Assessment of Harrison River Chinook Salmon

P.J. Starr and N. D. Schubert

Department of Fisheries and Oceans
Biological Sciences Branch
Pacific Biological Station
Nanaimo, British Columbia V9R 5K6

September 1990

Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 2085

Canadian Manuscript Report of Fisheries and Aquatic Sciences

Manuscript reports contain scientific and technical information that contributes to existing knowledge but which deals with national or regional problems. Distribution is restricted to institutions or individuals located in particular regions of Canada. However, no restriction is placed on subject matter, and the series reflects the broad interests and policies of the Department of Fisheries and Oceans, namely, fisheries and aquatic sciences.

Manuscript reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report is abstracted in *Aquatic Sciences and Fisheries Abstracts* and indexed in the Department's annual index to scientific and technical publications.

Numbers 1–900 in this series were issued as Manuscript Reports (Biological Series) of the Biological Board of Canada, and subsequent to 1937 when the name of the Board was changed by Act of Parliament, as Manuscript Reports (Biological Series) of the Fisheries Research Board of Canada. Numbers 901–1425 were issued as Manuscript Reports of the Fisheries Research Board of Canada. Numbers 1426–1550 were issued as Department of Fisheries and the Environment, Fisheries and Marine Service Manuscript Reports. The current series name was changed with report number 1551.

Manuscript reports are produced regionally but are numbered nationally. Requests for individual reports will be filled by the issuing establishment listed on the front cover and title page. Out-of-stock reports will be supplied for a fee by commercial agents.

Rapport manuscrit canadien des sciences halieutiques et aquatiques

Les rapports manuscrits contiennent des renseignements scientifiques et techniques qui constituent une contribution aux connaissances actuelles, mais qui traitent de problèmes nationaux ou régionaux. La distribution en est limitée aux organismes et aux personnes de régions particulières du Canada. Il n'y a aucune restriction quant au sujet; de fait, la série reflète la vaste gamme des intérêts et des politiques du ministère des Pêches et des Océans, c'est-à-dire les sciences halieutiques et aquatiques.

Les rapports manuscrits peuvent être cités comme des publications complètes. Le titre exact paraît au-dessus du résumé de chaque rapport. Les rapports manuscrits sont résumés dans la revue *Résumés des sciences aquatiques et halieutiques*, et ils sont classés dans l'index annuel des publications scientifiques et techniques du Ministère.

Les numéros 1 à 900 de cette série ont été publiés à titre de manuscrits (série biologique) de l'Office de biologie du Canada, et après le changement de la désignation de cet organisme par décret du Parlement, en 1937, ont été classés comme manuscrits (série biologique) de l'Office des recherches sur les pêcheries du Canada. Les numéros 901 à 1425 ont été publiés à titre de rapports manuscrits de l'Office des recherches sur les pêcheries du Canada. Les numéros 1426 à 1550 sont parus à titre de rapports manuscrits du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom actuel de la série a été établi lors de la parution du numéro 1551.

Les rapports manuscrits sont produits à l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur dont le nom figure sur la couverture et la page du titre. Les rapports épuisés seront fournis contre rétribution par des agents commerciaux.

Canadian Manuscript Report of

Fisheries and Aquatic Sciences No. 2085

September 1990

ASSESSMENT OF HARRISON RIVER CHINOOK SALMON

by

P.J. Starr and N.D. Schubert[1]

Department of Fisheries and Oceans

Biological Sciences Branch

Pacific Biological Station

Nanaimo, B.C. V9R 5K6

[1]Department of Fisheries and Oceans
Fisheries Branch
Fraser River, NBC and YT Division
New Westminster, B.C. V3M 5P8

Cat. No. Fs 97-4/2085E ISSN 0706-6473

Correct citation for this publication:

Starr, P.J. and N.D. Schubert. 1990. Assessment of Harrison River chinook salmon. Can. MS. Rep. Fish. Aquat. Sci. 2085: 47 p.

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

ABSTRACT

Starr, P.J. and N.D. Schubert. 1990. Assessment of Harrison River chinook salmon. Can. MS. Rep. Fish. Aquat. Sci. 2085: 47 p.

The Harrison River supports one of the largest naturally spawning chinook salmon (Oncorhynchus tshawytscha) stocks on the Pacific coast. This report results from a request from the Pacific Stock Assessment Review Committee for a comprehensive assessment of the status of this stock.

Five indicators of terminal abundance, CPUE in the commercial gill net, Indian food and test fisheries, mark-recapture escapement estimates, and an emigrant fry index, declined by an average 16% per year since 1981 and collapsed since 1986.

The mark-recapture escapement program, implemented in 1984 due to the inadequacies of previous escapement estimation procedures, was evaluated with the conclusion that large, systematic biases were unlikely. The escapement goal of 241,700 was consistent with other stock productivity estimates but could not be evaluated without monitoring for density dependent effects at goal escapements.

A mortality agent has resulted in average mortalities of 33% in Harrison chinook alevins reared at Chehalis Hatchery. The identity and natural activity of this agent are unknown. If active in the wild, recruitment may be reduced through density dependent alevin mortality.

Three fisheries harvest up to three-quarters of coded wire tagged Harrison chinook: the Strait of Georgia sport and troll and west coast of Vancouver Island troll fisheries. Harrison chinook may comprise one-half, one-third and one-quarter of the harvest in these fisheries, respectively. The collapse of the 1986 Strait of Georgia fisheries was coincident with poor survivals in 1983-84 brood Harrison chinook.

Trends in the survival of hatchery reared Harrison chinook were correlated with survival trends in Strait of Georgia chinook stocks and with the relative strength of returning brood years of the naturally spawning population. The latter suggests that observed variations in natural recruitment were not directly attributable to the Chehalis hatchery mortality agent.

In the absence of further evidence, we concluded that abundance declines resulted from a combination of overexploitation and temporary reductions in marine survival. We recommended further research into the Chehalis mortality agent, achieving goal escapements to permit monitoring for density dependent effects, and commitment to further monitoring programs.

RÉSUMÉ

Starr, P.J. and N.D. Schubert. 1990. Assessment of Harrison River chinook salmon. Can. MS. Rep. Fish. Aquat. Sci. 2085: 47 p.

La rivière Harrison supporte un des plus importants stock naturels de géniteurs quinnats (Oncorhyncus tshawytscha) de la côte du Pacifique. Le présent rapport a été fait à la suite d'une demande du Comité d'examen de l'évaluation des stocks du Pacifique pour une évaluation complète du statut de ce stock.

Cinq indicateurs de l'abondance en estuaire: de la PPUE de la pêche commerciale au filet maillant, de la pêche de subsistence des Indiens et des pêches expérimentales, les nombres du saumon de remonte, et un indice d'alevins émigrants, ont diminué en moyenne de 16% par année depuis 1981 et se sont effondrés depuis 1986.

L'éstimation des nombres du saumon de remonte avec la méthode par marquage et recapture, mis en application en 1984 en raison des imperfections des procédures précédentes d'évaluation des poissons de remonte, a été évalué et on en est venu à la conclusion qu'il ne renfermait pas d'importantes erreurs systématiques. L'objectif de 241,700 saumons de remonte correspondait aux autres éstimations de productivité des stocks quinnat de la Colombie Britannique, mais ne pouvait être évalué sans la surveillance des effets qui dépendent sur la densité.

Un agent de mortalité a donné lieu à un taux de mortalité de 33% chez les alevins de saumons quinnats de la rivière Harrison élevés dans l'alevinière de Chehalis. L'identité et l'activité naturelle de cet agent sont inconnues. Si cet agent est actif chez les populations sauvages, le recrutement pourrait être réduit à la suite d'une mortalité des alevins dépendent de la densité.

Trois pêcheries récoltent jusqu'aux trois quarts des saumons quinnats de la rivière Harrison marqués d'un fil codé: la pêche sportive et la pêche à la traîne du détroit de Géorgie et la pêche à la traîne de la côte ouest de l'île de Vancouver. Le saumon quinnat d'origine de la rivière Harrison compte probablement pour la demie, le tiers et le quart respectivement de ces pêcheries. L'effondrement des pêcheries du détroit de Géorgie en 1986 correspondait en piètre taux de survie de quinnats réproducteurs de la rivière Harrison en 1983-84.

Les tendences au niveau de la survie des quinnats de la rivière Harrison élevés dans les alevinières ont été mises en corrélation avec les tendances de survie des stocks de quinnats du détroit de Géorgie et avec la force relative de population de réproducteurs naturels retournant à la rivière de l'année de génération. Cette denière corrélation suppose que les variations observées au niveau de recrutement naturel n'étaient pas directment attribuables à l'agent de mortalité de l'alevinière de Chehalis.

En l'absence d'autres preuves, nous avons conclu que les baisses de l'abondance de cette espèce sont dues à la surexploitation combinée aux réductions temporaires au niveau de la survie marine. Nous avons recommandé de faire d'autres recherches sur l'agent de mortalité de Chehalis, d'atteindre les objectifs en matière de remonte pour permettre la surveillance des effets dépendant de la densité, et de mettre en application d'autres programmes de surveillance.

INTRODUCTION

The Harrison River is part of a complex system which drains a mountainous coastal watershed in southern British Columbia (Fig. 1). The river supports one of the largest naturally spawning chinook salmon (Oncorhynchus tshawytscha) stocks on the Pacific Coast. Harrison chinook are a white flesh fall stock which returns to the river in September and October and spawns in stable main channel areas which are protected from flow fluctuations by Harrison Lake. The stock is notable in that the fry emigrate immediately after emergence and rear in side channels and sloughs in the Fraser estuary. Harrison chinook are harvested in the hook and line fisheries in the Strait of Georgia and the west coast of Vancouver Island. Other fisheries of importance include the net fisheries in Juan de Fuca Strait, Johnstone Strait, northern Puget Sound and the Fraser River. A recent analysis of Strait of Georgia chinook stocks found Harrison chinook the largest contributor to the Strait of Georgia fisheries (DFO MS 1988).

The Harrison River was selected as a "key stream" to evaluate responses to chinook management actions resulting from the Pacific Salmon Treaty (Anon. 1985). Since 1984, escapement to the Harrison River has been monitored by a mark-recapture study (Staley 1990; Farwell et al. 1990). After an initial increase, escapements declined to a low of only 15% of the escapement goal in 1988, recovering to 31% of goal in 1989. In the 1989 review of progress toward rebuilding of depressed chinook stocks, the Chinook Technical Committee (CTC) of the Pacific Salmon Commission classified the Harrison chinook as "Probably Not Rebuilding" (Pacific Salmon Commission 1989). The status of this stock, therefore, presents serious domestic and international concerns.

This report provides a comprehensive stock assessment statement for Harrison chinook. The report reviews available terminal abundance, harvest distribution, and survival data, summarizes biological sample data, and evaluates escapement estimation techniques and the escapement goal. The report concludes with recommendations for further research and for the management of this stock. Two drafts of this report were prepared for the Salmon Subcommittee of the Pacific Stock Assessment Review Committee (PSARC). These reports were subject to peer review and were carefully scrutinized by the members of the subcommittee. Final subcommittee recommendations form the Recommendations section of this report.

METHODS

TERMINAL AREA

Definition of Harrison Chinook

The identification of Harrison River chinook in the lower Fraser River was complicated by the presence of other chinook stocks and the lack of reliable stock discrimination techniques. We defined Harrison chinook as any white flesh chinook in the lower Fraser River from September through December. This definition was based on four observations:

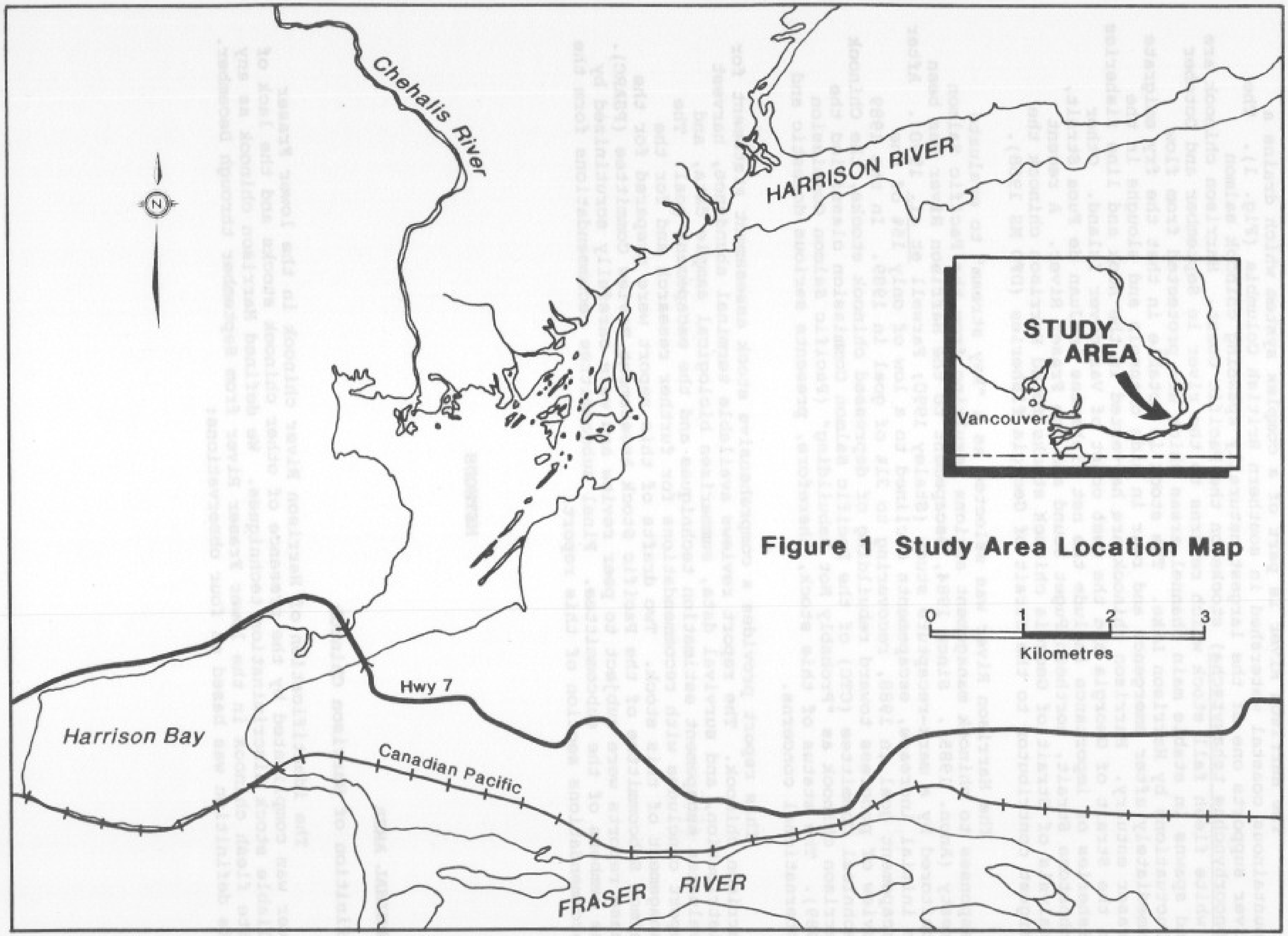

Fig. 1. Study area location map.

1. Spawning timing and assumed rates of travel (Fraser et al. 1982) indicate most upper Fraser stocks are through the lower Fraser River by September 1.

2. The seasonal minimum abundance of white chinook in the commercial gill net (Fraser et al. 1982) and Albion test fisheries occurred in late August to early September. This was interpreted as the end of the white upriver chinook migration and the start of the Harrison chinook migration.

3. All coded wire tagged (CWT) chinook recovered in the September and October in river commercial, sport and test fisheries were of Harrison River origin. No Harrison chinook CWT's were recovered before September 1.

4. Preliminary electrophoretic analyses of the September and October test fishery showed the estimated proportion of Harrison chinook was almost identical to the proportion of white chinook.

Terminal harvest and escapement data reported Harrison chinook adults only; jack data were unavailable in most cases. Percent annual change in terminal harvest and escapement data was calculated by fitting annual data to a logarithmic model:

$$y = e^{ax+b}$$

$$\text{proportional change} = e^{a} - 1$$

The model assumed a constant rate of change. The slope of the non-transformed linear model is an absolute change which should not be expressed as a rate.

Commercial Net Fishery

In British Columbia, commercial catch and effort statistics were compiled from sales slips by the Department of Fisheries and Oceans for 32 statistical areas. The harvest of Harrison chinook in the terminal commercial gill net and seine fisheries was the Area 29 (Fraser River) harvest of white chinook from September to December. Harvest estimates, available by flesh colour for the period 1963-89, were from the Salmon Stock Assessment data base.

Indian Food Fishery

Harrison chinook were vulnerable to Indian food fisheries (IFF) in the lower Fraser and Harrison rivers. Weekly chinook harvest was estimated by fishery officers from data collected during boat patrols. Harvest was the product of the gear count and CPUE estimated from physical inspection of the nets. In general, each fishery was assessed at least once weekly; however, survey intensity was dependent on resources and varied from year to year.

The harvest of Harrison chinook was the sum, for September to December, of the reported chinook harvest in the Harrison River and the estimated Harrison chinook harvest in the lower Fraser River. The latter was the product of the weekly proportion of white chinook in the Albion test fishery (discussed below) and the weekly IFF chinook harvest (Schubert 1983, 1984, 1985, 1986; Macdonald 1987, 1988, 1989, 1990). Because test fishery data were unavailable in 1974-80, harvest was calculated from the 1981-88 mean weekly proportion of white chinook. Weekly catch and effort estimates were available for 1971-89 and 1974-89, respectively.

Sport Fishery

Harrison chinook were vulnerable to a sport fishery in the lower Fraser River. Harvest estimates were available for 1969-88. The 1969-79 Harrison chinook harvest could not be estimated because fishery officers did not stratify their estimates by month (Fraser et al. 1982). No harvest occurred in 1980-84 when the harvest of chinook adults (greater than 50 cm nose-fork length) was eliminated in response to declining returns of Fraser River chinook salmon. The 1985-88 harvest of Harrison chinook was the product of the monthly proportion of white chinook in the test fishery and the monthly chinook harvest from the creel survey (Schubert and Whyte MS 1990). The fishery was not assessed in 1989.

Visual Escapement Estimates

Chinook escapements to Harrison River estimated from visual observations were available for 1951-86. To evaluate these estimates, we required an annual record of survey methods, daily observations, sighting conditions and procedures used to convert observations into estimates. A record of daily observations existed for 1976-89; however, sighting conditions and survey methods were not recorded regularly until 1979 and 1980, respectively. While estimation procedures were not documented in detail, the general procedure used since 1982 involved three steps: helicopter counts of all species were recorded by river section, with coincidental section-specific species composition observations made by divers; section counts were calculated by species; and escapement by species was estimated by undocumented subjective techniques.

Mark-Recapture Escapement Estimates

In 1984, the Harrison River was designated a key stream for use in the evaluation of stock responses to management actions resulting from the Pacific Salmon Treaty. In recognition of the limitations of visual escapement estimates in this river, a mark-recapture study was implemented in 1984 and has been conducted each subsequent year. Mark-recapture escapement estimates are reported to 1988 by Staley (1990); the 1989 escapement estimate is reported by Farwell et al. (1990).

The mark-recapture study was described in detail by Staley (1990) and Farwell et al. (1990). Chinook adults were captured in October and November using a seine net set from a power boat. They were marked with a numbered spaghetti tag; an operculum punch served as a secondary mark. The population was examined after spawning by recovering carcasses on the spawning grounds. Escapement by sex was estimated using the Chapman modification of the Petersen formula; however, sex identification error in the tag application sample was first corrected using a technique developed for this study (Staley 1990). Confidence limits were calculated using the Pearson formula.

The application and recovery samples were routinely tested for spatial, temporal, size and sex biases, and the impact of capture and tagging stress was evaluated by: a) examining spawning success of tagged and untagged females; b) comparing recovery rates within each condition at release category, with stressed fish removed from the application data; and c) comparing mark rates in carcasses recovered on the shore, in deep water main channel areas and at a carcass weir constructed in a fast flowing main channel area. As well, the susceptibility of the stock to handling stress was evaluated in 1986 and 1987. As a result of that evaluation, a low stress tag application technique was adopted in 1988.

Total Return to the River

The total return of Harrison River chinook to the Fraser River was defined as the sum of the Harrison chinook escapement and catches in the Area 29 commercial net, Indian food, and sport fisheries. Total return was calculated only for 1984-89, the period for which mark-recapture escapement estimates are available.

Test Fishery

A gill net test fishery for chinook salmon has been conducted annually in the lower Fraser River near Albion since June 1980. The test fishery was established to assess inseason chinook abundance and run timing and for use in terminal fishery management. It was implemented when the directed harvest of chinook salmon by the Fraser River commercial gill net and sport fisheries was eliminated in 1980 in response to declining returns to the river.

The test fishery was conducted at the same location and by the same fisherman each year using standardized gear and schedules. The 1980-86 test fisheries were conducted three days per week; the 1987-89 test fisheries were conducted seven days per week. Test fishery procedures and results through 1987 were reported by Schubert et al. (1988). Data for 1988 and 1989 were from unpublished files. Test fishery data were treated as follows:

1. The Harrison chinook index was defined as the white chinook index from September 1 to October 20. Although white chinook also exist in a number of upper Fraser River stocks, those stocks spawn earlier; therefore, we assumed that the September 1 seasonal minimum in the white index corresponded to the end of the upriver migration and the beginning of the Harrison migration. This assumption was supported by two observations: a) all chinook CWT recoveries in the September and October inriver commercial, sport and test fisheries were of Harrison origin; and b) preliminary electrophoretic results showed similar proportions of Harrison and white chinook in the September and October test fishery.

2. The 1980-86 daily indices on nonfishing days were estimated by interpolating between adjacent day indices.

3. The index during inriver commercial gill net fisheries was assumed to be zero; i.e. the inriver harvest rate was assumed to be 100%.

4. Flesh colour data were unavailable for 1980. Because the Harrison River index was defined by flesh colour, 1980 was excluded from analysis.

Fry Index

The spring emigration of Fraser River salmon fry was monitored in the lower Fraser River at Mission since 1962 (Vernon 1966; Bailey MS 1979). The river was sampled from March 1 to May 31 by a boat with two traps supported by floats. One trap sampled the surface while the other simultaneously sampled the surface and one of three vertical depths (approximately 1 m, 2 m or 3 m). The trap fished three runs, each a set distance from shore, for an eight hour shift using standardized procedures.

The fry program was designed to index the pink and chum fry migrations, with unique analytic procedures developed for each species. Total pink fry production was estimated from the mobile (surface) and vertical trap in conjunction with estimates of the proportion of the water column sampled. The chum fry index used a simpler approach of calculating the catch per effort from the mobile trap. Bailey (MS 1979) proposed a third approach which estimated daily emigration by species. This paper used the chum fry procedure; however, because chinook and chum fry behaviours differ, these data may be misleading and were intended only as a preliminary indicator of trends in fry abundance. The data were treated in two ways:

1. Indices for non-fishing days were interpolated from adjacent day indices.

2. A standardized period of March 20 to May 16 was selected because this period was covered for all years.

We assumed that all chinook fry were of Harrison River origin. The date of peak emigration of other major upriver chinook stock ranged from April 19 to May 16 (Appendix 6). When travel distance and migratory growth were considered, it was unlikely that fry trapped at Mission were of other than Harrison River origin.

CODED WIRE TAG ANALYSES

Harvest Sampling

A coast-wide harvest sampling program, supported by government management agencies in British Columbia and the Pacific Coast states of Alaska, Washington, Oregon and California, was conducted since 1974 to enable estimation of fishery contributions of coded wire tagged salmonid groups.

In British Columbia, commercial harvest statistics were compiled by the Department of Fisheries and Oceans for 32 statistical areas and 14 catch regions (statistical area aggregates) (Fig. 2). Salmon landings by the commercial fishery were sampled for adipose fin clips with the objective of examining 20% of the harvest by gear type, week and statistical area (Sager and Associates MS 1985). The 20% harvest sampling level has been adopted by all agencies participating in the coast-wide mark recovery program. The fishery contribution of each CWT group was estimated, by area and time, from the number of observed recoveries and the estimated proportion of the harvest examined for marks. Harvest estimates by CWT group were obtained by catch region, gear and month from the regional mark recovery program data base (Kuhn et al. 1988).

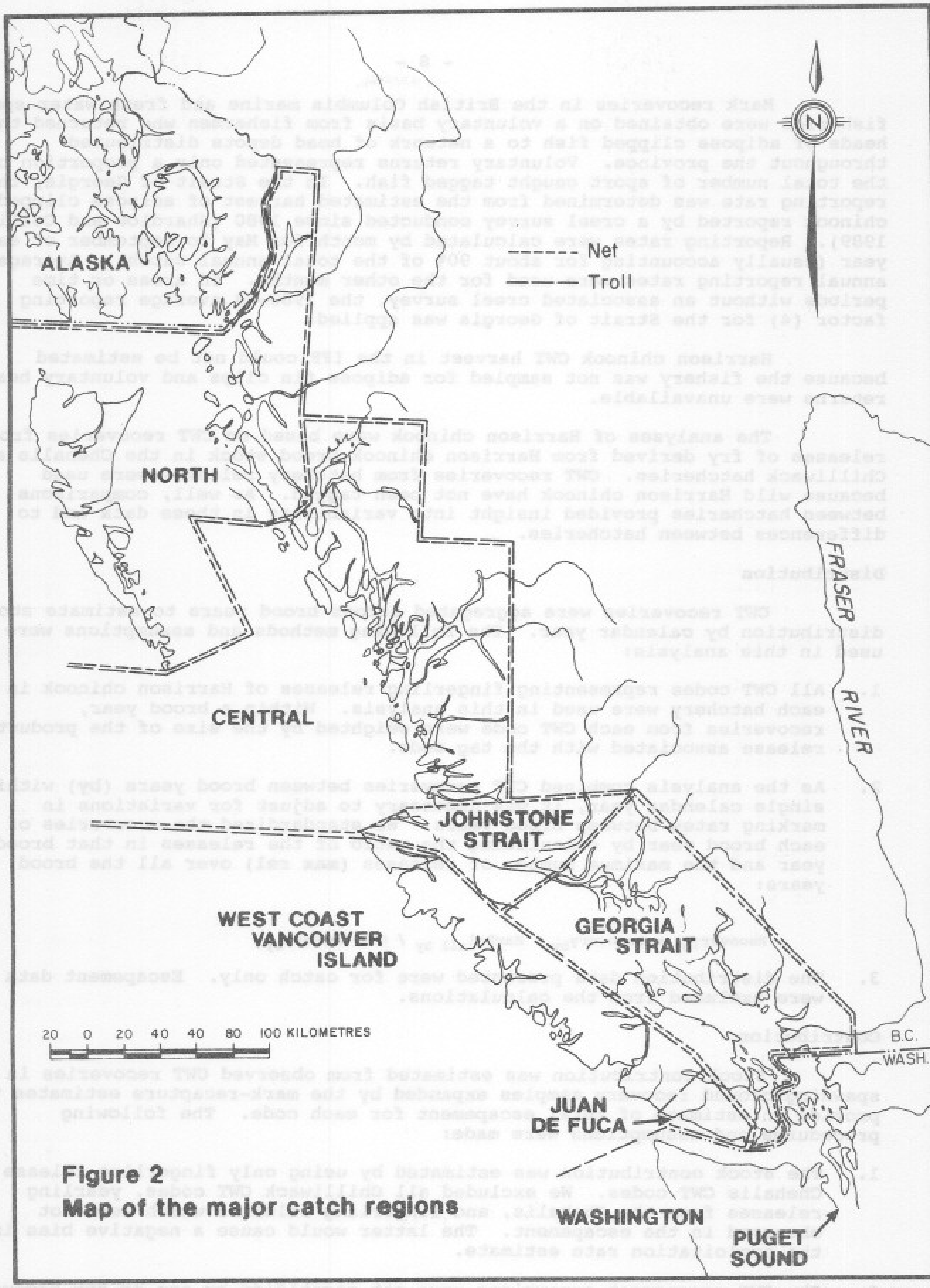

Figure 2
Map of the major catch regions

Fig. 2. Map of the major catch regions used for sampling CWT in British Columbia.

Mark recoveries in the British Columbia marine and fresh water sport fisheries were obtained on a voluntary basis from fishermen who returned the heads of adipose clipped fish to a network of head depots distributed throughout the province. Voluntary returns represented only a proportion of the total number of sport caught tagged fish. In the Strait of Georgia, the reporting rate was determined from the estimated harvest of adipose clipped chinook reported by a creel survey conducted since 1980 (Shardlow and Collicut 1989). Reporting rates were calculated by month for May to September of each year (usually accounting for about 90% of the total annual catch). Average annual reporting rates were used for the other months. In areas or time periods without an associated creel survey, the 1980-84 average reporting factor (4) for the Strait of Georgia was applied.

Harrison chinook CWT harvest in the IFF could not be estimated because the fishery was not sampled for adipose fin clips and voluntary head returns were unavailable.

The analyses of Harrison chinook were based on CWT recoveries from releases of fry derived from Harrison chinook brood stock in the Chehalis and Chilliwack hatcheries. CWT recoveries from hatchery releases were used because wild Harrison chinook have not been tagged. As well, comparisons between hatcheries provided insight into variability in these data and to differences between hatcheries.

Distribution

CWT recoveries were aggregated across brood years to estimate stock distribution by calendar year. The following methods and assumptions were used in this analysis:

1. All CWT codes representing fingerling releases of Harrison chinook in each hatchery were used in this analysis. Within a brood year, recoveries from each CWT code were weighted by the size of the production release associated with the tag code.

2. As the analysis combined CWT recoveries between brood years (**by**) within a single calendar year, it was necessary to adjust for variations in marking rates between brood years. We standardized the recoveries of each brood year by calculating the ratio of the releases in that brood year and the maximum number of releases (**max rel**) over all the brood years:

$$\text{Recovery}_{by} = \text{Recovery}_{by} * \text{MaxRel}_{all\ by} / \text{CWT Release}_{by}$$

3. The distribution data presented were for catch only. Escapement data were excluded from the calculations.

Contribution

Stock contribution was estimated from observed CWT recoveries in the spawning ground recovery samples expanded by the mark-recapture estimates to provide an estimate of total escapement for each code. The following procedures and assumptions were made:

1. The stock contribution was estimated by using only fingerling release Chehalis CWT codes. We excluded all Chilliwack CWT codes, yearling releases from the Chehalis, and fingerling releases which were not observed in the escapement. The latter would cause a negative bias in the exploitation rate estimate.

2. The CWT escapement expansions were not stratified by age or sex because

the number of recoveries was inadequate to represent all strata.

3. Rack recoveries of CWT's were excluded from the analysis.

4. The stock contribution was the sum of all estimated CWT recoveries for each of the selected codes in all fisheries.

5. Fishery expansion factors by age were calculated by using the age and sex composition of the spawning ground recovery sample to estimate escapement by age for each year. The spawning ground recovery data were not corrected for size and sex biases when estimating escapement by age. The following formula was used to estimate total catch of Harrison River chinook in each fishery:

$$\text{Expansion Factor}_{age,year} = \text{Escapement}_{age,year} / \text{CWT Escapement}_{age,year}$$

$$\text{Stock Catch}_{fishery,age,year} = \text{Expansion Factor}_{age,year} * \text{CWT Catch}_{fishery,age,year}$$

The CWT catch and escapement were summed each year for each age represented. Stock catch was not estimated if CWT escapements were not observed in a particular age and year stratum.

6. Exploitation rates by catch year were the ratio of the sum of the CWT catch over all fisheries and ages within a year and the sum of all catches and escapement. If an age stratum was not present in the CWT escapement, then that age was dropped in the calculation of exploitation rate.

An assumption underlying this analysis was that the Chehalis CWT distribution was representative of naturally spawning Harrison chinook. This assumption may be tenuous because wild and cultured fry emigrate at markedly different times and sizes; however, this analysis was not presented as a true representation of the contribution of the Harrison stock to each fishery. Rather, it demonstrated the level of production expected from a large, productive stock given plausible annual exploitation rates and the distribution of the selected Chehalis hatchery CWT codes.

Survival

Survival indices were calculated as follows:

1. Catch was the sum, for each CWT code, of all fishery recoveries expanded to represent the total production release associated with that code; therefore, each survival estimate was a measure of the total performance of each hatchery by brood year.

2. Escapement data were excluded from the analysis because not all hatcheries recovered escapement CWT's at a comparable rate. This was especially true for the Harrison stock which does not home to the hatchery of release.

3. Estimates of associated mortalities due to fishing, such as size limit changes, shakers, and mortality from nonretention fisheries, were included. The methods used to estimate these mortalities were documented in Supplement B of Appendix 2 of the Pacific Salmon Commission (1988).

RESULTS

TERMINAL AREA

Commercial Net Fishery

The 1963-89 harvest of Harrison chinook in terminal commercial net fisheries averaged 13,800 (range 500 to 48,600) (Table 1). Harvest declined by an average 9% per year, with decade averages of 14,300 (1960's), 21,100 (1970's) and 6,200 (1980's) (Fig. 3). Effort (gill net deliveries) declined by 5% per year over the same period, with decade averages of 8,900 (1960's), 8,900 (1970's) and 4,300 (1980's). Catch per unit effort (CPUE) declined by 4% per year, with declines of 20% per year in the 1980's (Table 2).

Because Harrison chinook were harvested incidentally in fisheries directed at other species, gear, fishing time and area varied annually by target species and stock. One exception has been that, since 1976, large mesh gill nets (greater than 216 mm) were not permitted after September 1. The intent of this regulation was to reduce exploitation on large chinook. Such changing management regulations introduced variability in the chinook CPUE.

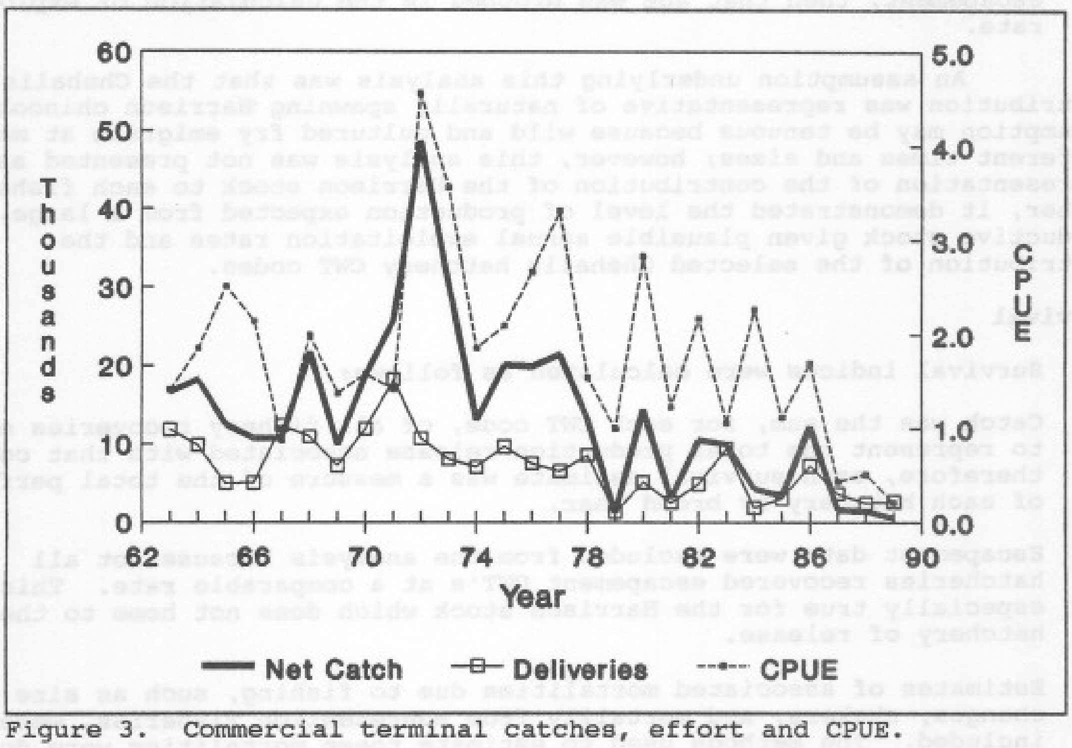

Figure 3. Commercial terminal catches, effort and CPUE.

Table 1. Harvest of Harrison River chinook salmon in terminal Fraser River commercial net, Indian food and sport fisheries, 1963-89.

	Commercial net fisheries							
	Gill net							
Year	Area 29AB	Area 29C	Area 29D	Seine	Area 29 total	Indian food fishery	Terminal sport fishery	Total terminal harvest
1963	9,479	698	6,451	0	16,628	n/a	n/a	n/a
1964	9,244	804	8,149	0	18,197	n/a	n/a	n/a
1965	6,646	437	5,371	0	12,454	n/a	n/a	n/a
1966	5,621	82	5,002	0	10,705	n/a	n/a	n/a
1967	6,891	363	3,448	0	10,702	n/a	n/a	n/a
1968	10,842	512	10,352	0	21,706	n/a	n/a	n/a
1969	5,881	136	3,814	0	9,831	n/a	n/a	n/a
1970	10,949	608	7,175	0	18,732	n/a	n/a	n/a
1971	19,273	759	5,705	17	25,754	1,571	n/a	27,325
1972	32,301	2,441	13,899	0	48,641	2,258	n/a	50,899
1973	15,906	2,125	10,724	0	28,755	709	n/a	29,464
1974	7,597	505	4,889	0	12,991	2,211	n/a	15,202
1975	11,808	1,887	6,425	0	20,120	3,056	n/a	23,176
1976	13,840	843	5,235	0	19,918	3,163	n/a	23,081
1977	12,592	1,358	7,512	0	21,462	4,063	n/a	25,525
1978	7,167	258	5,683	0	13,108	2,491	n/a	15,599
1979	892	77	279	0	1,248	3,230	n/a	4,478
1980	9,061	411	4,935	0	14,407	5,318	0	19,725
1981	2,330	258	515	0	3,103	1,797	0	4,900
1982	7,527	144	2,829	0	10,500	5,557	0	16,057
1983	9,528	68	381	2	9,979	1,606	0	11,585
1984	3,866	97	319	0	4,282	6,638	0	10,920
1985	2,418	0	994	0	3,412	1,065	584	4,477
1986	9,478	354	2,339	176	12,347	1,592	742	13,939
1987	1,294	4	292	0	1,590	1,051	692	2,641
1988	777	0	503	165	1,445	3,510	462	4,955
1989	479	3	65	0	547	253	n/a	800
Average Harvest:								
1963-69	7,801	433	6,084	0	14,318	n/a	n/a	n/a
1970-79	13,233	1,086	6,753	2	21,073	2,528	n/a	23,861
1980-89	4,676	134	1,317	34	6,161	2,839	620	9,000

Note 1. The commercial net harvest of Harrison River chinook was defined as the harvest of white flesh chinook from September 1 to December 31.
Note 2. Commercial harvest data were from the Salmon Stock Assessment data base.
Note 3. The Indian food fishery harvest of Harrison River chinook was defined as the harvest of white flesh chinook, as determined from the weekly ratio observed in the test fishery after September 1.
Note 4. Sport harvest estimates were from a creel survey (unpublished); average reported for adult retention period only.
Note 5. Sport harvest was excluded from Total Terminal Harvest because estimates were unavailable for 1963-79.
Note 6. The 1989 sport fishery was not assessed. Retention of chinook adults was legal from September 1 to 21.

Indian Food Fishery

The 1971-89 IFF harvest of Harrison chinook averaged 2,700 (range 253 to 6,600) (Table 1). The 1974-89 harvest declined by 3% per year, and by 18% per year in the 1980's (Fig. 4). The 1974-89 fishing effort (September to December) averaged 3,400 net-days (range 2,000 to 6,700) (Table 2). While effort increased by 3% per year, it was relatively constant until 1986 (Fig. 4). Effort in the 1980's increased by 5% per year. The 1974-89 CPUE averaged 0.90 (range 0.08 to 1.97) (Table 2). CPUE declined by 4% per year, with declines of 20% per year in the 1980's (Fig. 4). CPUE's in 1985-89 were the lowest recorded.

These trends should be interpreted in the context of IFF regulations. The 1971-89 IFF was managed through area specific time and gear restrictions which, with four exceptions, were unchanged since 1967:

1. A drifted gill net fishery in the Steveston area was established in 1979 and has since expanded rapidly.

2. Gill net mesh size was restricted to a maximum 152 mm (later reduced to 140 mm) since 1983. Although intended to conserve summer run chinook, this restriction applied to the early part of the Harrison run.

3. In 1988, seven additional fishing days were permitted in most areas in response to sockeye allocation objectives.

4. In 1989, Harrison chinook conservation was addressed in two ways: gill net mesh size was restricted to a maximum 140 mm in September and October; and additional fishing time to meet sockeye allocation objectives was not permitted. CPUE in 1989, the lowest on record, reflected mesh size restrictions and probable net saturation from high pink salmon abundance.

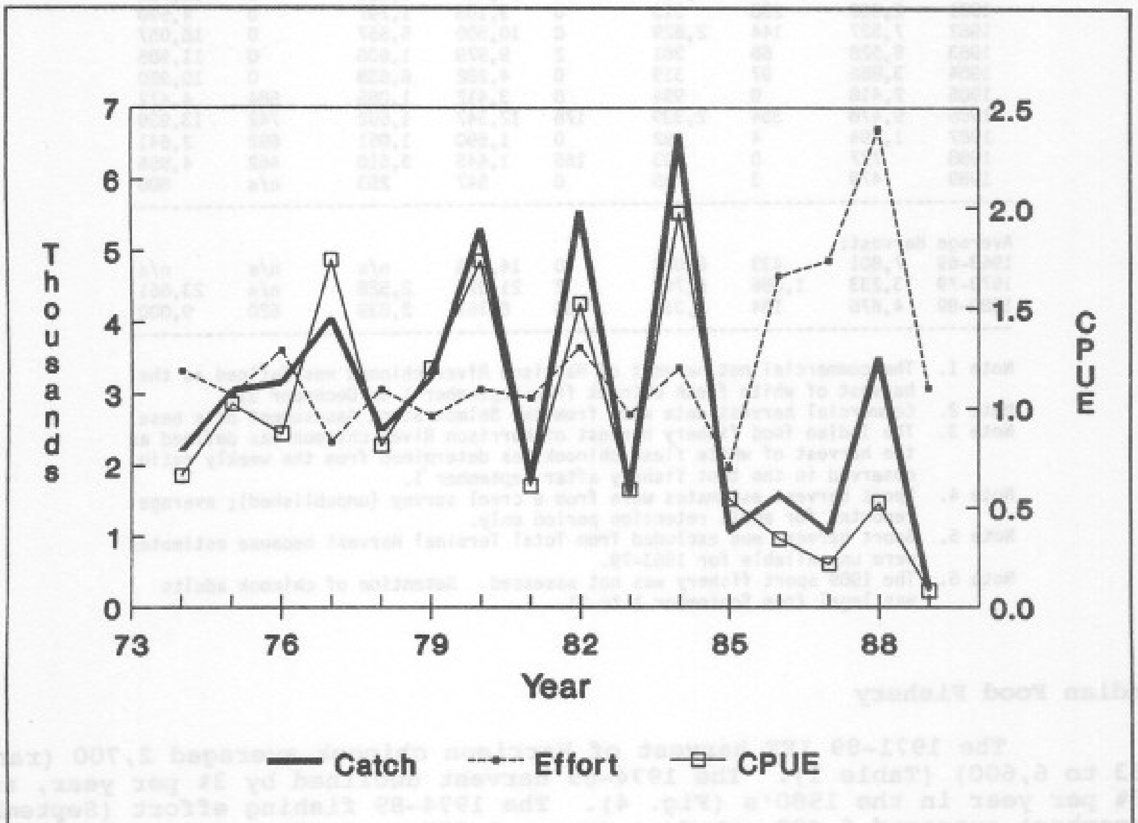

Figure 4. Indian food fish catch, effort and CPUE.

Table 2. Fishing effort, Harrison chinook harvest and catch per unit effort (CPUE) in the Fraser River commercial gill net and Indian food fisheries.

	Commercial gill net fishery			Indian food fishery		
Year	Harrison chinook harvest	Effort (deliveries)	Harrison chinook CPUE	Harrison chinook harvest	Effort (net-days)	Harrison chinook CPUE
1963	16,628	11,813	1.41	n/a	n/a	n/a
1964	18,197	9,849	1.85	n/a	n/a	n/a
1965	12,454	4,967	2.51	n/a	n/a	n/a
1966	10,705	5,012	2.14	n/a	n/a	n/a
1967	10,702	12,361	0.87	n/a	n/a	n/a
1968	21,706	10,916	1.99	n/a	n/a	n/a
1969	9,831	7,177	1.37	n/a	n/a	n/a
1970	18,732	11,883	1.58	n/a	n/a	n/a
1971	25,737	18,186	1.42	1,571	n/a	n/a
1972	48,641	10,663	4.56	2,258	n/a	n/a
1973	28,755	8,068	3.56	709	n/a	n/a
1974	12,991	7,015	1.85	2,211	3,325	0.66
1975	20,120	9,631	2.09	3,056	2,986	1.02
1976	19,918	7,488	2.66	3,163	3,619	0.87
1977	21,462	6,492	3.31	4,063	2,333	1.74
1978	13,108	8,511	1.54	2,491	3,065	0.81
1979	1,248	1,252	1.00	3,230	2,685	1.20
1980	14,407	5,092	2.83	5,318	3,065	1.74
1981	3,103	2,529	1.23	1,797	2,943	0.61
1982	10,500	4,840	2.17	5,557	3,653	1.52
1983	9,977	9,426	1.06	1,606	2,714	0.59
1984	4,282	1,887	2.27	6,638	3,363	1.97
1985	3,412	3,051	1.12	1,065	1,959	0.54
1986	12,168	7,186	1.69	1,592	4,653	0.34
1987	1,590	3,670	0.43	1,051	4,864	0.22
1988	1,272	2,473	0.51	3,510	6,709	0.52
1989	547	2,638	0.21	253	3,078	0.08
Average:						
1963-69	14,318	8,871	1.61	n/a	n/a	n/a
1970-79	21,071	8,919	2.36	2,528	3,002	1.01
1980-89	6,126	4,279	1.43	2,839	3,700	0.77

Sport Fishery

The 1985-88 terminal sport harvest of Harrison chinook averaged 620 (range 462 to 742) (Table 1). Both harvest and CPUE peaked in 1986 (742 and 0.0015, respectively) and declined for two consecutive years. During 1985-88, the fishery was regulated through daily and annual chinook adult bag limits of one and ten. In 1989, Harrison chinook conservation was addressed by eliminating chinook adult retention after September 21.

Visual Escapement Estimates

Evaluation of Bias: Visual estimates of Harrison chinook escapement were available for 1951-86. The inadequacies of Department of Fisheries and Oceans escapement estimates have been reviewed elsewhere (Fraser et al. 1982); however, the Harrison chinook estimates were especially questionable for four reasons:

1. Spawning occurred in diverse habitats ranging from side channels to broad, deep, fast flowing main channels. Visual inspection by boat or foot was extremely difficult.

2. The Harrison River is subject to frequent fall and winter storms which produce turbid run-off. Visual monitoring of spawners in deep water was impossible under such conditions.

3. The Harrison River supports large escapements of pink and chum salmon

and, to a lesser extent, coho salmon. Because spawning periods overlap, visual enumeration and discrimination between species was difficult and varied annually.

4. Chinook salmon are less vulnerable to diver observation than other species such as chum. The use of observed species ratios, therefore, would bias the count to chum.

To evaluate the degree of subjective versus objective data used in the estimation of escapement since 1976, we compared annual escapement estimates with the respective peak counts (Table 3). For visual presentation, the annual data were transformed by subtracting 1 from the ratio of the count or estimate and the 1979-82 average count or estimate (Fig. 5). This provided a relative comparison with the base period selected by the CTC for visual escapement estimates. We observed the following:

1. While both positive and negative variability was noted in the 1976-84 transformed data, the magnitude of the variability was low (Fig. 5).

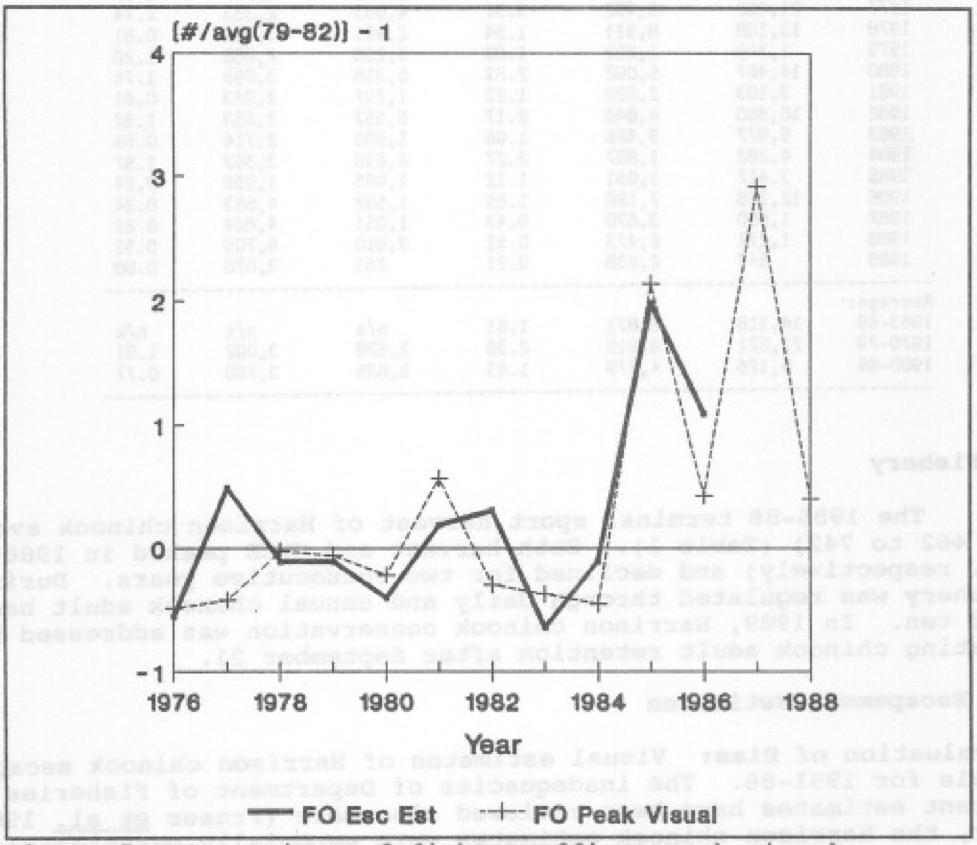

Figure 5. Comparison of fishery officer peak visual observations with final escapement estimate. Plotted values are relative to the 1979-82 average observations or escapement estimates. Petersen estimates not included.

Beginning in 1985, however, variability was large and entirely positive. While the first mark-recapture study was conducted in 1984, the visual estimate was filed before the mark-recapture estimate was released. We believe, therefore, that the mark-recapture study introduced a positive bias in subsequent visual estimates. Two sources of bias were likely: a) the interpretation of diver observations by species may have changed; and b) a change in survey intensity was noted. For example, surveys were terminated on October 26, 1984 after a count of 7,000 chinook under "fair" conditions (Appendix 1). A similar observation was recorded on October 28, 1985; however, rather than terminating the survey, additional observations in November recorded a peak count of 40,000.

2. Less variability was noted in the counts that in the estimates. For example, in seven of nine years between 1976-84 the deviation from zero was less in the counts than in the estimates. In two years, the counts were below the base period average while the estimates were above, and in one year the estimate was lower than the peak count (Table 3). These observations suggest that the visual escapement estimates relied largely on subjective evaluation rather than observation data.

Table 3. Harrison River chinook peak spawning ground counts and escapement estimates, 1976-88.

	Peak chinook count				Transformed data	
Year	Date	Survey method	Chinook count	Chinook escapement estimate	Chinook count	Escapement estimate
1976	13-Oct	Aircraft	6,600	7,500	-0.48	-0.55
1977	11-Oct	Helicopter	7,400	25,000	-0.42	0.49
1978	31-Oct	Not recorded	12,500	15,000	-0.02	-0.10
1979	20-Oct	Not recorded	12,000	15,000	-0.06	-0.10
1980	28-Oct	Helicopter	10,000	10,000	-0.22	-0.40
1981	24-Oct	Helicopter	20,000	20,000	0.57	0.19
1982	01-Nov	Aircraft	9,000	22,000	-0.29	0.31
1983	23-Oct	Aircraft	8,000	6,000	-0.37	-0.64
1984	26-Oct	Helicopter	7,000	15,000	-0.45	-0.10
1985	04-Nov	Helicopter	40,000	50,000	2.14	1.99
1986	04-Nov	Helicopter	18,250	35,000	0.43	1.09
1987	27-Oct	Helicopter	50,000	n/a	2.92	n/a
1988	18-Nov	Helicopter	17,900	n/a	0.40	n/a
Average 1979-82	-	-	12,750	16,750	-	-

Note 1. Data were transformed as follows: (N/(1979-82 average)) - 1.

In summary, although visual estimates of Harrison chinook escapements exist for 1951-86, we concluded that the estimates were largely subjective and of questionable value. Furthermore, the 1985-88 visual data were biased by the mark-recapture study and were not comparable to previous years.

Estimated Escapements: The 1951-86 visual estimates of Harrison chinook escapement averaged 15,800 (range 1,500 to 75,000) (Table 4). Escapement increased by 1% per year, with decade averages of 17,300 (1950's), 7,000 (1960's), 18,500 (1970's) and 22,600 (1980's) (Fig. 6).

Mark-recapture Escapement Estimates

Evaluation of Bias: There are five basic assumptions which must be met for a mark-recapture study to provide a valid population estimate. First, the study must deal with a closed population. The Harrison is one of two fall

Table 4. Estimated escapement of Harrison River chinook salmon, using visual (1951-86) and mark-recapture (1968 and 1984-88) techniques.

Year	Visual estimate	Mark-recapture estimate	Ratio of estimates	Year	Visual estimate	Mark-recapture estimate	Ratio of estimates
1951	1,500	n/a	n/a	1971	15,000	n/a	n/a
1952	75,000	n/a	n/a	1972	15,000	n/a	n/a
1953	15,000	n/a	n/a	1973	35,000	n/a	n/a
1954	15,000	n/a	n/a	1974	35,000	n/a	n/a
1955	7,500	n/a	n/a	1975	15,000	n/a	n/a
1956	3,500	n/a	n/a	1976	7,500	n/a	n/a
1957	3,500	n/a	n/a	1977	25,000	n/a	n/a
1958	16,500	n/a	n/a	1978	15,000	n/a	n/a
1959	18,000	n/a	n/a	1979	15,000	n/a	n/a
1960	3,500	n/a	n/a	1980	10,000	n/a	n/a
1961	5,000	n/a	n/a	1981	20,000	n/a	n/a
1962	2,000	n/a	n/a	1982	22,000	n/a	n/a
1963	13,500	n/a	n/a	1983	6,000	n/a	n/a
1964	6,000	n/a	n/a	1984	15,000	120,837	8.06
1965	8,500	n/a	n/a	1985	50,000	174,778	3.50
1966	9,000	n/a	n/a	1986	35,000	162,596	4.65
1967	7,500	n/a	n/a	1987	n/a	79,038	n/a
1968	7,500	34,000	4.53	1988	n/a	35,116	n/a
1969	7,500	n/a	n/a	1989	n/a	74,685	n/a
1970	7,500	n/a	n/a				

Note 1. Visual estimates are from B.C.16's submitted by fishery officers.
Note 2. Mark-recapture estimates are from Staley (1990), Farwell et al. (MS 1990) and Walker and Tofsrud (MS 1969).

spawnings stocks in the Lillooet River system. A second stock migrates through the Harrison River and spawns in the lower Lillooet River in October and November. While part of this stock may have been vulnerable to capture efforts in the Harrison River, two factors suggest the potential impact on the Harrison River study was minor: a) CPUE in the lower Lillooet River Indian food fishery shows that, on average, less than 20% of the migration was coincident with the period of fish capture in the Harrison River, from mid October through November; b) study period chinook escapement to the lower Lillooet River averaged only 275; therefore, given the relative size of the two populations, an unrealistically large differential vulnerability to capture would be necessary to produce any impact on the Harrison River escapement estimate.

Second, either the mark application or recovery samples must be representative of the total population, and the probability of observing a fish in the recovery sample must be independent of mark status. In the Harrison River study, the latter was addressed by using colours which made tag detection difficult. The former was addressed by designing the study so both tag application and recovery occurred throughout the migratory and spawning period, with extra crews added during peak to maintain consistent effort. While these and other concerted efforts were made to ensure both the mark application and recovery samples were representative, representative sampling is rarely achieved in field studies. It was not possible to definitively test for representativeness because the true population parameters were not known. Instead, we examined the samples for four biases, spatial, temporal, size and sex, as indicators of problems with the study design (Appendix 2). While biases were identified in all years, it was unlikely that the impact on the escapement estimates was large. Some biases were corrected analytically (e.g. by stratifying estimates by sex), while others, such as the size bias, would have little impact on the population estimate (Ricker 1975). Sample selectivity can exist in both the application and recovery samples without introducing population estimation biases if the sources of selectivity are independent, and if the source of selectivity is independent of mark status. There was little evidence that these conditions were violated in this study.

Third, capture and tagging must not influence the subsequent catchability of the fish. A consistent positive bias in the spawning success of tagged Harrison River females suggested capture and tagging did change subsequent behaviour; however, we were unable to determine if a behaviourial change associated with increased spawning success would also influence catchability. A second concern related to stress was the differential loss of tagged fish from the population. We evaluated this factor in two ways. We assumed the downstream loss of tagged Harrison River chinook would have been detected in the Indian food, sport and test fisheries in the Fraser River. Over the six year study, three tagged Harrison River chinook were recovered, all in the test fishery at Albion. Relative to the recovery of marked pink salmon, this figure was very low and there is no reason to believe it reflected differential loss of marked fish rather than the marked component of the group that normally showed this behaviour. We further evaluated differential loss by comparing the mark incidence in carcasses recovered on the shore, in deep water main channel areas, and at a carcass weir set in a fast flowing section of the main channel. We assumed that stressed fish would be more vulnerable to the carcass weir as they passively moved downstream, and that the most stressed individuals would die in the river. Mark incidence, therefore, would be higher in the weir and main channel recoveries. Because no difference was noted in the 1987-89 samples, we believe differential loss of marked fish was minor.

Fourth, marks must not be lost between the two samples. The impact of this problem was eliminated through the use of a secondary mark.

Fifth, the mark status of sampled fish must be identified correctly. Crews were trained to inspect every carcass, first for the secondary mark and then for the tag. Error was minimal because the number of fish inspected per person each day was low, and the crew supervisor periodically monitored crew performance.

In summary, biases were identified in the Harrison River mark-recapture study; however, there was no indication of either a large systematic bias or that the Harrison River study was more susceptible to bias than other mark-recapture studies. We note that the proportion of the Harrison River stock which was marked was low, averaging 2.3%. However, this would tend to introduce random error in the population estimate rather than bias.

Estimated Escapement: Escapement increased from 120,800 in 1984 to a peak of 174,800 in 1985, with declines to 162,600 in 1986, 79,000 in 1987 and 35,700 in 1988 and an increase to 74,700 in 1989 (Table 4; Fig. 6). The mark-recapture estimate averaged 5.2 (range 3.5 to 8.6) times the visual estimate.

Escapement was estimated by sex, with the trend in females similar to the total except the peak occurred in 1986 and the 1989 recovery was less pronounced (Table 5). Escapement by age was the product of the age

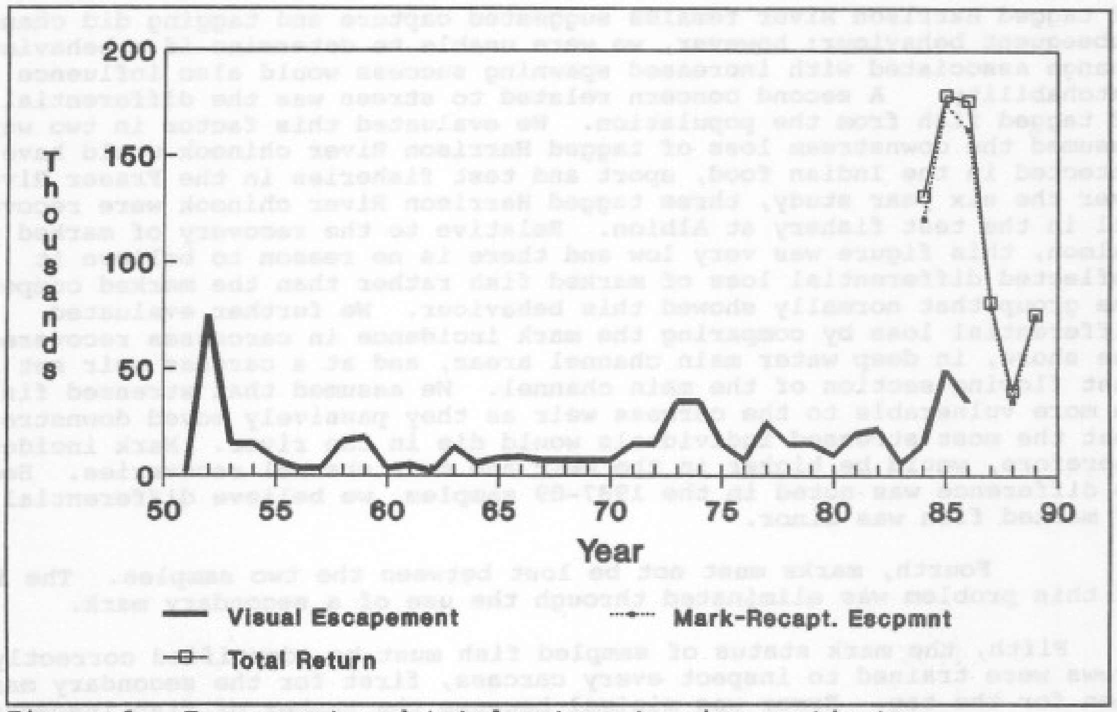

Figure 6. Escapement and total return to river estimates.

Table 5. Estimated escapement by sex and age of adult Harrison River chinook salmon, with 95% confidence limits calculated using the Pearson formula.

Sex	Year	Escapement at age: Age 2	Age 3	Age 4	Age 5	Total escapement	95% confidence limits: Lower	Upper
Male	1984	1,806	37,714	29,983	2,745	72,249	55,457	89,042
	1985	0	47,809	59,274	7,682	114,650	78,343	150,957
	1986	3,393	4,750	73,368	3,393	84,819	64,336	105,302
	1987	247	10,847	24,242	5,752	41,088	33,166	49,011
	1988	143	1,818	14,349	1,515	17,825	13,533	22,117
	1989	1,052	34,178	11,042	4,207	50,478	36,652	64,304
Female	1984	0	11,078	32,748	4,762	48,588	37,881	59,296
	1985	0	12,266	43,954	3,908	60,128	46,951	73,304
	1986	0	778	73,188	3,811	77,777	65,683	89,872
	1987	0	797	26,110	11,043	37,950	33,560	42,341
	1988	0	415	15,060	1,816	17,291	14,222	20,361
	1989	0	13,364	7,817	3,026	24,207	16,638	32,907
Total	1984	1,806	48,792	62,732	7,507	120,837	100,921	140,752
	1985	0	60,075	103,228	11,590	174,778	136,153	213,402
	1986	3,393	5,528	146,557	7,204	162,596	138,811	186,385
	1987	247	11,644	50,352	16,796	79,038	69,981	88,096
	1988	143	2,233	29,410	3,331	35,116	29,839	40,392
	1989	1,052	47,542	18,859	7,233	74,685	58,737	90,663

Note: Escapement by age was the product of the age composition in the spawning ground sample (Appendix 3) and the escapement by sex. Age data may be biased.

composition in the spawning ground sample (Appendix 3) and the escapement by sex. While size bias was noted in the spawning ground sample in most years (Appendix 2), a comparison of size at age and sex in the 1988 spawning ground and Albion test fishery samples (Appendix 4) indicated that, unless the samples had similar biases, overall bias was small. Ages three and four dominated the escapement; however, annual age composition was variable, ranging from 3%-63% age three and 26%-90% age four.

Escapement Goal: Interim escapement goals for British Columbia chinook stocks were established by the Chinook Technical Committee (Pacific Salmon Commission 1986) and later declared regional policy by the Director General. The goals were intended as initial targets to guide joint management actions under the Pacific Salmon Treaty. Goals for natural and enhanced stocks were double the 1979-82 base period or, for key streams, double the 1984 escapement. Because the Harrison River was designated a key stream, the interim escapement goal is 241,700, double the 1984 mark-recapture estimate. This goal was the largest of those set by the CTC.

The suitability of the 1984 base period was evaluated against the visual counts and estimates, the only independent measure of escapement (Fig. 5). We noted that the 1984 peak count and escapement estimate were both below the respective 1979-82 averages, and the 1979-82 variability in the escapement estimate was small and was not consistent with peak count variability. We concluded, therefore, that the selection of 1984 as a base period did not result in an overestimate of goal and that the variability represented in the 1979-82 visual estimates may have been artificial.

An evaluation of the capacity of the available spawning and rearing habitat to support the chinook abundances associated with goal escapements was made difficult by the lack of reliable data and of established theoretical relationships between habitat parameters and production. A subjective evaluation showed no indication of a spawning capacity limitation to production. Flows are naturally regulated by the presence of Harrison Lake, and river channel depth limited the susceptibility of the stock to freezing or dewatering. We note, however, that density related effects may result from large coincident escapements of several salmon species in some years. An evaluation of rearing capacity should focus on the Fraser estuary because of extensive use by the immediate fry migrants which typify this stock. The capacity of the estuary to produce chinook fry has probably been degraded by extensive human encroachment over the past 20 to 50 years; however, we know of no major impacts coincident with the recent decline in the terminal area, and we were unable to assess the effect of any habitat degradation on the suitability of the escapement target. Further research is required to evaluate this factor.

In summary, the escapement goal of 241,700 is consistent with the policy which established goals for all British Columbia chinook stocks; however, existing data were inadequate to evaluate the suitability of the goal. Evaluation of the will be contingent upon observing the production from goal escapements.

Total Return to the River

The 1984-89 return to the river averaged 114,200 (range 40,100 to 179,300) (Table 6). Return declined by 20% per year (Fig. 6).

Table 6. Estimated total return to the river of Harrison River chinook salmon, 1984-89.

Year	Total terminal harvest[a]	Escapement estimate	Total return
1984	10,920	120,837	131,757
1985	4,477	174,778	179,255
1986	13,936	162,596	176,532
1987	2,641	79,038	81,679
1988	4,955	35,116	40,071
1989	800	74,685	75,485
Average	6,288	107,842	114,130

[a]Excludes terminal sport harvest.

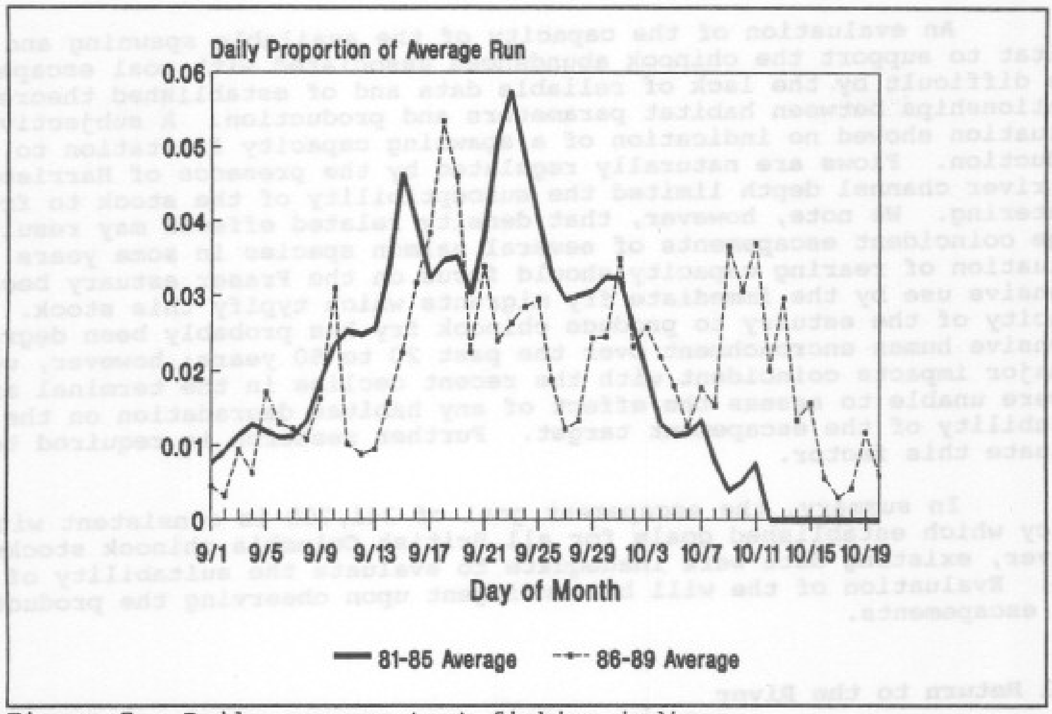

Figure 7. Daily average test fishing indices.

Test Fishery

The mean daily test fishery index shows the majority of the Harrison chinook run passes through the lower Fraser River from mid September to early October; however, estimated daily timing was biased by the early termination of the test fishery in 1981-85 (Fig. 7). In 1986-89, an average 23% of the index was recorded after October 7.

The annual test fishery indices showed a sharp decline over time (Table 7; Fig. 8), averaging 13% per year with declines of 27% per year since 1984. The decline since 1981 was underestimated due to the early termination of the test fishery in 1981-85. The Harrison River chinook index was poorly correlated with total return to the river (mark-recapture estimate) (r^2 = 0.44), probably reflecting three factors:

1. The assumption that the run began on September 1 each year probably introduced error in the relationship between index and return. Interannual salmon run timing can vary by several weeks.

2. Harrison River chinook comigrate with pink salmon (odd years) and Adams River sockeye salmon (1990 cycle). Large catches of nontarget species probably saturated the test fishery net.

3. Termination of the test fishery before October 8 in 1980-86 introduced an obvious negative bias in the index for those years.

Test fishery sample data are provided by year in Appendix 5 and summarized in Table 8. Relative to earlier Fraser chinook stocks, chinook sampled during the Harrison migratory period were younger, by almost a year, and larger, both on average and by age.

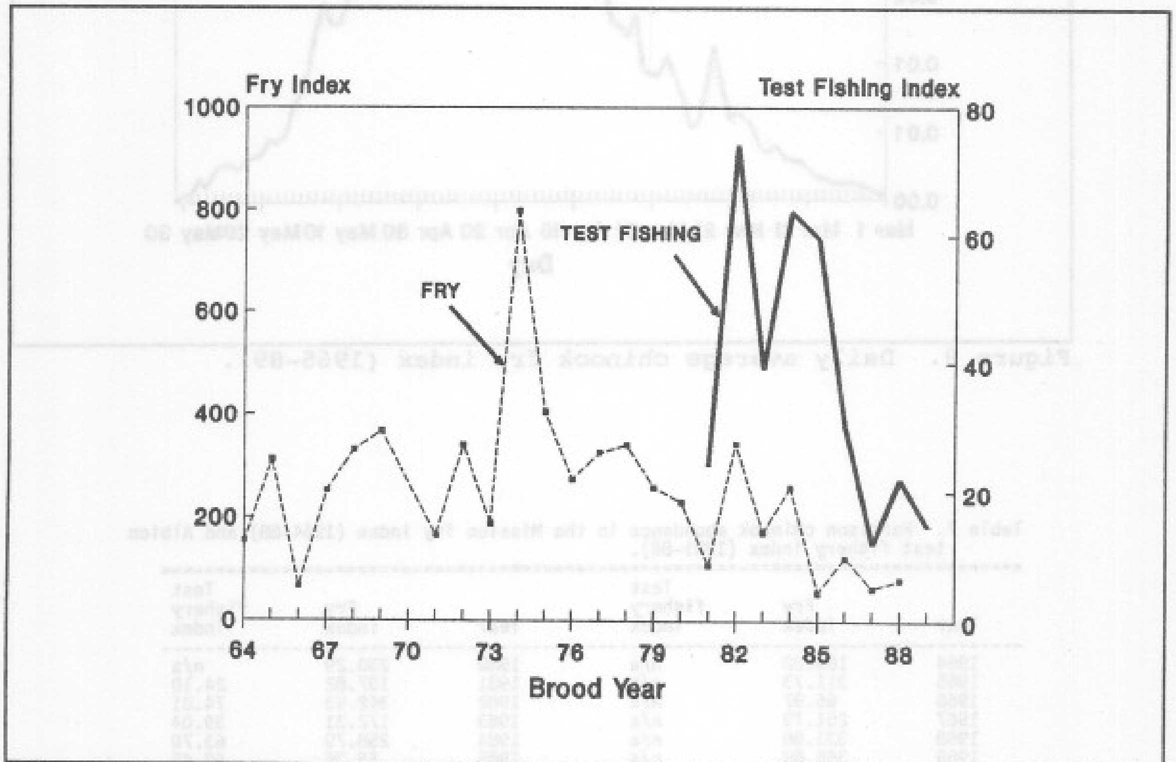

Figure 8. Comparison of two annual abundance indices.

Fry Index

Chinook fry emigrated from March through May, with the mean date of 50% migration on April 21 (range March 28 to May 8) (Fig. 9). A tendency was noted toward later migrations in recent years (Table 9). The 1965-89 Harrison fry index averaged 222.8 (range 55.4 to 798.3) (Table 7). The index declined over that period by an average 8% per year, with decade averages of 222.8 (1960's), 347.1 (1970's) and 169.3 (1980's) (Fig. 8). Four of the six lowest indices were recorded between 1986-89.

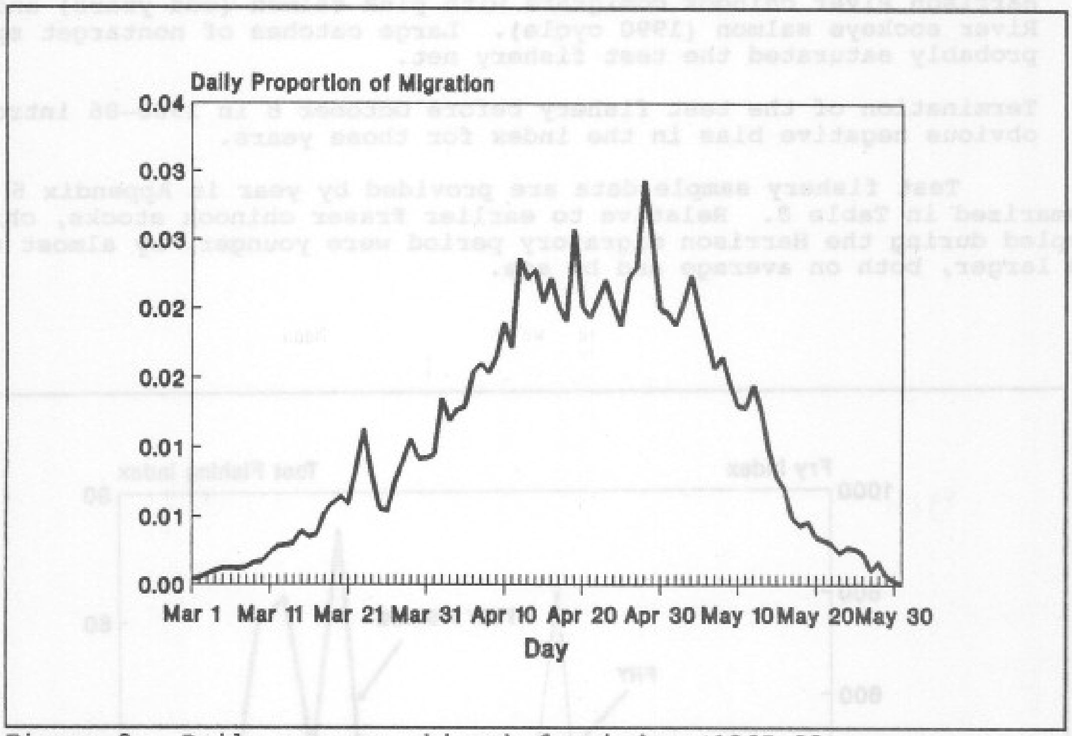

Figure 9. Daily average chinook fry index (1965-89).

Table 7. Harrison chinook abundance in the Mission fry index (1964-88) and Albion test fishery index (1981-89).

Year	Fry index	Test fishery index	Year	Fry index	Test fishery index
1964	153.20	n/a	1980	230.29	n/a
1965	311.73	n/a	1981	107.82	24.10
1966	65.97	n/a	1982	342.93	74.01
1967	251.79	n/a	1983	172.31	39.04
1968	331.08	n/a	1984	258.79	63.70
1969	366.89	n/a	1985	55.36	59.45
1970	n/a	n/a	1986	122.84	30.29
1971	165.41	n/a	1987	63.43	11.93
1972	340.81	n/a	1988	80.63	22.04
1973	188.38	n/a	1989	n/a	14.73
1974	798.25	n/a			
1975	404.22	n/a	Average		
1976	274.28	n/a	1964-69	246.78	n/a
1977	325.99	n/a	1970-79	343.99	n/a
1978	340.44	n/a	1980-89	159.38	37.70
1979	258.17	n/a			

Note: Fry index is reported for the adult brood year (n). The index was actually recorded in the subsequent year (n+1).

STOCK PRODUCTIVITY

The average weight and age data (Table 8) depicted a stock which tended to be larger at younger ages than other chinook stocks captured in the Fraser River test fishery. The same data show little variation between years (Appendix 5), although the 1988 mean size was larger because of the high proportion at age 4. Because the proportion female does not vary a great deal throughout the entire period (Table 8), we concluded that Harrison chinook would have a larger spawning potential at an earlier age than any other major chinook stock in the Fraser. We also concluded that there was no evidence of declining productivity per spawner from these data. The escapements in 1987 and 1988 were the progeny of large brood year escapements and showed no decline in mean size or increase in mean age.

Table 8. Mean annual chinook size, age and sex in the Fraser River test fishery.

Month	Period	Sample size	Mean weight (kg)	Mean length (cm)	Mean age	Percent female
Apr	Early	14	8.7	69.0	5.0	39.0%
	Middle	18	8.6	68.3	4.9	41.9%
	Late	25	8.6	68.4	5.0	40.7%
May	Early	50	8.5	68.4	4.9	49.5%
	Middle	40	8.2	67.3	4.8	47.2%
	Late	61	8.8	68.6	4.8	37.0%
Jun	Early	93	9.3	68.9	4.8	40.7%
	Middle	121	9.3	69.3	4.8	41.4%
	Late	155	9.5	69.2	4.7	41.5%
Jul	Early	102	9.7	69.6	4.8	46.4%
	Middle	102	10.2	70.6	4.7	44.4%
	Late	90	10.7	71.4	4.7	45.3%
Aug	Early	58	10.4	71.4	4.6	47.0%
	Middle	59	9.9	70.3	4.4	46.7%
	Late	49	9.9	70.5	4.2	46.9%
Sep	Early	47	10.2	70.4	4.1	40.7%
	Middle	69	10.2	70.8	3.9	38.7%
	Late	66	10.1	70.1	3.8	39.0%
Oct	Early	47	10.2	70.2	3.8	42.7%

Table 9. Chinook fry emigration peaks observed at Mission, 1965-89.

	Migration date			Migration date	
Year	50%	Peak	Year	50%	Peak
1965	22-Apr	23-Apr	1981	08-Apr	23-Mar
1966	06-Apr	06-Apr	1982	27-Apr	28-Apr
1967	17-Apr	14-Apr	1983	13-Apr	13-Apr
1968	03-Apr	28-Mar	1984	03-May	04-May
1969	23-Apr	17-Apr	1985	08-May	12-May
1970	06-Apr	02-Apr	1986	05-May	12-May
1972	08-May	08-May	1987	15-Apr	01-May
1973	01-May	04-May	1988	21-Apr	21-Apr
1974	15-Apr	29-Mar	1989	17-Apr	19-Apr
1975	29-Apr	02-May			
1976	19-Apr	12-Apr	Mean:		
1977	11-Apr	19-Apr	1965-69	14-Apr	11-Apr
1978	18-Apr	28-Apr	1970-79	22-Apr	21-Apr
1979	03-May	02-May	1980-89	24-Apr	25-Apr
1980	03-May	28-Apr	1965-89	21-Apr	20-Apr

ENHANCEMENT HISTORY

Production Strategy

Harrison chinook have been enhanced at two hatcheries in the lower Fraser River, the Chehalis and Chilliwack. The Chehalis Hatchery, located on a major tributary of the Harrison River, has enhanced Harrison chinook since it opened in 1981. The hatchery has suffered high egg and alevin mortalities from the outset (discussed below); production, therefore, has generally been below capacity.

The Chilliwack Hatchery is located on the Chilliwack River, a major tributary which enters the Fraser River from the south approximately 16 km downstream from the Harrison River. Harrison chinook were transplanted to the Chilliwack River in 1981-84 because few native chinook remained in the river. Transplants were suspended in 1985 pending the identification of the mortality agent impacting Harrison chinook at the Chehalis Hatchery. Since that time, all Chilliwack production of Harrison chinook has been from enhanced fish returning to the Chilliwack River.

Harrison chinook production groups at each hatchery were released with CWT's. Recoveries from these groups form the basis of the harvest and survival estimates presented in this working paper.

Disease

Harrison chinook cultured at the Chehalis hatchery suffered high alevin mortalities since first enhanced in 1982. Alevin mortality, which averaged 33% (range: 4.4% to 81.3%), was the major contributor to a total egg to fry mortality of 47% (range: 37.7% to 84.1%) (Table 10). Studies undertaken since 1982 support the hypothesis that alevin mortality results from an infectious agent (Alderdice and Harding 1987), with adult infection rates ranging from 3% to 40%; however, the presence of an agent has not been confirmed.

A number of observations were reported by Alderdice and Harding:

1. Transmission from infected to noninfected egg groups through water effluent was stopped by ultraviolet irradiation and filtration; however, irradiation and filtration of water not previously exposed to infected eggs had no effect on the later occurrence of infection. This indicated that the agent was not in the water supply.

2. Challenge experiments transmitted the agent to other chinook stocks but not to other salmon species. Of the stocks tested, Harrison chinook were the most susceptible to the agent.

3. The syndrome did not occur in Harrison River chinook transferred to Chilliwack (1981-84) or Capilano (1970) rivers. The mineral composition of the water in both receiving rivers was significantly different from the Chehalis River. Other experiments showed the addition of minerals to the Chehalis water conferred some protection from the agent. Water quality, therefore, may play a role in activating the agent.

4. Because surface disinfection had no impact on the expression of the syndrome, it was concluded that the agent was carried within reproductive products; however, not all fertilized eggs from an individual female were infected.

We concluded from the above that an infectious agent of unknown origin may exist in chinook adults returning to the Harrison River. Apparent adult infection rates ranged from 3% to 40%, high alevin mortalities occurred and, under hatchery conditions, infected alevins were contagious. However, although the agent probably existed in wild spawners, activity under natural conditions was not demonstrated. Harrison River water quality (one sample) lies between the Chehalis and Chilliwack/Capilano levels, although it was closer to the former. It was uncertain if Harrison River water quality is sufficiently similar to the Chehalis River to cause activation of the agent. However, if the agent is active in the wild, the potential impact may differ from that observed at the Chehalis River Hatchery for three reasons:

1. Measured infection rates may not have been representative of the wild stock because brood stock was taken during compressed time periods and areas.

2. Challenge experiments exposed alevins to concentrations of the agent much higher than likely to be encountered in the wild. Contagiousness, therefore, may be overestimated.

3. Lateral movement by alevins after hatching may further reduce the level of contagion.

Table 10. Summary of Chehalis Hatchery performance with Harrison chinook, 1982-89.

Brood Year	Eggs taken	Infection rate	Mortality rate: Eggs	Mortality rate: Alevins	Mortality rate: Total	Fry ponded	Fry to smolt mortality	Smolts released
1982	1,345,317	11.0%	26.9%	20.4%	41.8%	782,808	12.7%	683,630
1983	3,102,415	12.0%	18.4%	23.7%	37.7%	1,931,588	15.0%	1,641,491
1984	3,171,607	38.0%	15.0%	81.3%	84.1%	504,127	11.5%	446,377
1985	941,343	23.0%	14.3%	43.6%	51.7%	454,996	18.7%	370,081
1986	1,271,310	26.0%	23.9%	34.4%	50.1%	634,658	14.4%	543,355
1987	1,894,232	3.0%	22.6%	4.4%	26.0%	1,401,626	14.3%	1,201,084
1988	1,007,760	40.0%	13.2%	40.2%	48.1%	523,092	34.8%	341,263
1989	2,725,558	9.3%	9.3%	22.1%	33.2%	2,124,107	n/a	n/a
Mean	-	20.3%	19.5%	32.8%	46.6%	-	17.3%	-

Note 1: Data were compiled by D. Harding and L. Kahl.
Note 2: Infection rates for 1982-83 were estimated from mortality using infection:alevin mortality ratio observed in subsequent years.

CODED WIRE TAG ANALYSES

Distribution

Chehalis Hatchery: Up to 70% of the catch of Harrison chinook released from the Chehalis Hatchery was taken (in descending order of importance) in the Strait of Georgia sport fishery, the west coast Vancouver Island troll fishery, and the Strait of Georgia troll fishery (Table 11). The remainder

Table 11. Distribution of catch (reported and total mortalities) for the Chehalis hatchery coded wire tag releases.

Year	Geo St Sport	Geo St Troll	WCVI Troll	Other Troll	Canad Net	US Net	Canad Sport	US Sport	Fraser Net	Fraser Sport
without incidental mortalities										
1984	30%	17%	32%	8%	3%	3%	0%	4%	3%	0%
1985	35%	9%	32%	5%	7%	5%	0%	5%	1%	0%
1986	30%	21%	19%	7%	9%	1%	0%	6%	6%	0%
1987	49%	9%	11%	2%	6%	17%	0%	3%	3%	0%
1988	25%	21%	5%	7%	11%	19%	4%	4%	3%	1%
1989	30%	7%	30%	6%	7%	6%	0%	9%	4%	0%
84-89 Avg	33%	14%	21%	6%	7%	9%	1%	5%	3%	0%
with incidental mortalities										
1984	28%	15%	29%	7%	7%	5%	0%	5%	5%	0%
1985	33%	11%	30%	5%	9%	5%	0%	5%	1%	0%
1986	27%	22%	17%	7%	15%	1%	0%	6%	5%	0%
1987	42%	9%	10%	2%	9%	19%	0%	3%	5%	0%
1988	20%	13%	4%	5%	23%	16%	5%	6%	8%	0%
1989	33%	8%	32%	6%	5%	5%	0%	7%	3%	0%
84-89 Avg	31%	13%	20%	5%	11%	9%	1%	5%	4%	0%

Table 12. Distribution of catch (reported and total mortalities) for the Chilliwack hatchery coded wire tag releases.

Year	Geo St Sport	Geo St Troll	WCVI Troll	Other Troll	Canad Net	US Net	Canad Sport	US Sport	Fraser Net	Fraser Sport
without incidental mortalities										
1984	28%	18%	34%	9%	2%	2%	0%	3%	2%	2%
1985	24%	6%	40%	8%	7%	5%	0%	6%	2%	1%
1986	23%	10%	25%	4%	12%	8%	0%	9%	8%	1%
1987	30%	21%	23%	8%	2%	5%	1%	7%	2%	1%
1988	23%	13%	34%	10%	2%	7%	0%	4%	3%	3%
1989	31%	3%	39%	5%	7%	8%	0%	4%	2%	1%
84-89 Avg	26%	12%	33%	7%	5%	6%	0%	5%	3%	2%
with incidental mortalities										
1984	27%	17%	33%	9%	3%	3%	0%	3%	4%	2%
1985	23%	7%	35%	7%	11%	7%	0%	6%	2%	1%
1986	19%	10%	20%	4%	17%	8%	0%	9%	12%	1%
1987	26%	22%	26%	8%	2%	4%	1%	6%	2%	1%
1988	20%	11%	29%	8%	8%	9%	0%	7%	5%	3%
1989	35%	3%	40%	5%	5%	6%	0%	3%	3%	1%
84-89 Avg	25%	12%	31%	7%	8%	6%	0%	6%	5%	1%

was harvested primarily in the Canadian net fisheries and the U.S. net fisheries of northern Puget Sound, particularly those off Point Roberts near the mouth of the Fraser. The 1989 distribution reversed a trend beginning in 1986 of declining contribution to the west coast Vancouver Island troll fishery and of increasing contributions to the Puget Sound net fishery. When the effect of the increased size limit was considered (lower half of Table 11), the proportion harvested by the west coast Vancouver Island troll fishery was the highest on record for this hatchery .

Chilliwack Hatchery: More than 70% of the catch of Harrison chinook released at the Chilliwack Hatchery was taken in the same three fisheries as above (in descending order of importance): the west coast Vancouver Island troll, the Strait of Georgia sport, and the Strait of Georgia troll fisheries (Table 12). The remainder was divided primarily between the Canadian and US net fisheries, although the proportion was lower than for Harrison chinook released from the Chehalis Hatchery. The proportion harvested in the west coast of Vancouver Island troll fishery did not decline as did the Chehalis Hatchery releases. However, the Chilliwack Hatchery releases had a higher proportion of the harvest in outside waters relative to the Chehalis Hatchery releases. Chilliwack Hatchery releases had a correspondingly low distribution in the Strait of Georgia fisheries.

Contribution

Large escapements of Harrison chinook translate into substantial catches in the three primary fisheries which harvest this stock (Table 13). Even given the uncertainty associated with this analysis, it is probable that Harrison chinook made up a large fraction (probably greater than one-half) of the Strait of Georgia troll catch. The Strait of Georgia sport fishery was probably made up of one-quarter to one-third of this stock, and about one-quarter of the west coast of Vancouver Island troll fishery may be composed of this stock in years of high abundance. The 1989 harvest of Harrison chinook in this fishery was large due to high 1986 brood survival.

Table 13. Calculated example contribution (in thousands) to catch for the Harrison chinook using exploitation rates derived from CWT recoveries on the spawning grounds and an estimated stock distribution from Chehalis tag codes for each recovery year.

Year	Total Stk Cat	Geo St Troll Stk Cat	Geo St Sport Stk Cat	WCVI Troll Stk Cat	Geo St Troll %Tot Cat	Geo St Sport %Tot Cat	WCVI Troll %Tot Cat	Annual Exploit Rates
1984	652	122	200	228	139%	54%	49%	93%
1985	118	10	39	43	19%	17%	12%	53%
1986	516	116	139	130	264%	76%	38%	77%
1987	72	10	32	10	26%	26%	3%	52%
1988	91	26	24	11	130%	20%	3%	72%
1989	297	23	87	100	82%	64%	50%	80%
Avg:	291	51	87	87	114%	45%	24%	78%

Notes for each year:
1984: only age 3's recovered in CWT.
1985: only age 4's recovered in CWT.
1986: only age 4's & 5's recovered in CWT.
1987: age 2's, 4's & 5's in the CWT escapement.
1988: all ages represented in the CWT escapement.
1989: no age 2's in the CWT escapement.
Average: a weighted average summing all valid catches and escapements.

The lack of some age classes in the escapement biased the annual exploitation rate estimates (Table 13). Exploitation rates in 1985 and 1987 were low because only the older age classes were used in the analysis. On the other hand, the high exploitation rate in 1984 resulted from using only age 3's. Only 1988 and 1989 have all age classes represented. The calculated exploitation rates, although high, were similar to those calculated for the Big Qualicum hatchery, where almost all the escapement was examined for CWT returns. The similarity in exploitation rates for these two stocks provided indirect evidence that the mark-recapture escapement estimates were not large overestimates for those two years.

Survival

Except for the 1981 and 1982 brood years, Chilliwack Hatchery release survival to catch was 5 to 12 times higher than for Chehalis Hatchery releases (Table 14). Since catch distributions were similar for each release group (see Section 4.2), differential fishery effects were probably not the cause for this observed variation in survival. Chehalis survivals were equivalent to or higher than those calculated for chinook released from the Big Qualicum and Capilano hatcheries (Table 14). We concluded, therefore, that the survival of the Chilliwack releases were atypically high. Survivals of Harrison chinook released from the Chilliwack Hatchery (range 0.3% to 12.7%) also far exceeded those of upper Fraser chinook stocks released at the same hatchery. Survival to catch of those stocks ranged from 0.4% (1981-82 brood years) to 0.02% (1985 brood year). These unusually high survivals in the Chilliwack Hatchery may result from the warmer water and larger size at release typical at this hatchery (L. Kahl, pers. comm.).

Table 14. Comparison of survivals (% recovery from release to catch) for seven recent brood years in two lower Georgia Strait and two lower Fraser hatcheries. Brood years 85 to 87 are incomplete. Survival estimates are also presented which include "associated" or "incidental" fishing mortalities.

Brood Year	Big Qualicum	Capilano	Chehalis	Chilli-wack
w/o incidental mortalities:				
81	0.69%	1.47%	7.61%	8.40%
82	0.86%	0.20%	1.07%	1.35%
83	0.70%	0.25%	0.18%	2.12%
84	0.08%	0.14%	0.25%	2.72%
85	0.09%	0.02%	0.26%	0.78%
86	0.17%	0.35%	0.86%	4.35%
87	0.02%	0.00%	0.07%	0.09%
with incidental mortalities:				
81	1.21%	2.38%	11.29%	12.74%
82	1.29%	0.28%	1.53%	1.90%
83	1.03%	0.45%	0.25%	2.96%
84	0.15%	0.22%	0.38%	4.19%
85	0.17%	0.03%	0.36%	1.14%
86	0.37%	1.09%	1.61%	8.21%
87	0.03%	0.01%	0.09%	0.28%

Survival indices, described in Pacific Salmon Commission (1988), were calculated for chinook released from the Chehalis (Fig. 10) and Chilliwack hatcheries (Fig.11). It has been shown that, within a given brood, the survival of chinook salmon to a given age is a reliable indicator of future survivals of older age classes (Pacific Salmon Commission 1986). This implies that most of the variation in natural mortality occurs before recruitment and that natural mortality after recruitment is either very low or very stable. The pattern of survival of the early age classes, therefore, would be similar to the total brood year survival once all the data were collected. Both of these hatcheries showed a similar pattern of initially high survivals in the first two brood years followed by steep declines in survival in the middle 1980's. Similar patterns were recorded for other B.C. hatcheries (Table 14). The 1986 brood year was the most successful brood year since the early 1980's. This was also true for the Big Qualicum and Capilano hatcheries, although survivals at these hatcheries were lower than for Harrison chinook. Survivals for the 1987 brood chinook at all these hatcheries will probably decline relative to 1986 (Figures 10 and 11; Table 14).

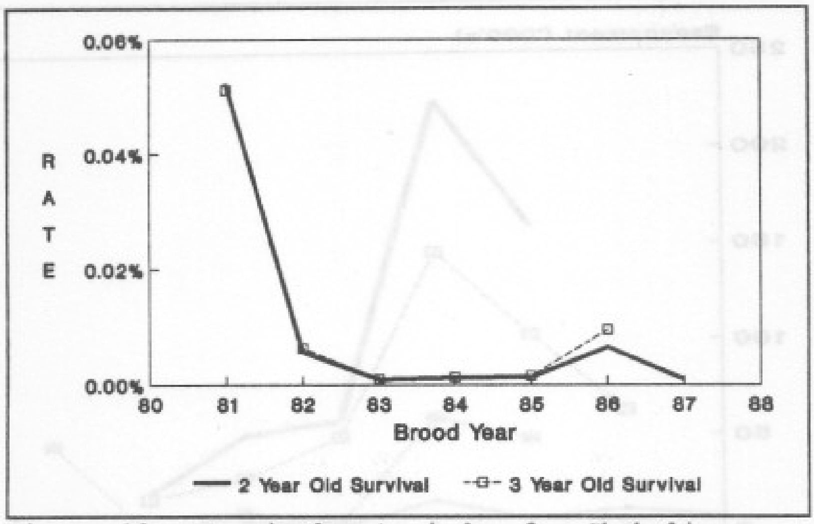

Figure 10. Survival rate index for Chehalis hatchery.

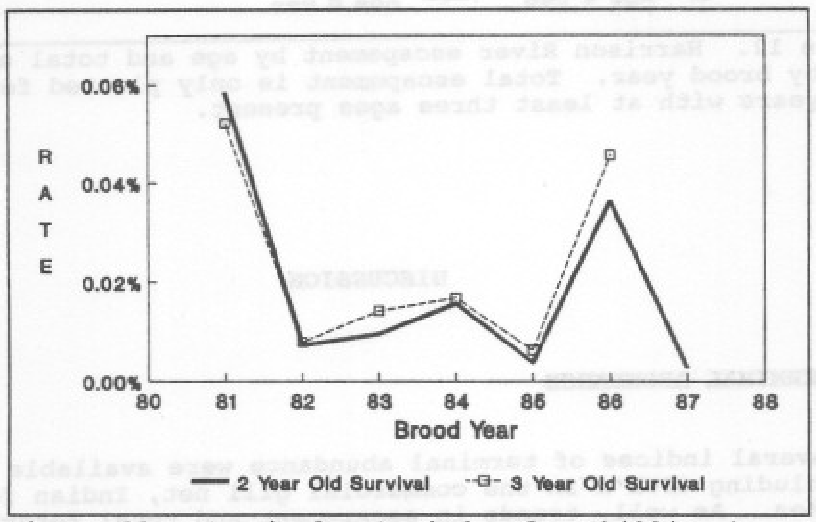

Figure 11. Survival rate index for Chilliwack Hatchery.

A plot of escapement at age arranged by brood year indicated that the pattern of survival documented for hatchery stocks was similar for naturally spawning Harrison chinook (Fig. 12). In terms of escapement at age, the 1981-82 brood years were the most productive, with the 1983-85 brood years showing progressively poorer returns as three and four year old escapements. The 1986 brood year, however, showed a substantial increase in age three escapements, nearly equivalent to the 1981 brood year, but not as high as the 1982 brood year. These observations were qualitative and were influenced by ocean fishing patterns; however, the within brood year correlation between returns at age held true for ages three and four escapement of Harrison chinook (biases and small sample size probably precluded good correlations for ages 2 and 5).

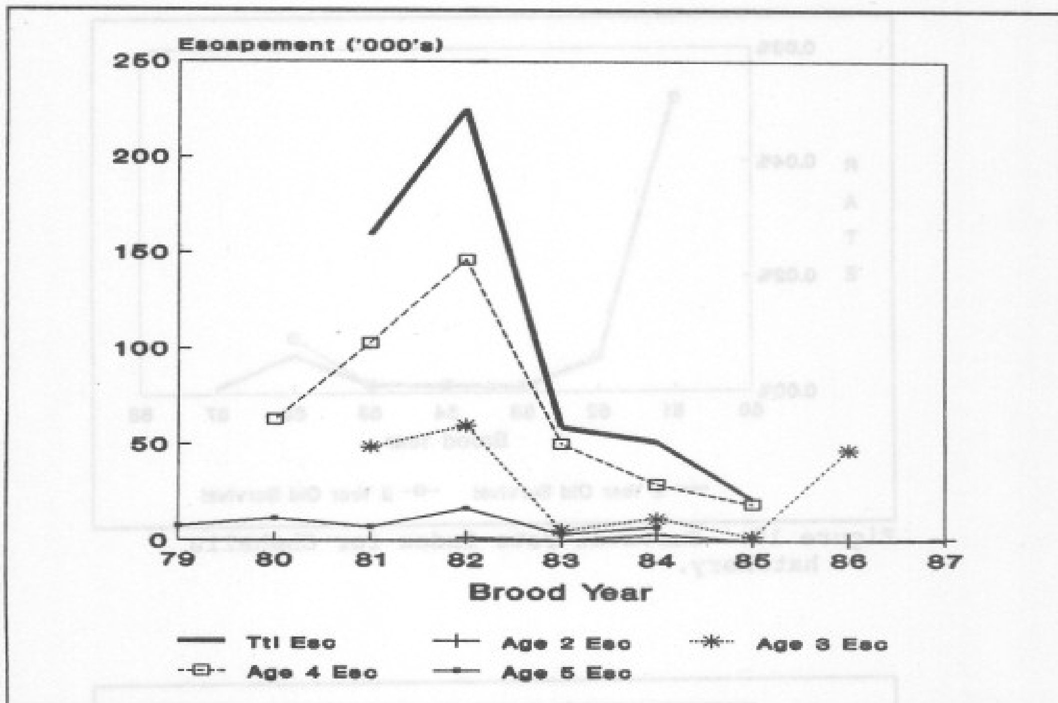

Figure 12. Harrison River escapement by age and total escapement by brood year. Total escapement is only plotted for brood years with at least three ages present.

DISCUSSION

TRENDS IN TERMINAL ABUNDANCE

Several indices of terminal abundance were available for Harrison chinook, including CPUE's in the commercial gill net, Indian food and Albion test fisheries. As well, trends in escapement and total return measured terminal abundance, and the Mission fry program provided an index of spawning and incubation success. Trends in these indices were compared for 1981-89, a period when estimates were available for most indicators (Table 15). While the correlation between indices was poor, each index showed a similar negative trend averaging 16% (range 14% to 20%) and 26% (range 20% to 36%) per year in 1981-89 and 1984-89, respectively (Table 15). We conclude, therefore, that the terminal abundance of Harrison chinook declined since 1981, and that sharp declines occurred in 1987 and 1988.

Table 15. Summary of terminal abundance indicators and estimated proportional change over two recent periods (1981-89 and 1984-89).

Year	Area 29 commercial net fishery net CPUE	Indian food fishery CPUE	Escapement	Total return to the river	Test fishery index	Mission fry index
1981	1.23	0.61	n/a	n/a	24.10	107.82
1982	2.17	1.52	n/a	n/a	74.01	342.93
1983	1.06	0.59	n/a	n/a	39.04	172.31
1984	2.27	1.97	120,837	131,757	63.70	258.79
1985	1.12	0.54	174,778	179,255	59.45	55.36
1986	1.69	0.34	162,596	176,532	30.29	122.84
1987	0.43	0.22	79,038	81,679	11.93	63.43
1988	0.51	0.52	35,116	40,071	22.04	80.63
1989	0.21	0.08	74,685	75,485	14.73	n/a
Average percent change/year:						
1981-89:	-20.2	-15.1%	n/a	n/a	-13.5%	-14.4%
1984-89:	-36.1	-30.0%	-20.2%	-20.5%	-27.4%	-19.7%

Note 1. Because IFF gill net mesh size was restricted in 1989, that year was excluded from mean % change/year.
Note 2. Escapement and total return were from the mark-recapture study.

IMPLICATIONS OF CODED WIRE TAG ANALYSIS

Contribution

The contribution analysis suggested that Harrison chinook make up a large fraction of the harvest in the Strait of Georgia sport and troll and the west coast of Vancouver Island troll fisheries (Table 13); however, there was an apparent discrepancy between these estimates and the proportion of white flesh chinook in the harvest of those fisheries. Carter *et al.* (1986) reported that the incidence of white flesh chinook in samples of the Strait of Georgia troll harvest rarely exceeded 50%, with an overall incidence of 38% in 1983 and 22% in 1984. This compared to 14% and 22% reported from sales slips for the same two years. Sales slips have reported a white percentage as high as 32% in this decade. There are several possible explanations for the discrepancy between the Contribution Index and these other observations:

1. Not all Harrison fish are identified as white when caught;

2. Not all white chinook are sold in that category; or,

3. The estimates presented in Table 13 are too high.

A consumer preference for red flesh salmon provides fishermen with an economic incentive to sell white fleshed chinook in the red flesh category; however, while such practices would explain an underestimate of the white flesh harvest by the sales slips, they do not explain the sample program results. Furthermore, only one-third of the Harrison chinook released with CWT's from Chehalis hatchery were identified as white fleshed upon recovery in the Strait of Georgia troll fishery, with even lower incidences in all other fisheries except the Fraser gillnet (Appendix 7). A higher incidence in the terminal fishery supports the hypothesis that flesh colour was ambiguous or slightly red at the life stages which predominate in the ocean fisheries but become unambiguous at maturity. This hypothesis is more likely than a large (100%) positive bias in the escapement estimate.

Exploitation and Survival

The ocean exploitation rate on naturally spawning Harrison chinook was not assessed because our estimate of wild stock distribution was uncertain and because of we could not reliably estimate the escapement of CWT's. In consequence, we could not correlate the declining terminal abundances with changes in exploitation rate. Similar trends in abundance could result from overexploitation, from the Chehalis mortality agent, or from reduced ocean survivals. One effect of the mortality agent, if active under natural conditions, would be a reduction in recruits per spawner and, therefore, in the exploitation rate sustainable by the stock. The observed stock collapse could have occurred without any change in exploitation rate if the Chehalis mortality agent first became active in recent years.

The estimated survivals of Harrison chinook released from the Chehalis Hatchery, although low, were similar to those seen in other lower Strait of Georgia hatcheries (Table 14). We could not extrapolate survivals from the hatchery stock to the natural population because fry size and time of release differed and because of uncertainty in the impact of the Chehalis mortality agent; however, we presented evidence which suggested that trends in survival were similar between natural and post-release enhanced production (Fig. 12). Furthermore, the sharp decline in escapement in 1983 brood Harrison chinook (Appendix 8) was coincident with the 1986 collapse of the Strait of Georgia sport fishery harvest and with declines in the survival of the hatchery stock (Table 14). This suggests that, if present, the Chehalis mortality agent did not have an overriding impact on the survival pattern of naturally spawning Harrison chinook.

IMPLICATIONS OF CHEHALIS HATCHERY MORTALITY AGENT

Although there is no doubt that a serious mortality agent is active in the Chehalis Hatchery, the implications for naturally spawning Harrison chinook are uncertain. Despite investigations in the winter of 1989, neither the identity of the agent or it's level of activity under natural conditions has been determined. Further efforts are required to establish the identity of the agent, whether it is active in the Harrison River and, if so, it's level of virulence under natural conditions.

If activity under natural conditions is assumed, there are two potential productivity effects which have profound and potentially different management implications:

1. Reduced recruits per spawner. This would reduce the exploitation level sustainable by the stock and, if the mortality agent was a recent phenomenon, cause a stock collapse without any change in exploitation rate. The appropriate management action would be to reduce the exploitation rate regardless of the method of transmission.

2. Density dependent alevin mortality. If there is a density dependent factor in the transmission of the agent, and if the critical density is less than the escapement goal, then the appropriate management action would be to decrease the escapement goal.

The answer to the above questions will determine what level (if any) of fishery action is necessary to rebuild Harrison chinook and what adjustment (if any) is necessary to the Harrison chinook escapement goal.

ALTERNATIVE MANAGEMENT OPTIONS

The data presented in this report support the conclusion that there has been a recent decline in the abundance of Harrison chinook. Alternate hypotheses for the cause of the decline, the underlying assumptions for each hypothesis, and the recommended subsequent management actions are presented in Table 16.

Table 16. Matrix of possible alternate hypotheses for observed stock decline in the Harrison, some of the underlying assumptions for each hypothesis, and the expected consequences of these hypotheses in terms of the performance of the stock in the ocean fisheries.

	Overfishing in Ocean Fisheries	Poor Ocean Survival	Disease Agent	Over-escapement
Recruits Per Spawner	High	Temporarily Reduced	Low	Low
Probable Optimum Escapement	Large	Large	Large or Small (depends on method of transmission)	Smaller
Contribution to Ocean Fisheries	Temporary Low	Temporary Low	Low	Low
Recommended Action	Lower Exploitation	Lower Exploitation	Lower Exploitation	Reduce Target Escapement

Only the hypothesis of overescapement permits the maintenance of current exploitation rates. The production of three year olds from the 1986 brood escapement of 162,600 chinook has been high (Appendix 8); therefore, this hypothesis was rejected as a plausible explanation for the observed declines in Harrison chinook. The remaining three hypotheses require reductions in current exploitation rates regardless of stock productivity assumptions. Given the sum of the evidence, we cannot conclude that the Harrison stock is small and unproductive. The contribution of Harrison chinook to the three primary fisheries may have, in some years, exceeded one-half the fishery catch (Table 13). Conservation actions are required, therefore, to rebuild this stock to goal levels in order to achieve the potential benefits available to these fisheries.

The observed production from large escapements in 1984, 1985 and 1986 was variable, with low production in the initial two years and high relative production in 1986. This shows that, while large escapements will produce high recruitment, factors other than escapement are involved. Given the correlation of survival estimates between different hatcheries (Table 14), other mechanisms, such as variations in ocean conditions, affect survival. The issue for the Harrison chinook, as it is for all other salmon stocks, is whether variability in ocean conditions is sufficient to preclude the optimization of the density dependent component of the recruitment variation. The answer for other actively managed salmon stocks has been to attempt to achieve an escapement goal. Any escapement goal makes the underlying assumption that density dependent factors affect the recruitment. At this time, there is no evidence that the Harrison chinook are more or less affected by density dependence than other chinook stocks.

RECOMMENDATIONS

The following are recommendations of the Salmon Subcommittee of the Pacific Stock Assessment Review Committee (PSARC) to the Steering Committee of PSARC. These recommendations were based on a review by external examiners of an earlier draft of the present report and a full subcommittee discussion.

1. The identification of the Harrison chinook disease agent and the determination of its impact on the natural stock is a high priority; further study is strongly recommended.

2. The present Pacific Salmon Treaty (PST) escapement goal (241,700) is consistent with the analysis presented in this report. Achieving this goal by the PST target date (1998), while monitoring the resulting recruitment for apparent density-dependent effects, will be a test of the appropriateness of the current goal. Exploitation rate reductions are most likely necessary to reach this target. Decisions are required on the specific management actions required. These decisions must consider issues that are beyond the mandate of PSARC and and a process to reach them should be identified.

3. Given the potential importance of this stock to Canadian fisheries, the subcommittee recommends that the Region ensure that a monitoring program is established to fully evaluate production from important life phases of this stock as it rebuilds.

SUMMARY

1. All the terminal abundance indicators show declines in this decade with a "collapse" since 1986.

2. A review of the visual observations and escapement estimates performed by Fishery Officers concluded that the 1976-84 estimates were largely subjective and of questionable value and that the 1985-86 estimates were biased by the mark-recapture study. The latter introduced error in the correlation between the two estimation procedures.

3. A review of the mark-recapture study concluded that, although specific biases do exist, a large systematic bias in the escapement estimates was unlikely. We also concluded that this program produced a consistent measure of escapement abundance since its inception.

4. A review of the escapement goal concluded that there is insufficient evidence to recommend a change in the interim goal. Available measures of habitat and biological parameters were consistent with a large, productive stock. Data pertaining to habitat productive capacity and historic abundance were unavailable or of insufficient quality to recommend change. The goal can best be evaluated by increasing escapements until density dependent effects are noted.

5. A serious mortality agent is active on Harrison chinook in the Chehalis Hatchery. It is currently unknown whether this agent is also active in the naturally spawning population. If active, the Chehalis mortality agent would reduce the average recruits per spawner through elevated and potentially density dependent alevin mortality.

6. Three fisheries harvested two-thirds to three-quarters of the reported catches of cultured Harrison chinook: the Strait of Georgia sport and troll and the west coast of Vancouver Island troll fisheries. Because harvest distribution was consistent between Chilliwack and Chehalis hatchery releases in all years, this distributions may represent that of naturally spawning Harrison chinook.

7. A Contribution Index constructed from the CWT escapement to the natural spawning grounds and from the corresponding fishery CWT recoveries estimates that at least one-half of the Strait of Georgia troll fishery, one-quarter to one-third of the Strait of Georgia sport fishery, and one-fifth to one-quarter of the west coast Vancouver Island troll fishery could be of Harrison chinook origin. This conclusion is tentative and is highly dependent on the accuracy of the mark-recovery escapement estimate and the underlying distribution of CWT's.

8. The survival of Harrison chinook released at Chilliwack Hatchery was higher than those released at Chehalis Hatchery; however, survival trends were consistent between these hatcheries and other Strait of Georgia hatcheries. Examination of the return of spawners by age class to the Harrison River also showed that the relative strength of the contributing brood years have the same general trend as the hatchery chinook survivals.

9. A consistent decline in survival was noted in cultured and naturally spawning Harrison chinook beginning with the 1983-84 brood years. This decline was coincident with the 1986 collapse of the Strait of Georgia fisheries. If the survival trend for naturally spawning Harrison chinook were correlated with survivals of other chinook stocks which are known to be free of the disease agent, it is likely that the Chehalis mortality agent was not directly responsible for variations in Harrison chinook survivals. Therefore, if the disease agent were the cause of the current reduced returns, it was a very recent phenomenon.

10. Because Harrison chinook productivity can be high when escapements are large, we reject the hypothesis that overescapement occurred in 1984-86. Also, based on No. 9 above, we conclude that there is insufficient evidence to support the conclusion that the Chehalis mortality agent is responsible for the observed declines in terminal abundance. In the absence of further evidence, therefore, we concluded that the observed declines resulted from a combination of overexploitation by the ocean fisheries and a temporary reduction in ocean survival which was shared by other chinook stocks harvested in the same fisheries.

ACKNOWLEDGEMENTS

This report was reviewed by A.W. Argue, T.D. Beacham, and B.R. Riddell. The report was formally reviewed and approved by the Salmon Subcommittee of PSARC, and prepared for publication by the Publications Unit of the Pacific Biological Station.

LITERATURE CITED

Alderdice, D.F. and D.R. Harding (editors). 1987. Studies to determine the cause of mortality in alevins of chinook salmon (Oncorhynchus tshawytscha) at Chehalis Hatchery, British Columbia. Can. Tech. Rep. Fish. Aquat. Sci. 1590: 96 p.

Anon. 1985. An agreement between the Government of Canada and the Government of the United States of America concerning Pacific salmon. 36p.

Bailey, M.D. MS 1979. Enumeration of salmon in the Fraser River. Dept. Fish. Oceans, unpublished. 121 p.

Carter, E.W., L.A. Lapi, E.A.R. Ball. 1986. Catch, size, and age of chinook and coho salmon taken in the Strait of Georgia troll fishery in 1984 and comparisons with 1983 data. Can. Tech. Rep. Fish. Aquat. Sci. 1456: 66 p.

Delaney, P.W., A.L. Kahl, W.R. Olmsted and B.C. Pearce. 1982. Studies of chinook salmon (Oncorhynchus tshawytscha) in the Chilcotin River watershed, 1975-1980. Can. MS Rept. Fish. Aquat. Sci. 1674: 162p.

DFO MS. 1988. Strait of Georgia Chinook: A Process for Rebuilding. Dept. of Fisheries and Oceans, unpublished MS. 24p.

Farwell, M.K., N.D. Schubert and L.W. Kalnin. 1990. Enumeration of the 1989 Harrison River chinook escapement. Can. MS Rep. Fish. Aquat. Sci. 2078: in press.

Fedorenko, A.Y. and B.C. Pearce. 1982. Trapping and coded wire tagging of wild juvenile chinook salmon in the South Thompson/Shuswap River system, 1976, 1979 and 1980. Can. MS Rep. Fish. Aquat. Sci. 1677: 63 p.

Fedorenko, A.Y., P.E.I. Fee and A.L. Kahl. 1983. Trapping and coded wire tagging of wild juvenile chinook salmon in the upper Fraser River, 1979-81. Can. MS Rep. Fish. Aquat. Sci. 1733: 46 p.

Fraser, F.J., P.J. Starr and A.Y. Fedorenko. 1982. A review of the chinook and coho salmon of the Fraser River. Can. Tech. Rep. Fish. Aquat. Sci. 1126: 130 p.

Kuhn, B.R., L. Lapi, and J.M. Hamer. 1988. An introduction to the Canadian database on marked Pacific salmon. Can. Tech. Rep. Fish. Aquat. Sci. 1649: 56 p.

Lister, D.B., I. Wallace and D.G. Hickey. MS 1981. Salmon enhancement baseline investigations at Stuart River, British Columbia. Part I - 1980 juvenile chinook salmon study (Volume I). Prepared for Dept. Fish. Oceans, Vancouver. 65 p.

Macdonald, A.L. 1987. The Indian food fishery of the Fraser River: 1986 Summary. Can. Data Rep. Fish. Aquat. Sci. 623: 103 p.

Macdonald, A.L. 1988. The Indian food fishery of the Fraser River: 1987 Summary. Can. Data Rep. Fish. Aquat. Sci. 690: 113 p.

Macdonald, A.L. 1989. The Indian food fishery of the Fraser River: 1988 Summary. Can. Data Rep. Fish. Aquat. Sci. 725: 107 p.

Macdonald, A.L. 1990. The Indian food fishery of the Fraser River: 1989 Summary. Can. Data Rep. Fish. Aquat. Sci. 787: 111 p.

Pacific Salmon Commission. 1986. Final 1985 report of the chinook technical committee. TCCHINOOK-8601. 55p. Vancouver, B.C.

Pacific Salmon Commission. 1988. 1987 Annual Report. Joint Chinook Technical Committee. TCCHINOOK-8802. 188p. Vancouver, B.C.

Pacific Salmon Commission. 1989. 1988 Annual Report. Joint Chinook Technical Committee. TCCHINOOK-8901. 62p. with appended graphs and tables. Vancouver, B.C.

Rice, C.W., K.H. Wilson and L.W. Kalnin. MS 1987. Spawning escapement of chinook salmon (Oncorhynchus tshawytscha) to selected Fraser River key streams in 1984 and 1985. Dept. Fish. Oceans, New Westminster. Unpublished.

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

Rosberg, G.E., D. Aitken and E. Oguss. MS 1981. Juvenile chinook salmon studies in four tributaries to the upper Fraser River, 1981. Prepared for Dept. Fish. Oceans, Vancouver. 158 p.

Sager and Associates. MS 1985. Salmonid tag recovery program - 1984 operations Summary. Prepared for Dept. of Fisheries and Oceans, Vancouver. Unpublished. 147p.

Schubert, N.D. 1983. The Indian food fishery of the Fraser River: catch Summary, 1951 to 1982. Can. Data Rep. Fish. Aquat. Sci. 412: 357 p.

Schubert, N.D. 1984. The Indian food fishery of the Fraser River: 1983 Summary. Can. Data Rep. Fish. Aquat. Sci. 479: 67 p.

Schubert, N.D. 1985. The Indian food fishery of the Fraser River: 1984 Summary. Can. Data Rep. Fish. Aquat. Sci. 512: 64 p.

Schubert, N.D. 1986. The Indian food fishery of the Fraser River: 1985 Summary. Can. Data Rep. Fish. Aquat. Sci. 560: 80 p.

Schubert, N.D., P.G. Paterson and C.M. McNair. 1988. The Fraser River chinook salmon test fishery: data summary, 1980-87. Can. Data Rep. Fish. Aquat. Sci. 709: 193 p.

Schubert, N.D. and I.W. Whyte. MS 1990. Assessment of the 1985-89 lower Fraser River sport fishery. Dept. of Fisheries and Oceans, New Westminster. Unpublished.

Shardlow, T.F. and L.D. Collicutt. 1989. Strait of Georgia sport fishery creel survey statistics for salmon and groundfish, 1988. Can. MS Rep. Fish. Aquat. Sci. 2036: 63 p.

Staley, M.J. 1990. Abundance, age, size, sex and coded wire tag recoveries for chinook salmon escapements of the Harrison River, 1984-1988. Can. MS Rep. Fish. Aquat. Sci. 2066: 42 p.

Vernon, E.H. 1966. Enumeration of migrant pink salmon fry in the Fraser River estuary. Internat. Pacific Salmon Fish. Comm. Bull. XIX: 83p.

Walker, C.E. and W.L. Tofsrud. MS 1969. Enumeration of Harrison River chinook salmon run. Dept. Fish. Oceans, unpublished. 7 p.

Whelen, M.A., W.R. Olmsted and R.W.J. Stewart. MS 1981. Studies of juvenile chinook salmon (Oncorhynchus tshawytscha) and other salmonids in the Quesnel River drainage during 1980. Prepared for Dept. Fish. Oceans, Vancouver. 105 p.

Appendix 1. Spawning ground observations of Harrison River chinook reported by fishery officers, 1976-89.

Year	Annual escapement estimate	Date	Method	Chinook Live	Chinook Dead	Comments
1976	7,500	13-Oct	Aircraft	5,000	n/r	Did not include fish in deep water.
		25-Oct	Not recorded	4,000	n/r	
		01-Nov	Not recorded	6,600	n/r	
		01-Dec	Not recorded	50	n/r	
1977	25,000	11-Oct	Helicopter	2-4,000	n/r	
		17-Oct	Not recorded	2-2,200	n/r	
		26-Oct	Not recorded	7,400	1,100	Poor visibility.
1978	15,000	31-Oct	Not recorded	9,500	3,000	Water level normal.
1979	15,000	26-Oct	Not recorded	10,400	250	Water up, visibility poor.
		01-Nov	Not recorded	11,600	400	Normal water level.
1980	10,000	01-Oct	Helicopter	1,000	n/r	Good visibility.
		09-Oct	Not recorded	1,000	n/r	Water level normal.
		17-Oct	Helicopter	5,000	n/r	Water low.
		28-Oct	Helicopter	8,000	2,000	Normal water level.
1981	20,000	14-Sep	Helicopter	10	n/r	Water slightly turbid.
		06-Oct	Helicopter	500	n/r	Species i.d. difficult (120,000 counted, all species)
		24-Oct	Helicopter	15,000	5,000	"Not a good look".
		05-Nov	Helicopter	0	0	"Not a good look"; water high, slightly turbid.
1982	22,000	02-Oct	Helicopter	200	50	Water level normal.
		05-Oct	Aircraft	4,000	250	Water level normal.
		29-Oct	Aircraft	500	2,500	Water high; could not count in deep water.
		01-Nov	Aircraft	8,000	1,000	Water high.
		08-Nov	Helicopter	6,700	1,500	
		13-Nov	Helicopter	4,675	2,800	
1983	6,000	26-Sep	Aircraft	50	0	Water turbid; visibility poor.
		05-Oct	Aircraft	3,500	0	Water low but turbid; could not count in deep water.
		11-Oct	Aircraft	2,600	n/r	Water level normal; water clear.
		23-Oct	Aircraft	8,000	n/r	Surveyed 60%-100 of the spawning area.
		28-Oct	Aircraft	2,000	n/r	Water level normal; water clear.
		23-Nov	Helicopter	0	n/r	Water high; slightly turbid.
1984	15,000	25-Sep	Helicopter	3,000	n/r	Water high; turbid; 50% coverage.
		26-Oct	Helicopter	7,000	n/r	Water very turbid; 50% coverage; reliability 3-.
1985	50,000	17-Sep	Helicopter	5	0	Water low; turbid; 80% coverage; reliability 3.
		08-Oct	Helicopter	1,000	n/r	Water low; slightly turbid; 90% coverage; reliability 3.
		28-Oct	Helicopter	7,000	2,000	Reliability 3 (fair).
		04-Nov	Helicopter	40,000	n/r	Reliability 3.
		09-Nov	Helicopter	40,000	n/r	Reliability 1 (high).
1986	35,000	04-Nov	Helicopter	18,250	n/r	Water low; slightly turbid; reliability 2-3.
		10-Nov	Helicopter	12,000	n/r	Water low; slightly turbid; reliability 2-3.
		17-Nov	Helicopter	1,520	n/r	Water low; clear; reliability 1.
1987	n/a	27-Oct	Helicopter	50,000	n/r	Low flows confined fish to main channel; reliability 3.
1988	n/a	27-Oct	Helicopter	-	n/r	35,000 chinook and chums; reliability 3.
		18-Nov	Helicopter	17,900	n/r	Water slightly turbid; reliability 2.
1989	n/a	No surveys				

Appendix 2a. Results of bias evaluation of the application sample in the Harrison River mark-recapture study, 1984-89.

Year	Period	Location	Fish size	Fish sex
1984	Not reported	No bias	Bias to small fish	Not reported
1985	Not reported	Bias to upper/lower	Bias to small fish	Not reported
1986	Not reported	Bias to lower reach	No bias	Bias toward females
1987	Not reported	No bias	No bias	Not reported
1988	Bias to middle	No bias	No bias	No bias
1989	No bias	No bias	No bias	No bias

Appendix 2b. Results of bias evaluation of the recovery sample in the Harrison River mark-recapture study, 1984-89.

Year	Period	Location	Fish size	Fish sex
1984	Not reported	Not reported	Bias to large fish	Bias toward females
1985	Not reported	Not reported	Bias to large fish	Bias toward females
1986	Not reported	Not reported	Bias to large fish	Bias toward females
1987	Not reported	Not reported	No bias	Bias toward females
1988	Bias to late	No bias	Bias to large fish	Bias toward females
1989	No bias	No bias	No bias	Bias toward females

Note 1: 1984-87 results were from Staley (1990).
1988 results were from Rice *et al.* (MS 1989).
1989 results were from Farwell *et al.* (1990).

Note 2: "Not reported" indicates analysis not reported in cited paper; data not readily available.

Appendix 3. Age and postorbital-hypural plate (POH) length, by sex and year, of Harrison River chinook sampled on the spawning grounds.

Sex	Year		Age 2/1	3/1	4/1	4/2	5/1	6/1
Male	1984	Number sampled	4	83	66	0	6	0
		Percent of total	2.5%	52.2%	41.5%	0.0%	3.8%	0.0%
		Mean POH length (mm)	446	601	718	-	803	-
	1985	Number sampled	0	25	31	0	4	0
		Percent of total	0.0%	41.7%	51.7%	0.0%	6.7%	0.0%
		Mean POH length (mm)	-	599	726	-	846	-
	1986	Number sampled	5	7	109	0	5	0
		Percent of total	4.0%	5.6%	86.5%	0.0%	4.0%	0.0%
		Mean POH length (mm)	374	550	741	-	801	-
	1987	Number sampled	1	47	105	0	25	0
		Percent of total	0.6%	26.4%	59.0%	0.0%	14.0%	0.0%
		Mean POH length (mm)	361	608	736	-	805	-
	1988	Number sampled	1	12	95	0	10	0
		Percent of total	0.8%	10.2%	80.5%	0.0%	8.5%	0.0%
		Mean POH length (mm)	437	625	750	-	848	-
	1989	Number sampled	2	63	21	0	8	0
		Percent of total	2.1%	67.0%	22.3%	0.0%	8.5%	0.0%
		Mean POH length (mm)	444	632	737	-	815	-
Female	1984	Number sampled	0	51	151	0	22	0
		Percent of total	0.0%	22.8%	67.4%	0.0%	9.8%	0.0%
		Mean POH length (mm)	-	628	699	-	760	-
	1985	Number sampled	0	22	78	1	7	0
		Percent of total	0.0%	20.4%	72.2%	0.9%	6.5%	0.0%
		Mean POH length (mm)	-	636	714	620	755	-
	1986	Number sampled	0	4	386	0	20	0
		Percent of total	0.0%	1.0%	94.1%	0.0%	4.9%	0.0%
		Mean POH length (mm)	-	629	718	-	777	-
	1987	Number sampled	0	8	267	0	113	0
		Percent of total	0.0%	2.1%	68.8%	0.0%	29.1%	0.0%
		Mean POH length (mm)	-	645	732	-	773	-
	1988	Number sampled	0	6	215	1	25	1
		Percent of total	0.0%	2.4%	86.7%	0.4%	10.1%	0.4%
		Mean POH length (mm)	-	662	736	679	773	864
	1989	Number sampled	0	53	30	1	12	0
		Percent of total	0.0%	55.2%	31.3%	1.0%	12.5%	0.0%
		Mean POH length (mm)	-	646	725	734	798	-
Total	1984	Number sampled	4	134	217	0	28	0
		Percent of total (both sexes)	1.0%	35.0%	56.7%	0.0%	7.3%	0.0%
		Mean POH length (mm)	446	606	705	-	769	-
	1985	Number sampled	0	47	109	1	11	0
		Percent of total (both sexes)	0.0%	28.0%	64.9%	0.6%	6.5%	0.0%
		Mean POH length (mm)	-	617	716	620	788	-
	1986	Number sampled	5	11	495	0	25	0
		Percent of total (both sexes)	0.9%	2.1%	92.4%	0.0%	4.7%	0.0%
		Mean POH length (mm)	374	579	723	-	781	-
	1987	Number sampled	1	55	372	0	138	0
		Percent of total (both sexes)	0.2%	9.7%	65.7%	0.0%	24.4%	0.0%
		Mean POH length (mm)	361	613	733	-	779	-
	1988	Number sampled	1	18	310	1	35	1
		Percent of total (both sexes)	0.3%	4.9%	84.7%	0.3%	9.6%	0.3%
		Mean POH length (mm)	437	645	735	679	783	864
	1989	Number sampled	2	116	51	1	20	0
		Percent of total (both sexes)	1.1%	61.1%	26.8%	0.5%	10.5%	0.0%
		Mean POH length (mm)	444	635	730	734	805	-

Appendix 4. Chinook size by age and sex in the 1988 Albion test fishery and Harrison River spawning ground samples.

		Test fishery[a]			Harrison River spawning ground		
Age	Sex	Sample size	Percent of sample	Mean POH length (mm)	Sample size	Percent of sample	Mean POHL length (mm)
2/1	Male	3	1.2%	393	2	0.5%	424
	Female	1	0.4%	432	0	0.0%	-
	Total	4	1.7%	403	2	0.5%	424
3/1	Male	12	5.0%	591	15	3.8%	630
	Female	3	1.2%	611	12	3.0%	664
	Total	15	6.2%	595	27	6.9%	645
4/1	Male	81	33.5%	731	99	25.1%	751
	Female	105	43.4%	720	224	56.9%	728
	Total	186	76.9%	725	323	82.0%	735
4/2	Male	4	1.7%	627	0	0.0%	-
	Female	0	0.0%	-	1	0.3%	679
	Total	4	1.7%	627	1	0.3%	679
5/1	Male	7	2.9%	797	11	2.8%	839
	Female	12	5.0%	773	29	7.4%	762
	Total	19	7.9%	782	40	10.2%	783
5/2	Male	5	2.1%	762	0	0.0%	-
	Female	7	2.9%	720	0	0.0%	-
	Total	12	5.0%	737	0	0.0%	-
6/1	Male	0	0.0%	-	0	0.0%	-
	Female	0	0.0%	-	1	0.3%	864
	Total	0	0.0%	-	1	0.3%	864
6/2	Male	1	0.4%	951	0	0.0%	-
	Female	1	0.4%	924	0	0.0%	-
	Total	2	0.8%	938	0	0.0%	-

[a] White fleshed chinook after September 1.

Appendix 5. Annual chinook size, age and sex in the Fraser River test fishery.

Year	Month	Period	Sample size	Mean weight (kg)	Mean length (cm)	Mean age	Percent female
1981	Apr	Early	8	8.6	66.6	5.0	25.0%
		Mid	16	7.8	66.6	4.7	75.0%
		Late	9	8.5	68.3	5.0	88.9%
	May	Early	63	7.7	65.5	4.8	68.3%
		Mid	15	8.1	66.6	4.8	66.7%
		Late	20	7.9	66.8	4.9	70.0%
	Jun	Early	35	8.3	67.4	4.8	80.0%
		Mid	81	8.6	68.3	4.7	55.6%
		Late	88	8.7	67.6	4.6	58.0%
	Jul	Early	38	9.3	68.3	4.6	52.6%
		Mid	46	9.5	68.8	4.5	50.0%
		Late	58	9.9	70.4	4.6	50.0%
	Aug	Early	81	9.5	69.0	4.2	60.5%
		Mid	49	9.6	68.9	4.3	71.4%
		Late	29	9.2	68.5	4.0	75.9%
	Sep	Early	33	11.4	71.9	4.2	48.5%
		Mid	48	9.4	66.5	3.6	47.9%
		Late	50	9.5	68.8	3.6	44.0%
	Oct	Early	36	10.8	72.2	3.9	50.0%
1982	Apr	Early	7	9.0	68.7	5.0	71.4%
		Middle	5	7.9	64.2	4.7	40.0%
		Late	14	8.4	67.0	4.9	64.3%
	May	Early	51	8.4	65.6	4.7	62.7%
		Middle	41	8.7	67.2	4.6	63.4%
		Late	58	8.7	67.1	4.6	50.0%
	Jun	Early	49	8.6	66.8	4.5	46.9%
		Middle	48	9.3	69.0	4.7	73.3%
		Late	104	9.6	68.9	4.4	61.5%
	Jul	Early	84	9.3	68.1	4.6	61.9%
		Middle	94	9.9	69.1	4.6	56.4%
		Late	90	12.1	69.9	4.6	52.2%
	Aug	Early	61	10.5	70.9	4.5	62.3%
		Middle	36	10.7	71.4	4.4	58.3%
		Late	31	9.9	69.5	4.1	61.3%
	Sep	Early	57	10.9	70.8	3.9	54.4%
		Middle	108	12.1	71.6	3.8	47.2%
		Late	92	10.8	69.2	3.8	48.9%
	Oct	Early	17	10.2	68.0	3.7	47.1%
1984	Apr	Early	10	9.1	67.6	4.9	40.0%
		Middle	14	10.0	69.1	4.9	57.1%
		Late	8	9.0	66.9	4.9	37.5%
	May	Early	9	9.0	69.7	5.1	55.6%
		Middle	21	6.4	61.9	4.6	57.1%
		Late	57	7.8	66.2	4.7	42.1%
	Jun	Early	71	9.0	68.3	4.9	59.2%
		Middle	92	9.3	68.0	4.7	59.8%
		Late	67	8.3	65.1	4.6	52.2%
	Jul	Early	68	8.8	66.9	4.7	61.8%
		Middle	98	9.5	68.5	4.7	62.2%
		Late	73	9.9	69.2	4.6	60.3%
	Aug	Early	62	9.8	69.4	4.5	61.3%
		Middle	27	9.1	67.7	4.4	63.0%
		Late	47	9.5	69.5	4.2	53.2%
	Sep	Early	42	8.8	67.6	3.8	35.7%
		Middle	70	10.0	71.1	3.7	44.3%
		Late	79	9.2	67.9	3.7	41.8%
	Oct	Early	92	9.2	67.9	3.7	51.1%

Appendix 5 (cont.). Annual chinook size, age and sex in the Fraser River test fishery.

Year	Month	Period	Sample size	Mean weight (kg)	Mean length (cm)	Mean age	Percent female
1985	Apr	Early	12	8.6	68.7	5.0	8.3%
		Middle	5	10.0	70.4	5.0	0.0%
		Late	11	8.2	67.5	5.0	45.5%
	May	Early	14	7.6	65.9	4.8	71.4%
		Middle	31	8.4	67.4	4.9	64.5%
		Late	28	9.0	68.3	4.8	35.7%
	Jun	Early	71	8.6	67.2	4.7	54.9%
		Middle	80	8.5	67.2	4.7	48.8%
		Late	78	8.6	69.2	4.7	56.4%
	Jul	Early	72	8.8	68.3	4.7	70.8%
		Middle	71	10.0	70.8	4.8	53.5%
		Late	54	10.2	72.6	4.7	66.7%
	Aug	Early	20	10.3	71.2	4.5	55.0%
		Middle	66	9.6	70.0	4.4	57.6%
		Late	59	8.9	68.5	4.2	47.5%
	Sep	Early	54	9.3	68.5	3.9	46.3%
		Middle	81	4.6	68.0	3.8	51.9%
		Late	80	6.7	67.1	3.5	36.3%
	Oct	Early	59	9.2	68.2	3.7	47.5%
1986	Apr	Early	10	9.7	72.6	5.2	50.0%
		Middle	9	7.9	66.2	4.9	66.7%
		Late	28	8.4	68.0	5.1	50.0%
	May	Early	55	8.7	68.1	5.0	65.5%
		Middle	30	7.8	65.4	4.7	53.3%
		Late	20	8.7	67.5	4.8	45.0%
	Jun	Early	20	10.2	70.2	4.7	40.0%
		Middle	89	9.3	69.1	4.8	51.7%
		Late	80	9.3	68.9	4.7	42.5%
	Jul	Early	72	9.5	70.5	4.8	56.9%
		Middle	80	10.3	71.7	4.7	55.0%
		Late	89	10.5	72.5	4.7	59.6%
	Aug	Early	47	10.6	72.1	4.5	66.0%
		Middle	53	10.0	71.5	4.2	67.9%
		Late	51	10.5	73.1	4.3	66.7%
	Sep	Early	33	11.0	73.9	4.4	72.7%
		Middle	24	11.7	74.3	4.2	54.2%
		Late	32	10.7	71.7	3.9	71.9%
	Oct	Early	65	10.7	72.3	4.1	56.9%
1987	Apr	Early	10	7.6	68.8	5.1	90.0%
		Middle	35	8.1	70.0	4.9	82.9%
		Late	69	9.0	71.1	4.9	62.3%
	May	Early	108	8.7	70.7	5.0	68.5%
		Middle	96	8.6	70.0	4.9	65.6%
		Late	163	8.8	70.4	5.0	72.4%
	Jun	Early	179	9.7	72.3	5.0	64.8%
		Middle	295	9.5	71.1	4.9	60.7%
		Late	396	10.0	71.4	4.9	58.3%
	Jul	Early	174	11.2	73.5	4.9	62.1%
		Middle	202	10.9	73.3	4.9	63.4%
		Late	205	10.8	73.6	4.9	61.5%
	Aug	Early	54	11.4	75.1	5.0	66.7%
		Middle	64	10.3	73.5	4.6	64.1%
		Late	53	10.9	73.9	4.5	75.5%
	Sep	Early	32	9.6	71.1	4.4	71.9%
		Middle	34	10.7	72.3	3.9	52.9%
		Late	47	11.2	73.0	4.0	48.9%
	Oct	Early	35	10.1	72.1	3.9	65.7%
		Middle	20	10.5	72.7	4.2	60.0%

Appendix 5 (cont.). Annual chinook size, age and sex in the Fraser River test fishery.

Year	Month	Period	Sample size	Mean weight (kg)	Mean length (cm)	Mean age	Percent female
1988	Apr	Early	41	8.2	70.5	5.0	85.4%
		Middle	45	8.4	71.2	5.0	68.9%
		Late	36	8.2	70.3	5.0	58.3%
	May	Early	80	8.3	71.0	5.1	68.8%
		Middle	44	8.8	71.7	5.1	70.5%
		Late	101	9.2	71.6	5.0	58.4%
	Jun	Early	258	9.2	71.8	5.0	58.5%
		Middle	201	9.4	71.9	5.1	60.7%
		Late	345	10.4	72.5	5.1	62.6%
	Jul	Early	229	10.0	71.1	5.0	59.4%
		Middle	167	10.0	71.7	4.8	59.3%
		Late	124	10.3	71.6	4.8	54.8%
	Aug	Early	89	10.2	71.6	4.7	65.2%
		Middle	144	9.1	69.5	4.3	59.7%
		Late	110	8.5	68.8	4.2	53.6%
	Sep	Early	61	10.2	71.1	4.2	41.0%
		Middle	122	11.0	72.0	4.1	50.8%
		Late	88	11.4	73.1	4.2	55.7%
	Oct	Early	40	9.1	68.9	3.9	60.0%
		Middle	8	8.6	68.6	3.9	75.0%

Appendix 6. Timing of chinook fry emigrations in selected Fraser River tributaries, 1978-81.

Year	Location	Study period	Date of peak migration: Daily	Date of peak migration: 50%	Peak fry migration at Mission
1978	Chilko River	Apr 21 - Jun 4	09-May	10-May	18-Apr
1979	Chilko River	Apr 26 - May 7	14-May	14-May	03-May
	Fraser River, upper	Apr 27 - Jun 5	23-May	15-May	
	Nicola River	n/a	26-Apr	n/a	
	Shuswap River, lower	Apr 12 - May 19	28-Apr	30-Apr	
1980	Fraser River, upper	Apr 24 - Jun 18	15-May	16-May	03-May
	Quesnel River	Apr 1 - Aug 31	17-Apr	01-May	
	Shuswap River, lower	Apr 13 - May 3	19-Apr	19-Apr	
	Stuart River	Apr 16 - Sep 9	16-May	15-May	
1981	Holmes River	Apr 5 - Aug 7	11-May	n/r	08-Apr
	Slim Creek	Apr 4 - Oct 15	12-May	06-May	

Note: Data sources were:
Chilko River - Delaney *et al.* (1982).
Upper Fraser River - Fedorenko *et al.* (1983).
Holmes River and Slim Creek - Rosberg *et al.* (MS 1981).
Nicola River - Fraser et al. (1982).
Quesnel River - Whelen et al. (MS 1981).
Shuswap River - Fedorenko and Pearce (1982).
Stuart River - Lister et al. (MS 1981).

Appendix 7. Percent of observed tags which were reported as white fleshed relative to all recoveries with a valid colour code in the fishery strata indicated. Reported percentages are weighted averages for the period 1983 to 1989. There are usually few recoveries for ages 2 and 5.

Hatchery	Age 2	Age 3	Age 4	Age 5	Total
Strait of Georgia Troll Fishery					
Chehalis	0.0%	27.5%	56.3%	0.0%	34.9%
Chilliwack	0.0%	22.3%	54.2%	0.0%	27.4%
West Coast Vancouver Island Troll Fishery					
Chehalis	0.0%	21.3%	42.5%	100.0%	25.7%
Chilliwack	0.0%	17.7%	54.0%	25.0%	31.3%
South Central Troll Fishery					
Chehalis	0.0%	29.2%	75.0%	0.0%	35.7%
Chilliwack	0.0%	23.5%	71.4%	0.0%	31.0%
Combined Net Fisheries: Johnstone Strait, Juan de Fuca Strait, Georgia Strait					
Chehalis	31.3%	43.3%	55.6%	0.0%	37.9%
Chilliwack	25.0%	63.6%	50.0%	50.0%	45.5%
Fraser Gillnet Fishery					
Chehalis	87.5%	81.8%	76.9%	100.0%	81.5%
Chilliwack	100.0%	81.0%	93.8%	100.0%	88.9%

Appendix 8. Annual Harrison chinook escapement and observed subsequent escapement by brood year.

Brood year	Total escapement	Subsequent escapement from brood year				Total
		Age 2	Age 3	Age 4	Age 5	
1979	n/a	n/a	n/a	n/a	7,507	7,507
1980	n/a	n/a	n/a	62,732	11,590	74,322
1981	n/a	n/a	48,792	103,228	7,204	159,223
1982	n/a	1,806	60,075	146,557	16,796	225,234
1983	n/a	0	5,528	50,352	3,331	59,210
1984	120,837	3,393	11,644	29,410	7,233	51,680
1985	174,778	247	2,233	18,859	n/a	21,339
1986	162,596	143	47,542	n/a	n/a	47,595
1987	79,038	1,052	n/a	n/a	n/a	1,052
1988	35,116	n/a	n/a	n/a	n/a	0
1989	74,685	n/a	n/a	n/a	n/a	0