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Status Review of the Puntledge River Summer Chinook

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Summary

The population of summer chinook that spawn in British Columbia's Puntledge River once numbered about 3,000 fish, but declined following expansion of hydroelectric development in the early 1950s. By 1965, only a few hundred fish remained. Following enhancement efforts (construction of a spawning channel, fish way, and fishing closures and restrictions), the population slowly recovered and reached a high of 1,200 in the mid 1980s. Numbers of males increased more rapidly than females, which on average outnumber females by a ratio of two-to-one. A second, and potentially more disastrous decline began in 1990. Only 208 spawners returned in 1995 compared to 1,629 five years earlier.

Males return to the river before females and are significantly younger and smaller than females. Differences in body size and numbers may be partly explained by size selectivity of fisheries that release undersized fish. Chinook that use the spawning channel are physically smaller than those that stay in the river to spawn.

In 1980, fisheries intercepted 74% of the summer chinook as they returned to the Puntledge River compared to 9% that were taken by harbour seals. In 1990, fisheries and seals caught 32% and 24%, respectively.

The problems faced by the summer chinook are varied and complex. It is not clear whether the Puntledge River can ever again sustain the historic numbers that once made it one of the most important producers of chinook salmon in British Columbia. Development of a conservation plan is urgently needed for the Puntledge River summer chinook and should be given high priority given the recent low levels of spawning escapements, and evidence of high mortalities incurred at sea and in the terminal area.

Introduction

The Puntledge River on Vancouver Island, British Columbia, used to be a significant producer of chinook salmon in British Columbia with an annual return of 6,000 spawners (Dept. of Fisheries 1958; Hourston 1962). Prior to 1955, the Puntledge produced twice as many fish as Campbell River and four-times that of Qualicum River (the two adjacent rivers to the north and south). At that time, chinook spawning populations were known in only 259 of over 1,600 salmon spawning streams in British Columbia, and only 15 streams had total runs of 5,000 or more chinook.

The Puntledge River has both a summer and fall run of chinook that once numbered about 3,000 of each during the first half of this century (Hourston 1962; Marshal 1972; MacKinnon *et al.* 1978). However, chinook numbers in the Puntledge declined precipitously following expansion of hydroelectric development on the river in the early 1950s (Dept. of Fisheries 1958). Enhancement efforts were invoked during subsequent decades, but failed to restore the populations to their historic highs. In 1986, the fall run of Puntledge chinook was effectively extinct when only 3 females returned (H. Genoe, pers. comm., Puntledge Hatchery). Summer chinook have fared little better, with returning numbers ranging from 150 to 1,600 over the past 10 years.

It is not entirely clear what happened to the fall and summer chinook runs, nor what should now be done to restore the summer run. Summer chinook are caught by sport and commercial fisheries, and are vulnerable to harbour seal predation in the river and estuary. In addition, the fish must contend with the hydroelectric facilities built on the river, as well as with prevailing climatic and oceanographic conditions.

The following examines the status of the remaining indigenous run of summer chinook. Hydroelectric development of the Puntledge River is reviewed and compared with trends in chinook abundance from 1949 to 1995. Biology of the chinook is also reviewed, and morphometric measurements taken from spawning fish are examined for signs of selection by fisheries and seals.

Finally, estimates of exploitation rates by seals and humans are presented in an attempt to understand where the missing fish have gone.

Hydroelectric Development & Enhancement Efforts

The Puntledge River flows into the south end of Comox Lake, and out the north end, until it reaches the Strait of Georgia near the community of Courtenay on the east side of Vancouver Island (Fig. 1). Three smaller streams (Browns River, Morrison Creek and Tsolum River) join the Puntledge below Comox Lake. Chinook, pink, chum, coho and steelhead all spawn in the Puntledge River.

In 1913, Canadian Colliers constructed a hydro electric power plant on the Puntledge River to supply electricity to the many coal mines in the area (Dept. of Fisheries 1958). An impounding dam was built at the outlet of Comox Lake (Fig. 1). Three kilometers downstream from the dam (above Barbers Pool), a low diversion dam and intake were constructed to divert water into a wooden flume leading to the powerhouse. The company was licensed to draw off 1,000 cfs, but in practice used less than 300 cfs. Fish were able to pass over the diversion dam, and in 1927 were able to enter the lake via a wooden fish way (a permanent concrete fishway was constructed in 1946 and redesigned in 1957). There is no written account of Canadian Colliers adversely affecting the summer chinook run. The small amount of water drawn off does not appear to have altered the behaviour of returning adults and allowed most migrating fry to pass over the diversion dam and down the river (Dept. of Fisheries 1958).

In 1953, the British Columbia Power Commission purchased the installations with plans to increase power production eight-fold by diverting the total 1,000 cfs of water allowed under the license (Dept. of Fisheries 1958; Marshall 1973). Construction of a new power plant (4.5 miles below the diversion dam and intake) began in 1954, and the first power was generated in March 1955. Normally, 1,100 to 1,200 cfs of water is released from the impounding dam, of which 1,000 is diverted for power generation, and approximately 100 to 200 cfs spills over the diversion dam to provide water for migration, spawning and rearing fish.

The dam was reconstructed between 1957 and 1958. Beginning in September of 1957, many truckloads of earth were dumped on the impounding dam to decrease leakage through it (Hourston 1962). Most of the earth fill eventually washed into the river and was deposited down stream of the dam. In December 1957, a section of the dam broke. Over the next two months thousands of cubic meters of material eroded. The silt level virtually destroyed all of the spawning ground leading to almost complete loss of fry during the winter of 1957 to 1958 (Hourston 1962).

Four solutions were introduced to reverse the decline of summer chinook (Marshal 1972, 1973). First, blasts of water (freshets) were sent down the main river beginning in 1958 to lure the returning adults away from the power house and up the main river. Unfortunately, the fall and winter freshets damaged fall chinook eggs and alevins, and washed out spawning gravel, thus severely reducing the return of fall chinook in 1961 and subsequent years. Second, B.C. hydro built a spawning channel next to the diversion dam in 1965 to replace the natural spawning ground above the dam and to reduce the number of summer fry dying each spring in the turbines (Lister 1968). Third, baffles were constructed at Stotan Falls to ease upstream migration between 1969 and 1971, and water flow was adjusted to provide moderate migration flows (a fishway was constructed in 1986 at Stotan Falls and in 1987 at Nib Falls). The diversion dam was also modified to encourage the fish to enter the spawning channel and prevent adults from jumping against the diversion dam and injuring themselves. Finally, sport fisheries in the river and estuary were closed in 1965 and 1969 for summer and fall chinook, respectively (remaining closed to the present day). In addition, commercial troll fishing boundaries were pushed back in 1970 to give extra protection to the two runs.

The spawning channel maintained the summer chinook stock but failed to rebuild the species to previous levels (MacKinnon *et al.* 1978). In 1972, production of chinook was enhanced with the addition of a hatchery near the powerhouse (Fig. 1). Later in 1977, the spawning channel at the upper site was replaced with a smolt rearing channel and an adult holding channel.

Chinook Biology

The summer and fall runs of Puntledge chinook have reasonably discrete timings of migration and spawning distributions in the river.

The summer run begins entering the lower river in late May and early June, with peak numbers returning in July (MacKinnon *et al.* 1978). Most females are 4-years-old (range 3- to 5-y). The greatest proportions of males are 3- and 4-years-old, although ages range from 2- to 5-y. Historically, the summer chinook were spread throughout the river from Stotan Falls to Barbers Pool, spending 2 or more months in the deeper pools before moving onto the spawning grounds between Barbers Pool and Comox Lake (Dept. of Fisheries 1958; Hourston 1962). Some fish over-summered in the cool waters of Comox Lake, moving either to Cruikshank River or returning downriver to spawn in the fall (Dept. of Fisheries 1958). Spawning begins in early October, and peaks in mid-October. By the end of the first week in November, virtually all summer chinook have finished spawning and have died.

Since 1974, summer chinook that do not enter the spawning channel are seined from the river and put into holding ponds. Eggs and milt from the 'river' and 'channel' fish are taken to the hatchery for incubation and rearing.

The fall run enters the river in early September and uses the lower reaches of the river between Tsolum River and Stotan Falls for spawning (Hourston 1962; MacKinnon *et al.* 1978). They are much larger than the summer chinook, but spawn at the same time of the year. In 1986, chinook from Big Qualicum and Quinsam Hatcheries were transplanted in the river, when the indigenous run failed to return. Some genetic crosses were also made with the summer run.

Chinook eggs are deposited in the gravel and incubate over winter. The fry begin to emerge in March and begin to move down stream, with peak numbers of fry leaving the river in April. Decreasing numbers leave from May until July. Some take up residency in the river and rear to smolts, migrating the following year.

It has been suggested that the two runs maintained their racial integrity by spatial segregation in the river (Marshall 1973). Summer chinook may have evolved from early migrants of an ancestral fall run stock that were able to ascend the Stotan Falls between high spring and low summer run off periods. Electrophoretic sampling of the remanent fall population and the up-river summer chinook indicate genetic differences between these races (B. Riddell, unpub. data).

Changes in Abundance

The total numbers of summer chinook spawning in the Puntledge from 1949 to 1991 were estimated by Hourston (1962) [1949-61]; the Comox Fishery Office [1962-64]; Marshall (1973) [1965-72]; and the Puntledge Hatchery [1973-95]. Sex of the spawners was noted from 1965 to 1995.

Between 1949 and 1965 the total number of summer chinook spawning in the Puntledge River dropped from approximately 2,500 fish to a few hundred (Fig. 2). The population showed signs of recovery in the mid 1970s, increasing to roughly 1,200 fish by the mid 1980s. However, male abundance increased more rapidly than female abundance during the 1980s (Fig. 2b). The increasing abundance of males might be linked to size limits imposed on fisheries, which affords greater protection to males than to females (see - Exploitation by Fisheries).

A second period of decline began in 1990. From a high of 1,629 spawners, the population has declined continuously in each year since (Fig. 2; 1991: 1,329, 1992: 739, 1993: 469, 1994: 370). In 1995, only 208 Puntledge summer chinook spawned (Fig. 2).

The ratio of male to female spawners has varied considerably since sex specific counts were begun in 1965 (Fig. 3). On average, about 2 males return for every female ($\bar{x}$ = 1.91, sd = 0.97, n = 25, excluding the 1966 and 1985 returns); although in some years the ratio has been as high as 9 to 1. Variability in sex ratio of the summer chinook is influenced by a number of factors, including varying marine survivals of different brood years and differences in age at sexual maturity.

Changes in Mass and Length

From 1967 to 1993, body lengths and mass were recorded from aged [1975-93; SEP files] and unaged summer chinook [1967-88; Puntledge Hatchery files]. Linear regressions, fit to mean lengths and weights of unaged spawners (Fig. 4) suggest a significant rise in female body size from 1979 to 1991 (Weight $F_{1,7} = 5.7$, $p = 0.048$; Length $F_{1,7} = 7.9$, $p = 0.026$). However there was no discernable trend in male body size over the same time period (Weight $F_{1,7} = 0.08$, $p = 0.784$; Length $F_{1,7} = 0.41$, $p = 0.544$).

MacKinnon *et al.* (1978) noted that summer chinook were smaller after expansion of the hydroelectric facilities in 1955. The decrease in body size of returning adults through the 1960s and 1970s was possibly due to an increase in sport fishing pressure applied to Georgia Strait chinook stocks (MacKinnon *et al.* 1978). Data available since 1979 suggest that channel females have been getting longer and heavier unlike the males which have shown no apparent trend with time (Fig. 4). This too might be linked to changes in the size of fish that may be kept by fishermen.

One of the difficulties in interpreting changes in mean body size is that the spawning population is composed of different age classes. This is particularly true of males that range in age from 2 to 5 y. Most females return at age 4 y, although there can be some variation in year class strength that could mask or incorrectly suggest a change in body condition with time.

In 1991, mass and length was recorded from over 55% of the spawning males and more than 81% of the females. Two groups of fish were measured: those that entered the spawning channel, and those that were seined from the river. Each fish removed from the holding pools was struck on the head and suspended from a spring scale to measure body weight (to the nearest 0.05 kg). Females were then bled and the eggs removed, after which post-orbital-hypural body length (eye to end of spine) was measured to the nearest millimeter using a measurement bar. Total body length (tip of snout to V-notch of tail) was measured for a subsample of fish.

The relationship between mass and length of fish sampled in 1991 (Fig. 5; $F_{1,658} = 9572$, $p < 0.001$, $r^2 = 0.936$) was linearized by taking the square root of weight. Mass can be estimated from the equation,

$$\text{Weight} = (-1.0 + 5.3 \times 10^{-3}\ \text{Length})^2 . \qquad (1)$$

A linear regression was also used to describe the relationship between post-orbital-hypural length (POH) and total body length, so that fishing length restrictions (total body) could be compared with lengths recorded by fisheries biologists (POH). Total body length was 21% longer than post-orbital-hypural length (Fig. 5). The model fit to the data,

$$\text{Total} = 1.21 \times \text{POH} \qquad (2)$$

was highly significant and did not require a constant (mixed model $t_{109} = 567$, $p < 0.001$, $r^2 = 0.960$).

Distributions of lengths and weights of the 1991 spawners were displayed using box-plots (Tukey 1977) and histograms superimposed with density plots (Systat 1988). The sample distributions were compared to theoretical normal distributions using quantile-quantile plots. Body lengths of males and females appear normally distributed (Figs. 7 and 8), as are female body weights (Fig. 9). The only departure from this was a log-normal distribution for the body weights of males. None of the distributions showed significant skewness that might indicate that seals or fisheries were preferentially selecting fish of any specific size.

Spawning females were significantly bigger than the males sampled in 1991 (ANOVA: Length $F_{1,728} = 322.9, p < 0.001$; Weight $F_{1,656} = 323.3, p < 0.001$). On average, the unaged females weighed about 4 kg more than the males (Table 1, Fig. 7). There was also a significant difference between the size of fish that entered the spawning channel and those that stayed in the river (ANOVA: Length $F_{1,728} = 22.8, p < 0.001$; Weight $F_{1,656} = 45.8$ $p < 0.001$). In 1991, river fish weighed an average of 1.5 kg more than channel fish.

River males showed greater variability in body lengths and weights than channel males (Table 1). A number of the channel males were unusually large (see outliers in Fig. 7), and may have been river fish that entered the channel and could not return to the lower river to spawn. The size of these outliers (plotted in Fig. 7) is more in keeping with the size of the river males than with the bulk of the channel fish. Unfortunately the numbers of males sampled from the river is small compared to the other three categories of fish. However, within the channel, variability in male length greatly exceeded female length, but there was virtually no difference between the variabilities in each of their weights (Table 1). Why this should be is not clear.

ANOVA assumptions of normality and homogeneity of variance were not fully met. In addition to the log-normal distribution of male weights, sample variances of the lengths and weights (Table 1) were not homogeneous (Bartlett's test: length $\chi_3^2 = 74.5$, $p < 0.001$; weight $\chi_3^2 = 27.9$, $p < 0.001$). While analysis of variance is generally robust to departures from normality and homogeneity of variances, it is sensitive to differences in sample sizes. One solution proposed by Box (1954) is to reduce the degrees of freedom. Applying such a conservative approach does not alter our conclusion that the size of river and channel fish differ significantly, as do the size of the unaged males and females.

The difference in size between river fish and channel fish is intriguing (Fig. 7) and is not readily explained. One explanation is that some sort of hybridization has occurred between the summer and fall runs. Such a concern was expressed by Marshall (1973) at the prospect of the two runs returning to a single artificial propagation site in the river. However, the fall run has traditionally stayed in the lower reaches of the river and is not found higher in the river. It is possible that some of the size difference is related to genetic crosses made at the hatchery beginning in 1985 when both summer and fall chinook from the Puntledge were bred with chinook from Big Qualicum and Quinsam. However, electrophoretic profiles in 1991 have shown no statistically significant difference between channel and river summer chinook. (B. Riddell, unpubl. data). It may be that some other selection mechanism, such as the inability of large fish to enter the channel, may explain the difference in body size of river and channel spawned fish.

Further insight into the difference in size of males and females can be gleaned from a sample of 858 males and 376 females that was aged from coded wire tags removed from fish heads between 1977 and 1990 (data from SEP, Carol Cross pers. com.). For a given cohort, the average male run was made up of 8% 2 yr-olds, 66% 3 yr-olds, 25% 4 yr olds and 1% 5 yr-olds. Eighty-six percent of the females were age 4, 13% were 3 yr-olds and 2% were 5 yr-olds. Body measurements reveal that females are significantly longer than males of a given age (Fig. 10). For example at age 4-yrs mean lengths of males and females were 63.1 and 67.5 cm respectively (t_{834} = 8.25, $p < 0.001$); while mean lengths at age 3-yrs were 54.0 and 61.3 cm for males and females respectively (t_{591} = 7.06, $p < 0.001$).

Coded wire tags were recovered from fish taken by both fishermen and hatchery biologists. Over 90% of the length and weight measurements from the fish that contained coded wire tags were recorded in the fall at the spawning channel. Fewer than 10% of the sampled fish were caught at sea, although more may have been caught and not reported. Of the 108 fish sampled before September 1, males were intercepted significantly earlier than females (mean date of sampling July 31 versus Aug 9, t_{106}= 3.43, $p = 0.001$), presumably because males return earlier than females to the spawning river. Overall however, females were measured before males (mean date of sampling October 4 versus October 13, t_{1641} = 6.95, $p < 0.001$) because most of the males were held in Burrows ponds until after the eggs had been removed from the majority of females. Note however that such differences in sampling dates are unlikely to explain differences in male and female body size.

Exploitation by Fisheries

Sport fisheries in the river and estuary were closed in 1965 and 1969 for summer and fall chinook, respectively (remaining closed to the present day). In addition, commercial troll fishing boundaries were pushed back in 1970 to give extra protection to the two runs.

Numbers of Puntledge summer chinook caught by sport and commercial fisheries during the 1980s and late 1970s were estimated by SEP (Carol Cross and Sue Lehmann, pers. comm.) and are shown in Fig. 11. Adding the number of fish caught to the number that spawned, suggests the size of the run, in the absence of fishing, might have exceeded 4,000 fish from 1978-82, 1,500 fish between 1983-88, and close to 3,000 spawners in 1989 and 1990. Since then, the potential size of the spawning stock has fallen to only 424 fish in 1995.

Sport fishermen caught 70% of the run in 1975 (assuming that predation by marine mammals was negligible). Over the next 10 years, the sport share of the run dropped to approximately 20% (Fig. 12). Since 1988, it has averaged about 35% of the fish destined for the Puntledge system. Commercial catches of Puntledge river summer chinook rose through the late 1970s (from 20 to 40% of the run) and dropped through the 1980s (from 40 to 20%). Since 1988, it has averaged 15% of the run. All told, the combined catch by sport and commercial fisheries removed 84% of the run between 1975 and 1981 (Fig. 12). Total exploitation rate has since dropped to about 50% (1990-95).

Most of the summer chinook catch occurs in the Strait of Georgia sport fishery (Fig. 13). Smaller numbers have been caught in the Strait of Georgia troll fishery and Johnstone Strait net fisheries. In contrast, most of the fall chinook have been taken further north in the northern and central BC fisheries as well as in Alaska (Fig. 14).

Until 1981, sport fishermen could keep all chinook that exceeded 30.5 cm (12 inch fork length). The length limit was increased to 45 cm in 1981 and to 62 cm in 1988 (51 cm post-orbital-hypural length, from Eq. 2). This meant, for example, that all summer females in 1991 were vulnerable to the sport fishery, but that only half of the males could be legally kept (Fig. 8). Thus it is conceivable that the sport fishery contributed to the high ratio of spawning males to females (Fig. 3). A second concern is whether the sport fishery enhances the survival of smaller males which might ultimately affect the genetic integrity of the summer chinook and potentially lead to the production of smaller fish with time.

Exploitation by Harbour Seals

There are no records to indicate how many seals historically used the Comox Harbour for feeding and breeding. But numbers during the first half of this century must certainly have been low because a bounty was paid for each seal killed in British Columbia between 1913 and 1964. Seals were perceived to compete with fishermen and were shot on sight. Fewer than 10 seals were counted at one time in Comox Harbour between 1974 and 1983 (Fig. 15). Since the mid 1980s however, the population increased exponentially to approximately 400 animals in 1990, and continues to increase today.

In 1990, harbour seals killed an estimated 869 summer chinook of which 362 were caught in the Comox estuary and 507 were taken in the Puntledge River (P. Olesiuk, Pacific Biological Station, Nanaimo, pers. comm.). The estimated numbers killed were based on the average number of successful pursuits observed per hour over the summer and fall of 1990. Thus, in the absence of harbour seal predation, 2,498 fish should have spawned in 1990 (869 killed + 1,629 escapement). This means that harbour seals intercepted 35% of the fish that arrived in the Comox estuary.

In addition to killing adult salmon in the summer and fall, harbour seals also consume out-migrating fry and smolts in the spring (Olesiuk et al. 1995). Harbour seals observed to congregate during the night in the Puntledge River appear to use the light cast from two bridges to silhouette and capture small fish. In 1995, seals were estimated to consume 3.1 million chum fry (about 16% of the total 1995 chum fry production) and 138,000 coho smolts (about 15% of the total 1995 coho production). Predation on chinook smolts was not specifically addressed, but was believed to have been about 33% of the 1995 chinook smolt production.

Overview

The Puntledge River used to be one on the most important producers of chinook in the Strait of Georgia until hydroelectric development was expanded in the early 1950s. Early reports suggest that most, if not all, of the decline of summer chinook observed through the 1950s and 60s (Fig. 2) can be attributed to power development during the 1950s (DFO 1958, Hourston 1968, Marshall 1973). First, the large amount of cold water diverted from the river attracted migrating spawners to the powerhouse and away from the small volume of warm water in the main stream. Adults that entered the trail race of the powerhouse were bashed against the cement walls by the force of the water and suffered high mortalities due to fatigue and injuries. Second, most fry that moved downriver in the spring from the spawning grounds (between Comox Lake and the diversion dam) on their way to sea, passed through the turbine and experienced high mortalities (30 to 40% died within 48 hours - Marshall 1973). Finally there was siltation of the spawning grounds between the Comox Lake and the diversion dam.

Whether or not the conservation efforts were responsible for the increase in numbers of summer chinook spawning since the early 1970s (Fig. 2) cannot be ascertained, although there is every reason to believe that they were contributing factors. The summer chinook run has yet to reach historical levels, and indeed has varied considerably from year to year. Males have been returning at a higher rate than females, who showed a slow but steady increase in abundance until 1990. Such changes might be related to the production and survival of smolts and fry, or perhaps they could be explained by predation and an intense selection by fisheries.

Since 1975, seals and humans have intercepted, at a minimum, between 54% and 82% of the adult summer chinook that were destined for the Puntledge River. In 1990, the accountable stock size was 3,673 fish (= 929 commercial catch + 246 sport catch + 869 harbour seal kill + 1,629 escapement), of which, 32% were caught by sport and commercial fishermen, 24% were consumed by harbour seals, and 44% reached the security of the spawning grounds. Ten years earlier (1978-81), only 17% of the stock escaped (74% were intercepted by fisheries and 9% were consumed by harbour seals - assuming harbour seals consumed 35% of the chinook that return to the estuary, as in 1990).

Fisheries have historically been a greater source of mortality on the summer chinook than have harbour seals. However, in recent years they appear to be inflicting comparable levels of mortalities due to reductions in fishery exploitation rates on this stock and the growth of the seal population in the Comox estuary.

Fishery takes could be further reduced by raising the size limit imposed on the fishery to protect adult females, or by closing all chinook fisheries to protect the few Puntledge fish that are mixed with other targeted stocks. Chinook are commonly harvested in mixed-stock fisheries that are unable to differentiate between fish from healthy productive populations and those from populations in need of conservation. Actions to conserve these less productive populations would likely have significant social and economic costs from lost fishing opportunities on the healthier and more abundant chinook populations.

Harbour seal predation on the summer chinook may be easier to address because it is concentrated like a terminal fishery in the estuary and lower river. Deterring seals from feeding in the river (using acoustical devices) or physically removing (either lethal or live capture) from the Puntledge system could conceivably raise the spawning escapement by up to 53%. Further reductions in ocean fisheries could theoretically raise this to as high as 118%.

There seems little doubt that hydroelectric development caused the initial decline of the summer chinook through the 1960s and into the 1970s. It is also likely that significant catches by sport and commercial fisheries impeded recovery through the late 1970s and early 1980s. Similarly, fishery size restrictions and genetic crosses may have affected the integrity of the stock through the 1980s. In the 1990s, the summer chinook continue to contend with fisheries, albeit at reduced levels, but are now faced with an increasing harbour seal population that has taken up residency in the Comox Estuary.

Development of a conservation plan is urgently needed for the Puntledge River summer chinook and should be given high priority. Management actions need contemplation given the severely depressed size of the spawning population of Puntledge summer chinook and the generally poor marine survival of chinook in the Strait of Georgia (see Appendix I, PSC 1994). Such decisions will likely involve difficult choices. Commercial fishing mortalities have recently been reduced and will be further reduced if conservation actions are taken in ocean fisheries during 1996 and 1997. Sport fishing mortalities may also be reduced in the coming years for similar reasons. However, the benefit of these actions will likely be curtailed by seal predation in the terminal area unless they too reduce their take. As things now stand, the mature chinook that escape the ocean fisheries, appear to be highly vulnerable to being eaten by the expanding harbour seal population in the river and estuary.

Historically, Puntledge summer chinook were consumed by both marine mammals and aboriginal peoples in a relatively pristine system. Since that time however, the river has been dammed and dredged, and ocean fisheries have undergone dramatic technological changes. The summer chinook population has already been through one major depression in population size in recent times, and appears to now be in the throws of another. Whether or not the Puntledge population can be conserved in the long term, and whether it can be done at a socially acceptable cost, remains to be seen.

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Tables

Table 1. Mean weight and post-orbital -hypural length of males and females seined from the river and spawning channel in October 1991.

Sex	Location	Number	Weight (kg)			Length (cm)		
		Returned	*n*	$\bar{x}$	*sd*	*n*	$\bar{x}$	*sd*
Males	Channel	582	325	3.64	1.96	366	54.62	9.58
	River	93	44	5.20	3.28	46	59.64	12.78
Females	Channel	247	190	7.58	1.96	217	70.82	6.50
	River	110	101	8.91	2.15	103	73.88	6.14

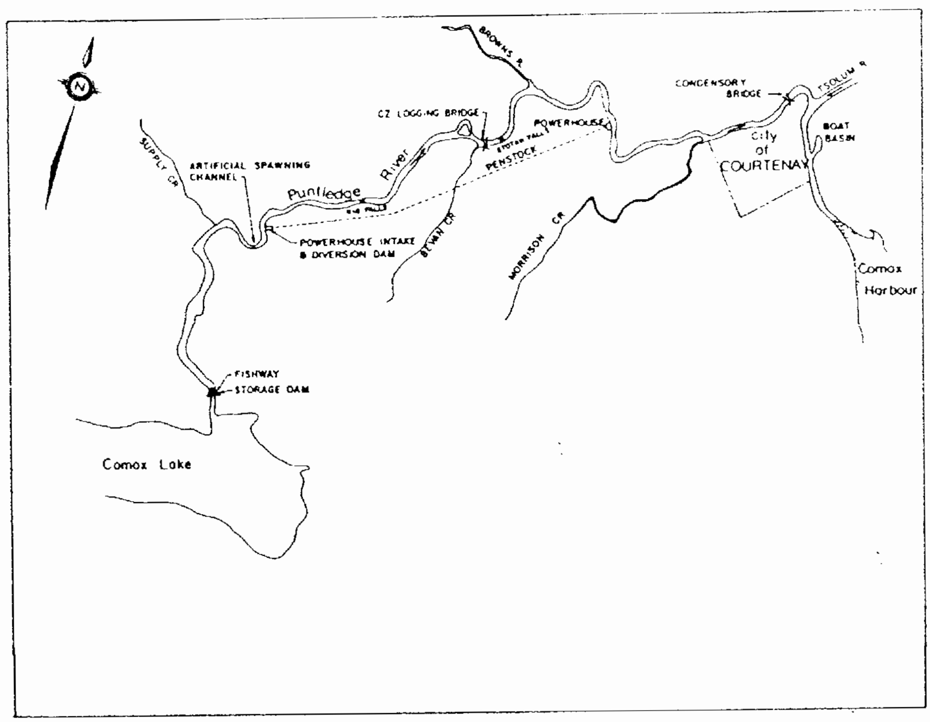

Fig. 1. Map of the Puntledge River showing the hydro-electric installations and location of the spawning channel and major tributaries.

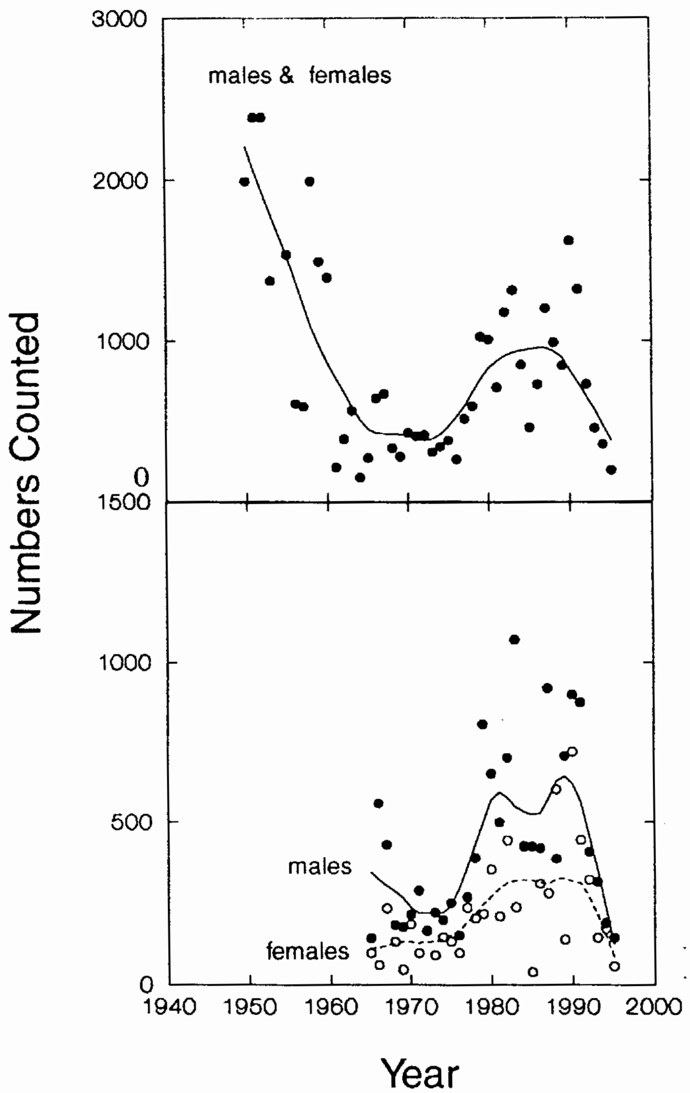

Fig. 2. Numbers of male and female summer chinook counted at the spawning channel and in the river from 1949 to 1995. Note that in 1949 and 1954 the total number of fish counted were 5,000 and 5,200 respectively. The data were fit with nonparametric regressions (lowess), using f=0.33.

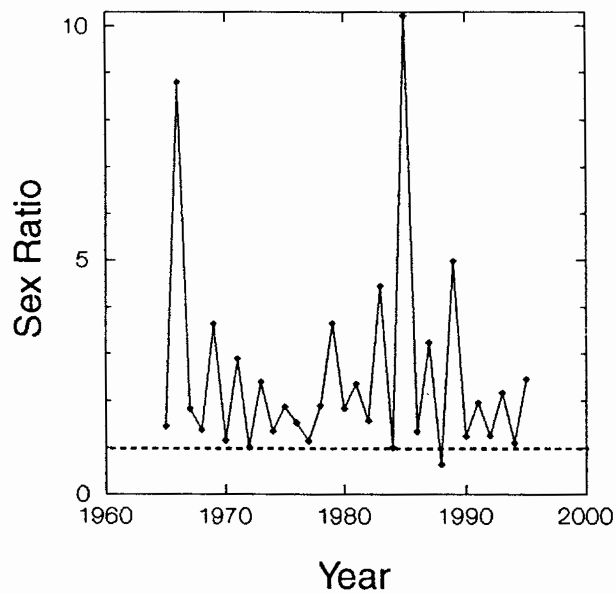

Fig. 3. Ratio of male to female spawners. The dashed line represents one male for every female.

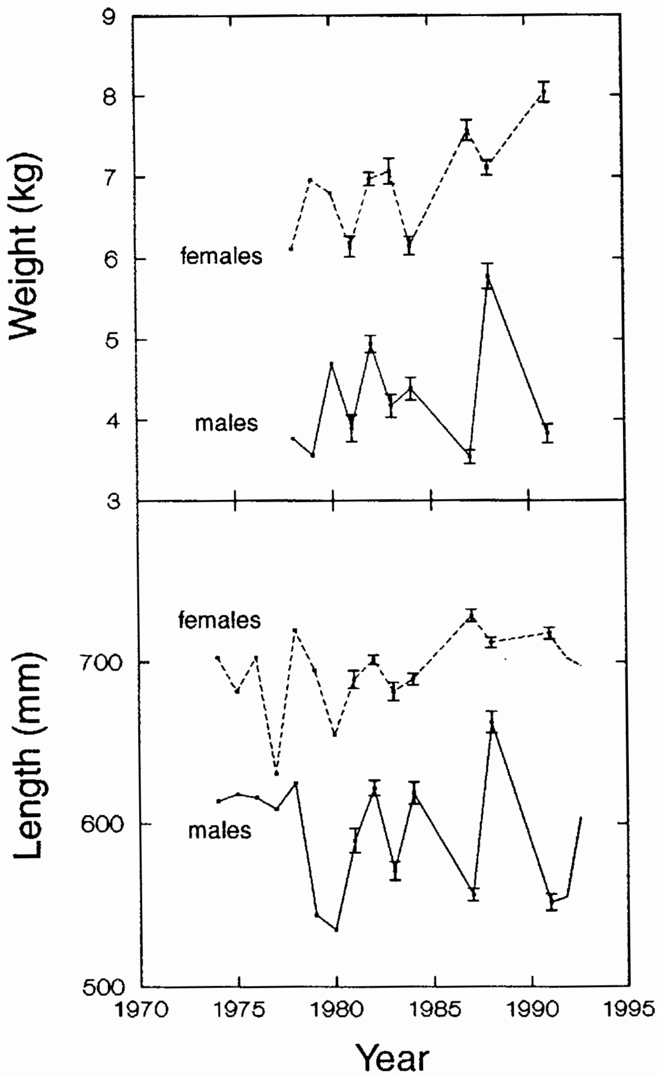

Fig. 4. The mean length and weight of spawning males and females from 1974 to 1993. Standard error bars were unobtainable prior to 1981.

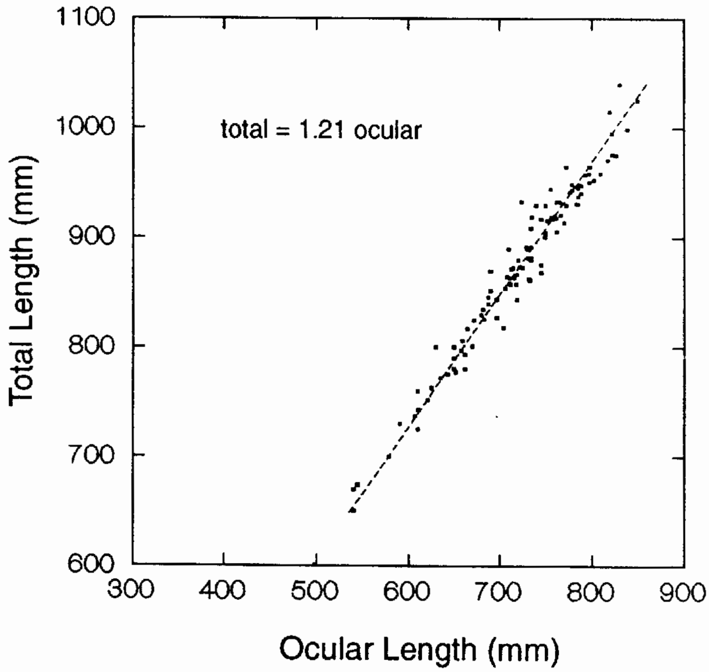

Fig. 5. Relationship between post-orbital-hypural length and total body length.

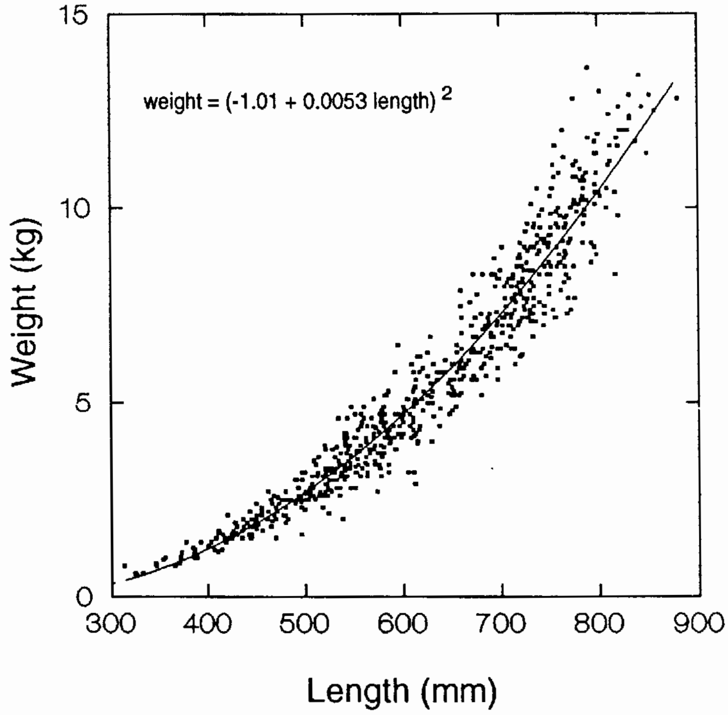

Fig. 6. Length-weight relationship for spawners sampled in October 1991.

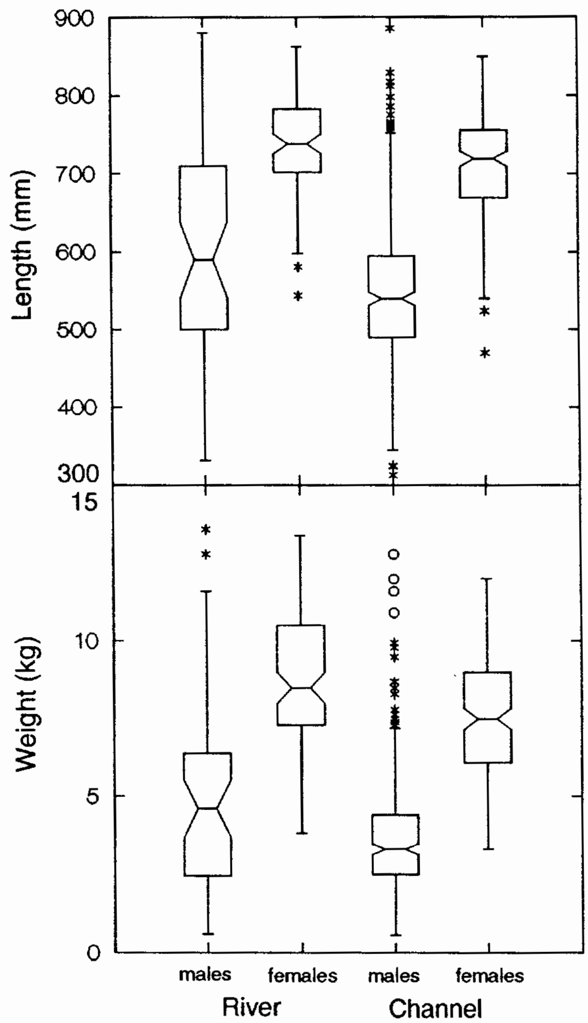

Fig. 7. Distribution of weights and post-orbital-hypural lengths of male and female chinook sampled from the river and spawning channel in 1991. The line in the middle of each box shows the median. The central 50% of the data is shown by the length of the rectangle, and the vertical lines show how stretched the tails of the distribution are (25% of the data in each tail). Outliers are shown by stars and open circles. If the notches (confidence limits) in the box plots do not overlap, the null hypothesis that the true medians are equal can be rejected with approximately 95% confidence.

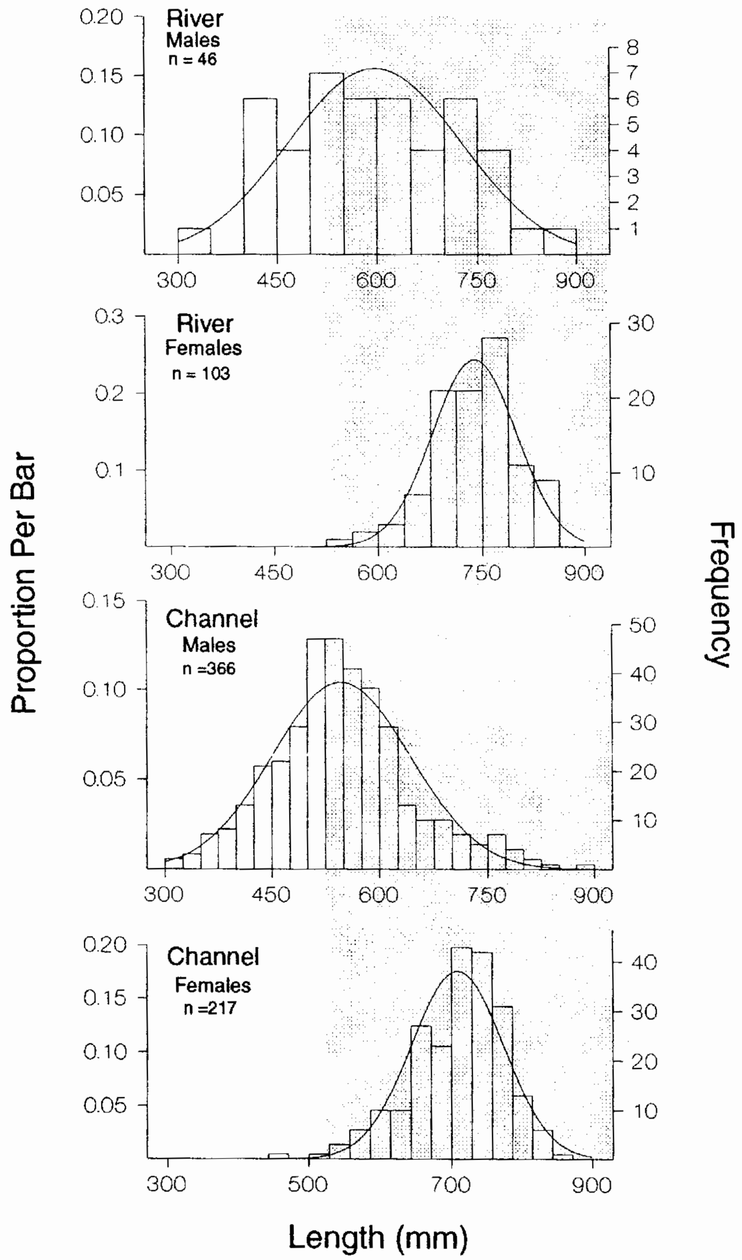

Fig. 8. Histogram of post-orbital-hypural length of males and females sampled from the river and spawning channel in 1991. The scale on the right measures the count in each bar. The scale on the left measures the proportion of cases falling in each bar divided by the sample standard deviation. The sample mean and standard deviation were used to superimpose a normal curve to visually determine whether the data were sampled from a normal distribution. The shaded region (Length > 560 mm) highlights the size of fish that could be legally kept by the sport fishery in 1991.

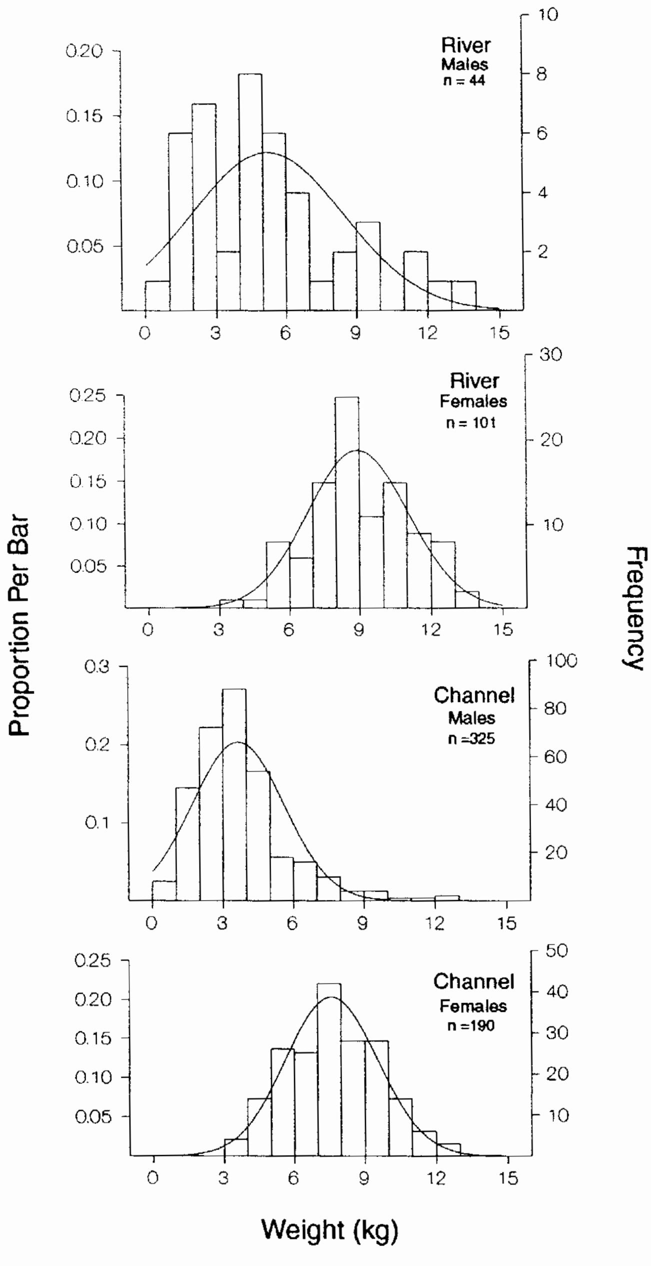

Fig. 9. Histogram of body weight of males and females sampled from the river and spawning channel in 1991. Rest of caption as in Fig. 8.

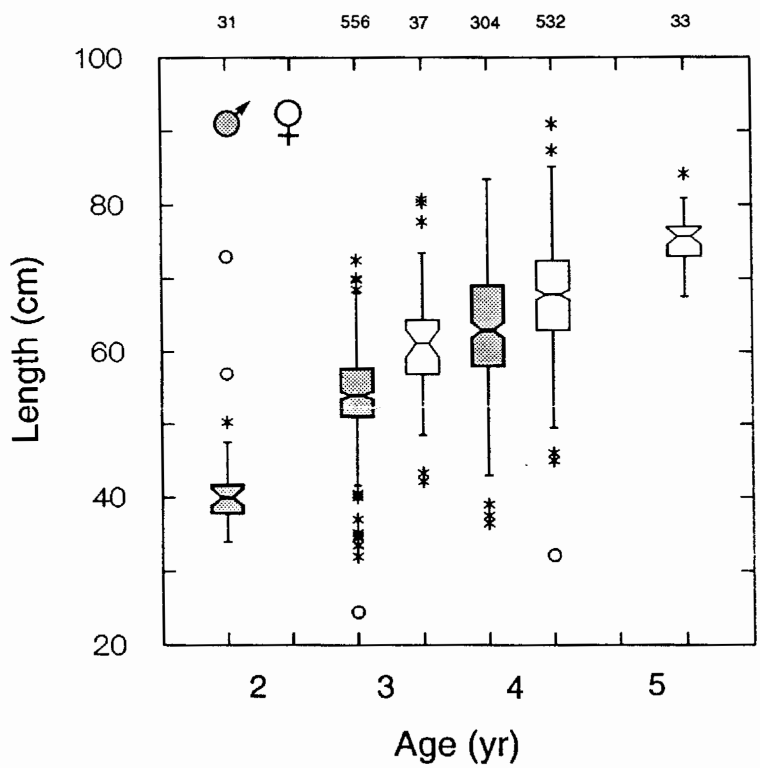

Fig. 10. Distribution of lengths (post-orbital-hypural) from known aged male and female summer chinook (1975-91). Ages were determined from coded wire tags. Sample sizes are shown at the top of the figure. Rest of caption as in Fig. 6.

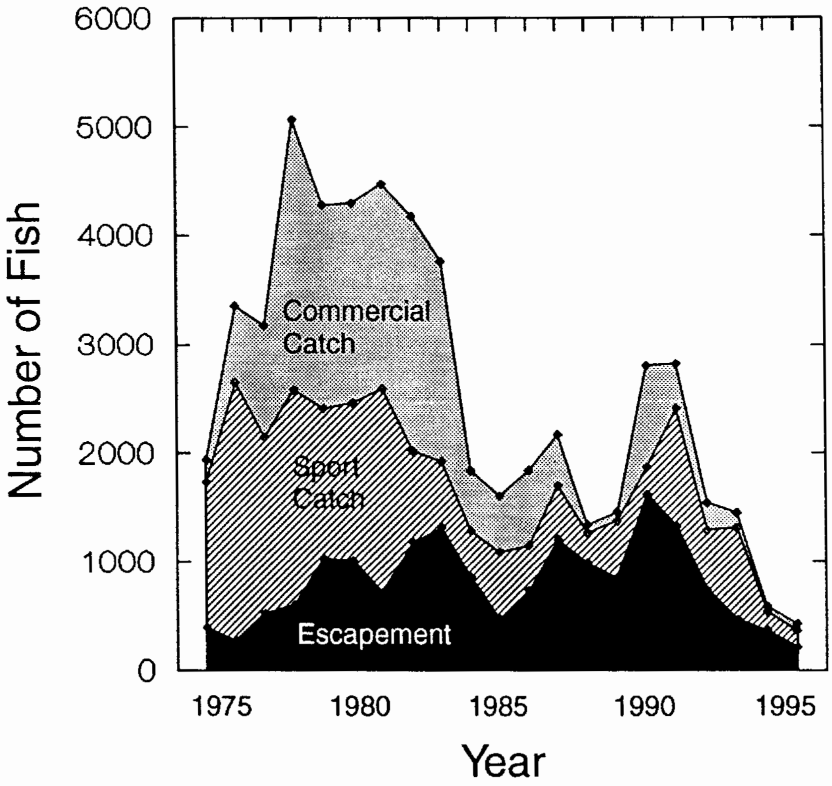

Fig. 11. Number of spawners (escapement) and the number of Puntledge river summer chinook caught by sport and commercial fisheries.

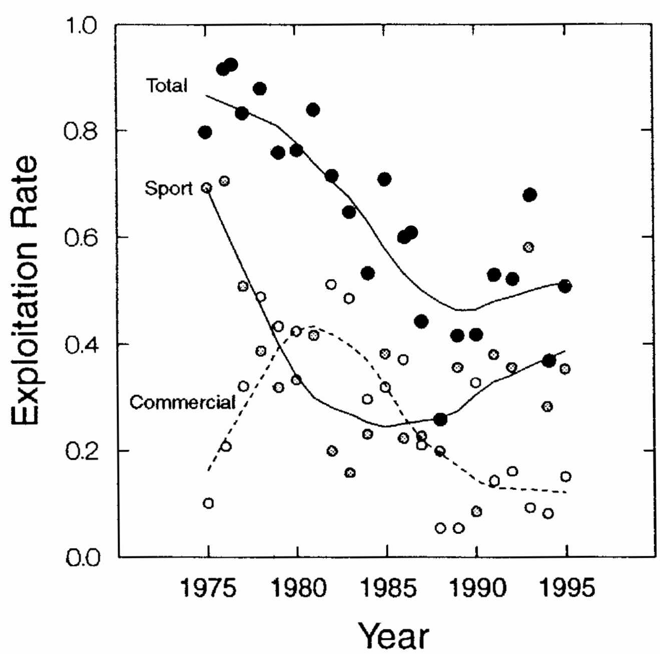

Fig. 12. Rate of exploitation by sport and commercial fisheries on Puntledge River summer chinook. Exploitation rates equalled the number of fish caught by the respective fisheries divided by the total catch plus escapement (from Fig. 11). Trends in exploitation rates are described with nonparametric regressions, *lowess* (Cleveland, 1984; Efron and Tibshirani, 1991).

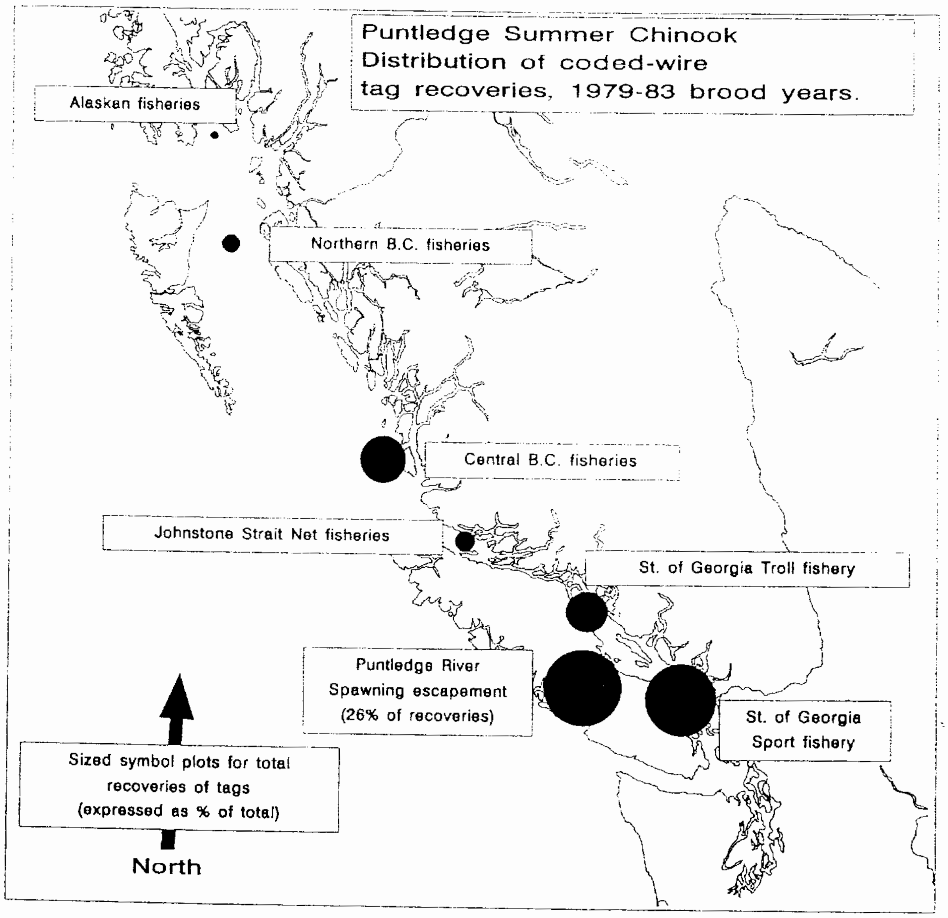

Fig. 13. Distribution of coded wire tags recovered from Puntledge summer chinook (brood years: 1979-83).

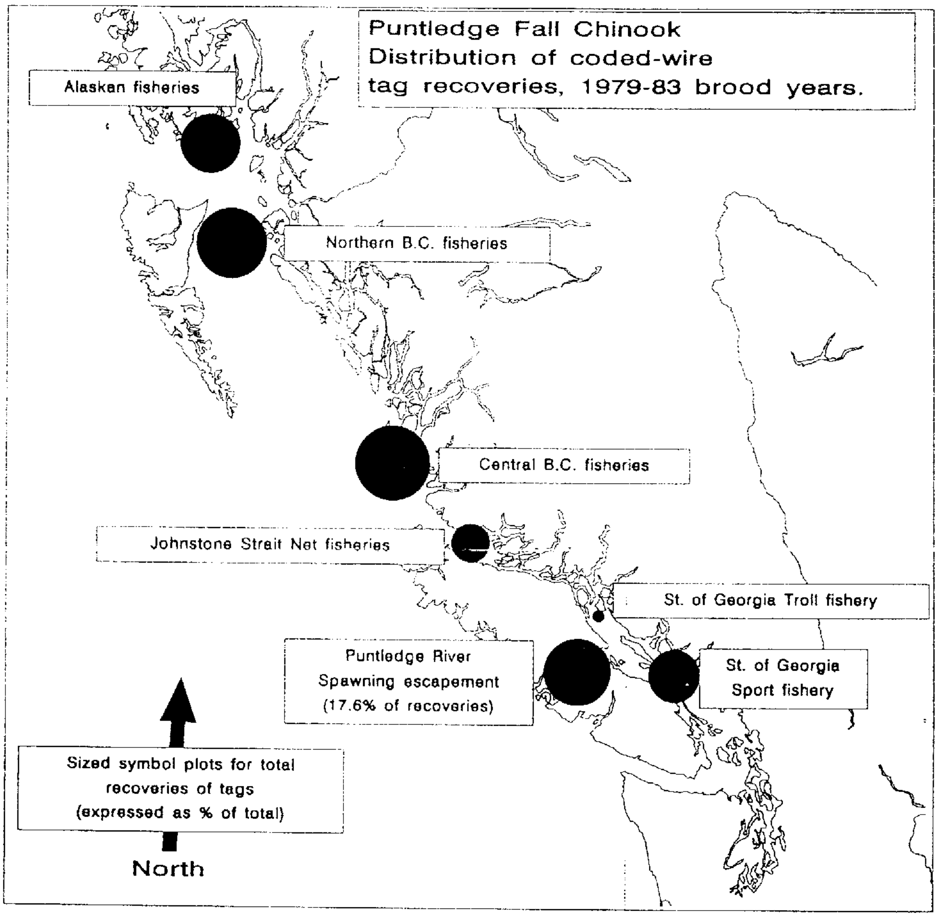

Fig. 14. Distribution of coded wire tags recovered from Puntledge fall chinook (brood years: 1979-83).

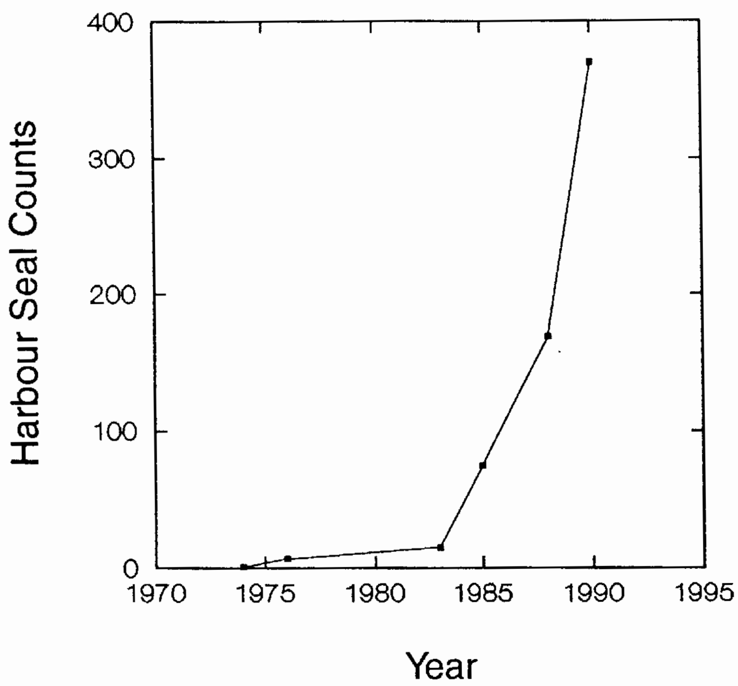

Fig. 15. Numbers of harbour seals counted in Comox Harbour during the month of August.