Results of Rotary Auger Trap Sampling in the Nanaimo River, 1996

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ABSTRACT

Nagtegaal, D. A. and E. W. Carter. 1997. Results of rotary auger trap sampling in the Nanaimo River, 1996. Can. Manuscr. Rep. Fish. Aquat. Sci. No. 2391: 30 p.

In 1996, the Dept. of Fisheries and Oceans, Pacific Biological Station, initiated a study of juvenile chinook salmon (*Oncorhynchus tshawytscha*) productivity in the Nanaimo River. This study was implemented in conjunction with the Nanaimo First Nations and the key components of this ongoing project include: i) enumeration of juvenile outmigrants, ii) monitoring growth of hatchery and naturally-reared fry, iii) monitoring hatchery releases and interaction between hatchery and naturally-reared fry in the river. A rotary screw trap was used to estimate naturally-reared fry production. Bismarck Brown dyed hatchery and naturally-reared chinook juveniles were released above the trap and mark-recapture results were used to expand trap catches to estimate total production. The minimum estimate of the production of naturally-reared juvenile chinook for 1996 brood year was 366,725 (range: 348,352 - 385,006). Hatchery releases of chinook fry and smolts (based on hatchery records) were 601,298, of which approximately 188,648 were estimated to have left the river by May 30. The interaction between the early release hatchery group and naturally-reared juveniles was believed to be minimal since most of the hatchery fish moved out of the river in just a few days after release.

RÉSUMÉ

Nagtegaal, D. A. and E. W. Carter. 1997. Results of rotary auger trap sampling in the Nanaimo River, 1996. Can. Manuscr. Rep. Fish. Aquat. Sci. No. 2391: 30 p.

En 1996, le ministère des Pêches et des Océans, à la Station de biologie du Pacifique, a lancé une étude sur la productivité des juvéniles de saumon quinnat (*Oncorhynchus tshawytscha*) dans la rivière Nanaimo. L'étude a été mise en oeuvre avec la collaboration des Premières Nations de Nanaimo, et les grands volets du projet en cours sont : i) le dénombrement des juvéniles en dévalaison; ii) une surveillance de la croissance des alevins en élevage et dans la nature; iii) une surveillance des lâchers des écloseries et de l'interaction entre les alevins d'élevage et sauvages dans la rivière. Un piège à vis sans fin a servi à estimer la production des jeunes élevés dans la nature. Des juvéniles élevés dans la nature et des juvéniles d'écloserie marqués au brun Bismarck ont été relâchés au-dessus du piège, et les résultats de l'opération de marquage-recapture ont été utilisés pour estimer la production totale à partir des prises du piège. La production minimale de quinnats juvéniles élevés dans la nature pour l'année de ponte 1996 a été estimée à 366 725 (fourchette : 348 352 - 385 006). Les alevins et smolts libérés des écloseries (d'après les dossiers des établissements) se chiffraient à 601 298, dont environ 188 648 semblaient avoir quitté la rivière au 30 mai. L'interaction entre le groupe de poissons libérés précocement des écloseries et les juvéniles élevés dans la nature est jugée minimale, car la plus grande partie des poissons d'élevage avaient quitté la rivière quelques jours après leur lâcher.

INTRODUCTION

Considerable interest has been focused on the chinook salmon (*Oncorhynchus tshawytscha*) stocks in the southern portion of the Strait of Georgia over the past several years due to the decline in these stocks and their importance to the local fisheries (Farlinger et. al. 1990). Three indicator stocks (Nanaimo, Cowichan, Squamish) are used to assess the status of Lower Georgia Strait chinook stocks. The objectives of this assessment includes: i) quantitatively determining the optimum spawning requirement for chinook salmon (this involves investigations of the determinants of juvenile production, interactions between hatchery and wild chinook, and estimation of the spawning escapement and catch attributed to the hatchery and wild components of the total run), and ii) developing guidelines for establishing escapement targets for other B. C. chinook stocks (Nagtegaal et al., 1994a). In 1988, the Department of Fisheries and Oceans, Pacific Biological Station, initiated an intensive study of chinook productivity on these three indicator stocks to assess rebuilding strategies and to evaluate the effects of harvest management policies for these stocks. For practical purposes the primary focus of this research has been on the Cowichan River, where adult enumeration and downstream fry migration studies have been conducted for the past several years.

In 1995, the opportunity arose to also expand assessment of the Nanaimo River chinook stocks. Prior to 1995, adult chinook enumeration was based on overflight information and standardized swim surveys conducted by the Nanaimo River hatchery in conjunction with the Fishery Officers. In the fall of 1995, an adult chinook enumeration study was implemented in conjunction with the Nanaimo First Nations. A counting fence was constructed in the lower river and operated from the beginning of August till the end of October. Then in the spring of 1996, the juvenile component of this study was initiated. The scope of the juvenile component of this assessment was to: i) determine the timing and abundance of juvenile chinook outmigrants, ii) monitor the growth of hatchery and naturally-reared juveniles, and iii) monitor the hatchery releases and assess the interaction between hatchery and naturally-reared juveniles in the river and in the estuary.

Chinook salmon in the Nanaimo River, exhibit three juvenile life history types characterized by different ages at seaward migration (Healey and Jordan 1982; Carl and Healey 1984). The first type migrates to sea immediately after emergence from the spawning gravel and rears in estuarine habitats, a second migrates seaward after rearing for about two months in freshwater ('90-day smolts'), and the third type after rearing for a year in freshwater. It is believed that these three life history types originate from subpopulations that spawn in separate areas of the river (Healey 1980). Fishery managers and biologists have expressed concern over the potential loss of genetic variation in economically valuable species due to selective harvesting and artificial propagation and are uncertain about the effects of this loss on stock productivity. The opportunity to implement a productivity study on Nanaimo R. chinook may in part address some of these issues.

Hatchery production of chinook on the Nanaimo River began in 1980 (Cross et al.,1991). Chinook fry releases have increased from 61,474 in 1980, to 601,298 in 1996. Coded-wire tagged releases also began in 1980, and in 1996 approximately 16% of the total number of chinook released were tagged. Three main release strategies are employed by the hatchery. The early release, 5 g pre-smolts, are generally released in the beginning of May just below the Island Highway bridge in the lower river. The lake release, 6-7 g pre-smolts, are initially reared at the hatchery. They are then moved to lake net pens just at the mouth of First lake prior to being released into the lake in late May. The late release, 6 g pre-smolts, are generally released below the Island Highway bridge during late May.

The purpose of this report is to present the results of the juvenile chinook downstream migration study conducted on the Nanaimo River during the spring of 1996. We refer to hatchery 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

METHODS

STUDY AREA

The Nanaimo River flows into the estuary on the east coast of Vancouver Island, British Columbia, just south of the city of Nanaimo, approximately 80 km north of Victoria (Fig. 1). The river is approximately 56 km long and has a watershed of 830 km^2. The system includes four small lakes and two storage reservoirs. Flow varies from about 3 m^3/sec in summer to over 400 m^3/sec during winter freshets and averages about 42 m^3/sec. The Nanaimo River system supports chinook, coho, pink, and chum salmon populations (Aro 1973).

A Community Economic Development Program (CEDP) hatchery is situated alongside the Nanaimo River approximately 8 km upstream from the Nanaimo estuary. The hatchery is managed by the Central Island Community Development Society under the auspices of the Habitat and Enhancement Branch of Fisheries and Oceans Canada. The facility began chinook production with adults from the 1979 brood year.

FISH CAPTURE

A rotary screw trap[1], 2.4 m in diameter, was used to trap salmonid juveniles migrating downstream to the estuary from Mar. 1 to May 30, 1996. The trap was situated approximately 5 km upstream of the estuary (Fig. 1). The trap was held in position by galvanized steel cables suspended across the river. The trap was fished overnight from 1900 hours to 0700 hours on Monday, Wednesday and Friday evenings. On several occasions throughout the study period, trapping occurred for a 24 hour period to observe diel movement. In addition, when hatchery releases occurred, the trap was fished 24 hours a day for several days after the release in an attempt to closely monitor the movement of hatchery juveniles at the site. When trapping occurred over a 24 hour period, the fish were collected after 12 hours either at 0700 or 1900, to observe the differences in movement during the day and night.

All fish captured by the trap were enumerated by species and recorded by time period and capture date. Chinook juveniles were identified as being either hatchery or naturally-reared based on length and weight characteristics. Generally, the length and weight of hatchery chinook at the time of release was consistently greater than for naturally-reared fish. No hatchery fish were assumed to be in the river prior to the first release on May 2. The number of adipose-clipped hatchery fish captured were recorded and coho juveniles were identified as either fry or one and two year old smolts. Water temperature, flow rate[2] and weather conditions were also recorded for each sampling event. River discharge information was acquired from Water Survey Canada.

An inclined-plane trap was placed at a site below First Lake (Fig. 1) between April 11 and June 3 in an attempt to monitor the downstream fry migration from upper river spawners. This trap was monitored on an intermittent basis.

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[1]**Manufactured by E.G. Solutions, Corvallis, Oregon, USA**

[2] **Flow metre, Model 2030R, General Oceanic, 1295 NW 163rd St., Miami, Florida, USA**

ABUNDANCE ESTIMATES

Trap efficiency information was used to expand trap catch to the estimated total numbers of fish migrating past the trap site. Trap efficiency was estimated by marking 100-300 hatchery and naturally-reared chinook juveniles using Bismarck Brown stain (Ward and VerHoeven 1963), releasing them approximately 500 m above the trap site, and recording the number of marked fish that were recaptured over the next 3-4 days. Mark-recapture efficiency tests were done on a weekly basis throughout the study. The proportion of marked fish recaptured was used to expand the unmarked catch and estimate the total number of fish.

Trap efficiency was estimated by:

$$E_{ij} = R_{ij} / M_{ij}$$

where:

E is the estimated trap efficiency at site i and sampling week j
R is the number of marked fish recaptured
M is the number of marked fish releases

Assumptions inherent in these efficiency tests were that i) marking did not affect short term survival after release, ii) all marked fish released above the trap site migrated downstream past the trap, iii) marked fish behaved the same as unmarked fish, and iv) all recaptured marked fish were counted.

The total number of fish was estimated by:

$$N_i = U_{ij} / E_{ij}$$

where:

N is the estimated number of fish
U is the catch of unmarked fish in the trap

Total fish numbers were estimated by summing the daily estimates generated by dividing the daily catch by the trap efficiency for that week. For those days the trap was not in operation, the number of fish that migrated past the trap site that day was assumed to be the mean of the number recorded for the previous and subsequent sampling days. The total abundance estimate was assumed to be the sum of the daily estimates for the duration of the study. Confidence limits were determined from the trap efficiency using the adjusted Petersen estimate (Ricker 1975). This is a minimum estimate of confidence limits since there is added uncertainty from using weekly trap efficiency estimates, interpolating for unsampled days, and extrapolating for unsampled parts of the day.

SIZE

Observations on the changes in the size of chinook juveniles was accomplished by simultaneously collecting samples on a weekly basis from both hatchery and naturally-reared fish. At the hatchery approximately 30 chinook juveniles were collected each week from each of the two main release strategies (early and late). Random samples of 20-30 naturally-reared juveniles were measured for length and weight at the trap site for each sampling evening. Fish were measured for overall length to the nearest mm and weight to the nearest one-hundredth of a gram. A subsample of adipose-clipped chinook juveniles was collected and frozen for each sampling evening after a hatchery release and kept for coded-wire tag analysis to determine the release group.

RESULTS

MIGRATION TIMING

At the rotary screw trap site, 3,609 naturally-reared (Table 1a) and 2,987 hatchery chinook juveniles (Table 1b) were captured in the rotary screw trap. Downstream movement was observed from the beginning of March to the end of May (Fig. 2). Peak migration of naturally-reared juveniles occurred in the middle of April.

The majority of chinook juveniles were caught at night (Table 2). The difference between night and day catches for both naturally-reared and hatchery fish was substantial; approximately 95% of the fry were caught at night.

Water discharge was high in March and had declined dramatically by the middle of April while river temperature increased slowly over the duration of the sampling period (Fig. 7).

Based on hatchery records, 601,298 hatchery chinook were released into the Nanaimo River of which 100,645 were coded-wire tagged (Table 3). The early release group (approx. 215,000) was released in the lower Nanaimo R. on May 2; the late group (approx. 308,000) was released in the lower Nanaimo R. on May 30; and the Lake release group (Spring stock; approx. 78,000) was released from the lake pens in First Lake on May 23. Since 1988, hatchery releases have ranged from 500,000 to 700,000, except in 1991 (Fig. 3).

At the inclined-trap site only two hatchery chinook juveniles were captured, presumably from the lake pen (spring stock) release group. Several 1 yr coho smolts were captured which indicated that the trap was operating properly, even though few chinook were caught.

ABUNDANCE ESTIMATES

Rotary screw trap efficiency tests were conducted every other week at the trap site (Table 4). Trap efficiency for hatchery fish was more consistent than for naturally-reared chinook. As water flow decreased, some minor adjustments were made, to the position of the trap relative to the main flow, to optimize trapping efficiency. Trap efficiency was calculated for each test and there were significant differences ($P < 0.05$; chi-square test) between consecutive tests (Zar 1984). Although data were limited, trap efficiency generally decreased as discharge decreased (Fig. 4). Daily extrapolated abundance estimates are listed in Table 5 for both naturally-reared and hatchery juveniles. Based on these data, the total number of naturally-reared chinook outmigrants during the sampling period was estimated to be 366,725 with 95% confidence limits of 348,352 and 385,006. The total number of hatchery juveniles was calculated to be 183,387 with confidence limits of 174,209 and 201,466. According to hatchery records, 601,298 hatchery chinook juveniles were released above the trap site.

SIZE

Mean daily length and weight of naturally-reared chinook remained fairly constant from the beginning of March until May (Figs 5 and 6). Mean length began at 42 mm and weight at approximately 0.45 g. By the end of the sampling period the mean length had only marginally increased to 49 mm and mean weight was .57 g.

Mean daily length and weight of hatchery chinook juveniles steadily increased from early March until these fish were released in the river (Figs 5 and 6). Both mean length and mean weight of all hatchery release groups was substantially greater than for the naturally-reared fish at any given time.

DISCUSSION

Healey (1980) indicated that the majority of juvenile outmigrants in the Nanaimo River move to the estuary in the first few weeks after emergence. It was assumed that the numbers of chinook outmigrants generated from our calculations reflect an estimate of the size of this group. Implicit in this is the assumption that we did not observe the fry production for those juveniles that remain in the river for more than a few weeks. Based on their observations, Healey and Jordan (1982) reported that only the upper river spawners (Spring stock) produced juveniles (approx. 7.6%) that remained in the river for up to a year ('stream-type' life history strategy), and that lower river spawners primarily produced (> 99%) juveniles that immediately migrate to the estuary ('ocean-type' life history strategy).

The rotary screw trap performed well in capturing both naturally-reared and hatchery chinook juveniles over a wide range of flow rates experienced on the Nanaimo River. As a measure of the accuracy of estimating chinook juveniles based on trap efficiency expansions of daily trap catches, we compared our abundance estimates of the early hatchery release with known numbers released based on hatchery records. On May 2, 215,136 chinook fry (early release group) were released into the Nanaimo River just below the Island highway bridge (Fig. 1). Between May 3 and 20 we estimated 173,381 early release hatchery fry had passed the trap site. This time frame should have encompassed the majority of the total outmigration of the early group since towards the end of May few hatchery fish were observed at the trap site. Based on this information, our abundance estimate of the early group was aproximately 80% of the known numbers of fry that should have passed the trap site. No comparison was made for the other hatchery releases since our observations were incomplete.

Although the inclined-plane trap did not trap many chinook juveniles, we assumed that the trap was functioning properly. Candy et al. (1995) determined that the inclined-plane trap they used was only about 20% as efficient as the rotary screw trap. No expanded estimates of juvenile migration were generated based on the inclined-plane trap data in this study.

The greatest potential for significant error in the abundance estimates would be from the trap efficiency tests. No obvious problems were observed during these tests and all dyed fish used in the mark-recapture tests were in good condition at the time of release. If dyeing reduced fish health and as a result caused trap efficiency to be biased high, then abundance would be underestimated. If dyed fish that were released upstream were not uniformly distributed in the river when they moved past the trap site, this could also have caused the efficiency tests to incorrectly estimate the true abundance. Roper and Scarnecchia (1996) reported that under low flow conditions, larger hatchery fish could avoid being caught by a rotary screw trap more likely than smaller naturally-reared fish. When such trap efficiency data were the basis for expansion to total abundance, it was emphasized that the results could be misleading if trap efficiencies were not measured independently for hatchery and naturally-reared fish. We were convinced that neither of these possiblities caused any significant problems in this study because we maintained the trap in higher flow conditions, and estimated trap efficiency for both hatchery and naturally-reared chinook.

EGG TO FRY SURVIVAL

Carter et. al (unpubl) reported that escapement of fall chinook in the Nanaimo River in 1995 was estimated to be 1,679 of which 42% were females. Based on swim survey results (Preston, 271 Pine Street, Nanaimo, B.C., V9R-2B7, pers. comm.), the spring stock was estimated to be 100 adult chinook of which approximately 42% were considered to be females. According to hatchery broodstock records, average fecundity of the 1995 chinook (Fall stock) was calculated to be 4,285 eggs per female and for the Spring stock it was calculated to be 3,817 eggs per female. Based on these data, we estimated egg deposition to be a little more than 3.1 million (Table 5). Egg to fry survival for the 1995 brood was estimated to be 11.7% (range: 11.1% - 12.3%). This estimate was considered conservative since according to Healey (1980) approximately 8% of the progeny of upper river spawners rear in the upper river for up to a year.

The results compare favourably with information from previous studies on the Nanaimo River (Healey and Jordan 1982; Healey et al. 1977) although adult escapement estimates in those studies were based on limited swim survey data. More recently, this estimate is considerably better than the egg to fry survival rate estimated in the Cowichan River of 1.3% - 3.4% (Candy et al. 1995, 1996) and for the Lower Stuart River of approximately 5% (Taylor and Bradford 1993).

Two factors that may have affected survival were environmental conditions and spawner distribution. Discharge during January and February, was considerably higher than the 10 year average monthly discharge in the Nanaimo River (Fig. 7). The higher water levels caused the water to remain cloudy during the time of peak migration. This may have had a positive effect on juvenile survival by protecting them from predation. It has been suggested that spawning success is poorer in the lower river partially due to chum spawning on top of chinook redds in this area. Chum escapement in 1995 was considerably less than previous years (R. Brahniuk, 60 Front St., Nanaimo, B.C., V9R-5H7, pers. comm.) and may have allowed for better chinook survival.

SIZE

Since the mean size of naturally-reared outmigrant chinook fry only marginally increased over the study period until May, we assumed that we were likely not monitoring fry growth by measuring and weighing fry at the trap site. During the entire sampling period we were likely trapping only juveniles that had emerged and moved downstream to the estuary. Our length and weight measurements simply reflect the size of juveniles moving downstream. By the end of May, a few larger chinook were caught in the trap and were likely some that remained in the river above the trap for some weeks prior to migrating downstream, as observed in previous studies (Healey and Jordan 1982; Healey et al. 1977). Although few in number, these larger chinook may be indicative of the '90 - day' life history strategy described by Healey (1991) and likely represent some of the progeny from upper river spawners. Similar life history patterns were also observed in the Cowichan River studies (Candy et al. 1995, 1996).

Hatchery juveniles grew faster and were considerably larger than naturally-reared fry at the time of the hatchery releases.

INTERACTION

Preliminary information indicated that approximately 80% of hatchery juveniles (early release group) released in the river moved to the estuary within the first few days after release (Fig. 8). Since trap sampling was terminated on May 30, the downstream movement of the second lower river release and the upper river release was not monitored. No comment could be made regarding the fate of these releases. Observations made regarding the early release group compared favourably with previous results (Candy et al., 1996) and other studies (Taylor and Bradford 1993; Healey 1991). Seelbach (1985) concluded that for those hatchery fish which move out of the river to the estuary fairly quickly, interaction with naturally-reared juveniles is likely minimal. This also seemed to be the case in the Nanaimo system. Based on earlier studies conducted in the Nanaimo River (Healey 1980), it could be expected that some hatchery and naturally-reared juveniles remain in the river for some time. The level of interaction in the river environment is also expected to be limited because the bulk of hatchery releases occurred when the majority of naturally-reared juveniles had already emigrated to the estuary.

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LITERATURE CITED

Aro, K.V. 1973. salmon and migratory trout of the Nanaimo River and adjacent streams (Revised 1973). Fish. Res. Board Can. MS Rep. 1284: 15p.

Candy, J.R., D.A. Nagtegaal, and B. Riddell. 1996. A preliminary report on juvenile chinook production in the Nanaimo River during 1991 and 1992. Can. MS Rep. Fish. Aquat. Sci: 2329.

Candy, J.R., D.A. Nagtegaal, and B. Riddell. 1996. A preliminary report on juvenile chinook production in the Nanaimo River during 1993 and 1994. Can. MS Rep. Fish. Aquat. Sci: 2354.

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

Carter, E.W. and D. A. Nagtegaal. A preliminary report on adult chinook production in the Nanaimo River during 1995. (unpubl)

Cross, C.L.,L. Lapi, E. A. Perry. 1991. Production of chinook and coho salmon from British Columbia hatcheries, 1971 through 1989. Can. Tech. Rpt. Fish. Aquat. Sci: 1816.

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

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.

Healey, M.C. 1980. Utilization of the Nanaimo River estuary by juvenile chinook salmon, *Oncorhynchus tshawytscha*. Fishery Bull. Vol. 77, No. 3: 653-668.

Healey, M.C., R.V. Schmidt, F.P. Jordan, and R.M. Hungar. 1977. Juvenile salmon in the Nanaimo area 1975: 1. Distribution and abundance. Fish. Mar. Serv. Man. Rep. No. 1369: 161p.

Healey, M.C., R.V. Schmidt, F.P. Jordan, and R.M. Hungar. 1977. Juvenile salmon in the Nanaimo area 1975: 2. Length, weight and growth. Fish. Mar. Serv. Man. Rep. No. 1438: 147p.

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

Inland Waters Directorate. Historical stream flow summary, British Columbia, 1996. Water Survey of Canada, Ottawa.

Kuhn, B.R. 1988. The MRP-Reporter Program: a data extraction and reporting tool for the mark-recovery program database. Can. Tech. Rep. Fish. Aquat. Sci. 1625: 145p

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

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

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

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

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.

Taylor, G.C. and M.J. Bradford.1993. Results of rotary auger trap sampling, lower Stuart River, British Columbia, in April and May 1992. Can. MS Rep. Fish. Aquat. Sci: 2211 18p.

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

Zar, J. 1984. Biostatistical analysis. Prentice-Hall Inc., Englewood Cliffs, New Jersey. 718

Table 1a. Naturally-reared chinook rotary trap catch data at the trap site, Nanaimo River, 1996.

Date	Observed	Missing cells Interpolated	24-hour Estimates	Extrapolated Estimates	Cumulative Total
01-Mar	0		0	0	0
02-Mar			0	0	0
03-Mar			0	0	0
04-Mar	1		1	46	46
05-Mar			0	0	46
06-Mar			0	0	46
07-Mar	3		3	139	185
08-Mar	3		3	139	325
09-Mar			0	0	325
10-Mar			0	0	325
11-Mar	2		2	93	417
12-Mar		1	1	46	464
13-Mar	1		1	46	510
14-Mar		1	1	46	556
15-Mar	2		2	93	649
16-Mar		2	2	93	742
17-Mar		2	2	93	835
18-Mar	3		3	139	974
19-Mar		4	5	185	1159
20-Mar	5		6	232	1391
21-Mar	3		3	139	1530
22-Mar	1		1	46	1577
23-Mar		5	6	232	1808
24-Mar		5	6	232	2040
25-Mar	9		10	417	2458
26-Mar		24	28	1113	3570
27-Mar	39		45	1808	5379
28-Mar		34	39	1577	6955
29-Mar	29		33	1345	8300
30-Mar		29	33	1345	9645
31-Mar		29	33	1345	10989
01-Apr	30		35	1391	12380
02-Apr		15	17	696	13076
03-Apr	2		2	93	13169
04-Apr		2	2	93	13261
05-Apr	2		2	93	13354
06-Apr	34		39	1577	14930
07-Apr	241		277	11175	26105
08-Apr	87		100	4034	30139
09-Apr		113	130	5240	35379
10-Apr	140		161	6492	41870
11-Apr		161	185	7465	49336
12-Apr	183		210	8485	57821
13-Apr		343	394	15904	73725

Date	Observed	Missing cells Interpolated	24-hour Estimates	Extrapolated Estimates	Cumulative Total
14-Apr		343	394	15904	89629
15-Apr	503		578	23323	112952
16-Apr		463	532	21468	134421
17-Apr	423		486	19614	154034
18-Apr		508	584	23555	177589
19-Apr	594		683	27543	205132
20-Apr		500	575	23184	228316
21-Apr		500	575	23184	251500
22-Apr	406		467	18825	270325
23-Apr		346	398	16043	286369
24-Apr	286		329	13261	299630
25-Apr		190	219	8810	308440
26-Apr		190	219	8810	317250
27-Apr	94		108	4359	321608
28-Apr		79	91	3663	325272
29-Apr		79	91	3663	328935
30-Apr	65		75	3014	331949
01-May		47	54	2179	334128
02-May	29		33	1345	335472
03-May	40		46	1855	337327
04-May	26		30	1206	338533
05-May		26	30	1206	339738
06-May		26	30	1206	340944
07-May	26		30	1206	342149
08-May		22	25	1020	343170
09-May	19		22	881	344051
10-May		16	18	742	344792
11-May	13		15	603	345395
12-May	14		16	649	346044
13-May	48		55	2226	348270
14-May	48		55	2226	350496
15-May	48		55	2226	352721
16-May		38	44	1762	354483
17-May		38	44	1762	356245
18-May		38	44	1762	358007
19-May		38	44	1762	359769
20-May		38	44	1762	361531
21-May	28		32	1298	362830
22-May	28		32	1298	364128
23-May	7		8	325	364452
24-May		5	6	232	364684
25-May	4		5	185	364870
26-May	4		5	185	365055
27-May	4		5	185	365241
28-May	8		9	371	365612
29-May	8		9	371	365983
30-May	8		9	371	366354
	3609			366725	

Table 1b. Hatchery-reared chinook rotary trap catch data at the trap site, Nanaimo River, 1996.

Date	Observed	Missing cells Interpolated	24-hour Estimates	Extrapolated Estimates	Cumulative Total
01-May	0		0	0	0
02-May	314		361	20171	20171
03-May	2315		2662	148713	168884
04-May	68		78	4368	173253
05-May		35	40	2248	175501
06-May		35	40	2248	177749
07-May	2		2	128	177878
08-May			0	0	177878
09-May	0		0	0	177878
10-May			0	0	177878
11-May			0	0	177878
12-May			0	0	177878
13-May			0	0	177878
14-May			0	0	177878
15-May			0	0	177878
16-May			0	0	177878
17-May			0	0	177878
18-May			0	0	177878
19-May			0	0	177878
20-May			0	0	177878
21-May			0	0	177878
22-May			0	0	177878
23-May			0	0	177878
24-May			0	0	177878
25-May	6		7	208	178086
26-May	6		7	208	178295
27-May	6		7	208	178503
28-May	90		104	3127	181630
29-May	90		104	3127	184757
30-May	90		104	3127	187883
31-May	22		25	764	188648
	2987		3541	188648	

Table 2. Diel migration pattern observed for chinook fry, Nanaimo R., 1996.

	Night Movement		Day Movement		% Daytime Movement	
Date	Wild	Hatchery	Wild	Hatchery	Wild	Hatchery
07-Mar	3		0		0.00	
21-Mar	1		0		0.00	
22-Mar	1		0		0.00	
04-Apr	2		0		0.00	
05-Apr	18		0		0.00	
06-Apr	241		16		6.64	
24-Apr	274		12		4.38	
01-May	29	221	1	0	3.45	0.00
02-May	40	2200	1	12	2.50	0.55
03-May	26	114	2	68	7.69	37.36
Total:	635	2489	34	126	5.35	5.06

Table 3. Juvenile chinook releases, Nanaimo hatchery, 1980-1995.

Tag Code	BY	Number Tagged	Number Released	CWT % Mark	Weigh (gm)	Release Date ddmmmyy:ddmmmyy	Release site
081929	79	16964	61474	27.6	5.7	19Jun80:20Jun80	0126-NANAIMO RIVER
021600	80	72623	179500	40.5	4.4	:01Jun81	0126-NANAIMO RIVER
021909	80	19231	20338	94.6	4.8	:02Jun81	0126-NANAIMO RIVER
NOCN8108	81	0	2809	0.0	4.1	:02Jul82	0126-NANAIMO RIVER
NOCN8109	81	0	11537	0.0	7.3	:02Jul82	0126-NANAIMO RIVER
022324	82	1879	4766	39.4	12.4	:27Jul83	0126-NANAIMO RIVER
022504	82	21516	105114	20.5	7.0	04Jul83:08Jul83	0126-NANAIMO RIVER
022712	83	56911	57640	98.7	6.5	:22Jun84	0126-NANAIMO RIVER
NOCN8315	83	0	292260	0.0	6.3	28May84:18Jun84	0126-NANAIMO RIVER
NOCN8413	84	0	16974	0.0	5.1	11Jun85:12Jun85	0126-NANAIMO RIVER
NOCN8414	84	0	82576	0.0	5.1	:19Jun85	0126-NANAIMO RIVER
NOCN8415	84	0	251047	0.0	4.6	26Jun85:27Jun85	0126-NANAIMO RIVER
NOCN8527	85	0	295387	0.0	6.7	12Jun86:27Jun86	0126-NANAIMO RIVER
NOCN8528	85	0	74233	0.0	6.0	:23Jun86	0126-NANAIMO RIVER
NOCN8662	86	0	70003	0.0	8.2	:01Jun87	2726-FIRST LAKE
NOCN8663	86	0	6002	0.0	13.5	:29May87	0126-NANAIMO RIVER
NOCN8664	86	0	127196	0.0	6.8	01Jun87:02Jun87	0126-NANAIMO RIVER
NOCN8673	86	0	2895	0.0	22.9	:09Oct87	2707-SECOND LAKE
025002	87	25308	25308	100.0	6.7	:10Jun88	0126-NANAIMO RIVER
025003	87	25385	25590	99.2	6.7	:10Jun88	0126-NANAIMO RIVER
025004	87	24141	24141	100.0	6.7	:10Jun88	0126-NANAIMO RIVER
025005	87	24107	24204	99.6	6.7	:10Jun88	0126-NANAIMO RIVER
NOCN8720	87	0	72723	0.0	8.3	:02Jun88	2726-FIRST LAKE
NOCN8732	87	0	443593	0.0	6.8	20May88:24May88	0126-NANAIMO RIVER
026058	88	26832	84250	31.8	5.0	:15May89	0407-NAPOLEON CREEK
026059	88	25538	82955	30.8	5.0	:15May89	0407-NAPOLEON CREEK
026060	88	26108	47634	54.8	6.4	:08Jun89	0126-NANAIMO RIVER
026061	88	26326	47852	55.0	6.4	:08Jun89	0126-NANAIMO RIVER
NOCN8849	88	0	157013	0.0	3.8	:07Jun89	2726-FIRST LAKE
NOCN8850	88	0	144648	0.0	5.7	:05Jun89	0126-NANAIMO RIVER
NOCN8851	88	0	95768	0.0	3.9	:06Jun89	0126-NANAIMO RIVER
026303	89	27171	74720	36.4	6.5	12Jun90:14Jun90	0126-NANAIMO RIVER
026304	89	26837	74720	35.9	5.4	:07May90	0126-NANAIMO RIVER
026305	89	27074	50174	54.0	6.7	28May90:29May90	0126-NANAIMO RIVER
026308	89	26352	49452	53.3	6.7	28May90:29May90	0126-NANAIMO RIVER
NOCN8930	89	0	157322	0.0	7.2	:05Jun90	2726-FIRST LAKE
NOCN8945	89	0	5696	0.0	9.6	:08May90	0126-NANAIMO RIVER
021141	90	26389	26389	100.0	6.6	17May91:17May91	0126-NANAIMO RIVER
021142	90	27006	27006	100.0	5.4	10May91:10May91	0126-NANAIMO RIVER
021143	90	26199	26199	100.0	6.5	31May91:31May91	0126-NANAIMO RIVER
026156	90	10645	19897	53.5	5.7	24May91:24May91	0126-NANAIMO RIVER
026157	90	10799	20052	53.9	5.7	24May91:24May91	0126-NANAIMO RIVER
NOCN9038	90	0	33661	0.0	2.8	24Jun91:24Jun91	0126-NANAIMO RIVER
NOCN9039	90	0	39444	0.0	8.0	09May91:23May91	2726-FIRST LAKE
180523	91	27353	112904	24.2	4.8	21May92:27May92	0126-NANAIMO RIVER
180524	91	27443	112995	24.3	4.8	21May92:27May92	0126-NANAIMO RIVER
180525	91	27564	193704	14.2	3.3	26May92:28May92	0126-NANAIMO RIVER
180526	91	27406	193546	14.2	3.3	26May92:28May92	0126-NANAIMO RIVER
NOCN9140	91	0	49328	0.0	5.6	16May92:16May92	2726-FIRST LAKE
180548	92	26234	112389	23.3	6.0	04May93:26May93	0126-NANAIMO RIVER
180549	92	26398	113091	23.3	6.0	04May93:26May93	0126-NANAIMO RIVER
181013	92	27361	118399	23.1	6.0	04May93:26May93	0126-NANAIMO RIVER
181014	92	27103	117286	23.1	6.0	04May93:26May93	0126-NANAIMO RIVER

Table 3 (cont.)

Tag Code	BY	Number Tagged	Number Released	CWT % Mark	Weigh (gm)	Release Date ddmmmyy:ddmmmyy	Release site
NOCN9239	92	0	50686	0.0	5.8	27Apr93:27Apr93	2726-FIRST LAKE
181032	93	25157	49954	50.4	6.0	02May94:02May94	0126-NANAIMO RIVER
181033	93	25106	66474	37.8	6.7	12May94:12May94	0126-NANAIMO RIVER
181034	93	25130	66538	37.8	6.7	12May94:12May94	0126-NANAIMO RIVER
181035	93	24896	187781	13.3	6.1	24May94:24May94	0126-NANAIMO RIVER
NOCN9337	93	0	418622	0.0	5.9	05May94:05May94	2726-FIRST LAKE
181323	94	25286	96450	26.2	6.6	24May95:25May95	0126-NANAIMO RIVER
181324	94	25147	95919	26.2	6.6	24May95:25May95	0126-NANAIMO RIVER
182159	94	25347	111844	22.7	5.5	04May95:04May95	0126-NANAIMO RIVER
NOCN9418	94	0	153376	0.0	6.9	16May95:16May95	2726-FIRST LAKE

Tag code: refers to Coded Wire tag code (NOCN refers to releases unassociated with a given tag code)

BY: refers to brood year

Data compiled from the Mark Recovery Program (MRP) database (Kuhn 1988)

Table 4. Trap efficiency data for the rotary screw trap, 1996.

Date	Releases		Recoveries		Efficiency	
	Wild	Hatchery	Wild	Hatchery	Wild	Hatchery
06-Mar	73	299	8	11	10.96	3.68
20-Mar	773	608	24	11	3.10	1.81
03-Apr	1000	390	19	7	1.90	1.79
23-Apr	326	279	8	6	2.45	2.15
01-May	32	346	0	14	0.00	4.05
13-May	450	177	0	16	0.00	9.04
30-May		289		14		4.84
Total:	2654	2388	59	79	2.22	3.31

Table 5. Egg to fry chinook survival estimates[1] , 1995 brood year, Nanaimo River.

Brood Year	Escapement Estimate	% Females	Estimated Females	Fecundity	Estimated Egg Production	Estimated Fry	Egg/fry Survival
1995							
Fall Stock	1679	42 %	693	4285	2,969,505		
Spring Stock	100	42 %	42	3817	160,314		
Total Stock					3,129,819	366,725	11.7%
					Minimum:	348,352	11.1%
					Maximum:	385,006	12.3%

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[1] Escapement estimate based on fence count and swim survey data.

Fecundity data provided from broodstock data (Preston, pers comm.)

FIGURES

Fig. 1 Trap sampling and hatchery release sites on the Nanaimo River.

Juvenile Trapping sites:

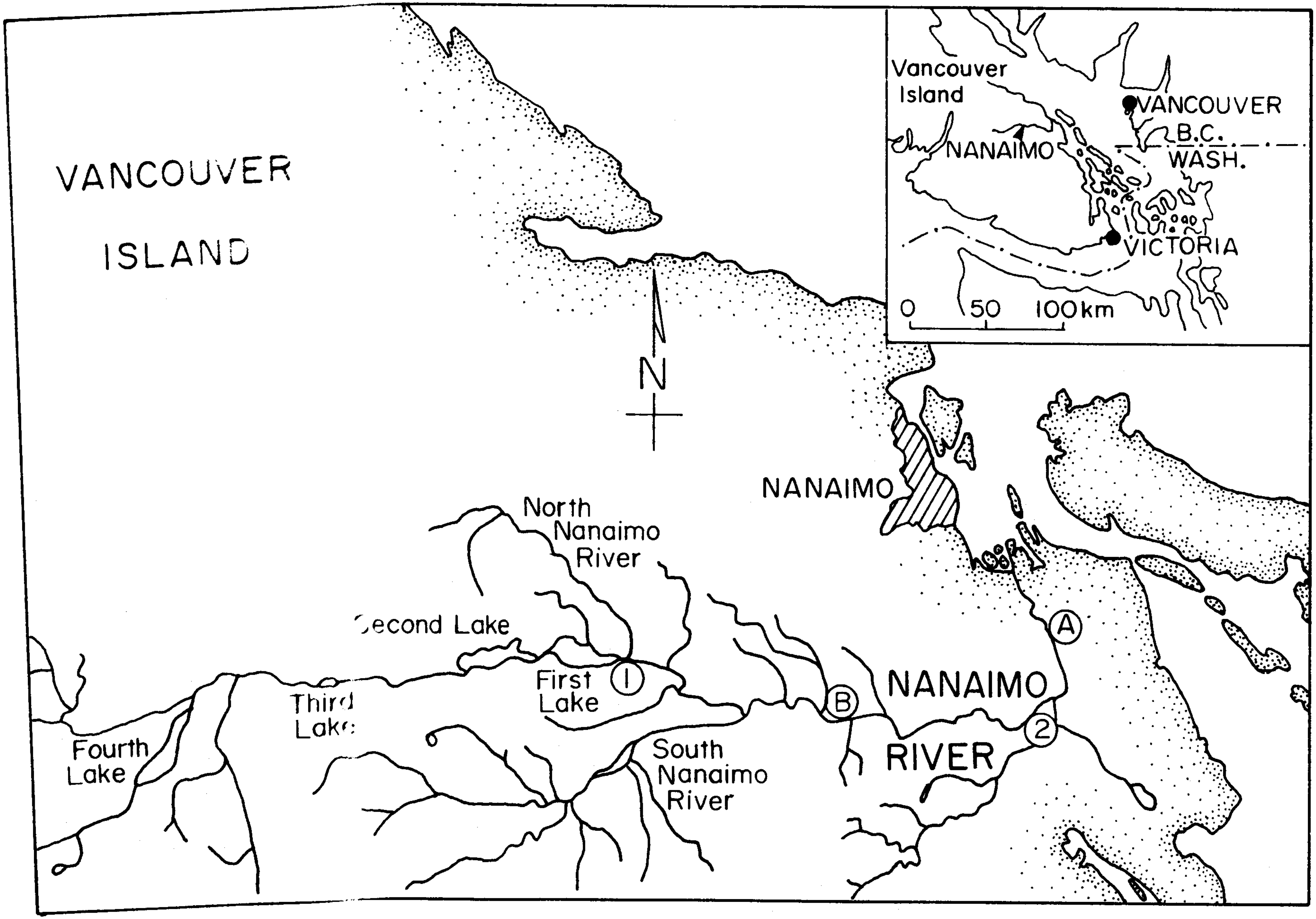
A - Rotary auger trap

B - Inclined plane trap

Nanaimo hatchery chinook release sites:

1 - Spring stock upper river site

2 - Fall stock lower river site


VANCOUVER ISLAND
N
NANAIMO
North Nanaimo River
Second Lake
First Lake
Third Lake
Fourth Lake
South Nanaimo River
NANAIMO RIVER
A
B
1
2
Vancouver Island
NANAIMO
VANCOUVER
B.C.
WASH.
VICTORIA
0 50 100km

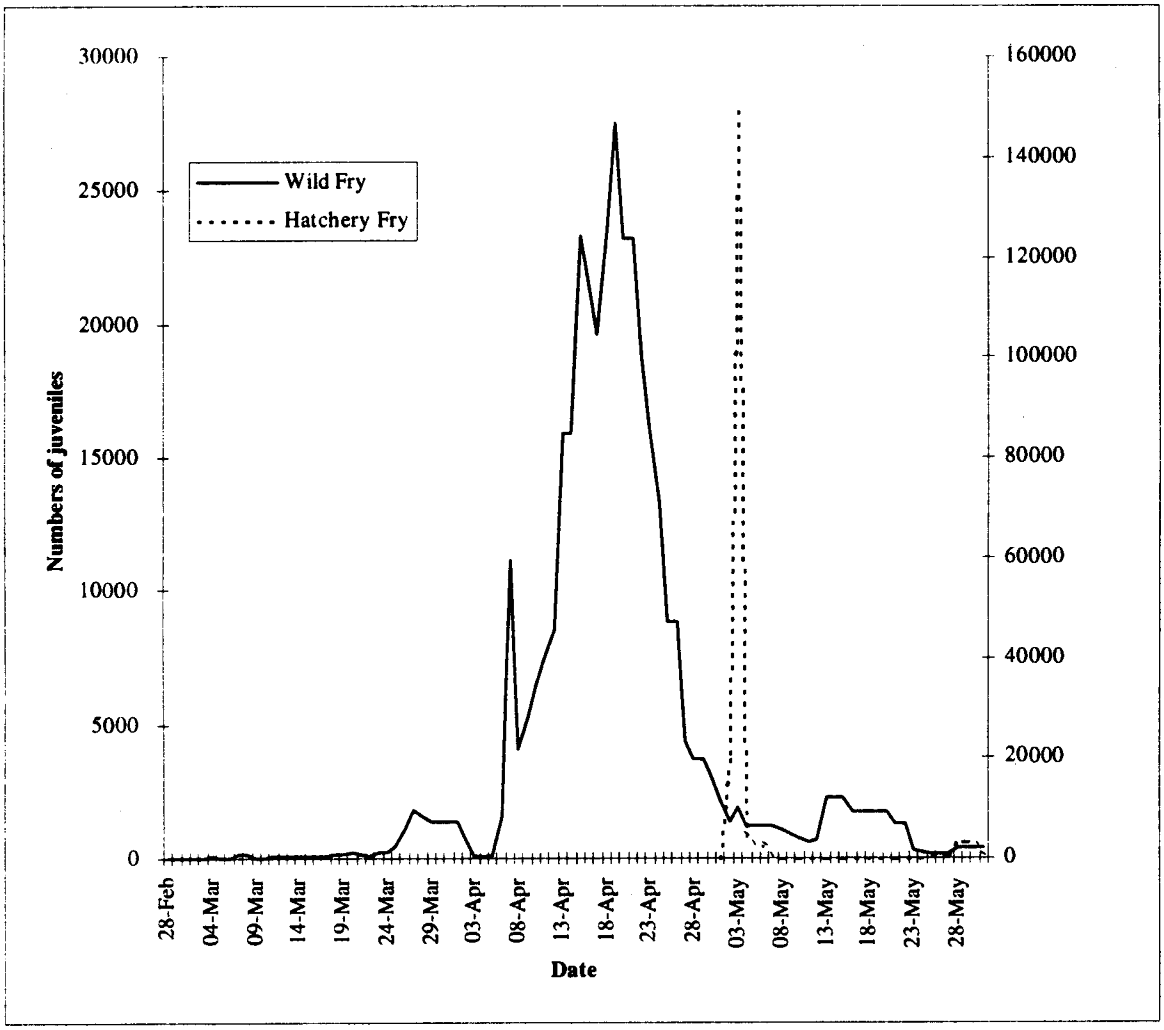


Fig. 2. Expanded estimates of chinook juvenile migration by day at the trap site, Nanaimo River, 1996.

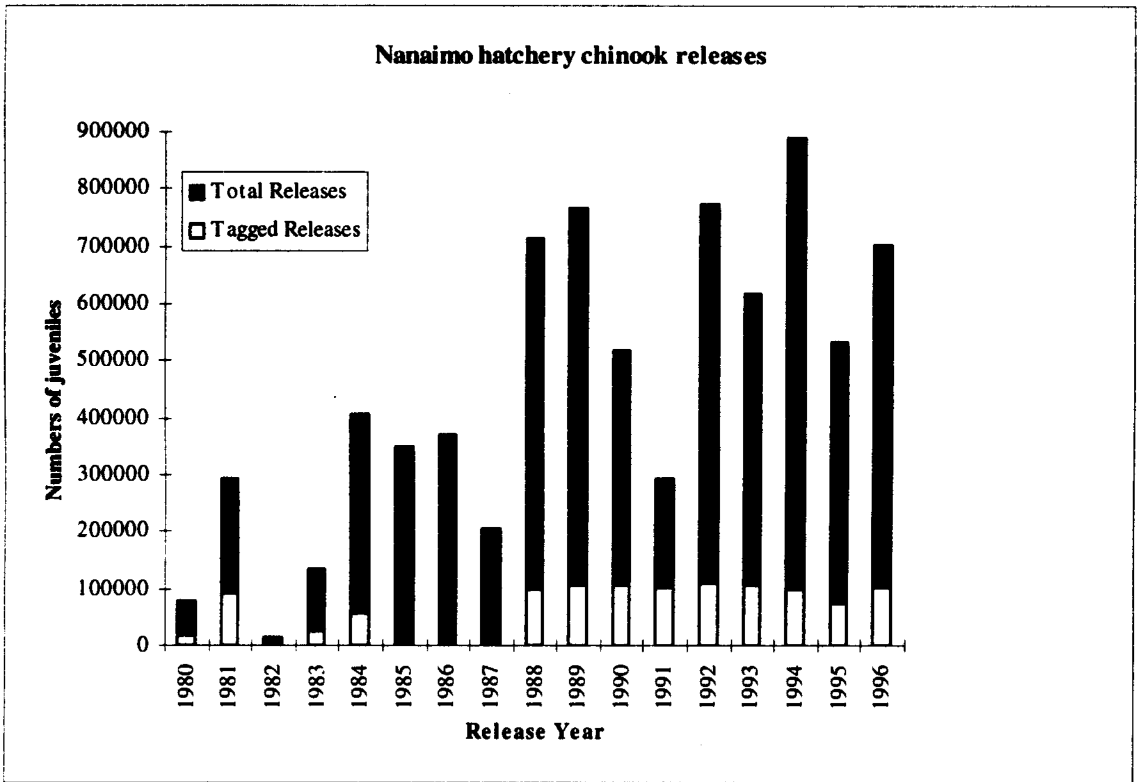


Fig. 3. Hatchery chinook released into the Nanaimo system as fry (3 g) and as pre-smolts (6 g).

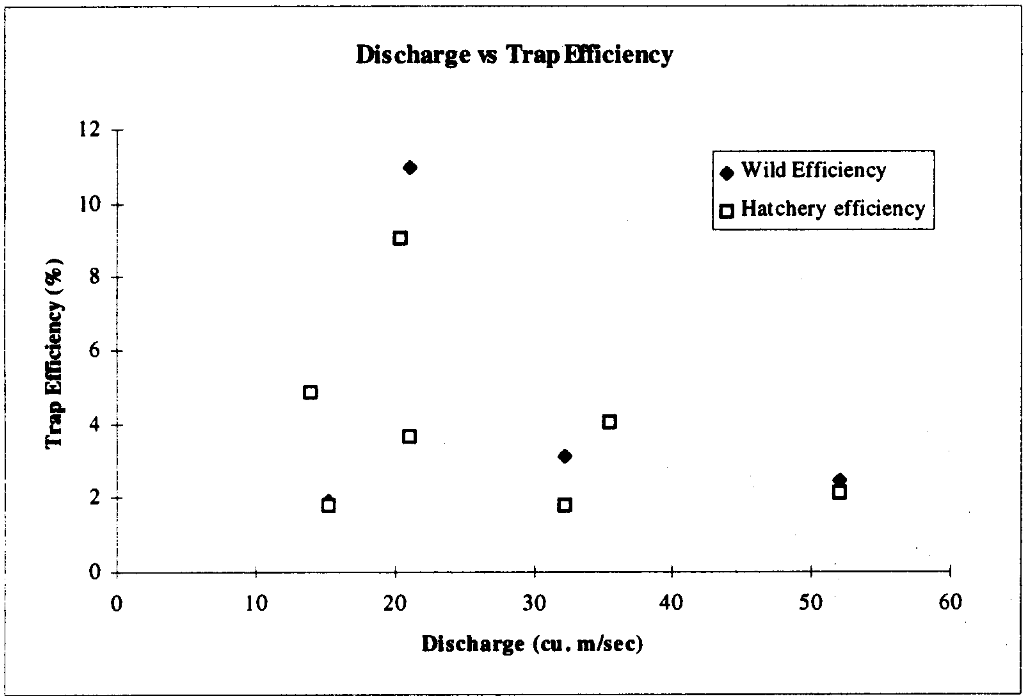


Fig. 4. Trap efficiency compared with the flow at the trap and river discharge.

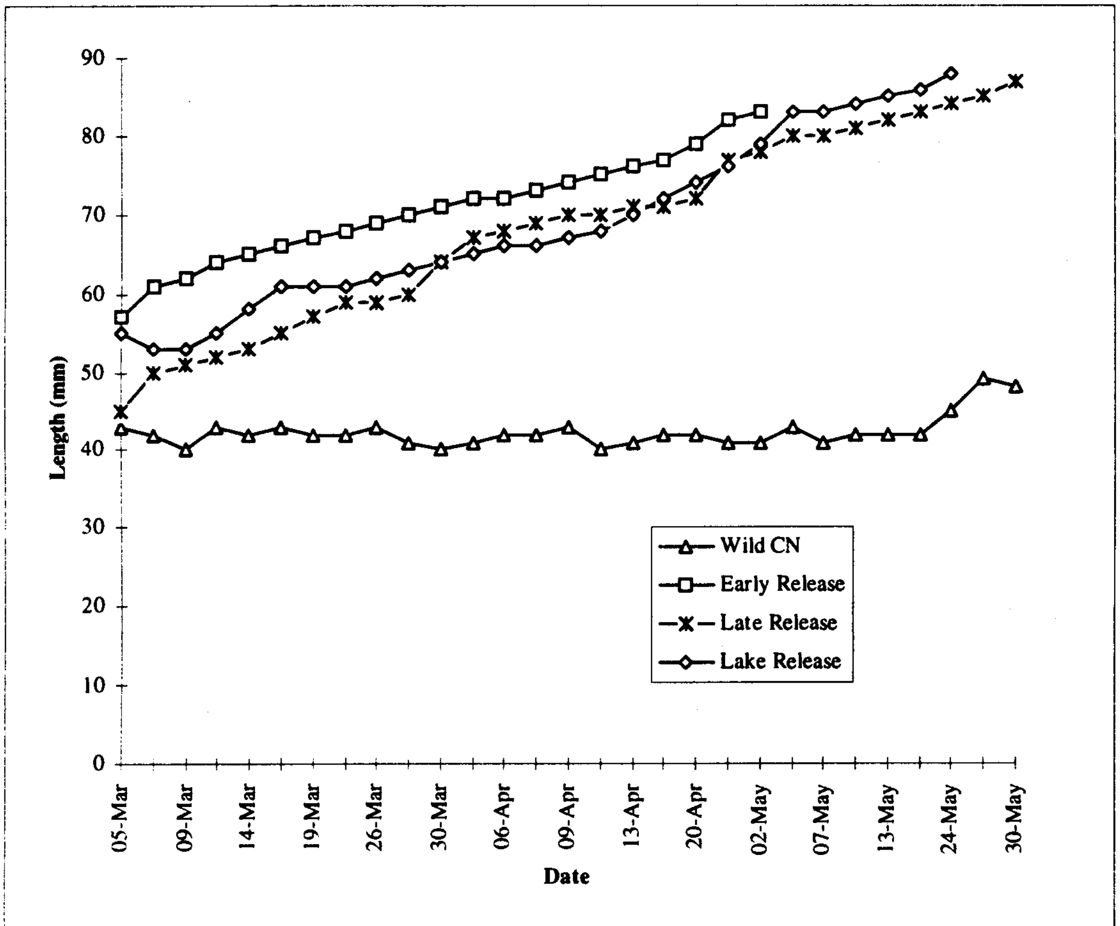


Fig. 5. Mean length of chinook fry by day, Nanaimo River, 1996

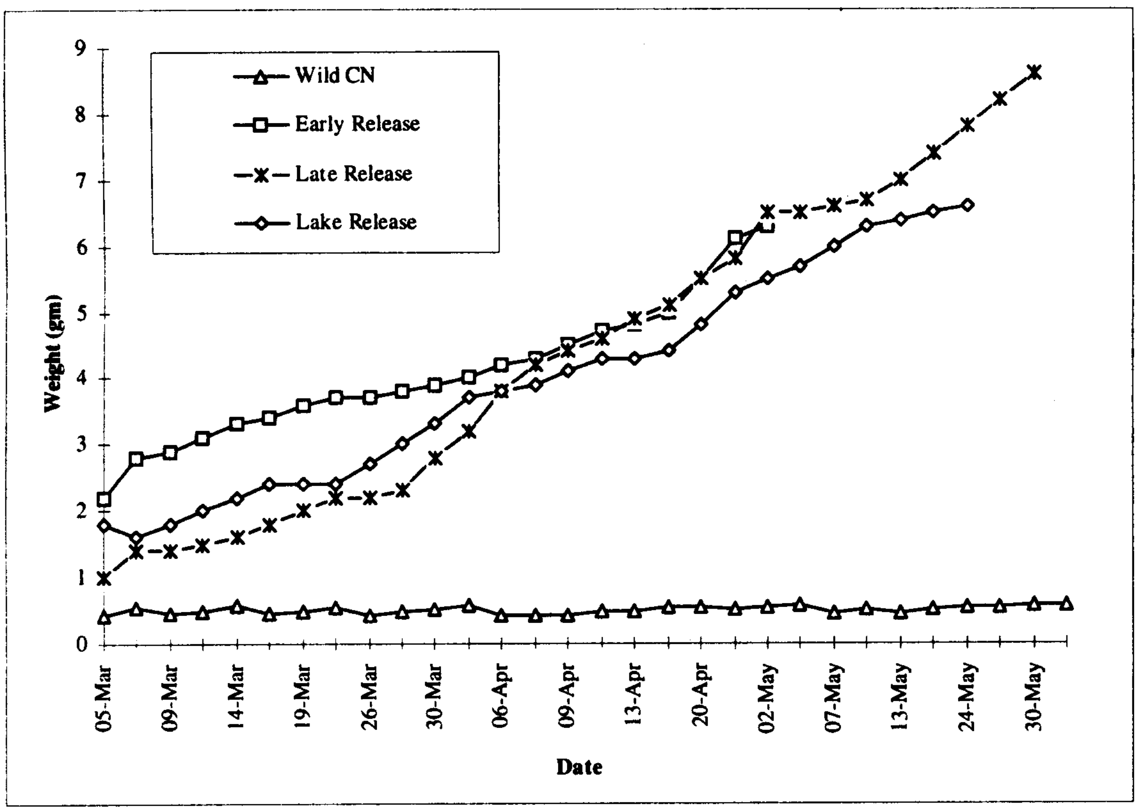


Fig. 6. Mean weight of chinook fry by day, Nanaimo River, 1996.

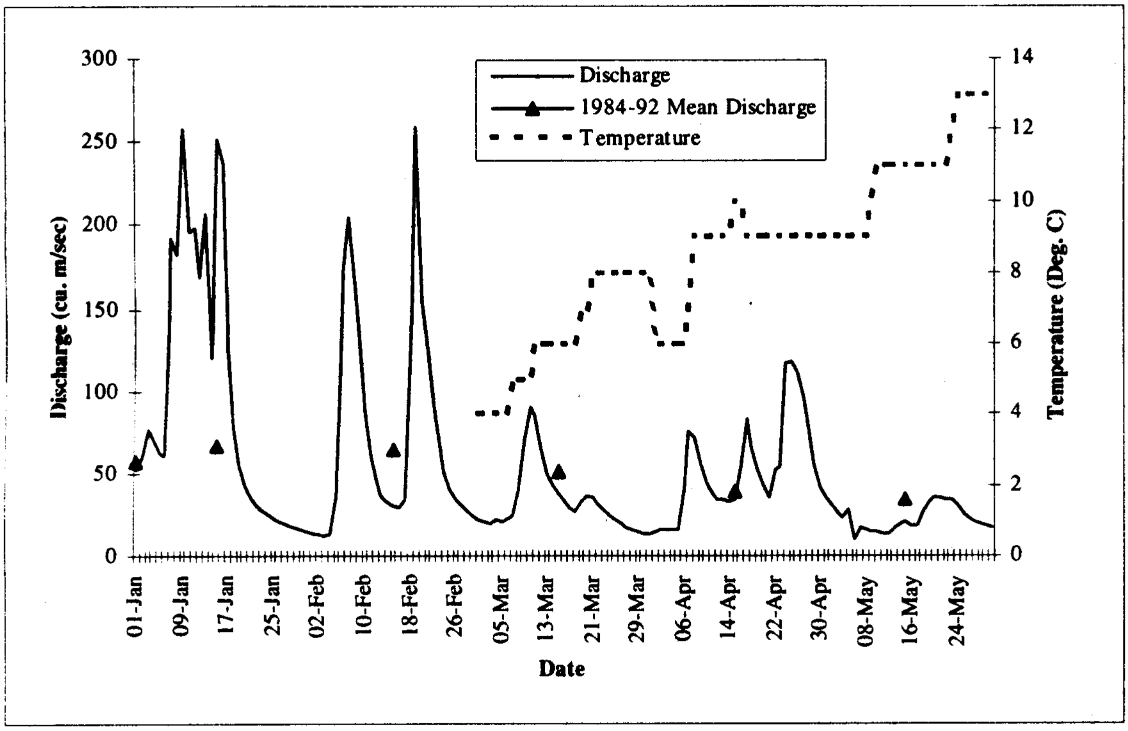


Fig. 7. Monthly discharge measured at the Island Highway bridge in Nanaimo.

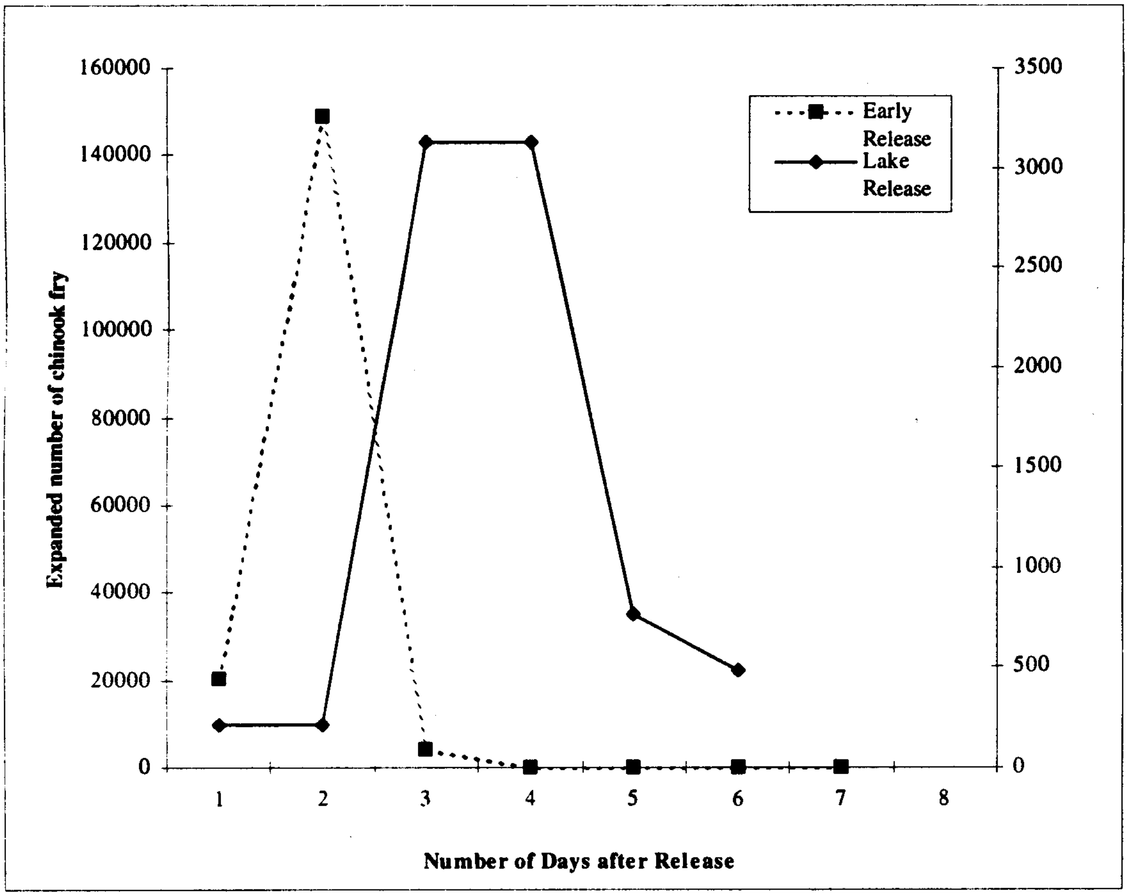


Fig. 8. Hatchery chinook recoveries at the trap site, 1996.