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Review Committee

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Stock Status of Cowichan Chinook Salmon (*Oncorhynchus tshawytscha*)

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INTRODUCTION

Background Information:

Four Canadian stock groupings of chinook salmon (*Oncorhynchus tsawhytscha*) are recognized in the Strait of Georgia. The differences between stocks are based on run timing of the spawning migration, ocean distribution of catch, and age at maturity of the stocks. Chinook from the Fraser River above Hope, B.C. are spring and summer migrant chinook, and are far-north migrating chinook caught primarily in Alaska and northern B.C. The lower Fraser River chinook spawn predominantly in the Harrison River and are fall migrant, white-fleshed chinook. These fish are caught in the Strait of Georgia and off the west coast of Vancouver Island. The upper Strait of Georgia stock is also a fall migrant stock but is a far-north migrant stock and has older ages at maturity than the Harrison or lower Strait stocks. The lower Strait of Georgia stock is a late summer-fall migrant stock, which has a more restricted northward distribution, and is a younger maturing stock.

Considerable interest has been focused towards the chinook stocks in the southern portion of the Strait of Georgia due to the perceived decline in these stocks and their importance to the local fisheries (Farlinger et al. 1990). In 1985, a chinook rebuilding plan was initiated through the Pacific Salmon Treaty between the United States and Canada, that required both parties to stop the decline in escapements to naturally spawning chinook stocks and attain escapement goals in selected indicator stocks (Cowichan, Nanaimo, Squamish) by 1998 (TCCHINOOK 87-4). To achieve these objectives the Treaty established catch limits in mixed-stock chinook fisheries, and required that the catch of chinook in other fisheries be limited by harvest rate controls so that most of the savings from fisheries under ceilings could be passed through to the spawning grounds. However, by the fall of 1987, the escapement to these LGS indicator stocks was only 11% of escapement goals set for these chinook stocks. In addition, catch by sport, troll, and native fishers had also declined substantially. In response to the continued decline in escapement, further conservation measures were taken to reduce harvest rates and enhancement guidelines were implemented for these indicator stocks (Riddell and Kronlund 1993).

Chinook salmon in the Lower Strait of Georgia (LGS) chinook aggregate, include 17 rivers originating from the east coast of Vancouver Island, south of Big Qualicum, and from the large mainland inlets between Howe Sound and Toba Inlet (excluding the Fraser River). The majority of the production from this stock comes from three rivers managed for naturally spawning populations (Squamish, Nanaimo, and

Cowichan) and three rivers predominated by hatchery production (Big Qualicum, Little Qualicum, and Capilano.

The Cowichan River flows into Cowichan Bay on the east coast of Vancouver Island, British Columbia, approximately 40 km north of Victoria (Lister et al. 1971). The river flows from Cowichan Lake eastward for 50 km into Cowichan Bay. Skutz Falls, 18 km downstream from Cowichan Lake, presented a partial obstruction to salmon migration which was alleviated by fishways constructed in 1956. The Cowichan drainage area is 840 km^2 and carries a mean annual discharge of 55 m^3/sec. Mean monthly discharges range from 117 m^3/sec in December to 8.3 m^3/sec in August. A low-level flow control dam at the outlet of Cowichan Lake, built in 1957, provides a minimum river discharge of 7 m^3/sec. A fishway in the dam permits fish passage to Cowichan Lake. The Cowichan River system supports chinook, coho and chum salmon populations. Chinook salmon spawn in the main Cowichan River, principally upstream of Skutz Falls.

In 1988, the Pacific Biological Station, initiated an in-depth study of chinook productivity on the Cowichan River to assess rebuilding strategies and to evaluate the effects of harvest management policies for the Lower Georgia Strait chinook stocks (Nagtegaal et al. 1994). Similar projects were also initiated on the Squamish and Nanaimo Rivers.

For this assessment, we compiled the information available to date on the status of the Cowichan chinook stock, within the context of the lower Georgia Strait stock complex, and review it in light of escapement goals and enhancement guidelines established in 1987.

Escapement goals:

The aggregate escapement goal for the three indicator stocks (Cowichan, Nanaimo, Squamish) is 22,800 adult chinook and represents 75% of the total escapement goal for all naturally spawning chinook in the lower Georgia Strait. The escapement goal set for the Cowichan River was 12,500 adult chinook.

Enhancement guidelines:

In 1987, guidelines for lower Georgia Strait chinook stocks were established to meet two objectives: 1) increasing productivity of the depressed stocks, and 2) maintaining the genetic variation in the natural populations (TCCHINOOK (87)-4). Maintaining natural production was intended to meet Canadian obligations under the Pacific Salmon Treaty, increase fish production, preserve genetic diversity, and provide a strong rationale for protection of the freshwater, estuarine, and marine environments. The Cowichan chinook stock was to be managed for natural production with supplementation from the hatchery. Enhancement facilities in the three indicator rivers

(Cowichan, Nanaimo, Squamish) do not maintain domesticated broodstocks but select spawners randomly from the total return to each river. In the Squamish, chinook broodstock are captured by seining them out of the ocean at Britannia Beach. In both the Cowichan and Nanaimo rivers, broodstock capture occurs in the lower reaches of the river. Guidelines were set on the balance of hatchery and natural production to be maintained and on how quickly enhanced production could expand. There are no formal guidelines for establishing the permissable balance, so in order to provide direction to the role of enhancement in rebuilding the lower Strait of Georgia chinook stock some pragmatic decisions were made:

1. enhanced returns were not to exceed 50% of the total adult escapement goal, when the population was achieving this goal (ie. rebuilt).
2. enhanced production was not to increase beyond the 1987 level until escapement exceeded the 1987 escapement level. The 1987 enhancement production would, however, be maintained in 1988 and beyond if the escapement decreased from the 1987 level.

Two qualifiers were placed on the second item. Transplanting of surplus chinook eggs from other stocks to accelerate the enhanced production in the indicator stocks was not considered acceptable. Other innovative techniques such as sea pen rearing of smolts from these populations was considered acceptable to help accelerate the attainment of egg capacities.

Cowichan River Chinook Assessment

In 1988, an intensive assessment of chinook in the Cowichan River was initiated in response to the conservation concerns and rebuilding obligations under the Pacific Salmon Treaty (Nagtegaal et al. 1994). The major components of this study included: i) enumeration of chinook spawners and total return to the system, ii) estimation of native food fishery catch, iii) recording of hatchery broodstock removals, iv) collection of biological information (age, sex, size) for the stock, and v) recovery of coded-wire tag (CWT) data from the escapement, broodstock, and native food fishery.

In 1991, a project to estimate natural juvenile production was initiated (Candy et al. 1995). Key components of this study included: i) enumeration of juvenile chinook 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.

Escapement Enumeration:

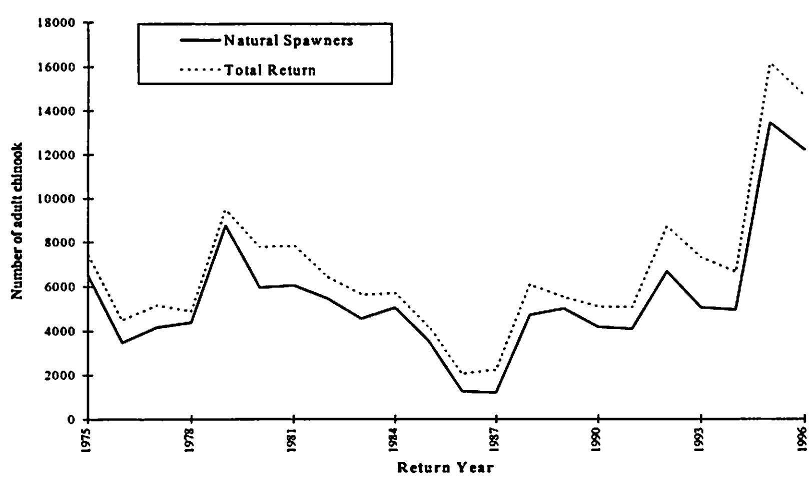
Prior to 1988, fishery officers estimated total escapement in the Cowichan River on the basis of swim surveys, observation of spawning grounds, and aerial counts (helicopter) of spawners during peak spawning periods. Attempts were made to keep the timing of these counts comparable from year to year (Table 1).

Since 1980 swim surveys have been conducted by Fishery Officers to estimate the spawning population of chinook in the Cowichan River. Generally, only the upper river (Lake Cowichan to an area referred to as "Three Firs" which is approximately 4 miles upstream from Skutz Falls) was surveyed since few fish had been observed below this area. Counts were usually made by 2-3 swimmers equipped with snorkelling gear accompanied by another person in a canoe or boat. The upper stretch of the river was divided into segments (usually associated with pools) and counts recorded by segment. Total numbers of adult and jack chinook were discussed by the swimmers at the end of each of these segments before the final tally was recorded by the boat operator. The swim survey count was then extrapolated for the whole river on the basis of the area sampled and past observations, discussions with Cowichan Indian Band members and local knowledge (T. Fields, Fishery Officer, Duncan, pers. comm.). Early in the season (July-Sept) swim counts were multiplied by a factor of 4.8 to get an estimate of the number of fish in the entire river. This expansion factor was based on the proportion of river observed relative to the total length of the river and the assumption that at this time of the season fish were distributed evenly throughout the river. Towards the end of the season, upper river visual counts were expanded to total escapement using a factor less than 4.8 assuming that by this time most of the fish had moved into the upper section of the river. The quality of the data collected was variable and dependent to a great extent on water conditions (depth and clarity). When the opportunity arose and water conditions were good, a helicopter flight was used to count chinook on the spawning grounds during peak periods and this count was used to augment the swim survey data.

Since 1990, swim surveys have been conducted in conjunction with Cowichan Tribes Aboriginal Fisheries Management to estimate the spawning population of chinook (Paige 1992, 1995). The swims were made in the upper section of the river. Each survey was conducted by three experienced swimmers and one person in a canoe who recorded the data. Each swimmer (one in the middle and one on each side of the river) counted the fish seen within their range of visibility. The three swimmers attempted to keep abreast as they approached each pool while the person in the canoe lagged behind within hailing distance. Counts were recorded by pool/riffle and then compiled by river section. When possible the same swim team was used for each survey to maintain consistency in counting procedures. Swim counts were expanded by a factor of 3.4 to derive an escapement estimate. This expansion factor was consistently applied to all swim counts with no adjustments made for run timing or the changes in the distribution of chinook in the river.

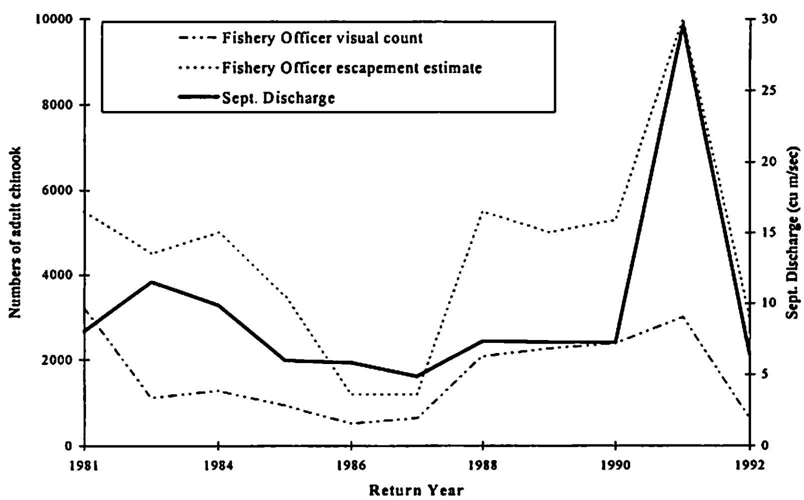
In 1988, an enumeration fence was constructed at a site approximately 5 km. upstream of the estuary and well below the traditional chinook spawning grounds (Nagtegaal et al. 1994). The fence is operational from the end of August until the end of October. All species are counted by personnel that maintain the facility 24 hours per day. In some years, to augment the fence count, a carcass mark-recapture program involving the tagging and subsequent recovery of chinook jack and adult carcasses has been conducted on the spawning grounds. Adult chinook salmon escapement estimates are generated from the carcass mark-recapture data using the Petersen model (Chapman modification) stratified by sex and river section (Sykes and Botsford 1986).

Chinook escapement has fluctuated from a low of 1200 in 1986/87 to over 16,000 in 1995, the largest escapement recorded for the past 40 years. For ten out of the past 16 years escapements have ranged between 5000 and 6000 adult chinook but in recent years the numbers of chinook returning to the Cowichan River have increased substantially (Table 2). The dramatic increases in escapement since 1986 are probably due to a combination of factors which likely include the substantial increases in hatchery production and reductions in the commercial and sport fishing effort.



To gain a better understanding of the relative value and accuracy of past Fishery Officer visual escapement estimates, we compared these visual estimates, in particular swim survey counts and extrapolated escapement estimates, to fence counts. Among the biases typically associated with swim surveys, the extrapolation of actual swim counts to total escapement estimates warrants some consideration. Assumptions concerning the distribution of chinook in the river at the time of the survey are the basis for expanding these counts to estimate total escapement. Fishery Officers adopted a strategy that consistent expansion factors were to be applied to swim survey counts from the upper river, to estimate the total numbers of chinook spawners. In 1991, it became apparent that during high water flow conditions in early fall, expansions based on swim survey results over-estimated total escapement (Nagtegaal et al. 1994b). The results of the 1992 swim surveys supported the hypothesis that during low water flow conditions in the late fall, expansions based on swim survey results under-estimate the numbers of spawners. The standardized swim survey strategy adopted by Fishery Officers has likely lead to incorrect estimation of spawners because the distribution of fish in the river is affected by the flow. Generally, under low flow conditions in late fall, not as many chinook make it to the traditional spawning areas in the upper river above Skutz Falls. Expansion of swim surveys conducted in the upper river alone tend to underestimate the number of spawners. Conversely, during high flow conditions in the early fall, most of the chinook move into the upper river and as a result the expansion of swim survey results tends to overestimate the number of spawners.

If we apply this approach to past visual escapement estimates then the very low estimate of spawners in 1986 and 1987 were likely an under-estimate, and the estimate in 1991 was likely an over-estimate.



Native Fishery:

Although poorly documented, the terminal native fishery has been considered minimal relative to the total catch. Chinook are caught for food and ceremonial purposes using a variety of traditional techniques. The Cowichan Tribes Band, comprised of approximately 600 family units, resides on reserve land that encompasses much of the area surrounding the lower reaches of the Cowichan River. The native fishery for chinook takes place in the form of a spear fishery during the months of June-October.

Prior to 1983, the native food fishery was monitored by DFO. Fishery Officers would estimate total catch on the basis of observations and discussions with local native groups. Since then the Cowichan Tribes established the Cowichan River Management Unit (CRMU) to enforce conservation by-laws on the reserve. The amount of time and resources spent on monitoring the native food fish catch varies from year to year. The River Management Team regularly patrols the food fishery and collects data to estimate total food fish catch, however their first priority is enforcement. Routine patrols for these activities do not always coincide with the activities of the spear fishermen, who account for virtually all the chinook native food catch.

In 1990, a systematic approach was developed by the Cowichan Tribes Aboriginal Fisheries Management program to monitor the fishery more closely and to better estimate the native food fish catch (Paige 1992, 1995). This approach involved recording catch and effort by management zone within the native fishing boundaries. A crew of four observers patrolled the fishery on a daily basis and interviewed fishermen for numbers caught by area and total time spent fishing. In this way, weekly estimates of catch per unit effort (CPUE) were obtained. CPUE was adjusted for daily changes in fishing effort and differences in effort among fishing zones. These data were then extrapolated over time and area to estimate total catch by week.

Since 1988, an observer was employed by DFO to independently collect catch and biological data from the in-river chinook spear fishery (Fig 6). Since we are not given the opportunity to directly assess catch estimation procedures developed by the Cowichan Tribes, no comments can be made regarding the methodologies used. At best these two estimates of native catch provide a range of the actual food fish catch (Nagtegaal et al. 1995).

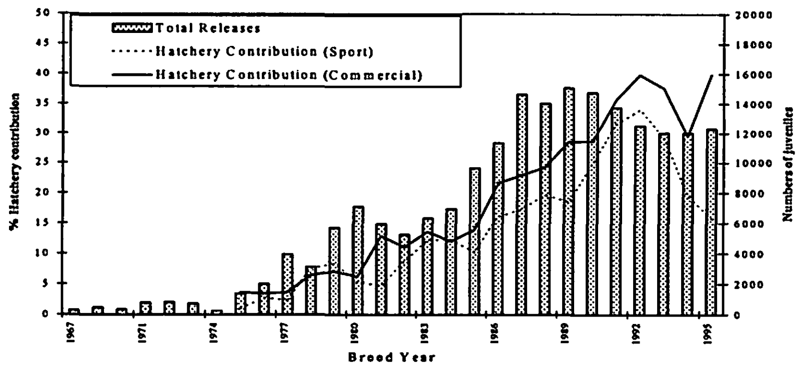
Enhancement History:

A community economic development program hatchery (CEDP) is situated alongside the Cowichan River approximately 2 km upstream from Cowichan estuary. The hatchery is managed by the Salmon Enhancement Program of DFO in conjunction with Cowichan Tribes. Hatchery production of chinook on the Cowichan River began in 1980 (Cross et. al.,1991). Total chinook fry releases have increased from 64,681 in 1980 to 2,581,333 in 1996 (Millerd, pers comm). Marked releases began in 1980, and in 1996 approximately 9% of the total number of chinook released were coded-wire tagged. Three main release strategies are employed by the hatchery: early fry, lake-pen rearing, and in-river smolt releases. The early release of fry (3 g) takes place in mid-April in the upper reaches of the river or just above the north and south forks of the lower river. The lake release, 5-6 g smolts, are initially reared at the hatchery. These fish are then moved to net pens just above the weir in Cowichan Lake prior to being released from the net pen site in late May. The late release, 5-6 g smolts, are generally released in the upper reaches of the river during late May. Recently, smaller releases have occurred directly for the hatchery site and from saltwater sea pens situated in Cowichan Bay.

Assessment of hatchery production is based on coded-wire tag information. A proportion of all chinook produced by each hatchery are nose-tagged with a small coded-wire tag (Kuhn et al. 1988). Recovery information from coded-wire tagged chinook provides the basis for assessing exploitation rates and marine survival for these stocks. Since no naturally spawning LGS chinook stocks are coded-wire tagged, information compiled from the hatchery facility is used to assess both hatchery and naturally-spawned chinook.

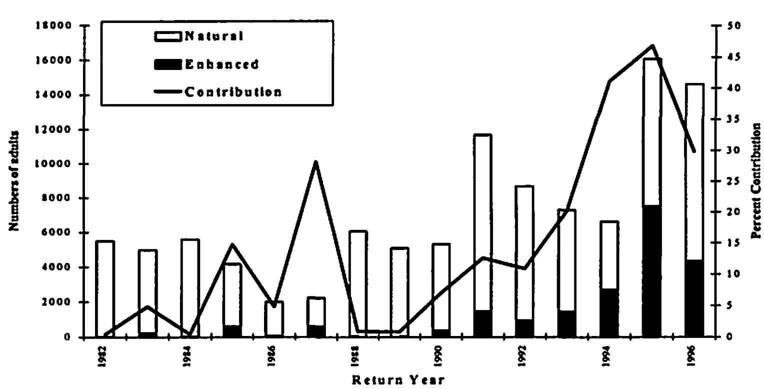
Since the early 80's, enhancement in some of the LGS populations has been substantially increased with the expansion of several hatchery facilities, including Cowichan and Squamish (Cross et al. 1991), and the initiation of many new enhancement programs. Subsequently, the contribution of hatchery production to chinook fisheries in the Strait of Georgia has increased significantly. Present estimates, based on expanded CWT recoveries in commercial and sport fisheries, indicate that up to 40% of the annual chinook harvest can be attributed to hatchery production.

Hatchery Chinook Releases for Lower Georgia Strait Indicator Stocks



Enhanced contribution to the Cowichan chinook stock has also increased considerably since the hatchery was established in 1979. In 1995, contribution to escapement, based on the incidence of coded-wire tagged (adipose fin-clipped) chinook recovered in the escapement, was estimated to be approximately 47%. At the same time the numbers of naturally produced chinook have been maintained and showed some increase. Based on otolith microstructure (Zhang et al. 1995), however, the proportion of hatchery chinook in the Cowichan River in 1993 and 1994 has been estimated to be as high as 60%. In either case, it is clear that enhancement has played a central role in the increases to escapement.

Cowichan R. natural and enhanced contribution



Habitat and Environmental factors:

Recent studies in the Strait of Georgia have indicated that marine environmental factors may have contributed to the decline in chinook abundance (Beamish et al. 1995). There is some evidence that the changes in the oceanographic conditions in the Strait of Georgia are correlated to this decline. Changes in water temperature and discharge from the Fraser River may have adversely affected the marine survival of hatchery-produced (and presumably naturally-reared) chinook (Walters and Riddell 1996). A dramatic decline in survival in the late 70's was experienced while hatchery production of chinook continued to be substantially increased. Environmental changes may have caused a reduction in carrying capacity. Climatic changes, particularly in temperature, may also contribute to increased predator abundance (eg: mackerel).

Degradation of freshwater and estuarine habitats have seriously impacted the survival of juvenile salmon. Loss of available habitat has caused a reduction in the rearing capacity of many rivers (Healey 1982). Both hatchery-produced and naturally-reared juvenile chinook extensively utilize the estuarine environment in Cowichan Bay (Candy et al. 1995).

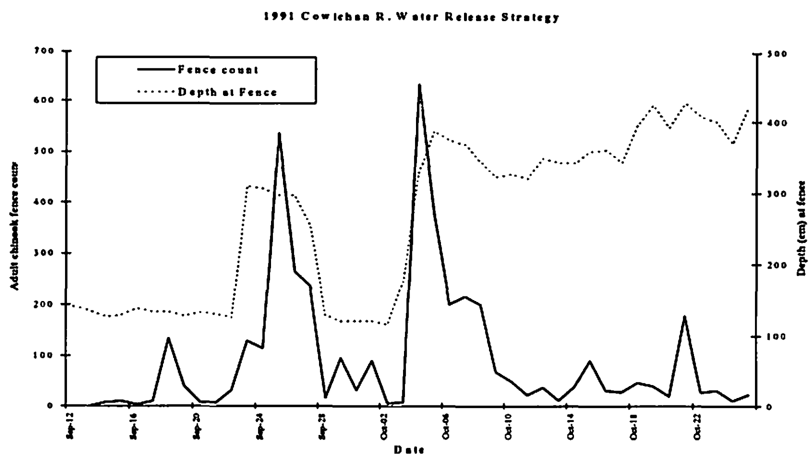
In 1984, a Federal/Provincial Salmonid Habitat Information Project (S.H.I.P.) was initiated (Chamberlin et al. 1984). The S.H.I.P. methodology used available information about fish distribution, air-photo interpretation of significant stream features and quantitative measurements of gradient classes from topographic maps to estimate the relative value of present and potential fish habitat. The spatial distribution of these habitat classes within the Cowichan basin was plotted on interpretive maps for each species. The amount (measured in km) of each habitat class was also tabulated by species. The S.H.I.P. product was designed for application to strategic level fish production planning. Additional application areas include habitat management (pesticide and logging referrals), inventory design and major urban development review.

In 1986, a Cowichan - Koksilah water management review process was initiated (Burns et al. 1988). Since 1958, the Cowichan River discharge has been regulated by a weir at the outlet of Cowichan Lake, 50 km upstream from the mouth of the river. The discharge is controlled to meet the water licence requirements of Fletcher Challenge Ltd. Water is withdrawn from the river at a pumphouse 10 km upstream from the mouth for use at the Crofton pulpmill. The rule curve requirements established in 1958 to manage river flows were amended in 1974 (Debeck 1974) and these amendments are still in effect. The Cowichan Water Management Plan recommended that flow releases from the Cowichan Lake weir be re-examined and operational strategies be reviewed to optimize fisheries management objectives while meeting the water licence requirements of the pulpmill. Key concerns to the Federal and Provincial fisheries agencies were the effects the timing and the rate of water releases from the Cowichan Lake weir had downstream on egg incubation, rearing and growth of fry and juvenile salmonids, and adult migration and spawning. The report identified 142 side-channels on the Cowichan River and classified them into four categories defined as flood channels, active channels, back channels, and relic channels. Field assessments were conducted to ascertain the amount of wetted side-channel fish habitat that was lost as discharge to the Cowichan River was reduced. A significant loss of active side-channel habitat occurred when discharge was reduced below 7 m^3/sec. This represented an average loss of 12 - 17% of the total wetted area of this side-channel type in the upper, middle and lower Cowichan River side-channel habitat. The other categories did not appear to sustain any significant loss. The report recommended that discharge be maintained above 7 m^3/sec throughout the year and that this be accomplished by storing additional water in the lake during the spring rains and releasing it according to the provisional curve over the dryer summer months.

An intergovernmental task force was established in 1974 by the Provincial government to address land development issues and their possible effects on the environment of the Cowichan Estuary (MOELP 1994). Four land use options were identified ranging from complete preservation to full industrial use. The status quo was selected and no further development was to occur in the estuary. A task force report was released in 1980 and contained recommendations relating to flood control, log management and overall land use. Due to the high value placed on fish and wildlife habitat and forest industrial activity, the report recommended a cautious approach. In 1986 this environmental management plan was implemented and it was designed to achieve the goal of balanced land and resource use in the Cowichan estuary. Due to further concerns, the plan was again reviewed in 1991. The demand for industrial use of the Cowichan estuary has increased and has continued to compete with concerns for protecting the special environment resources that the estuary provided. Continued loss and degradation of estuarine habitat has resulted from dyking for agriculture, filling for industrial and commercial land, log handling and water pollution by municipal waste discharges and agricultural runoff. A revised plan was implemented in 1994, after further review, and sought to limit the detrimental environmental impacts of any activities to avoid further habitat losses and to support rehabilitation of any degraded habitat in the estuary.

Recently, implementation of stream stewardship programs and land development guidelines have heightened the awareness of the importance of habitat preservation both in the estuary and in the mainstem.

As an adjunct to this review, a special water management plan on the Cowichan River was implemented in 1988 to aid upstream migration of spawning salmon. The Department of Fisheries and Oceans (DFO), B.C. Ministry of Environment and Parks, and the B.C. Forest Products Ltd., Pulp and Paper Division in Crofton negotiated a water flow management plan as part of a Cowichan watershed salmon production plan (K.P.A. Engineering Ltd.,1991). The rationale behind the water plan was to improve chinook escapement by increasing water flow for a short period (5-10 days), during low flow conditions in early fall, in an attempt to encourage chinook to migrate upstream. These fish may otherwise be obstructed in their upstream migration, due to typically low water levels in the fall, and suffer pre-spawn mortalities. The construction of an enumeration fence offered a unique opportunity to assess the success of this type of water release strategy. When appropriate environmental and river conditions prevailed, short term increases in water flow have successfully aided in the upstream movement of both adult and jack chinook.



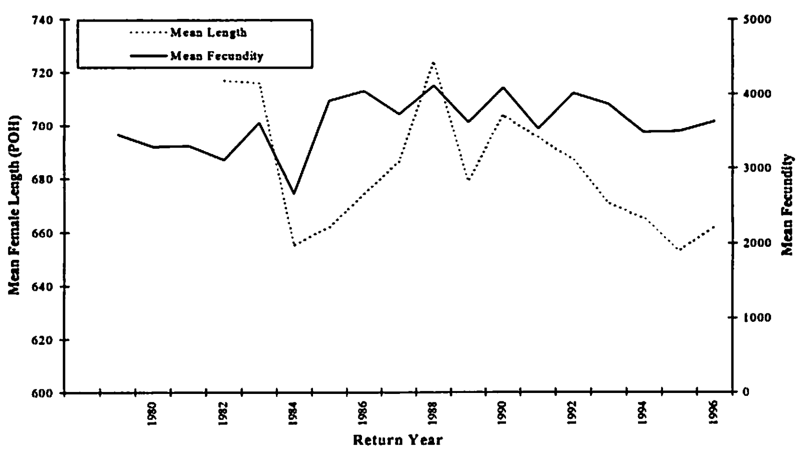
Biological Characteristics:

Biological data for chinook were typically collected from three sources: 1) hatchery broodstock biosampling, 2) spawning ground biosampling, and 3) random sampling of the native food fishery (Nagtegaal et al. 1994). Cowichan hatchery staff randomly biosample approximately 25% of all chinook collected for broodstock and then selectively sample all remaining adipose-clipped chinook. As part of the carcass mark-recapture all chinook recovered on the spawning ground are biosampled. A biological observer interviewed native fishers and a random sample of chinook caught in the native food fishery are biosampled. Since this is a voluntary program, sampling is dependent on the approval of the fisher and as such may introduce some sampling bias. All chinook are sampled for length, sex, age, and presence/absence of adipose fin-clip.

Chinook from the Cowichan R. stock mature primarily as 3 and 4 year old fish; 5 year olds usually comprise less than 2% of the returning adults. Age composition of returning spawners varies considerably among years and is in a large part determined by the numbers of returning jacks. The proportion of females by age in the escapement has remained fairly consistent among years. Differences among years are most noticeable in 1990 and 1991, however, this may be a sampling artifact since sample sizes were small.

AGE	% Age in broodstock (1988-96 mean)	% Age in escapement (1990-96 mean)	% Age in native fishery (1990-96 mean)	% Females by age (1990-96 mean)
2	12%	40%	29%	0%
3	44%	28%	35%	43%
4	43%	30%	33%	71%
5	1%	2%	3%	80%

Fecundity information for this stock is acquired through sampling of the broodstock collected by the Cowichan hatchery. Average fecundity (ranging between 3000 - 4000) has varied among years without any observable trend except in 1984, when there was some question as to the quality of the data recorded. Mean postorbital-hypural (POH) length of females has declined since 1990, relative to the mean fecundity, again however, sample sizes were small. Size-specific fecundity of a chinook population can vary from year to year, but such variation appears to be small in relation to variation between populations. In a comparison of fecundity in a large number of chinook populations, Healey and Heard (1984) found that mean fecundity was positively related to age at maturity, but that the slope of the fecundity-age relationship in a single population was less than expected if increases in fecundity were to offset the effects of natural mortality at older ages. Hankin and McKelvey (1985) suggested that this finding may be due to the fact that egg size, which is positively related to fish size, is also an important contributor to reproductive potential.



Virtually all adults are produced from an ocean-type juvenile life history (0+ age at migration). Lister et al. (1971) divided the chinook migrants into an early and late group based on size. The early group (March/April), comprising the majority of the migrants, consisted of primarily emergent fry averaging 42 mm in length. The late group (less than 15%) categorized as late migrants or '90-day' smolts, were considered to be fingerlings averaging over 55mm. These were presumed to spend up to 90 days in freshwater prior to migrating out to sea.

Juvenile Chinook Production:

Rotary screw traps were used to estimate naturally-reared fry production. Dyed juveniles (hatchery and naturally-reared) were released above the trap and the mark-recapture efficiency results were used to expand trap catches to estimate total production (Candy et al.

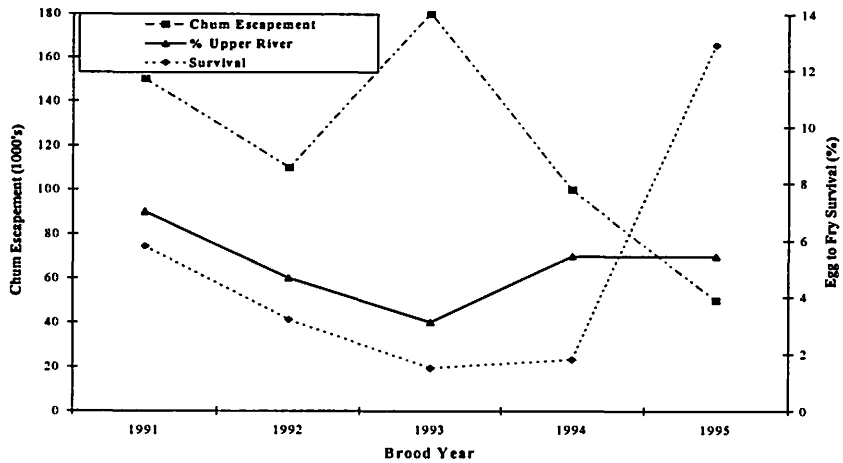
1995). Downstream movement of naturally-reared fry typically occurs between mid-February and the end of June. Downstream movement of chinook juveniles has been observed from the beginning of March to the end of May since 1991.

Egg to fry survival:

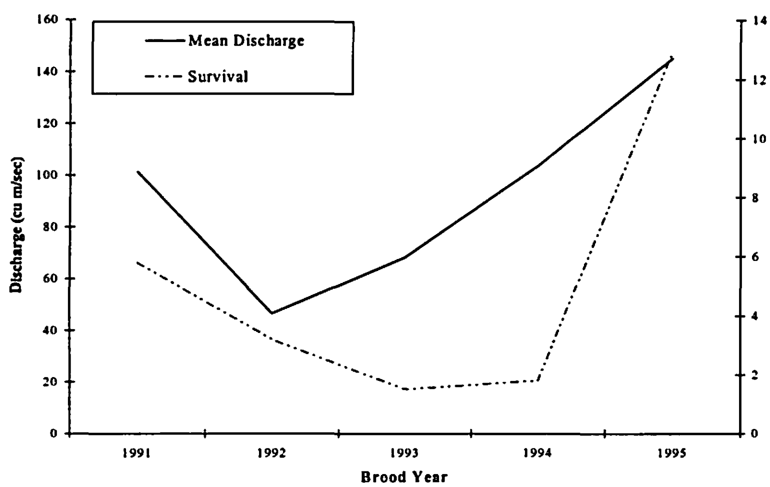
Egg to fry survival was calculated based on the relationship of estimated egg deposition to downstream fry production. In the late 60's, Lister et al. (1971) estimated egg to fry survival for Cowichan chinook to be approximately 3%, although admittedly this was based on questionable spawner enumeration data. Healey (1991) reported from several sources that egg to fry survival of chinook ranged from 8% to 16%. Survival estimates for Cowichan chinook for the 1991 - 95 brood years ranged from approximately 1% to almost 13% (Nagtegaal et al. 1997). Although there was an increase in fry survival in 1995, there had been a decreasing trend since the 1991 brood year.

Brood Year	Escapement	% females	Estimated females	Fecundity	Estimated total eggs	Estimated fry	Egg to fry survival
1990	5300	55	2915	4082	11,899,030	479,856	4.03%
1991	10000	54	5400	3531	19,067,400	810,240	4.25%
1992	6676	55	3671	4013	14,731,723	349,298	2.37%
1993	5047	59	2977	3861	11,494,197	173,387	1.51%
1994	4936	55	2715	3484	9,459,060	169,828	1.80%
1995	13452	51	6841	3484	23,834,044	3,092,626	12.98%

Two contributing factors that may have affected survival were environmental conditions and spawner distribution. Spawner distribution was considered in terms of the proportion of spawners in the upper river section above Skutz Falls. Depending on the water levels in the fall, chinook will move into the upper or middle river sections to spawn (Nagtegaal et al., 1994b). Presumably during higher flow conditions in the early fall, a larger proportion of spawners will move into the upper reaches of the Cowichan R. It has been suggested that spawning success is poorer in the lower and middle river partially due to overriding chum spawning in this area.

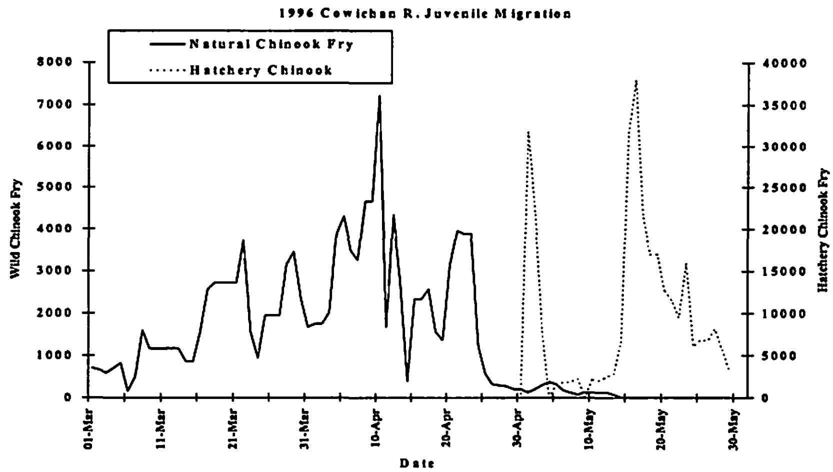


Mean discharge from November to February and the proportion of spawners in the upper river section were also compared to fry survival. There is some suggestion that fry survival may increase when discharge is higher. Part of the explanation for this comes from the fact that during higher flows in the spring, the water is cloudy and may act as a protection against predation.



Juvenile Interaction:

Preliminary observations (Candy et al. 1996) indicate that the majority of hatchery juveniles released in the river move to the estuary within the first few days after release. These results compared favourably with other studies (Taylor and Bradford 1993; Healey 1991). Seelbach (1985) concluded that since hatchery fish moved out of the Little Manistee River to the estuary fairly quickly, interaction with naturally-reared juveniles was minimal. This also seemed to be the case in the Cowichan system. Interaction also seems to be limited in the river environment because the bulk of hatchery releases occurred when the majority of naturally-reared juveniles had already emigrated to the estuary.



Seal Predation:

Although seal predation was not directly assessed in this study, others have examined the impact of seals on salmon in Cowichan Bay. An estimated 23% (Sept.) to 48% (Nov.) of the harbour seal's diet in Cowichan Bay was comprised of salmon (Bigg et. al. 1990). In 1988, the number of seals gradually increased from a low of 30 in April to a peak of about 100 in December. Olesiuk et al. (1990) estimated that harbour seals consume an estimated 9 tonnes of salmon annually in Cowichan Bay. Based on these data, consumption of chinook salmon could potentially range from 100 to 500 adults. These data were collected in 1988 when low flows in the Cowichan River persisted until the end of October. Predation likely increases with the length of time chinook salmon remain in the estuary.

Coded-wire tag expansions and Cohort analysis

Annual coded-wire tag recoveries from ocean fisheries are maintained in the Mark-Recovery database at the Pacific Biological Station. Annual CWT recoveries from the hatchery and river are maintained in a Salmonid Enhancement Program database (Habitat and Enhancement Branch, Vancouver, B.C.). For the Cowichan River, in-river recoveries are maintained by return year, sampling location, and tag code. The estimated number of each tag code recovered was based on sample sizes (brood stock, Native catch, deadpitch by location) and the estimated number of chinook in each location. For example, in brood stock samples the expansion for each tag recovered (i.e., observed recovery) was normally one since all fish were examined for tags. However, the upper river deadpitch sampling examines only a portion of the estimated return. The estimated number of tags is then determined by dividing the observed recoveries in a sample by the portion of the escapement sampled. Estimated recoveries by tag code were determined within sample location and summed over locations. The estimated annual recoveries in the total return to the Cowichan River provided the escapement data used in calculating cohort analyses for each brood year with adequate tagging. The list of tag codes used by brood year is provided in Appendix 1. The cohort model used is documented in Appendix 2 of Starr and Argue (1991) and used by the Chinook Technical Committee (CTC) of the Pacific Salmon Commission (current version: COHSHAK9H.BAS; available from B. Riddell). However, in determining the incidental mortalities, only the brood year method was used. The alternative calendar year method results in biased estimates when the survival between brood years is highly variable.

Two refinements to the cohort analysis procedures were implemented to more accurately determine impacts on this stock. These were: definition of terminal sport recoveries (so that these do not inflate the estimated cohort sizes by age), and implementation of revised incidental morality rates as reported by the CTC (1997). Tags from the Cowichan River that were recovered after the first statistical week in August and in Statistical areas (Areas 17-10 through 17-17, Areas 18 and 19A, and sub-areas 29-45 and 29-25) were included as terminal sport recoveries. Incidental mortality rates applied were:

Gear:	Sub-Legal sized chinook	Legal sized chinook
Troll	27.2%	22.8%
Sport	15%	15%
Net (gillnet plus seine)	90% (not changed)	65%

CTC. 1997. Incidental fishing mortality of chinook salmon: mortality rates applicable to Pacific Salmon Commission Fisheries. TCCHINOOK (97)-1. 44p. (Pacific Salmon Commission, 600-1155 Roson Street, Vancouver, B.C. V6E 1B5)

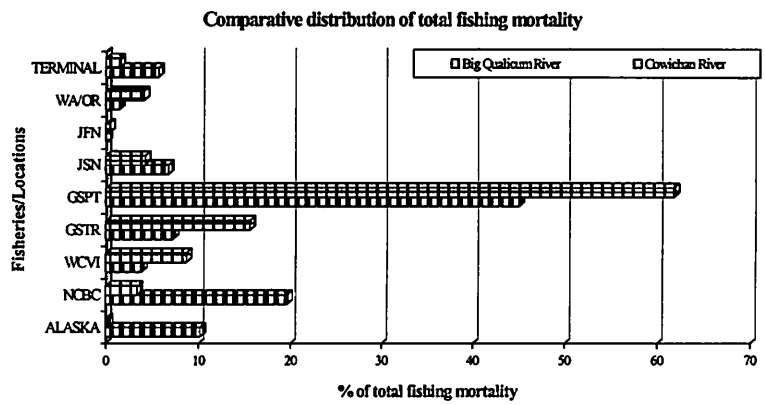
For each brood year, cohort analysis provides information on:

a) annual distribution of catch and total fishing mortalities by fishery and age;
b) cohort size and survival rate by age; and
c) ocean (catch or total fishing mortality) and total exploitation rates by fishery and age.

Results of the Cohort Analysis

Catch Distribution:

To calculate the annual distribution of total fishing mortalities, each brood year contributing to an annual catch must be represented by CWT groups. For the Cowichan chinook stock, this limits the information for years prior to 1991, due to the absence of tagging in the 1984 and 1986 brood years. Further, in 1995 and 1996, regulations limiting chinook catch will obviously influence the catch distributions. The most representative years available for this stock are 1991 to 1994. The majority of the fishing mortality on this stock occurs in the northern Strait of Georgia sport fishery (GSPT); on average, the Strait of Georgia sport fishery accounted for 62% of the total fishing mortality and 50% of the Cowichan chinook production (total fishing mortality plus total terminal per calendar year) for the period 1991-1994. During 1995 and 1996, the portion of the total production represented by the GSPT was reduced to 35% and 45%, respectively, and the terminal run increased to 50% of the annual production accounted for in these years.



Trends in Survival Rate:

The estimated survival rate for Cowichan chinook, from time at release to age 2 recruitment has varied between 2 and 9%, including a notable decline in survival estimated for the 1991 to 1993 brood years. The 1993 brood returns are incomplete but are extraplotated based on age 2 and age 3 recoveries and average maturation rates for age 3 Cowichan chinook. Note also that the spawning escapement for the 1983 brood year was not sampled quantitatively and will therefore be an under-estimate of the survival rate. This correction would increase the range in observed survival rates, although likely only 15 to 25% given estimated exploitation rates.

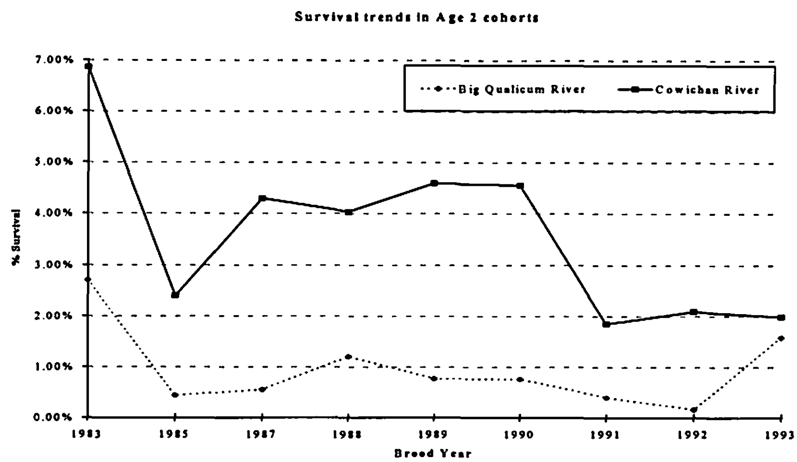
Estimated Survival Rates (Estimated tags @ Age 2 recruitment/Tags released) and Maturation Rates by Age:

BROOD YEAR	SURVIVAL RATE	AGE 2 MATURITY RATE	AGE 3 MATURITY RATE	AGE 4 MATURITY RATE
1983	6.86%	0.0046	0.0355	1.00
1985	2.40%	0.0234	0.1732	1.00
1987	4.29%	0.0480	0.1776	0.9963

1988	4.03%	0.0731	0.2783	0.9644
1989	4.59%	0.0529	0.1691	0.9590
1990	4.55%	0.0314	0.5377	0.9781
1991	1.85%	0.0831	0.2581	0.9086
1992	2.09%	0.0520*	0.2657*	0.9677*
1993	1.99%			

* AVERAGE values for previous years, excluding the 1983 brood year which was not sampled quantitatively in the escapement

Survival trends are compared with Big Qualicum chinook survivals in the figure below.



Brood Exploitation Rates:

Brood year exploitation rates for the Cowichan River are similar in magnitude and trend to the Big Qualicum River (BQR) indicator stock. This is an interesting comparison since the accuracy of any assessment based on tag recoveries is highly dependent upon the accuracy of the spawning escapement estimate and the sampling for tags in the escapement. Returns and sampling at Big Qualicum have been considered very accurate with the exception of concerns about tags being missed in escapement samples during the mid-1980s. This concern may explain the similarity of the 1983 brood values since, as noted above, the Cowichan returns were not sampled quantitatively during these return years. The values estimated for the Cowichan stock and their similarity to the BQR stock, adds confidence to the adequacy of the escapement sampling and these cohort analyses. However, in comparing exploitation rates, the Cowichan stock does have a higher total exploitation rate in 6 of 8 brood year comparisons; and, on average, has a 20 to 25% higher total exploitation rate. This result could reflect an under-representation of terminal returns in the Cowichan stock but it may also reflect differences in the exploitation pattern. This degree of difference is very consistent with the difference between the annual fishing mortality attributed to the Strait of Georgia sport fishery (based on the proportion of the annual production accounted for by the GSPT... 40% in BQR, 1991-1994 versus 50% in Cowichan, 1991-1994).

Both stocks have shown a marked reduction in total exploitation during 1995 and 1996. In the following table, exploitation rates are based on reported catch only (Catch exploitation rates) and based on total fishing mortality (includes estimates of incidental mortality plus reported catches). For both estimates, however, the denominator used total fishing mortality and total spawning escapement).

Brood year exploitation rates for Cowichan River chinook stock. The 1992 brood year is the last complete brood through 1996 recoveries since there are very few Age 5 chinook in this stock.

Brood Year	Catch Exploitation Rate			Total Mort. Exploit. Rate
	Ocean	Terminal	Total	
1983	0.622	0.146	0.667	0.737
1985	0.678	0.439	0.767	0.884
1987	0.543	0.110	0.574	0.739
1988	0.563	0.126	0.586	0.808
1989	0.590	0.068	0.601	0.829
1990	0.559	0.091	0.574	0.832
1991	0.468	0.071	0.494	0.643
1992	0.340	0.103	0.386	0.530

The total exploitation rate is very dependent on the portion of the Age 2 cohort that is vulnerable to the GSPT fishery. At present and based on the size distribution of age 2 chinook sampled in the Strait, 97.5% of the Age 2 cohort in the Strait of Georgia is estimated not to be vulnerable at the 62cm size limit. This results in a large incidental mortality associated with fisheries in the Strait and estimates very high ratios of released-to-retained age 2 chinook. Over all ages, however, the ratio of released-to-retained chinook is very reasonable and ranges from 3.5 to 6 chinook released per chinook retained in the GSPT fishery. B. Riddell will continue to investigate the incidental mortality attributed to the GSPT and how to relate estimated rates to rates observed in this fishery.

Cowichan Chinook Stock Status

The status of Cowichan chinook might best be understood within the context of the original goals of the Pacific salmon Treaty chinook rebuilding program as outlined in TCCHINOOK (88)-2. The Pacific Salmon Treaty (PST) established a system of fishery specific catch and harvest rate restrictions intended to:

"halt the decline of spawning escapements of depressed stocks; and attain by 1998, escapement goals established in order to restore production of naturally spawning chinook stocks, as represented by indicator stocks identified by the Parties, based on a rebuilding program begun in 1984".

The goal of the program was to increase production through progressive increases in spawning escapements achieved by a combination of catch ceilings in selected mixed-stock fisheries and harvest rate restrictions in non-ceilinged, pass-through fisheries.

In assessing the status of individual stocks under the rebuilding program, the Chinook Technical Committee (CTC) identified three main elements for examination: 1) spawning escapement trends and levels; 2) fishery and stock-specific exploitation rates; and 3) production responses to increases in spawning escapements.

Within the context of this rebuilding strategy, and based on improved escapement levels and enhancement results, the status of the Cowichan chinook is considered to be in a rebuilding mode. However, since estimates of hatchery contribution to escapement for this system have dramatically increased in recent years, the impact of enhancement on this natural chinook stock may be of concern. It is apparent that continued efforts to rebuild this stock, and the Lower Strait of Georgia chinook stock as a whole, and meet escapement goals, will require continued harvest level controls. With expanding enhancement efforts, habitat protection measures and continued management restrictions, the Cowichan stock in particular, has shown considerable improvement. Chinook escapement to the Cowichan River in both 1995 and 1996 have exceeded the original escapement goal.

Conclusions:

1. The decline in escapement has been stopped and for the past two years returns have been above the original escapement goal. Estimate of natural production is presently at approximately 50% of the total return.
2. The Cowichan chinook stock is extensively exploited by the northern Strait of Georgia sport fishery.
3. Evaluation for the biological basis for the escapement goal will require continued monitoring and biosampling of the escapement.

Recommendations:

1. Further assessment is necessary to determine the impact of chum spawning on the reproductive success of chinook in the Cowichan River.

2. Enhancement impact on natural chinook populations in the LGS chinook stock complex should be assessed, relative to the results in the Cowichan system, and a review of enhancement procedures and outcomes should be initiated.

3. Assessment of Cowichan chinook should continue past 1998 to continue monitoring this important indicator of the Lower Strait of Georgia chinook stock.

4. Further study should be conducted on the impact of seals in the estuary.

Literature Cited

Argue, A. W., R. Hilborn, R. Peterman, M. Staley, and C. Walters. 1985. Strait of Georgia Chinook and Coho fishery. Can. Bull. Fish. Aquat. Sci. 211: 91p.

Beamish, R. J., B. Riddell, C. M. Neville, B. L. Thomson, and Z. Zhang. 1995. Declines in chinook salmon catches in the Strait of Georgia in relation to shifts in the marine environment. Fish. Oceanogr. 4: 243-256.

Bigg, M.A., G.M. Ellis, P. Cottrell, and L. Milette. 1990. Predation by Harbour seals and Sea lions on adult salmon in Comox Harbour and Cowichan Bay, British Columbia. Can. Tech. Rep. Fish. Aquat. Sci. 1769: 31p.

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: 155p

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. MS Rep. Fish. Aquat. Sci: 2329.

Candy, J.R., D.A. Nagtegaal, and B. Riddell. 1995. A preliminary report on juvenile chinook production in the Cowichan River during 1993 and 1994. Can. MS Rep. Fish. Aquat. Sci: 2354.

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: 80p

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.

Chamberlin, T.W., E.A. Harding, and B.D. Tutty. 1984. Salmonid habitat information project (S.H.I.P); a strategic level inventory approach. Can. Manuscr. Rep. Fish. Aquat. Sci. 1821: 25p

Collicutt, L. D. and T. F. Shardlow. 1992. Strait of Georgia sport fishery creel survey statistics for salmon and groundfish, 1990.

Can. Manuscr. Rep. Fish. Aquat. Sci. 2109: 76 p.

Debeck, H.D. 1974. Cowichan Lake water storage regulation - provisional rule curve. B.C. Water Rights Branch.

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

Hankin, D.G., and R. McKelvey. 1985. Comment on fecundity of chinook salmon and it's relevance to life history theory. Can. J. Fish. Aquat. Sci. 42: 393-394.

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

Healey, M. C. 1982. Juvenile Pacific salmon in estuaries: the life support system. p. 315-341. In V.S. Kennedy (ed.) Estuarine Comparisons. Academic Press, New York, NY.

Healey, M.C., and W.R. Heard. 1984. Inter- and intra-population variation in the fecundity of chinook salmon and it's relevance to life history theory. Can. J. Fish. Aquat. Sci. 41: 476-483.

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

K.P.A. Engineering Ltd. 1991. Cowichan Lake Storage Assessment. Unpublished Report.

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.

Millerd, D. 1995. Personal communication. Cowichan River Community Economic Development hatchery manager. P.O. Box 880, Duncan, B.C., V9L-3Y2.

Ministry of Environment and Parks. 1986. Cowichan - Koksilah water management plan - final report. Vancouver Island Region, Water Management Branch. 2569 Kenworth Road, Nanaimo, B.C.

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: 53p

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: 71p

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: 73p

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: 84p

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: 84p

Olesiuk, P.F., M.A. Bigg, G.M. Ellis, S.J. Crockford, and R.J. Wigen. 1990. An assessment of the feeding habits of Harbour seals (Phoca vitulina) in the Strait of Georgia, British Columbia, based on scat analysis. Can. Tech. Rep. Fish. Aquat. Sci. 1730: 135p

PSC (Pacific Salmon Commission). 1987. Joint chinook technical committee 1986 annual report. TCHINOOK (87)-4.

PSC (Pacific Salmon Commission). 1988. Joint chinook technical committee 1987 annual report. TCHINOOK (88)-2.

PSC (Pacific Salmon Commission). 1996. Joint chinook technical committee 1994 annual report. TCHINOOK (96)-1.

Paige, W. 1992. Cowichan River Management Unit: Salmon Catch Statistical Program for 1991/1992. Cowichan Indian Band. Unpublished manuscript.

Paige, W. 1995. Cowichan Tribes Aboriginal Fisheries: Salmon Catch Statistical Program for 1994/1995. Cowichan Indian Band. Unpublished manuscript.

Riddell, B.E., and A.R. Kronlund. 1993. 1992 Evaluation of the conservation program for chinook salmon in the southern Strait of Georgia; 1988-1991 (excludes Fraser River stocks). PSARC Working Paper S93-07. 28p.

Sykes, S.D., and L.W. Botsford. 1986. Chinook salmon (Oncorhynchus tshawytscha), spawning escapement based on multiple mark-recapture of carcasses. Fish. Bull. 84(2).

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.

Walters, C., and B.E. Riddell. 1996. An assessment of chinook salmon *(Oncorhynchus tshawytscha)* in the Strait of Georgia. PSARC Working Paper S96-17. 42p.

Zhang, Z., R.J. Beamish, and B.E. Riddell. 1994. Differences in otolith microstructure between hatchery-reared and wild chinook (*Oncorhynchus tshawytscha*).Can. J. Fish. Aquat. Sci. 52: 344-352.

Table 1. Visual survey data collected for the Cowichan River by Fishery Officers stationed in the Duncan subdistrict.

			Chinook				
			Jacks		Adults		
	Method[1]	Date	Count	Estimate	Count	Estimate	River Segment[2]
1981	S	Sept. 12	175		208	1000	2-4
	S	Oct. 2	103		93	1500	2-4
	S	14	364		1160	4000	2-4
	H	22			2000		1-7
	S	23			3200	5000	2-4
Estimate for Season[3]						5500	
1982	S	Sept. 14	199		131	600	2-4
	S	Oct. 13			153		2-4
	H	19	saw few fish on spawning grounds				1-13
	F	Nov. 8				4000	
Estimate for Season						4500	
1983	S	Sept. 8	38		61	254	2-6
	S	15	62		121	504	2-6
	S	28	190		470	1838	1-2
	S	Oct. 7	207		425	1804	2-6
	S	14	802		997	2836	2-7
	S	25	901		1113	4500	1-6
Estimate for Season						4500	
1984	S	Aug. 28	80		84	400	2-5
	S	Sept. 6	25		72		
	S	13	79		80		3-11
	S	19	35		71		2-6
	S	26	291		434		2-6
	S	Oct. 3	205		283		3-7
	S	"	206		282	2200	8-11
	S	23	525		1300	5000	1-6
	S	Nov. 1	350		1276		1-6
Estimate for Season						5000	
1985	S	Sept. 12	39		46	220	2-6
	S	17	42		10		12-13
	S	27	245		104	456	2-6
	S	Oct. 3	244		99	360	2-6
	S	10	285		219		2-6
	S	16	293		347		2-6
	S	31	229		934	3500	1-6
Estimate for Season						3500	

Table 1. (cont.)

				Chinook			
			Jacks		Adults		
	Method[1]	Date	Count	Estimate	Count	Estimate	River Segment[2]
1986	S	Sept. 9	295		85	300	2-6
	S	18	46		29	300	3-6
	S	24	161		56	350	12-13
	S	Oct. 7	1310		223	1000	2-6
	S	29	613		473	1200	1-6
	S	Nov. 6	1178		491	1200	
	H	8			515		1-13
Estimate for Season						1200	
1987	S	Sept. 9	30	300	10	50	3-8
	S	17	111		16	75	2-6
	S	25	112		16	75	3-6, 11-12
	S	Oct. 6	196	800	115	400	2-6
	S	15	196		96		1-6
	H	16		saw very few spawners			1-13
	S	28	417		468		1-6
	S	Nov. 6	329		649		1-6
Estimate for Season						1200	
1988	S	Aug. 25	100		50		2-6
	S	Sept. 1	271		149	700	2-6
	S	23	1464		271	1000	2-6
	S	Oct. 3	821	1600	1094	3500	2-6
	S	14	2008		2076	4000	1-6
Estimate for Season						5500	
1989	S	Sept. 11	151		58	300	2-6
	S	21	95		39	350	3-6
	S	Oct. 5	95		48	700	2-3
	S	18	719		350	1200	2-6
	S	Nov. 1	1537		2267		2-6
Estimate for Season						5000	
1990	S	Aug. 29	254		54	250	2-6
	S	Sept. 14	385		89	1000	3-6
	S	27	3169		477	2200	2-3
	S	Oct. 19	4297		2382	5000	2-6
Estimate for Season						5300	

Table 1. (cont.)

	Method[1]	Date		Chinook Jacks Count	Chinook Jacks Estimate	Chinook Adults Count	Chinook Adults Estimate	River Segment[2]
1991	S	Sept.	19			1882	6000	2-6
	S	Oct.	2			2873	7500	2-6
	S		17			2924	8700	2-6
	S		31			3502[4]	9000	2-6
Estimate for Season							10000	
1992	S	Sept.	16	5		8		2-5
	S	Oct.	2	124		46	200	2-6
	S		15	359		291	700	2-6
	S		15	113		162		2-6
	S		27	514		797	2000	1-6
	S		28	591		767		1-6
	S	Nov.	13	506		467		1-6
	S		13	450		640[5]		1-6
Estimate for Season							7500	
1993	S	Sept.	23	23		14	47	2-6
	S		30	81		62	210	2-6
	S	Oct.	14	207		199	676	2-6
	S		28	127		327	1111	2-6
	S	Nov.	4	480		987	3355	
Estimate for Season[6]							5200	
1994	S	Aug.	24	39		3		2-6
	S	Sept.	14	67		46	156	2-6
	S		28	421		323	1098	2-6
	S	Oct.	13	1253		1146	3896	2-6
	S		26	442		1450	4930	2-6
Estimate for Season[6]							5500	
1995	S	Sept.	28	294		267	1170	2-6
	S	Oct.	25	490		1798	6653	2-6
Estimate for Season[6]							15500	

Table 1. (cont.)

			Chinook				
			Jacks		Adults		
	Method[1]	Date	Count	Estimate	Count	Estimate	River Segment[2]
1996	S	Sept. 13	45		46	147	2-6
	S	26	166		150	510	2-6
	S	Oct. 2	254		534	1815	2-6
	S	9	579		1157	3933	2-6
	S	15	195		707	2403	2-6
	S	22	557		1699	5776	2-6
Estimate for Season[6]						6500	

[1]S - Swim survey, H - Helicopter survey, F - boat survey
[2]Refer to Fig. 1
[3]Total escapement estimate for adult chinook
[4]516 chinook carcasses were counted in this total
[5]28 chinook carcasses were counted in this total
[6]swim surveys conducted by Cowichan Tribes River Management Unit, total escapement determined by Fishery officers.