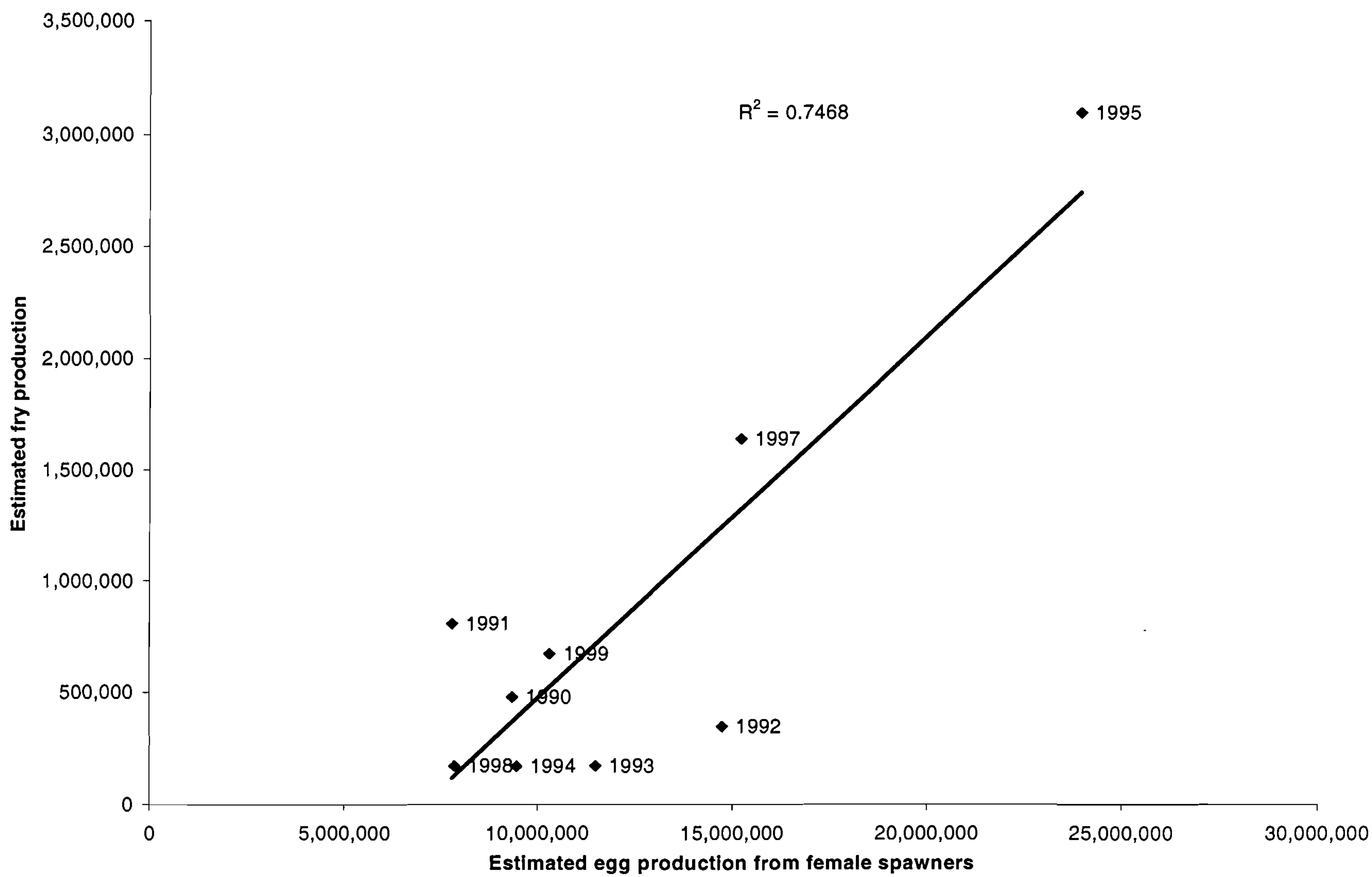

Figure 8. Chinook eggs deposited compared with subsequent fry production, Cowichan River.

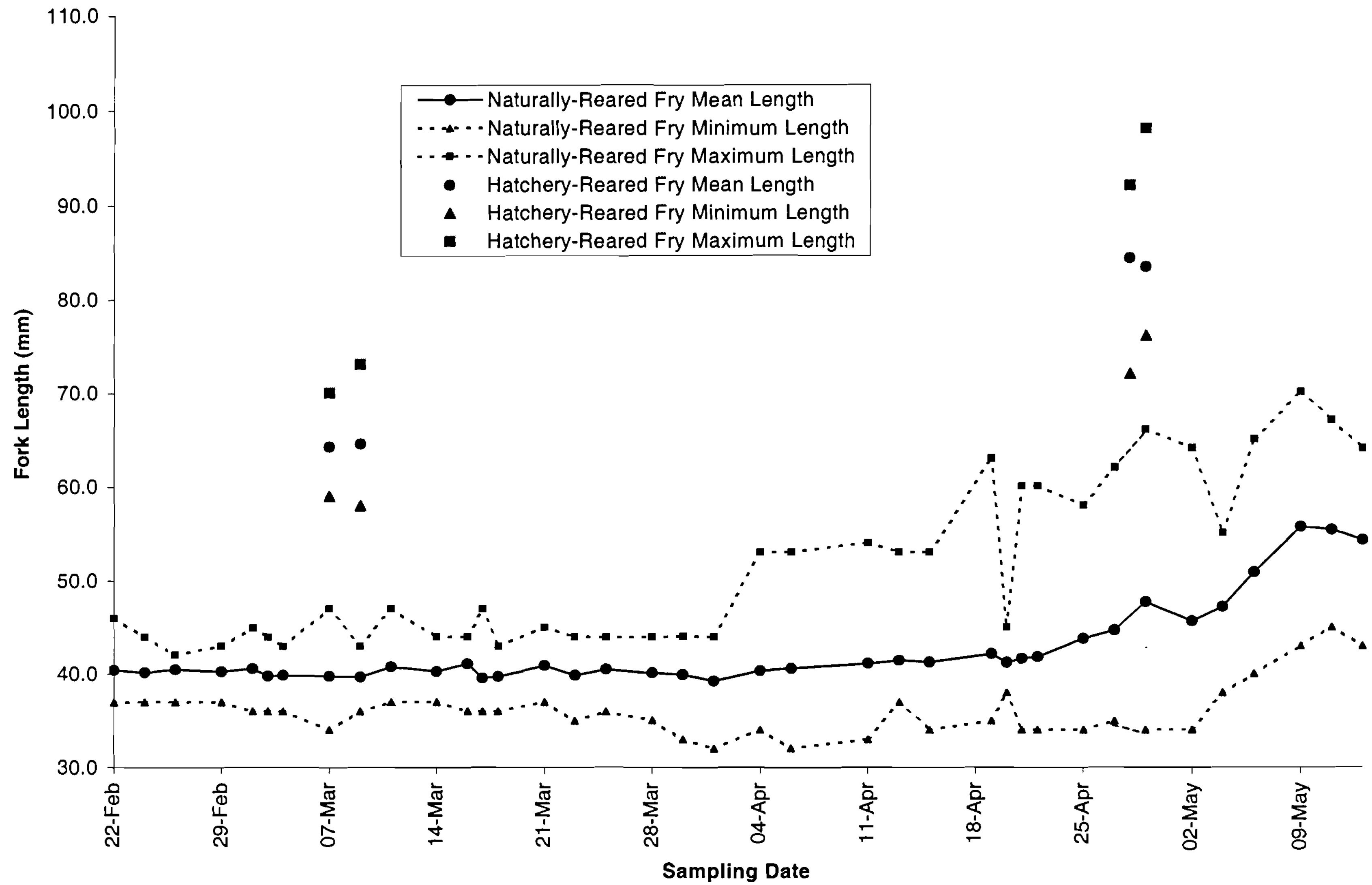

Figure 9. Mean lengths of hatchery-reared and naturally-reared chinook fry, Cowichan River, 2000.

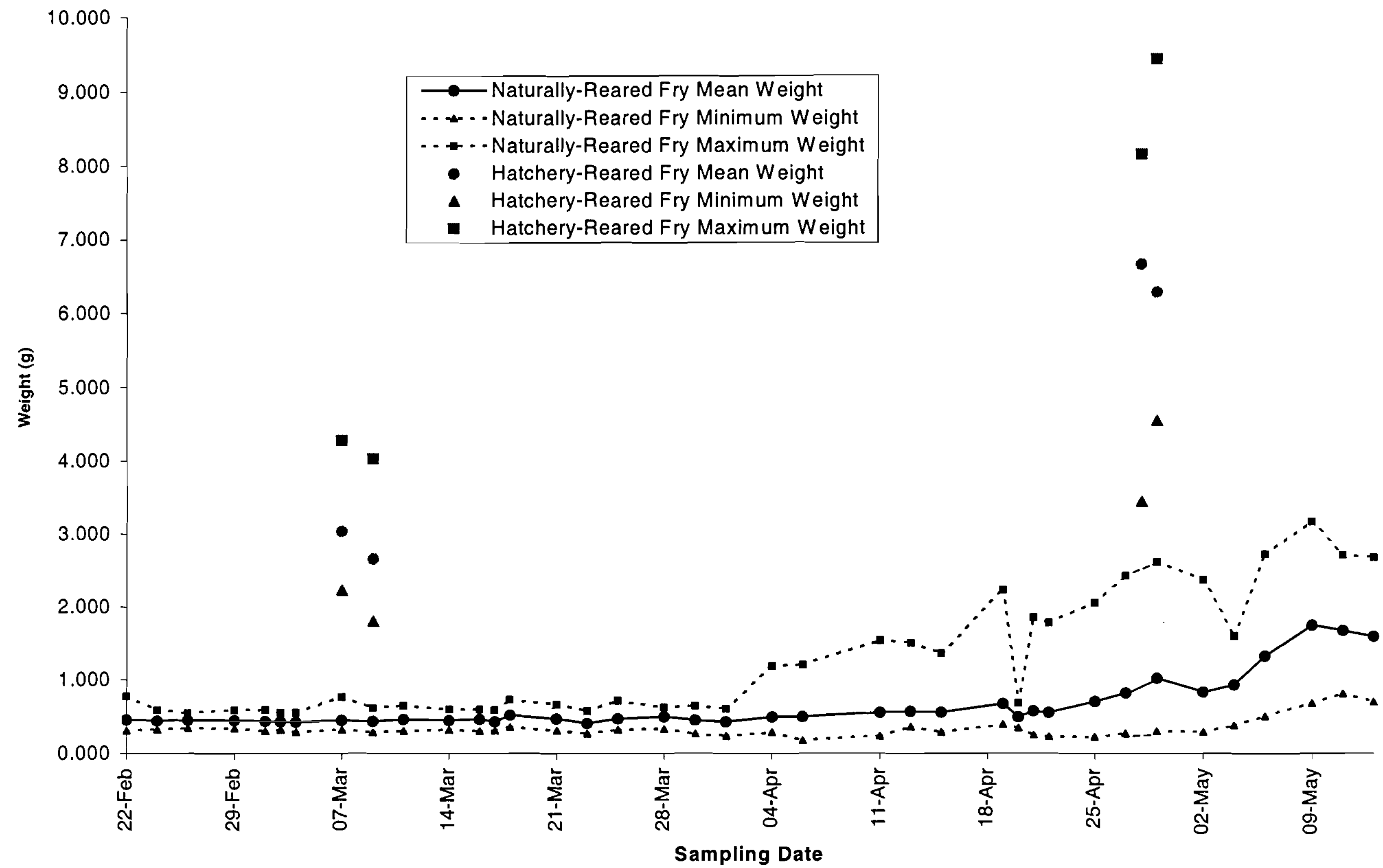

Figure 10. Mean weights of hatchery-reared and naturally-reared chinook fry, Cowichan River, 2000.