A Preliminary Report on the Adult Chinook Productivity Study Conducted on the Nanaimo River During 1995

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A PRELIMINARY REPORT ON THE ADULT CHINOOK PRODUCTIVITY STUDY CONDUCTED ON THE NANAIMO RIVER DURING 1995

by

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ABSTRACT

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In 1995, the Science Branch, Pacific Biological Station in co-operation with Nanaimo First Nation initiated a productivity study of chinook salmon (*Oncorhynchus tshawytscha*) in the Nanaimo River. Areas of concentration for this study included: i) enumeration of returning chinook; ii) collection of biological and coded-wire tag (CWT) data; iii) estimation of returning chinook using a carcass mark-recapture project as a comparison. Based on the enumeration fence count, we estimated the total return of adult fall chinook to the Nanaimo River to be 1903 in 1995. After removal of broodstock by the hatchery, the number of natural spawners was estimated at 1592 for fall chinook. Based on swim survey and overflight information, the spring chinook stock was estimated to be 100 adult spawners. We also examined the effects of a water management plan implemented in 1989 to aid the upstream movement of fall chinook.

RÉSUMÉ

Carter, E. W. and D. A. Nagtegaal. 1997. A preliminary report on the adult chinook productivity study conducted on the Nanaimo River during 1995. Can. Manuscr. Rep. Fish. Aquat. Sci. 2414: 31 p.

En 1995, la direction des sciences de la Station biologique du Pacifique, en collaboration avec la Première Nation Nanaimo, a entrepris une étude sur la productivité du saumon quinnat (*Oncorhynchus tshawytscha*) dans la rivière Nanaimo. Cette étude comportait les volets suivants: i) dénombrement des quinnats en remonte; ii) collecte de données biologiques et relatives aux micromarques codées; iii) estimation des quinnats en remonte au moyen d'un projet de marquage et de recapture des carcasses, à titre de comparaison. Selon le dénombrement réalisé aux barrières de dénombrement, nous avons estimé à 1 903 la remonte totale de quinnats adultes d'automne dans la rivière Nanaimo en 1995. Après prélèvement des géniteurs par l'écloserie, on a estimé à 1 592 le nombre de géniteurs naturels chez le quinnat d'automne. Selon des relevés effectués dans l'eau et des informations obtenues par voie aérienne, le stock printanier de quinnat a été estimé à 100 géniteurs adultes. Nous avons aussi examiné les effets d'un plan de gestion de l'eau mis en oeuvre en 1989 pour favoriser la montaison du quinnat d'automne.

INTRODUCTION

Since 1988, considerable interest has been focused on the status of chinook salmon (*Oncorhynchus tshawytscha*) stocks in the lower Strait of Georgia. Fisheries and Oceans Canada (DFO) implemented a chinook productivity study on the Cowichan River in the fall of 1988. Along with the Cowichan and Squamish Rivers, the Nanaimo River is one of the Lower Strait of Georgia indicator stocks where spawning escapement information has also been collected in an attempt to evaluate rebuilding strategies and harvest management policies for these stocks (Farlinger et al. 1990). In 1995, DFO, Science Branch, Pacific Biological Station, in conjunction with the Nanaimo First Nation initiated a more intensive study of chinook productivity on the Nanaimo River.

There are at least four distinct chinook life history patterns within the Nanaimo River (Ministry of Environment, Lands and Parks, 1993). Both the upper and lower fall chinook enter the system in August and hold until water conditions allow their passage into their respective spawning habitats. After the eggs have hatched, fry from both of these stocks rear for approximately 90 days before migrating to sea. These are referred to as ocean type chinook. Virtually all chinook in the lower Nanaimo River are ocean type (Healey and Jordan, 1982). The two upper spring chinook stocks enter the system in February, migrate upstream during spring runoff, and hold in lakes or deep river pools until spawning in October. Fry from one stock are ocean type while fry from the second stock are stream type which rear in freshwater for up to one year before migrating to sea.

Due to increased fishing pressure, habitat degradation, and other environmental influences, Nanaimo River natural chinook stocks have declined. In order to help maintain and enhance the stocks, hatchery production was introduced.

Hatchery production of chinook on the Nanaimo River began in 1979 (Cross et al. 1991). In that first year, eggs were incubated at the Pacific Biological Station and later released into the river. The first year of production at the hatchery facility was 1980 (1979 brood) when 100,000 chinook fry were released. Over the years this number has increased and in 1995 there were about 480,000 fry released. Coded-wire tagging (CWT) of chinook began in 1979 and by 1995, 25% of chinook fry were coded-wire tagged (P. Preston, pers. comm.).

In addition to chinook, the Nanaimo River also supports stocks of coho salmon (*O. kisutch*), chum salmon (*O. keta*), pink salmon (*O. gorbuscha*), steelhead trout (*O. mykiss*), cutthroat trout (*Salmo clarki clarki*), and Dolly Varden (*Salvelinus malma*).

In consultation with various user groups, the B.C. Ministry of Environment, Lands and Parks (MOELP) initiated a Nanaimo River Water Management Plan in June 1989. The primary goal was to increase flows during typically low water levels in the fall and thereby improve salmon escapement while maintaining adequate flows to satisfy industrial and domestic use. Without this water release, many salmon would be unable to migrate upstream and would suffer pre-spawn mortalities. The presence of the enumeration fence in 1995 made it possible to measure the effectiveness of the water release.

The purpose of this report is to present the results and describe the methodology of the adult enumeration study of the fall chinook stock and to summarize additional survey data collected on the spring stock on the Nanaimo River during the fall of 1995.

METHODS

For the fall stock, we estimated escapement using two methods; i) enumeration of chinook salmon at the counting fence; ii) carcass mark-recapture studies for adult and jack chinook. Spring stocks were estimated using swim survey and overflight information.

Until 1993, chinook escapement estimates have been made by Fisheries Officers during two flights over the Nanaimo River (H. Poschmann, pers. comm). Since then, hatchery staff have independently participated in overflights and conducted swim surveys to assist in determining the number of chinook in the system. In 1995, the enumeration fence was the most reliable source for estimating the number of fall chinook entering the system.

STUDY AREA

The Nanaimo River flows easterly from the origin at Mount Whymper for 56 km to it's mouth at the south end of Nanaimo Harbour (Fig. 1). The river flows through Second and First Nanaimo Lakes but has many tributary lakes, rivers and creeks. The Nanaimo River drains a watershed of 813 km^2 and carries a mean annual discharge of 39.3 m^3/sec for the years 1966-1988 (Water Survey of Canada).

Two man-made reservoirs (South Fork and Jump Lake) owned by the Greater Nanaimo Water District to supply water to residents, and one reservoir (Fourth Lake) owned by MacMillan Bloedel Harmac Division to supply the Harmac pulpmill, influence water flow in the Nanaimo River. The principal effect of these reservoirs has been to increase flows during periods of low flow, between late summer and early fall maintaining a minimum flow of 1.38 m^3/sec. (Ministry of Environment, Lands and Parks, 1993).

White Rapids Falls (Fig. 2), located several kilometres upstream of the Island Highway, impedes the migration of spring and fall chinook when periods of low flow occur. This problem was partially solved in 1989 when blasting occurred to eliminate the low flow velocity rock barrier. Further alterations were made to create a plunge pool at the base of the falls. Finally, a cement fishway was constructed in 1992-93 allowing significantly easier passage for spawning chinook (P. Preston, Pers. Comm).

CONSTRUCTION OF COUNTING FENCE

We selected a fence site approximately 1.5 km upstream of the Nanaimo River estuary and well within tidal influence. The site we chose was about 90 m wide. Cost of materials and labour made it necessary to use two different types of fence designs and to construct a bulkhead in the middle of the river for the fences to tie into. The two fence designs used were a resistance-board weir and a less expensive, cedar panel/vexar type.

Crews began installing the resistance-board type weir in late July 1995 which comprised about half of Nanaimo River fence. This design is modelled after the Cowichan River fence used in that river system since 1990 and is able to adjust to changes in water depth and flow (Nagtegaal et al. 1994).

The weir consisted of twenty-five 1.2 x 6 m panels connected together to form a picket fence. Each panel was constructed of seventeen 6 m x 3.2 cm Schedule 40 PVC pipes, connected together with 1.2 m x 3.2 cm Schedule 80 PVC cross braces and 3.8 cm stainless steel gear clamps (Fig. 3). Wood cross braces (5 x 7.6 cm pressure treated wood) were used at the base of each panel and where the resistance boards were attached. Aluminum pipes (6m x 3.2 cm Schedule 40) threaded through aluminum couplings joined panel sections together and allowed lateral movement of the fence.

The resistance boards were made of a 122 x 61 x 5 cm styrofoam sheet laminated on either side with 0.6 cm plywood and bolted together. The resistance board was connected to the panel's cross brace using heavy duty galvanized hinges. The other side of the resistance board was held in place beneath the panel using galvanized chain allowing for adjustment to the correct angle to maintain bouyancy.

Panels were secured to the riverbed using steel rail. Fifteen 6 m lengths of railroad rail were placed on the riverbed and fastened together with rail connectors. Each length of rail had two 46 x 46 x 46 cm blocks of cement fastened to it. Steel eyes were welded to the top of the rail at intervals corresponding to the spacing of connectors on the fence panels. The rails were laid perpendicular to the river flow in a pre-excavated trough and back-filled with river gravel leaving only the top of the rail exposed. In addition, rails were held in place using duckbill anchors which consisted of 0.9 cm galvanized cable attached to 5 x 25 cm aluminum pipe. The cable was secured around the rail and the pipe driven into the substrate upstream which would lock it into place.

At the base of each panel, two stainless steel plates and pipes were fastened to the wood cross brace (Fig. 4). Pipe and t-bar connectors were threaded onto 0.9 cm galvanized cable which ran through the eyes on the rail. Panels were attached to the rail by sliding the plate/pipe over the t-bar and threading 0.3 cm airline cable from the top of the panel, down through the t-bar and back up to the top where the cable was secured by pipe clamps. This system allowed for removal and repair or replacement of an individual panel if one should be damaged.

The panels were butted up against a fish trap on one side of the river and a bulkhead in the middle of the river. The bulkhead was constructed using 5 x 7.6 cm pressure-treated wood and was 4.3 x 2.4 x 3.7 m . The upstream end was pointed to deflect flow. Approximately 1 m of the bulkhead was buried into the river bottom and 1.5 m was above the water. The bulkhead was filled with gravel to about 1 m from the top to ensure stability.

The second side of the fence was made of 17 cedar panels. Each panel was 3 x 2.4 m constructed of 5 x 5 cm rough cedar frame and covered with 5 cm plastic vexar fencing. Floatation for each panel was provided by a 30 cm x 30 cm x 3 m styrofoam block attached to the top of the panel. At the base of each panel, approximately 0.6 m from either end, were two 2.5 x 20 cm aluminum pipes held in place by 0.3 cm airline cable which ran from the top of the panel, around the pipe and back to the top where it was tightened and secured by cable clamps. After encountering several very high tides we added 3 x 0.6 m cedar/vexar panels to increase the height of each panel to 3 m.

Panels were connected to the rail by threading 0.9 cm galvanized cable through the eyes on the rail and through the aluminum pipes on the panels. The cable was secured to an eye on the rail at the centre bulkhead and tensioned after each panel was installed. Once all panels were in place, the cable was secured to another eye at the end of the rail at a second bulkhead on shore. This bulkhead consisted of three 5 x 3 m panels constructed of 5 x 7.6 cm pressure-treated wood. Bulkhead panels were tied together using 1 cm cable and to the shore using duckbill anchors.

The fish trap was also constructed of 5 x 7.6 cm pressure-treated wood and was similar in design to that described by Nagtegaal et al. (1994) with a sliding gate at the trap opening which could be closed while the fence was being maintained. A wooden 3.6 m counting tower was built on the bank adjacent to the fish trap. This allowed observers to view downstream and upstream of the fence in addition to having a clear view of fish passing through the trap. The tower was supplied with 110 v power and floodlights were used at night to enhance counting.

FENCE OPERATION

Observations at the fence began on 08 August 1995 with fish counts being recorded in 15-minute intervals for adult and jack chinook, adult and jack coho and chum. When identification was in doubt, fish were recorded in the unknown category. Other information including water depth, water temperature, water clarity, and weather was recorded three times daily. Fence staff were responsible for keeping the fence clear of leaves and other debris to ensure optimal operating capability. For safety reasons, cleaning was only done during daylight hours and when two or more people were at the fence site.

COUNTING SURVEYS

As in previous years, swim and aerial surveys were jointly conducted by Nanaimo River hatchery staff, Nanaimo First Nation members and DFO employees to estimate numbers of spawning chinook. Surveys were carried out independently and without knowledge of counts from previous surveys which may bias the results. Swim surveys in the vicinity of First Lake were conducted on 28 June, 03 August, 31 August, 27 September and 28 September to estimate number of spring chinook. Swim surveys in the lower river between the highway bridge and the estuary were conducted on 31 August, 22 September, and 27 September to estimate the number of fall chinook. In addition, two fixed wing overflights and a helicopter overflight were conducted on 01 September, 20 September and 15 October, respectively, to estimate the number of chinook from both spring and fall chinook stocks.

Swim surveys were normally carried out using three to five swimmers and a person in a boat. Swimmers attempted to stay abreast of each other while moving downstream and counts were made independently. Swimmers relayed their counts to the boat operator who recorded the counts by pre-defined localities in the river (Fig. 2).

BIOLOGICAL DATA - MARK-RECAPTURE

Biological data were collected primarily from spawned out chinook carcasses collected and marked during a mark and recapture carcass recovery program on the spawning grounds. Additional data were collected from pre-spawn mortality chinook which floated downstream onto the fence.

The carcass recovery operation involved a two or three-man crew in an inflatable boat searching the river daily for spawned out chinook carcasses. The search was concentrated on the fall chinook stock in the area of highest spawning activity between the Island Highway bridge and San Salvadore (Fig. 2). Occasional excursions were made to a section of river approximately one km below First Lake but with little success locating spring chinook stock carcasses. We investigated these areas in an attempt to estimate spring chinook escapement since our fence operation was not in place until after these fish were already in the system.

Each carcass was tagged with a numbered Ketchum[1] aluminum sheep ear tag on the left operculum and released into the river. Any time a previously captured carcass was recovered, the tag number and location were recorded. Information taken for each chinook carcass included capture location, orbital-hypural length, sex, scale sample, and presence or absence of adipose fin. If the adipose fin was absent, indicating a coded-wire tagged fish, the head was removed and placed in a bag with a numbered label. Heads were later catalogued and shipped to J.O. Thomas' lab for decoding of cwt's. In addition, 100 otoliths were collected to assist in age verification.

[1] Ketchum Manufacturing Ltd., Ottawa, Canada

ESCAPEMENT ESTIMATE

In addition to the fence counts, adult chinook escapement estimates for the fall stock were also generated from the carcass mark-recapture data using a simple Petersen model (Chapman modification; Ricker 1975). Although the fence counts were considered accurate, the mark-recapture data enabled us to estimate the proportion of males and females in the population.

Population estimates for the spring stock were primarily based on swim surveys in the vicinity of First Lake and on the overflights. Our attempts to recover carcasses immediately downstream of First Lake and include these in a mark-recapture estimate for the spring stock were unsuccessful.

WATER MANAGEMENT PLAN

As discussed, the three man-made reservoirs in the Nanaimo River system have been utilized to increase flows during periods of low flow between late summer and early fall. Prior to 1989, water releases were conducted based on an informal arrangement between local Fisheries Officers and Harmac Pacific. Fisheries Officers would request a water release depending on the number of fish holding in the lower end of the river and the request would be granted once Harmac had determined whether there was sufficient water in reserve to release.

A test water release of ~10 m^3/sec was conducted in 1989. A release flow target of 4 days at 11.3 m^3/sec was established by DFO in consultation with Nanaimo River Hatchery staff. Continuation of the fall water releases from the reservoirs since 1989 have enhanced spawning migration. These releases have taken place during late September or early October depending on the volume of stored water available. The water release in 1995 took place between 26 and 28 September.

RESULTS AND DISCUSSION

ENUMERATION FENCE

The counting fence was in continuous operation from 08 August until 16 October 1995 when it was evident that virtually all chinook were in the system. We encountered continuous problems with fish refusing to pass through the trap. We observed fish holding below the fence, swimming from side to side, even entering into the mouth of the trap, but usually turning back to once again hold below the fence. The low flow in the Nanaimo River may be a cause of the poor fish movement. An attempt was made to divert water and increase flow through the trap by placing and anchoring plywood in the river upstream of the fence. Unfortunately, this had little effect on flow or fish movement.

A possible solution to the flow problem may be to excavate a longer, wider, deeper trough leading up to the opening on the downstream end of the trap and/or to build a larger barrier upstream to divert greater amounts of water through the trap. The larger holding area below and potential increased flow may encourage fish to swim through the trap.

The first large pulse of chinook (548 adults, 813 jacks) passing through the fence occurred on 8 September when we herded fish upstream with a seine net from a large pool where they had been holding (Table 1). The second large pulse (1122 adults, 1995 jacks) occurred on 26 September following the water release when we removed a panel from the fence close to the observation tower. Staff had noticed several hundred fish holding below the fence. Final counts indicate that jack chinook comprised about 64% and adult chinook about 36% of the run.

Since the two large pulses were related to human intervention, it was difficult to determine a particular time interval when a larger proportion of chinook naturally moved past the counting fence. With this in mind, the period between 0900 and 1100 h showed the highest percentage of movement with 42% of adults and jacks (Table 2). Another peak occurred between 1500 and 1600 h with 25% of adults and 18% of jacks passing the fence.

Comparisons of fish movement to water depth and temperature (Table 3) indicated no obvious trends although on a rising tide staff observed more fish holding below the fence.

The floating fence design worked well provided that debris was removed regularly. Although surface debris could be easily removed from the resistance-board fence panels, the low flow in the river allowed large amounts of algae to build up beneath the fence and was difficult to remove. The cedar/vexar panels were much more difficult to clean. Heavy build up of algae caused the fence to submerge on 10 October. We were able to raise the resistance-board fence but were unable to raise the cedar panel/vexar section. The fence remained operational with few fish passing over the top.

SWIM AND AERIAL SURVEYS

Because the counting fence was put into place on 08 August, the intention was to enumerate the fall chinook run. Swim surveys conducted prior to fence installation were used to estimate the spring chinook stock (Table 4). Estimates below the counting fence by aerial surveys on 01 September and 20 September (1000 and 2500 chinook) were corroborated by large movements of chinook through the fence on 08 September (1374) and 26 September (3011) (Table 1). In addition, the swim survey estimate on 22 September compared favourably with the aerial survey count from 20 September.

BIOLOGICAL DATA - MARK-RECAPTURE

The carcass recovery program began on 17 October and was discontinued on 3 November. Heavier rain typically associated with the fall, and resulting increase in water flows and suspended debris create problems when attempting to recapture carcasses in the river. Commonly, carcasses are swept off the spawning grounds and into deep pools or back eddies where recovery can be quite difficult. Given the conditions in 1995 we were able to sample about 9% of the chinook that passed the counting fence.

During the sampling period 464 carcasses were examined and 173 of these were recaptured (Table 5). There were more males than females recovered (50.7%, 37.3%) with the jacks making up the balance (12.0%). Adult chinook were comprised of 3, 4, and 5 year olds with the majority being 3 year olds (Table 6). The escapement estimate of adults based on carcass mark-recapture data was 1466 (Table 8) with lower and upper 95% confidence limits of 1367 and 1565, respectively. Based on the mark-recapture data, the simple Petersen model underestimated the fence count by 23%.

Length-frequency data from carcass recovery show a larger mean length for females compared to males and jacks (65.2 cm, 60.1 cm, 41.1 cm, respectively; Table 7).

From the mark-recapture data we determined an adipose-clip mark rate of 15.4% of the total run. The mark rate for males was 16.6%, females 11.5%, and jacks 22.2%. As mentioned, the hatchery adipose-clip mark rate is about 25% of the chinook released. Coded-wire tag data showed that all but two chinook were Nanaimo River releases and the majority (58%) were 1992 brood year (Appendix Table 1).

ESCAPEMENT ESTIMATE

The fence count was considered to be the most accurate estimate of escapement since it was a direct count of fall chinook moving into the system. The fence was situated close to the river mouth so there was very little possibility of chinook spawning downstream of the fence. In addition, chinook selected for broodstock by the hatchery were removed upstream of the fence so these would also have been accounted for at the fence. Based on counts at the enumeration fence, we estimated the total return of fall run adult chinook to be 1903 and jack chinook to be 3324.

Chinook entering the system prior to fence installation were enumerated using swim and aerial surveys. According to these surveys, the escapement estimate for spring chinook in 1995 was 100 adults and 200 jacks.

Chinook escapements have fluctuated over the last 20 years from a low of 210 (1981) to a high of 3000 (1984; Table 9) . The adult return in 1995 represents the highest in ten years and gives reason for optimism for the survival and increase of Nanaimo River chinook stocks.

WATER MANAGEMENT PLAN

With the increase in population in the Nanaimo area and in an effort to satisfy domestic, industrial, agricultural, fishery, wildlife, and recreational needs, a Nanaimo River Water Management Plan was initiated by the B.C. Ministry of Environment, Lands and Parks (MOELP) in June 1989. A team comprised of members from the MOELP, Greater Nanaimo Water District, MacMillan Bloedel Limited, Nanaimo First Nation, and Fisheries and Oceans Canada (DFO) negotiated a water flow management plan. The primary water management issue has been to enhance flows to meet fisheries requirements while maintaining flows to satisfy industrial and municipal needs. This is particularly important during periods of lowest flow (September and October) and in the 10 km section of river below the MacMillan Bloedel Harmac pulpmill water intakes.

The low flow and water levels likely result in delayed fish movement and higher water temperatures which may potentially increase levels of disease and parasites. This is particularly true for the parasite Ich (*ichthyophthirius*) which matures more rapidly with higher temperature (Ministry of Environment, Lands and Parks, 1993).

The water release in 1995 occurred on 24 September. Although we did not observe an increase in the number of fish passing through the trap, the water release resulted in an increase of fish moving up to the fence. Removal of a fence panel allowed these fish to pass and was the largest pulse of chinook throughout the monitoring period.

NATIVE FOOD FISHERY

The Nanaimo Indian Band has traditionally fished the Nanaimo River targeting their efforts on chum and chinook salmon primarily using gillnets or spears. A self-imposed ban due to conservation concerns all but eliminated the in-river chinook fishery since the mid-1970's (L. Littlefield, Pers. Comm.).

An in-river chum gillnet fishery still exists and usually commences annually in mid-October. The bulk of the chum quota for the Band is taken in tidal waters off the Nanaimo River and may even come from as far away as Johnstone Strait (J. White, Pers. Comm.).

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LITERATURE CITED

Cross, C.L., L. Lapi, E.A. Perry. 1991. Production of chinook and coho salmon from British Columbia hatcheries, 1971 through 1989. Can. Tech. Tech. Rpt. Fish. Aquat. Sci. No. 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. Manuscr. Rep. Fish. Aquat. Sci. 2064: 236p.

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: iv + 31 p.

Inland Waters Directorate. Historical stream flow summary, British Columbia, 1994. Water Survey of Canada, Ottawa.

Littlefield, Lorraine, 1996. Researcher, Nanaimo First Nation, Treaty Negotiations, 674 Centre Nanaimo, B.C. Personal Communication.

Ministry of Environment, Lands and Parks. 1993. Nanaimo River Water Management Plan. Water Management, Vancouver Island Regional Headquarters

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. 226: 71p.

Poschmann, H. 1996. Fishery Officer, Fisheries and Oceans Canada, 304 - 60 Front Street, Nanaimo, B.C., V9R 5H7. Personal communication.

Preston, P. 1996. Nanaimo River Salmonid Enhancement Project Manager, Community Futures Development corporation of Central Island, 271 Pine Street, Nanaimo, B.C., V9R 2B7. Personal communication.

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

White, J. 1996. Fisheries Guardian, Nanaimo First Nation, 1145 Totem, Nanaimo, B.C. Personal communication.

Table 1. Daily counts at the Nanaimo River enumeration fence, 1995.

Month	Day	No. Chinook Adults	No. Chinook Jacks	No. Coho Adults	No. Coho Jacks	No. Chum
August.	8	2	1	0	0	0
	9	0	0	0	0	0
	10	1	0	0	0	0
	11	0	0	0	0	0
	12	0	0	0	0	0
	13	0	1	0	0	0
	14	0	1	0	0	0
	15	0	1	0	0	0
	16	0	0	0	0	0
	17	0	0	0	0	0
	18	0	0	0	0	0
	19	0	1	0	0	0
	20	1	2	0	0	0
	21	1	2	0	0	0
	22	0	0	0	0	0
	23	0	0	0	0	0
	24	4	5	0	0	0
	25	2	4	0	0	0
	26	2	6	0	0	0
	27	1	2	0	0	0
	28	0	2	0	0	0
	29	3	10	0	1	0
	30	2	3	0	0	0
	31	0	5	0	0	0
September	1	0	0	0	0	0
	2	0	1	0	0	0
	3	0	1	0	0	0
	4	3	0	0	0	0
	5	0	2	0	0	0
	6	0	1	0	0	0
	7	0	2	0	0	0
	8	555	819	1	1	2
	9	1	10	0	0	0
	10	2	2	0	0	0
	11	3	4	0	0	0
	12	18	20	1	4	0
	13	14	50	1	3	2
	14	8	64	0	0	0
	15	3	12	0	0	0

Table 1. (cont'd)

Month	Day	Chinook Adults	Chinook Jacks	Coho Adults	Coho Jacks	Chum
September	16	0	1	0	0	0
	17	3	2	0	2	0
	18	1	0	0	0	0
	19	0	1	0	0	0
	20	3	3	0	3	0
	21	0	1	0	0	0
	22	0	2	0	0	0
	23	3	3	0	0	0
	24	11	38	0	0	1
	25	8	46	1	5	0
	26	1122	1889	10	35	16
	27	29	22	0	1	0
	28	4	6	0	0	0
	29	1	4	0	0	0
	30	0	0	0	1	0
October	1	0	0	0	0	0
	2	9	48	2	5	2
	3	57	85	2	0	8
	4	0	1	0	0	0
	5	0	0	0	0	0
	6	1	5	0	0	3
	7	0	12	0	3	11
	8	4	59	7	4	59
	9	11	31	70	70	370
	10	5	15	26	17	182
	11	1	10	22	21	39
	12	3	6	19	26	75
	13	1	0	2	5	3
	14	0	0	0	1	0
	15	0	0	0	0	1
	16	0	0	0	0	0
Total		**1903**	**3324**	**164**	**208**	**774**

Table 2. Daily counts by time interval at the Nanaimo River enumeration fence, 1995

Time	No. Chinook Adults	Percent	No. Chinook Jacks	Percent
0000-0100	31	1.6	75	2.3
0100-0200	31	1.6	88	2.6
0200-0300	22	1.2	51	1.5
0300-0400	20	1.1	57	1.7
0400-0500	18	1.0	55	1.6
0500-0600	10	0.5	45	1.3
0600-0700	0	0	16	0.5
0700-0800	5	0.2	13	0.4
0800-0900	38	2.0	74	2.2
0900-1000	232	12.2	439	13.2
1000-1100	574	30.2	969	29.1
1100-1200	177	9.3	265	8.0
1200-1300	51	2.7	89	2.7
1300-1400	15	0.8	26	0.8
1400-1500	86	4.5	201	6.1
1500-1600	481	25.3	605	18.2
1600-1700	14	0.7	17	0.5
1700-1800	35	1.8	39	1.2
1800-1900	6	0.3	14	0.4
1900-2000	6	0.3	39	1.2
2000-2100	9	0.5	35	1.1
2100-2200	15	0.8	17	0.5
2200-2300	13	0.7	25	0.8
2300-2400	14	0.7	70	2.1
Total	**1903**	**100.0**	**3324**	**100.0**

Table 3. Average depth and water temperature at the Nanaimo River enumeration fence, 1995.

Month	Day	Depth (cm.)	Temp. (°C)
Aug.	8	66	18
	9	70	19
	10	82	19
	11	86	19
	12	85	19
	13	79	19
	14	85	19
	15	82	18
	16	76	18
	17	71	18
	18	54	18
	19	60	18
	20	61	18
	21	61	18
	22	62	19
	23	62	18
	24	61	18
	25	63	34
	26	77	33
	27	71	18
	28	68	19
	29	72	19
	30	79	18
	31	82	18
Sept.	1	100	18
	2	77	19
	3	74	19
	4	64	18
	5	58	18
	6	61	18
	7	64	19
	8	61	19
	9	76	20
	10	67	20
	11	57	20
	12	62	19
	13	68	19
	14	71	19
	15	70	19
	16	65	19
	17	63	18
	18	60	19
	19	60	19
Sept.	20	58	18
	21	61	18
	22	59	18
	23	63	19
	24	75	17
	25	85	17
	26	76	17
	27	72	17
	28	77	16
	29	76	16
	30	77	16
Oct.	1	78	16
	2	80	14
	3	113	15
	4	74	14
	5	60	14
	6	64	12
	7	70	14
	8	83	14
	9	74	14
	10	107	13
	11	112	12
	12	105	13
	13	95	12
	14	103	12
	15	108	11
	16	108	12

Table 4. Swim and aerial surveys conducted on the Nanaimo River, 1995.

Survey Type	Date	Area	No. Chinook Adults	No. Chinook Jacks
Swim	28 June	Below First Lake	14	2
Swim	03 August	Above/Below First Lake	56	149
Swim	31 August	Above First Lake	2	13
Swim	31 August	Below First Lake	38	168
Swim	31 August	Below Hwy Bridge	2	5
Fixed Wing Aircraft	01 September	Estuary to First Lake	1300[1]	
Fixed Wing Aircraft	20 September	Estuary to First Lake	2500[1]	
Swim	22 September	Fence to Forks	1000	1500
Swim	27 September	Below First Lake	16	29
Swim	27 September	Below Hwy Bridge	486	205
Swim	28 September	Above First Lake	46	56
Swims	02-31 October	Below Hwy Bridge	98[1]	
Swims	02-19 October	First Lake	113[1]	
Helicopter	15 October	Estuary to First Lake	400[1]	
Swims	01-16 November	Below Hwy Bridge	59[1]	

[1] Adult and jack chinook were combined.

Table 5. Summary of Chinook sampled during the carcass recovery program on the Nanaimo River, 1995.

Date	Male		Female		Jacks		Adults
dd/mm	Unclipped	Ad Clip[1]	Unclipped	Ad. Clip	Unclipped	Ad. Clip	Recaptured
17/10	4	2	1				0
23/10	24	4	20	5	4	2	0
24/10	16	6	28	1	3	0	33
25/10	43	8	24	1	12	4	36
26/10	12	1	1	0	1	1	4
27/10	18	2	13	2	2	0	11
28/10	16	4	6	1	3	2	8
30/10	14	3	23	2	6	0	20
31/10	23	5	11	3	2	3	29
01/11	10	1	12	2	5	2	7
02/11	10	2	8	1	4	0	1
03/11	5	2	5	3	0	0	7
Total	195	40	152	21	42	14	156

[1]Adipose fin-clipped

Table 6. Summary of age data for chinook sampled during the carcass recovery program on the Nanaimo River, 1995.

Age	Males	Females	Total
2	80	3	83
3	121	85	206
4	15	42	57
5	3	3	6
Total	219	133	352

Table 7. Length-frequency of chinook sampled during the carcass recovery program on the Nanaimo River, 1995.

Length (cm)	Males	Females	Jacks	Total
28	0	0	1	1
29	0	0	0	0
30	0	0	1	1
31	0	0	0	0
32	0	0	1	1
33	0	0	2	2
34	0	0	1	1
35	0	0	0	0
36	0	0	2	2
37	0	0	1	1
38	0	0	1	1
39	0	0	3	3
40	0	0	1	1
41	0	0	4	4
42	0	0	8	8
43	0	0	9	9
44	0	0	11	11
45	0	0	6	6
46	13	0	0	13
47	11	0	0	11
48	11	1	0	12
49	4	0	0	4
50	1	0	0	1
51	6	0	0	6
52	2	0	0	2
53	1	2	0	3
54	5	0	0	5
55	3	1	0	4
56	6	1	0	7
57	7	2	0	9
58	10	8	0	18
59	10	6	0	16
60	18	9	0	27
61	20	7	0	27
62	8	10	0	18
63	15	22	0	37
64	11	17	0	28
65	21	16	0	37
66	10	12	0	22
67	10	10	0	20
68	5	6	0	11
69	10	8	0	18
70	4	5	0	9
71	2	6	0	8
72	5	6	0	11
73	1	4	0	5
74	3	3	0	6
75	3	5	0	8

Table 7. (cont'd)

Length (cm)	Males	Females	Jacks	Total
76	1	3	0	4
77	0	1	0	1
78	0	2	0	2
Total	**237**	**173**	**52**	**462**
Mean Length	**60.1**	**65.2**	**41.1**	**59.7**

Table 8. Petersen chinook escapement estimates by sex, Nanaimo River, 1995.

Carcass mark-recapture

Sex	Escapement Estimate	95% Confidence Limit Lower	Upper
Male[1]	780	716	844
Female	704	622	786
Total	1466	1367	1565

[1] Adult males only, jacks not included.

Table 9. Total adult chinook returns to the Nanaimo River, 1975-1995.

Year	Natural Spawners	Hatchery Broodstock	Indian Food Fish Catch	Total Returns
1975	475		15	490
1976	880		50	930
1977	2380		60	2420
1978	2125		40	2165
1979	2700	41	23	2764
1980	2900	82	200	3182
1981	210	15	100	325
1982	1090	62	21	1173
1983	1600	240	30	1870
1984	3000	178	50	3228
1985	650	264	185	1099
1986	700	258	190	1148
1987	400	357	50	807
1988	650	429	0	1079
1989	1150	402	0	1552
1990	1275	122	0	1397
1991	800	135	0	935
1992	800	377	0	1177
1993	850	528	0	1378
1994	400	280	0	742
1995	2003[1]	311[2]	0	2003

[1] **Count at enumeration fence plus estimate of summer run.**
[2] **Included in Total Returns, collected above fence.**

FIGURES

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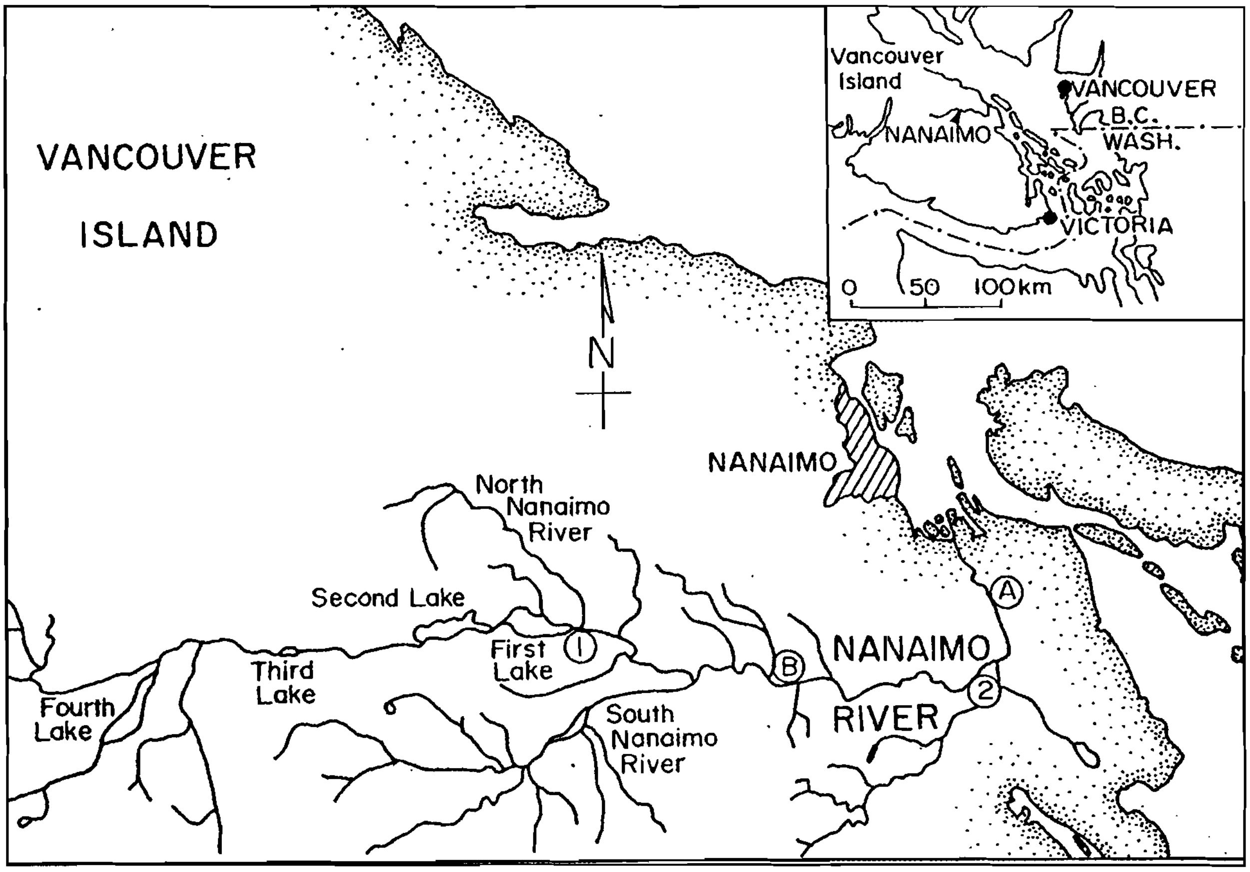

Figure 1. Nanaimo River study area.

LEGEND:

1	Hatchery Release Site
2	Hatchery Release Site
A	Enumeration Fence Site
B	Downstream Fry Trapping Site

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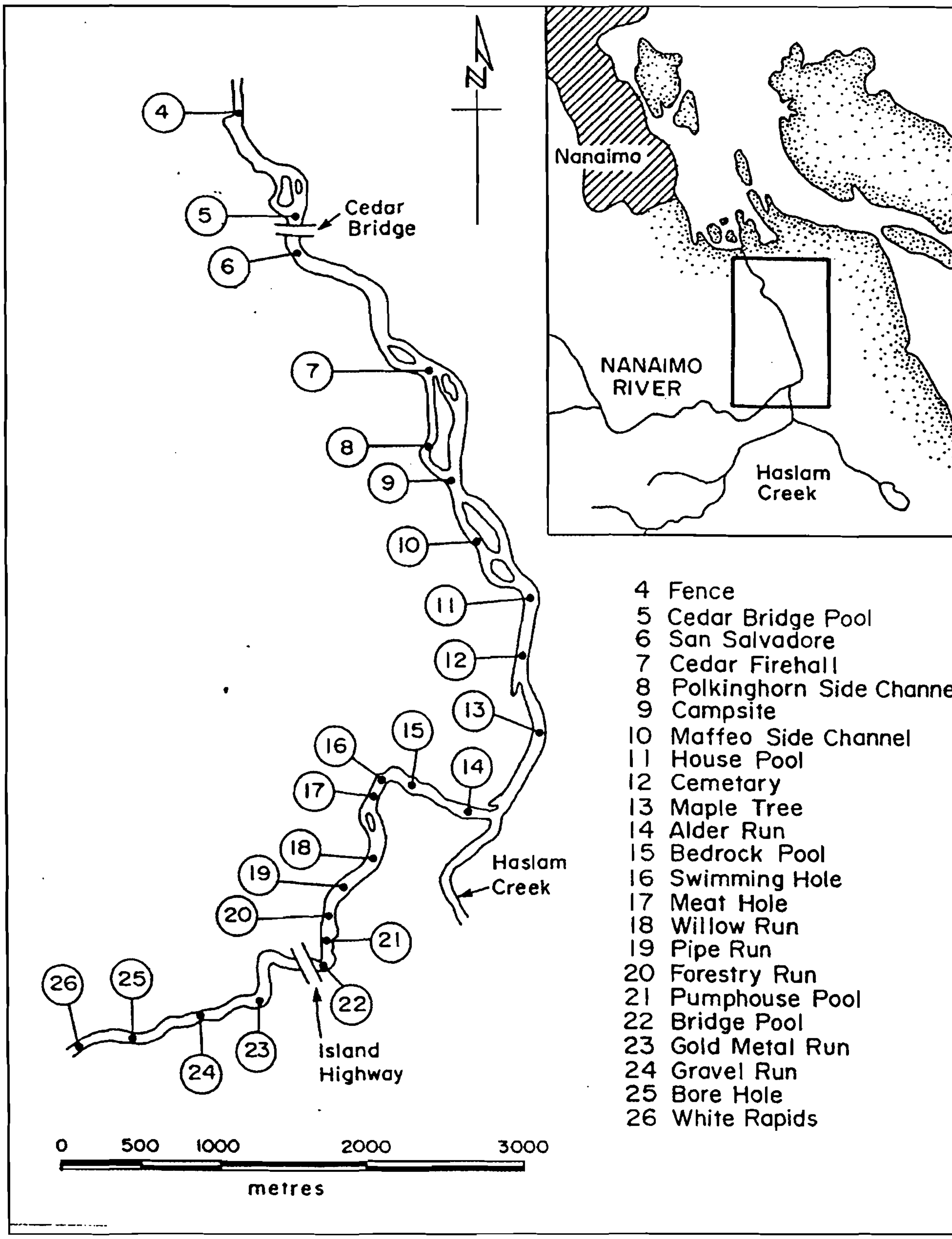

Figure 2. Swim and mark-recapture sites on the Nanaimo River.

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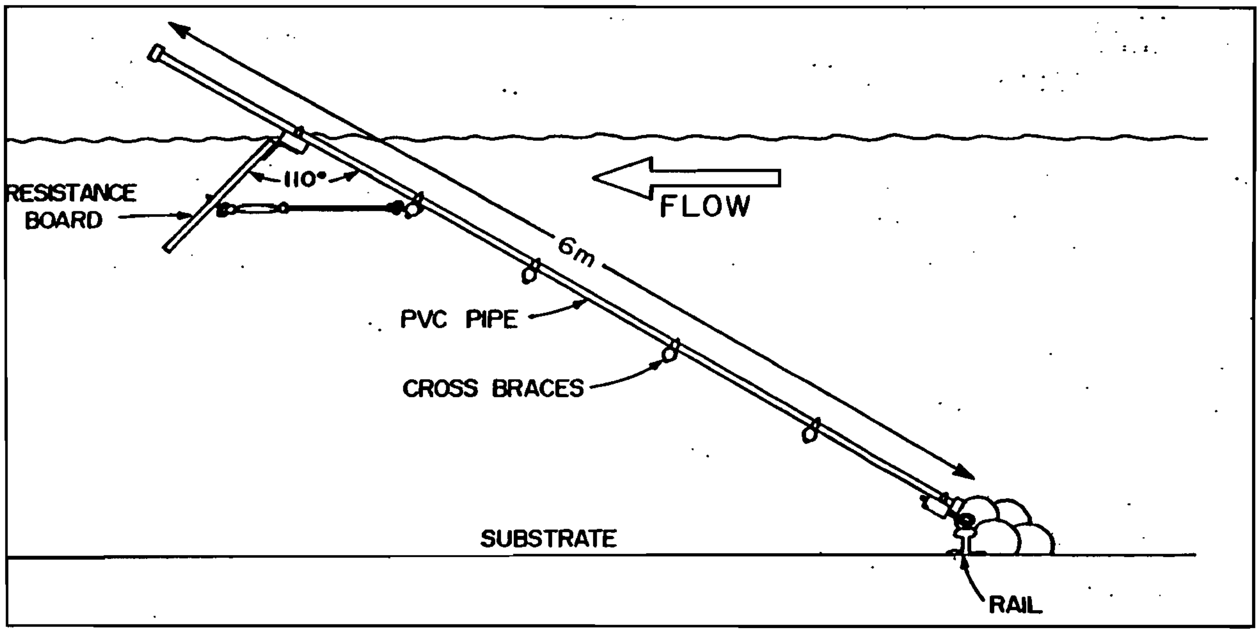

Figure 3. Side view of PVC resistance board panel.

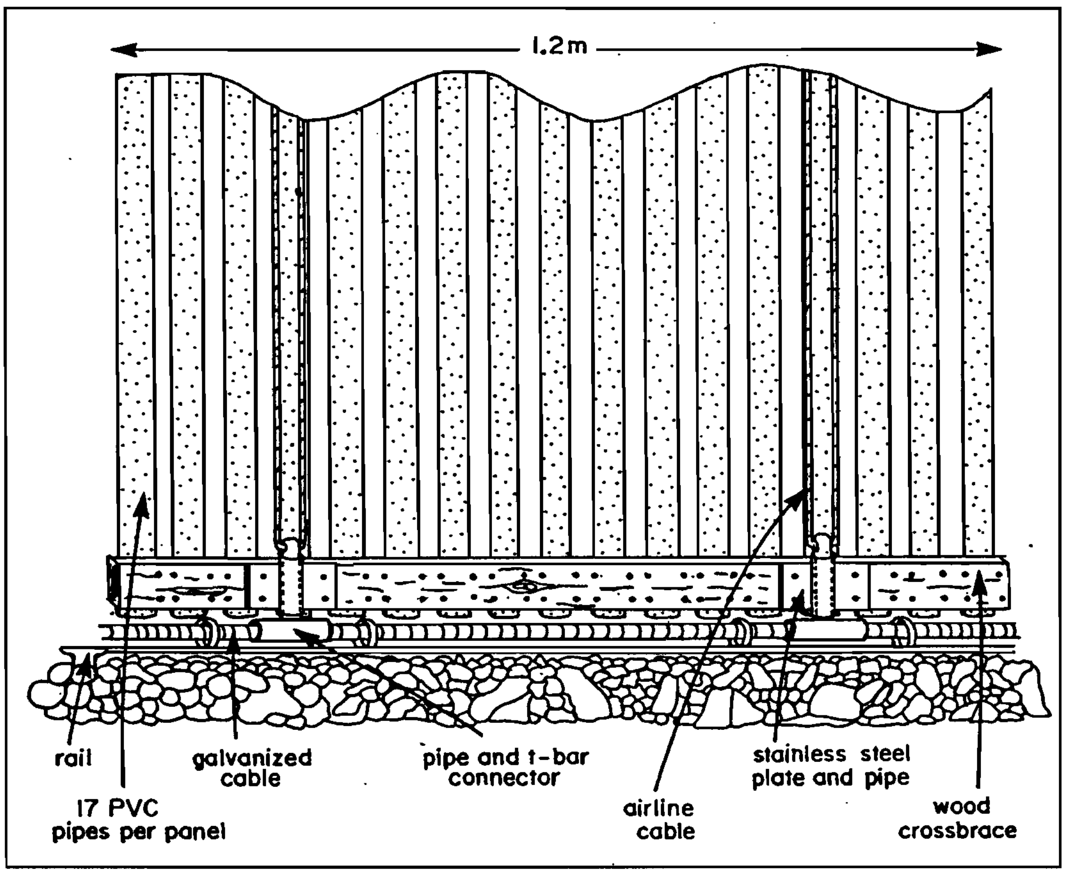

Figure 4. Bottom view of PVC resistance board panel showing connections.

Appendix Table 1. Tag code data from chinook sampled during the carcass recovery program on the Nanaimo River, 1995.

Recovery Date	Length	Sex[1]	BY	Tagcode	Release Location	Recovery Location[2]
951023	763	2	90	02-06-13	Sooke R	13
951030	674	2	91	02-11-62	Chemainus	18
951023	718	1	91	18-05-23	Nanaimo R	18
951023	735	2	91	18-05-24	Nanaimo R	20
951031	711	2	91	18-05-24	Nanaimo R	11
951025	613	1	91	18-05-25	Nanaimo R	18
951023	590	2	92	18-05-48	Nanaimo R	16
951024	598	1	92	18-05-48	Nanaimo R	18
951025	326	1	92	18-05-48	Nanaimo R	21
951026	645	1	92	18-05-48	Nanaimo R	14
951027	648	1	92	18-05-48	Nanaimo R	20
951028	640	2	92	18-05-48	Nanaimo R	07
951028	565	1	92	18-05-48	Nanaimo R	09
951028	610	1	92	18-05-48	Nanaimo R	09
951031	555	1	92	18-05-48	Nanaimo R	14
951101	642	2	92	18-05-48	Nanaimo R	11
951102	637	2	92	18-05-48	Nanaimo R	15
951102	710	1	92	18-05-48	Nanaimo R	15
951023	638'	1	92	18-05-49	Nanaimo R	16
951024	678	1	92	18-05-49	Nanaimo R	18
951024	602	1	92	18-05-49	Nanaimo R	10
951027	651	1	92	18-05-49	Nanaimo R	13
951030	645	1	92	18-05-49	Nanaimo R	15
951031	551	2	92	18-05-49	Nanaimo R	19
951031	600	1	92	18-05-49	Nanaimo R	11
951031	634	2	92	18-05-49	Nanaimo R	11
951102	530	1	92	18-05-49	Nanaimo R	18
951023	690	1	92	18-10-13	Nanaimo R	18
951024	615	1	92	18-10-13	Nanaimo R	18
951025	619	2	92	18-10-13	Nanaimo R	14
951027	648	2	92	18-10-13	Nanaimo R	19

[1] 1-Male, 2-Female, 3-Jack
[2] See Fig. for Recovery Locations

Appendix Table 1 (cont'd)

Recovery Date	Length	Sex[1]	BY	Tagcode	Release Location	Recovery Location[2]
951030	575	2	92	18-10-13	Nanaimo R	15
951030	545	1	92	18-10-13	Nanaimo R	15
951101	600	1	92	18-10-13	Nanaimo R	11
951102	631	2	92	18-10-13	Nanaimo R	17
951017	674	1	92	18-10-14	Nanaimo R	20
951023	645	2	92	18-10-14	Nanaimo R	16
951023	630	1	92	18-10-14	Nanaimo R	16
951024	625	2	92	18-10-14	Nanaimo R	18
951025	635	1	92	18-10-14	Nanaimo R	21
951025	687	1	92	18-10-14	Nanaimo R	13
951025	648	1	92	18-10-14	Nanaimo R	12
951025	655	1	92	18-10-14	Nanaimo R	12
951101	615	2	92	18-10-14	Nanaimo R	20
951102	600	1	93	18-10-14	Nanaimo R	14
951102	603	2	93	18-10-14	Nanaimo R	14
951023	484	2	93	18-10-32	Nanaimo R	18
951024	459	3	93	18-10-32	Nanaimo R	20
951031	510	1	93	18-10-32	Nanaimo R	20
951031	417	3	93	18-10-32	Nanaimo R	11
951031	444	3	93	18-10-32	Nanaimo R	11
951031	488	3	93	18-10-32	Nanaimo R	11
951025	441	3	93	18-10-33	Nanaimo R	12
951025	470	3	93	18-10-33	Nanaimo R	12
951028	453	3	93	18-10-33	Nanaimo R	11
951031	485	3	93	18-10-33	Nanaimo R	11
951102	467	3	93	18-10-33	Nanaimo R	14
951023	440	3	93	18-10-34	Nanaimo R	13
951025	423	3	93	18-10-34	Nanaimo R	14
951025	451	3	93	18-10-34	Nanaimo R	14
951025	509	1	93	18-10-34	Nanaimo R	14
951025	454	3	93	18-10-34	Nanaimo R	12
951028	425	3	93	18-10-34	Nanaimo R	11
951101	296	3	93	18-10-34	Nanaimo R	11
951026	406	3	93	18-10-34	Nanaimo R	10
951028	464	3	93	18-10-34	Nanaimo R	09
951102	657	2	92	18-10-52	Nanaimo R	16

[1] 1-Male, 2-Female, 3-Jack
[2] See Fig. for Recovery Locations