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Status in 1999 of Coho Stocks on the West Coast of Vancouver Island

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ABSTRACT

The assessment of West Coast Vancouver Island (WCVI) coho stocks indicates a general trend of improving escapement and juvenile density since the period of extremely low marine survival rates resulting from the El Nino event of the early 1990s. This improvement is attributable mostly to dramatically reduced exploitation rates. Prior to the severe restrictions implemented for conservation in 1997 and 1998, exploitation rates of WCVI coho averaged approximately 62%. Since then, estimated exploitation rates have ranged between 5 to 10%. In recent years marine survival rates have been higher than the critically low level experienced in 1994, but 1996 brood survival still remained below long-term averages and decreased from the previous year.

In the absence of significant exploitation, escapement has improved to the point that 1999 levels exceeded 1996 brood year escapement for most WCVI streams having reliable escapement data. An important exception to this trend was the Carnation Creek wild indicator stock. The 1996 brood year experienced an extremely low marine survival rate (1.1%) compared to the long-term average (9.0%) and consequently escapement was below brood replacement levels. The Robertson Creek Hatchery 1996 brood also had a low survival rate of 1.8%, but this rate deviates less from the 4.5% long-term average survival experienced by this stock.

Patterns of juvenile abundance are consistent with escapement trends. In the summer of 1999, the highest juvenile densities were observed since the survey began in 1995. These levels likely resulted from high 1998 brood escapement and suggest there may have been a relatively strong 2000 smolt run on the WCVI. Correspondingly, smolt counts from wild indicator streams were high. Preliminary data from 2000 returns indicates escapement will meet or exceed 1999 levels.

RÉSUMÉ

L'évaluation des stocks de coho de la côte ouest de l'Île de Vancouver (COIV) a révélé une tendance générale à la hausse de l'échappée et de la densité des juvéniles depuis la période des taux de survie en mer extrêmement faibles résultant de l'épisode El Niño au début des années 90. On attribue cette hausse principalement à la forte baisse des taux d'exploitation. Avant la mise en œuvre de mesures de conservation rigoureuses en 1997 et 1998, le taux d'exploitation du coho de la COIV se chiffrait en moyenne à environ 62 %. Depuis, les taux d'exploitation estimés ont fluctué entre 5 et 10 %. Au cours des dernières années, les taux de survie en mer ont atteint un niveau plus élevé que le niveau dangereusement faible observé en 1994, mais le taux de survie de la classe 1996 est encore inférieur aux moyennes à long terme, ayant par ailleurs diminué par rapport à l'année précédente.

En l'absence d'une exploitation importante, l'échappée s'est améliorée au point où les niveaux de 1999 dépassent l'échappée de la classe 1996 dans la plupart des cours d'eau de la COIV pour lesquels on dispose de données fiables sur l'échappée. L'indicateur du stock sauvage de Carnation Creek est une importante exception à cette tendance. La classe 1996 de ce stock a souffert d'un taux de survie en mer extrêmement faible (1,1 %) en comparaison de la moyenne à long terme (9,0 %); par conséquent, l'échappée était inférieure aux niveaux de remplacement de cette classe. La classe 1996 provenant de Robertson Creek Hatchery affiche un faible taux de survie de 1,8 %, mais celui-ci s'écarte moins de la moyenne à long terme de 4,5 % pour ce stock.

La courbe de l'abondance des juvéniles concorde aux tendances de l'échappée. On a observé à l'été 1999 les densités de juvéniles les plus élevées depuis que le relevé a commencé en1995. Ces niveaux résultent probablement d'une forte échappée de la classe 1998 et portent à croire à une remonte relativement abondante de smolts sur la COIV en 2000. De ce fait, les dénombrements de smolts dans les cours d'eau indicateurs des stocks sauvages se chiffrent à des valeurs élevées. Les données préliminaires sur les retours en 2000 indiquent que l'échappée se situera ou sera supérieure aux niveaux de 1999.

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1 INTRODUCTION

This paper provides scientific advice concerning the overall status of coho populations on the West Coast of Vancouver Island (WCVI). The purpose is to evaluate the impact of recent management actions on stock abundance and to assess, in a general sense, what level of exploitation can be sustained given current productivity. The assessment information includes survival and exploitation rates of indicator stocks, catch and distribution of fisheries, and abundance data from juvenile and escapement surveys. The 1999 data presented here update the last report on WCVI coho (Baillie et al. 1999). Forecasts of the 2000 marine survival, abundance and distribution of southern BC coho were previously submitted (Holtby et al. 2000).

Conservation concerns for Upper Fraser coho originating from the Thompson River area and upper Skeena R. coho resulted in severe restrictions of BC salmon fisheries beginning in 1998. Ostensibly, fisheries have been managed with an objective of zero mortality on coho stocks of most concern plus a move towards more selective fishing (Department of Fisheries and Oceans, 1999). Consequently, there have been no directed coho fisheries and retention of coho has been prohibited except for some terminal fisheries targeting hatchery coho.

While these restrictions precipitated from concern over Thompson coho (Irvine et al. 2000), the status of other southern BC coho stocks was also deteriorating. Since the 1990s Strait of Georgia coho showed decreases in abundance resulting from declining marine survivals in conjunction with high exploitation rates (Simpson et al. 2000). Similarly, WCVI coho have experienced extremely low survival over the past decade particularly during the El Nino event from 1993 to 1995. It is important to emphasize that conservation concerns for coho are not restricted to Upper Fraser stocks. Although perhaps not as critical, low abundances have been observed in all southern BC regions.

With regard to WCVI fisheries, the most significant closure was the WCVI troll fishery, which averaged 77% of the WCVI coho catch as estimated by coded-wire tag (CWT) analysis of Robertson Hatchery recoveries. Since 1998, terminal fisheries have been permitted at various times on the Somass and San Juan Rivers specifically targeting hatchery supplemented populations. During the current 2000 season, restrictions have been relaxed further and retention of unmarked coho has been allowed later in the season in Areas 23 and 24 (Barkley and Clayoquot Sounds). With perceived recovery of coho stocks on the WCVI due to increasing levels of escapement, there will be greater pressure to provide more fishing opportunities. In this paper we attempt to evaluate whether or not productivity has increased sufficiently to produce levels of abundance more similar to long-term averages.

2 METHODS

Similar to other areas in BC, the assessment of WCVI coho stocks relies upon the use of indicator stocks to provide information about other stocks in the area. Indicators are wild and hatchery stocks with reliable smolt counts and catch and escapement data. Assuming populations located within the same area have similar marine distributions, exploitation and survival rates estimated from the indicators are assumed to represent the entire stock aggregate.

Marine distribution and catch information are gathered from the recovery of coded wire tags (CWT's) in various commercial and recreational fisheries. In the WCVI, the only stock with long-term CWT catch and release data is from Robertson Hatchery which is located off the Stamp River, near Port Alberni. The one wild stock with long-term smolt and escapement data is Carnation Creek, near Bamfield. However, marine exploitation rates for this population are unknown because Carnation coho have not been coded-wire tagged. For that reason, Carnation survival rates are calculated by assuming that Carnation coho are exploited at the same rate as Robertson Hatchery. A second wild indicator was developed on Kirby Creek in 1997 and these fish have been coded-wire tagged since 1999. These three indicators are described in more detail below.

Intensive collection of data from indicator stocks is supplemented with more extensive enumeration of juvenile and adult populations in streams throughout the WCVI area. Late summer fry surveys have been conducted annually since 1995 to provide information on juvenile densities and sizes which are correlated with brood year escapement (Simpson et al. 1996; 2000). Visual estimates of escapement have been made on various WCVI streams since 1953. However, before 1995, methods were poorly documented and surveyed rivers varied yearly. Beginning in 1995, systematic adult counts conducted approximately weekly through snorkeling and stream walks have allowed Area-under-the-curve (AUC) estimates of escapement to selected WCVI streams. Although the fry surveys and visual escapement estimates provide less accurate data than fence counts, they help provide a larger picture of the overall status of WCVI stocks.

2.1 SURVEY COVERAGE

There are approximately 700 streams on the WCVI where coho have been observed spawning (Simpson et al. 1996). More coho streams occur in Statistical Areas 24, 25 and 27 than other areas. Escapement reports exist for up to 223 streams for at least one year. Of streams with reported escapement, many support relatively small populations. Less than 85 spawners per year were reported in 50% of the rivers with reported escapements and less than 225 per year in 75% of the streams. Only two systems average over 5,000 spawners per year. These are the Somass and San Juan Rivers and both are enhanced by large-scale hatcheries. Robertson Creek hatchery on the Somass releases approximately 800,000 smolts annually and the San Juan hatchery releases approximately 300,000 fry.

In terms of survey coverage, the indicator streams encompass one large hatchery system and two relatively small wild populations. All three indicators are located in the southern half of WCVI. Escapement surveys are conducted on a variety of streams, but biased toward medium to large chinook-bearing streams supporting relatively large populations of coho. On the other hand, fry surveys are biased toward small streams supporting smaller populations of coho.

2.2 INDICATOR STOCKS

Carnation Creek

Carnation Creek is a small stream near Bamfield on the south side of Barkley Sound in Statistical Area 23. It drains approximately 10 km^2 of watershed area. About 3.1 km of the stream is accessible to spawning coho. Coho and chum salmon are annual spawners to Carnation, and chinook, sockeye, and pink have occurred sporadically. There are also resident cutthroat and rainbow trout in the system.

In 1971, a joint project was initiated between the DFO, provincial government, and forest industry to study the effects of forestry practices on coastal salmon-bearing watersheds. As part of this study, a fish counting weir was constructed at the upper tidal influence and annual counts of returning salmon (coho and chum) and juvenile fry and smolts have been conducted since. The resulting 30-year time series of fry, smolt, and adult counts plus environmental and habitat correlates represents the best coho data set on the west coast of Vancouver Island, indeed one of the best anywhere. For more details concerning the Carnation Creek Project see Hartman and Scrivener (1990).

The counting weir is a rigid structure that is used for counting both upstream migrating adults and downstream migrating juveniles. The adult weir operates from the low flow period in August through to the end of the run in November. All adults are blocked at the weir and examined for sex, fork length, and weight. As well, the presence of external marks is noted and a scale sample is taken for age analysis.

The juvenile weir is set up during March prior to fry emergence and the smolt run. Migrating smolts are funnelled into a set of fan traps (a variant of an inclined plane trap built into the fence). The trapped fish are counted daily and then released downstream. A sample of the smolts are identified to species, measured for fork length and weight, and a scale sample is taken for age analysis.

The data were analysed for trends in smolt and spawner abundance. Marine survival was estimated for Carnation by assuming an exploitation rate equal to Robertson hatchery marine exploitation as estimated from CWT recoveries. We also calculated the annual intrinsic rate of increase for the population. This rate is a measure of productivity and described by Bradford and Irvine (2000). When R_t, the adult recruitment for a given year (t), is first calculated from escapement (S_t) and exploitation rate (ER), the intrinsic rate of increase (r_t) is the logarithm of the proportion of recruits to spawners (S_{t-3}):

$$R_t = \frac{S_t}{1-ER}, \quad r_t = \ln\left(\frac{R_t}{S_{t-3}}\right)$$

Kirby Creek

Kirby Creek is a small stream located on the southwest corner of Vancouver Island in Statistical Area 20. It drains into the Strait of Juan de Fuca approximately 13 km west of Sooke. The mainstem has 6.4 km of accessible reach, and a major tributary enters the system 1.2 km upstream providing an additional 1.1 km of accessible reach. Coho and chum salmon, as well as steelhead trout, are anadromous migrants to this system and resident cutthroat trout are present. Fence operations began in the fall of 1997.

Escapement is counted using a weir located 800-m upstream from the estuary and about 400 m above tidal influence. All salmon passing through the weir are identified to species and sex, measured for fork length and weight, and a scale sample is taken for age analysis. The fish are also tagged with external markers before being released upstream. The weir operates for the duration of the run into late December. During this period, visual counts are conducted regularly to provide a backup AUC estimate of escapement for high flow periods when the counting weir is inoperable. Tagged and untagged carcasses are counted and survey life is estimated using the interval between the application date and the collection date, adjusting for the condition of the carcass. Mark-recapture estimates are also made.

The juvenile counting weir is operated for the duration of the smolt run. Migrating smolts are examined for species and fork length, and weight and scale samples are taken from a portion. Since the 1997 brood year, coho smolts have been coded-wire tagged for later exploitation and marine survival analysis. Pre-smolts occupying habitat in the 800m reach below the weir are enumerated prior to the smolt run using mark-recapture sampling. These fish captured below the weir are also coded-wire tagged.

The Kirby Creek Project is a study operated by the Community Fisheries Development Centre - South Island Streams and has received funding from the World Fisheries Trust and the DFO's HRSEP program.

Hatchery and Enhanced Stock Indicators

Coded-wire tagged hatchery stocks provide much of the critical data for determining catch distribution, survival and exploitation rates. Hatchery stocks have been tagged since the late 1960's and thus have a long time series of data. Generally, hatchery coho do not survive as well as adjacent wild stocks, but their survival, exploitation rate and catch distribution pattern correlate well with wild stock patterns. Hatchery indicator stocks were chosen because they represent other stocks in their area and have complete escapement information. Data from hatcheries with absent of incomplete escapement data can only be used for catch distribution.

There are three major enhancement facilities and five smaller facilities releasing coho smolts on the west coast of Vancouver Island. Only one, Robertson Creek, has been identified as an indicator stock and is the only site producing significant numbers of coho. Smaller numbers of both fry and smolts are released from Nitinat and Conuma hatcheries, to compensate for interception of coho during terminal chum fisheries. The causative agent for bacterial kidney disease is endemic in Nitinat River stock. Disease screening protocols and outbreaks of the disease mean that not all brood years have been coded-wire tagged and survival rates for this stock may not be indicative of survivals for other stocks. Also, most spawning occurs in the river, which is difficult to enumerate or sample. Conuma Hatchery smolt releases have been marked consistently since 1982 brood. Like Nitinat, however, most spawning occurs in the river. In 1998, a deadpitch was conducted and an area-under-the curve estimate calculated for Conuma River.

Stamp Falls and Robertson Hatchery

The Somass River is one of the largest coho systems on the WCVI. The Somass is formed at the confluence of the Stamp and Sproat Rivers, which drain Great Central and Sproat lakes, respectively. The Somass flows for approximately 8 km into the head of the Alberni Inlet. Robertson Hatchery is a major producer of hatchery coho on WCVI and is located at the outlet of Great Central lake on Stamp Lagoon. The facility was originally developed, unsuccessfully, as a spawning channel in 1959 to introduce pink into the Somass River system. In 1971, a successful pilot operation led to construction of a full-scale salmon hatchery. Production began with chinook and coho in the fall of 1972, with steelhead added later. The facility consists of two fishways and incubation and rearing facilities for coho, chinook and steelhead. A fishway at

Stamp Falls was constructed in 1927 to aid fish passage to the upper Stamp River. Coho have been released mainly as yearling smolts and have been tagged consistently from 1972 to the present. Starting with 1996 brood, Robertson Creek smolt releases have been represented by both 40,000 Ad-CWT and 40,000 CWT-only tag groups. Mass marking (adipose clipping) started with 1997 brood. This stock is the only survival and exploitation indicator on the WCVI, although data from Kirby Creek will be available after 1999.

Coho escapement is counted at the fishway located at Stamp Falls and at Robertson Hatchery. The Stamp Falls count includes both fish returning to the hatchery and those spawning in the river upstream of the fishway. At the hatchery, separate counts of escapement and CWT escapement are conducted. The former count includes all fish returning to the hatchery, both hatchery and naturally spawning. The latter provides an estimate of escapement originating from hatchery releases. Once fish have entered the fishway they are crowded into the brailer, then lifted out onto a sorting and sampling table where they are counted and sampled. Jack coho are able to get through the bars of the crowder and do not like to enter the brailer, especially when there are lots of adults present, so not all jacks are enumerated. In 1999, it was estimated that only 40% of the jacks who returned to the site were enumerated. The remainder went back out the fishway into the river. In 1998 and 1999 escapements increased dramatically as a result of reduced fishing pressure. Prior to 1999, the goal of the hatchery sampling program was to sample 100% of the escapement for marks. In 1999, this was reduced to 20% (37% was achieved) to reduce labour costs, while still providing reliable data. All adults were counted and all jacks handled were both counted and sampled for marks.

From 1990 to 1995, coho migrating through the Stamp Falls fishway were counted as they passed over a flashboard placed on the floor of the fishway. Fish were trapped and closely examined for approximately one hour each day for varying times, and viewing conditions in order to verify species identification and to calibrate the counts of the observers. During these years the fishway was closed to night time migration. Since 1996, migration has been monitored with the use of underwater video cameras. These cameras are placed in a counting tunnel installed within the fishway. Observations are conducted in real time through a 21-inch high-resolution colour monitor and simultaneously recorded on videotape. Time, date, observer, species, direction of migration and maturity (adult or jack) are recorded for each migrating fish. During 1996 and 1997, the fishway was unmonitored at night and migration during these nighttime periods is unknown. Since 1998, with a few exceptions, night counts have been obtained, either through real time monitoring or review of videotapes shot at night.

Observer error is estimated by comparing the real-time count with 96 hours of randomly chosen videotape. Videotape verifications are conducted by an experienced observer and are considered to be a true estimate of migration. The resulting regression relationships between the adjusted verified video observations for adult and jack coho (*COADadj* and *COJKadj*) and the real time (*RT*) observations were used to correct the initial data:

$$COAD_{adj} = \frac{RT}{0.9893} \quad r^2 = 0.9989, \quad df = 95$$

$$COJK_{adj} = \frac{RT}{1.0045} \quad r^2 = 0.9622, \quad df = 95$$

A component of the coho return is potentially not counted due to potential bypass of the fishway through Stamp Falls but this is difficult to quantify. During the run, many coho are observed in pools part way up the falls and well above the entrance to the fishway. However, very few are observed successfully passing through the more difficult upper portion of the falls. This suggests that the majority of fish ascending part way up the falls eventually drop back down and enter the fishway.

Although the hatchery is located upstream of the fishway, hatchery coho were not distinguished in the Stamp Falls count before 1998. Prior to this, a rough estimate of the number of natural spawners was assumed to be the difference between the coho escapement into Robertson Creek Hatchery and the fishway count (e.g. Simpson et al. 1996). Thus, accurate detection of wild trends required that few Robertson coho stray beyond the hatchery and few naturally produced coho stray into the hatchery. In addition, analyses of coded-wire tag data to calculate estimates of exploitation and survival rates have always assumed that hatchery fish home to the hatchery. No sampling is done for marks in the river. We know this is not the case for chinook, and an extensive deadpitch sampling program is conducted for chinook.

Beginning in 1998, the proportions of marked and unmarked coho at the Stamp Falls fishway were estimated using video data. Assuming that the proportion of wild and hatchery fish bypassing the fishway and the proportions migrating in unmonitored periods are not significantly different than the observed proportions, the video data provides information on the proportion of wild fish passing through the fishway. Given the circumstance that all spawners in the river are naturally produced, the expected mark-incidence at Stamp Falls is equal to:

$$Stamp\ Falls\ MI\% = \frac{Hatchery\ MI\% \times Hatchery\ escapement}{Stamp\ Falls\ Count}$$

Correspondingly, if all fish spawning in the river are also of hatchery origin then the expected Stamp Falls mark incidence ratio would be similar to the hatchery ratio whereas a mix of hatchery and naturally produced river spawners would yield an intermediate mark-incidence ratio.

Additional Data Sets

Two other data sets are used to indicate abundance trends in more detail, but are not accredited full indicator status. These are the Gold River escapement estimates and Cherry Creek smolt counts. The BC Ministry of Environment, Land and Parks (MELP) has counted coho in Gold River (Area 25) during summer steelhead swims almost continuously since 1977. These swims are conducted in a consistent manner on the same day every year providing an index of interannual abundance for that time. On Cherry Creek, in Port Alberni, a smolt fence has been operated since 1992 by the Alberni Enhancement Society. This group has also focused considerable effort on habitat enhancement within the area. The fence is not operated during spawning although juvenile density is surveyed within the system.

2.3 Survival and Exploitation Analysis

All our survival and exploitation analyses follow the convention of excluding age .0 catches and escapements (jacks). Analyses of hatchery data are for marked adipose clipped coho (CWT-ad's). Robertson Hatchery had the only smolt release on the WCVI which was consistently tagged before 1999 (Kirby Creek smolts are now being tagged). Thus, all estimates of exploitation and catch distribution for WCVI are derived from Robertson Hatchery coded-wire tag recoveries. Recoveries were from voluntary hand-ins of marked fish from fishers, from port sampling and from sub-sampling of the hatchery return. Potential hatchery River spawners were not sampled for hatchery tags. As noted above, fishing mortality estimates for survivals of Carnation Creek coho were estimated by assuming their exploitation equaled Robertson hatchery marine exploitation rates. This assumption was not made for the second wild indicator, Kirby Creek, because of its more southerly location. However, since 1999 Kirby Creek fish have been tagged and therefore exploitation rate analysis will be possible for the 2000 return pending recoveries of tagged fish in numbers suitable for analysis.

Catch Monitoring

From 1970 to 1999, recreational and commercial catch estimates are from the Salmon Stock Assessment Catch Database (Catch Database Spreadsheet System ver 3.4). This was accessed through the ALPHA computer at PBS. Data for 1999 are preliminary.

The WCVI creel survey began in 1984 and continues. However, starting in 1993, the temporal coverage and the number of fisher interviews conducted during the survey period were reduced through budget limitations. In 1999, WCVI creel surveys on the West Coast Vancouver Island covered the June to September period. Surveys are conducted over the Statistical Areas 20-1 to 26, but not in Area 27. Additional recreational catch monitoring activities began in 1998. Logbooks and independent observers were used in some areas to augment the catch and release information collected by the creel survey and to provide better and more timely in-season coho management. To estimate hooking mortality, an assumed release mortality of 10% was applied to the number of coho encounters in the sport fishery. The overall goal of these programs was to avoid coho by-catch and reduce the mortality associated with catch and release, when coho were encountered. A coho encounter rate program was conducted in 1998 and continued in 2000 (but not in 1999) to compare. On water catch and release data are compared to landing site data.

Up to 1997, most commercial catch was well estimated through the commercial sales slip system. However, in 1998 and 1999, severe coho conservation measures were imposed to protect upper Skeena and Thompson stocks. With no directed coho fisheries, fishing mortality associated with catch was due to either retained coho by-catch, when permitted, or mortality associated with releasing by-caught coho, when retention was not permitted. This mortality was assessed by mandatory logbook programs (both written and phone-in) in which fishers recorded and reported catches of all species and release data. To verify logbook information, a program of on-board observers was implemented to directly monitor catch encounter and releases. Fishing mortalities are the sum of kept coho, where permitted, plus encounters multiplied by assumed release mortality rates of 26%, 25% and 60% for troll, seine and gillnet fisheries, respectively. Coho mortality in previous years was likely underestimated due to ‘take home’ of coho and possibly the erroneous reporting of coho on sales slips as other species. Using observers, Bison (1992) estimated that the reported coho catch in the Nitinat chum fishery was one third of the actual catch.

Aboriginal catches of coho are not well recorded before 1999 but coverage has improved greatly since.

Coded Wire Tag Recoveries

Recoveries of CWT’s from each catch region were used to estimate the fishing mortality and distribution of Robertson coho. All CWT information is obtained from the MRP database, version 3.9, maintained at PBS, Nanaimo. Recoveries were restricted to ‘adults’ only, i.e. age .1 or brood year + 3 coho and off-site hatchery releases were excluded. Estimated recoveries are the observed recoveries multiplied by the catch:sample ratio. In the case of sport fisheries, observed recoveries are expanded by an awareness factor which represents participation in the Voluntary Head Recovery Program. For hatchery stocks, these are expanded by dividing the estimated recoveries by the tagged proportion of the total hatchery release. Recoveries by catch region were not filtered to exclude strata with few recoveries where the sampling rate was low (causing a large number of recoveries to be estimated from a few recoveries with correspondingly large confidence limits on the estimate). This is a problem for WCSpt and ACSpt as shown by the following data. In 1999 there was no sampling so the default awareness factor applied is 4. In other years the low sampling rate factor is applied, which ranged up to 22 in recent years. Using factors from previous years for the 1999 data instead of 4 would increase the survival, although not greatly since the catch was so low. It is also possible that catch in other years was overestimated.

Expansions of CWT recoveries of Robertson hatchery coho in Alberni Canal (ACSPT) and WCVI (WSPT) sport fisheries, 1999 and 1996-1997 return years. Expansions in 1998 were similar to 1999. The table combines recoveries from all tagcodes.

	1999		1997		1996	
Catch region	ACSPT	WSPT	ACSPT	WSPT	ACSPT	WSPT
OBS	16	8	8	35	1	9
EST	64	33	32	230	4	136
EXP	494	122	96	694	76	2617

Estimates of fishing mortality were made by equating catch with expanded coded wire tag recoveries of Robertson Hatchery in fisheries. This is the standard method, but it does not account for mortality associated with release during coho encounters in non-retention fisheries. The resultant under-estimation of exploitation becomes significant in relative terms when catch is small and retention restrictions increase release rates, as in 1998 and 1999. It also results in underestimates of survival. To compensate for this, potential rates of release-associated mortality are accounted for in ‘Total Unallowable Mortality’ (TUM) tables, where assumed release mortality rates are applied to the estimated number of encounters. These and mortalities can be apportioned into various areas of origin, e.g. WCVI, using DNA samples from the catch (see below). For untagged wild indicator stocks, such as Carnation and Kirby Creek, no direct estimates of fishing mortality are possible. For Carnation Creek, fishing mortality was calculated by assuming an exploitation rate equal to the Robertson Hatchery exploitation rate minus the Alberni Canal sport catches. For Kirby Creek and nearby populations, there is no CWT derived estimate of fishing mortality.

DNA estimated mortality

Traditional CWT analysis relies on the recovery of tagged fish from the catch sample to elucidate exploitation information about tagged hatchery and wild stocks. Non-tagged stocks from the same region as the indicator stocks are assumed to have similar catch distributions and exploitation rates. Alternatively, DNA methods apportion an entire catch sample into stock groupings based upon known patterns of genetic variation between stocks. Currently, errors associated with the DNA approach are potentially large and its use for areas other than interior Fraser has only received a cursory review.

DNA-based identification methods were used to estimate the stock composition of coho killed in all marine fisheries, most of which were non-retention for coho and were not sampled for coded wire tags. Observers were present for most fisheries in BC and coho encounter rates were estimated similar to that described for 1998 (Irvine et al. 1999). Monitoring of First Nations fisheries in 1999 was more thorough than the previous year. Coho encounter data and samples for Washington fisheries were obtained from Washington Department of Fish and Wildlife personnel. In non-retention fisheries, release mortalities were determined by applying standard gear mortality estimates (sport 10%, gill net 60%, troll 26%, and seine 25%) to the encounter data. Similar values, provided by American colleagues, were used to estimate the numbers of coho mortalities in selective mark fisheries conducted in Areas 5 and 6 in Washington. Sample collection and DNA methodology and analysis are described in detail in Irvine et al. 2000.

Using the estimated stock compositions of the catch samples, coho mortalities were estimated for the following stock groupings: Thompson; non-Thompson interior Fraser (Ufr); lower Fraser (below Hells Gate); East Coast Vancouver Island (the Vancouver Island portion of Area 13, Area 14, and Areas 17-19); Southern Mainland (Areas 12 and 13, excluding Vancouver Island; Areas 15 – 16; Area 28); North Coast Vancouver Island (Area 27 and Vancouver Island portion of Area 12), and West Coast Vancouver Island (Areas 20 – 26) (Irvine et al. 2000). Stock composition results from 1999 samples were generated whenever possible, otherwise stock compositions from similar 1998 fisheries were used (Appendix 2 in Irvine et al. 1999).

The estimate of abundance for each stock grouping is very imprecise and based upon summing 1999 escapement estimates (from extensive surveys and also indicator stock and hatchery counts) and using this information to extrapolate the potential escapement for rivers with no surveys, but known coho spawning. The quality and coverage of escapement surveys in many WCVI areas is poor.

DNA sample sizes used to generate the stock compositions for some fisheries was less than adequate, consequently the estimated precision around these estimates was large. Tissue sampling was opportunistic, not random, so the samples may not represent the true distribution of the catch. In addition, the mortality estimate relies on a prior estimate of the total abundance of each stock grouping and that also is subject to large error as noted above. This information is arbitrarily determined from escapement data. We do not advocate that fisheries should be managed solely on the basis of these results.

2.4 ABUNDANCE

Fry Surveys

Data obtained from indicator stocks are supplemented using extensive annual assessments of fry and escapements. The rationale and general methods of the fry survey were presented by Kadowaki et al. (1995). Fry data are used in two ways in this report: to use extensive fry densities to assess the adequacy of our small sample of escapement time series in representing regional escapement trends; and to use fry densities and sizes to qualitatively estimate the size of smolt runs in the region in 1999 and speculate on the same for 2000.

Streams were sampled in the early fall, one site per stream in about two thirds of the streams and usually two sites elsewhere. Streams were selected that were small enough to allow reaches to be isolated with nets, that had road access, and that had no or minimal coho population supplementation. We tried to sample the same sites each year although there have been some deletions and additions to the survey.

Site selection was not random: accessible reaches were selected that were judged to be coho habitat (we favoured lower gradient areas with pool and cover habitat). Although the fry survey methodology will be reviewed and some form of stratified random design may be deemed necessary for new analysis requirements, random selection has not been considered necessary for the first purpose of the data which is to aggregate densities to provide an index of inter-annual variations in abundance. This goal of detecting annual trends and perhaps discerning regional differences requires several years of data. The WCVI fry survey began in 1995.

Most sampled reaches were 20 to 35 m long. The reach was isolated with barrier nets and the abundance of coho fry estimated using a removal technique, usually three pass, with equal shocking and netting effort in each pass (Seber and LeCren 1967). The area and length of the reach was measured to calculate fry densities, with the area of water greater than 10 cm deep being recorded as well as total wetted area. Areas of riffles, glides and pools were also distinguished. The only other habitat measures taken were water temperature and since 1995, water conductivity. Calculated densities include age 1. or 2. fry. Most catches consist of >95% underyearlings (age 0. fry). Densities were expressed in this report as numbers of fry per m^2 of pool area (i.e. wetted area >10cm depth). In previous reports (e.g. Baillie et al. 1999) juvenile density was expressed as number per linear meter, but expressing density by pool area allows a comparison of our data with the longer time series of data collected from Carnation Creek (Holtby and Scrivener 1989)

Fork lengths were recorded and scales taken from fish that may have been older than underyearlings. Where the catch in the measured section was less than 100 fry, we usually extended sampling immediately upstream and/or downstream from the density reach to obtain a larger sample. We did not do this if catches were so poor that obtaining an adequate sample was not practical. The catches in the extended reach areas were not used to calculate density and the sample data were recorded separately from the sample data in the density reach.

All data are shown but spatial and temporal comparisons were made using a sub-sample of sites. Data were selected largely on the basis of having no or very little coho supplementation. A few were rejected due to sampling problems, e.g. the site frequently drying into isolated pools. For summaries of inter-annual trends, only sites having at least four years of surveys were considered. Many streams have more than one site and these were averaged for each stream to calculate a system density. Densities within Statistical Areas and the NWVI and SWVI aggregates were expressed as medians.

Escapement

Systematic surveys of coho escapement were initiated in WCVI streams in 1995. These surveys are conducted approximately weekly and yield data amenable to area-under-the-curve (AUC) estimates of escapement. Spawners are counted during stream walks, flights, or swims for the duration of the run. Survey rivers are not randomly chosen and generally reflect the distribution of major chinook-bearing systems. This is because the coho counts are made as part of the WCVI chinook escapement survey, with that survey having been extended later in the year to accommodate later spawning coho. Therefore, the majority of escapement work for coho on the WCVI is conducted on a specific habitat type: medium to large systems with fast flowing water. Although effort is made to extend the reach of the surveys upstream once coho move into the system, many smaller, localized stocks are not enumerated on the West Coast. The focus is on ‘production streams’. Of course, the exceptions to this trend are Kirby Creek and the long-term study site at Carnation Creek.

The estimates of coho escapement since 1995 are calculated using the AUC technique when the data is sufficient. Otherwise a peak count is generated. The AUC calculation uses the following relationship between spawner count (*c*), observer efficiency (*OE*), survey day (*t*), and survey life (*SL*) for *n* surveys:

$$Escapement = \frac{0.5\sum_{i=2}^{n}(t_i - t_{i-1})(c_i OE_i + c_{i-1} OE_{i-1})}{SL}$$

Although there are well-documented biases and limitations of AUC methodology, including the choice of survey life and observer efficiency (Perrin and Irvine 1990), these estimates are considered an improvement over those escapements recorded prior to 1995 with inconsistent and undocumented methodologies. Surveyors self-evaluate and report their observer efficiency based on weather and water condition guidelines provided by StAD. Survey days with reported observer efficiency less than 50% are excluded from the AUC calculations.

Accurate estimates of survey life have not been determined through a detailed mark-recapture type study for larger coastal systems, such as those typically enumerated on the WCVI. On these systems survey life is assumed to average 21 days considering anecdotal information reported by surveyors such as the condition of holding fish from week to week and the difference between peak live and dead counts. This number contrasts with survey life estimates from Georgia Basin streams where mark-recapture studies conducted in the Cowichan and Lower Fraser yielded estimates of 13 and 7 days, respectively (Simpson et al. 2000). Most coastal streams in BC with reported survey lives average 14 days and the survey life is fairly constant from year to year in many systems. The large size of WCVI systems and the coverage of the surveys likely account for observed differences. In many of these surveys, survey life is equal to stream life since the most of the accessible reach is surveyed from the upstream limit to the estuary. For the 2000 run, a mark-recapture study has been initiated on the Tranquil River in Statistical Area 24 to calibrate larger west coast streams and determine reasonable survey life estimates.

To create a simple index of escapement on WCVI streams, rivers with 5 years of AUC estimates were summed. This number does not represent total escapement to WCVI streams, but only the sum of rivers with consecutive and reliable data. It excludes escapement estimates for the San Juan, Stamp, Nitinat and Conuma Rivers which all have significant stock enhancement.

Since 1953, visual estimates of coho escapement have been made on WCVI streams. Prior to 1995, fisheries officers or stream guardians conducted most of these surveys. These data are unreliable with undocumented counting methodologies and estimation procedures. The estimates most likely underestimate true escapement and, for most rivers, the time-series of escapement is incomplete. However, we have not disregarded the available information. Using Holtby et al.'s (1999a,b) criteria, we created a regional escapement index for the WCVI in order to examine annual trends. The data were collected from the Salmon Escapement Database (SEDS) at PBS and also include the AUC estimates discussed above.

The index is the proportion of maximum-recorded escapement for a given river in the period from 1953-1999 averaged yearly over all rivers in an area (p_{max}). Rivers with less than 10 years observations were not included and years in which no estimate was recorded were ignored. Where i = stream, j = year, E_{ij} = escapement to the i^{th} stream in the j^{th} year, and n_i = number of escapement records in the area for the i^{th} stream, the p_{max} for a given stream and the average p_{max} of all streams in an area are calculated by the following equations:

$$p_{\max,ij} = \frac{E_{ij}}{\max E_i}, \quad p_{\max,j} = \frac{\sum_{i=1}^{n} p_{\max},ij}{n}$$

We divided the WCVI into two areas, south west Vancouver Island (SWVI) and north west Vancouver Island (NWVI) and calculated the p_{max} index for each. The SWVI area encompasses Statistical Areas 20 to 24, from William Head near Sooke north to Estevan Point. The NWVI area encompasses Statistical Areas 25 to 27, from Estevan Point north to the Cape Scott. The division is not necessarily biological, but corresponds to management units defined under the Pacific Salmon Treaty Coho Technical Committee.

Nootka Sound Test Fishery

Since 1984 a test seine fishery has been conducted within Nootka Sound from September to November. The test fishery is primarily directed at chum populations, but routinely catches migrating coho. We explored the data to determine if it provides a useful index of coho abundance in Nootka Sound. This was to address concern expressed by fisheries managers that the test fishery indicates more positive trends of abundance than the recent escapement data.

Since its inception, the test fishery has been operated at different times. In the mid-1980s, the fishery began in early September and terminated in the beginning of October. Over the years the timing has gradually shifted later and most recently in 1999 the fishery ran from September 29 to October 24. In addition to shifts in timing, the total effort has varied by year and day. In any given year, between 8 and 30 days have been fished and in a given day between 1 and 17 sets have been cast. These inconsistencies make standardising and comparing the data from year to year problematic.

An index was created by restricting the data set to catch periods days when at least 9 annual observations within the 1984 to 1999 period exist for that day. All other daily records from days with fewer than 9 observations were ignored. The choice of 9 observations per day is mostly arbitrary, but it reflects the period of most overlap between years. The data set that met these criteria was a consecutive 19-day period from September 28 to October 16. Within this period, daily catch/set values were averaged to calculate an annual mean catch/set value for the index.

Assuming that most of the coho by-catch is migrating Nootka Sound coho, we compared the test fishery trends with annual trends in local escapement. Two indices of escapement were used. The first was the p_{max} escapement index calculated for Statistical Area 25 for the period corresponding from 1984 to 1999. The second was the sum of escapement for rivers within Area 25 with consecutive AUC estimates of escapement ($\sum E$). The former escapement index takes into account all escapement information whereas the latter was calculated using only the more reliable 1994 to 1999 AUC estimates. Pearson's correlation coefficients were calculated for both comparisons to compare trends.

3 STOCK STATUS UPDATE

3.1 INDICATOR POPULATIONS

Carnation Creek

Adult escapement to Carnation Creek in 1999 was 47, including 23 adult females, which corresponds to approximately 8 females/km of accessible reach (Table 1, Figure 1). This escapement represents the 3.8 percentile in the 29-year time series of data and an 84% decline compared to the 1998 escapement which was near record highs. While the 1998 escapement appeared to signal a recovery of sorts, even in the absence of directed fisheries the 1999 escapement return was poorer than its 1996 brood year. The intrinsic rate of increase, *r*, was equal to -0.42 (Table 3, Figure 2). It is only the second year in the time series of data that the population has shown a negative rate of increase. The other year was 1994 return year, which corresponded with unfavourable marine conditions. A negative intrinsic rate of increase implies the population was below replacement (Bradford and Irvine 2000).

Since the mid-seventies when exploitation rates were increasing, escapement to Carnation creek has become more variable and generally trending downwards with the exception of a few remarkable years (Figure 1). The 1994 survival was extremely low (0.49%) and was likely related to changes in ocean conditions related to the El Nino event. It has been hypothesised that ocean changes affected early marine survival by either reducing prey (euphasiids) or increasing the frequency of warm water predators (mackerel). Others have suggested regime shifts in climatic conditions coupled with density-dependent mortality created by excess hatchery production has resulted in lower marine survival (Beamish et al. 1998), however the evidence for this is weak (Coronado and Hilborn 1998). Marine survivals improved after 1994 although they generally remained below long-term averages.

The smolt-to-adult survival of Carnation Creek fish for the 1999 return year was 1.2% (Table 1, Figure 9). This survival rate is one of the lowest on record, representing the 4.3 percentile. There is no direct measure of catch for Carnation fish and Robertson hatchery marine exploitation rates are applied. Even if a higher exploitation rate is assumed, such as the additional 5.7% release mortality suggested by DNA sampling of encounters (Table 16), the survival estimate increases by less than a percentage. The poor 1999 survival may indicate a return to unfavourable ocean conditions for early marine survival. Interestingly, the 'biological' forecast model, which predicts coho survivals from a regression of euphasiid abundance, most accurately predicted 1999 survivals (Holtby et al. 2000).

Summer juvenile densities averaged 0.81 fish/m^2 from 1996 to 1998, within the lower range of a 'fully seeded' stream (between 0.75 and 2.0 fish/m^2, Holtby et al. 1999b). However, recent smolts per female ratios are higher than average suggesting freshwater abundance in Carnation is not currently limited by density-dependent processes (Table 3). Because over-winter survival is positively correlated with size at Carnation (Holtby and Scrivener 1989), smolt production does not decrease linearly with declining fry densities.

Smolt abundance in 1999 was lower than in recent years (Table 3, Figure 3). However, at 2842 it was still within one standard deviation of the long term mean (3476 ± 1057, from 1975 to 2000). The 1997 return was only 49 spawners and produced 95% of the smolts in 1999. However, the smolt per female ratio remained higher than average suggesting that freshwater survival was high (Table 3). Preliminary data for 2000 indicates an abundant smolt run at 4828.

Kirby Creek

Adult escapement to Kirby Creek in 1999 was 206, which corresponds to 13.5 females/km assuming a 50:50 sex ratio (Table 1, Figure 4). The estimate was derived from a fence count combined with a mark recapture estimate to correct for periods of high flow when fish bypassed the fence. This escapement represents a 36% decrease from the previous year. The relative change compared to the 1996 brood year is unknown because the fence was not installed until 1997. Pre-fence estimates of escapement were poorly documented and appear to have grossly underestimated abundance. No direct estimate of smolt-to-adult survival is possible because fishing mortality is unknown. (Kirby fish were not tagged until the 1997 brood year and there are no nearby tagged hatchery fish coho, which would provide an estimate of exploitation rate). However, a minimum estimate of survival is 2.2%, the smolt-to-escapement survival rate. Assuming the DNA-based estimate of exploitation for the WCVI of 5.7% yields a survival of 2.4%.

Smolt output at Kirby Creek has been estimated since the spring of 1998. The highest record was the first year, 1998, with the smolt run estimated at 9309 (Figure 3). The 2000 smolt run was estimated at 4132. Although the data are limited to two years, abundance does not appear correlated with spawner abundance. For example, the 1998 return was the highest of the three years yet it yielded only 12.7 smolts per spawner as compared with 27.1 from the 1999 return. Over the same period of time, late summer juvenile densities have increased (Table 8). Again, for the limited data, it is unclear whether these densities are correlated with subsequent smolt output. For example, the first year of fence operations the smolt output was double the subsequent years, but fry densities the previous summer were lower. These preliminary results suggest that egg-to-fry survival and/or overwinter survival are quite variable in this system.

Interpretation of Kirby trends are complicated by errors associated with the abundance estimates. Both the adult and smolt counts are combined estimates of fence counts and mark-recapture estimates. In the adult case, mark-recapture is used to account for periods of high- flow when the fence is breached. In the smolt case, we use a mark-recapture survey to estimate the number of pre-smolts utilizing habitat downstream from the fence.

Stamp Falls and Robertson Hatchery

The 1999 adjusted count at Stamp Falls was 46,379 (after adjusting for uncounted periods during night time migration and observer error). Escapement to the hatchery was counted at 22,823 (CWT derived estimate was 16,601) leaving 23,556 fish to spawn in the river (Table 6). The Stamp Falls count is a 34% decrease over the previous year although the 1996 brood smolt release from Robertson Hatchery increased by approximately 8%. Correspondingly, Robertson Hatchery smolt-to-adult survival decreased from 3.5% to 1.8%, one of the lowest survivals on record (Table 1, Figure 9). Approximately 51% of the Stamp Falls fish spawned in the river (Table 6). From 1988 to 1999 the average proportion of ‘in-river’ spawners is 47%. In the past, river spawners have been considered an index of naturally produced coho spawning above Stamp Falls, but the numbers of straying hatchery fish are unknown.

Examination of the differences in mark incidence ratios between the Robertson Hatchery 1996 brood year release and escapement through Stamp Falls fishway and the hatchery (‘rack escapement’) suggests 1) that there was a downward bias in the CWT estimate of hatchery escapement and/or 2) the assumption that all hatchery releases return to the hatchery is wrong.

First of all, the estimated mark (ad-clipped) and CWT incidence rates of Robertson Hatchery escapement were both lower than the applied rates. In fact, the counted return of Robertson coho swim-ins was 37% greater than the return of 16,601 estimated from expanded CWT recoveries (number of recoveries at the hatchery divided by the tagged proportion of the brood year release). This observation is consistent with Schnute et al.'s (1990) conclusion that CWT-based estimates of escapements to Robertson and other BC hatcheries are usually biased low to comparable counts due to sampling. The lower mark rate at return rates and differences between hatchery and fishway mark rates may also indicate mortality associated with tagging and handling of fish at the hatchery before release or result from a large number of wild fish returning to the hatchery. Other reasons for the differences may be hatchery fish spawning naturally in the river, errors in estimating either/both the marked & unmarked numbers of fish released, in-river anglers selectively removing marks, non-randomness of fishway tapes selected for verification, and missed marks at hatchery.

Applied mark rates (ad-clip) of Robertson Hatchery Fish and observed mark rates of returning coho at Robertson Hatchery and Stamp Falls.

Brood	Applied	Return Mark Rate (1998)		Return Mark Rate (1999)		Stamp Falls 2000*
	RCH	RCH	Stamp Falls	RCH	Stamp Falls	
1995	4.6%	4.2%	6.5%	-	-	
1996	4.2%	4.7%	11.4%	3.0%	4.5%	-
1997	95.2%	-	-	86.9%	53.4%	79.8%

***Data for 2000 are preliminary and are based on unadjusted and partial counts of the run.**

Secondly, the 4.5% adipose mark rate of fish passing through the fishway at Stamp Falls was 50% higher than the mark rate estimated at the hatchery and more comparable with the applied rate. This was also true for 1998 and applies throughout the counting period. One would expect the rate to be lower since only a portion of the coho at Stamp Falls should be hatchery origin fish. Three explanations for this observation are: (1) ad-marked coho are being under-counted at the hatchery (this is also one explanation for the lower mark rate at return compared to the estimated mark rate at release); (2) unmarked coho were mis-identified as being marked on the video-tapes from the fishway; or (3) there is an overwhelming number of hatchery origin coho that are naturally spawning. With respect to (2), videotape observations are verified and adjusted for observer error. These explanations are not exhaustive and may not account for other causes, but in any case the high mark rate at Stamp Falls suggests that many hatchery origin fish passing through the fishway do not return to the hatchery. This observation has implications for the approximation of naturally produced spawners in Stamp River system and the long-term estimates of Robertson Hatchery survival and exploitation rates (i.e. Robertson is an index rather than a true indicator).

Given the fact there is good habitat available for wild coho upstream of Stamp Falls, a program should be initiated to assess the naturally produced production. The current estimates of the mark rate at Stamp Falls are preliminary, based on sample of two years data and the error and bias of these estimates are not well quantified. There is little information on the abundance of smolts entering the Stamp River above the fishway, but coho are enumerated spawning in tributaries upstream of the fishway. For example, the escapement to the Ash River was estimated to be over 2000 in 1998. As well, juvenile coho are also observed rearing upstream of the fishway. The higher mark rate at Stamp Falls suggests that hatchery returns have been underestimated. Without further information, we are uncertain of what component of river production results from hatchery spawners.

Since 1988, the 'in-river' escapement has averaged approximately half of the hatchery escapement and both are fairly well correlated with each other, but not with the hatchery release. Hatchery and in-river escapement are also well correlated with Carnation Creek and Gold River (Figure 6). These observations indicate that marine conditions (survival and exploitation rates) are the overriding factors affecting recent return rates. Clearly more effort is needed to assess the potential impact of Robertson Creek Hatchery on the Somass system and to determine the causes of the observed discrepancies between mark rates. Sampling natural spawners for mark rate and checking the accuracy of total, marked and tagged counts at hatcheries are two obvious actions. The 1997 brood year was mass-marked (approximately 95% with ad-clips), thus analysis of mark rates at both Stamp Falls and Robertson Hatchery for the 2000 return should be more revealing of the magnitude of potential straying between hatchery and wild stocks and bias in CWT-derived estimates of escapement.

3.2 Survival and Exploitation Analysis

Catch

There were no commercial fisheries in 1999 that allowed coho retention, and only limited recreational fisheries, directed at WCVI coho. These restrictions continued conservation measures which were implemented in 1997 to protect weak and declining stocks of coho in southern BC. Retention of marked coho was allowed in the Somass and San Juan Rivers in 1999 to allow opportunity to fish hatchery returns. Lack of fisheries seriously affects the ability to estimate abundance and distribution because of the increased error associated with small recovery samples. In addition, it becomes less valid to apply hatchery exploitation rates to unmarked wild indicator stocks. However, more recently double-index tagging allows for CWT-only groups to represent unmarked wild stocks. The difference in exploitation rate shows the effect of mark-only fisheries and the difference in survival rate between ad-cwt and cwt-only groups will be hook & release mortality (cwt-only survival will be lower).

The catch distribution of Robertson Hatchery coho for the period, 1976 to 1999, is shown in Table 2. These values are determined from expanded coded-wire tag recoveries. Figure 8 shows the average distribution in regional fisheries from 1976 to 1996 and from 1997 to 1999. Robertson hatchery is the only WCVI stock with consistent tag recovery data and these data are used to indicate the distribution of other WCVI wild and hatchery stocks. Before 1997, by far the vast majority of Robertson coho were caught off Vancouver Island in the SWVI and NWVI troll fisheries. The average catch in the WCVI troll fisheries from 1970 to 1996 was over 1.5 million pieces annually (Table 7). Most (i.e. approximately 90%) coho caught in the WCVI troll fisheries originated from rivers and hatcheries located elsewhere, predominately from Georgia Strait and U.S. stocks. Severe non-retention restrictions were implemented after 1997 and the coho catch in the WCVI troll dropped to virtually nil (Figure 7). Since 1997, the catch has been limited to retention in terminal BC sport fisheries and Washington and Alaska fisheries.

Similar to other southern BC fisheries, the WCVI troll fishery showed declining catches in the 1990s. However, the decline of the WCVI troll lagged at least a few years behind. For all southern BC sport and commercial fisheries, combined, coho catch generally increased from the early 1970s until 1986. The five-year averages for 1983-87, 1988-92 and 1993-97 are 3.23, 2.96 and 1.34 million coho, respectively. In contrast, the WCVI troll coho catch was relatively steady or increasing until 1992. Correspondingly, the catch of Robertson Hatchery coho trended upward from 1976 to 1992 (Table 2). This was also a period of increasing exploitation rates as discussed below. Catch then decreased from approximately 50,000 to virtually zero in the next two years, probably due to the El Nino related effects on marine survival. During 1995 and 1996, exploitation rates remained high despite the disastrous 1994 year and continued low survival rates (Figure 9, Figure 10). The negligible catches since 1996 are primarily the result of the regulatory elimination of the WCVI troll harvest in 1997 and the virtually complete ban on coho retention in other fisheries beginning in 1998.

Decreasing catches in the WCVI troll were due to actual declines in abundance. Firstly, exploitation rates only began decreasing significantly in 1996. While reduced abundance may be partly the result of decreased wild smolt production; lower smolt-to-adult survival was more likely the over-riding cause. Wild smolt production from indicator stocks within the Georgia Basin and WCVI was not trending down in this period and smolt releases from Washington, Georgia Basin, and WCVI hatcheries were not declining either (Simpson et al. 2000). While there are gaps in the data in terms of our knowledge of freshwater survival, the concordance of recent escapement trends from hatchery and wild indicators on the WCVI suggest the marine environment is the overriding factor affecting abundance. This decline in abundance has been experienced by all major stock regions contributing to the WCVI troll fisheries, including WCVI coho (Figure 1, Figure 16).

The estimated kill of coho in southern BC in 1998 and 1999 based on catch monitoring programs was 23,030 and 30,103, respectively (B. Shaw, pers.com, DFO, 3225 Stephenson Point Rd. Nanaimo). These estimates include not only fish landings but also mortalities associated with catch and release, calculated by applying gear-specific mortality rates to the numbers of coho caught and released. A DNA analysis of stock composition was applied to a sample of these encounters and is discussed further below.

Exploitation Rates

Marine exploitation rates for Robertson Hatchery are shown in Table 1 and Figure 10. The 1999 exploitation rate of 4.1% was determined by coded wire tag recoveries. The exploitation rate of Robertson coho slowly trended upward until 1993 when it reached a peak of almost 80%. From 1994 to 1996 it declined slightly, but was still near or above the long-term average of 62%. In 1997, there was a sharp decline with the implementation of non-retention of coho in the WCVI troll fisheries. This decline was accelerated in 1998 when severe restrictions were extended to all fisheries catching coho. Since then, both commercial and sport fisheries directed at coho have been closed or are highly restricted and exploitation rates are less than 5%.

With low exploitation rates, mortality associated with catch and release becomes significant in relative terms. In WCVI fisheries, there were 11,654 and 12,120 release mortalities of coho estimated in 1998 and 1999, respectively (B. Shaw, pers.com, DFO, 3225 Stephenson Point Rd. Nanaimo). The DNA stock composition analysis of the sampled encounters, yielded an estimate of 6.7% exploitation associated with release mortality of WCVI coho (Areas 20 to 26) and 13.0% of NVI coho (including Area 27). Except for Alaska, these estimates only include mortality associated with catch and release. If the non-Alaskan catch of Robertson coho is added to DNA derived estimates of hooking mortality; the estimated exploitation rate increases to approximately 10%.

There are several problems with estimating catch and release mortality of encountered coho. For one thing, there are good reasons to expect estimates of release mortality to be imprecise (high dependency on variable handling, variable presence of predators, etc.). A method has not been devised that probably accurately assesses even short-term mortality of coho released into open water, as opposed to experimental enclosures. As well, there may be longer-term negative affects associated with encounters that are not accounted for. For example, the viability and fecundity of surviving fish may be reduced after the stress of handling.

In terms of the DNA stock composition analysis, it relies on a prior estimate of the total escapement to each stock aggregate for that year. For many aggregates, including the WCVI and NVI stocks, these estimates were generated with considerable error by categorising streams into small, moderate, and large runs and assigning an escapement value to them from a similar sized stream within the same area. This generalisation ignores differences in local stock productivity that are often quite pronounced. Similarly, the ability of DNA methods to discriminate differences between local stocks is limited and samples are assigned to stock aggregates statistically. These errors are compounded by the fact that encounters are sampled opportunistically, not randomly, over either the duration or breadth of the fisheries. We recognise the uncertainty of these approaches and highlight the need for improved area-based escapement estimates, DNA resolution, and sampling if stock composition estimates in marine fisheries are used to calculate exploitation rates.

The following table shows recoveries of double-indexed tag groups from the 1996 and 1997 brood years releases from Robertson hatchery. The total exploitation rate of tag groups with adipose clips was 9.64%, over 6% higher than CWT-only groups. In 1999, there were no mark-only fisheries on the WCVI so the exploitation rates should be similar. However, the two estimates of exploitation were calculated with different expansions because tags were recovered with different methods. The CWT-ad fish recoveries were from both direct sampling and voluntary hand-ins of marked fish whereas the CWT-only recoveries were from direct sampling only. Therefore, CWT-ad expansions include an ‘awareness’ factor that is based on historical averages which may not be appropriate for current conditions (Section 2.3). In addition, it is possible that fishers preferably retain marked (ad-clipped) fish over unmarked fish even when retention of unmarked fish is permitted.

Releases and recoveries (expanded) of 1996 and 1997 brood year coho from Robertson Creek Hatchery. 1996 BY recoveries include Alaska and Washington state recoveries. 1997 BY recoveries only include jack returns.

	Releases [1]			Recoveries				
	CWT release		Total Release	1999				1998
	Adipose Clip	No Clip		Catch	Esc	Survival	ER	Esc
1996 Brood Year:								
182149		29807	670108	450	12655			895
182307		9982	224411	90	3008			92
Total (no mark)		39789	894519	540	15663	1.81	3.33	987
182421	9910		9910	44	268			17
182422	9929		9929		174			3
182423	9868		9868	20	161			
182424	9871		9871	16	147			37
Total (cwt +mark)	39578		39578	80	750	2.10	9.64	57
1996 BY Total:			**934097**	**620**	**16413**	**1.82**	**3.64**	**1044**
1997 Brood Year:								
181720	10102		200050		686			
181721	10098		199971		426			
181722	10193		201853		101			
181723	10106		200130		101			
Total (marked)	40499		802004		1314			
183919		10173	10173		75			
183920		10197	10197		36			
183921		10189	10189		18			
183922		10109	10109		18			
Total (CWT + no mark)			40668		147			
1997 BY Total:			**842672**		**1461**			

1 Both 1996 and 1997 brood years were double indexed. However, in 1997 the brood was mass marked with adipose clips. Only 4 taggroups (40,668 smolts) were released without ad-clips as a double-index reference group.

Marine Survival

The marine survival rates of 1.8% at Robertson and 1.1% at Carnation are well below long-term averages and represent the lowest survival rates since the extremely poor 1994 return (Figure 9). Average annual marine survival rates of Robertson and Carnation coho since 1976 are 4.5% and 9.0%, respectively. Carnation coho survival rates were calculated using a catch that was estimated assuming the same marine exploitation rate as Robertson Hatchery coho (where catches are measured from CWT recoveries). Adding DNA-based estimates of release mortality to return increases the estimated survival rate marginally by less than 0.5%.

With the exception of 1989 to 1992 returns, Robertson hatchery coho survival rates have been generally declining since 1980. The first three years of hatchery return were at or near wild survival rates as measured at Carnation Creek. After the 1979 return year, which corresponded to the first second-generation hatchery return, hatchery survival rates have typically been well below wild survival rates. This decline may be a coincidence since other hatcheries (e.g. within the

Georgia Basin) do not show a similar trend. In general, the survival rate of WCVI coho through the 1970s and 1980s matches trends observed throughout southern BC and Washington State (Coronado and Hilborn 1998). Both Robertson and Carnation survival rates reached a record low in the 1994 return year probably resulting from ocean changes related to the El Nino event of 1993 (although survival rates had been decreasing since 1990-91).

Survival rates of both indicators were improving from the 1994 collapse until 1999. The reduced survival rate this past year showed a downward trend (Figure 9). However, in past years, forecast models based on sibling and euphasiid regressions have most accurately predicted survival rates better than time series models (Holtby et al. 2000). The forecasts for 2000 were 3.3% and 1.9% using the sibling and euphasiid models, similar or worse than 1999. Initial indications are that survival rates in 2000 have in fact substantially improved over 1999.

There are few years on record when the Carnation and Robertson survival rates are similar and most of these occurred in the first years of the hatchery. Since wild runs also experience higher survival rates elsewhere (Simpson et al. 2000, Emlen et al. 1990), it is puzzling that the relative decline of the Carnation survival rate from 1998 to 1999 is so much greater than Robertson. However, the Carnation Creek run is small and as a small population it is more susceptible to random events. There is no direct measure of exploitation rate for Carnation Creek and assuming that Carnation Creek coho experience similar exploitation rates to a large population (as calculated from CWT recoveries from Robertson hatchery) or an aggregate of populations (as calculated from DNA stock composition analysis) is problematic. Under certain conditions, even modest fisheries could severely impact a small return the size of Carnation. In such a case, smolt-to-survival would be underestimated. On the other hand, if straying from Robertson Hatchery has been significantly underestimated, as the mark-incidence ratio observed at Stamp Falls suggests, then marine survival rates of hatchery fish may have more closely matched wild survivals throughout the time series.

3.3 ABUNDANCE INDICES

While exploitation and survival analyses rely upon data from intensive sampling of indicator stocks, overall patterns in abundance are determined through more extensive surveying: namely juvenile density estimates and escapement surveys.

Fry Surveys

In 1999, a total of 53 sites on the WCVI were surveyed for fry abundance. Median densities in the both the SWVI and NWVI regions were less than 0.5 fry/m^2 in 1995, almost certainly below densities indicating a 'fully seeded' stream (Holtby et al. 2000). Since 1995, densities have improved so that the highest fry densities were observed in the fall of 1999 likely resulting from the large escapements observed in 1998 and favourable freshwater survival. The median density in NWVI was 0.971 fry/m^2 (Table 9, Figure 10). It was lower than the density of 1.283 fry/m^2 observed in SWVI areas (Table 8, Figure 11). (These medians exclude sites, such as the San Juan River, having significant enhancement activity.) Correspondingly, a relatively large smolt run was observed on those indicator streams where smolts are counted; Carnation, Kirby and Cherry creeks (Figure 3). In addition to the effect of the strong brood escapement of 1998, the increase in smolt abundance at Cherry Creek may at least be partially attributable to significant habitat enhancement activities that have occurred there.

Patterns of fry density trends are similar across the WCVI with the exception of Statistical Area 26 (Kyoquot Sound) and Area 24 (Clayoquot Sound). The Kyoquot Sound surveys indicated lower densities in 1999 than 1998 and in Clayoquot Sound densities increased less dramatically than other areas. However, escapement trends in these areas were similar to other WCVI areas.

Therefore, it is unclear whether or not their different fry density trends reflect actual differences in freshwater habitat conditions or are simply anomalies of the sampling. On a regional level, the fry data for both NWVI and SWVI were positively correlated with brood year escapement data (Figure 13). In other regions, such as the Georgia Basin where extensive fry surveys have been conducted over a longer time period, this relationship is more established (Simpson et al. 2000). There are very few WCVI rivers where accurate escapement and fry survey data are coupled. The fry survey, in fact, is meant to provide an alternative index of stock status particularly for rivers where escapement surveys are difficult to conduct.

With increasing juvenile density, lower average fry size is observed (Figure 12). In Carnation Creek, fall fry length was positively correlated with overwinter survival and those years with lower fry densities resulted in higher winter survival rates (Holtby and Scrivener 1989). As yet, there is no evidence of non-linearity in the relationship between escapement and fry density suggesting that escapements have not been sufficient to produce density-dependent fry mortality (Figure 13). However, the surveys are limited to one strong brood year and a longer time series encompassing the variance of escapement is required to rigorously explore these relationships. Also important to note, the correlation between brood year escapement and subsequent fry density remains weak for WCVI stocks, therefore caution is required when hindcasting escapement through fry data and interpreting density-dependent relationships which may be suggested by the data.

Notwithstanding limitations of the data, the fry data have mostly provided a retrospective perspective on brood year escapement by verifying and augmenting escapement trends. The timing of fry surveys in late summer is after or concurrent with potential bottlenecks in egg-to-fry and summer survival. It appears that egg to fry mortality and summer mortality are not so variable that this connection is lost. In studies of juvenile coho, environmental correlates such as summer low flows and nutrient status have limited freshwater production of coho smolts (Slaney and Ward 1993, Bilby et al. 1998). In Carnation Creek, fall fry densities reflected both environmental and density-dependent processes (Holtby and Scrivener 1989). However, because fry surveys are conducted before the period of overwinter mortality this potential bottleneck to smolt production is not captured. The degree to which overwinter mortality varies is likely related to system-specific habitat characteristics such as the availability of off-channel habitat or in-stream cover (Skeesick 1970).

Of course, if overwinter survival is the major bottleneck to coho production in some WCVI streams, the fry data will not be well correlated with smolt production unless overwinter mortality shows little annual variation. However, the fry data still provide information on population size particularly at low densities where density-dependent processes are not significant and year-to-year trends in fry density provide information on annual variation in abundance by correlating fairly well with brood year escapement indices. While in recent times marine survival has been the most severe bottleneck to coho production, freshwater rearing is a significant phase of coho life history. Late summer fry size affects overwinter survival in freshwater habitat and later, the condition and abundance of smolts will be a factor in early marine survival. A model formulating the relationship between fry abundance and size, overwinter survival and subsequent smolt output has been described for Carnation Creek (Holtby and Scrivener 1989). This aspect of the regional fry data set deserves more treatment to determine if similar relationships exist for streams unlike Carnation and if they can be described on a larger scale.

Escapement

The area-under-the-curve estimates of coho escapement to WCVI streams from 1995 to 1999 are displayed in Table 12 and Table 13. These data indicate that, on average, the 1999 return was larger than the 1996 brood year, but that escapement declined to less than 1998. The average of decline from 1998 was 38% and the most significant declines were observed in Areas 22, 26 and 27. The only rivers showing improved escapements in 1999 were in Area 25, however Area 25 also had 3 AUC stocks showing a decline over the 1996 brood escapement.

Escapement has improved since 1995 on streams where surveys have been conducted in consecutive years (Figure 14). Escapements in 1998 and 1999 were the highest in this period. The 1997 return was the lowest resulting from the extremely poor 1994 brood year. For rivers surveyed in both years, the 1999 return averaged approximately 300% higher than the brood year escapement in 1996. Clearly, the severe fishing restrictions have been instrumental in producing higher escapements in 1998 and 1999 in light of probable below average marine survival.

The trend of improving escapement since 1995 and the particularly strong 1998 brood year cycle is consistent over all Statistical Areas. However, the data are limited from certain areas, such as 24 (Clayoquot), 26 (Kyoquot Sound) and 27 (Quatsino Inlet)), where it is extremely difficult to conduct accurate surveys because of high flows and poor visibility. Survey coverage is not consistent by either area or distribution of known coho bearing streams. As discussed above, the fry data augment the escapement surveys. There is a discrepancy in Area 26 between the 1998 escapement data, which were relatively strong, and the density of the progeny in 1999, which did not increase. The fry density decreased in Area 26 in 1999 whereas it showed an increase more consistent with escapement trends in Areas 24 and 27. The discrepancy may be attributable to significant winter-summer mortality or a survey problem.

In terms of the provisional 3 females/km Limit Reference Point (LRP) for escapement, four rivers surveyed in the WCVI had escapements below this limit. Two were located in Area 20 and the others were in Areas 22 and 25. These streams were King (20), Lannon (20), Doobah (22), and Deserted (25). Five more rivers had female density estimates of less than 13 females/km, the upper limit for MSY escapement estimated at Carnation Creek. Overall, the lowest median female densities were observed in Area 27. These data should be interpreted with caution since the entire accessible reach was not always surveyed for every stream, but female densities are calculated assuming the entire population was enumerated. Lengths were assigned by determining accessible reach through records cited in the BC Watershed Atlas and there are inconsistencies in this database. As well, the AUC estimates are calculated with assumed survey lives greater than other coastal systems. Although they are likely reasonable for the WCVI, they have not been verified by a detailed mark-recapture study. However, a study is in progress to quantify survey life for the 2000 return on the Tranquil River.

Escapement to indicator streams follows the same patterns as indicated by the AUC surveys over the period of estimates from 1995 to 1999. Like most AUC stocks, there were fewer spawners in Carnation Creek, Gold River and Conuma Hatchery (Area 25) in 1999 than in 1998. However, all three escapements to these indicators were also poorer than the 1996 brood year. (Escapement to Gold River in 1999 may have been underestimated due to a barrier in fish migration). Gold River escapement is correlated with Stamp Falls and Carnation escapements, two indicators located farther south (Figure 6). The other indicators, Stamp River/Robertson Hatchery and Kirby Creek, showed a decline in escapement in 1999 but like many AUC stocks improved over the 1996 brood year.

The p_{max} indices for the time series of data from 1953 to 1999 are shown in and Figure 15. During the 1970s, the rate of exploitation was increasing significantly and continued to increase until the mid 90s. The general trend in escapement seems to be downward from the late-70s onward for both NWVI and the SWVI regions, although the SWVI decline appears more directed. There are a few exceptional years, such as 1990, when escapement was relatively high and 1994, when escapement was extremely low corresponding with exceptionally high and low periods of marine survival.

Most of the information for the p_{max} index comes from visual estimates of escapement conducted by stream Stream Guardians. These data are unreliable with poorly documented methodologies and most likely underestimate true escapement. For example, on Kirby Creek where a counting fence was established in 1997, average escapement estimates in the 3 years after the fence was installed were over 6 times greater than the 10-year average estimated prior to fence operations. For this reason and because the surveys began during a period of extremely low marine survival, it is not entirely clear how escapements observed in the last 5 years compare to long-term trends. However, escapement to Carnation Creek in 1998 was near the record high recorded over the last 30 years.

Nootka Sound Test Fishery

Due to the inconsistency of the data collection and timing of the fishery the usefulness of the Nootka Sound test fishery as an index of coho abundance is questionable, but in recent years the test fishery data does concur more strongly with escapement indices. However, while the 1998-1999 trend in the test fishery shows little change in abundance, escapement showed a decline averaging 29% in Area 25. Neither the p_{max} escapement index nor the summed escapement index were significantly correlated with the test fishing index although the coefficient indicated a stronger relationship between the summed escapement index and the test fishery (Figure 17). The non-significant result is not surprising considering the data is limited to 5yrs. However, it is not clear that had the escapement information extended back to 1984 the results would be similar. For the 5 years from 1994 to 1999 the p_{max} index and the $\sum E$ are correlated. It is the early years of the test fishery when the test index shows no correlation with available escapement information. This may be a reflection of its inconsistent timing. During the period from 1984 to 1990, most of the test fishing effort was conducted in late September. For these years only a few days are used to calculate the index and the variation of daily catch was high. In recent years, it has become more consistent: fishing is mostly in mid-October and the variation of daily catch is lower. As well, the timing of the fishery is more likely correlated to local coho migration.

4 DISCUSSION

Stock assessment data gathered from hatchery and wild indicator stocks and extensive surveys of juvenile density and adult escapement to WCVI streams indicate a gradual improvement in escapement and juvenile abundance over the past five years.

Given understandable social and economic concerns, there is pressure to relax fishery restrictions, especially considering perceived improvement in the status of WCVI coho stocks since the mid 1990s. However, it must be emphasised that improvements in escapement and juvenile abundance have only been achieved in the absence of significant exploitation. Despite low exploitation rates, overall abundance still remains below long-term averages and in the case of Carnation Creek 1999 escapement was below brood replacement (Figure 1). While improving marine survival since 1994 has also contributed to increased escapement, it still remains below the long-term average (Figure 9).

Recognising the depleted status of coho salmon stocks (and other managed species), the Department of Fisheries and Oceans has placed a priority on conservation and achieving sustainable exploitation of marine resources. As a result of this and other departmental mandates, such as the Pacific Salmon Treaty (PST), more emphasis has been placed on determining abundance-based exploitation and habitat-based escapement targets. Although difficult to achieve, this conservation emphasis implies consideration of ecosystems and bio-diversity at all scales.

The methods currently used to assess the status of WCVI coho stocks are population-directed. There is a distinction between population-directed approaches and habitat-based approaches towards conservation with a general consensus that neither approach provides a complete understanding of factors causing population decline (Caughley 1994). For coho salmon, which are opportunistic in their use of habitat and typically have small populations, it is very likely that small population processes are important at the local level. These effects include but are not limited to stochastic events involving genetics and demographics, overharvesting, loss of habitat, and disease among other possibilities.

Attempts to include the effect of additional factors, such as habitat quality, land use, or species interactions, in the analysis of abundance trends might reveal significant regional trends within the WCVI. This information is important for identifying conservation units (Wood 1998) and understanding demographic patterns not directly attributable to marine survival and exploitation rates. Recent examples of this are efforts to integrate patterns of habitat change with abundance trends through landscape modelling (Bradford et al.1997, Thompson and Lee 2000).

5 CONCLUSIONS

1996 Brood

1. Escapement to WCVI streams in 1999 was lower than 1998, but on average improved over 1996 brood year escapements. Since 1995, when systematic escapement surveys were begun on WCVI streams, escapement has improved yearly. Escapements in 1998 and 1999 equal average escapements over the long term record. However, these escapements were achieved only in the near absence of commercial fishing pressure: stock abundance remained poor in 1999.
2. Area-under-the-curve estimates of escapement on WCVI indicate that 4 streams out of the 53 surveyed had female densities less than the provisional 3 females/km limit reference point. These streams were all located in the southern half of the west coast.
3. Marine survival rates of both indicator stocks were significantly lower in 1999 than long-term averages. For Robertson Creek Hatchery, survival was estimated to be 1.8% and for the Carnation Creek, the wild indicator, marine survival was estimated to be 1.0%. Notably, 1999 was the first year on record that Carnation survivals have been lower than Robertson. These low survivals are the primary short-term cause of poor abundance, which remains below long-term levels.
4. Exploitation rates of Robertson Hatchery coho in 1999 estimated from CWT analysis remained low (<5%) given the continuing fisheries restrictions implemented to conserve weak coho stocks. When mortality from coho encountered in non-retention fisheries is considered, the estimated exploitation rate of WCVI coho increases to approximately 10%.

1997 Brood

5. Smolt runs counted in 1999 decreased from the previous year, but were still likely were near long-term averages for these stocks (Carnation, Kirby and Cherry creeks). Preliminary data from the 2000 return of coho to Robertson Creek Hatchery indicates that escapement has improved significantly, but it is not yet clear whether this trend is the same for wild indicator stocks and other populations.

1998 Brood

6. Escapement to WCVI streams in 1998 was particularly strong and probably contributed to the relatively high juvenile densities observed in 1999. Based on smolt counts in 2000 and summer fry densities from 1999, the 2000 smolt run may have been the largest in the past 5 years.

Fry Data

7. Fry densities on average improved in 1999 showing the highest densities since the survey began in 1995. The concurrent decline in fry sizes suggests density dependence. While we don't have adequate knowledge to define a sufficient density for every system, density in many streams remained below levels indicating a 'fully-seeded' system when compared to long-term data of Carnation Creek. Thus there may be capacity for greater production. Juvenile density is somewhat correlated with brood-year escapement and may provide an index of abundance for systems where enumerating spawners is difficult. However, more analysis is needed to determine regional relationships between fry density indices and subsequent smolt abundance.

Robertson Hatchery Indicator Stock

8. Mark incidence rates observed at the Stamp Falls fishway suggest that many more coho returning to spawn above the falls are of hatchery origin than previously assumed. This observation raises concerns about the use of Robertson Hatchery as a survival and exploitation indicator – especially if such a significant proportion of the hatchery return has not been accounted for in previous years. The production of wild (or river spawning) coho in this system needs to be studied more to determine the impact of the hatchery on wild coho in the Somass system. However, the assessment of interactions will be difficult. Other studies have shown that hatchery and wild smolts typically occupy different areas of the estuary. To determine the impact of hatchery fish, we also need to know the capacity and limitations to natural production.

9. Conservation implies a consideration of factors, both abiotic and biotic, affecting the abundance and long-term persistence of populations. To date, stock assessment of WCVI coho has mostly relied on population-directed approaches. More effort is needed to include the effect of additional factors, such as habitat quality, species interactions, etc., in the analysis of abundance trends.

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Table 1. Escapement, exploitation and survival data for WCVI indicator stocks. For Robertson Hatchery the data is based on expanded coded-wire tag recoveries.

Return Year	Robertson Hatchery					Carnation Creek			Kirby Creek		
	Total Released	Adult Escapement	Catch	% Marine Exploitation	% Survival	Smolt Enumeration	Adult Escapement	% Survival[1]	Smolt Enumeration	Adult Escapement	% Smolt to ESC[2]
1971							189				
1972							162				
1973							156				
1974							158				
1975						2,658	158				
1976	92,824	4,611	5,178	52.7	10.55	2,121	123	12.3			
1977	253,707	10,939	12,153	52.6	9.10	3,062	127	8.8			
1978	794,227	37,800	26,077	40.8	8.04	2,560	102	6.7			
1979	469,997	20,516	26,014	55.9	9.9	4,646	312	15.2			
1980	387,536	11,491	9,812	45.9	5.5	3,530	175	9.2			
1981	485,213	6,935	6,853	49.5	2.8	4,567	119	5.2			
1982	1,117,774	8,235	16,597	66.8	2.2	4,164	174	12.6			
1983	991,262	16,055	34,172	67.9	5.1	3,470	103	9.2			
1984	980,084	14,889	46,463	75.5	6.3	3,745	49	5.3			
1985	1,269,181	9,524	16,433	63.3	2.0	3,113	69	6.0			
1986	1,601,236	23,294	40,995	63.1	4.0	1,978	119	16.3			
1987	1,459,566	18,387	23,956	55.2	2.9	2,833	64	5.0			
1988	1,155,807	5,943	15,354	72.1	1.8	2,648	57	7.7			
1989	1,144,494	16,659	39,783	69.7	4.9	2,712	156	19.0			
1990	547,233	15,648	33,312	67.5	8.9	3,862	195	15.5			
1991	1,195,149	23,990	45,226	65.3	5.8	3,222	211	18.9			
1992	1,548,640	19,649	51,767	72.2	4.6	3,103	107	12.4			
1993	1,428,737	7,693	25,329	75.5	2.3	5,253	95	7.4			
1994	770,779	141	232	62.3	0.0	3,989	9	0.6			
1995	775,457	3,946	5,796	59.5	1.3	4,759	175	9.1			
1996	807,278	6,452	7,945	55.2	1.8	3,480	74	4.7			
1997	129,570	2,556	1,397	35.3	3.1	892	49	8.5		146	
1998	863,524	30,502	672	2.8	3.5	4,942	285	5.9		323	
1999	934,097	16,413	694	4.1	1.8	4,865	47	1.0	9,309	206	2.2
2000	842,672					2,842	80+	3.0+	3,957		
Average	881,842	13,844	20,509	55.4	4.5	3,454	125	9.3	6,633	225	2

1 Estimated assuming a Robertson hatchery marine exploitation rate. 2 This number represents a minimum estimate of marine survival because catch is unknown.

Table 2. Expanded recoveries of Robertson Hatchery coho plus annual survival and exploitation rates, 1976 to 1999.

Return Year:	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
No. Smolts Rel'd:	92,824	253,707	794,227	469,997	387,536	485,213	1,117,774	991,262	980,084	1,269,181	1,601,236	1,459,566
Fishery:												
NTR	8	55	705	468	30	-	82	624	783	31	684	583
NCTR	94	94	790	297	200	62	333	709	729	52	103	218
SCTR	219	398	2,605	911	614	202	456	2,155	2,490	943	2,729	1,221
NWTR	1,626	2,060	9,357	12,496	3,554	2,958	5,821	12,402	17,995	8,563	18,657	9,470
SWTR	2,343	6,601	6,363	10,203	4,351	2,945	8,973	15,082	20,378	6,166	14,003	9,512
GSTR	3	-	36	19	-	-	-	-	-	-	-	-
JFTR	-	15	-	-	-	-	-	-	-	-	-	-
NN	-	26	-	402	53	-	-	112	150	-	58	-
CN	9	25	178	245	76	-	332	130	5	-	-	82
NWVN	103	259	-	-	-	9	-	-	5	-	-	-
SWVN	22	1,216	3,249	95	559	144	-	620	1,869	-	76	53
JSN	78	72	799	34	35	-	129	704	-	-	317	-
GSN	-	-	-	-	-	-	-	-	-	-	-	-
FGN	-	-	-	-	-	-	-	-	-	-	-	-
JFN	69	340	639	93	16	144	-	-	252	244	125	258
FSN	-	-	-	-	-	-	-	-	-	-	-	-
NSPT	-	-	-	-	-	-	-	-	-	-	-	-
CSPT	-	18	-	-	-	44	69	124	87	26	-	-
ACSP	8	-	62	-	30	37	-	82	56	35	1,497	127
WSPT	72	229	471	175	30	112	92	579	305	252	1,040	1,638
GSPTN	-	19	63	47	-	-	48	117	-	23	242	-
GSPTS	-	20	65	47	-	-	-	45	64	20	-	-
JFSP	25	-	-	98	-	-	-	68	85	-	-	-
FWSP	17	-	-	-	30	35	-	69	133	-	416	577
WASHINGTON	477	707	696	387	215	131	262	235	553	55	982	89
ALASKA	6	-	-	-	19	30	-	317	524	25	66	128
TOTAL BC TROLL	4,292	9,223	19,856	24,393	8,748	6,167	15,665	30,972	42,375	15,755	36,176	21,004
TOTAL BC NET	280	1,937	4,864	868	739	297	461	1,566	2,281	244	576	393
TOTAL BC SPORT	122	286	661	365	91	228	209	1,082	729	355	3,195	2,342
ESCAPEMENT (Adults)	4,611	10,939	37,800	20,516	11,491	6,935	8,235	16,055	14,889	9,524	23,294	18,387
% SURVIVAL	10.5	9.1	8.0	9.9	5.5	2.8	2.2	5.1	6.3	2.0	4.0	2.9
% EXPLOITATION[1]	52.9	52.6	40.8	55.9	46.1	49.7	66.8	68.0	75.7	63.3	63.8	56.6
% Marine exploitation[2]	52.7	52.6	40.8	55.9	45.9	49.5	66.8	67.9	75.5	63.3	63.1	55.2

[1]FWSP as part of catch. [2] FWSP as part of escapement.

Table 2 (cont'd).

Return Year:	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
No. Smolts Rel'd:	1,155,807	1,144,494	547,233	1,195,149	1,548,640	1,428,737	770,779	775,457	807,278	129,570	863,524	934,097
Fishery:												
NTR	-	287	1,092	778	864	1,332	-	321	89	233	-	-
NCTR	-	31	158	679	-	-	-	-	-	-	-	-
SCTR	341	669	1,607	242	799	508	-	-	-	-	-	-
NWTR	3,239	13,809	18,771	16,734	15,787	10,122	50	1,416	1,962	-	-	-
SWTR	7,056	14,905	6,800	14,410	24,262	8,694	183	2,481	1,936	-	-	-
GSTR	-	-	53	-	-	-	-	-	-	-	-	-
JFTR	-	-	-	-	-	-	-	-	-	-	-	-
NN	-	50	136	115	-	95	-	-	43	31	-	-
CN	-	-	103	-	121	-	-	-	-	-	-	-
NWVN	-	-	-	-	-	-	-	-	-	-	-	-
SWVN	395	1,497	315	49	312	-	-	-	-	-	-	-
JSN	49	275	326	138	-	-	-	-	95	21	-	-
GSN	-	-	-	-	-	-	-	-	-	-	-	-
FGN	-	-	-	-	-	-	-	-	-	-	-	-
JFN	104	3,234	156	1,647	691	94	-	-	-	5	-	-
FSN	-	-	-	-	-	-	-	-	-	-	-	-
NSPT	-	-	-	61	-	-	-	-	153	27	-	-
CSPT	-	-	-	99	230	-	-	-	-	50	-	-
ACSP	223	180	97	5,572	-	-	-	-	76	96	-	494
WSPT	3,852	3,119	2,667	3,191	6,415	2,465	-	1,484	2,617	694	87	126
GSPTN	-	-	-	185	-	-	-	-	-	-	-	-
GSPTS	-	-	-	-	386	-	-	-	-	-	-	-
JFSP	-	195	211	-	181	-	-	-	258	37	-	-
FWSP	-	461	281	-	214	393	-	-	-	-	116	-
WASHINGTON	95	1,072	299	1,046	878	552	-	-	74	12	435	66
ALASKA	-	-	240	280	628	1,075	-	93	642	190	325	8
TOTAL BC TROLL	10,636	29,701	28,482	32,843	41,712	20,655	232	4,219	3,987	233	-	-
TOTAL BC NET	548	5,056	1,036	1,949	1,124	189	-	-	138	58	-	-
TOTAL BC SPORT	4,075	3,954	3,256	9,108	7,426	2,858	-	1,484	3,104	904	203	620
ESCAPEMENT (Adults)	5,943	16,659	15,648	23,990	19,649	7,693	141	3,946	6,452	2,556	29,363	16,413
% SURVIVAL	1.8	4.9	8.9	5.8	4.6	2.3	0.0	1.3	1.8	3.1	3.5	1.8
% EXPLOITATION[1]	72.1	70.5	68.0	65.3	72.5	76.7	62.3	59.5	55.2	35.3	3.2	4.1
% Marine exploitation[2]	72.1	69.7	67.5	65.3	72.2	75.5	62.3	59.5	55.2	35.3	2.8	4.1

[1]FWSP as part of catch. [2]FWSP as part of escapement.

Table 3. Carnation Creek stock-recruit data, 1968 to 1999.

Brood Year	Spawners			Smolts	Escapement			Smolts per Spawner	Returns per Smolt	Returns per Spawner	Robertson ER	Catch + ESC	*r* [1]	*h** [2]
	Females	x.0 Males	x.1 Males		Females	x.1 Males	Total ESC							
1968	N/A	N/A	N/A	N/A	81	108	189	__	__	__				
1969	N/A	N/A	N/A	1,636	75	87	162	__	0.241	__				
1970	N/A	N/A	N/A	2,121	71	85	156	__	0.269	__				
1971	81	62	108	2,559	70	88	158	13.5	0.193	2.62	0.51	321	0.53	0.41
1972	75	76	87	2,088	69	89	158	12.9	0.190	2.45	0.52	327	0.70	0.50
1973	71	43	85	2,315	55	68	123	14.8	0.166	2.46	0.53	260	0.51	0.40
1974	70	75	88	2,929	51	76	127	18.5	0.106	1.96	0.53	268	0.53	0.41
1975	69	54	89	2,403	56	46	102	15.2	0.118	1.79	0.41	172	0.09	0.08
1976	55	35	68	4,536	176	136	312	36.9	0.173	6.38	0.56	708	1.75	0.83
1977	51	53	76	3,853	65	110	175	30.3	0.097	2.96	0.46	324	0.94	0.61
1978	56	233	46	3,972	43	76	119	38.9	0.093	3.64	0.49	235	0.84	0.57
1979	176	114	136	4,390	71	103	174	14.1	0.143	2.02	0.67	525	0.52	0.41
1980	65	101	110	3,153	51	52	103	18.0	0.097	1.76	0.68	321	0.61	0.45
1981	43	61	76	3,559	22	27	49	29.9	0.060	1.80	0.76	200	0.52	0.41
1982	71	61	103	3,184	26	43	69	18.3	0.062	1.13	0.63	188	0.08	0.07
1983	51	83	52	1,876	55	64	119	18.2	0.156	2.84	0.63	323	1.14	0.68
1984	22	25	27	2,985	26	38	64	60.9	0.052	3.20	0.55	143	1.07	0.66
1985	26	59	43	2,436	23	34	57	35.3	0.084	2.97	0.72	204	1.09	0.66
1986	55	27	64	3,064	63	93	156	25.7	0.183	4.71	0.70	514	1.46	0.77
1987	26	58	38	3,670	102	93	195	57.3	0.165	9.40	0.67	599	2.24	0.89
1988	23	98	34	3,332	76	135	211	58.5	0.173	10.11	0.65	609	2.37	0.91
1989	63	160	93	3,410	53	54	107	21.9	0.120	2.61	0.72	385	0.90	0.59
1990	102	128	93	5,143	29	66	95	26.4	0.073	1.91	0.76	388	0.69	0.50
1991	76	51	135	3,759	1	8	9	17.8	0.012	0.21	0.62	24	-2.18	0.00
1992	53	43	54	4,719	78	97	175	44.1	0.096	4.24	0.59	432	1.40	0.75
1993	29	6	66	3,772	44	30	74	39.7	0.053	2.09	0.55	165	0.55	0.42
1994	1	104	8	518	32	17	49	57.6	0.095	5.44	0.35	76	2.13	0.88
1995	78	90	97	5,697	148	137	285	32.6	0.050	1.63	0.03	293	0.52	0.40
1996	44	85	30	4,230	23	24	47	57.2	0.011	0.64	0.04	49	-0.42	0.00
1997	32	123	17	2,689+				54.9+						
1998	148	69	137											
1999	23	79	24											

1 *r* is the intrinsic rate of increase. 2 h* is the exploitation rate that maintains a stable population given *r*.

Table 4. Escapement to wild indicator stocks, Carnation and Kirby creeks.

Return Year	Carnation	Kirby	Return Year	Carnation	Kirby
1971	189		1986	119	
1972	162		1987	64	
1973	156		1988	57	
1974	158		1989	156	
1975	158		1990	195	
1976	123		1991	211	
1977	127		1992	107	
1978	102		1993	95	
1979	312		1994	9	
1980	175		1995	175	
1981	119		1996	74	
1982	174		1997	49	146
1983	103		1998	272	323
1984	49		1999	49	206
1985	69				

Table 5. Smolt abundance at wild indicators: Carnation, Kirby and Cherry creeks.

Brood Year	Carnation	Kirby	Cherry	Brood Year	Carnation	Kirby	Cherry
1972	2658			1986	2712		
1973	2121			1987	3862		
1974	3062			1988	3222		
1975	2560			1989	3103		
1976	4646			1990	5253		4466
1977	3530			1991	3989		1403
1978	4567			1992	4759		5516
1979	4164			1993	3480		2087
1980	3470			1994	892		473
1981	3745			1995	4942		3182
1982	3113			1996	4865	9309	8742
1983	1978			1997	2842	3957	6958
1984	2833			1998	4828*	4132	16438
1985	2648						

* 1998 count for Carnation is preliminary.

Table 6. Counts of coho at Stamp Falls and Robertson Hatchery (RH), both swim-in and CWT expansion, 1986 to 1999.

Return Year	Stamp Falls*		RH Count		RH CWT Expansion		Stamp - RH Count		Proportion river spawning
	Jacks	Adults	Jacks	Adults	Jacks	Adults	Jacks	Adults	
1986		27,195	2,396	28,771	1302	23,294		-1,576	-6%
1987		17,050	2,547	22,982	2385	18,387		-5,932	-35%
1988	1,735	10,594	12,059	6,616	8,896	5,943	(-10,324)	3,978	38%
1989	4,633	33,886	6,723	17,508	5,268	16,659	(-2,090)	16,378	48%
1990	5,331	45,441	3,686	18,883	3,800	15,648	1,645	26,558	58%
1991	7,572	37,949	5,254	37,801	2,113	23,990	2,318	148	0%
1992	7,568	50,148	4,878	24,567	4,875	19,649	2,690	25,581	51%
1993	861	15,480	67	9,293	0	7,693	794	6,187	40%
1994	2,986	977	409	252	42	141	2,577	725	74%
1995	3,198	18,380	786	7,032	439	3,946	2,412	11,348	62%
1996	3,885	15,665	943	10,432	685	6,452	2,942	5,233	33%
1997	3,315	6,496	703	3,145	1,169	2,556	2,612	3,351	52%
1998	5,005	70,711	1,836	36,658	1,045	29,363	3,169	34,053	48%
1999	9,124	46,379	1,045	22,823	1,462	16,601	8,079	23,556	51%

*1996 to 1998 Stamp Falls counts have been adjusted for observer error.

Table 7. Coho catches in BC fisheries from 1970-1999.

YEAR	WCVI			North Central			Inside			Total
	Troll	Net	Sport	Troll	Net	Sport	Troll	Net	Sport	
1970	779433	28031	0	914116	672803	0	178892	773252	0	3346527
1971	2175719	41284	0	854837	368548	0	246115	921729	0	4608232
1972	988425	33640	0	1162329	628892	0	70315	324660	0	3208261
1973	1406301	37045	0	790179	319400	0	94005	690911	0	3337841
1974	1644003	66462	0	718630	341109	0	153738	586547	0	3510489
1975	781248	76447	0	401130	260398	0	116703	589308	0	2225234
1976	1640259	39783	0	938632	303428	0	84000	479151	0	3485253
1977	1567879	50796	0	475608	233311	0	150508	785675	0	3263777
1978	1360274	29333	0	880979	372998	0	328203	361852	0	3333639
1979	1912878	25378	0	767218	282488	16733	225735	399578	0	3630008
1980	1738470	15170	0	860840	279160	25905	153021	367750	393500	3833816
1981	1385323	7392	0	657207	198985	6568	69137	496936	317091	3138639
1982	1777436	13400	0	604096	297965	16065	117286	350269	411686	3588203
1983	2167438	9208	0	1230421	370171	7202	57938	287753	404031	4534162
1984	2172166	10559	2995	892156	223500	2467	84058	216712	443590	4048203
1985	1389055	7515	2190	662999	273356	4280	191517	422004	728197	3681113
1986	2156833	10581	2579	1682862	490079	188	184311	378239	571980	5477652
1987	1821022	7242	26834	810223	193595	11712	217728	297719	641572	4027647
1988	1595801	10968	5626	531895	169535	5587	256667	171402	1084790	3832271
1989	1952009	39660	45268	696659	190259	9315	73375	473360	497223	3977128
1990	1863608	2740	20177	1236021	317218	7623	163294	281533	630033	4522247
1991	1889946	5234	50086	1088026	243802	3400	11583	267907	157111	3717095
1992	1671822	9739	37654	754113	189644	5900	137289	194674	595554	3596389
1993	953811	3477	14322	409801	172317	5736	275953	74783	838731	2748931
1994	1251817	4752	16397	797687	268675	17889	50754	174980	294767	2877718
1995	1353949	1544	41571	315887	143121	17144	15	56884	86145	2016260
1996	792805	1013	25712	437389	166806	6132	741	10546	127890	1569034
1997	38	13	29581	173018	46725	2358	19	7068	110469	369289
1998	0	0	0	0	996	2859	0	127	1689	5671
1999	0	0	8398	0	2783	0	0	180	402	11763

Table 8. Density of fry at SWVI sites from September 1995 to 1999. Density is the number of fry per m² of wetted area with depth greater than 10cm.

Area	System	Location	Density (n/m²)					
			1995	1996	1997	1998	1999	Mean
20	**Kirby**		**0.61**	**1.44**	**1.95**	**2.02**	**3.28**	1.94
	Muir		**0.56**					1.10
	San Juan	Mosquito	**0.34**	**1.28**	**0.94**	**1.88**	**4.19**	1.73
21	**Cheewhat**	Cheewhat trib. S1	0.45	0.88	1.30	1.70	2.11	1.29
		Cheewhat trib. S2	0.56	0.52				0.54
		Average	**0.51**	**0.70**	**1.30**	**1.70**	**2.11**	0.91
	Klanawa	Blue		0.15	0.03	0.15	0.55	0.38
		Gorge				0.13		0.13
		Moon					0.52	0.52
		Ralf	0.05	0.96	0.35	0.37	0.35	0.39
		Average	**0.05**	**0.56**	**0.19**	**0.22**	**0.47**	0.36
22	**Doobah**			**0.23**	**0.23**	**0.62**	**0.42**	0.37
	Nitinat						3.67	3.67
23	**Cherry**	Cherry				5.17	5.57	5.37
		Cold (Cherry Trib)				4.41	4.19	4.30
		Average				**4.79**	**4.88**	4.84
	China	Child - north	1.75	5.10	1.81	2.80	6.20	3.53
		Child - south	0.21					0.21
		Average	**0.98**	**5.10**	**1.81**	**2.80**	**6.20**	1.87
	Fredrick						**0.65**	0.65
	Sarita	Sarita River					0.37	0.37
		South Sarita					0.00	0.00
		Average					0.19	0.00
	Somass	Gracie				**1.44**	**3.08**	2.26
		Taylor				**2.38**	**1.07**	1.72
	L. Toquart	Trib	**0.34**	**0.56**	**0.76**	**0.34**	**1.12**	0.62
	Twin Rivers E.		**0.04**	**0.42**	**0.31**	**0.69**	**1.11**	0.51
24	**Arnett**					**0.33**		0.33
	Bawden Bay					**0.78**	**0.80**	0.79
	Icey					**0.82**	**1.05**	0.93
	Kennedy	Muriel	0.11	0.10				0.10
		Muriel L. trib.		1.02	1.88	0.31	1.45	1.17
		Average	**0.11**	**0.56**	**1.88**	**0.31**	**1.45**	0.63
	Megin					**0.65**	**0.31**	0.48
	Moyeha					**1.59**	**3.60**	2.59
	Sutton Mill					**0.00**	**0.00**	0.00
	Timber					**0.21**	**0.75**	0.48
	Watta					**0.41**	**0.63**	0.52
	Woods Island					**0.12**	**0.24**	0.18
	Young Bay						**0.06**	0.06
		Area 20-24 Medians:	0.34	0.56	0.94	0.69	1.05	0.63
		Selected data:	0.34	0.56	1.03	0.65	1.28	0.63

Table 9. Density of fry at NWVI sites from September 1995 to 1999.

Area	System	Location	Density (n/m²)					
			1995	1996	1997	1998	1999	Mean
25	**Burman**					**0.61**	**0.30**	0.45
	Espinosa Head		**0.82**	**0.41**	**1.03**	**1.11**	**1.14**	0.90
	Gold	Dunlop	0.64	1.33	2.53		5.22	2.43
		Waring	0.77	5.66	4.81		7.94	4.80
		Average	**0.71**	**3.50**	**3.67**		**6.58**	3.61
	Hanna		**0.07**	**0.24**	**0.47**	**0.55**	**0.49**	0.36
	Leiner		**0.19**	**0.22**	**0.91**	**0.04**	**1.73**	0.62
	Little Zebellos			**0.38**	**1.45**	**0.57**	**0.81**	0.80
	Owossitsa					**0.49**		0.49
	Port Eliza #2					**0.69**	**1.92**	1.30
	Tsowwin	Tsowwin	0.79	1.57	0.22	0.25	3.88	1.34
		Tsowwin trib	1.81	2.94	0.27	3.23	5.10	2.67
		Average	**1.30**	**2.26**	**0.24**	**1.74**	**4.49**	2.01
26	**Catchalot**					**0.59**	**0.48**	0.54
	Clear (WCVI)					0.05		0.05
	Easy			**0.10**	**0.18**	**1.02**	**0.65**	0.59
	Kaouk		**0.35**	**0.11**	**3.18**	**27.84**	**2.99**	6.89
	Kashutl					**0.35**	**0.53**	0.44
	Kawinch					**0.18**		0.18
	Narrowgut					**0.69**	**2.89**	1.79
	Porritt					**0.32**	**0.06**	0.19
27	**Colony**						**1.12**	1.12
	Denad						**0.07**	0.07
	Hathaway						**0.95**	0.95
	Keith		**0.01**	**0.09**	**0.87**	**0.38**	**0.71**	0.46
	Kloochlimis						**2.74**	2.74
	Koprino						**1.00**	1.00
	Kwatleo						**0.77**	0.77
	Kwokwesta						**1.90**	1.90
	Mahatta		**0.97**	**1.00**		**0.37**	**2.04**	1.41
	Monkey						**0.08**	0.08
	Nuknimish						**0.16**	0.16
	Ronning		**0.16**	**0.09**	**0.31**	**0.14**	**0.22**	0.19
	San Josef	Sharp	**0.86**	**2.32**	**1.65**	**0.96**	**1.57**	1.49
		Area 25-27 Medians:	0.59	0.30	0.91	0.57	0.95	0.69
		Selected data	0.27	0.23	0.87	0.56	0.97	0.71
		SWVI and NWVI Medians:	0.47	0.56	0.92	0.61	1.03	0.65
		Selected data	0.34	0.42	0.89	0.62	1.14	1.22

Table 10. Fork lengths of coho fry in SWVI streams, September 1991 to 1999.

Area	System	Location	Average length (mm)					
			1995	1996	1997	1998	1999	Mean
20	**Kirby**		**69.6**	**61.7**	**57.9**	**60.8**	**56.6**	61.3
	Muir		**83.8**					83.8
	San Juan	Mosquito	**67.3**	**57.7**	**59.4**	**61.3**	**63.8**	61.9
21	**Cheewhat**	Cheewhat trib. S1	59.6	61.6	61.9	65.5	58.4	61.4
		Cheewhat trib. S2	65.3	72.3				68.8
		Average	**62.5**	**67.0**	**61.9**	**65.5**	**58.4**	63.0
	Klanawa	Blue		73.4	76.6	75.1	58.2	70.8
		Gorge				76.0		76.0
		Moon					60.9	60.9
		Ralf	88.0	64.3	67.7	69.0	60.5	69.9
		Average	**88.0**	**68.9**	**72.2**	**73.4**	**59.9**	72.4
22	**Doobah**			**67.2**	**63.8**	**61.0**	**58.0**	62.5
	Nitinat						**50.6**	50.6
23	**Cherry**	Cherry				51.4	48.6	50.0
		Cold (Cherry Trib)				55.8	52.2	54.0
		Average				**53.6**	**50.4**	52.0
	China	Child - north	55.5	52.3	56.7	49.0	55.4	53.8
		Child - south	62.9					62.9
		Average	**59.2**	**52.3**	**56.7**	**49.0**	**55.4**	54.5
	Fredrick						**57.3**	57.3
	Sarita	Hunter (Sarita)					67.8	67.8
		Sarita River					59.1	59.1
		Average					**63.4**	63.4
	Somass	Gracie				**50.3**	**52.0**	51.2
		Taylor				**49.1**	**55.3**	52.2
	Toquart		**62.6**	**69.6**	**61.0**	**64.7**	**56.8**	62.9
	Twin Rivers		**82.3**	**72.1**	**63.8**	**62.5**	**57.3**	67.6
24	**Arnett**					**60.9**		60.9
	Bawden Bay					**56.5**	**55.9**	56.2
	Icey					**61.5**	**54.7**	58.1
	Kennedy	Muriel	66.3	71.2				68.8
		Muriel L. trib.		73.6	64.0	69.7	61.0	67.1
		Average	**66.3**	**72.4**	**64.0**	**69.7**	**61.0**	66.7
	Megin					**60.2**	**46.3**	53.2
	Moyeha					**53.3**	**42.1**	47.7
	Sutton Mill						**75.3**	75.3
	Timber					**57.1**	**53.9**	55.5
	Watta					**55.9**	**55.7**	55.8
	Woods Island					**77.6**	**59.9**	68.8
	Young Bay						**53.7**	53.7
		Area 20-24 Medians:	67.3	67.2	61.9	60.8	56.2	60.3
		Selected data	66.3	68.0	62.9	63.6	57.7	63.9

Table 11. Fork lengths of coho fry in NWVI streams, September 1991 to 1999.

Area	System	Location	Average length (mm)					
			1995	1996	1997	1998	1999	Mean
North West Vancouver Island (Statistical Areas 25-27)								
25	**Burman**					**65.4**	**53.3**	59.3
	Espinosa Head		**65.6**	**69.2**	**60.6**	**60.4**	**60.7**	63.3
	Gold	Dunlop	46.6	52.6	54.5		48.1	50.4
		Waring	57.2	46.7	45.9		44.7	48.6
		Average	**51.9**	**49.7**	**50.2**		**46.4**	49.5
	Hanna		**69.1**	**66.0**	**66.0**	**57.6**	**52.2**	62.2
	Leiner		**61.7**	**64.4**	**61.9**	**56.0**	**59.3**	60.7
	Little Zebellos			**74.2**	**59.0**	**61.0**	**61.6**	63.9
	Owossitsa					**60.9**		60.9
	Port Eliza #2					**62.0**	**53.6**	57.8
	Tsowwin	Tsowwin	59.8	61.8	55.1	60.7	52.3	57.9
		Tsowwin trib	67.7	55.5	79.5	62.9	52.4	63.6
		Average	**63.8**	**58.7**	**67.3**	**61.8**	**52.4**	60.8
26	**Catchalot**					**61.1**	**66.4**	63.8
	Clear (WCVI)					**65.0**		65.0
	Easy			**75.1**	**77.7**	**59.3**	**45.2**	64.3
	Kaouk		**68.3**	**59.1**	**56.7**	**55.7**	**48.5**	57.7
	Kashutl					**70.9**	**65.5**	68.2
	Kawinch					**69.5**		69.5
	Narrowgut					**57.6**	**49.8**	53.7
	Porritt					**76.4**	**64.0**	70.2
27	**Colony**						**67.2**	67.2
	Denad						**62.3**	62.3
	Hathaway						**52.8**	52.8
	Keith		**75.0**	**58.0**	**60.7**	**66.0**	**57.2**	63.4
	Kloochlimis						**56.5**	56.5
	Koprino						**53.5**	53.5
	Kwatleo						**68.7**	68.7
	Kwokwesta						**65.4**	65.4
	Mahatta		**62.1**	**63.3**		**61.4**	**51.9**	59.7
	Monkey						**65.8**	65.8
	Nuknimish						**72.1**	72.1
	Ronning		**69.7**	**78.7**	**69.6**	**77.9**	**67.9**	72.8
	San Josef	Sharp	**65.0**	**68.6**	**62.4**	**68.8**	**60.4**	65.0
		Area 25-27 Medians:	65.3	66.5	61.9	61.8	60.4	63.0
		Selected data	67.0	65.2	61.9	60.7	54.8	62.9
		SWVI and NWVI Medians:	66.3	67.0	61.9	61.1	57.0	62.0
		Selected data	66.3	67.1	61.9	61.2	57.2	63.3

Table 12. Escapement estimates for SWVI streams. All are AUC estimates unless indicated.

Area	Stream	Accessible Length (km)	1998		1999		Percent Difference
			Total	Females/km	Total	Females/km	
19	Colquitz	6.4	20	2	10	1	-50
	Craigflower	6.8			94	7	
20	Ayum	0.8			16	10	
	De Mamiel[1]	3.3	1020	154			
	Falls	0.3			27	45	
	Gordon	24.0	668	14	1790	37	168
	King				4		
	Kirby[2]	7.3	323	22	312	21	-3
	Lannon	0.6			2	2	
	Mosquito	5.0			417	42	
	Muir	4.8	886	92	845	88	-5
	San Juan[1]	36.0	49959	694	35000	486	-30
	Tugwell	4.8	130	14	94	10	-28
21	Blue	1.2	40	17			
	Cheewhat	3.2	23	4			
	Klanawa	22.5	768	17	400	9	-48
	Ralf	1.0	46	23			
22	Doobah	3.2	21	3	9	1	-57
	Nitinat[1]	19.0	6030	159	2651	70	-56
23	Carnation[3]	3.1	272	44	49	8	-82
	Drinkwater		191				
	McBride		575				
	Nahmint	4.8	424	44	225	23	-47
	Sarita	9.7	895	46	786	41	-12
	Taylor	10.0	2558	128	2244	112	-12
	Toquart	4.0	3170	396	1922	240	-39
24	Bedwell/Ursus	10.5	3689	176	2682	128	-27
	Megin	20.0	2007	50	1120	28	-44
	Moyeha	19.0	5137	135	3079	81	-40

1 Stocks are supplemented by significant hatchery production.
2 Combined mark-recapture, AUC's, and fence-estimate.
3 Fence Count.

Table 13. AUC estimates of escapement for NWVI streams.

Area	Stream	Accessible Length (km)	1998		1999		Percent Difference
			Total	Females/km	Total	Females/km	
25	Burman	13.0	860	33	654	25	-24
	Canton	4.5	1369	152	662	74	-52
	Conuma[1]	7.6	1645	108	1094	72	-33
	Deserted	4.5	43	5	0	0	-100
	Gold[2]	54.0	489	5	25		-95
	Leiner	5.0	507	51	692	69	36
	Sucwoa	6.1	790	65	1083	89	37
	Tahsis	5.0	773	77	2026	203	162
	Tlupana	6.4	1099	86	346	27	-69
	Tsowwin	7.4	973	66	630	43	-35
	Zebellos	1.6	578	181	1052	329	82
26	Amai	2.4	426	89			
	Artlish	10.6	2002	94	501	24	-75
	Chamiss	2.0	80	20			
	Easy	3.3	477	72			
	Kaouk	9.0	5077	282	1950	108	-62
	Kashutl	3.1	337	54			
	Kauwinch	12.7	1083	43			
	Narrowgut	1.7	1269	373			
	Tahsish	6.3	1824	145	1380	110	-24
27	Cayeghle/Colonial[1]	8.3	4980	300	1597	96	-68
	Goodspeed	11.0	2776	126	695	32	-75
	Hathaway	11.8	550	23	109	5	-80
	Keith	6.5	1185	91	361	28	-70
	Klaskish	6.4	458	36			
	Klootchchimmis	5.0	1075	108	182	18	-83
	Mahatta	22.5	2161	48			
	Marble	8.6	2566	149	852	50	-67
	Wanokana		418				

1 Stocks is supplemented by significant hatchery production.

2 The 1999 Gold River estimate is most certainly an underestimate due to a barrier in migration.

Table 14. Escapement to WCVI streams with 5 years continuous data. All are AUC estimates except for Carnation creek which is a fence count.

Statistical Area	Stream	Year					Mean	Percent Difference	
		1995	1996	1997	1998	1999		Previous Year 1998 to 1999	Brood Year 1996 to 1999
20	GORDON R	16	480	283	668	1790	647	168	273
20	SAN JUAN R	19542	18919	4665	49959	35000	25617	-30	85
22	NITINAT R	3564	133	1109	6030	2651	2697	-56	1893
23	CARNATION C	175	74	49	272	49	124	-82	-34
23	NAHMINT R	84	53	69	424	225	171	-47	325
23	SARITA R	124	58	162	895	786	405	-12	1255
24	BEDWELL R / URSUS C	2004	479	908	3689	2682	1952	-27	460
24	MEGIN R	918	357	649	2007	1606	1107	-20	350
24	MOYEHA R	1370	746	657	5137	3079	2198	-40	313
25	BURMAN R	888	714	510	860	654	725	-24	-8
25	CANTON C	549	393	323	1369	662	659	-52	68
25	CONUMA R	1254	2167	658	1645	1094	1364	-33	-50
25	DESERTED C	130	5	18	43	0	39	-100	-100
25	GOLD R	1019	442	150	489	25	425	-95	-94
25	LEINER R	143	196	181	507	692	344	36	253
25	SUCWOA R	156	98	107	790	1083	447	37	1005
25	TAHSIS R	308	99	667	773	2026	775	162	1946
25	TLUPANA R	609	216	505	1099	346	555	-69	60
25	ZEBALLOS R	121	170	555	578	1052	495	82	519
26	ARTLISH R	160	212	678	2002	501	711	-75	136
26	KAOUK R	1080	813	1263	5077	1950	2037	-62	140
26	TAHSISH R	1186	409	564	1824	1380	1073	-24	237
27	MARBLE R	1833	743	638	2566	852	1326	-67	15

Table 15. SWVI and NWVI p_{max} escapement indices. The p_{max} index is described in the text (Section 2.4 Escapement).

Year	SWVI				NWVI			
	Row Count	p_{max}	ESC Index	Average deviate	Row Count	p_{max}	ESC index	Average deviate
1953	50	0.40	1505.59	-0.27	64	0.62	1551.49	0.49
1954	58	0.32	1205.57	1.78	70	0.46	1160.58	21.47
1955	53	0.34	1296.74	3.16	62	0.32	790.91	84.51
1956	55	0.38	1436.46	3.65	75	0.39	980.37	47.69
1957	57	0.37	1395.39	3.88	81	0.23	566.54	37.26
1958	57	0.36	1358.10	3.78	81	0.22	554.33	16.04
1959	58	0.33	1230.54	8.54	81	0.19	472.61	65.15
1960	56	0.17	650.43	6.84	67	0.09	217.60	108.07
1961	58	0.37	1399.80	13.44	67	0.11	267.55	64.30
1962	57	0.32	1224.09	-40.03	71	0.24	599.12	69.55
1963	59	0.15	554.47	13.20	71	0.21	524.97	64.11
1964	60	0.37	1393.05	-8.49	69	0.40	991.90	-270.06
1965	64	0.24	897.41	22.01	74	0.32	802.31	-174.00
1966	62	0.34	1277.38	-7.59	56	0.30	744.60	-48.14
1967	60	0.27	1016.40	18.17	64	0.13	330.37	98.49
1968	62	0.47	1758.73	-16.99	73	0.18	455.87	-138.06
1969	61	0.33	1233.67	-132.18	53	0.09	232.28	-44.28
1970	62	0.41	1535.20	-6.30	65	0.26	663.26	-236.85
1971	56	0.23	869.30	6.29	69	0.21	516.30	-30.60
1972	57	0.19	718.55	20.47	60	0.21	514.94	-70.17
1973	57	0.51	1919.56	-5.35	60	0.22	553.19	-88.97
1974	60	0.31	1178.17	-3.97	64	0.22	554.91	-12.40
1975	60	0.22	841.40	18.41	64	0.17	422.05	61.02
1976	56	0.23	883.53	17.45	52	0.10	240.82	30.47
1977	57	0.30	1134.06	2.82	57	0.16	395.97	-83.16
1978	59	0.30	1146.97	7.87	51	0.19	467.53	-235.64
1979	57	0.28	1052.24	-21.47	63	0.15	365.83	-168.19
1980	23	0.19	716.58	59.83	37	0.13	327.71	106.13
1981	16	0.09	336.43	24.69	38	0.15	371.42	-21.00
1982	19	0.18	684.27	30.13	24	0.22	548.24	159.07
1983	4	0.23	857.43	-0.63	19	0.18	448.14	170.57
1984	3	0.10	382.59	-0.55	23	0.12	309.83	185.86
1985	18	0.18	684.68	37.73	56	0.14	345.22	46.79
1986	28	0.17	631.29	1.46	67	0.18	459.02	-40.72
1987	17	0.15	571.14	-71.58	58	0.17	417.17	69.17
1988	17	0.16	611.67	-60.00	37	0.10	245.35	147.50
1989	19	0.20	770.14	-90.96	41	0.16	406.17	1.71
1990	23	0.21	785.94	-7.22	37	0.21	538.00	-24.47
1991	30	0.17	627.33	16.76	55	0.22	554.26	-15.74
1992	17	0.17	626.27	19.95	41	0.12	303.28	111.32
1993	20	0.09	345.30	50.43	38	0.05	119.62	144.69
1994	20	0.12	455.59	43.30	23	0.10	243.19	28.14
1995	28	0.16	614.51	27.61	47	0.12	304.50	88.13
1996	33	0.14	532.24	57.32	29	0.10	243.13	149.32
1997	28	0.12	466.29	26.60	36	0.08	206.88	135.98
1998	29	0.32	1213.63	-5.43	51	0.32	801.36	-18.41
1999	26	0.25	959.65	-16.04	32	0.16	398.06	118.59

Table 16. Summary estimates of 1999 escapements, fishery mortalities, and exploitations for southern BC (Irvine et al. 2000).

	Thompson	WCVI	ECVI	NVI	SoMnLnd	LFr	UFr
Approximate Escapement	17,000	285,000	70,000	45,000	145,000	92,000	5,400
1999 Alaska Exploitation[1]	0.003	0.000	0.007	0.007	0.007	0.003	0.003
N/Central Coast Morts	80	2,019	1,879	1,716	6,591	1,213	28
1999 N/Central Exploitation	0.005	0.007	0.026	0.037	0.043	0.013	0.005
Southern BC morts	353	12,120	3,191	1,954	2,300	4,365	148
1999 SBC Exploitation	0.020	0.041	0.044	0.042	0.016	0.045	0.027
Wa Mort's[2]	1,164	2,461	4,228	1,328	4,047	7,157	56
1999 Wa Exploitation	0.064	0.009	0.057	0.029	0.027	0.072	0.010
Total Fishery Expoitation[3]	0.092	0.057	0.133	0.114	0.093	0.133	0.045

[1] Obtained from MRP estimates for 1999 returns. WCVI estimated from releases from Robertson Creek; ECVI the mean exploitation from Quinsam and Big Qualicum; LFr the mean of Chilliwack and Inch Creek. Thompson and UFr assumed to be the same as LFr; NVI and SoMnLnd assumed to be same as ECVI.

[2] Does not include retention mortalities in mark only fisheries in US Areas 5 and 6.

[3] Does not include terminal freshwater exploitations which can be high for some enhanced populations (e.g. Chilliwack, Inch, and Quinsam).

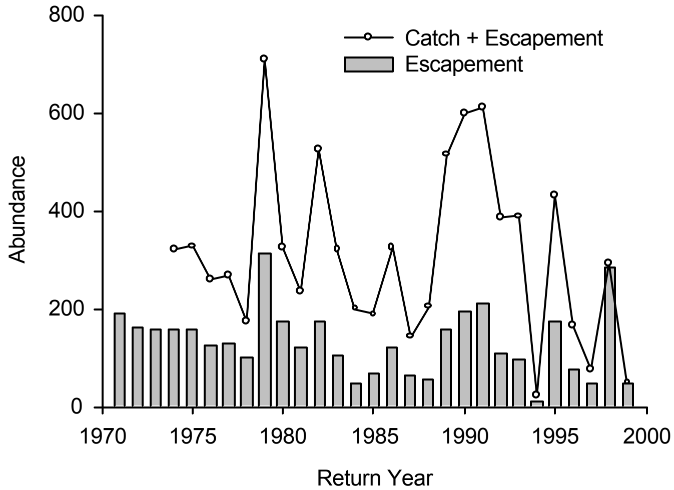

Figure 1. Carnation Creek return, 1971-1999. In order to estimate catch, the exploitation rate was assumed to equal Robertson Hatchery marine exploitation rate.

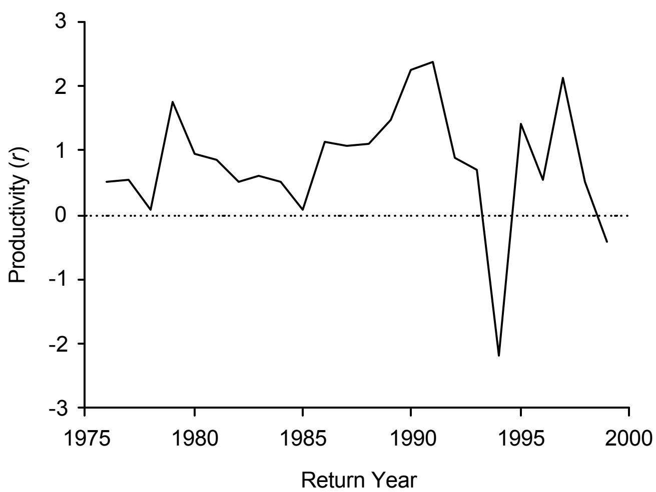

Figure 2. Carnation productivity described the intrinic rate of increase (*r*), 1976 to 1999. Exploitation rate was assumed to equal Robertson Hatchery marine exploitation rate. Productivity was below replacement levels in 1999.

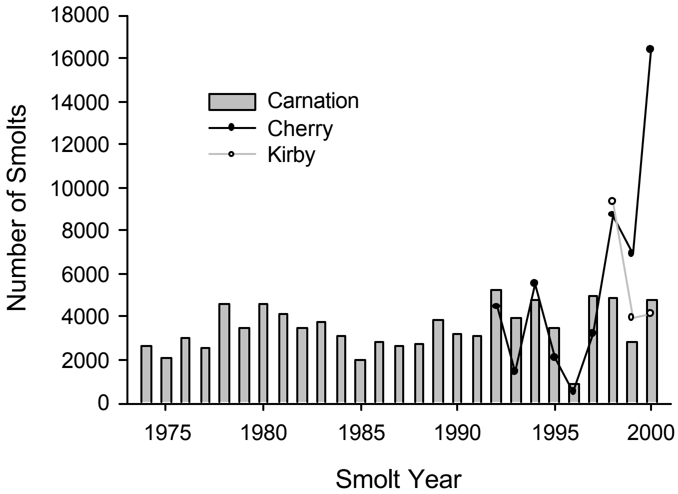

Figure 3. Smolt counts from Carnation, Cherry and Kirby Creeks, three wild indicator streams.

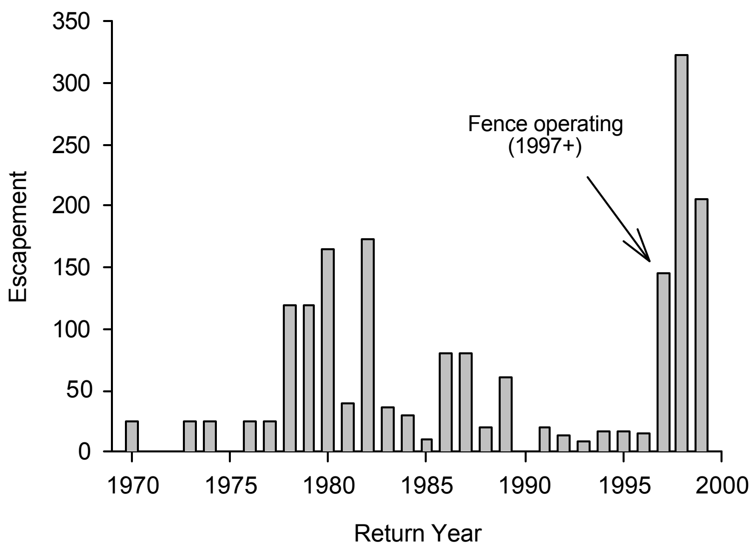

Figure 4. Escapement to Kirby Creek. Fence operations began in 1997. Prior to then, escapement was described through visual estimates with poorly documented records.

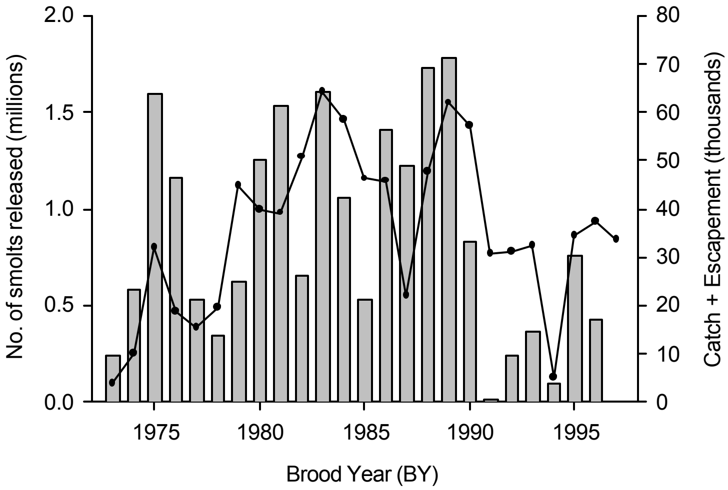

Figure 5. Robertson Hatchery smolt releases in year BY+2 (line) and return in year BY+3 (bars). Return is the expanded CWT-derived estimate of hatchery escapement and catch.

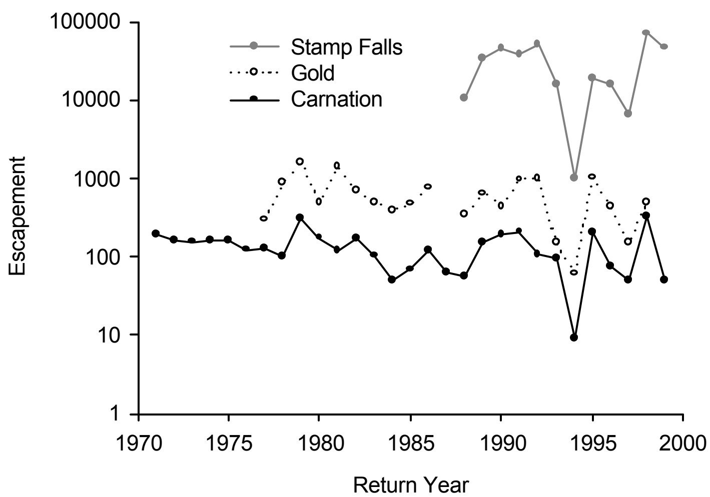

Figure 6. Correlation of Carnation, Gold and Stamp Falls coho escapement. The correlation coefficients between Carnation-Gold, Carnation Stamp, Gold-Stamp are 0.52, 0.70 and 0.49, respectively.

Figure 7. WCVI troll coho catch, 1970 to 1999.

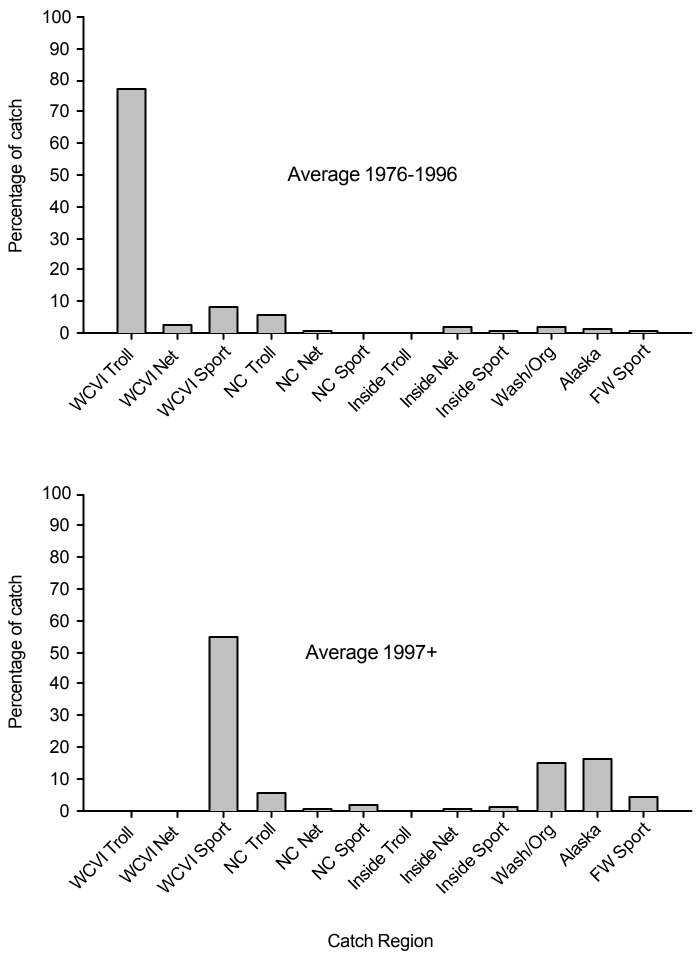

Figure 8. Distribution of Robertson Hatchery catch in major west coast fisheries before and after severe restrictions were implemented in 1997 (i.e. closure of directed coho commercial fisheries). 'NC' refers to North Central BC.

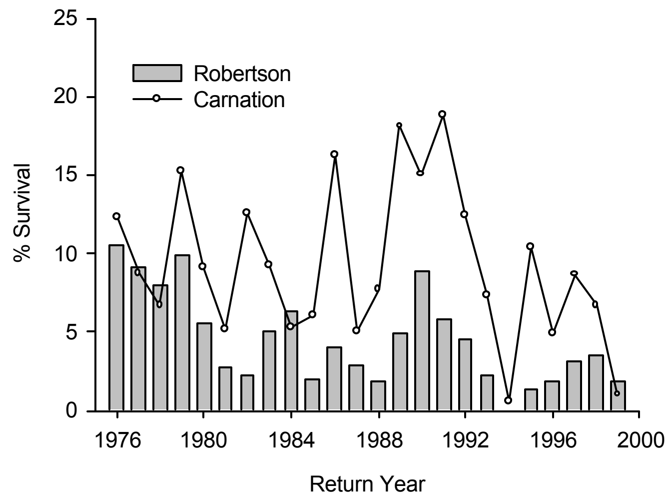

Figure 9. Survival rates of Carnation Creek (line) and Robertson Hatchery (bars) stocks, 1976 to 1999 return years. The average survival rates are 9.0% and 4.5% of Carnation and Robertson, respectively.

Figure 10. Marine exploitation of Robertson Hatchery fish, 1976 to 1999.

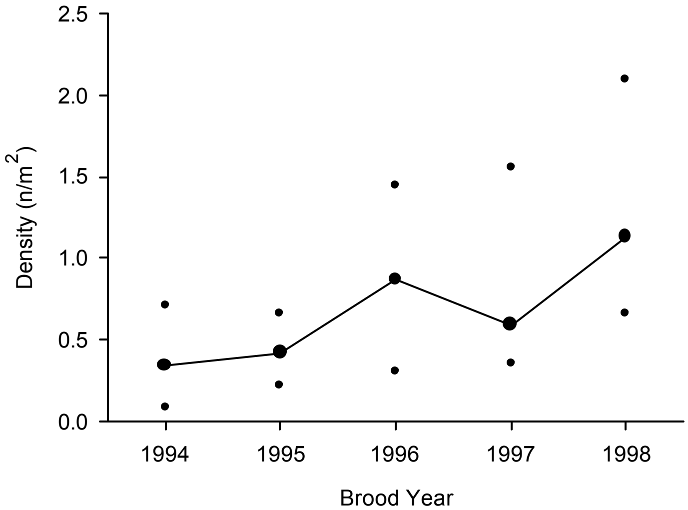

Figure 11. Median densities (n/m^2) for the entire WCVI aggregate (line). Variation is shown by the 1st and 3rd quartiles represented by the dots below and above the line.

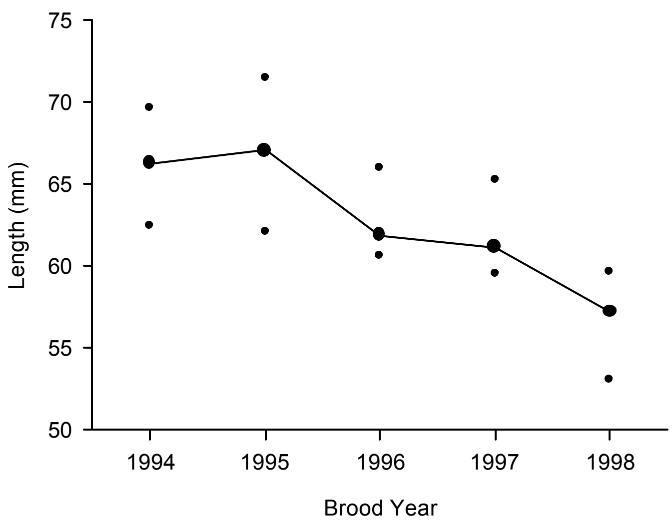

Figure 12. Median fry length (mm) for the entire WCVI aggregate (line). Variation is shown by the 1st and 3rd quartiles represented by the dots below and above the line.

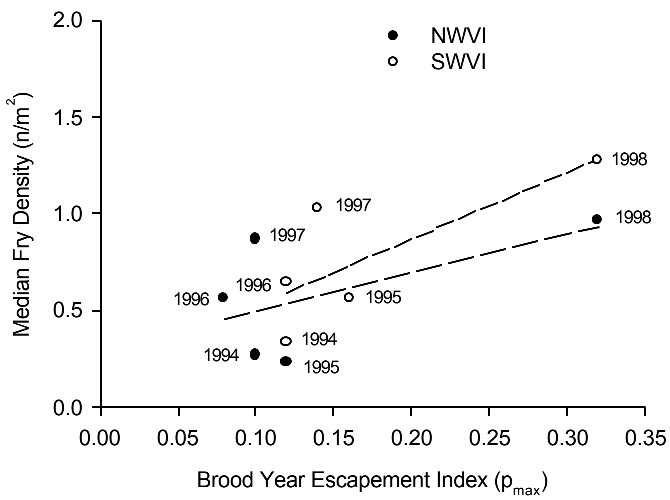

Figure 13. Relationship of median fry densities in NWVI and SWVI streams to brood year escapement index. Lines are regressions for each plot (r^2=0.59 for both, neither regressions are significant).

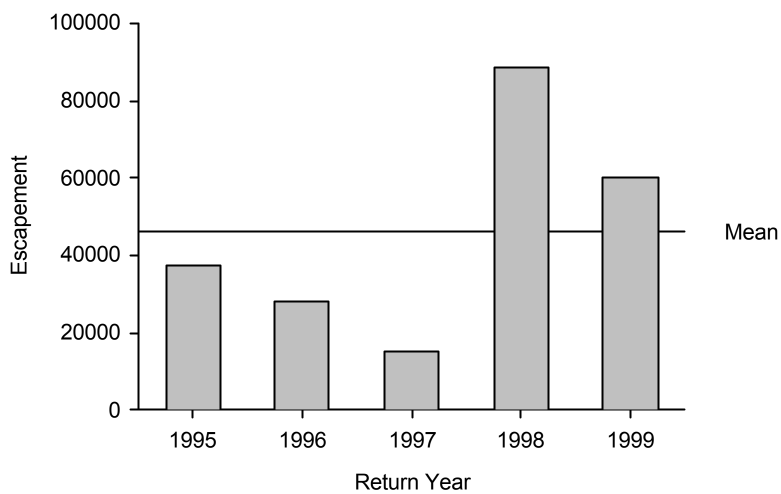

Figure 14. Total escapement to WCVI streams with 5 consecutive years of data, 1995 to 1999. The mean is the 5 year average.

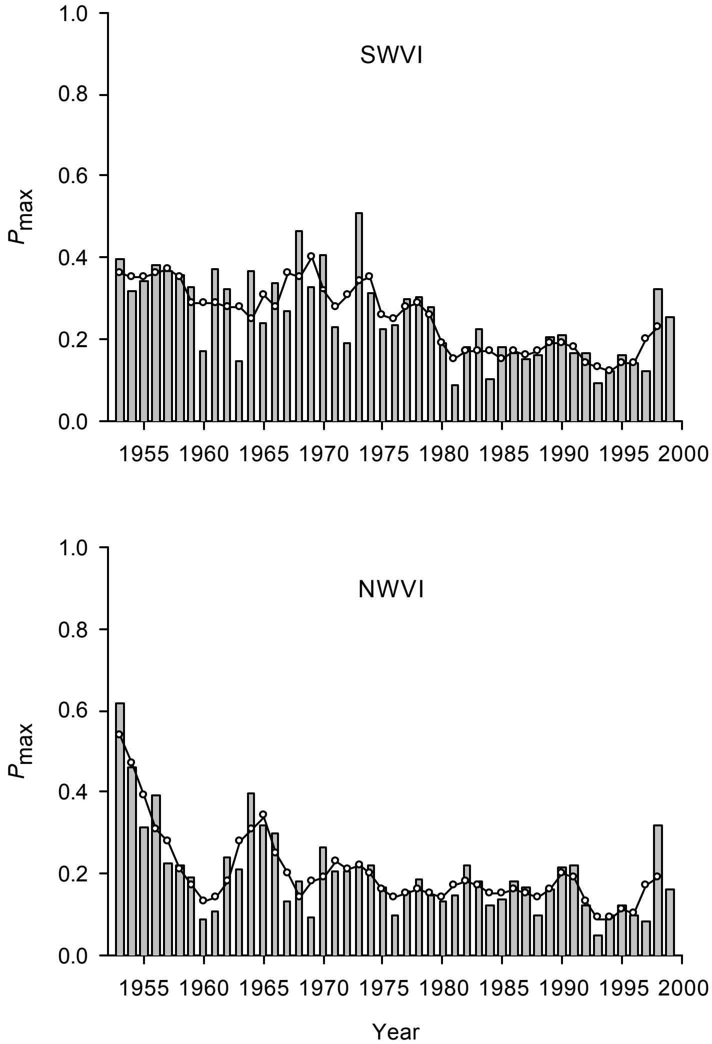

Figure 15. SWVI and NWVI 'p_{max}' escapement indices, 1953 to 1999. The line is the 3-year moving average.

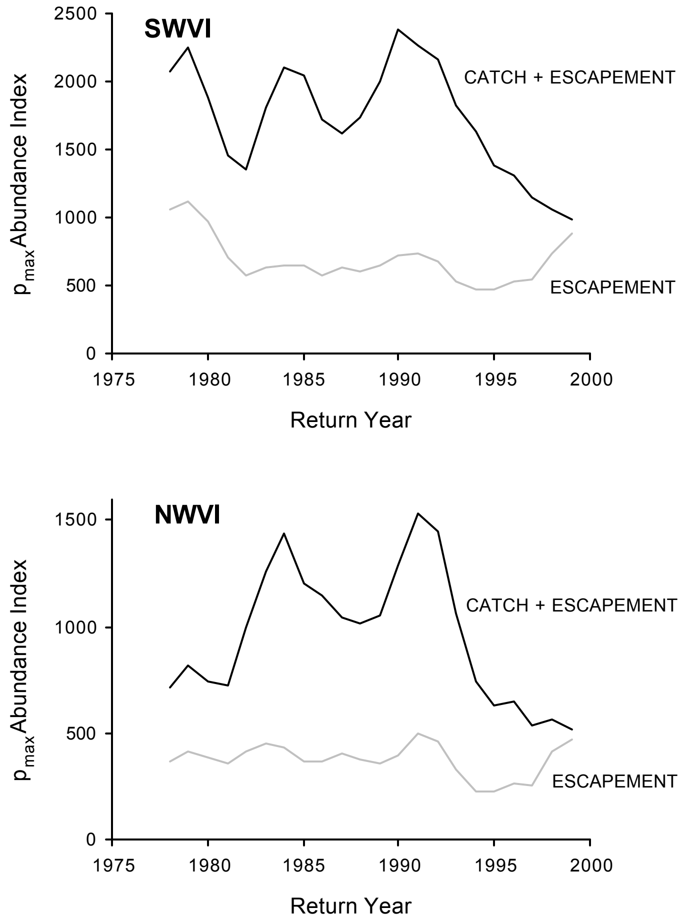

Figure 16. Abudance indices of SWVI (top) and NWVI (bottom) coho. Abudance in each graph is displayed in the top line (catch plus escapement) and calculated by expanding the p_{max} escapement index by an exploitation rate equivalent to that calculated for Robertson hatchery coho.

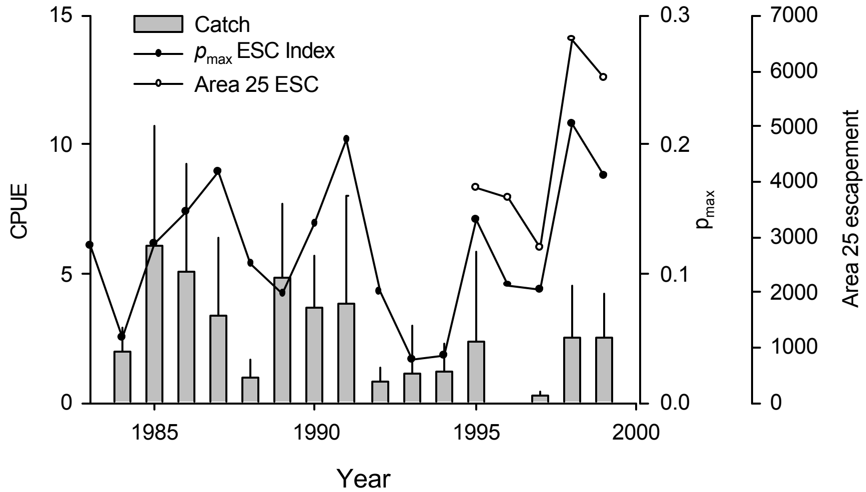

Figure 17. Correlation of Nootka Sound Test Fishery catch with Area 25 p_{max} escapement index and summed AUC escapement to Area 25 streams with 5 consecutive years of data. The correlation coefficient for the CPUE and pmax is 0.37 . The correlation coefficient for the CPUE and Area 25 escapement is 0.95 (limited to 5 yrs data).