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Assessment of Campbell/Quinsam Chinook Salmon (*Oncorhynchus tshawytscha*)

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ABSTRACT

The development and assessment of effective management strategies for the rebuilding of chinook salmon stocks to historical levels requires accurate estimates of escapement as well as estimates of the relative contribution of hatchery and natural production to that escapement. In 1984, various "key streams" were chosen including the Campbell/Quinsam River system. The key stream program was designed as a means of monitoring escapement parameters in specific spawning areas and initiated in response to objectives set out in the Canada-U.S. Pacific Salmon Treaty. The goal for these selected streams was to use the escapement and exploitation information from these stocks as an indicator of harvest and exploitation rates for neighbouring stocks. The Quinsam/Campbell was chosen to represent Upper Georgia Strait/Johnstone Strait chinook.

Interim escapement goals for British Columbia chinook stocks were established by the Chinook Technical Committee (Pacific Salmon Commission 1986). Goals for natural and enhanced stocks were double the 1979-82 base period or, for key streams, double the 1984 escapement. The interim escapement goal for the Quinsam/Campbell was set at 5,970. Since 1989, chinook returns to the Campbell/Quinsam system initially continued to decline but in recent years have rebounded. However, the escapement goal has only been reached once (1999), even with substantial enhancement efforts.

The Campbell River was historically one of the most important producers of chinook in the Strait of Georgia. Three over-riding key aspects were identified to have contributed to the decline of the Campbell River chinook stock. Hydroelectric development and associated construction of dams and water diversions are suggested to have significantly contributed to the decline of salmon stocks. Major changes in river discharge and flow regimes are known to have considerable detrimental effects to both the adult and juvenile life stages. Secondly, the estuary has been used extensively by industry and for urban development which has also been documented to have had a considerable impact on the rearing capacity for juveniles. And finally, high exploitation of this stock in previous years at non-sustainable levels has obviously been detrimental to the natural chinook stock in the Campbell River.

Reduction in exploitation by approximately 50% since the late 70's and up to 500% improvements in marine survival in recent years should contribute substantially to the rebuilding process. In 1999 there were double the number of natural spawners in the Campbell River compared to the previous 5 years.

RÉSUMÉ

L'élaboration et l'évaluation de stratégies de gestion efficaces visant le rétablissement des stocks de saumon quinnat à leurs niveaux historiques requièrent des estimations précises de l'échappée ainsi que des estimations de la contribution relative de la production des écloseries et du milieu sauvage à celle-ci. Un programme lancé en 1984 en réponse à des objectifs établis dans le Traité sur le saumon du Pacifique signé par le Canada et les États-Unis a servi à identifier divers cours d'eau « clés », y compris le réseau des rivières Campbell et Quinsam, où des paramètres de l'échappée dans des frayères spécifiques ont été contrôlés. L'objectif était d'utiliser les renseignements sur l'échappée et l'exploitation de ces stocks comme un indicateur des taux de récolte et d'exploitation des stocks voisins. Le réseau Quinsam-Campbell a été choisi comme représentatif du quinnat du haut détroit de Georgia et du détroit de Johnstone.

Le Comité technique du saumon quinnat (Commission du saumon du Pacifique, 1986) a fixé les objectifs intérimaires d'échappée pour les stocks de quinnat de la Colombie-Britannique. Dans le cas des stocks naturels et mis en valeur, les objectifs étaient deux fois ceux pour la période de référence 1979-1982 et, dans le cas des cours d'eau clés, deux fois les niveaux de 1984. L'objectif intérimaire d'échappée pour le réseau Quinsam-Campbell a été fixé à 5 970 saumons. À partir de 1989, les remontes de quinnat dans ce réseau ont continué à baisser, mais elle ont repris dans les dernières années. L'objectif d'échappée n'a toutefois été atteint qu'une fois (1999), en dépit de grands efforts de mise en valeur.

La rivière Campbell était autrefois l'un des tributaires du détroit de Georgia les plus producteurs de quinnat. Trois aspects clés prépondérants qui ont contribué au déclin du stock de quinnat de ce cours d'eau. Ils sont d'avis que l'aménagement hydroélectrique et la construction conséquente de barrages et le détournement des eaux ont grandement contribué à l'appauvrissement des stocks de saumon car il a été établi que d'importants changements dans les régimes de débit et d'écoulement ont de graves incidences sur les adultes et les juvéniles. En deuxième lieu, le développement urbain et le grand nombre d'industries dans l'estuaire sont reconnus comme ayant un effet marqué sur la capacité de grossissement des juvéniles. Et en dernier lieu, la forte exploitation de ce stock à des niveaux non soutenables par les années passées a visiblement nuit au stock de quinnat sauvage de la Campbell.

La réduction du taux d'exploitation d'environ 50 % depuis la fin des années 70 et l'amélioration allant jusqu'à 500 % du taux de survie en mer au cours des dernières années devraient nettement contribuer au processus de rétablissement. Ainsi, en 1999, le nombre de reproducteurs sauvages dans la rivière Campbell étaient deux fois celui observé au cours des cinq années précédentes.

Introduction

The Campbell/Quinsam watershed has received considerable attention, has been studied extensively and has a very colorful history. The system has been extensively dammed and diverted for hydro-electric power, has historically been considered a unique system for its tyee fishery, has been enhanced through a large hatchery facility since 1978, and was selected as an indicator stock for Upper Georgia/Johnstone Strait chinook. This document represents the first comprehensive compilation and examination of the data collected to date.

Groupings of chinook salmon populations in British Columbia are distinguished by geographic location, run timing of the spawning migration, distribution of catch in the ocean, and age at maturity. Five major groups of Canadian-origin chinook salmon are recognized around the Strait of Georgia; including upper Fraser River spring and summer chinook, Harrison River white fall chinook, Mainland inlet summer chinook, far-north migrating fall chinook in the upper Strait, and the Lower Strait of Georgia fall chinook group. For the purposes of this report, we use the assessment to the Quinsam/Campbell system as a stock representing the Upper Strait of Georgia fall chinook group.

The development and assessment of effective management strategies for the rebuilding of chinook salmon stocks to historical levels requires accurate estimates of escapement as well as estimates of the relative contribution of hatchery and natural production to that escapement. In 1984, various “key streams” were chosen for study, including the Campbell/Quinsam River system, in order to represent the overall status of chinook bearing streams along the British Columbia coast. The key stream program was designed as a means of monitoring escapement parameters in specific spawning areas. These selected streams provide ongoing information to fisheries managers in response to artificial (hatchery) and natural production, and harvest management strategies. The key stream program began in 1984, in accordance with objectives set out in the Canada-US Salmon Treaty. Chinook stock assessment requires an accurate estimation of escapement, and the contribution from artificial and natural means to fisheries and escapement.

The major objectives of the key stream program are:

1) to accurately estimate chinook escapement on key streams;
2) to estimate harvest rates and contributions to fisheries and escapement based on coded-wire tagged/adipose clip returns; and
3) to estimate the contribution of hatchery and natural production to the escapement.

Study Area

Campbell River originates east of the Vancouver Island mountain ranges and flows in an easterly direction for 65 km into Discovery Passage immediately north of the City of Campbell River (Fig 1). The Quinsam River, a major tributary of the Campbell River, flows in a northerly direction through a series of small lakes for approximately 30 km, flowing into the Campbell River approximately 3.8 km upstream of the Campbell River estuary. The drainage area of the Campbell system is 1,460 km^2 and of the Quinsam system is 265 km^2. Fish passage in the Campbell River is blocked by natural falls and an hydroelectric dam 5.5 km upstream of the estuary. Approximately

27 km of the Quinsam River is accessible to natural spawning but most chinook spawning usually takes place in the lower 4 km of the river (Shardlow *et al.* 1986).

Five species of Pacific salmon are found within the Campbell/Quinsam system. In order of abundance, these are pink (Oncoryhnchus gorbuscha), chinook (O. tshawytscha), chum (O. keta), coho (O. kisutch), and sockeye (O. nerka). There are also Steelhead trout (O. mykiss), and Cutthroat trout (O. clarki). Chinook salmon have been observed spawning in the Campbell River above the Quinsam River confluence and in the Quinsam River from the confluence with the Campbell to above the hatchery counting fence (Andrew *et al.* 1988). Some chinook are allowed to proceed through the counting fence to spawn in the higher reaches of the lower Quinsam.

Mature chinook begin entering the Campbell River in mid-August with the migration peaking in October. Spawning occurs over several weeks from the middle of October to mid-November. Chinook entering the Quinsam River are more dependant on rainfall and consequently enter and spawn a little later than in the Campbell River, through November into early December.

Habitat and Environmental Factors

Commercial & Industrial Development

The city of Campbell River and its associated industry surrounds the lower two kilometres of the river. Therefore, the estuary and this lower section is highly modified. Urban development includes several road crossings, housing, and the Campbell River road which runs adjacent to the river along the south bank (Andrew *et al.* 1988).

Commercial development (Fig. 2) in the estuary includes log booming, sawmills, shake mills, a seaplane base, and moorage facilities for pleasure boats (Andrew *et al.* 1988). The estuary has been utilized for industrial activities since the early twentieth century. Commercial development in the Campbell R. estuary includes log booming, sawmills, shake mills, a seaplane base at Tyee spit, and pleasure boat moorage. Man-made islands have been constructed in the estuary in an effort to improve fish habitat (Levings 1986).

The International Timber Company began shipping logs out of the area in 1904. In 1905, the company took charge of a water lot lease for log storage in the estuary. Forestry operations in the region continued to make log storage in the estuary a necessity. As recently as 1980 approximately 40 hectares of the estuary waters were used for log storage. A Redi-Mix gravel operation at Tyee Spit ran from 1964 to 1974 (Lauga and Associates, 1994).

The upper watersheds of both the Quinsam River and the Campbell River have been logged for decades. Numerous roads have been built to allow access to the timber. As well, the upper watershed of the Quinsam River has been and is currently being mined for coal. According to Alderdice and McLean (1982), zinc and copper levels are rising in the system. Mineral mining is conducted in the headwaters of the Campbell, and forestry harvesting in the vicinity of the large lakes in the watershed.

Hydro-electric development

Development of the hydroelectric potential of the Campbell River commenced after the Second World War. At the time, the British Columbia Power Commission anticipated that the development would provide the foundation for economic growth in North Vancouver Island. The project originally consisted of the construction of three major dams and three generating stations (1947). As construction of Strathcona Generating station (the third and most upstream) project in the development was nearing completion, the Commission realized that the economic growth would surpass the electrical energy that could be generated from the Campbell River watershed. As a result three adjacent watershed basins, the Salmon River/Grilse Creek, the Heber River/Hunter and Crest Creeks, and the Quinsam River were partially diverted to the Campbell River basin to increase the net drainage area of the overall watershed.

The Campbell River hydroelectric development is made up of three impoundments and a series of diversions. The lowest dam on the system, completed in 1953, is the John Hart Dam which impounds John Hart Lake. Above John Hart Lake, Campbell Lake is impounded by Ladore Dam, built in 1957. Strathcona Dam is the highest impoundment in the watershed. It impounds Upper Campbell Lake and Buttle Lake (Hirst, 1991). The diversions are the Heber River diversion and Crest Creek diversions to Upper Campbell Lake, and both the Salmon and Quinsam Rivers to Campbell Lake (Burt and Burns, 1995).

The flow in the Campbell River is controlled by the John Hart generating station, located 5.5 km upstream of the estuary (Marshall *et al.* 1977). Flow varies from 1.2 m^3/sec to 826.0 m^3/sec (Table 1). Minimum flows on the Campbell River are dictated by an informal agreement between DFO and BC Hydro (Hirst, 1991). The terms of this agreement include: 1) minimum flows of 34 m^3s^{-1} (1200 cfs) below John Hart Dam; 2) preferred flows of 51 m^3s^{-1} (1800 cfs); and 3) a ramping rate of 80 minutes for flow changes between 34 and 51 m^3s^{-1} (Burt and Burns, 1995). These flow regimes were not always adhered to since excess water storage had to be discharged due to safety concerns with the dam. For example, in some years the discharge levels were substantially outside the preferred range (Fig. 2), as described in the B.C. Hydro agreement.

The effects of modified hydrology on salmonids has been studied for many systems (Burt and Mundie 1986) and an extensive study was conducted on the Campbell River (Hamilton and Buell, 1976). Investigations into the effect of flow regulation on Campbell River salmonids suggest that flow fluctuations have had four adverse effects: 1) disruption of spawning, 2) stranding of juveniles, 3) diminution of food items, and 4) scouring of spawning gravel. Under the present flow regime, small and intermediate sized gravel are scoured from the lower river by the frequent rapid fluctuations in discharge and occasional excessive discharges.

The John Hart Dam is also thought to have stopped the natural recruitment of spawning gravel to the lower reaches of the Campbell River (Burt and Burns, 1995; Hamilton and Buell, 1976). Prior to construction of the John Hart Dam the limit of chinook upstream migration in the mainstem of the Campbell R. was a natural obstruction known as Elk Falls, located in a canyon about 5 km from the river mouth. Construction of the dam and total diversion of flow in the canyon area reduced flows to a very low level sustained by seepage from the dam. As a result, the post-development upstream limit of anadromous fish distribution in the river is the canyon pool adjacent to the John Hart powerhouse. The diversion of nearly all of the river around Moose, Deer and Elk Falls and the Campbell River canyon bypassed what was probably a good gravel transport and production area. Historically, a quantity of various sized gravels, produced in the upstream drainage areas, would have been transported through the canyon area during periods of high flow. Under present conditions, periodic spilling of flood waters through the canyon is insufficient to produce or recruit significant amounts of replacement gravels. Second, gravels produced by tributaries of the Upper Campbell River never reaches the lower river because it becomes trapped in the man-made impoundments of Upper and Lower Campbell Lakes and John Hart Lake.

The Quinsam River watershed drains an area of 209 sq. km (Blackmun et al. 1985). The Quinsam River is the major tributary of the Campbell River and their confluence is 3.5 km above the Campbell River estuary. Major tributaries to the Quinsam River are Cold Creek, Iron River and Flintoff Creek. The Quinsam watershed is bounded north and west by a mountainous divide that isolates it from the Campbell watershed. Flows in the Quinsam system have been regulated by the British Columbia Hydro and Power Authority (B.C.H.P.A.) since 1956. There is a storage dam on Upper Quinsam Lake and a diversion dam above Middle Quinsam Lake which diverts Quinsam water via Gooseneck Lake into the Campbell system. There were no established minimum flow requirements for the Quinsam system prior to 1963. The B.C.H.P.A. water license, revised in 1963, established flow requirements for the Quinsam River above Middle Quinsam Lake and immediately below lower Quinsam Lake. Even with flow regulation, flooding still occurs in the lower river and possibly in other areas of the watershed.

Impacts

The Campbell River has historically been an important chinook salmon spawning habitat. The impoundment of the system, since 1947, has effected natural river dynamics, with minimal opportunity for gravel, organics and food items to be added to the system. Before dam construction the Campbell River was 65km long draining a watershed of nearly 1500km^2. The high kinetic energy of the lower river restricts rearing areas for juveniles. Since the construction of John Hart dam natural gravel recruitment to the Campbell River has virtually ceased. Over the past 50 years, periodic high flow events have resulted in the remaining gravel bed being flushed downstream through the estuary, leaving the river armoured with large cobbles and boulders, material unsuitable for salmonid spawning. Burt and Burns (1995) estimated the lower Campbell River contained only 1972 m^2 of usable spawning gravel for chinook (Table 2; Fig 4) and was considered to have a shortfall of 15,000 to 20,000 m^2 of spawning gravel based on a target escapement of 4000 chinook spawners and a requirement of 7.5 to 10 m^2 per female. A comparison with the analysis of river substrate in 1973 (Fig. 5) indicate that already then there had been a loss of appropriate gravel for spawning and the problem has become worse since then.

Discharges below 70 m^{3}s^{-1} have been found to reduce the available spawning habitat, expose redds, reduce rearing habitat as well as lower available protective production areas for most salmonids (Hamilton and Buell, 1976).

High discharges above 100 m^{3}s^{-1} impact negatively on the benthos, flushing both the benthos and supportive detritus from the river, scour out the gravel and reduce available rearing habitat. Although short term increases may be tolerable, the cumulative effects of very high discharge rates must be considered detrimental. The salmonid under incubation is therefore, at risk (Burt and Burns, 1995; Hamilton and Buell, 1976; Hirst, 1991). Moderate fluctuations in discharge (increases of 50% or decreases of 30%) were shown to have major disruptive impact on the spawning behaviour of chinook. The effects of sharp decreases were more significant than the effects of corresponding increases. On the basis of comparisons of values before and after river regulation (Gailbraith 1973), the conclusion was reached that reductions in average maxima and increases in average minima demonstrate improved spawning and rearing conditions during the regulated period. While occasional flooding or low discharge may have been deleterious in the historical sense, it was believed that it is far more important to consider environmental variability under average circumstances. Daily fluctuations of 3000 cfs have far more serious consequences than one or two very large but comparatively gradual natural discharge changes per year, each taking several days to complete, or low flows occurring occasionally during a few weeks in August.

The Campbell River Estuary is very important to the salmonid resources. Hamilton and Buell (1976) reported that the estuary serves as a nursery for many species of salmonids. Campbell River chinook are dependent on the estuary as primary rearing habitat (Anderson, 1998).

The extensive history of log storage and industrial development has impacted the carrying capacity of the estuary. Large deposits of bark, the mooring facilities, dredging, and the alteration of the shoreline have reduced the productive capacity of the estuary (Anderson, 1998).

The increased heavy metal load in the flows of the Campbell/Quinsam system may affect salmonid survival rates. Steelhead trout, chinook, and coho, are most susceptible. Between February 1980 and September 1981, levels of heavy metals in water samples (3 tests in 38) were recorded to have been toxic for chinook (Alderdice and McLean, 1982).

In 1995, the Campbell River Hydro/Fisheries Advisory Board was established to address the concerns that were raised following a fall season of intensive rainfall. The Campbell River Interim Flow Management Strategy (CRIFMS) was then released in 1997. This document provides the framework for change to the existing discharge protocol to a more natural hydrograph (Anon, 1997).

Changes in spawner distribution and holding patterns

Prior to construction of the B.C. Hydro dam, the natural outflow of the water from Campbell Lake into the river occurred through a canyon section (with impassable falls). The dam blocked the flow and reduced flow through the canyon to a trickle. Based on historical information, the section of the canyon below the falls to where it meets with the main river (approx. 3-4 km) was presumed to be a good spawning area. As a result of the reduction in flow through this canyon chinook have no longer accessed the area below the falls. This is somewhat corroborated by swim survey spawner distribution information (Fig. 6) that shows that the numbers of spawners holding in the lower canyon pools (Area 1; Appendix Table 2) has decreased substantially over time.

In addition, alterations to the lower river/estuary also have caused changes in the holding patterns of spawners as they returned to the Campbell R. Prior to 1982, when there was a large pool and holding area in the estuary (Fig. 3, section 2). Returning chinook entered this area in September and remained there until October and then moved into the upper river. Subsequent changes to the estuary changed the structure of the holding area and as a result chinook no longer hold in this area but rather move into the upper river in September. This is corroborated by a considerable change in broodstock capture techniques and timing. According to hatchery staff, prior to 1983, chinook broodstock were captured in this large holding area in October but are now captured in holding pools below the Quinsam River broodstock fence below the hatchery (M. Trenholme, Quinsam Hatchery, pers. comm).

Mitigating Projects

The habitat restoration projects that have taken place in this system are the result of community initiative and partnerships between all levels of government, local groups, industry and stakeholders (Appendix A). There are two strategies in place that have gained support from all interested parties and government. The Campbell River Estuary Management Plan and the Campbell River Interim Flow Management Strategy provide a comprehensive approach to improving salmonid production in the watershed (Anderson, 1998).

In 1992, the Vancouver Island Hydro/Fisheries Technical Committee began to address hydroelectric impacts on anadromous fish resources on Vancouver Island and as a result a study of the lower Campbell River, below the John Hart Generating Station, was commissioned (Burt and Burns, 1995). An assessment report of carrying capacity of juvenile chinook based on 1994 data with historical 1982-86 data comparison of the Campbell River Estuary was completed in 1997 (Korman *et al.* 1997).

A number of restoration projects on the lower Campbell River mainstem have been initiated to address the shortfalls identified in the Burt and Burns (1995) report. Among these are: the Elk Falls Spawning Channel (1992, 1995); the Elk Falls Twin Side Channel; the Second Island Spawning Channel (1985, 1995, 1996); the Campbell River Gravel Placement Project (1997, 1998); and Raven Channel (1998). Most of these projects deal specifically with the lack of spawning habitat available to salmonids. Approximately 11,500 m^2 of spawning habitat and 1500 m^2 of rearing habitat have been created to date (Anderson, 1998).

Estuarine rearing capacity has been identified as a limiting factor to increased salmon production (Anderson, 1998; CRIFMS, 1997). A series of projects have been implemented in recent years to try and improve over past activities in the intertidal zone. These projects include: the creation of four intertidal islands (1982); river beach and intertidal bench creation (1996 and 1997); an intertidal bench creation at the abandoned Marine Link landing (1997); bank stabilization (1998); and east bank intertidal benching (1998). The net estuarine habitat production from these projects include 5700 m^2 of intertidal sedge marsh bench and 7800 m^2 of intertidal beach (Anderson, 1998).

Escapement Trends and Goals

Prior to 1984, chinook escapement to the Campbell River was estimated based on visual surveys conducted by DFO Fishery Officers. Since then an intensive escapement enumeration program for both the Campbell and Quinsam systems has been completed each year by Quinsam hatchery staff. This includes a Petersen carcass mark-recapture that provides an escapement estimate for the Campbell and Quinsam rivers, total enumeration of returns to the Quinsam hatchery, an estimate of the spawners above the hatchery fence, and a biosamping program for age and sex composition and coded-wire tag mark rates for each component.

Overall escapement of chinook to the Campbell/Quinsam watershed (Fig. 7) ranged from 2500-6000 in the 40's, 50's and 60's, experienced a substantial decline in the late 70's, increased dramatically in the 80's primarily due to significant hatchery production, and then again declined to low levels similar to those experienced in the late 70's. Specifically, chinook escapement to the Campbell River has declined from 4,200 (ten year average; 1967-77) to 536 (ten year average;

1987-97) in recent years. At the same time the Quinsam River chinook escapement has increased from negligible returns to an average of 2,800 chinook spawners (ten year average; 1987-97 hatchery plus Quinsam R. escapement). In the past two years however, there has been considerable improvement in escapement and for the first time in many years the numbers of spawners in the Campbell River has increased.

Interim escapement goals for British Columbia chinook stocks were established by the Chinook Technical Committee (Pacific Salmon Commission 1986). 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. The interim escapement goal for the Quinsam/Campbell system was set at 5,970, double the 1984 adjusted mark-recapture estimate.

Enhancement History

The Quinsam River Hatchery, a Fisheries and Oceans enhancement facility, built in 1972 (Andrew et. al., 1988) approximately 3.7 kilometers up from the confluence with the Campbell River, enhances salmon and anadromous trout from the Quinsam and neighbouring streams. In recent years, various remote net pen sites have been used to examine alternate rearing and release strategies. Since 1986, chinook escapements to the Campbell River have ranged from 219 (1993) to 4,057 (1986). Escapements to the Quinsam River have ranged from 2,267 (1993) to 11,982 (1990). Total escapements to the system have ranged from a low of 2,486 (1993) to a peak of 15,380 (1990) (Frith, 1992). Prior to the operation of Quinsam Hatchery, the escapement of chinook salmon to the Quinsam River was negligible (Fish Habitat Inventory and Information Program, 1991).

The Quinsam River hatchery consists of a diversion dam at "COLD C", three concrete adult holding ponds, 15 concrete rearing ponds, a fish diversion fence, a fishway, residences and hatchery buildings. Annual production of chinook juveniles has ranged from 162,516 (1975) to 4,402,686 (1992). The current chinook production target is 2.3 million smolts released to the river and 1.0 million released from saltwater netpens. The facility also produces 1.2 million coho smolts, 3.5 million pink fry, 25 thousand steelhead smolts, small numbers of cutthroat and coho fry for planting in local streams and above barriers.

Hatchery reared chinook juveniles are typically released from early to late May (Table 3). Morley *et al.* (1996) studied the effects of juvenile chinook size and time of release in relation to returns at maturity. Highest survival rates were recorded for juveniles (6-10 g) released in early May. May releases showed the strongest release size effects, with larger juveniles returning at higher rates. These data form the framework for the release strategy utilized by Quinsam hatchery.

Intensive mark sampling at the Quinsam hatchery and in the Quinsam and Campbell rivers from a deadpitch program conducted annually since 1984 has provided the recovery of coded-wire tag information (Table 4). Estimates of enhanced contribution using adipose clip/coded-wire tag data requires a number of assumptions including that all hatchery releases are represented by a mark and that sampling of the adult spawners is random. Enhanced contribution to escapement (Fig. 9) has increased significantly in the Campbell River. Straying of hatchery chinook originating from Quinsam hatchery has been ongoing (Burt and Burns, 1995). Annual escapement estimates for the wild chinook stock show a declining trend. The percentage of hatchery contribution to the

Campbell River chinook population is increasing. The straying of hatchery produced chinook spawners into the Campbell River may give the illusion that the Campbell River chinook stock is doing relatively well (Burt and Burns, 1995). The hatchery contribution to the Quinsam River and Quinsam hatchery chinook returns is high. This is expected since prior to the hatchery opening there was no run of consequence on the Quinsam River. In some years the hatchery contribution to the Quinsam hatchery returns has been calculated at 100%. But in recent years there has been an increase in naturally spawning fish has reduced the enhanced contribution.

An alternate method of estimating enhanced contribution was developed by using otolith microstructure to determine hatchery and river-reared origin (Zhang *et al.* 1994). Samples of adult spawners were collected for several years but only the 1996 data has been analyzed. The percentage of spawners recovered in the Campbell River that was determined to be hatchery-reared was 60%. This compares favourably with the estimate of 57% based on coded-wire tag data. Since 1996, all chinook production has been marked with a thermal otolith mark. Sampling of subsequent spawning populations will permit a more direct and definitive assessment of the contribution of enhanced production.

Biological Characteristics

Biological data for chinook have been collected from two sources; hatchery and spawning ground. Hatchery staff routinely biosample chinook collected for brood stock. As part of the carcass mark-recapture program, all chinook recovered on the spawning grounds are sampled for marks.

Approximately 90% of the returning chinook adults have been 4 and 5 year olds in most years (Table 5), although recently there is an increasing proportion of 3 year old males. Chinook returning to the Quinsam/Campbell system are relatively large fish. Weighted mean post-orbital hypural (POH) length of adult male spawners has ranged between 673 – 806 mm, while those of adult females has ranged from 765 – 851 mm (Appendix Table 1).

Both female and male chinook salmon from the Campbell system primarily mature as four and five year olds. Age distribution of the Campbell River spawners has shifted slightly towards a younger returning spawner (Table 6). This trend seems to be evident in both sexes (Andrew *et al.* 1988; Bocking, 1991; Bocking *et al.* 1990; Frith, 1992; Frith and Nelson, 1995; Frith *et al.* 1993; Nagtegaal and Graf, 1998).

Quinsam River chinook mean age distribution for 1986 to 1990 show spawners returning primarily as four (53.1%) and five year olds (29.9) for males while females returned primarily as five (57.9%) and four year olds (36.9%). The 1991 to 1996 mean age distributions for Quinsam River again shows a slight shift to younger spawners returning, with males primarily returning at age four (55.6%) and age three (24.4%). A 10% decline in age five male spawners was evident while age three male spawners increased almost 10%.

The Quinsam hatchery chinook spawner age distribution differed very little between the periods 1986-90 and 1991-96. In both periods, males were primarily age four (1986-90: 55.7%; 1991-96: 56.5%) and age three (1986-90: 25%; 1991-96: 24.3%) while females were primarily age five (1986-90: 43.7%; 1991-96: 49.2%) and age four (1986-90: 52.4%; 1991-96: 47.3%).

Other studies conducted into the release and timing of chinook juveniles revealed larger hatchery juveniles at the time of release returned with a younger age distribution (Bilton, 1984; Bilton *et al.* 1982).

Fecundity information was collected by the Quinsam hatchery during broodstock biosampling (expressed as total eggs divided by number of females). Average fecundity of Quinsam chinook broodstock is approximately 6,000. Using the available adjusted fecundity estimates compared to female mean postorbital-hypural (POH) length there was no observable trend, however, mean fecundity has declined (Fig. 10). It should be noted that sample sizes were small.

According to Nagtegaal and Graf (1998), size specific fecundity of Quinsam chinook varies from year to year. Using a large number of chinook populations, Healey and Heard (1984) determined that mean fecundity was positively related to age at maturity. However, in a single population, the slope of the fecundity age relationship was less than expected if fecundity increases were to offset the effects of natural mortality in older age classes.

Juvenile Chinook Production

Campbell and Quinsam River chinook juveniles are considered to be ‘ocean type’ that migrate to the estuary shortly after emerging. Healey (1991) indicated that this life strategy is common for chinook in coastal streams.

Downstream movement of naturally reared chinook fry occurs primarily in April to June. Prior to 1989, there was no significant information on the downstream migration of juvenile chinook. Burt and Burns (1995) report that trapping in Elk Falls Spawning Channel indicated that chinook fry migrate from early April to the end of June with their migration peaking in early May. Campbell River mainstem chinook fry migrate during the same period, with their migration peaking in mid April.

Hatchery releases of chinook begin in early May and usually are completed by mid to late May. Both hatchery reared and naturally reared chinook fry densities peak in the estuary in late May (Korman *et al.* 1997).

Egg to fry Survival

A measure of egg to fry survival for the Quinsam/Campbell system was determined from counts (adults and juveniles) for chinook that spawned above the Quinsam R. fence facility just above the hatchery. The calculation of egg to fry survival rates is dependent on both good escapement and fry abundance data and unfortunately there was only minimal information available. A counting fence is located above the hatchery, and above the main spawning area on the Quinsam River. The fence is monitored daily for brood stock collection in the fall, however, when the fence goes down, any upstream movement of salmonids is based on visual identification.

Brood Year	Mean Fecundity	Female spawners	Est. # of Eggs	Juvenile Migrants	Egg to Fry Survival
1988	6000	282	1,692,000	63,864	3.77%
1989	6209	626	3,725,400	73,037	1.96%
1990	6052	1157	7,002,164	26,297	0.38%
1991[1]	5918	297	1,757,646	13,864	0.80%
1996	6000	8	48,000	2,161	4.50%
1997	5495	131	719,845	42,684	5.93%

[1]The Quinsam River hatchery had to suspend the operation of the downstream fence between 1993 to 1996 due to a funding shortfall.

According to Healey (1991), egg to fry survival for chinook ranges from 8% to 16%. Differences in the rates obtained may be due to low reliability in the numbers and sex of spawners above the fence. The male:female ratio above the fence may be skewed due to broodstock removals, and excess broodstock males being placed above the fence. There are no data on egg to fry survival rates for the rest of the system.

Juvenile Interactions

All hatchery chinook are presumed to migrate to the estuary shortly after release. Since both naturally reared chinook and hatchery reared chinook reach peak densities in the Campbell River estuary in late May, it is likely that most of the juvenile interaction occurs here (Levings *et al.* 1986; Korman *et al.* 1997). The estuarine habitat and productivity of the Campbell River system has been intensively studied (Macdonald *et al.* 1987; Levings *et al.* 1986; Bravender *et al.* 1997; McAllister and Brown, 1991; Korman *et al.* 1997; Brownlee *et al.* 1984,). These studies confirm the complexity of estuarine interactions (Burt and Burns, 1995).

Feeding patterns of juvenile chinook in the estuary and Discovery passage indicate a fluctuation in diet based upon abundance and availability of organisms. This implies that juvenile chinook eat a wide variety of prey and are opportunistic feeders (Kask *et al.* 1988; Brown *et al.* 1987a). Most studies also revealed that food sources are more abundant in the transition and marine zones (Brown *et al.* 1987a). Beach seine data from 1982 to 1986 found an inverse relationship between total biomass of salmonids and wild chinook fry growth. This indicates a density dependent competition for resources in the estuary (McAllister and Brown, 1991). It also indicates that the carrying capacity of the estuary may reach its limit during peak migration times (Burt and Burns, 1995). Korman *et al.* (1997) re-examined McAllister and Brown's results and added data from 1994. This study used Peterson mark-recapture techniques to determine the carrying capacity of the estuary. Results from this study re-affirmed McAllister and Brown's original findings supporting the contention that the growth of wild chinook in the Campbell River estuary may be density dependent.

Utilization of the estuarine habitat by naturally reared and hatchery chinook differs. Wild chinook fry densities were highest in estuarine zones while hatchery chinook densities were generally higher in the transition zone (Fig. 3). The chinook fry, both hatchery and wild, found in the transition zone were larger than those found in the estuarine zone (Mcdonald *et al.* 1987; Korman *et al.* 1997). Hatchery and naturally reared chinook also exhibited different estuarine residency times. The naturally reared chinook were present in the estuary for three months while hatchery chinook resided in the estuary for approximately 1.5 months (Korman, *et al.* 1997).

Residency of wild chinook fry in the transition zone lasts approximately 50 days. Peak wild fry density in the transition zone coincided with the peak in the estuarine zone. According to Levings *et al.* (1986) there is no lag between peak densities in the transition and the estuarine zones. The duration and the timing of the competition may be largely driven by hatchery releases (Korman *et al.* 1997).

Seal Predation

Although seal predation was not directly assessed in this report, there is anecdotal evidence that it may have a limited impact on Campbell/Quinsam River chinook populations. According to Bocking (1991) live tagging of chinook, for a Petersen mark-recapture program to estimate 1990 chinook escapement in the Campbell River estuary, was halted due to heavy seal predation on tagged releases. It is estimated that the current harbour seal herd in the estuary is in the range of 12-14 (S. Anderson, Quinsam Hatchery, pers. comm).

According to Olesiuk (1993), Pacific salmon make up about 4% of a harbour seal's annual diet. Within an estuary, the annual consumption of salmon may be as high as 12%. Harbour seals can be viewed as terminal predators of salmon with predation becoming more intense as salmon school in the estuary prior to upstream migration to spawn. The most abundant salmon species will be preyed on most heavily (Bigg *et. al* 1990). In other systems (Comox harbour), the predation rate of harbour seals on chinook salmon was estimated as high as 46%.

Cohort Analyses of Coded-wire Tag Data

Quantitative assessments of the Quinsam Hatchery/Campbell River chinook populations are heavily reliant on coded-wire tagging of chinook released from the Quinsam Hatchery since the 1974 brood year. Records of the tag groups applied and the recovery of those tags in coastwide fisheries are maintained at the Pacific Biological Station in the Mark Recovery database. Tag codes used to represent production from the Quinsam Hatchery are listed in Appendix B.

Cohort analysis is conducted using 'estimated' CWT recoveries to determine survival rates and exploitation patterns by brood years. Recoveries of tags in the spawning escapement at the hatchery and in the Quinsam and Campbell rivers allows estimation of the true total exploitation rates. The cohort model used is documented in Appendix 2 of Starr and Argue (1991) and as modified by the Chinook Technical Committee (CTC) of the Pacific Salmon Commission (PSC, TCCHINOOK (99)-2). In determining incidental mortality, only the brood year method was used. The cohort model was modified by the CTC to account for the chinook non-retention fisheries implemented in Canada during 1996. Modifications are documented by the CTC in Appendix G of TCCHINOOK (99)-2.

For each brood year, information derived from the cohort analyses included:

- annual distribution of catch and total fishing mortalities;
- survival of CWT groups to Age-2 recruitment; and
- ocean (catch or total fishing mortality) and total exploitation rates by fishery and age.

Distribution of Fishing Mortality (Catch plus incidental mortality)

Quinsam/Campbell chinook are referred to as "Far-North" migrating fall chinook since they are caught in Alaskan fisheries and migrate back to their natal streams in the late summer and early autumn. Alaskan and northern BC fisheries encounter both immature feeding chinook and mature chinook, while more southerly fisheries primarily catch adults during their migration back to the Campbell River. The extent and distribution of fishing mortality has changed over time but the majority of mortality on this stock occurs in SE Alaskan fisheries and northern BC fisheries (Table 8). Mortality in fisheries more local to the Campbell River is less due to the northward migration of the immature chinook. Catches of this stock in the Johnstone Strait net and Strait of Georgia sport fisheries are primarily mature chinook during their return migration.

There have been limited in-river fishing opportunities in Campbell River in the past and there has been no recreational freshwater fishery since the 80's. There is also no in-river chinook harvest by First Nations.

Exploitation Rates

Exploitation rates can be estimated for catch only or can also include incidental moralities. The rates are estimated by fishery and age but have been combined for presentation. Figure 11 presents the time series of total exploitation rates (catch plus incidental mortality) and the portion of the mortality accounted for in ocean fisheries and terminal fisheries (total minus ocean values). Terminal fisheries include Age-4+ chinook caught in net fisheries and sport catch off the Campbell River. Total exploitation on this stock has decreased substantially since the 1970s. Previous to the 1985 Pacific Salmon Treaty, total exploitation had reached values exceeding 85% of the production from a brood year. Following the Treaty, total exploitation decreased to, on average, approximately 66%. Exploitation has decreased further in recent years due to conservation actions for west coast Vancouver Island chinook and southern BC coho salmon and terminal area closures. Extrapolated values for total exploitation on the most recent brood years, based on expanding observed returns by the average maturation rates at age, indicate total exploitation rates between 30 and 40%.

Marine Survival Trends

Returns to spawning escapement may vary depending on the exploitation pressures on a stock and/or variation in the ocean survival. The coded-wire tags released from Quinsam Hatchery allow for examination of both exploitation patterns (above) and comparison of marine survival between brood years. Marine survival is defined as the percentage of the tagged (CWT) smolts released from Quinsam Hatchery that survive to the Age-2 pre-fishery cohort and is estimated via cohort analysis.

The time series of marine survival rates for Quinsam Hatchery fall chinook is presented in Figure 12. Marine survival has varied by approximately 40 fold between brood years and was particularly poor during the 1989 through 1992 period. The most recent brood years indicate a marked improvement in survival but are based on incomplete data.

Summary

The Campbell River was historically one of the most important producers of chinook in the Strait of Georgia. Three over-riding key aspects were identified which have contributed to the decline of the Campbell River chinook stock. Hydro-electric development and associated construction of dams and water diversions are suggested to have significantly contributed to the decline of salmon stocks. Major changes in river discharge and flow regimes are known to have substantial detrimental effects to both the adult and juvenile life stages. Spawning areas used by salmon (chinook in particular) were surveyed in 1993 and a comparison with a previous survey conducted in 1973 indicated that less than 20% of the usable spawning areas remain. Secondly, the estuary has been used extensively by industry and for urban development which has been documented to have had a considerable impact on the rearing capacity for juveniles and the holding patterns for returning spawners. And finally, high exploitation of this stock in previous years at non-sustainable levels has obviously been detrimental to the natural chinook stock in the Campbell River.

Reduction in exploitation by approximately 50% since the late 70's and up to 400% improvements in marine survival in recent years should contribute substantially to the rebuilding process. In 1999, there were double the number of natural spawners in the Campbell River compared to the previous 5 years. It is suggested that in the next few years returns to the Campbell River could increase to 2000-3000. Significant reduction in the available natural spawning habitat in the Campbell River provides an opportunity to implement a full scale habitat assessment and determine limitations and changes to spawning distribution. In addition, further assessment should be conducted to determine the impact of exploitation levels on the enhanced and natural components of the stock with respect to spawning habitat limitations.

Recommendations:

1. A full scale habitat assessment be initiated for the Campbell River and mitigative measures be implemented. The minimum and maximum flow requirements to preserve spawning and rearing habitat needs to be revisited and an assessment of the total available spawning habitat made. (Some of this is already in progress)

2. The interim escapement goal needs to be reviewed with consideration given to a habitat-based approach.

3. Consideration should be given to a juvenile assessment program. Such a program could provide estimates of egg-fry survival and juvenile production, particularly for the Campbell River component. This could help to understand the relationship between freshwater conditions and juvenile production.

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Table 1. Historical mean monthly discharge (cu. m/sec) measured at the Island Highway, Campbell River[1].

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
1949	-	-	-	-	-	-	-	-	-	-	-	157	---
1950	57.9	74.6	75.5	76.9	102	164	116	38.7	62	106	131	153	96.5
1951	115	74.7	34	88.1	116	60.5	46.8	38.1	38.9	87	84.5	71.4	71.2
1952	32.3	46.3	37.9	90.7	106	141	129	58.1	52.6	61.2	63.2	91.4	75.8
1953	137	108	48.6	56.2	140	125	120	70.9	70.2	88.6	277	144	115
1954	79.8	149	78.2	68.1	103	107	125	81.5	68.3	-	268	145	---
1955	82.2	84.3	-	-	47.7	79.9	99.4	66.1	66.1	57.1	122	65.7	---
1956	73.4	69.1	66.1	62	131	133	120	67.8	63.1	56.6	123	124	90.9
1957	65.3	70.5	64.4	56.8	27.3	20.7	23.6	34	29.1	51.8	51.6	31.9	43.7
1958	90.6	147	90.9	85.8	174	129	80.5	108	86.3	91.6	100	207	116
1959	117	95.5	88.6	87.4	120	180	85.5	79.6	80.2	78	83.5	99.9	99.5
1960	76.3	88.9	75.9	111	130	145	96.1	64.6	72.3	92	119	108	98.2
1961	241	183	113	101	120	152	98.9	72.3	71.9	71.2	80.4	66	114
1962	146	123	91	80.2	72.7	74.3	68.3	71.9	51.6	75	207	236	108
1963	116	127	76.7	103	80.6	88	96.1	76.6	74.9	139	168	193	111
1964	154	118	93.5	71.7	57.3	120	147	89.4	72.6	99.4	101	108	103
1965	118	111	74.3	59.9	53.5	61.7	67	66.8	55.1	72.8	140	172	87.5
1966	138	125	120	114	115	122	82.7	54.5	96	100	124	245	120
1967	132	128	121	122	70.3	116	97.6	73	68.1	140	141	158	114
1968	279	136	126	124	115	84.2	49	44.4	66	143	191	144	125
1969	123	79.8	88	111	125	188	119	92.9	100	109	118	126	115
1970	117	108	97.5	76.8	54.1	69.1	70	60.2	60.6	65.8	52.7	63.4	74.4
1992	233	198	102	82.2	67.4	50	61.1	42.6	40.2	80.9	111	119	98.7
1993	82	105	60.7	51.4	141	129	69.3	56.6	45	66.6	55.4	98.7	79.9
1994	120	130	124	118	116	45.5	51.1	51.3	53.9	99.2	78.9	96.3	90.1
1995	124	131	128	128	136	131	107	73.8	42.1	113	310	200	135
1997	178	108	115	103	103	81.7	67.9	32.4	52.6	115	104	76.4	
1961-70 mean	156.40	123.88	100.10	96.36	86.35	107.53	89.56	70.20	71.68	101.52	132.31	151.14	107.19
1950-60 mean	84.25	91.63	66.01	78.30	108.82	116.83	94.72	64.31	62.65	76.99	129.35	112.85	89.64
1992-97 mean	122	112	86.5	88.6	101	109	89	65.3	63.5	89.4	132	132	99.2

[1] Information recorded by Water Survey Canada.
Apparently due to lack of funding, data was not recorded during the period between 1970-90.

Table 2. Chinook spawning capacity estimate in 1993 taken from Burt and Burns (1995).

Table 10. Estimation of chinook spawning capacity using spawning areas prorated by the proportion of suitably sized bed material.

LOCATION	TOTAL AREA (sq m)	SUBSTRATE (%) (f/sg/lg/sc/lc/b)	% USABLE (lg+sc)	USABLE AREA (sq m)	# OF FEMALE SPAWNERS	COMMENTS (unless specified, comments are pers. comm. from D. Ewart, Quinsam Hatchery)
			Main Chinook Spawning Areas (Historic and Current):			
1	2,816	0/2/5/15/26/52 (based on T4.5a)	20%	563	28	Historic spawning area; currently supports limited spawning; substrate is mainly large cobble and boulder, gravel is sparse and in pockets; no chinook observed here in 1993.
2	2,760	1/0/1/13/24/61 (based on T4.3)	14%	386	19	Historically was main spawning area. Currently, limited spawning; substrate is mainly large cobble and boulder, gravel is sparse; no chinook observed here in 1993.
Total Main	5,576			949	47	
			Marginal Chinook Spawning Areas:			
3	2,086	6/0/21/15/20/39 (based on T4.1b)	36%	marginal	10	Gravel is shallow, large, and in pockets. Gravel placed in this side channel in 1985 is no longer present.
4	1,769	23/15/19/20/16/08 (based on T3.4)	39%	marginal	10	Gravel is abundant and uncompacted but on the small size for chinook spawners - recruited from left bank 130 m upstream (author's observations). Used mainly by other species, although chinook spawn here in some years. No chinook observed here in 1993.
6	3,537	0/5/9/19/34/32 (based on T3.1)	38%	marginal	10	Limited spawning; shallow water; substrate mainly large cobble and boulder; gravel sparse and in pockets. Some chinook spawned here in 1993.
7	1,874	22/6/12/15/15/30 (based on T2.4)	27%	marginal	10	Tailout of Sandy Pool. Limited spawning; gravel is sparse. No chinook observed here in 1993 but some chinook spawning has occurred here in previous years.
8	4,114	1/0/11/7/10/72 (based on T2.3)	18%	marginal	10	Limited spawning; substrate mainly boulder; gravel sparse and in pockets. No chinook observed here in 1993 but have spawned here in the past.
10	2,035	3/0/2/3/26/66 (based on T2.1)	5%	marginal	10	Mainly a chum spawning area. Substrate is mainly large cobble and boulder, gravel is sparse. Up to 10 chinook pairs have been observed here in the past
11	14,354	1/5/27/26/23/19 (based on T1.1)	53%	marginal	10	Mainly a pink and chum spawning area. Available gravel is shallow and compacted making redd digging difficult. Some chinook have spawned here over the years.
Total Marginal	29,769				70	
			Elk Falls Spawning Channel			
5	1,176	0/0/18/69/08/05 (based on T3.2b)	87%	1,023	160	147 m long spawning channel; constructed 1992; mainly 5.1 cm gravel; in 1992 both ends blocked off and 157 females/162 males retained till spawning occurred.
Total Natural	35,345			949	117	
Total All	36,521			1,972	277	

Notes:

"LOCATION" is from Figure 16.

"TOTAL AREA" is the total square meters of the spawning location as calculated by the GIS software QUIKMap.

"SUBSTRATE" is the percentages of fines (f), small gravel (sg), large gravel (lg), small cobble (sc), large cobble (lc), and boulder (b). Percentages are the average of cells from the portion of the transect within the indicated spawning location.

"% USABLE" is a rating of usable area based on the combined percentage of lg and sc in the substrate. This corresponds to a substrate size range of 1.6-12.8 cm, which approximates the preferred gravel size of 6-14 cm for spawning by ocean-type chinook (Beauchamp et al 1983).

"USABLE AREA" is "TOTAL AREA" prorated by the proportion with suitable substrate size ("% USABLE").

"NO. OF FEMALES" was derived by dividing "USABLE AREA" by the recommended square meters per spawning female. For ocean-type chinook the recommended spawning density is 20.1 sq m per female (Reiser and Bjornn 1979). The Elk Falls Spawning Channel was stocked with 157 females in 1992 resulting in a stocking density of 7.5 sq m per female (Dave Ewart, Quinsam Hatchery, pers. comm.). For marginal areas "NO OF FEMALES" was assumed to be 10.

Table 3. Quinsam Hatchery juvenile chinook releases by brood year, 1974-98.

Tag Code	BY	Number Tagged	Number Released	CWT % Mark	Weigh (gm)	Release Date ddmmmyy:ddmmmyy	Release site
20403	74	65683	162516	40.4	4.8	:09Jun75	0106-QUINSAM R
20108	75	99167	424567	23.4	4.3	10Jun76:18Jun76	0106-QUINSAM R
21916	76	97123	376480	25.8	9.4	06Jun77:09Jun77	0106-QUINSAM R
21736	77	50140	235443	21.3	7.4	:05Jun78	0106-QUINSAM R
21737	77	50707	319999	15.8	4	:12Jun78	0106-QUINSAM R
21738	77	51671	220945	23.4	4.5	:05Jun78	0106-QUINSAM R
21759	78	97316	849226	11.5	6.5	29May79:08Jun79	0106-QUINSAM R
21757	79	51025	512663	10	7.1	:29May80	0106-QUINSAM R
21758	79	51819	568770	9.1	7.2	:09Jun80	0106-QUINSAM R
21657	80	52900	411885	12.8	7.3	:21May81	0106-QUINSAM R
21943	80	51220	381729	13.4	6.8	:11May81	0106-QUINSAM R
21950	80	52001	343164	15.2	7.7	:03Jun81	0106-QUINSAM R
22303	81	49802	180173	27.6	8.2	:14May82	0106-QUINSAM R
22304	81	49953	258233	19.3	7.9	:04Jun82	0106-QUINSAM R
82119	81	6693	7163	93.4	2.2	:05May82	0106-QUINSAM R
82120	81	9161	9373	97.7	2.4	:05May82	0106-QUINSAM R
82121	81	8739	8959	97.5	2.2	:05May82	0106-QUINSAM R
82122	81	9705	9961	97.4	2.7	:05May82	0106-QUINSAM R
82123	81	10006	10184	98.3	2.9	:05May82	0106-QUINSAM R
82124	81	10050	10214	98.4	3.2	:05May82	0106-QUINSAM R
82125	81	9475	10342	91.6	3.7	:05May82	0106-QUINSAM R
82126	81	9692	10359	93.6	3.7	:05May82	0106-QUINSAM R
82127	81	9583	10258	93.4	3.8	:05May82	0106-QUINSAM R
82128	81	9403	10111	93	5.3	:26May82	0106-QUINSAM R
82129	81	9553	10134	94.3	5.2	:26May82	0106-QUINSAM R
82130	81	9041	9906	91.3	5.5	:26May82	0106-QUINSAM R
82131	81	10156	10342	98.2	6.9	:26May82	0106-QUINSAM R
82132	81	10266	10426	98.5	6.9	:26May82	0106-QUINSAM R
82133	81	9730	9943	97.9	6.7	:26May82	0106-QUINSAM R
82134	81	10188	10288	99	8.4	:26May82	0106-QUINSAM R
82135	81	10364	10470	99	8.1	:26May82	0106-QUINSAM R
82136	81	10144	10144	100	8.2	:26May82	0106-QUINSAM R
82137	81	9434	10087	93.5	8.4	:16Jun82	0106-QUINSAM R
82138	81	9720	10330	94.1	7.8	:16Jun82	0106-QUINSAM R
82139	81	9356	9915	94.4	7.3	:16Jun82	0106-QUINSAM R
82140	81	10003	10210	98	10.4	:16Jun82	0106-QUINSAM R
82141	81	10389	10570	98.3	9.6	:16Jun82	0106-QUINSAM R
82142	81	9705	9934	97.7	8.9	:16Jun82	0106-QUINSAM R
82143	81	10575	10575	100	11.2	:16Jun82	0106-QUINSAM R
82144	81	10092	10092	100	12.3	:16Jun82	0106-QUINSAM R
82145	81	10038	10128	99.1	10.5	:16Jun82	0106-QUINSAM R
82146	81	9004	9738	92.5	10.2	:07Jul82	0106-QUINSAM R
82147	81	9186	10067	91.2	9.8	:07Jul82	0106-QUINSAM R
82149	81	9510	9681	98.2	13.4	:07Jul82	0106-QUINSAM R
82150	81	6815	6944	98.1	12.8	:07Jul82	0106-QUINSAM R
82152	81	9646	9646	100	16.5	:07Jul82	0106-QUINSAM R
82153	81	9158	9158	100	15.7	:07Jul82	0106-QUINSAM R
22518	82	36234	304401	11.9	8.5	:16May83	0106-QUINSAM R
22519	82	35375	283288	12.5	11.5	:07Jun83	0106-QUINSAM R
82046	82	9763	9959	98	5.1	:05May83	0106-QUINSAM R
82047	82	9846	10043	98	5.1	:05May83	0106-QUINSAM R
82048	82	10159	10363	98	5	:05May83	0106-QUINSAM R

Table 3 (cont.)

Tag Code	BY	Number Tagged	Number Released	CWT % Mark	Weigh (gm)	Release Date ddmmmyy:ddmmmyy	Release site
82049	82	10637	10850	98	6	:05May83	0106-QUINSAM R
82050	82	9803	9999	98	6	:05May83	0106-QUINSAM R
82051	82	9880	10078	98	6.1	:05May83	0106-QUINSAM R
82052	82	10221	10426	98	7.3	:05May83	0106-QUINSAM R
82053	82	9794	9990	98	6.9	:05May83	0106-QUINSAM R
82054	82	9812	10008	98	7	:05May83	0106-QUINSAM R
82055	82	10494	10673	98.3	8.1	:26May83	0106-QUINSAM R
82056	82	9855	10023	98.3	7.8	:26May83	0106-QUINSAM R
82057	82	9935	10104	98.3	7.4	:26May83	0106-QUINSAM R
82058	82	10014	10184	98.3	9.3	:26May83	0106-QUINSAM R
82059	82	9870	10038	98.3	9.1	:26May83	0106-QUINSAM R
82060	82	9932	10101	98.3	8.9	:26May83	0106-QUINSAM R
82061	82	9831	9998	98.3	10.7	:26May83	0106-QUINSAM R
82062	82	9882	10050	98.3	10.4	:26May83	0106-QUINSAM R
82063	82	10160	10333	98.3	10.3	:26May83	0106-QUINSAM R
82101	82	9915	10027	98.9	11	:16Jun83	0106-QUINSAM R
82102	82	10176	10291	98.9	10.9	:16Jun83	0106-QUINSAM R
82103	82	9884	9996	98.9	10.4	:16Jun83	0106-QUINSAM R
82104	82	9928	10041	98.9	12.8	:16Jun83	0106-QUINSAM R
82105	82	9946	10059	98.9	12.8	:16Jun83	0106-QUINSAM R
82106	82	9944	10057	98.9	12.8	:16Jun83	0106-QUINSAM R
82107	82	9937	10050	98.9	14.7	:16Jun83	0106-QUINSAM R
82108	82	9922	10034	98.9	14.5	:16Jun83	0106-QUINSAM R
82109	82	9954	10067	98.9	14	:16Jun83	0106-QUINSAM R
82110	82	9842	10082	97.6	14.1	:07Jul83	0106-QUINSAM R
82111	82	9822	10062	97.6	13.4	:07Jul83	0106-QUINSAM R
82112	82	9883	10124	97.6	13.6	:07Jul83	0106-QUINSAM R
82113	82	9872	10113	97.6	16.2	:07Jul83	0106-QUINSAM R
82114	82	9812	10052	97.6	16	:07Jul83	0106-QUINSAM R
82115	82	9875	10116	97.6	16	:07Jul83	0106-QUINSAM R
82148	82	10547	10784	97.8	18.7	:07Jul83	0106-QUINSAM R
82151	82	9816	10056	97.6	18.6	:07Jul83	0106-QUINSAM R
82154	82	10021	10266	97.6	18.7	:07Jul83	0106-QUINSAM R
82207	82	11096	11681	95	3.7	:21Apr83	0106-QUINSAM R
82208	82	11039	11621	95	3.7	:21Apr83	0106-QUINSAM R
82209	82	11021	11602	95	3.7	:21Apr83	0106-QUINSAM R
82210	82	11413	11646	98	3.6	:21Apr83	0692-CAMPBELL R ESTUARY
82211	82	11666	11905	98	3.6	:21Apr83	0692-CAMPBELL R ESTUARY
82212	82	11499	11734	98	3.6	:21Apr83	0692-CAMPBELL R ESTUARY
82214	82	11178	11645	96	3.2	:21Apr83	0110-CAMPBELL TRANSITION
82215	82	11107	11570	96	3.2	:21Apr83	0110-CAMPBELL TRANSITION
82216	82	11499	11654	98.7	3.2	:21Apr83	0420-DISCOVERY PASS
82217	82	11501	11656	98.7	3.2	:21Apr83	0420-DISCOVERY PASS
82218	82	11588	11744	98.7	3.2	:21Apr83	0420-DISCOVERY PASS
82219	82	11168	11634	96	3.2	:21Apr83	0110-CAMPBELL TRANSITION
22631	83	49499	669326	7.4	12.6	11Jun84:14Jun84	0106-QUINSAM R
22632	83	50069	636553	7.9	14.1	08Jun84:09Jun84	0106-QUINSAM R
82213	83	11666	11725	99.5	3	:25Apr84	0131-DEEPWATER BAY
82220	83	11649	11708	99.5	3	:25Apr84	0131-DEEPWATER BAY
82221	83	11621	11679	99.5	3	:25Apr84	0131-DEEPWATER BAY
82257	83	10814	11616	93.1	3.2	:25Apr84	0106-QUINSAM R
82258	83	10878	11688	93.1	3.2	:25Apr84	0106-QUINSAM R
82259	83	10834	11640	93.1	3.2	:25Apr84	0106-QUINSAM R

Table 3 (cont.)

Tag Code	BY	Number Tagged	Number Released	CWT % Mark	Weigh (gm)	Release Date ddmmmyy:ddmmmyy	Release site
82260	83	12173	12322	98.8	3.1	:25Apr84	0692-CAMPBELL R ESTUARY
82261	83	11633	11775	98.8	3.1	:25Apr84	0692-CAMPBELL R ESTUARY
82262	83	11465	11605	98.8	3.1	:25Apr84	0692-CAMPBELL R ESTUARY
82263	83	11833	11881	99.6	3	:25Apr84	0110-CAMPBELL TRANSITION
82301	83	11641	11688	99.6	3	:25Apr84	0110-CAMPBELL TRANSITION
82302	83	11617	11664	99.6	3	:25Apr84	0110-CAMPBELL TRANSITION
23322	84	24584	341464	7.2	12	:31May85	0106-QUINSAM R
23323	84	24538	340826	7.2	12	:31May85	0106-QUINSAM R
23324	84	24527	340672	7.2	12	:31May85	0106-QUINSAM R
23325	84	26157	331514	7.9	15.5	16Jun85:21Jun85	0106-QUINSAM R
23326	84	24937	316051	7.9	15.5	16Jun85:21Jun85	0106-QUINSAM R
23327	84	23714	300551	7.9	15.5	16Jun85:21Jun85	0106-QUINSAM R
23328	84	24471	329345	7.4	14	14Jun85:24Jun85	0106-QUINSAM R
23329	84	29676	399397	7.4	14	14Jun85:24Jun85	0106-QUINSAM R
23330	84	24459	329183	7.4	14	14Jun85:24Jun85	0106-QUINSAM R
82351	84	9657	10165	95	3.1	:24Apr85	0106-QUINSAM R
82352	84	10317	10860	95	3.1	:24Apr85	0106-QUINSAM R
82353	84	10039	10567	95	3.1	:24Apr85	0106-QUINSAM R
82354	84	10228	10823	94.5	3.1	:24Apr85	0692-CAMPBELL R ESTUARY
82355	84	10073	10659	94.5	3.1	:24Apr85	0692-CAMPBELL R ESTUARY
82356	84	9940	10519	94.5	3.1	:24Apr85	0692-CAMPBELL R ESTUARY
82357	84	10333	10803	95.6	3.1	:24Apr85	0110-CAMPBELL TRANSITION
82358	84	10132	10593	95.6	3.1	:24Apr85	0110-CAMPBELL TRANSITION
82359	84	10009	10464	95.7	3.1	:24Apr85	0110-CAMPBELL TRANSITION
82360	84	10577	10887	97.2	3.1	:24Apr85	0131-DEEPWATER BAY
82361	84	10342	10645	97.2	3.1	:24Apr85	0131-DEEPWATER BAY
82362	84	10281	10583	97.1	3.1	:24Apr85	0131-DEEPWATER BAY
23522	85	19954	338289	5.9	14.8	:19Jun86	0106-QUINSAM R
23523	85	19975	340054	5.9	14.8	:19Jun86	0106-QUINSAM R
23524	85	20127	341828	5.9	14.8	:19Jun86	0106-QUINSAM R
23525	85	20038	293886	6.8	12.1	10Jun86:15Jun86	0106-QUINSAM R
23554	85	20110	294942	6.8	12.1	10Jun86:15Jun86	0106-QUINSAM R
23555	85	20096	294736	6.8	12.1	10Jun86:15Jun86	0106-QUINSAM R
23556	85	20145	304454	6.6	11.7	16Jun86:17Jun86	0106-QUINSAM R
23557	85	20110	303925	6.6	11.7	16Jun86:17Jun86	0106-QUINSAM R
23558	85	20096	303714	6.6	11.7	16Jun86:17Jun86	0106-QUINSAM R
23645	85	24843	123350	20.1	11	:29May86	0692-CAMPBELL R ESTUARY
24017	85	23294	23294	100	10.3	:18Jun86	0105-PUNTLEDGE R
24018	85	24984	24984	100	10.3	:18Jun86	0105-PUNTLEDGE R
24152	86	19947	296538	6.7	7.1	:08May87	0106-QUINSAM R
24153	86	19935	296526	6.7	7.1	:08May87	0106-QUINSAM R
24154	86	19990	296581	6.7	7.1	:08May87	0106-QUINSAM R
24155	86	18978	486533	3.9	8.1	19May87:22May87	0106-QUINSAM R
24156	86	20006	487561	4.1	8.1	19May87:22May87	0106-QUINSAM R
24157	86	19982	487537	4.1	8.1	19May87:22May87	0106-QUINSAM R
24158	86	19980	319493	6.3	9.9	:27May87	0106-QUINSAM R
24159	86	19899	319412	6.2	9.9	:27May87	0106-QUINSAM R
24160	86	19979	319492	6.3	9.9	:27May87	0106-QUINSAM R
24419	87	24457	357941	6.8	7.4	:29Apr88	0106-QUINSAM R
24420	87	24386	356906	6.8	7.4	:29Apr88	0106-QUINSAM R
24421	87	24486	358369	6.8	7.4	:29Apr88	0106-QUINSAM R
24736	87	20607	86118	23.9	7.7	:11May88	2729-HIDDEN HARBOUR
24737	87	20607	86118	23.9	7.7	:11May88	2729-HIDDEN HARBOUR

Table 3 (cont.)

Tag Code	BY	Number Tagged	Number Released	CWT % Mark	Weigh (gm)	Release Date ddmmmyy:ddmmmyy	Release site
24956	87	24641	355298	6.9	7.7	:13May88	0106-QUINSAM R
25324	87	24583	143705	17.1	10	:26May88	0221-INDIAN ARM
25325	87	24612	143735	17.1	10	:26May88	0221-INDIAN ARM
25358	87	24677	335041	7.4	6.6	:06May88	0106-QUINSAM R
25359	87	24727	335720	7.4	6.6	:06May88	0106-QUINSAM R
25360	87	24834	337174	7.4	6.6	:06May88	0106-QUINSAM R
25361	87	24504	353323	6.9	7.7	:13May88	0106-QUINSAM R
25362	87	24483	353019	6.9	7.7	:13May88	0106-QUINSAM R
25363	87	24222	75706	32	7.9	:06May88	1305-APRIL PT
25526	88	24624	207182	11.9	8.8	:04May89	2729-HIDDEN HARBOUR
25527	88	23937	268255	8.9	8.9	:09May89	1305-APRIL PT
25528	88	24329	279509	8.7	9.9	:10May89	2421-TAKU LDG/QUADRA ISL
25814	88	25246	314667	8	7.4	:28Apr89	0106-QUINSAM R
25815	88	25545	318334	8	7.4	:28Apr89	0106-QUINSAM R
25816	88	22344	278403	8	7.4	:28Apr89	0106-QUINSAM R
25817	88	25029	293909	8.5	5.7	:21Apr89	0106-QUINSAM R
25818	88	25096	294963	8.5	7.7	:05May89	0106-QUINSAM R
25819	88	25037	295995	8.5	9.2	:18May89	0106-QUINSAM R
25820	88	24810	431446	5.8	7.6	10May89:12May89	0106-QUINSAM R
25821	88	24609	427950	5.8	7.6	10May89:12May89	0106-QUINSAM R
25822	88	24884	432734	5.8	7.6	10May89:12May89	0106-QUINSAM R
20354	89	23306	197636	11.8	10.2	04May90:04May90	2729-HIDDEN HARBOUR
20355	89	22574	286523	7.9	8.9	06May90:06May90	1305-APRIL PT
20356	89	23041	282580	8.2	8.6	03May90:03May90	2421-TAKU LDG/QUADRA ISL
20357	89	23886	465403	5.1	6.5	26Apr90:07May90	0106-QUINSAM R
20358	89	24634	473787	5.2	6.5	30Apr90:09May90	0106-QUINSAM R
20359	89	24396	324505	7.5	5	23Apr90:24Apr90	0106-QUINSAM R
20360	89	24499	316471	7.7	7.1	17May90:18May90	0106-QUINSAM R
20361	89	24669	328077	7.5	6	04May90:05May90	0106-QUINSAM R
20362	89	24418	599332	4.1	3	09Apr90:10Apr90	0105-PUNTLEDGE R
26062	89	24929	219543	11.4	7.6	10May90:11May90	0106-QUINSAM R
26063	89	24904	221242	11.3	6.3	10May90:11May90	0106-QUINSAM R
26101	89	25007	442540	5.7	6.6	10May90:11May90	0106-QUINSAM R
26102	89	24739	215726	11.5	6.6	10May90:11May90	0106-QUINSAM R
20956	90	26953	216107	12.5	7.7	:09May91	0106-QUINSAM R
20957	90	26752	456930	5.9	7.2	:09May91	0106-QUINSAM R
20958	90	26658	232453	11.5	8	:09May91	0106-QUINSAM R
20959	90	25870	229390	11.3	7.2	:09May91	0106-QUINSAM R
21448	90	26509	523459	5.1	5.6	25Apr91:29Apr91	0106-QUINSAM R
21449	90	26602	359229	7.4	4.6	:19Apr91	0106-QUINSAM R
21450	90	26384	357439	7.4	6.6	:02May91	0106-QUINSAM R
21451	90	26502	346999	7.6	7.8	:16May91	0106-QUINSAM R
26016	90	27211	616103	4.4	7.6	:02May91	1305-APRIL PT
26017	90	25911	310172	8.4	7.1	02May91:03May91	0420-DISCOVERY PASS
26018	90	28265	212169	13.3	8.1	:01May91	2421-TAKU LDG/QUADRA ISL
26019	90	26817	529541	5.1	5.5	25Apr91:29Apr91	0106-QUINSAM R
21328	91	24770	316126	7.8	10.6	:13May92	0420-DISCOVERY PASS
21329	91	24661	623650	4	10.8	:13May92	1305-APRIL PT
21330	91	20328	207158	9.8	12.1	:14May92	0462-DREW HB CR
21331	91	24593	551333	4.5	6.3	:26Apr92	0106-QUINSAM R
180415	91	24676	554177	4.5	5.8	:23Apr92	0106-QUINSAM R
180416	91	23951	327065	7.3	5	:20Apr92	0106-QUINSAM R
180417	91	24967	342823	7.3	8.4	:19May92	0106-QUINSAM R

Table 3 (cont.)

Tag Code	BY	Number Tagged	Number Released	CWT % Mark	Weigh (gm)	Release Date ddmmmyy:ddmmmyy	Release site
180418	91	24864	338271	7.4	6.4	:27Apr92	0106-QUINSAM R
180419	91	24709	210451	11.7	7.6	:04May92	0106-QUINSAM R
180420	91	24952	460518	5.4	7.9	:04May92	0106-QUINSAM R
180421	91	23760	220124	10.8	7.1	:04May92	0106-QUINSAM R
180422	91	24936	250990	9.9	8.2	:04May92	0106-QUINSAM R
181147	92	24925	250826	9.9	7.8	:13May93	2421-TAKU LDG/QUADRA ISL
181148	92	23730	230851	10.3	7.6	:19May93	0008-MENZIES BAY
181149	92	24128	431813	5.6	6.7	:13May93	1305-APRIL PT
181150	92	24983	495041	5	4.4	:22Apr93	0106-QUINSAM R
181151	92	24731	490046	5	4.4	:24Apr93	0106-QUINSAM R
181152	92	24932	289532	8.6	3.7	:19Apr93	0106-QUINSAM R
181153	92	24450	288441	8.5	4.1	:27Apr93	0106-QUINSAM R
181154	92	23689	266462	8.9	6.5	:19May93	0106-QUINSAM R
181155	92	24123	222938	10.8	6	:13May93	0106-QUINSAM R
181156	92	24228	445162	5.4	7.2	:13May93	0106-QUINSAM R
181157	92	24101	214271	11.2	7.8	:13May93	0106-QUINSAM R
181158	92	23382	218204	10.7	7	:13May93	0106-QUINSAM R
180628	93	25362	231105	11	6.2	:06May94	0420-DISCOVERY PASS
180629	93	26632	142600	18.7	6.8	:18May94	0106-QUINSAM R
180630	93	26322	289207	9.1	5.8	:18May94	0106-QUINSAM R
180631	93	26719	285755	9.4	5.7	:18May94	0106-QUINSAM R
181356	93	26204	89928	29.1	6.8	:03May94	2729-HIDDEN HARBOUR
181357	93	26140	104505	25	7.5	:12May94	0106-QUINSAM R
181358	93	26574	108298	24.5	6.7	:12May94	0106-QUINSAM R
181359	93	25147	199756	12.6	6.6	:12May94	0106-QUINSAM R
181360	93	25631	205957	12.4	5.9	:12May94	0106-QUINSAM R
181361	93	26115	203120	12.9	6.6	:12May94	0106-QUINSAM R
181362	93	26370	214480	12.3	6.7	:12May94	0106-QUINSAM R
20960	94	24880	229164	10.9	6.3	:05May95	1305-APRIL PT
20961	94	24769	229650	10.8	5.4	:10May95	0008-MENZIES BAY
20962	94	24997	228417	10.9	7.4	:11May95	2421-TAKU LDG/QUADRA ISL
20963	94	26086	250492	10.4	5.1	04May95:10May95	0420-DISCOVERY PASS
181644	94	25528	110751	23	7.8	:10May95	0106-QUINSAM R
181645	94	25946	106226	24.4	6.5	:12May95	0106-QUINSAM R
181646	94	26471	219488	12.1	7.2	:10May95	0106-QUINSAM R
181647	94	26470	215557	12.3	6.6	:10May95	0106-QUINSAM R
181648	94	26529	211392	12.5	5.9	:10May95	0106-QUINSAM R
181649	94	26438	219269	12.1	5.8	:10May95	0106-QUINSAM R
181650	94	26397	152759	17.3	6.8	:17May95	0106-QUINSAM R
181651	94	26375	294063	9	6.5	:17May95	0106-QUINSAM R
181652	94	26770	301171	8.9	5.7	:17May95	0106-QUINSAM R
181658	95	24689	233165	10.6	7.9	21May96:23May96	0106-QUINSAM R
181659	95	26388	236219	11.2	9.1	21May96:23May96	0106-QUINSAM R
181660	95	26620	238597	11.2	9.9	21May96:23May96	0106-QUINSAM R
181661	95	26120	147472	17.7	2.3	:31May96	0210-QUINSAM R UP
182016	95	25543	130479	19.6	8.1	14May96:15May96	0106-QUINSAM R
182017	95	25494	50230	50.8	7.8	:03May96	6124-ELK FALLS CH #1
182018	95	25587	134370	19	8.4	14May96:15May96	0106-QUINSAM R
182019	95	25561	268923	9.5	11	:09May96	1305-APRIL PT
182020	95	26187	214864	12.2	8.2	14May96:15May96	0106-QUINSAM R
182021	95	26084	217582	12	8.7	14May96:15May96	0106-QUINSAM R
182022	95	25392	533324	4.8	6	03May96:03May96	0420-DISCOVERY PASS
181830	96	29220	205638	14.2	7.5	:20May97	0106-QUINSAM R

Table 3 (cont.)

Tag Code	BY	Number Tagged	Number Released	CWT % Mark	Weigh (gm)	Release Date ddmmmyy:ddmmmyy	Release site
181831	96	28465	179524	15.9	10.2	:18Jul97	1305-APRIL PT
182509	96	23689	532576	4.4	8.7	:01May97	0420-DISCOVERY PASS
182510	96	21449	267744	8	10	:13May97	0420-DISCOVERY PASS
182511	96	26826	533065	5	7.6	:02May97	1305-APRIL PT
182512	96	27938	296595	9.4	7.1	:13May97	0106-QUINSAM R
182513	96	28013	292127	9.6	7.8	:13May97	0106-QUINSAM R
182514	96	28770	302936	9.5	9.1	:13May97	0106-QUINSAM R
182515	96	28914	215252	13.4	8.2	:20May97	0106-QUINSAM R
182516	96	28956	214421	13.5	8.5	:20May97	0106-QUINSAM R
182517	96	29422	213776	13.8	8.5	:20May97	0106-QUINSAM R
182518	96	27933	219585	12.7	7.8	:20May97	0106-QUINSAM R
183031	97	29371	223582	13.1	10.6	:08May98	0420-DISCOVERY PASS
183032	97	28507	223721	12.7	10.5	:11May98	1305-APRIL PT
183033	97	26852	219735	12.2	9.7	:11May98	1305-APRIL PT
183034	97	26370	198991	13.3	9.4	:15May98	0420-DISCOVERY PASS
183035	97	28852	182479	15.8	9	:20May98	0106-QUINSAM R
183036	97	28609	218581	13.1	8.9	:13May98	0106-QUINSAM R
183037	97	29172	215456	13.5	8.2	:13May98	0106-QUINSAM R
183038	97	29371	220305	13.3	7.7	:13May98	0106-QUINSAM R
183039	97	30284	174073	17.4	8.8	:20May98	0106-QUINSAM R
183040	97	29850	257859	11.6	8.8	:20May98	0106-QUINSAM R
183041	97	30389	253480	12	9.1	:27May98	0106-QUINSAM R
183042	97	29825	203185	14.7	6.1	:06May98	0106-QUINSAM R
183735	98	24891	266431	9.3	8.1	30Apr99:30Apr99	0420-DISCOVERY PASS
183736	98	28222	270118	10.4	6.6	:29Apr99	0420-DISCOVERY PASS
183737	98	29121	269647	10.8	7.4	:06May99	0420-DISCOVERY PASS
183738	98	30058	267362	11.2	5.6	22Apr99:27Apr99	0692-CAMPBELL R ESTUARY
183739	98	27213	227236	12	9	:10May99	0106-QUINSAM R
183740	98	29374	220556	13.3	9.3	:11May99	0106-QUINSAM R
183741	98	26350	310849	8.5	8.8	:12May99	0106-QUINSAM R
183742	98	24768	309962	8	8.8	:14May99	0106-QUINSAM R
183743	98	25438	309559	8.2	8.7	:20May99	0106-QUINSAM R
183744	98	28316	443601	6.4	8.5	17May99:18May99	0106-QUINSAM R
183745	98	28924	393859	7.3	7.7	06May99:07May99	0106-QUINSAM R
183746	98	30048	150212	20	6.3	03May99:10May99	0420-DISCOVERY PASS

Table 4. Quinsam Hatchery expanded CWT recoveries for chinook escapement by return year, age and sex.

			Age								Chinook	Chinook
Rec Yr	Class	Area	1	2	3	4	5	6	7	Grand Total	Jacks	Adults
1977	Adult Unk	HATCHERY			31.55			28.13		59.68	0	59.68
	Adult Unk Total				31.55			28.13		59.68	0	59.68
1977 Total					31.55			28.13		59.68	0	59.68
1978	Adult Unk	BELOW FENCE				10.97				10.97	0	10.97
		HATCHERY				44.54				44.54	0	44.54
	Adult Unk Total					55.51				55.51	0	55.51
1978 Total						55.51				55.51	0	55.51
1979	Adult Unk	BELOW FENCE			11.63	29.97	118.76			160.36	0	160.36
		HATCHERY			47.74	35.15	139.66			223.58	0	223.58
	Adult Unk Total				59.37	65.12	258.42			383.94	0	383.94
1979 Total					59.37	65.12	258.42			383.94	0	383.94
1980	Adult Unk	BELOW FENCE				291	53.57	6.19		350.76	0	350.76
		HATCHERY		9.6	38.12	319.8	61.22	8.17		436.91	9.6	427.31
	Adult Unk Total			9.6	38.12	610.8	114.79	14.36		787.67	9.6	778.07
1980 Total				9.6	38.12	610.8	114.79	14.36		787.67	9.6	778.07
1981	Adult Unk	BELOW FENCE				155.84	723.7			879.54	0	879.54
		HATCHERY		11.12	26.52	39.26	255.23			332.13	11.12	321.01
	Adult Unk Total			11.12	26.52	195.1	978.93			1211.67	11.12	1200.55
1981 Total				11.12	26.52	195.1	978.93			1211.67	11.12	1200.55
1982	Adult Unk	BELOW FENCE			59.92	364.33	390.29	23.12		837.66	0	837.66
		HATCHERY		37.92	27.72	349.48	112.36	6.53		534.01	37.92	496.09
	Adult Unk Total			37.92	87.64	713.81	502.65	29.65		1371.67	37.92	1333.75
1982 Total				37.92	87.64	713.81	502.65	29.65		1371.67	37.92	1333.75
1983	Adult Unk	ABOVE FENCE				1.77	18.46			20.23	0	20.23
		BELOW FENCE				46.19	481.46			527.65	0	527.65
		HATCHERY	0.85	18.81	57.18	191.44	281.73			550.01	19.66	530.35
	Adult Unk Total		0.85	18.81	57.18	239.4	781.65			1097.89	19.66	1078.23
1983 Total			0.85	18.81	57.18	239.4	781.65			1097.89	19.66	1078.23
1984	Adult Fem	ABOVE FENCE				169.8	193.86	17.97		381.63	0	381.63
		HATCHERY				409.04	180.09	17.45		606.58	0	606.58
	Adult Fem Total					578.84	373.95	35.42		988.21	0	988.21
	Adult Male	BELOW FENCE		32.68	48.42	302.76	67.14			451	32.68	418.32
		HATCHERY	35.23	100.67	144.53	405.95	116.52	8.06		810.96	135.9	675.06
	Adult Male Total		35.23	133.35	192.95	708.71	183.66	8.06		1261.96	168.58	1093.38
1984 Total			35.23	133.35	192.95	1287.55	557.61	43.48		2250.17	168.58	2081.59

Table 4 (cont.)

						Age					Chinook	Chinook
Rec Yr	Class	Area	1	2	3	4	5	6	7	Grand Total	Jacks	Adults
1985	Adult Fem	BELOW FENCE			1.79	182.81	472.87	35.48		692.95	0	692.95
		HATCHERY			12.61	246.51	368.94	20.33		648.39	0	648.39
	Adult Fem Total				14.4	429.32	841.81	55.81		1341.34	0	1341.34
	Adult Male	BELOW FENCE			55.78	361.78	81.46			499.02	0	499.02
		HATCHERY		77.69	308.78	557.06	150.9	10.23		1104.66	77.69	1026.97
	Adult Male Total			77.69	364.56	918.84	232.36	10.23		1603.68	77.69	1525.99
	Adult Unk	ABOVE FENCE		1.8	7.36	18.62	12.07	0.71		40.56	1.8	38.76
	Adult Unk Total			1.8	7.36	18.62	12.07	0.71		40.56	1.8	38.76
1985 Total				79.49	386.32	1366.78	1086.24	66.75		2985.58	79.49	2906.09
1986	Adult Fem	BELOW FENCE				109.59	242.88			352.47	0	352.47
		HATCHERY				393.56	266	15.69		675.25	0	675.25
	Adult Fem Total					503.15	508.88	15.69		1027.72	0	1027.72
	Adult Male	BELOW FENCE		23.37	52.24	207.13	69.66			352.4	23.37	329.03
		HATCHERY		66.9	311.72	468.62	71.14			918.38	66.9	851.48
	Adult Male Total			90.27	363.96	675.75	140.8			1270.78	90.27	1180.51
	Adult Unk	ABOVE FENCE		0.56	2.65	7.44	2.96	0.14		13.75	0.56	13.19
	Adult Unk Total			0.56	2.65	7.44	2.96	0.14		13.75	0.56	13.19
1986 Total				90.83	366.61	1186.34	652.64	15.83		2312.25	90.83	2221.42
1987	Adult Fem	BELOW FENCE			21.38	155.12	319.81	84.39		580.7	0	580.7
		HATCHERY			13.94	249.53	551.09	44.78		859.34	0	859.34
	Adult Fem Total				35.32	404.65	870.9	129.17		1440.04	0	1440.04
	Adult Male	BELOW FENCE			648.44	304.33	217.82	7.47		1178.06	0	1178.06
		HATCHERY		14.61	1096.11	416.58	237.55	10.27		1775.12	14.61	1760.51
	Adult Male Total			14.61	1744.55	720.91	455.37	17.74		2953.18	14.61	2938.57
	Adult Unk	ABOVE FENCE		0.13	10.03	6.01	7.1	0.52		23.79	0.13	23.66
	Adult Unk Total			0.13	10.03	6.01	7.1	0.52		23.79	0.13	23.66
1987 Total				14.74	1789.9	1131.57	1333.37	147.43		4417.01	14.74	4402.27
1988	Adult Fem	BELOW FENCE				1278.28	549.6	33.34		1861.22	0	1861.22
		HATCHERY				1197.1	325.19	37.6		1559.89	0	1559.89
	Adult Fem Total					2475.38	874.79	70.94		3421.11	0	3421.11
	Adult Male	BELOW FENCE			88.69	1905.19	372.75		8.21	2374.84	0	2374.84
		HATCHERY		129.67	185.65	1844.72	110.38	1.83		2272.25	129.67	2142.58
	Adult Male Total			129.67	274.34	3749.91	483.13	1.83	8.21	4647.09	129.67	4517.42
	Adult Unk	ABOVE FENCE		19.28	27.58	454.2	65.3	5.92		572.28	19.28	553
	Adult Unk Total			19.28	27.58	454.2	65.3	5.92		572.28	19.28	553
1988 Total				148.95	301.92	6679.49	1423.22	78.69	8.21	8640.48	148.95	8491.53

Table 4 (cont.)

			Age								Chinook	Chinook
Rec Yr	Class	Area	1	2	3	4	5	6	7	Grand Total	Jacks	Adults
1989	Adult Fem	ABOVE FENCE					386.09			386.09	0	386.09
		BELOW FENCE				313.86	2364.87	1.54		2680.27	0	2680.27
		HATCHERY			57.64	55.27	1528.1			1641.01	0	1641.01
	Adult Fem Total				57.64	369.13	4279.06	1.54		4707.37	0	4707.37
	Adult Male	ABOVE FENCE				80.6	363.15			443.75	0	443.75
		BELOW FENCE		24.98	772.83	611.69	1112.6			2522.1	24.98	2497.12
		HATCHERY		14.3	1670.95	446.33	534.93			2666.51	14.3	2652.21
	Adult Male Total			39.28	2443.78	1138.62	2010.68			5632.36	39.28	5593.08
1989 Total				39.28	2501.42	1507.75	6289.74	1.54		10339.73	39.28	10300.45
1990	Adult Fem	BELOW FENCE				1107.36	1113.04	153.49		2373.89	0	2373.89
		HATCHERY				488.3	106.85	21.71		616.86	0	616.86
	Adult Fem Total					1595.66	1219.89	175.2		2990.75	0	2990.75
	Adult Male	BELOW FENCE			127.53	943.3	294.58	2.32		1367.73	0	1367.73
		HATCHERY		31.24	116.36	908.15				1055.75	31.24	1024.51
	Adult Male Total			31.24	243.89	1851.45	294.58	2.32		2423.48	31.24	2392.24
	Adult Unk	ABOVE FENCE		28	104.25	1259.14	97.46	19.81		1508.66	28	1480.66
	Adult Unk Total			28	104.25	1259.14	97.46	19.81		1508.66	28	1480.66
1990 Total				59.24	348.14	4706.25	1611.93	197.33		6922.89	59.24	6863.65
1991	Adult Fem	ABOVE FENCE				103.25	164.13			267.38	0	267.38
		BELOW FENCE				486.64	697.21	7.36		1191.21	0	1191.21
		HATCHERY				374.89	595.91			970.8	0	970.8
	Adult Fem Total					964.78	1457.25	7.36		2429.39	0	2429.39
	Adult Male	ABOVE FENCE	1.73		71.17	139.09	41.25			253.24	1.73	251.51
		BELOW FENCE			224.09	343.63	168.38			736.1	0	736.1
		HATCHERY	8.81		363.51	710.32	210.69			1293.33	8.81	1284.52
	Adult Male Total		10.54		658.77	1193.04	420.32			2282.67	10.54	2272.13
1991 Total			10.54		658.77	2157.82	1877.57	7.36		4712.06	10.54	4701.52
1992	Adult Fem	BELOW FENCE				217.44	298.3	66.3		582.04	0	582.04
		HATCHERY				665.95	631.17			1297.12	0	1297.12
	Adult Fem Total					883.39	929.47	66.3		1879.16	0	1879.16
	Adult Male	BELOW FENCE			23.95	321.73	84.9			430.58	0	430.58
		HATCHERY			77.92	1058.64	195.43			1331.99	0	1331.99
	Adult Male Total				101.87	1380.37	280.33			1762.57	0	1762.57
	Jack	BROODSTOCK	28.65	85.53						114.18	114.18	0
	Jack Total		28.65	85.53						114.18	114.18	0
1992 Total			28.65	85.53	101.87	2263.76	1209.8	66.3		3755.91	114.18	3641.73

Table 4 (cont.)

Rec Yr	Class	Area	Age 1	2	3	4	5	6	7	Grand Total	Chinook Jacks	Chinook Adults
1993	Adult Fem	BELOW FENCE			15.82	15.13	202.14	26.12		259.21	0	259.21
		BROODSTOCK			49.9	82.96	281.85			414.71	0	414.71
	Adult Fem Total				65.72	98.09	483.99	26.12		673.92	0	673.92
	Adult Male	ABOVE FENCE			53.24	24.84	21.46			99.54	0	99.54
		BELOW FENCE			72.61		87.47			160.08	0	160.08
		HATCHERY			312.13	145.68	125.82			583.63	0	583.63
	Adult Male Total				437.98	170.52	234.75			843.25	0	843.25
	Jack	ABOVE FENCE		5.39	20.6					25.99	5.39	20.6
		BROODSTOCK		11.41	43.59					55	11.41	43.59
	Jack Total			16.8	64.19					80.99	16.8	64.19
1993 Total				16.8	567.89	268.61	718.74	26.12		1598.16	16.8	1581.36
1994	Adult Fem	BELOW FENCE				155.92	158.42	30.66		345	0	345
		HATCHERY			12.76	551.88	142.13	40.34		747.11	0	747.11
	Adult Fem Total				12.76	707.8	300.55	71		1092.11	0	1092.11
	Adult Male	BELOW FENCE				104.73	95.5			200.23	0	200.23
		HATCHERY			241.49	506.78	111.21			859.48	0	859.48
	Adult Male Total				241.49	611.51	206.71			1059.71	0	1059.71
	Jack	HATCHERY	15.47							15.47	15.47	0
	Jack Total		15.47							15.47	15.47	0
1994 Total			15.47		254.25	1319.31	507.26	71		2167.29	15.47	2151.82
1995	Adult Fem	BELOW FENCE				58.25	233.88	23.14		315.27	0	315.27
Rec Yr	**Class**	**Area**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Grand Total**	**Jacks**	**Adults**
		BROODSTOCK			4	292.85	224.02			520.87	0	520.87
	Adult Fem Total				4	351.1	457.9	23.14		836.14	0	836.14
	Adult Male	BELOW FENCE				101.45	42.7			144.15	0	144.15
		BROODSTOCK			98.55	347.54	92.91			539	0	539
	Adult Male Total				98.55	448.99	135.61			683.15	0	683.15
	Jack	ABOVE FENCE	7.82	5.18						13	13	0
		BROODSTOCK	10.83	7.17						18	18	0
	Jack Total		18.65	12.35						31	31	0
1995 Total			18.65	12.35	102.55	800.09	593.51	23.14		1550.29	31	1519.29

Table 4 (cont.)												
			Age								Chinook	Chinook
Rec Yr	**Class**	**Area**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Grand Total**	**Jacks**	**Adults**
1996	Adult Fem	ABOVE FENCE			0.04	3.32	3.07			6.43	0	6.43
		BELOW FENCE				34.84				34.84	0	34.84
		BROODSTOCK			0.5	41.45	38.49			80.44	0	80.44
		HATCHERY			3.77	312.91	290.7			607.38	0	607.38
	Adult Fem Total				4.31	392.52	332.26			729.09	0	729.09
	Adult Male	ABOVE FENCE			114.7	87.58	24.38			226.66	0	226.66
		BELOW FENCE			38.45	61.61				100.06	0	100.06
		BROODSTOCK			40.63	31.03	8.63			80.29	0	80.29
		HATCHERY			386.43	295.04	82.14			763.61	0	763.61
	Adult Male Total				580.21	475.26	115.15			1170.62	0	1170.62
	Jack	ABOVE FENCE	8.8	18.75						28.01	27.55	0.46
		BELOW FENCE		13						13	13	0
		BROODSTOCK	10.51	22.41						33.46	32.92	0.54
	Jack Total		19.31	54.16						74.47	73.47	1
1996 Total			19.31	54.16	584.52	867.78	447.41			1974.18	73.47	1900.71
1997	Adult Fem	ABOVE FENCE			2.6	35.27	17.84	1.62		57.33	0	57.33
		BELOW FENCE				134.76	56.84			191.6	0	191.6
		HATCHERY			21.98	298.01	150.7	13.66		484.35	0	484.35
	Adult Fem Total				24.58	468.04	225.38	15.28		733.28	0	733.28
	Adult Male	ABOVE FENCE			95.76	46.91	6.11			148.78	0	148.78
		BELOW FENCE			49.38	138.85				188.23	0	188.23
		HATCHERY			517.48	253.57	33.01			804.06	0	804.06
	Adult Male Total				662.62	439.33	39.12			1141.07	0	1141.07
	Jack	ABOVE FENCE		6.39	4.1					10.49	6.39	4.1
		BELOW FENCE	2							2	2	0
		HATCHERY		19.4	12.48					31.88	19.4	12.48
	Jack Total		2	25.79	16.58					44.37	27.79	16.58
1997 Total			2	25.79	703.78	907.37	264.5	15.28		1918.72	27.79	1890.93
1998	Adult Fem	ABOVE FENCE			1.37	51.66	14.91			67.94	0	67.94
		BELOW FENCE				193.66	100.18	17.7		311.54	0	311.54
		BROODSTOCK			2.75	103.8	29.98			136.53	0	136.53
		HATCHERY			10.24	386.7	111.69			508.63	0	508.63
	Adult Fem Total				14.36	735.82	256.76	17.7		1024.64	0	1024.64
	Adult Male	ABOVE FENCE		13.52	253.67	229.74	15.07			512	13.52	498.48
		BELOW FENCE		77.84	260.77	203.81	73.34			615.76	77.84	537.92
		BROODSTOCK		5.51	103.57	93.79	6.16			209.03	5.51	203.52
		HATCHERY		20.92	392.9	355.84	23.33			792.99	20.92	772.07
	Adult Male Total			117.79	1010.91	883.18	117.9			2129.78	117.79	2011.99
	Jack	ABOVE FENCE		45.66	2.08					47.74	45.66	2.08
		HATCHERY		72.56	3.31					75.87	72.56	3.31
	Jack Total			118.22	5.39					123.61	118.22	5.39
1998 Total				236.01	1030.66	1619	374.66	17.7		3278.03	236.01	3042.02

Table 5. Age composition of Quinsam/Campbell Chinook escapement by sex and return year.

MALES

Return Year

	1984		1985		1986		1987		1988		1989		1990	
Total Age	N	%	N	%	N	%	N	%	N	%	N	%	N	%
2	101	5.7	0	0.0	51	4.1	3	0.3	8	1.0	2	0.3	5	0.9
3	65	3.6	35	5.7	209	16.9	274	31.5	37	4.5	256	32.3	39	6.9
4	755	42.4	434	70.7	565	45.8	233	26.7	660	81.3	177	22.4	402	71.3
5	785	44.1	136	22.1	409	33.1	321	36.9	100	12.3	356	44.9	110	19.5
6	75	4.2	8	1.3	1	0.1	40	4.6	4	0.5	1	0.1	8	1.4
7	0	0.0	1	0.2	0	0.0	0	0.0	3	0.4	0	0.0	0	0.0

	1991		1992		1993		1994		1995		1996		1997	
Total Age	N	%	N	%	N	%	N	%	N	%	N	%	N	%
2	0	0.0			6	2.1	4	1.6	11	3.9	52	13.1	16	4.8
3	69	17.0	24	6.0	93	32.2	56	23.0	53	19.0	160	40.4	118	35.5
4	223	55.1	287	71.6	76	26.3	149	61.1	165	59.3	141	35.6	164	49.2
5	111	27.4	87	21.7	110	38.0	34	13.9	48	17.2	42	10.6	33	9.9
6	2	0.5	3	0.7	4	1.4	1	0.4	1	0.6	1	0.3	2	0.6
7	0	0.0			0		0	0.0	0	0.0	0	0.0	0	0.0

FEMALES

Return Year

	1984		1985		1986		1987		1988		1989		1990	
Total Age	N	%	N	%	N	%	N	%	N	%	N	%	N	%
2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
3	0	0.0	3	0.5	7	0.5	5	0.4	0	0.0	12	1.2	2	0.3
4	289	24.0	217	37.4	441	32.5	193	16.6	503	58.7	116	11.6	491	61.0
5	756	62.9	324	55.9	898	66.3	782	67.1	291	33.9	867	86.6	261	32.4
6	158	13.1	35	6.0	9	0.7	186	15.9	62	7.2	6	0.6	51	6.3
7	0	0.0	1	0.2	0	0.0	0	0.0	2	0.2	0	0.0	0	0.0

	1991		1992		1993		1994		1995		1996		1997	
Total Age	N	%	N	%	N	%	N	%	N	%	N	%	N	%
2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
3	3	0.6	0	0.0	12	3.1	8	2.5	10	2.6	7	2.3	10	3.0
4	163	34.4	232	48.3	70	18.0	199	62.0	173	45.0	153	49.3	209	62.0
5	299	63.1	234	48.8	293	75.5	93	29.0	195	50.8	145	46.8	115	34.1
6	9	1.9	14	2.9	13	3.4	21	6.5	6	1.6	5	1.6	3	0.9
7	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0

COMBINED

Return Year

	1984		1985		1986		1987		1988		1989		1990	
Total Age	N	%	N	%	N	%	N	%	N	%	N	%	N	%
2	101	3.4	0	0.0	51	2.0	3	0.2	8	0.5	2	0.1	5	0.4
3	65	2.2	38	3.2	216	8.3	279	13.7	37	2.2	268	15.0	41	3.0
4	1044	35.0	651	54.5	1006	38.8	426	20.9	1163	69.6	293	16.3	893	65.2
5	1541	51.6	460	38.5	1307	50.5	1103	54.1	391	23.4	1223	68.2	371	27.1
6	233	7.8	43	3.6	10	0.4	226	11.1	66	4.0	7	0.4	59	4.3
7	0	0.0	2	0.2	0	0.0	0	0.0	5	0.3	0	0.0	0	0.0

	1991		1992		1993		1994		1995		1996		1997	
Total Age	N	%	N	%	N	%	N	%	N	%	N	%	N	%
2	0	0.0		0.0	6	0.9	4	0.7	11	1.7	52	7.4	16	2.4
3	72	8.2	24	2.7	105	15.5	64	11.3	63	9.5	167	23.7	128	19.1
4	386	43.9	519	58.9	146	21.6	348	61.6	338	51.1	294	41.6	373	55.7
5	410	46.6	321	36.5	403	59.5	127	22.5	243	36.7	187	26.5	148	22.1
6	11	1.3	17	1.9	17	2.5	22	3.9	7	1.0	6	0.8	5	0.7

Table 6. Comparison of five year mean age-class distributions.

% Age in Escapement

Campbell River

	1986-1990 (mean)			1991-1996 (mean)	
Age	male	female		male	female
2	0.05	0		0	0
3	5.81	0.1		8.7	0.4
4	40.53	18.2		45	28.6
5	50.14	71.5		44.4	64.3
6	0.1	10.1		1.9	6.7
7	3.37	0.1		0	0
Total	100	100		100	100

Quinsam River

	1986-1990 (mean)			1991-1996 (mean)	
Age	male	female		male	female
2	0.4	0		0.1	
3	15.6	0.1		24.4	0.7
4	53.1	36.9		55.6	41.7
5	29.9	57.9		19.3	54.7
6	0.6	5		0.6	0.4
7	0.4	0.1			2.5
Total	100	100		100	100

Quinsam Hatchery

	1986-1990 (mean)			1991-1996 (mean)	
Age	male	female		male	female
1	0	0		1.7	0
2	1.6	1		1.8	0
3	25	52.4		24.3	2.1
4	55.7	40.8		56.5	47.3
5	16.5	2.9		15.7	49.2
6	0.7	2.9			1.4
7	0.5				0
Total	100	100		100	100

Table 7. Distribution of total fishing mortality for the Quinsam/Campbell chinook stock by fishery and time periods (average values for distributions in calendar years). Analyses completed through the 1999 fishery recoveries and escapement programs.

	AVERAGES BY 5-YEAR PERIODS			
ANNUAL STOCK DISTRIBUTION	***1980-84***	***1985-89***	***1990-94***	***1995-99***
SE ALASKA TROLL	19.57	18.77	12.53	10.68
SE ALASKA NETS	6.64	9.20	5.28	4.89
SE ALASKA SPORT	3.67	2.80	1.91	1.79
NBC (A1-5) TROLL	11.01	5.64	8.03	3.21
CBC (A6-11) TROLL	10.67	4.13	6.12	0.94
NBC (A1-5) NETS	7.95	5.68	8.95	7.61
CBC (A6-10) NETS	7.34	4.88	2.82	0.24
NCBC (A1-10) SPORT	4.53	3.41	8.17	8.12
JOHNSTONE ST. NET	7.33	6.85	3.30	0.87
WCVI TROLL	0.50	0.34	0.68	0.17
ST. GEORGIA TROLL	0.96	0.13	0.71	0.00
ST. GEORGIA SPORT	6.27	4.73	5.33	5.94
OTHER FISHERIES	0.15	0.40	0.13	1.22
Total Fishing Mortality	86.58	66.95	63.96	45.68
Spawning escapement	13.42	33.05	36.04	54.32
TOTAL :	100.00	100.00	100.00	100.00

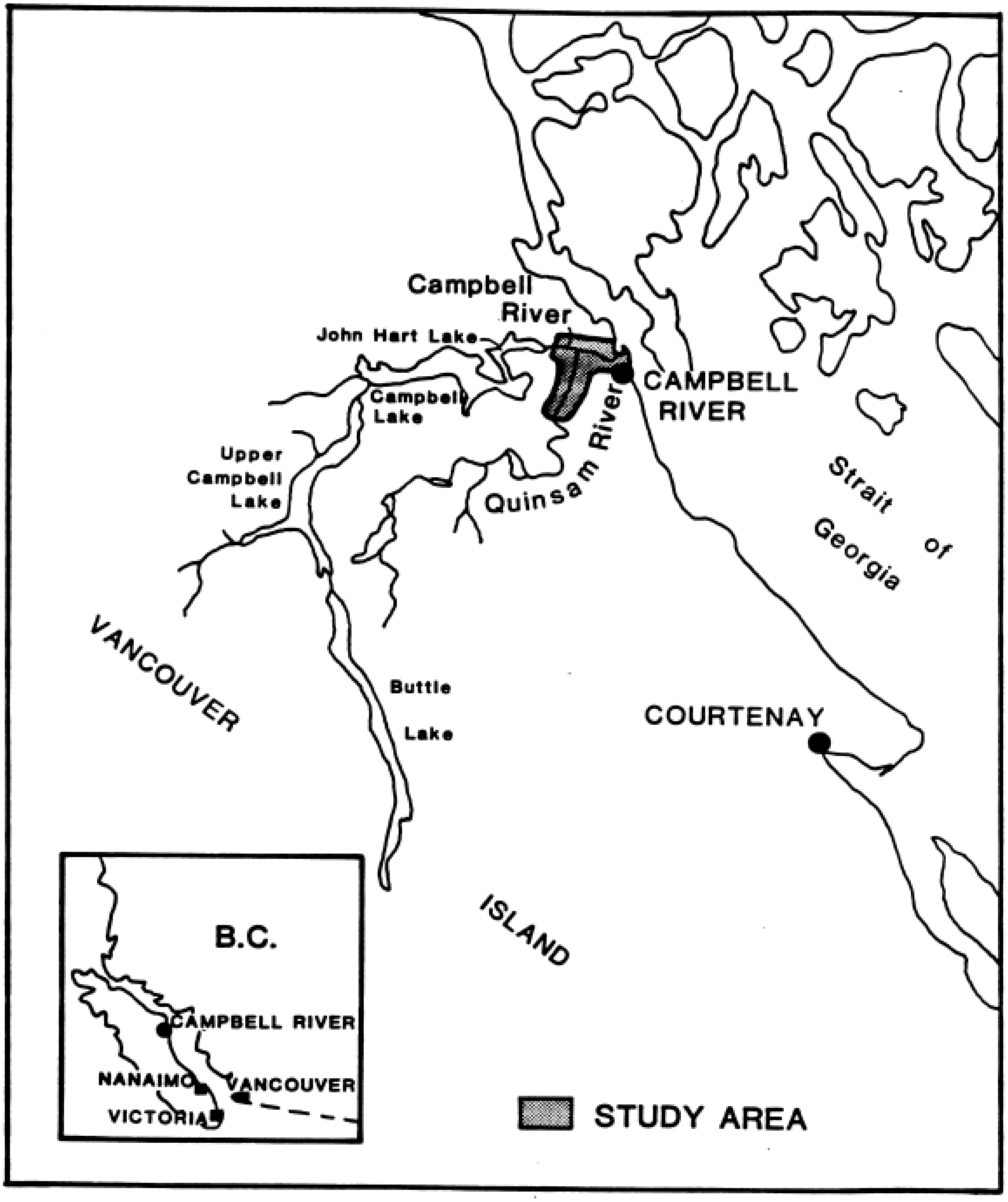

Fig. 1. Campbell/Quinsam watershed and study area.

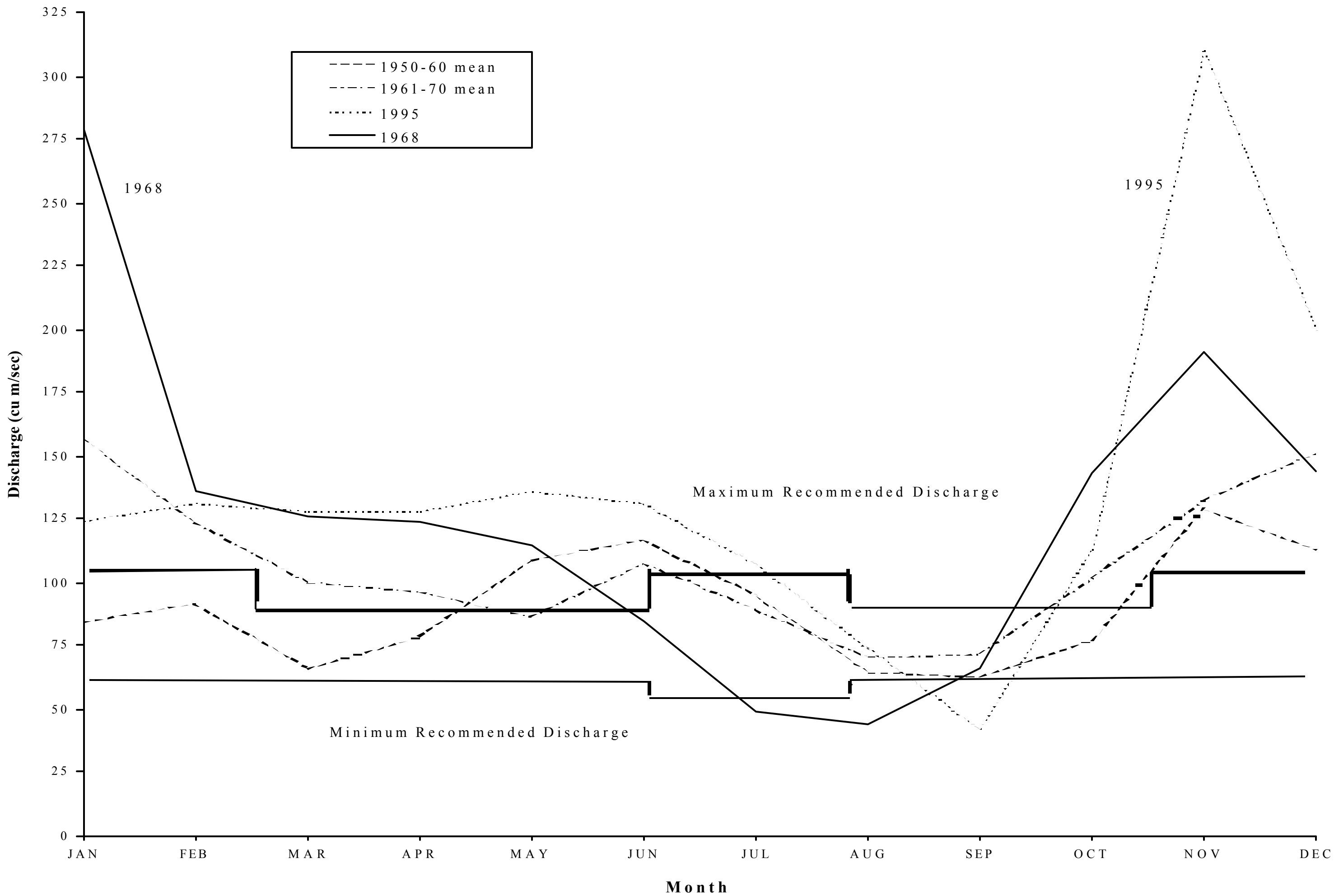

Fig. 2. Historical mean monthly discharge (cu.m/sec) measured at the Island highway bridge, Campbell River.

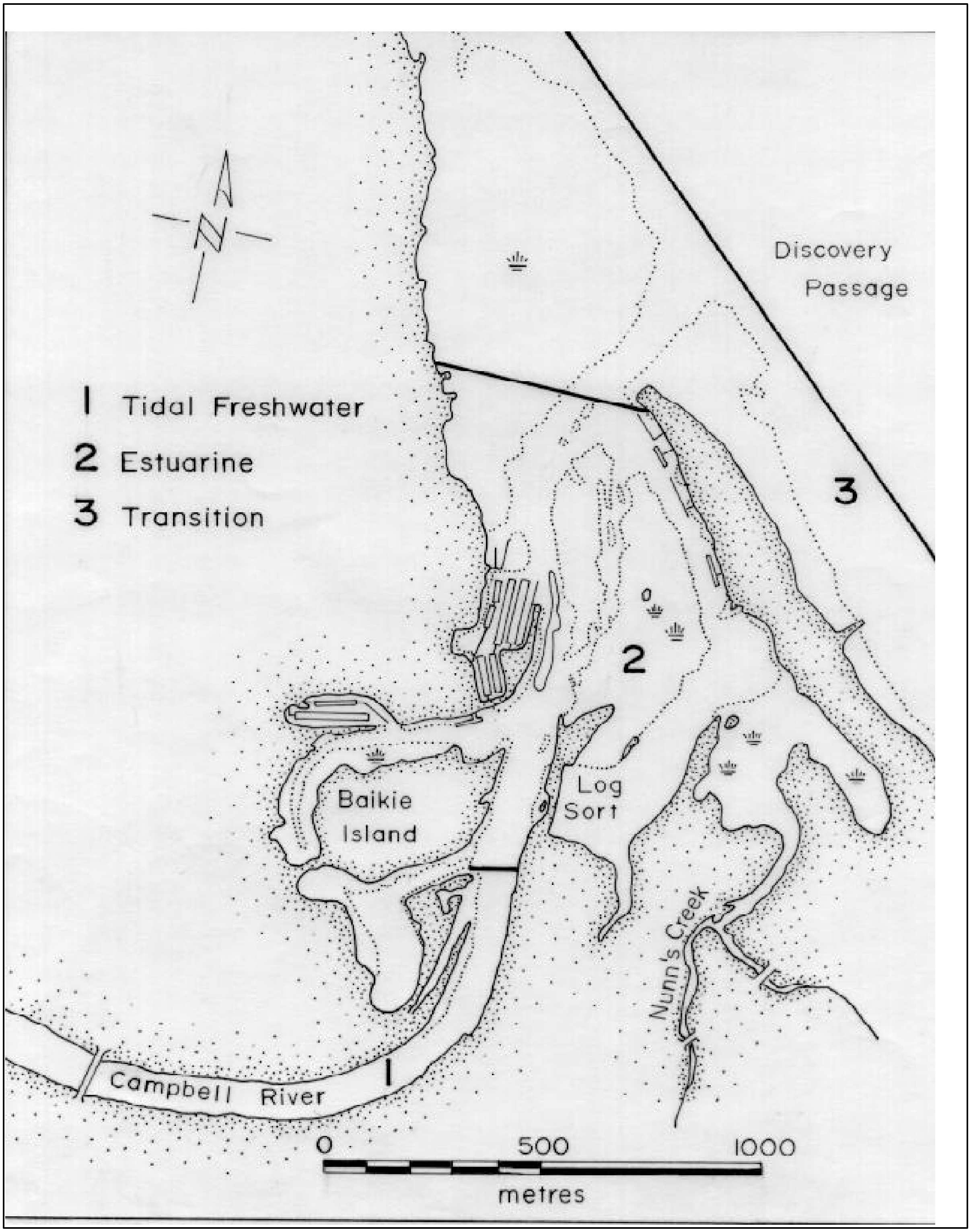

Fig. 3. Industrial development in the Campbell River estuary.
Chinook fry utilization zones for hatchery and naturally-reared juvenile

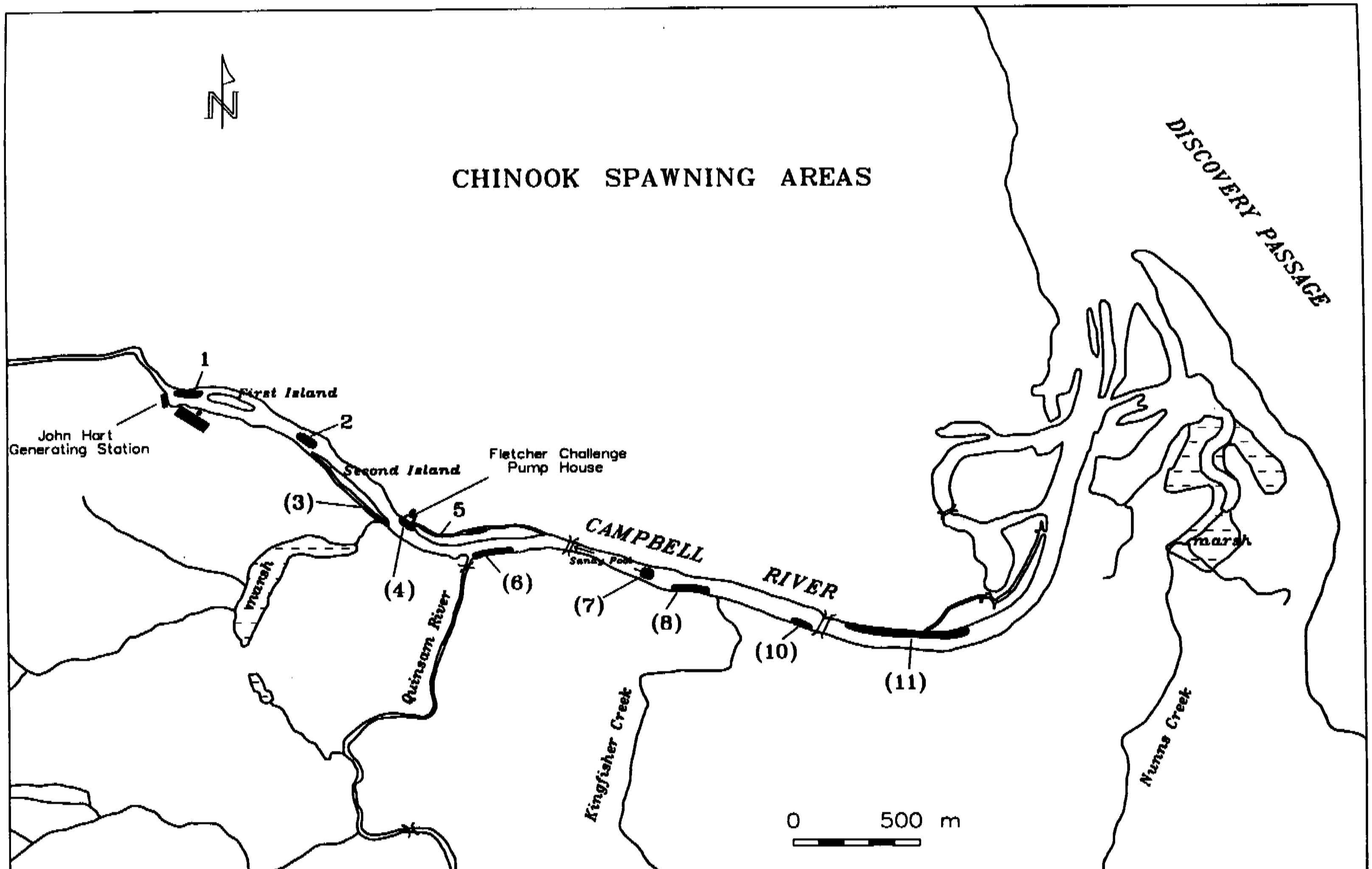

Figure 16. Chinook salmon spawning areas on the Lower Campbell River. Areas are based on snorkel and dead-pitch surveys by Quinsam Hatchery staff. Bracketed area numbers indicate minor spawning areas. Area 5 is a man-made spawning channel. Note: Sporadic spawning may occur in other locations.

Fig. 4. Chinook spawning areas in the Lower Campbell River based on data from Burt and Burns (1995).

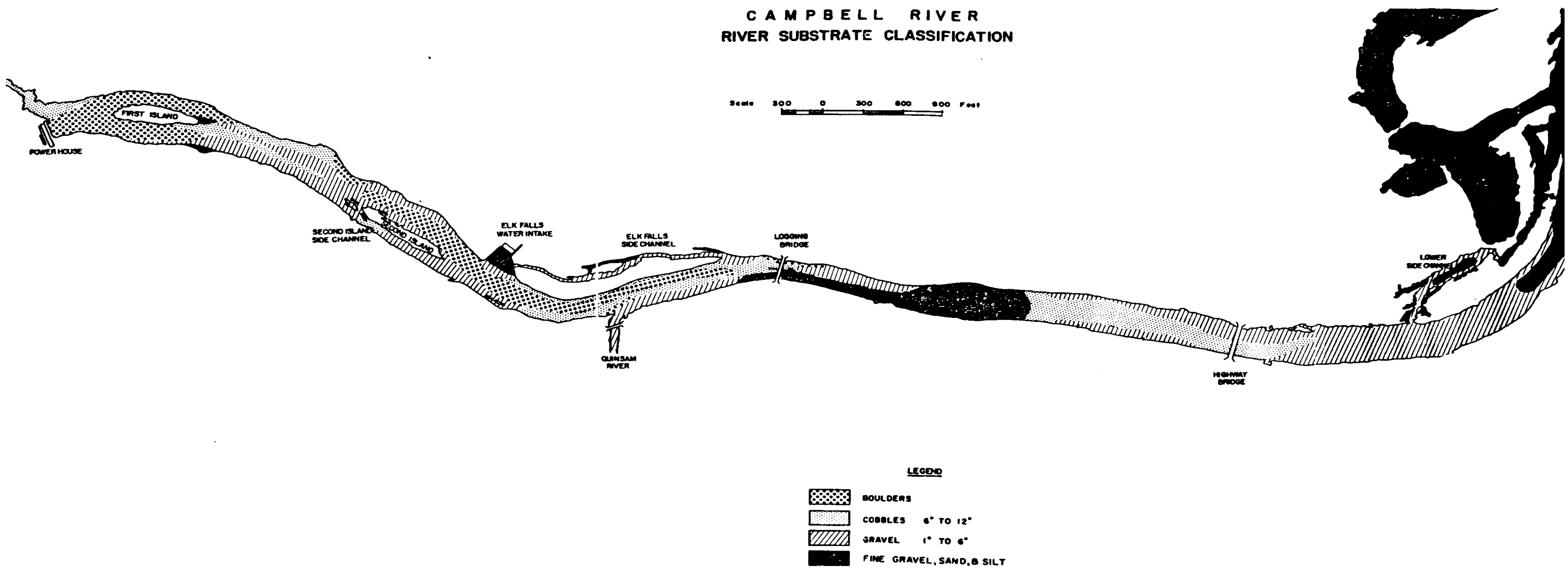

Figure 23. Distribution of substrate categories in 1973. From Hamilton and Buell (1976).

Fig. 5. Distribution of substrate categories in 1973 from Hamilton and Buell (1976).

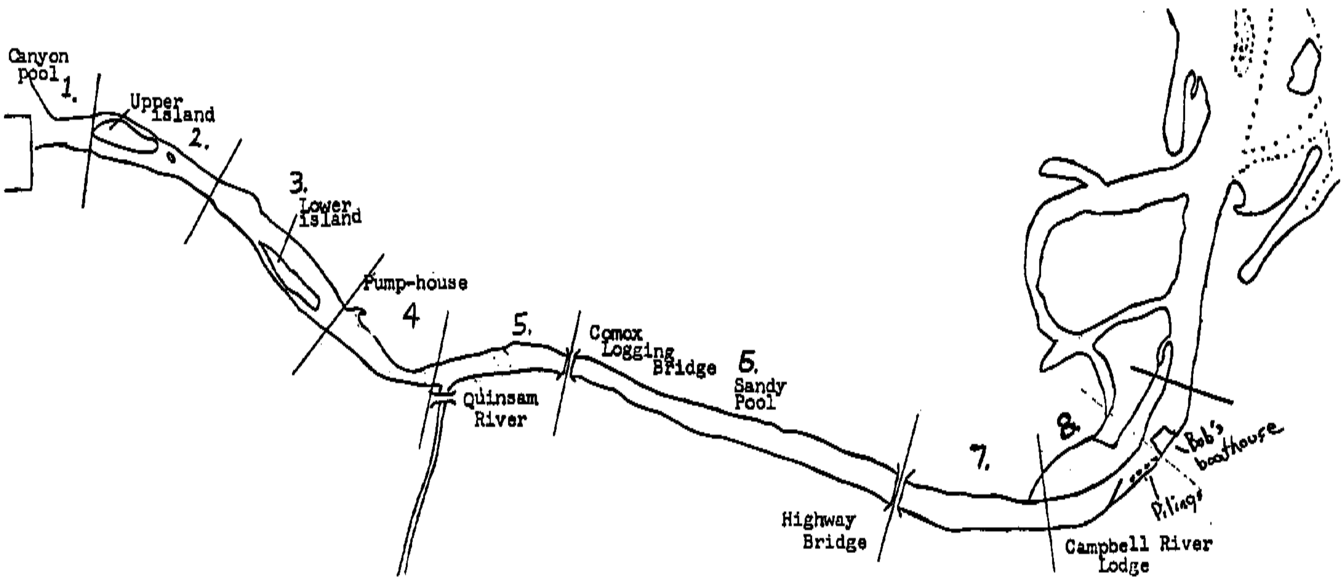

Fig. 6. Campbell River swim survey sections.

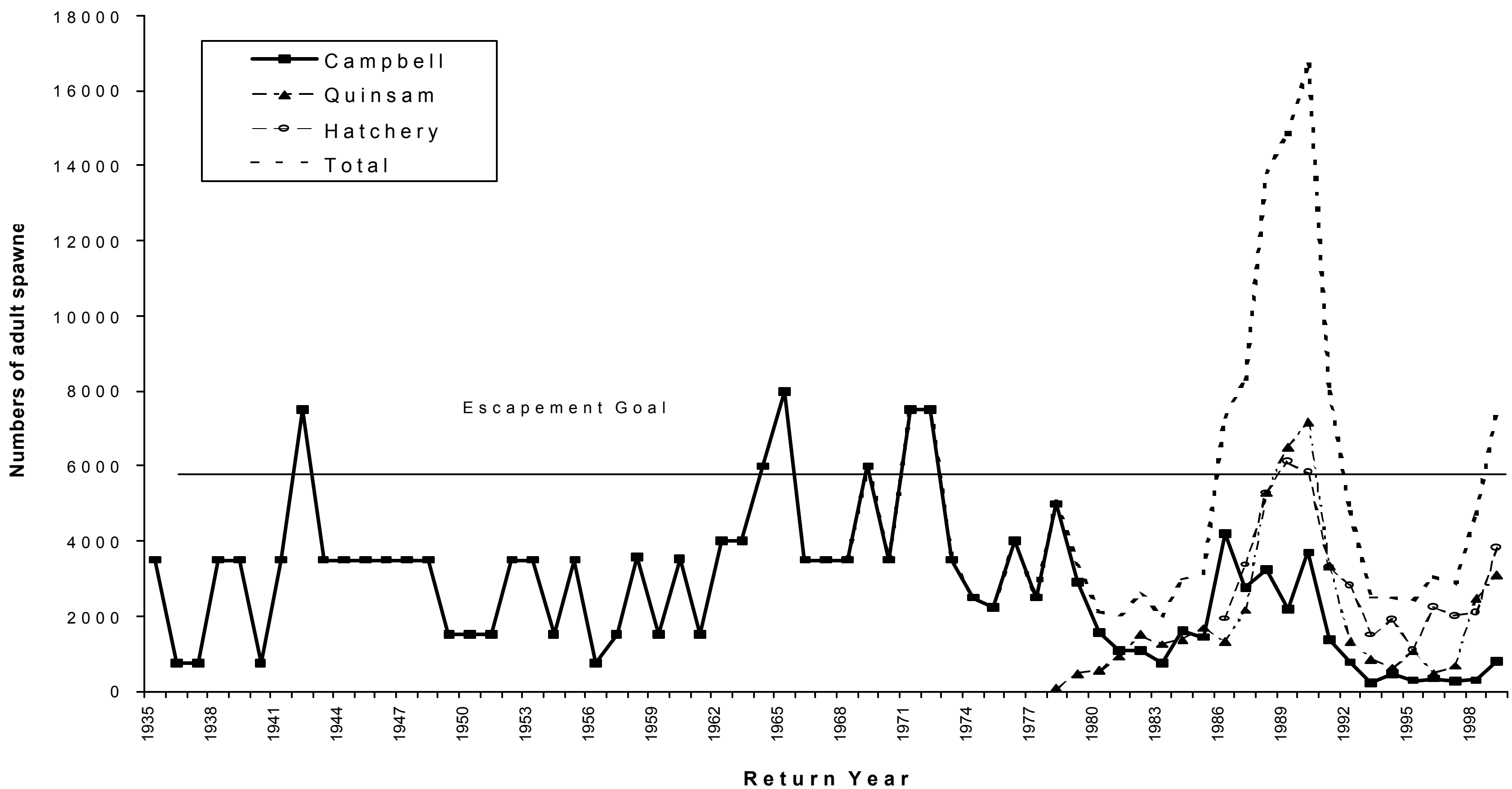

Fig. 7. Chinook adult escapement trends in the Campbell/Quinsam system.

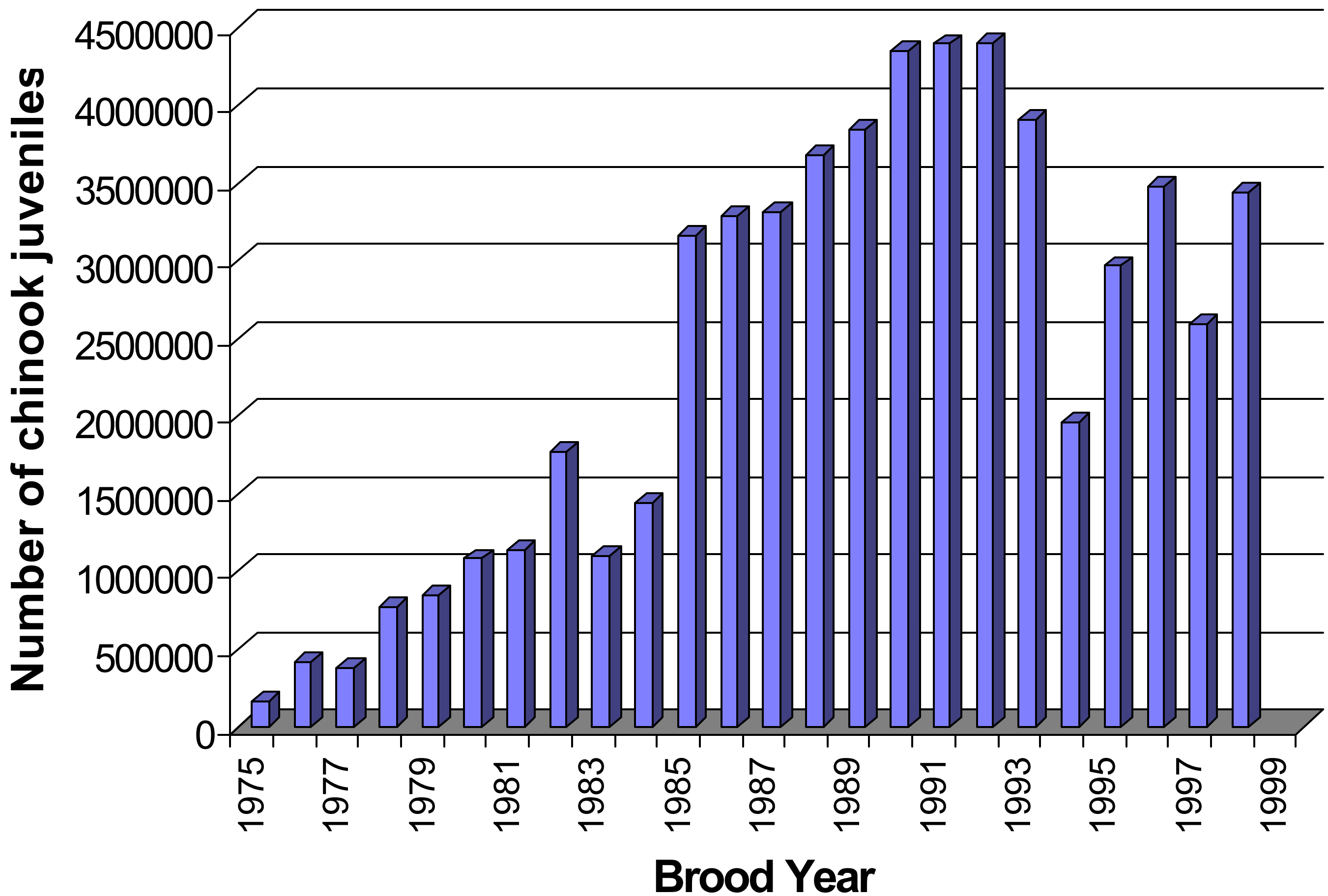

Fig. 8. Quinsam Hatchery juvenile chinook releases by brood year, 1975-97.

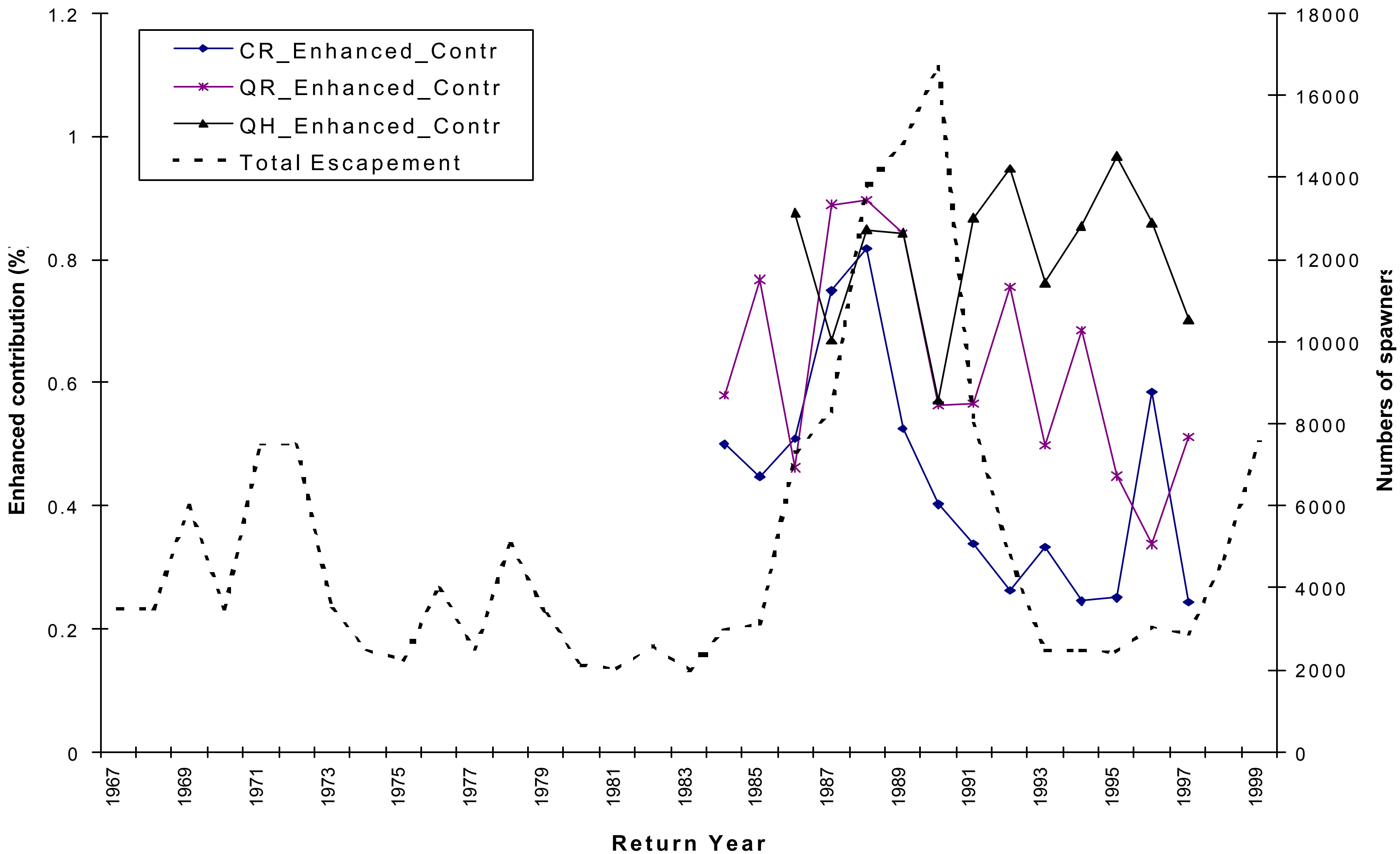

Fig. 9. Enhanced contribution to the Campbell R., Quinsam R. and Quinsam Hatchery escapement by return year.

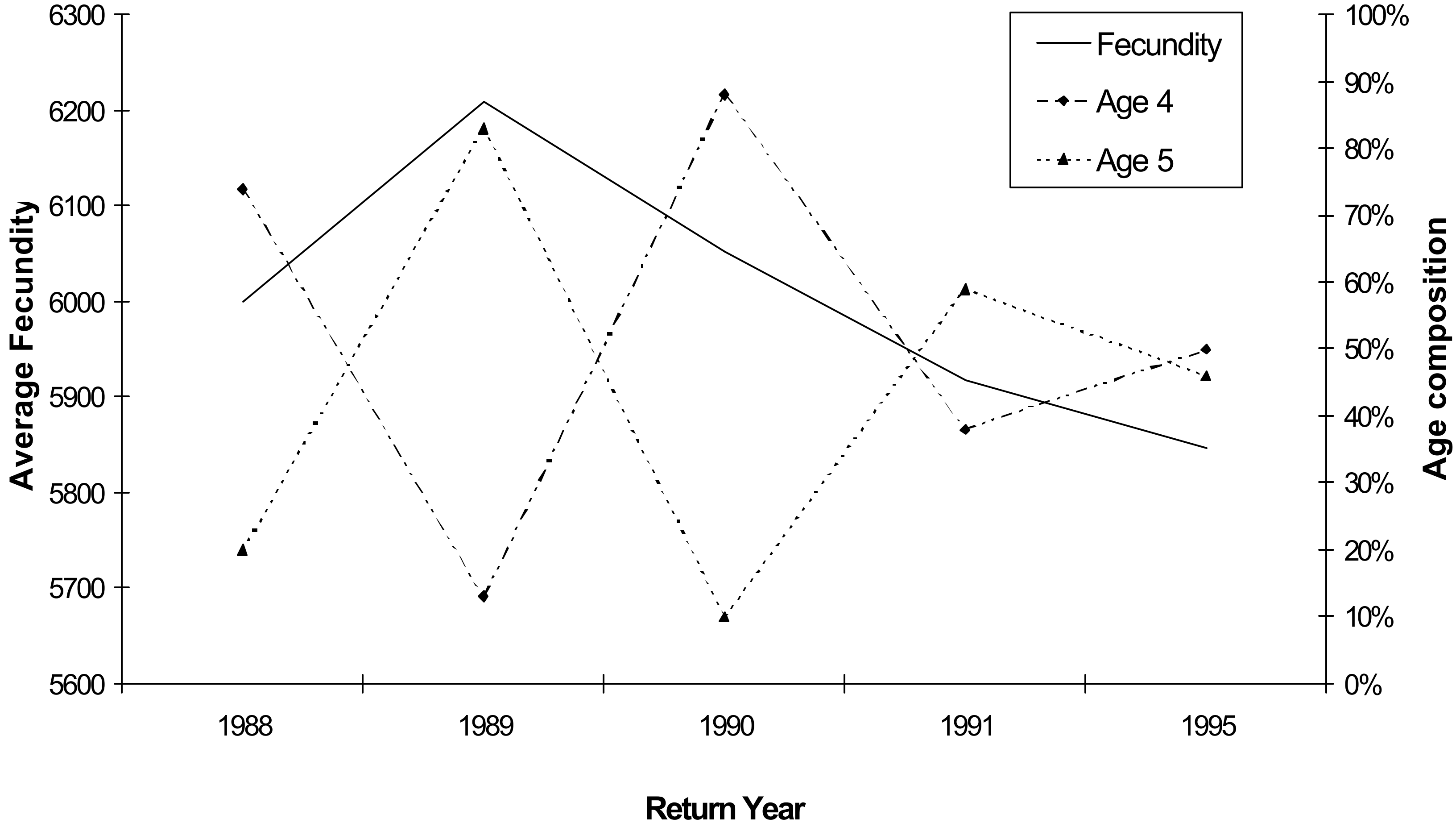

Fig. 10. Fecundity relative to female chinook age for Quinsam Hatchery broodstock.

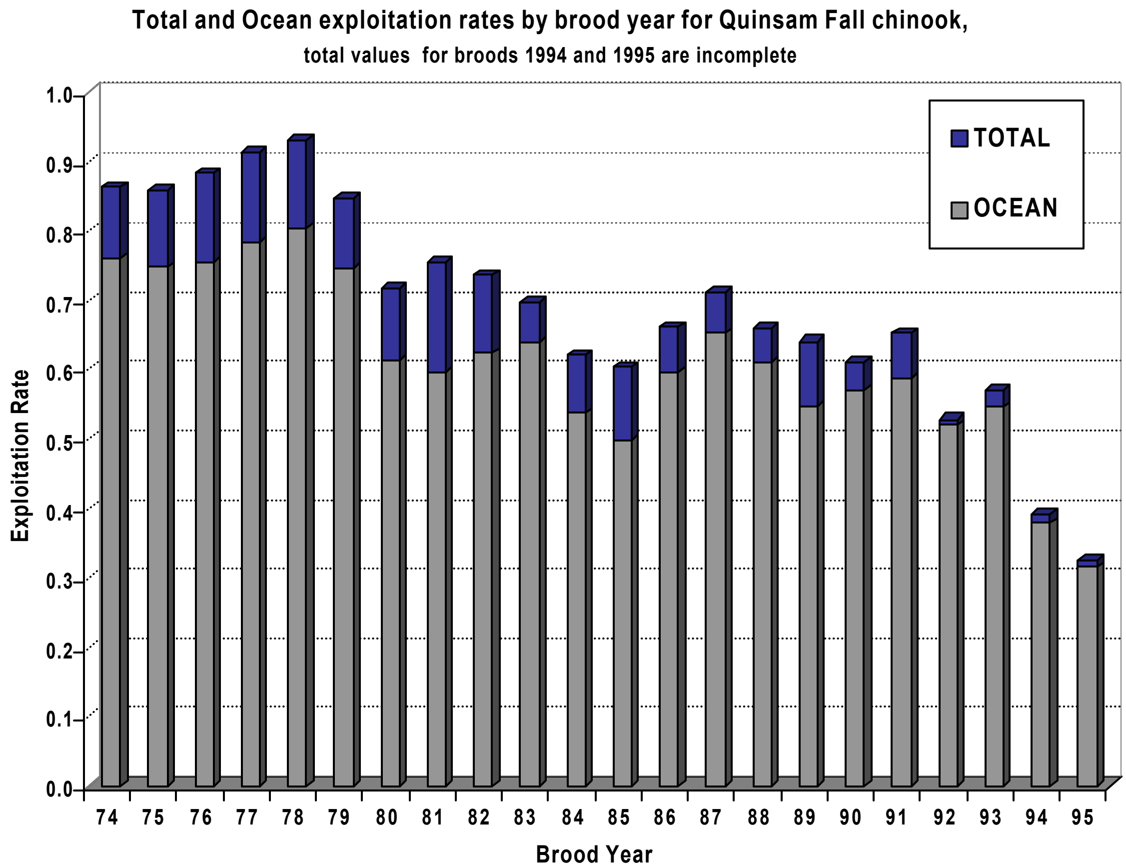

Fig. 11. Ocean and total exploitation rates by brood year for Quinsam fall chinook stock.

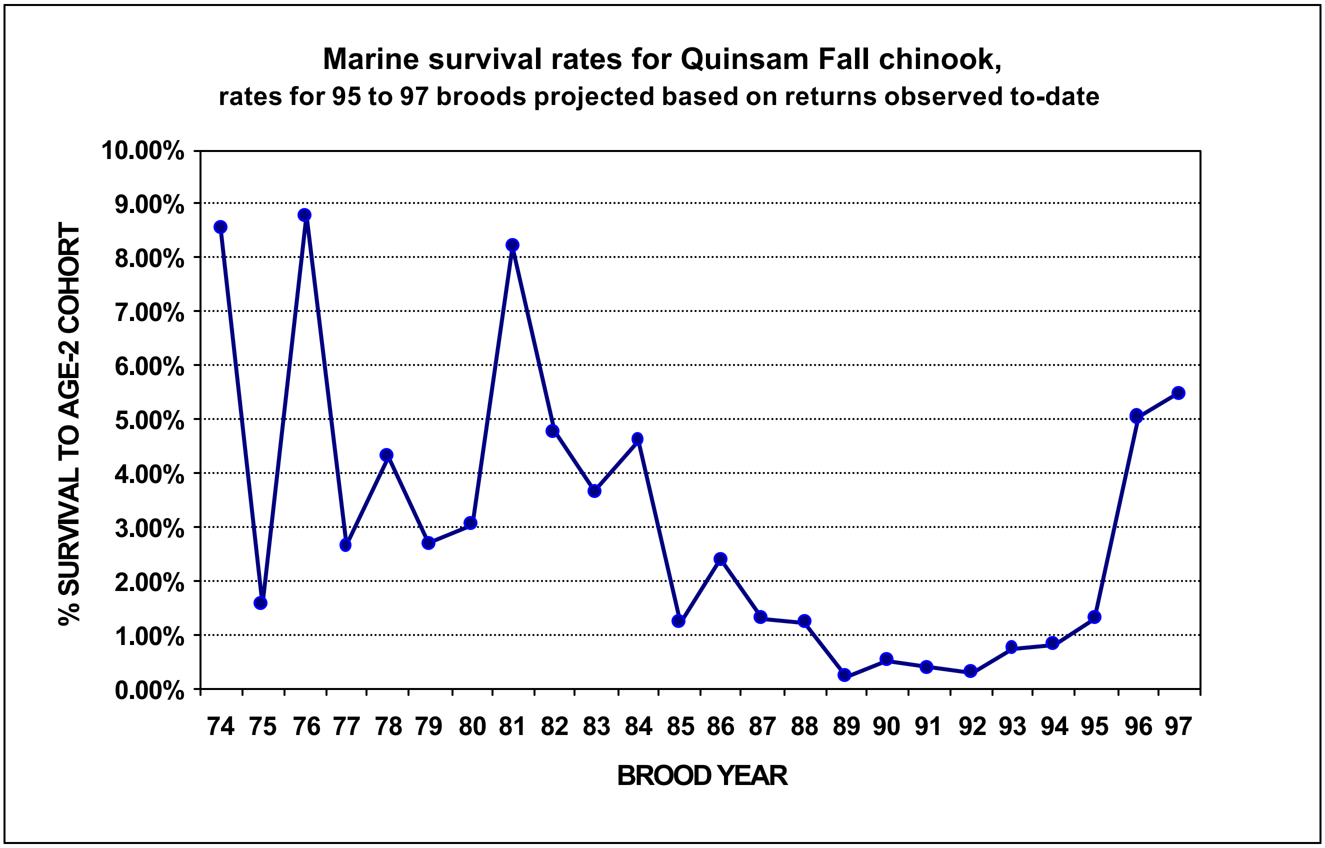

Fig. 12. Marine survival rates for Quinsam fall chinook stock.

Appendix Table 1. Size at age of Quinsam/Campbell chinook escapement by sex and return year.

MALES

		1984			1985			1986			1987			1988			1989			1990	
Total Age	**N**	**Mean**	**S.D.**	**N**	**Mean**	**S.D.**	**N**	**Mean**	**S.D.**	**N**	**Mean**	**S.D.**	**N**	**Mean**	**S.D.**	**N**	**Mean**	**S.D.**	**N**	**Mean**	**S.D.**
2	5			0	0		51	430		3	379		8	397		2	400	35.4	3	408	28.9
3	32	589		20	590.3	46.5	209	579		272	579		35	573		246	629	20.2	41	615	46.4
4	138	724		180	761.4	61.0	565	725		232	758		657	745		176	770	51.3	402	761	56.8
5	60	830		80	840.1	97.8	407	815		321	820		99	872		356	856	58.8	110	878	58.4
6	3	865		3	899.3	141.0	1	910		38	845		4	877		1	925		8	919	41.7
7	0			2	990	0	0			0			3	835		0				0	

		1991			1992			1993			1994			1995			1996			1997	
Total Age	**N**	**Mean**	**S.D.**	**N**	**Mean**	**S.D.**	**N**	**Mean**	**S.D.**	**N**	**Mean**	**S.D.**	**N**	**Mean**	**S.D.**	**N**	**Mean**	**S.D.**	**N**	**Mean**	**S.D.**
2	0			0			6	425	89.4	4	250	86.6	11	325	94.9	41	296	119.9	15	262	93.5
3	69	650	69.5	24	596	41.5	93	577	61.2	56	617	63.8	53	612	66.6	66	650	59.0	118	607	69.7
4	222	766	53.6	287	738	66.6	76	705	65.4	148	719	56.8	165	727	68.7	107	774	64.4	164	741	67.1
5	110	843	58.6	87	831	57.5	110	814	57.2	34	824	70.2	48	818	91.1	35	825	71.7	33	839	57.7
6	2	925	70.7	3	858	76.4	4	850	64.6	1	775		1	925		1	875		2	850	106.1
7	0			0			0			0			0			0			0		

FEMALES

		1984			1985			1986			1987			1988			1989			1990	
Total Age	**N**	**Mean**	**S.D.**	**N**	**Mean**	**S.D.**	**N**	**Mean**	**S.D.**	**N**	**Mean**	**S.D.**	**N**	**Mean**	**S.D.**	**N**	**Mean**	**S.D.**	**N**	**Mean**	**S.D.**
2	0			0	0		0			0			0	0		0	0		0		
3	0			3	736.6	60.8	7	663		5	654		0	0		12	679	54.2	2	625	70.7
4	153	762		117	767.0	40.3	441	749		192	778		502	758		116	779	49.6	491	771	46.3
5	136	827		156	839.0	49.4	897	826		780	832		288	849		865	849	48.3	261	858	50.1
6	13	867		24	862.8	54.1	9	829		183	863		60	861		6	908	60.6	51	917	53.3
7	0			0	0		0			0			2	883		0			0		

Appendix Table 1 (cont.)

	1991			1992			1993			1994			1995			1996			1997		
Total Age	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.
2	0			0			0			0			0			0			0		
3	3	675	100.0	0			12	663	37.7	8	700	65.5	10	685	90.7	6	675	44.7	10	660	58.0
4	163	776	44.1	231	748	44.6	70	728	44.9	198	741	46.7	173	760	50.0	128	785	54.1	209	748	46.2
5	299	839	49.5	234	815	50.5	293	802	48.7	94	816	52.9	195	806	53.0	121	818	49.0	116	829	46.9
6	9	864	48.6	14	879	30.8	12	825	42.6	20	868	46.7	6	850	68.9	5	865	41.8	3	825	0.0
7	0			0						0			0			0					

COMBINED

	1984			1985			1986			1987			1988			1989			1990		
Total Age	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.
2	5			0			51	430		3	379		8	397		2	400	35.4	3	408	28.9
3	32	589		23	609.8	66.46	216	621		277	609		35	573		258	631	55.0	43	616	46.6
4	291	743		297	760.5	56.73	1006	737		424	768		1159	752		292	774	50.8	893	766	51.6
5	196	829		236	833.9	52.85	1304	820		1101	826		387	860		1221	851	51.7	371	864	53.5
6	16	866		27	862	70.15	10	869		221	854		64	867		12	911	55.6	59	917	51.5
7	0			2	975	0	0			0			5	867		0			0		

	1991			1992			1993			1994			1995			1996			1997		
Total Age	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.
2	0			0			6	425	89.4	4	250	86.6	11	325	94.9	41	296	120.0	15	262	93.5
3	72	651	70.2	24	596	41.5	105	587	64.9	64	627	69.3	63	623	75.1	72	652	58.1	128	611	70.1
4	385	771	50.0	518	742	58.0	146	716	57.5	346	732	52.4	338	774	62.0	235	780	59.2	373	745	56.4
5	409	840	52.0	321	819	52.9	403	805	51.4	128	818	57.8	243	808	62.4	156	819	54.8	149	831	49.4
6	11	875	54.8	17	875	39.6	16	831	47.9	21	863	49.8	7	861	69.0	6	867	37.6	5	835	54.8
7	0			0			0			0			0			0			0		

Appendix Table 2. Chinook spawner distribution based on swim survey data.

Area # 1 Canyon & outflow of canyon

Date	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Aug 3rd wk													2			1		5							1
Aug 4th wk					28											80	50			2					
Sep 1st wk	50		15		5																				5
Sep 2nd wk	60	1	8	24		2	1		10		1														
Sep 3rd wk		60	20	50	40			20	30	1		30							50			50		20	
Sep 4th wk		75	20		30			20	50	1								100	100					50	
Oct 1st wk	100	150	55	125	32	7	1	20	100	2	9	1						200				20		10	
Oct 2nd wk	130	70	151	135	56	5	2	30	50	6		10						5							
Oct 3rd wk	50	60	45		20	11		3	2										20						
Oct 4th wk	12	50	4		8	2			1															5	
Nov 1st wk			2																					1	

Appendix Table 2 (cont.)

Area # 2 Upper Island & Pool

Date	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Aug 3rd wk										5	1	50			5	2		2			12	5		70	1
Aug 4th wk		25			2				3	2		40	1	3	10	5	7	25		1	5	30	15	55	10
Sep 1st wk	12		3								1	70	1			200				1	20	100	100	120	10
Sep 2nd wk	60	60	62	52			7		2	3	2	50				80		50	10	1	125	100	140	180	30
Sep 3rd wk		6	74		10			3		5	1	55								10		80	75	350	10
Sep 4th wk		80	27	29				5	1	10	4	75			5			200			32		100	180	20
Oct 1st wk		66	25	156	1		2	22	10	10	3	60			60			100		5	120	200		250	30
Oct 2nd wk	60	240	78		4	3	5	45	10	20		140						20				125			50
Oct 3rd wk	200	175	228	311	35	4	1	20	2	27									10	200	35	40			50
Oct 4th wk	10	183	500	270			1		75		31						29							10	10
Nov 1st wk		40	8		41	9	1			12		5	5											1	
Nov 2nd wk				54	18																				

Appendix Table 2 (cont.)

Area # 3 Lower Island Pool & side channel

Date	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Aug 3rd wk								4	1			4		6	5	15	7	8		1	12	12		13	15
Aug 4th wk		20	4				1	7	2	5		16		10		50		20			2	20	15	30	3
Sep 1st wk			8				3	9			1	20		5						5	70	50	50	15	40
Sep 2nd wk	60	18	44			1	1	3			1	50			10	20		100	30	34	100	120	25	50	110
Sep 3rd wk			16	28	30		1	20	1	5	1	40		6					100			70	15	80	50
Sep 4th wk		5	20	124	10	4	14	18	10	10		20		1	20			50	50		85		35	95	350
Oct 1st wk	15	46	50	202	10	2	20	26	25	20	9	40			310			200		5	55	125		160	
Oct 2nd wk	230	480	84	345	45	40	50	125	57	25	6					70		60				30		5	70
Oct 3rd wk	110	125	91		40		98	20	30	24	15	130							5	120	32	30	100	105	180
Oct 4th wk	200	560		603			140		100		78			500			50							103	
Nov 1st wk		1100			250	90	33						60											5	100
Nov 2nd wk				20	15					45		20												3	

Appendix Table 2 (cont.)

Area # 4 Below Lower island to Quinsam inflow

Date	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Aug 3rd wk								2	16			15						3		6		6	12	5	10
Aug 4th wk			1				1	7	8	6		10	20	18	10	400					10	5	10	6	
Sep 1st wk	6	20	2				2	1	55	1		10	2	10						5	30	30	50	10	20
Sep 2nd wk		3		14		1	3		1	30	1				40	70		10	30		20	250	20	50	10
Sep 3rd wk		1	5		75	1		5	1	5	2	15							50	100		120	20	50	60
Sep 4th wk		52	15	20	2		7	8	70	56		5		20	200			50	200	100	50			100	100
Oct 1st wk	60	26	33	43		5	15	30	10	15	4	25			500			40	15	300	150	100	10	350	
Oct 2nd wk	25	190	75	334	20	13	45	16	75	20	6	150						5			97	20			125
Oct 3rd wk	10	320	153		100	45	76	75	100	33	70					125				150			15	20	40
Oct 4th wk	30	867	440	885			200		40		96			360			30		50			400		40	
Nov 1st wk		400	180		150	235	13			55			120												10
Nov 2nd wk				72	18							20													

Appendix Table 2 (cont.)

Area # 5 Quinsam confluence to Highway bridge

Date	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Aug 3rd wk							2	50	45		5	8	1	315		100	600	100	100	130	10	50	65	120	95
Aug 4th wk		2			6			50	200	70	200	400	620	610	250	450	100	350	100	210	550	400	228	200	186
Sep 1st wk	32		2		4	1	40	153	220	15	304	355	51	502		250			100	220	775	900	250	305	630
Sep 2nd wk	300	50	41			25	42	150	810	75	200	250	61			2400		550	400	300	1030	950	600	260	515
Sep 3rd wk		55	35	90	37	11	118	239	605	240	609	440		620	1240				400	425		530	400	450	475
Sep 4th wk		249	30	336	414	4	104	805	1015	362	426	350		900	6400			550	610	600	360		570	460	1575
Oct 1st wk	150		156	773	80	160	230	570	1300	510	278	680			2500			1210		350	1175	600		920	
Oct 2nd wk	70	710	133		172	25	300	670	1060	100	1230	800					3250	1250		1300		600		1100	2850
Oct 3rd wk	20	530	389	925	150		226	260	2400	325	225					1050			1450		120	600	35		2150
Oct 4th wk	100	655	319	1304			210		290					1750			760		110					30	
Nov 1st wk		244	133		123	45	14			22			320												10
Nov 2nd wk				86	13							10												3	

Appendix A. Summary of Campbell River habitat restoration projects, 1982 – present.

- **Introduction:**

Only 6.5 km long from the impassable Elk Falls to the estuary, the mainstem of the lower Campbell River has always had a limited area available for anadromous salmon rearing and spawning. The Campbell River has historically been important Chinook salmon spawning habitat. The impoundment of the system, since 1947, has effected natural river dynamics, with minimal opportunity for gravel, organics and food items to be added to the system. Before dam construction the Campbell River was 65km long draining a watershed of nearly 1500km^2. The high kinetic energy of the lower river restricts rearing areas for juveniles. Since the construction of John Hart dam natural gravel recruitment to the Campbell River has virtually ceased. Over the past 50 years, periodic high flow events have resulted in the remaining gravel bed being flushed downstream through the estuary, leaving the river armoured with large cobbles and boulders, material unsuitable for salmonid spawning. The upper streambank, or riparian zone, with trees, shrubs and other vegetation is extremely important as a source of food items, cover, and protection from high temperature. The addition of logs and stumps to the system increases the food production and cover available to salmon.

The habitat restoration projects on the Campbell River system are the result of community initiative to deal with issues raised in response to the pressures on fish stocks. In 1994, in response to industry's request to dredge in the estuary to allow more access to the area by tugs and barges, a commission was formed of all stakeholders to address all concerns and determine a vision for the estuary. The Campbell River Estuary Management Plan (CREMP) was developed and implemented. The Campbell River Interim Flow Management Strategy (CRIFMS) was developed in response to the high flow events of 1995, which caused a loss of created spawning habitat (a community initiated and funded-$210,000, spawning channel construction). A schedule outlining instream fisheries flows and constraints was developed by the Vancouver Island Hydro/Fisheries Technical Committee to provide a more natural hydrograph to the system and set criteria for ramping rates and a system of consultation for any unscheduled changes to flows. Through the implementation of these programs, systems are in place to monitor, assess and enhance habitat, as well as providing a protocol for activities relating to salmon habitat on the system. Local groups, all levels of government, industry and other stakeholders have had an opportunity to partner the various projects. The programs on the Campbell have been based on a comprehensive approach to habitat restoration. All stages of salmonid life history, including adult spawning and juvenile rearing, both within the river and estuary have been supported with restoration projects.

Enhancement opportunities were identified to address the limiting factors to salmonid production on the Campbell. A number of these habitat improvement strategies were identified by the Assessment of Salmonid Habitat in the Lower Campbell River (Burt & Burns, 1995). The Lower Campbell River was determined to have a shortfall of 15,000 to 20,000 m^2 of the Chinook spawning habitat required to meet target escapements, as set in the CRIFMS (2000 pairs). Gravel nourishment and placement, in side channel developments as well as mainstem spawning platforms, were considered a priority. Additional projects identified as key elements in improving salmonid production of the Campbell include; twinning of Elk Falls to provide additional spawning and rearing, mainstem river complexing, lower river rearing channels, estuary habitat and the canyon reach restoration. The Campbell River Hydro/Fisheries Advisory Committee (May 1997) recognized that the development of any new spawning areas must be evaluated in terms of other species and life stage requirements, recreational use of the river, and aesthetics, particularly in relation to incorporating projects into parks, both provincial and municipal.

- **ELK FALLS SPAWNING CHANNEL:**

1992

The Elk Falls Channel was constructed in 1992 immediately downstream of the Elk Falls Pulp Mill pumphouse. The channel consists of a spawning area of 1176m^2 (147m X 8m), with a settling pool immediately downstream of the intake structure and a natural rearing area for juveniles from below the lower fence of the channel outlet to the entrance to the mainstem Campbell. The gravel, at construction, was deposited to a depth of 30cm consisting of a range from 2.5cm to 15cm with most being 5cm. In 1995 a further 30cm of gravel was added due to concerns the initial deposition was insufficient for chinook spawning, bringing the total gravel placement to 60cm. Shore box cribbing (wooden) at the lower end of the constructed channel allows the placement of a fence to prevent out migration of adult chinook in the channel as well as inundation by chum which may result in over-spawning and decreased chinook survivals. As well there is a barrier preventing in and out migration through the intake structure on the channel entrance. The spawning channel has a controlled flow system with a valve on the intake structure to regulate flows for spawning and rearing. This valve greatly simplifies the control of flows over the initial stop log system.

During the fall of 1992 the channel was stocked with broodstock chinook captured from the Quinsam River (157 females and 162 males), then planted with eyed eggs (~231,000) from Quinsam Hatchery incubation. In 1994 there was a further stocking of 102 female and 96 male chinook to the channel. Following a number of years of stocking the channel with chinook broodstock captured from the Quinsam River it is hoped that it will only be necessary to supplement the natural return.

- **ELK FALLS TWIN SIDE CHANNEL PROJECT**

1998

Elk Falls Twin Side Channel is on the north bank of the Campbell River, adjacent to Fletcher Challenge's Elk Falls water pump station, and approximately 1 km downstream from the John Hart Generating station. Water diverted from the Elk Falls Chinook Spawning Channel (constructed 1992) twins that channel, rejoining it 140 metres before the combined flow re-enters the Campbell.

Cost Summary:	**Total**	**$135,000**
	Tyee	$ 85,000
	DFO (constr. costs)	$ 35,000
	DFO (in house costs)	$ 15,000

Project Description:

This system of side channels with a controlled intake allows protection from potential flooding flows in the main river, as well as providing areas of prey production and accumulation 515 metres of channel were excavated between July 23rd and August 27th 1998. The channel intake comes off a pool in the Elk Falls Side Channel 20 m downstream from three 1.8m x 1.2m box culverts providing flow from the Campbell into the two side channels. The Elk Falls Twin Channel lies on both Fletcher Challenge land and within Elk Falls Provincial Park.

Elk Falls Twin varies in width from 3.5 to 8 metres and provides 200 m by 6 m of spawning habitat. Some spawning gravel was imported to mix with the native gravel uncovered during excavation and a minimum depth of 0.6 to 1 metres was placed in the spawning sections.

200 metres downstream from the intake an island was created by excavating a 110 metre long watercourse off the main "Twin" channel and loaded with large woody debris (LWD) for fry rearing. 20m upstream from the new channel exit, water was diverted through a 0.6m steel box culvert into what was previously, a 100m long x 1m wide, ephemeral watercourse.

The channel bed has a 0.3% grade. Invert control for Elk Fall Twin is set to the same elevation as the invert control in Elk Falls Side Channel. The invert control weir was built from rock with a 20:1 downstream slope, designed for stability and fish passage.

- **SECOND ISLAND SPAWNING CHANNEL:**

1985, 1995, 1996

Cost Summary:

Aug. '95		*Aug. '96*	
Tyee	$120,000	B.C. Hydro (constr. costs)	$160,000
D.F.O. (constr. costs)	$50,000	B.C. Hydro (hydraulic study)	$50,000
D.F.O. (design/supervision)	$40,000	D.F.O. (design/supervision)	$20,000
Total	**$210,000**	**Total**	**$230,000**

Unlike the 1985 effort, built by DFO alone, the 1995 initiative was a co-operative effort between DFO and the Campbell River Gravel Committee, a local community group. DFO provided the engineering design, biological support, and construction management. To reduce the threat of washout from flood flows, the original 1985 design was modified by raising the spawning bed elevation in an attempt to limit the amount of water entering the channel without constructing an intake structure. Unfortunately, BC Hydro released 20,000 cfs down the Campbell River thus flushing out 45% of the gravel from the channel to the river.

The Hydro/Fisheries Advisory Committee representing all stakeholders was formed to oversee rehabilitation of the channel and review the management of the reservoir.

The 1996 project was funded by B.C. Hydro with DFO providing engineering and project supervision.

In 1995, 4600 cu.m. Of gravel was imported; in 1996, 3900 cu.m. was used.

The restored channel is 15 m to 20 m wide and 425 m long. Implementation of the project took place over 3 weeks during the instream construction window falling between July 1st and August 15th. Cofferdams were placed top and bottom of the channel coinciding with B.C. Hydro's ability to lower the river flow to 1200 cfs.

Three rock weirs were constructed in the channel with shot rock and round rock (the round rock covering the shot rock to provide as natural an appearance as possible). Spawning gravel, 2.5cm to 15cm (8" minus), was placed to a minimum depth of 0.6 m, in some locations over one metre was placed. The acceleration approach zone upstream of each notch in the weirs has a base of larger rock camouflaged with spawning gravel.

Additional features incorporated into the project include large boulders at the channel entrance to provide energy dispersion during flood events, and pools excavated into the banks that were provided with large root wads, logs and boulders to allow quiet backwater rearing habitat for juvenile fish. The project site falls within a provincial park, and extensive attention was paid to the rehabilitation of riparian areas affected by construction. Native plants were transplanted on the embankments in late September to take advantage of the fall rains.

- **CAMPBELL RIVER GRAVEL PLACEMENT PROJECT**

1997, 1998

Cost Summary:	**1997**	**1998**
Tyee Club	$5,000	
Steelhead Society	$5,000	
Tide Guide Association	$5,000	2,500
Habitat Conserv. Fund	$23,000	15,000

D.F.O. (constr. costs)	$87,000	
D.F.O. (design/supervision)	$ 4,000	$4,000
B.C. Hydro	$25,000	$25,000
Total:	**$154,000**	**$46,500**

Introduction:

The Department of Fisheries and Oceans and the local community initiated an experimental pilot project that attempts to restore salmon spawning habitat to the Campbell River. Gravel in the 2.5cm to 15cm (1 to 6 inch) range will increase the area available for naturally spawning salmon y. Gravel nourishment and placement was discussed at Vancouver Island Hydro/Fisheries Technical Committee following the results of the Lower Campbell River Aquatic Study (Burt & Burns Report 1995).

The gravel placement program was initiated through the Campbell River Gravel Committee with the co-operation DFO, MELP and BC Hydro, and community groups.
Site selection criteria included; preferred spawning conditions of chinook salmon, accessibility by helicopter longlining, hydraulic considerations, such as flow, depth, shear force at various flows, and the presence of naturally occurring boulders, large woody debris and backeddys that would slow the downstream migration of the gravel

Project Description:

This project was funded jointly by DFO, B.C. Hydro, MELP through the Habitat Conservation Fund, and community groups- the Tyee Club, Steelhead Society and Tideguide Association. DFO provided engineering, biological support and project administration and supervision. Dr. Bob Newberry, hydrologist, provided information and advice on the river dynamics, gravel stability and site suitability. Equipment and material requirements for the project included; a Bell 212 helicopter, supplied by Canadian Coast Guard; an excavator to load the buckets and trucks to supply and deliver washed spawning gravel to the staging site at the substation at John Hart Generating Station and the bridge site. A loader and tandem truck with a side cast conveyor was used at the bridge site to unload gravel off the bridge and an excavator placed the gravel**.**

A Coast Guard Bell 212 helicopter with 34m longline (110 foot) was used to deliver the gravel to the upper three sites. Two metal buckets were fabricated, each weighing 160 kg (350 lbs), able to carry $0.47m^3$ (0.62 cubic yards) of spawning gravel. The bucket design allowed for self-dumping, no additional pilot operated controls were required. A cable bridle fastened at the bottom of the bucket with locking shackles and fit into brackets with grooves welded to each side at the top of the bucket. The weight of the bucket and gravel kept the cables in the grooves. An excavator at the staging site filled each bucket. When the full bucket was lowered to the river site the cables slackened and released from the grooves, the gravel was dumped, and as the empty bucket was lifted it turned upside down. The empty bucket returned to the staging area, was unfastened by the two-man crew and the second full bucket attached. An additional ground crew member at the staging site was in communication with the pilot. Two pilots were on site, each flying about 20 round trips per hour then refuelling. A tally of the number of trips to each site was kept to determine the volume of gravel placed.

Initial surveys of the sites to receive gravel were used to estimate the amount of gravel to be deposited and the average depth of the placed gravel. Each site was marked out with coloured buoys, visible to the helicopter pilots. Low summer rearing flows of 1200cfs (34cms) meant that the gravel could be placed to water level, an easy benchmark for the pilots to follow. During spawning flows, about 4300cfs (122cms) these sites will be covered by 1m of water, suitable depth for chinook spawning. Spawning gravel was placed to an average depth of 0.6 to 1.0m at the three sites.

Topographical surveys and records of gravel delivered to the sites indicate that Site 1 received $123m^3$, with an average depth of 0.7m, for a spawning area of $175m^2$, Site 2 received $136m^3$ at 1.0m deep for $136m^2$, and Site 3 received $95m^3$ at 0.6m deep for $158m^2$. Spawning platforms totalled $469m^2$, creating habitat for up to 50 pairs of spawning chinook.

The three upper sites are located within Elk Falls Provincial Park and park officials were notified of the project and the activities involved. Parts of the river and a popular walking trail along the river had to be closed to recreational users.

In addition to the helicopter gravel placement a further $1400m^2$ spawning area was created at the site of the new Campbell River highway bridge construction. With the co-operation of the construction company, a temporary bridge, in place to construct the concrete support pier, was used to deliver $715m^3$ of gravel. Gravel was dumped off the bridge with a loader and a tandem with an attached side cast conveyor. After the temporary bridge was removed an excavator placed the gravel in the river over a specified area, to an average depth of 0.3 to 0.6m.

A program has been designed to monitor the stability and condition of the spawning gravel, and its usage by salmonids over the next few years.

During August 1998 spawning gravel was further supplemented at site 3 (Gravel placement 1997) and at three new smaller sites using Bobcats and a fabricated chute (1/4" steel plate) to deliver the spawning gravel to the river. A Bobcat (Case) delivered gravel to the river with the use of a 30ft chute down a steep bank. As the spawning gravel stands at an angle of 35 degrees the slope of the chute had to exceed this angle. A second Bobcat worked on top of the delivered gravel to spread it over the designated area. In addition tracked wheelbarrows deposited gravel in accessible areas off the Canyon View trail. Shovels and rakes were used to spread the gravel to create spawning pads along the river bank. The gravel will be monitored to determine movement over time and assess use by salmonids. This project will further increase the effective spawning area in the Campbell River, for chinook as well as coho, chum, pinks, steelhead and cutthroat trout.

- **RAVEN CHANNEL**

Raven Channel, constructed in August of 1998, is situated on the lower left bank of the Campbell River. The upstream end between the Highway and Tamarac bridges. The channel is 300m long and 4-6m wide excavated on a flood plain area of the Campbell and exiting into a natural slough. The lower river was historically an important chinook and chum natural spawning habitat which high river flows and reduced gravel recruitment had seriously depleted. Some spawning area has been incorporated, with an additional spawning area placed at the mainstem river entrance to the channel. The channel remains wetted at all target river flows, even low summer rearing flows (1200cfs, 35cms) providing additional year round rearing and spawning for all species. An important component of this fish habitat project is the creation of off-channel rearing habitat for juvenile salmonids, providing refuge from high flows, and riparian zones which contribute food to the system as well as shade and decaying plant material. Pools include alcoves with stumps, logs and large boulders to provide cover for juvenile and adult returning salmon. The area is tidally influenced with water levels and flow patterns changing with tide height, but remaining freshwater. Tidal influence increases the wetted area and adds more organics from channel banks to the system.

Campbell River Estuary Habitat Restoration Projects

Introduction:

- The Campbell River estuary comprises an intertidal area of about 72.5 hectares. Since 1904 the estuary has been used for industrial purposes, degrading the habitat by altering the shorelines, dredging, storing log booms and bundles on intertidal habitat, scouring and shading of substrate preventing vegetative production, deposition of wood waste, and construction of marinas and seaplane facilities. These activities have resulted in significant losses of estuarine habitats, areas extremely important to the survival of juvenile salmonids. The estuary functions as a nursery for all species of salmon. The Campbell River chinook are especially reliant on the estuary as primary rearing habitat. Food production within the estuary is directly related to the detrital food chain and depends on vegetated intertidal areas to fuel the system. Contribution from freshwater, terrestrial, and marine drift brought in with the tides are also important to the productivity of the environment. In addition to the food production the estuary provides juveniles with critical physiological transition from fresh to saltwater with its tidally varied and gradient salinity habitats. Estuarine rearing capacity has been recognized as a limiting factor to improved salmon production (CRIFMS p11). The implementation of the Campbell River Estuary Management Plan provides a system of checks and balances that will protect and monitor future activities affecting the estuary.

Intertidal Island Creation (1982)

- In 1981 the proposed construction of a dryland sort and log pond by BCFP resulted in the rehabilitation of part of the estuary to compensate for the destruction of marsh habitat. Four intertidal islands were constructed in the old booming area of the estuary, using the dredge spoil from excavation of the log pond. The islands were planted with marsh grasses to increase the productivity of the area and alcoves were excavated in the margins of the islands to provide refuge for juvenile salmonids. Completed in 1982 the islands have been monitored to assess the success of the grass transplants, the contribution to food production, bird usage and the overall utilization of the estuarine habitat by juvenile salmonids.

Intertidal Bench Creation (1997) MarineLink

- An intertidal bench was constructed at the abandoned MarineLink landing barge ramp. An area approximately 100m by 10m (1000m2) provides increased intertidal vegetation production and juvenile rearing habitat.

Intertidal Marsh Creation at Spit road to Discovery Harbour

- A habitat mitigation/compensation project on the marsh of Nunns Creek resulting from the construction of Discovery Harbour Mall reclaimed $9000m^2$ of sedge and rush habitat. Shallow channels were excavated and the slopes planted by hand with plugs of *carex* and *juncus* from donor stock salvaged from the construction site. Upland, riparian zones have also been included. The reclamation of 'old'Spit Road will add further habitat to the intertidal freshwater marsh area.

River Breach and Intertidal Bench Creation (1996/1997)

- Habitat improvements to increase the rearing capacity of the estuary were identified as priorities in order to support the proposed spawning targets for the Campbell. In accordance with Fisheries and Oceans requisite of "no net loss of productive capacity of habitat" four intertidal islands were constructed in 1981 in compensation for the loss of marsh and riparian habitat resulting from construction of the log sort pocket. The 5-7m deep dredged pond offered little of the productive margin habitat preferred by migrating and rearing juveniles and decay of accumulated wood waste had decreased the water quality, especially the dissolved oxygen levels. Breaching the training wall separating the now abandoned log sort pocket from the mainstem river in August 1996 allowed for an improved water exchange as well as allowing juveniles access to the east side of the estuary. A *carex* bench 600m^2 was created from the spoil excavated and *carex* salvaged from the breach site. To further increase the productivity of the estuary an area of 6000m^2, on the western and northern shores of the log sort pond of upland gravel was excavated to intertidal beach in August of 1997. This increased the potential for intertidal vegetation, 1700m^2 of which is at an elevation suitable for *carex* and *juncus* establishment. Four channels were excavated through the benches to allow further exchange between the river and the log sort pond.

Bank Stabilization Project (1998)

- Another concern in the tidal freshwater area of the estuary was 275m of bank with active erosion on the lower right bank of the river at the oxbow. A cut bank topped by asphalt was eroding with the asphalt breaking off into the river. A hydrologist report indicated that the river width was acceptable for the mean annual discharge of the system and the bank should not be under excessive velocities. Initial excavation in August 97 was halted when the site was found to be contaminated from a 1947 oil spill. Timberwest, owner of the property, hired a consultant, Pottinger Gaherty Environmental Consultants Ltd to deal with the remediation of the contamination. Contaminated soil was removed to a remediation pit on another Timberwest property and replaced with clean fill. In January of 1998 the site had been cleaned up and the habitat restoration and bank stabilization project commenced. By pulling the bank back at 2:1 from the river bottom and armouring this slope with riprap a stable toe was established. The creation of a tidal freshwater bench at 3.8m (chart datum) from the riprap, 10-14m wide, allowed for an increase in width of the river at higher flows, decreasing the erosional forces on the bank and providing increased wetted area, 3400m^2, allowing for greater fish habitat. The upper 3:1 slope of the bench, which is partially wetted on high tides, was planted with riparian species (~1500 red osier dogwood, willow, vine maple, alder, and hardhack) to further improve the habitat. Large boulder clusters were also placed on the bench to add complexity, creating backeddys and cover. The bench will be further planted with native species found on the opposite bank, if necessary.

East Bank Intertidal Benching (1998)

- The clean fill excavated from the bank stabilization project was used to produce further intertidal sedge marsh habitat on the eastern side of the log sort pocket. Cutting into the existing bank created additional benching when the excess spoil material had been used. This resulted in 3500m^2 of intertidal habitat.

Net production of Habitat 1996 to 1998 in the Campbell Estuary

- August 1996 to January 1998 has produced 5700m^2 of intertidal sedge marsh bench, and 7800m^2 of intertidal beach.

Present Habitat Restoration Projects 1999

- Reclamation of the Tyee Spit, returning the altered, armoured and bulkheaded shoreline to a natural slope with associated vegetation and habitats**. $30,000**
- Marsh grass planting on the intertidal benching produced in 1997/98. **$40,000**
- Additional channel creation and marsh planting in Nunns Creek. This project is in conjunction with the decommissioning of Spit Rd and habitat compensation agreement with the Discovery Harbour Mall. **$70,000**

Future Projects in the Campbell River Estuary

- Establishing a trail following the right bank from the foot of Maple Street to the end of the upland area downstream. This groomed trail will include interpretative signs; bridges to allow access over breach channels, and wildlife viewing areas. The trail will be built on municipal land. Fill removed from the Raven Park channel has already been moved on site and a preliminary base established.
- Habitat restoration of the west side of the estuary, including Baikie Slough, an area seriously degraded by log handling activities. Improvements include requiring more fish friendly industrial activities, improved fresh water flushing, establishing marsh grasses, cleaning up of deposited wood waste
- Groundwork is underway to attempt to acquire a parcel of 50 acres on the west side of the estuary.
- Continued removal of bulkheads on the shoreline of Tyee Spit, as possible to return to natural slope and/or marsh benches.

Appendix B. List of Coded-wire tag codes used to represent production of Quinsam Hatchery fall chinook in cohort analyses, by brood year (@ sign indicates the brood year).

@74	@85	@89	@93
020403	023522	026062	180629
@75	023523	026063	180630
020108	023524	026101	180631
@76	023525	026102	181357
021916	023554	020361	181358
@77	023555	020360	181359
021736	023556	020359	181360
021737	023557	020358	181361
021738	023558	020357	181362
@78	@86	@90	@94
021759	024152	020956	181644
@79	024153	020957	181645
021757	024154	020958	181646
021758	024155	020959	181647
@80	024156	021448	181648
021657	024157	021449	181649
021943	024158	021450	181650
021950	024159	021451	181651
@81	024160	026019	181652
022303	@87	@91	@95
022304	024419	180422	181658
@82	024420	180421	181659
022518	024421	180420	181660
022519	024956	180419	181661
@83	025358	180418	182016
022631	025359	180417	182017
022632	025360	180416	182018
@84	025361	180415	182020
023322	025362	021331	182021
023323	@88	@92	@96
023324	025814	181150	181830
023325	025815	181151	182512
023326	025816	181152	182513
023327	025817	181153	182514
023328	025818	181154	182515
023329	025819	181155	182516
023330	025820	181156	182517
	025821	181157	182518
	025822	181158	@97
			183035
			183036
			183037
			183038
			183039
			183040
			183041