Pacific Stock Assessment
Review Committee

PSARC Working Paper S94-4

APPROVED

Update of Stock Status Information for Early Run Skeena River Coho Salmon (Through the 1993 Return Year)

by

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INTRODUCTION

Conservation concerns for the upper Skeena River and Bulkley River coho stocks were first raised by the Pacific Stock Assessment Review Committee (PSARC) in 1986 (Stocker 1987). Subsequently, stock assessment advice for early run Skeena River coho salmon was provided in two PSARC working papers[1]. The recommendations contained in those papers and management responses are summarized in Table 1.

The primary advice of the previous assessments was the setting of a fishery escapement goal of 33,000 fish, expressed as a target test fishery index in the lower Skeena River. This goal was derived from a stock recruit relationship using reconstructed run size data and historical cumulative test fishery indices to and inclusive of August 25th.

This paper updates stock status information used in the previous two papers and examines some new information on juvenile rearing densities which has been collected over the past 7 years but which has not been formally analyzed to date. We do not review the appropriateness of the recommended escapement goal in this working paper. However, we do make recommendations for an improved assessment program for Skeena River coho.

STOCK DEFINITION

Early run Skeena River coho are comprised of fish from an unknown number of discrete populations that migrate upstream through the lower river prior to August 25th (Kadowaki et al. 1992). Coded wire tag information suggests that there is considerable overlap in run timing among these populations, that their run timing is usually very protracted, and that there is considerable overlap with the major Skeena pink and sockeye stocks. The designation of an early run stock aggregate is made for fishery management purposes. Other biological characteristics of the component stocks, e. g. productivity and age composition , may vary considerably.

TRENDS IN INDICES OF ABUNDANCE

Fishery Officer Estimates of Escapement

Fishery officer estimates of spawning escapement were reported previously in Kadowaki et al. (1992). The data of Figure 1 have been updated to include information collected through 1992. Data are from the Salmon Stock Assessment data base on the PBS VAX, with some modifications contained in the Fisheries Branch North Coast Management Biology data base. These modifications will be incorporated into the PBS data base. Lower Skeena escapements are a summation of escapements to all streams from Lorne Creek down to the McNeill River (Green River)(Sub-Areas 4B and part of 4A). The remainder of the Skeena watershed has been defined as the Upper Skeena (Sub-Areas 4C and 4D).

As noted in Kadowaki et al. (1992), fishery officer escapement estimates are not necessarily accurate or consistent indicators of spawning escapement. Rather they may be used with caution as trend indicators or indicators of presence and absence.

The temporal pattern of the fishery officer escapement estimates for the upper Skeena from 1970 onward is similar to the both the Babine fence index (Fig. 2) and to the Skeena test fishery index (Fig. 4). We do not know to what extent the fishery officer estimates are generated

[1] The 1987 working paper has been published as Kadowaki 1988.

independently of the Skeena test fishery and the Babine fence count, but the independence of the indices merits examination.

Babine Fence Coho Count

The Babine River salmon counting fence was constructed in 1946 with the intent of enumerating the large runs of sockeye salmon that spawn in the tributaries of Babine Lake. Other species spawn in the tributaries of the lake. Pink salmon can be abundant in some years while chinook, coho and steelhead runs are less numerous but are still important contributors to the total Skeena production of these species. Because the primary intent of the fence operation is the enumeration of sockeye, counts of the other species are often incomplete.

The coho run through the fence begins during the sockeye migration and extends well beyond it. The enumeration program has concluded on dates ranging from September 13th to November 13th (median date: October 1st). In many years only the first half or less of the coho run is counted before the enumeration program ends.

In most years the fence was closed in the last week of September or the first week of October (Table 2). Although the total count is affected by the date of closing the fence, use of the count to the earliest date of closure (Sept. 13th, herein terned the Babine fence index) assumes that there have been no systematic changes in the run timing of the fish through the fence. We present both the total counts and the cumulative count to September 13th (Table 2). In 1992 and 1993 the fence counts may be underestimates of the number of coho, perhaps by as much as 100%, due to either an inexperienced crew (1992) or to unfavorable viewing conditions (1993).

The fence counts indicate the following about the abundance of coho in the Babine Lake watershed:

a) The 1951 slide reduced the numbers of coho reaching Babine Lake. The count on Sept. 13th dropped to 444 from a pre-slide level that ranged between 4,983 and 8,687. The slide also appears to have delayed migrating salmon. The apparent magnitude of the reduction in 1951 was less severe when total counts are contrasted (Table 2; Figs. 2, 3). In the year following the slide, the count to Sept. 13th is among the lowest in the record, but the total count is the highest on record.

b) The number of coho in the affected cycle increased rapidly following the slide and by 1966 had reached probable pre-slide levels.

c) The marked three year periodicity in the fence count of the 1951 cycle Fig. 2 is strong evidence that the Babine produces mostly 1^+ (yearling) smolts. The periodicity introduced by the 1951 slide appears to persist until 1975.)

d) Abundance decreased abruptly in at least two of the three cycles (1952 and 1953 cycles) and more gradually in the other cycle, between 1973 and 1980 and has remained low in subsequent years in all cycles. Beginning in the 60's, decade averages of 7,533, 3,760, 1,667 and 1,235 have been recorded.

e) The index in 1993 was the lowest on record and 1992 was the third lowest on record Although actual coho escapement may not have been this low because of possible bias in the counts for these years (see above), it is unlikely that the bias was sufficiently large to substantially change their rankings.

The effects of the slide on coho abundance are important for two reasons. First, during the early period of the fence record, the Babine fence count is the only quantitative measure of abundance for early Skeena coho. It is therefore, the only point of reference for subsequent measures of abundance. Second, the rapid recovery in numbers of the affected cycle demonstrates that the population was resilient during the 60's. We infer from this recovery that the population was not over-exploited during that period.

The observed escapements at the Babine fence since the early 1970's are consistent with over-exploitation from the mid-70's to the present. The rapid recovery of escapements as indexed by the fence count following the slide of 1951 contrasts sharply with the failure of the index to recover after similarly poor returns that began in 1979. Significantly, the 6–yr. period in the mid 1970's during which the declines in coho escapements were observed coincides with the rapid expansion of the river mouth fisheries targeted on the enhanced Babine sockeye, and may also have been coincident with decreased smolt survivals for at least Babine coho (please see following section).

Skeena River Test Fishery

The Skeena River test fishery was established in 1956 to monitor the strength of pink and sockeye runs during the fishing season. Indices are generated for all salmon species, but only those for pink and sockeye are calibrated with estimated escapements. Test fishing has ended between August 24th and September 20th (median date: August 28th) so, as is the case at the Babine fence, the program does not cover the entire coho run.

The value of the Skeena test fishery index (Table 2) is the cumulative value of the fishery index to August 24th. Decadal averages from the 1960's to the 1990's of 117.17, 86.50, 55.47 and 39.15 have decreased at a rate of approximately 30%·decade^{-1}. The indices in 1992 and 1993 were the lowest and second lowest on record, respectively. However, very low river discharge levels in 1992 and 1993 resulted in extremely clear water conditions that appeared to make the test fishing net less efficient for all salmon species. For instance, the index for sockeye was found to have an approximate 30 percent negative bias. Even allowing for the same bias in the coho index, the rankings in 1992 and 1993 remain the lowest on record.

The test fishery index for coho is based on a constant expansion of the catch in the fishery (Kadowaki 1985). Although the test fishery indices for sockeye are compared to escapements, there has been no calibration for coho. Since 1981 the test fishery appears to have become progressively less efficient[2]. This loss of efficiency has been corrected through the development of a variable mulitiplier, which is based on a comparison of the test fishery index and estimated sockeye escapements. The effect of applying the variable multiplier to the coho index is to largely reverse the declining index through the 1980's and early 1990's (Fig. 5). The temporal pattern of the corrected index then more closely resembles the fishery officer counts (Fig. 1).

The temporal patterns of the uncorrected test fishery index (Fig. 4) and the Babine fence index and total count (Figs. 2 and 3) are superficially similar, in that they both show declines beginning in the mid–70's. When plotted against one another, however, a more complex relationship is revealed (Fig. 6). Before 1977 there was no relationship between the two indices of abundance while after 1977 there was a strong curvilinear relationship between the two

[2] DFO memorandum from Steve Cox-Rogers, NCD, DFO Prince Rupert to Bob Hooton, MELP, Smithers, dated 17 February 1994.

indices ($r = 0.81$, n=17, P<0.001). Large fisheries targeted on enhanced Babine sockeye began at this time in the approaches to the Skeena. The relationships are robust to changes of several years in either direction.

Over the period 1977 to 1993 the correlation between the corrected Skeena test fishery index and the Babine fence count is weaker than for the uncorrected index ($r = 0.53$ vs. 0.81). Correlations during other periods and between the total Babine fence count and the indices are similarly weaker for the corrected index. This suggests to us that acceptance of the corrected index as the best index of coho run strength is unwarranted at this time. Calibration of the index with more comprehensive escapement information is required.

Explanations for the improved correlation between the two indices for the period after 1976 compared to the period before include:

a) increased accuracy of the test fishing index that may have resulted from more consistent methods, or changes or reduced variability in fish behavior, i.e. the test fishery has become more accurate;

b) changes in the accuracy of counts of coho at the Babine fence;

c) an increase in the proportion of the early Skeena stock aggregate made up of Babine coho.

d) more similar abundance of all components of the early run Skeena coho, which includes Babine coho, due perhaps to more homogeneous environmental conditions across the watershed or to a uniform and high mortality factor exerted on all or most of the sub-stocks.

There are no data with which to directly assess any of these possible explanations. We know of no systematic change in the prosecution of the test fishery that would have resulted in increased accuracy. The possibility that fish behavior changed over a very short period in a way that dramatically increased the accuracy of the test fishery cannot be evaluated but, in our opinion, is unlikely. The accuracy of the counts at the Babine fence could have been affected by the increased numbers of sockeye being counted. However, any such changes that occurred would not have produced the reduced variability in the fence counts and would not have led to observed relationship between the indices.

The appearance of a strong relationship after 1976 would have been observed if stocks other than the Babine precipitously declined in abundance. The test fishing index would then be indexing only the Babine stock. However, if this shift in stock abundance had occurred then the resulting relationship should have had a markedly greater y–intercept, not a lower one as is observed.

Holtby and Scrivener (1990) have shown that under moderate levels of exploitation approximately 50% of the variability in adult coho abundance is due to variability in fresh water. The size of the upper Skeena watershed with accompanying differences in latitude, rainfall and the proportion of production originating in large lakes would likely result in an even greater proportion of the observed variability in the aggregate arising from factors acting during the juvenile phases in fresh waters. The scale of the watershed makes it unlikely, in our opinion, that a sudden homogenization of the environment could account for the synchronization of population levels.

Another critical period during which variations in survival account for most of the remaining variability in adult abundance is smolt migration (Holtby et al. 1990). The run timing of Babine coho is unknown, but in coastal lakes coho and sockeye leave at the same time (M. Johannes, BSB, PBS, Nanaimo, pers. comm.). Since they have similar distances to travel to the ocean it is likely that smolts from the entire upper Skeena are migrating at roughly the same time and experience similar conditions during early sea-life. Within Barkley Sound coho, sockeye and chinook smolts show similar temporal patterns in survival (Holtby et al. 1990, K. Hyatt, BSB, PBS, Nanaimo, pers. comm.).

Sockeye smolt survivals may be calculated over the period during which coho escapements fell in the mid-1970's from the data presented in Macdonal et al. (1987). The survival of sockeye smolts is inversely related to smolt numbers (Fig. 7A). It is presumed that smolt survival is inversely size-dependent and that size and rearing densities are inversely related. The Skeena test fishery index is not correlated with sockeye smolt survival however ($r = 0.203$, $P > 0.25$, $n = 23$; Fig. 7B). However, there is a inverse relationship between the Skeena test fishery index and the number of sockeye smolts ($r = -0.49$, $P = 0.02$, $n = 23$, Fig. 7C). There is insufficient data to exclude the possibility that coho smolt survival has declined because of some interaction with sockeye, possibly in the river during seaward migration.

Holtby and Scrivener (1990) modeled a coho population under moderate and constant exploitation rates. If a mortality factor such as smolt survival or the fishery exploitation rate were to suddenly increase to very high levels for most component stocks, we think it plausible that inter-stock variability due to environmental factors would be effectively masked, effectively synchronizing abundance levels in most component stocks.

Other escapement measures

We have four additional direct measures of escapement, three to various areas in the Skeena and the fourth to a coastal river close to the Skeena..

Houston fence counts

A volunteer group has operated a counting fence on the Bulkley River near Houston since 1987. A temporary fence was washed out in 1987 and 1988 and replaced with a permanent structure in 1989. The fence was operated for the entire period of the coho run and provided a complete count of coho into the Bulkley above Houston. There were operational problems in 1993 which may have allowed the undetected passage of a small numbers of adults, but in the opinion of the crew chief, few adults passed undetected (pers. comm. M. O'Neil, Toboggan Creek Hatchery).

The fence count at Houston has declined continuously since 1989 and the trend is nearly identical to that seen in the Babine fence index and very similar to the Skeena test fishing index (Fig. 8).

Telkwa River surveys

Helicopter surveys of a 16 to 26 km section of the Telkwa River have been conducted in 1982, 1984, 1988 and 1993 (Bustard 1988; K. Simpson, PBS, unpublished data). The surveys were done in two or three, 2 to 3 hr. flights in early mid and late November. (No early Nov. flights were done in 1982 and 1988). We have used peak counts of live and dead fish for the surveyed reaches including Elliott Creek (a tributary of the Telkwa River). No estimates of observer efficiency are available. Viewing conditions have probably been highly variable within and between years but the effect of conditions on observer efficiency are unknown. Interpretation of the counts is also compromised by the lack of quantitative information prior to 1982. Historical escapements have ranged from 100 to 1,200 (Smith and Lucop 1966). Since the river is only accessible by helicopter, we doubt that those estimates are based on more than a cursory inspection of areas near the confluence with the Bulkley River, areas in which few, if any coho, are now seen.

With these caveats in mind, we note that the count in 1993 was the highest of the four years and was nearly the same as the counts in 1982 and 1984. Recalling that both the Skeena test fishing index and the Babine fence index were thought to be biased low in both 1992 and 1993, the counts at Telkwa are not inconsistent with the index time series, which indicate low but stable coho numbers.

Simulation studies for coastal coho indicate that at escapements below 5 to 7 females•km^{-1}, population numbers become highly variable and extinction because of environmental variability is a frequent event (LBH, unpubl. data). The accessible length of the Telkwa and tributaries is over 30 km and those reaches that we have seen appear typical of other systems in the Bulkley River valley that are capable of producing coho salmon. Assuming that peak counts are scaleable to total escapement with a factor of between 2 and 5 (Holtby 1993), the peak counts in the Telkwa suggest escapements in the range of 150–600 adults. Assuming 30 km of productive habitat and a 1:1 sex ratio (Holtby and Healey 1988), the actual escapements were approximately 2 to 10 females•km^{-1}. For a coastal stream, the minimum escapement is approximately 7 females•km^{-1}, and the desirable escapement is 20 to 25 females•km^{-1} (LBH, unpubl. data). Further assuming that population levels in the 1950's and 1960's were near this desirable level, both the Skeena test fishery and the Babine fence count indicate that current escapements are approximately 25% of those levels. Thus, although the calculations for the Telkwa are crude, they are consistent with current levels of the two major abundance indices.

Toboggan Creek fence counts

Returning wild and cultured coho are counted at a fence on Toboggan Creek, a lower tributary of the Bulkley River near Smithers. The fence was operated throughout the adult migration beginning in 1988, although the fence procedures were not documented in the first year of operation. During the period of fence operations (mid-August to early November) the fence has been topped at least once in every year except 1990. To estimate the number of fish that pass upstream undetected, marks are applied to <u>most</u> of the fish passed through the fence. At various times throughout the run and at various locations above the fence, fish are netted out of the stream, and the numbers of marked and unmarked fish tallied.

There are several problems with the data that have been collected. The fish were not individually marked at the fence so it is not possible to determine the number of marks at risk during subsequent river recoveries. There was undoubtedly mortality in the river after marking and before recovery and the procedures followed do not allow any estimate of this mortality. Marks were not applied to all of the fish passed through the fence. While there may have been legitimate logistical reasons for this, daily marking records were not kept and we suspect that marking rates were dependent on the numbers of fish processed each day. In 1990 the fence did not wash out and all fish should have been passed over the fence. We would expect that the mark rates during up-river recoveries should have been approximately equal to the applied mark rate of 0.782. Only two recoveries were made that year (because the fence did not wash out) and in both the observed mark rate (0.43 and 0.63) was less than the applied rate. These discrepancies could have arisen because of missed marks during the recovery, undetected fish passage through the fence, migration into the system prior to the start of fence operations, greater or faster mortality of marked fish or different behavior of marked and unmarked fish. Unknown mortality schedules after marking, uncertainties about transit times for fish between the fence and recovery areas, variable marking rates, and uncertainties over mark recovery are violations of the assumptions imposed by mark-recapture estimations. Finally, variable numbers of coho spawn below the fence and no particular method was used to estimate the numbers of those fish and no attempt was made to determine the number of adipose clipped fish spawning below the fence.

Despite the numerous shortcomings of the fence program, the data collected there are the only escapement recoveries of CWT'd fish in the Skeena drainage and are one of only a very small number of escapement counts. Consequently, we have estimated escapements of wild (no CWT) and hatchery fish as follows:

1. We have assumed that the fish took two days to move between the fence and the recovery sites, that marked and unmarked fish had the same in-river mortalities, that marks were applied throughout the run at the overall average rate and that all marks recovered in-river were seen and recorded;
2. For each in-river recovery we estimated the number of CWT and non-CWT fish present by Peterson mark-recapture. We distinguished CWT'd and non-CWT'd fish because by doing so we could estimate the number of both wild and hatchery fish returning to the system;
3. We then divided each estimate by the number of fish actually counted to give a fence expansion factor;
4. We then found the average expansion factor and estimated the escapement of CWT'd and non-CWT'd fish by multiplying the final total fence counts by the average expansion factors. There were two principal areas where fish were recovered; in Elliot Crrek, the tributary where the hatchery is located, and in Glacier Gultch, a wild spawning area well upstream of Elliot Creek. Hatchery (CWT'd) fish were less common in Glacier Gultch, and vice versa, so only the average expansion factors from Elliot Creek were applied to hatchery fish and vice versa.
5. To that number we added the number of CWT and non-CWT'd fish that spawned below the fence calculated by multiplying the observed CWT'd rate at the fence by the estimated number of spawners below the fence.

Wild escapements to Toboggan Creek decreased in 1992 and 1993 from what was a relatively stable escapement in the previous three years (Fig. 8). The escapement time series has the same pattern as both the Skeena test fishery index and the Babine fence index (Fig. 8) and is significantly correlated with both ($r = 0.88$ & 0.87, $P = 0.048$ & 0.054 respectively). CWT returns will be discussed in a latter section.

Lachmach River fence counts

Coho smolts and adults were counted at fences on the Lachmach River beginning in 1987 for smolts and 1989 for adults (Finnegan et al. 1990; Davies 1991; Davies et al. 1991; Finnegan 1991; Lane and Finnegan 1991; Baillie 1994; Lane and Baillie 1994; B. Finnegan and S. Baillie, unpubl. data). The Lachmach is located at the head of Work Channel, and is not within the Skeena drainage. The Lachmach is a valuable contrast with the early run Skeena stock because the Lachmach is a coastal stock and most, if not all, of our understanding of exploited coho populations has been derived from the study of coastal populations. We will show later in this paper that the catch distribution of Lachmach fish is similar to that of coho originating in the upper Skeena. We hypothesize that escapement trends in the upper Skeena and at Lachmach should be similar if variations in ocean conditions and ocean fisheries underlie escapement trends in the early run Skeena stock.

The fence count at Lachmach shows no consistent trend between 1989 and 1993, and, in particular, shows no abrupt decline in 1992 and 1993 as do some components of the early run Skeena stock aggregate (Fig. 8).

Juvenile presence/absence

Newly emerged coho salmon fry show a pronounced dispersive behavior shortly after emergence (Chapman 1962; Mason and Chapman 1965). The presence of one or two females•km^{-1} and this dispersive behavior results in the presence of coho fry throughout small streams (≈3 km in length) (LBH, unpubl. data). Thus, at some very low level of escapement, presence/absence data becomes an insensitive indicator of spawner abundance. In contrast, if coho are absent from otherwise suitable habitat, there is justification for inferring that no escapement occurred to that stream. If coho are absent from a large proportion of suitable habitat over a broad geographic area, there is reason to believe that there is a serious conservation problem.

Sites in the upper Bulkley River and Morice River sites have been surveyed for juvenile coho since 1987. The surveys were done in mid to late August, generally over a 10–d period. Sampling locations have varied somewhat over this period as available manpower and time have fluctuated and as physical changes to the sites from storms have isolated pools etc. Nevertheless, there are continuous records or near-continuous records at approximately 50% of the sites (Tables 3, 4). The uppermost sites in the Bulkley River (the first two sites in Table 3) were above an obstruction that may block coho. All of the remaining sites were accessible to the mainstem Bulkley or Morice at the time of sampling and appeared to the field crews as potential coho habitat, i.e. they were low gradient with available pools. The sampling methods used varied with time and site. Various combinations of minnow traps, electro fishers, and seines have been used, as was deemed appropriate at each site by the field crew.

The proportion of sites or streams where coho were present was calculated in a variety of ways (Tables 3 and 4). The most appropriate calculation is that of the proportion of streams where 0^+ juveniles were present. This calculation circumvents problems with calculations based on sites rather than streams, where disproportionate effort on some streams may bias the proportion.

Age 0^+ coho were present in over 80% of the streams, side-channels and ponds of the Morice River in five of seven years and were present in over 60% of those locations in all years

(Table 4). In contrast, in the Bulkley River and its tributaries, coho were present in less than 40% of the locations in five of seven years, and were present in more than 80% of those locations in only one year (Table 3). The temporal trends in the proportion of occupied streams (Figs. 9A,B) indicate that escapements to the Morice have been stable. Escapements to the Bulkley River have been more variable and in recent years have been very low. The small proportion of sites in the Bulkley that are occupied and the high level of variability in occupancy indicate a serious conservation problem.

The proportion of occupied streams in the Bulkley was weakly related to the Skeena test fishery index ($r = 0.37$, $P = 0.27$; Fig. 10A). There was no relationship between the Skeena test fishery index and the proportion of occupied sites in Morice River (Fig. 10B).

Juvenile densities and size

The relationships between the size and abundance of juveniles and escapements is of considerable interest because of the potential cost savings and increased spatial coverage that would realized if population trends, and especially escapement, could be monitored through juvenile surveys (Milner et al. 1985).

In streams, coho juveniles are territorial at least in the sense that they aggressively interact with one another and appear to defend preferred feeding areas in the stream. There is also abundant evidence that streams have carrying capacities that can defined in terms of the long term average number of fish present at some fixed point in time (Burns 1971; Grant and Kramer 1990) (usually late fall parr or smolts). Thus, in wild systems that are not undergoing habitat alteration and where escapements are adequate to fully "seed" the stream, the numbers of smolts produced is much more constant than the numbers of spawners that produced them. The loss of fish (either through mortality or emigration) is characterized as being density-dependent. The actual loss processes that underlie density-dependent loss are not well understood.

Another process in salmonid stream communities that is strongly density-dependent is growth. Conceptually this is easy to understand if it is the case that the amount of food available is insufficient for all fish to grow to their potential. As competition for food becomes more intense (i.e. as densities increase) the amount of food per individual decreases and the mean size of individuals falls. Since coho in streams are territorial, as densities increase the distribution of food between individuals becomes less equitable. As a result the size distribution of the fish, which reflects individual access to food, becomes increasingly skewed. Thus as densities increase the mean size of fish falls and the size distribution becomes increasingly skewed toward smaller individuals.

These processes lead to three expectations about the relationships between size, size distributions, juvenile densities and escapements. First, within a site or a set of homogeneous sites, forklength (FL) and density should be inversely related, and skewness of the FL distribution and density should be positively related, both over time and between sites. Second, within a site or a set of homogeneous, densities an the skewness of the FL distribution should be positively related to brood-year escapements and the mean FL should be inversely related to brood year escapements. Third, mean FL and skewness of the FL distribution should be more strongly related to density than to escapement since there can be considerable spatial and temporal variability in egg-to-fry survival.

Quantitative estimates of juvenile densities were made at some of the sites sampled during the upper Bulkley survey. Density estimates were made using either two-pass removal with either seines or electro-fishers or with Peterson mark-recapture with fish caught using a variety of methods. The sizes (fork length) of most of the coho caught were recorded. The very low abundance in general meant that there were only a few fish caught in many of the locations and years. Enough density and size data were available to warrant analysis ($n \approx 10$) only from McBride and Owen Creeks in the Morice drainage. Also fork lengths of all fish caught in the Morice drainage were pooled by year for the calculation of mean sizes and the skewness of the size distribution. Only 0^+ fish were included in these analyses. Size at age data were fragmentary. A break point of 75 mm, the largest FL of age 0^+ fish, was used when there was no readily identifiable break in the size distributions that was presumed to separate 0^+ from 1^+ fish. Both streams have been affected by rapidly increasing beaver populations, which may have limited adult access to the streams in some years. Very few samples had enough fish to reasonably calculate skewness, so that parameter was not examined.

There was a significant relationship between $\log_{10}$ FL and $\log_{10}$ density (Fig. 11A,B) with data covering multiple years and multiple sampling sites within each stream (Owen Creek $r = -0.91$; $P < 0.001$, $n = 9$; McBride Creek: $r = -0.74$, $P = 0.015$, $n = 10$). The density and mean FL of coho in McBride Creek were significantly related to the Skeena test fishery index (density: $r = 0.60$, $P = 0.05$, Fig. 12A; mean FL: $r = 0.81$, $P < 0.01$). In Owen Creek, neither density nor mean FL varied with the Skeena test fishery index.

FL data were pooled within years for all sites in the Morice drainage. There were too few fish in the Bulkley drainage in four of seven years, so further analysis was not warranted for that system. The mean FL and the skewness, by year, for the Morice were then related to the Skeena test fishery index and to each other. Skewness was inversely related to mean FL (Fig. 13A, $r = 0.80$, $P = 0.03$, $n = 7$) and positively related to the Skeena test fishery index (Fig. 13B, $r = 0.85$, $P = 0.02$). Mean FL was inversely related to the Skeena test fishery index (Fig 13C), although the relationship was only marginally significant ($r = 0.71$, $P = 0.08$, $n = 7$).

We draw two conclusions from the juvenile sampling data. First, juvenile sampling appears to have potential to at least augment adult counts as an assessment tool. It is important to sample intensively over a wide geographical area and to obtain both densities and adequate numbers of fish to characterize size distributions. It is also important to develop multiple time series of observations collected at the same sites using comparable technologies. Second, the various relationships between the juvenile sampling data the the Skeena test fishery index indicate that the escapement trends indexed by the test fishery are indicative of escapements to at least one major tributary of the Bulkley River.

Coded Wire Tag Analyses

In response to previous recommendations of PSARC concerning the CWT tagging of Skeena coho (Table 1), tagging was initiated at several enhanced sites of SEP facilities in the Skeena in the late 1980's. Tagging was also started at a wild trapping site on the Lachmach River in Work Channel. At one of the Skeena sites (Toboggan Creek) and at Lachmach, returning CWT'd adults are enumerated, enabling the calculation of fishery exploitation rates and smolt survival rates. For the remaining sites, only the proportion of tagged fish caught in the ocean fisheries can be calculated. All tags can be used to examine the catch distribution of tagged stocks.

Coded Wire Tag Data Assembly and Analysis of Catch Distributions

CWT recovery data were obtained from the Mark Recovery Program (MRP) database on the VAX computer located the Pacific Biological Stations. Observed recoveries were expanded to account for catch sampling rates. All tag codes contributing to fisheries from southeast Alaska to California (Table 5) were included in the raw data sets for each year. Recoveries included all coho CWTs reported by calendar year, regardless of age. CWT recoveries were first grouped by release site. Only release sites having codes accounting for at least 30 observed recoveries in all fisheries were used in the analysis. This screening was applied to eliminate the large random variation that can result from small numbers of recoveries. Estimated recoveries of all tag codes for each release site were then summed by the fisheries. Fisheries were excluded if they caught fewer than 50 tags (estimated). This screening was applied to exclude small fisheries that might have highly biased sample of the targeted stocks. Estimated recoveries for each release site were then converted to proportions by fishery. We then clustered the release sites using average centroid linkage operating on the matrix of Euclidean distances between release sites. Results from the years 1990 through 1993 are presented.

The distribution of recoveries in the ocean fisheries from four release sites (Lachmach, Toboggan, Babine, and Kitimat) are shown in Figs. 14 through 17. The catch distributions are very similar for all of the release sites. In 1990 and 1991 over 50% of the catch of all four stocks was taken in the northern troll and net fisheries. About 30% of the catch was taken in the southern Alaskan troll fisheries. Escapements in both 1990 and 1991 were above near-term averages in most Skeena locations (Fig. 3). In 1992 and 1993, years of poor returns to most Skeena locations, a larger proportion of the catch of all stocks was taken in the southern Alaska troll fisheries, and especially in the troll fishery in the NW quadrant.

There are regional differences in the catch distributions that reflect, to some extent, latitudinal differences. Fish originating in the Lachmach River, a coastal location north of the Skeena, tend to be caught in more northerly fisheries compared to fish originating in Kitimat, another coastal site to the south of the Skeena (Figs. 18–21). In most years, fish from Babine had catch distributions more like Lachmach fish. In most years Toboggan fish cluster with other mid-river sites such as tributaries of the Kispiox (McQueen & Murder Creeks) and tributaries of the Kalum (Dry Creek). These associations are not perfectly constant over time, however. The catch distributions of Lachmach and Babine fish are very similar during 1990 through 1993 and distinct from the distribution of Toboggan fish, (Figs. 18–20). In 1993, Lachmach and Toboggan are grouped together while Babine fish are more similar to fish originating in the Nass (Fig. 21). The absolute Euclidean distances between the most dissimilar of these sites remained fairly constant (≈ 0.25). Analyses not presented here indicate that the differences between the sites within the north coast group are only slightly greater than the differences commonly observed between individual tag codes from a single release site.

On a larger scale the cluster analyses indicate that fish from the Nass, Lachmach, and Skeena Rivers and from a large segment of the central coast have very similar catch distributions. This large group is distinct from geographically proximate areas such as southern Alaska and the Queen Charlotte Islands (Figs. 18–21).

From this brief analysis of the CWT recovery data we conclude that the catch distributions in the ocean fisheries of fish originating on the north and central coasts are highly similar. Inferences about the implications of these similar catch distributions for ocean harvest rates await detailed analyses of the temporal patterns of catch and tag recovery that are currently underway (D. Peacock, North Coast Division, DFO, Prince Rupert, pers. comm.).

Exploitation and survival rate indicators for Skeena coho

The number of adult coho that return to spawn from a constant number of smolts depends on two mortality components: natural mortality and fisheries mortality. Most natural mortality is thought to occur within a few months of smolting (Holtby et al. 1990). Fisheries mortality is estimated through recovery of CWTs in the fishery and in the escapement. For most of the CWT releases in the Skeena there have been no attempts to enumerate returning tagged adults and, consequently, no estimates of fishing mortality are available for those releases. Assuming that the total fisheries harvest rate (the exploitation rate, η) is approximately constant, then the proportion of tags released that are caught (termed survival to the fishery, θ_f) is proportional to the smolt-to-adult survival (θ_t):

$$\theta_t = \theta_f\left(1+\frac{1-\eta}{\eta}\right) \quad (1)$$

At all of the sites survivals to the fishery increased from low values in the late 1980's to peak values in either 1990 or 1991 and then decreased in 1992 and 1993 (Table 6; Fig. 22). Survivals at Lachmach were substantially higher than at any of the Skeena locations and in 1993 were an order of magnitude greater at Lachmach than at three of the four Skeena locations. Survival to the fishery were less than 0.5% for major stocks like the Babine. At Dry Creek survival to the fishery was 0.03%, or two orders of magnitude less than the survival at Lachmach.

The differences between the survivals at Lachmach and the other sites vary over time. Survival rates at Lachmach increased faster from 1988 to 1991 compared to the other sites and the decrease in survival in 1992 was less sever at Lachmach (with the exception of Kispiox).

Exploitation rate and total smolt to adult survival is available at Lachmach and at Toboggan Creek (Table 7; Fig. 23). Total survival rates at Lachmach ranged between 4.4% and 12.1%. Survival rates decreased in both 1992 and 1993 (1991 and 1992 smolt years). Survival rates of Toboggan fish were considerably less than those of Lachmach fish in all years but 1989 (1988 smolt year). The temporal patterns were very similar however (Fig. 23). Exploitation rates varied between 39% and 69% and had a similar temporal pattern to the exploitation rate at Lachmach (Fig. 20).

The exploitation and survival rates at Toboggan are almost certainly underestimated. The in-river sport fishery is not monitored but is thought to be small. Native fisheries are not monitored. One of these fisheries, at Moricetown Falls, may be substantial. Until all in-river fisheries are monitored, the true exploitation rate on the Toboggan stock cannot be determined. A conservative estimate of the in-river harvest rate of 30% (D. Peacock, NCD, DFO, Prince Rupert, pers. comm.) places the likely exploitation rate on Toboggan coho in the range of 65% to 75% and survivals in the 2% to 6% range. Exploitation rates of that magnitude are currently thought to be at the upper end of the sustainable range for more productive coastal stocks and are probably too high for less productive interior stocks.

The two measures we have of exploitation rates in the ocean fisheries both indicate that variations in returns are not being driven by variations in fishing mortality alone, but are also

The two measures we have of exploitation rates in the ocean fisheries both indicate that variations in returns are not being driven by variations in fishing mortality alone, but are also responding to variations in smolt-to-adult survivals. What this means to the management of the early run Skeena coho is that it would be unwise to manage this stock aggregate with a target exploitation rate determined from a stock-recruitment analysis. Instead the stock aggregate should be managed to a harvest rate that is determined by current stock productivity.

CONCLUSIONS

Both of the long-term indicators of escapement for early run Skeena coho indicate a decline beginning sometime in the mid-1970's. Although neither the Skeena test fishery or the Babine fence were intended to index coho abundance, we have shown that the trends in both indices are consistent with other indicators of escapement in the Bulkley and Morice drainages. All available data indicate further deterioration in the status of the early run coho stock aggregate.

Exploitation rates calculated for the single available exploitation rate indicator in the Skeena have given near-term exploitation rates of between 30% and 69% but those values are probably underestimates with the true value in the range of 65% to 75%. Survival rates are likely in the 2% to 6% range. Escapements to a nearby coastal river appear robust even though the exploitation rate on that population have exceeded 70% in three of five years. One important difference between the two stocks is the smolt-to-adult survival. The survival of coastal fish is at least twice that of the interior fish and can be as much as five times greater. Survivals to the fishery of the coastal stock are two orders of magnitude higher than for some interior stocks.

We view the recent declines in smolt survivals for interior stocks within the early run aggregate with considerable concern. Declining smolt survivals that are already critically low and continued high exploitation rates make the prognosis for the early run aggregate very poor.

RECOMMENDATIONS

We offer several recommendations.

First, the assessment data which are collected for early run coho in the Skeena in particular, and more generally for coho in the Skeena, should be bolstered by the development of additional exploitation/survival rate indictors for interior Skeena stocks. The facilities and/or the release strategies and locations used by enhancement facilities currently releasing CWT'd coho in the Skeena drainage (Kispiox River CDP, the Terrace Enhancement Society, the Fort Babine CDP, the Toboggan Creek CDP (releases in the upper Bulkley)) should be immediately restructured to allow the collection of the tag escapement data necessary to generate survival and exploitation rates. A proposal to do this has been forwarded under the Skeena Green Plan. The Lachmach River may be an adequate indicator for coastal Skeena systems and should be continued while its adequacy as an indicator is examined further.

The extremely low smolt-to-adult survival rates of coho released from mid-river and upper-river enhancement facilities in the Skeena needs to be examined. We recommend that at least one wild tagging site be established in the upper river. Toboggan Creek, where there is still is a large run of wild coho, would be a logical location, if a reliable way could be found for discriminating wild and hatchery returns at escapement. Locations in the Kispiox or the Babine would also be suitable, especially if the objective was limited to measuring survival to the fishery for a wild stock. Determination of whether or not the problem of poor smolt survival is confined only to hatchery releases is necessary before further studies can be efficiently designed to identify, and possibly correct, the specific problem.

The current assessment program should be critically examined and then redesigned to provide a drainage wide system of indexed escapements (or proxy measures of escapement), estimates of in-river harvest, and a better understanding of stock productivities, all of which are needed for future assessments. Although this recommendations has been made before, it is becoming imperative for the conservation of the early runcoho that DFO begins to generate quality information that supports assessment and fisheries management of the early Skeena coho.

Our analyses strongly suggest that the escapement trends in early run Skeena coho are due to fluctuations in smolt survival coupled with excessive fisheries exploitation. To rebuild and sustain these stocks we recommend that a management approach be developed that can adapt to fluctuating ocean survivals through modification of harvest rates. It appears from the CWT data that reductions in the northern B.C. troll and SE Alaskan fisheries will be required to accomplish this since adjustments to the terminal net fishery alone would not be sufficient in some years.

Some form of pre-season survival (run strength) indicator would be useful in implementing an adaptive management approach of the sort briefly described above. To rebuild and sustain these stocks we recommend that work proceed on developing survival forecasting procedures for early run Skeena coho.

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Table 1. Previous management and assessment recommendations.

source recommendation	actions taken in response to recommendation
Kadowaki 1988	
1. set an escapement target of 33,000 at river mouth, equivalent to 68 units in the test fishery by Aug. 24th	A conservation plan was developed that included: time and area closures in the troll fishery; reduced fishing times in the gillnet fishery in the approach waters to the Skeena, elimination of the non-tidal sport fishery, and requests to native groups to avoid coho where possible and to reduce coho harvests. The escapement target has been achieved in two years.
2. generate timing & fisheries distributions of hatchery & wild fish to decompose the aggregate into components	Coho produced at Kispiox hatchery, Toboggan Creek hatchery and in net pens on the Babine have been regularly tagged with CWTs. There has been sporadic tagging at some 10 other sites in the watershed. Recovery of the tags in the river mouth fishery has given some information about variations in run timing.
3. tag fish to generate exploitation rates	Estimation of the numbers of tags in the escapement has not been attempted at most release sites and has not been satisfactory at the one site where recovery was attempted (Toboggan). Consequently no estimate of exploitation rate has been obtained. adults at
4. extend test fishery to end of Sept. to estimate relative magnitudes of early and late components	The test fishery was extended, by a variable amount in the the first or second week of Sept.
Kadowaki, Pendray & Jantz, S92-3	
1. continue with the escapement target of 33,000	The conservation plan has continued due to the continued poor performance of the early Skeena coho.
2. extend test fishery to first week of Sept.	This measure had been implemented and continues.
3. estimate CWT escapements and in-river harvest for determination of exploitation rates.	No substantive progress was made on either recommendation.

Table 2. Values of the Skeena test fishing index and the Babine fence index to the end of the consistently surveyed period and the total survey period.

	Babine fence			Skeena test fishery		
year	count to Sept. 13th	total count	end date	index to Aug. 24th	total index	end date
1946	8687	12489	Oct. 4	–	–	–
1947	4983	10252	Oct. 7	–	–	–
1948	–	–	–	–	–	–
1949	6044	11938	Oct. 3	–	–	–
1950	5205	11654	Oct. 15	–	–	–
1951	444	2120	Oct. 4	–	–	–
1952	1157	10554	Nov. 13	–	–	–
1953	5904	7648	Oct. 28	–	–	–
1954	1644	3094	Oct. 3	–	–	–
1955	4339	8947	Oct. 3	–	–	–
1956	5675	9250	Sept. 30	86.49	136.68	Sept. 10
1957	2475	4421	Oct. 29	94.27	116.04	Sept. 8
1958	5026	7606	Oct. 1	151.98	229.02	Sept. 10
1959	6347	10947	Oct. 2	76.20	85.34	Sept. 3
1960	5191	6794	Sept. 28	71.51	82.49	Sept. 8
1961	7297	10024	Sept. 21	54.38	113.95	Sept. 7
1962	8088	11000	Sept. 22	115.01	131.43	Sept. 4
1963	3600	3600	Sept. 13	90.23	107.08	Sept. 5
1964	–	–	–	119.09	133.73	Sept. 3
1965	20000	20000	Sept. 13	173.33	221.87	Aug. 29
1966	6784	7200	Sept. 15	168.46	168.46	Aug. 27
1967	7469	9378	Sept. 23	160.89	165.77	Aug. 29
1968	6393	6600	Sept. 14	77.37	77.37	Aug. 24
1969	2978	4660	Sept. 21	141.43	155.40	Aug. 30
1970	4968	5600	Sept. 15	136.01	147.01	Aug. 26
1971	4284	7700	Sept. 24	160.78	176.59	Aug. 27
1972	2415	2598	Sept. 21	65.43	75.93	Aug. 25
1973	5836	6247	Sept. 16	87.77	96.09	Aug. 28
1974	4886	8853	Sept. 20	47.27	54.44	Aug. 28
1975	2059	4429	Sept. 30	63.04	65.86	Aug. 26
1976	2085	4499	Oct. 15	67.13	72.26	Aug. 27
1977	4324	10474	Oct. 20	99.30	106.77	Aug. 26
1978	5600	11446	Oct. 10	110.10	114.75	Aug. 27
1979	1144	2909	Oct. 28	28.16	29.55	Aug. 26
1980	2172	4399	Sept. 30	73.50	73.50	Aug. 24
1981	1426	2167	Sept. 29	57.81	58.76	Aug. 26
1982	1704	2287	Sept. 28	62.46	64.07	Aug. 26
1983	1598	2704	Sept. 25	61.97	69.26	Aug. 28
1984	1539	2956	Oct. 2	70.98	76.90	Aug. 26
1985	914	2129	Oct. 24	45.29	53.27	Aug. 30
1986	1673	2757	Sept. 22	50.70	52.49	Aug. 25
1987	867	1894	Sept. 29	29.71	68.72	Sept. 6
1988	1639	3026	Oct. 4	23.37	42.16	Sept. 9
1989	3140	5228	Oct. 20	78.94	113.90	Sept. 8
1990	2477	5512	Oct. 14	76.09	124.25	Sept. 10
1991	1558	4904	Oct. 19	55.36	92.30	Sept. 4
1992	584	1302	Sept. 29	11.81	33.85	Sept. 10
1993	322	1988	Oct. 14	13.33	48.11	Sept. 20

Table 3. Sites in the Bulkley River and tributaries sampled for juvenile coho presence. Each circle represents a sample. Black circles (●) indicate the presence of coho, (❷) indicates that coho were present but that there were none of age 0^+, open circles the absence of coho (⊗). Sites (those shaded) were excluded from some calculations if no coho were detected in any of the samples taken, if a site was heavily sampled in only one year, or if a site was only sampled once.

site	1987	1988	1989	1990	1991	1992	1993
Maxan Lk/Crk incl. Foxy & Crow Crk	⊗⊗ ⊗⊗	⊗	—	● (fry plant)	⊗	⊗⊗	⊗⊗
Bulkley R. from falls to Lk (Forrestdale)	⊗	⊗	—	⊗	—	—	⊗
Ailport Crk.	●	⊗	⊗	●	⊗	⊗	⊗⊗
Bulkley R @Ailport	—	—	—	⊗	⊗	—	⊗
Bulkley R @Topley	—	—	⊗	—	—	—	—
Byman Crk.	●	⊗⊗	⊗⊗ ❷●	⊗	❷⊗	❷	⊗⊗
Bulkley R. @Byman	—	—	⊗	●⊗	●	—	—
McQuarrie Crk.	●⊗	⊗	⊗	—	—	—	⊗⊗
Bulkley R. @McQuarrie Crk.	●	❷●	●●	●	⊗⊗	●● ●	⊗
Bulkley R. @Barren Crk.	—	⊗⊗ ⊗	—	●	⊗	—	—
Bulkley R. @Houston	—	●	—	●●	●	❷●	●● ⊗
Buck Crk.	—	❷	⊗	●	⊗	●	⊗
Telkwa R.	—	—	—	—	—	—	●
proportion of sites coho present	0.40	0.31	0.36	0.64	0.27	0.70	0.19
proportion of sites where 0^+ coho present	0.40	0.15	0.27	0.64	0.18	0.50	0.19
proportion of sites where 0^+ coho present, excluding shaded sites	0.80	0.25	0.30	0.67	0.22	0.63	0.17
proportion of streams where 0^+ coho present	1.00	0.43	0.29	0.75	0.25	0.40	0.25

Table 4. Sites on the Morice River and tributaries sampled for the presence of juvenile coho. Each circle represents a sample. Black circles (●) indicate the presence of coho, (❷) indicates that coho were present but that there were none of age 0^+, open circles the absence of coho (⊗). Sites (those shaded) were excluded from some calculations if no coho were detected in any of the samples taken, if a site was heavily sampled in only one year, or if a site was only sampled once.

site	1987	1988	1989	1990	1991	1992	1993
Owen Creek	●●	●⊗	❷●	⊗⊗⊗	●⊗⊗	❷●● ●	●●⊗ ⊗
Morice River below Owen Creek	—	—	—	—	—	●	—
28km P (Bustard's Pond)	—	—	—	●	⊗	—	●
29km P	⊗	⊗	—	—	—	—	—
33km P	●	●	●	●	●	●	●
36km P	—	—	—	●	—	—	—
38km SC	—	—	⊗	●	—	●	—
38.5km SC	●	⊗	●	●	—	—	●
38.8km SC	—	●	—	—	—	—	—
45km P	●	●●	●⊗	●	⊗	—	—
46.5km SC	—	—	—	—	—	—	●
48km P (Pendray's Pond)	●	—	—	●	●	●	●
Gosnell Cr.	—	—	❷❷● ●⊗⊗	●	—	—	⊗
McBride Creek	●●●	❷●⊗ ⊗	●●⊗ ⊗	❷❷● ●●	❷❷● ●	❷●●	●●● ⊗⊗
proportion of sites coho present	0.89	0.58	0.65	0.81	0.64	1.00	0.67
proportion of sites where 0^+ coho present	0.78	0.50	0.47	0.69	0.46	0.82	0.67
proportion of sites where 0^+ coho present, excluding shaded sites	1.00	0.56	0.55	0.64	0.45	0.8	0.69
proportion of streams where o^+ coho present	0.86	0.71	0.86	0.90	0.67	1.00	0.88

Table 5. Fisheries used in the cluster analysis. Abbreviations are those used in Figs. 14 to 17. If a northern fishery has no abbreviation then no tags from the Lachmach, Kitimat or Skeena releases were recovered in that fishery.

Jurisdiction	Fishery	Abbreviation
Alaska	Southwest troll	AKSWt
	Southeast troll	AKSEt
	Northwest troll	AKNWt
	Northeast troll	AKNEt
	District 115 gillnet (Lynn Canal)	
	District 111 gillnet	
	District 106-108 gillnet (central inside)	AKCIn
	District 101-102 gillnet (south inside	AKSIn
	District 112,114 gillnet (central)	
	District 112,114 seine (central)	
	District 113 gillnet (central outside)	
	District 106-108 seine (central inside)	
	District 103-104 seine (south)	
	District 103-104 gillnet (south)	AKSOn
	District 105, 109, 110 seine (south central)	
	District 105, 109, 110 gillnet (south central)	AKSNn
	District 101, 102 seine (south inside)	
Canada	Northern troll	Nt
	North central troll	NCt
	South central troll	Sct
	Northwest Vancouver Island troll	NWVIt
	Southwest Vancouver Island troll	SWVIt
	Northern net	Nn
	Central net	Cn
	Johnstone Strait net	Jn
	8 additional troll, net, and sport fisheries	
Southern US	*25 troll, net, and sport fisheries*	

Table 6. Survivals to the fishery of CWT released fish from the Lachmach River and four sites in the Skeena drainage.

	survival to the fishery (proportion of tags released estimated to have been caught)				
catch year	Lachmach	Dry	Toboggan	Kispiox	Fort Babine
1987	–	–	–	–	0.0182
1988	0.0130	–	0.0040	0.0039	0.0074
1989	0.0273	–	0.0147	0.0150	0.0104
1990	0.0863	0.0230	0.0235	0.0169	0.0039
1991	0.0877	0.0046	0.0308	–	0.0288
1992	0.0663	0.0016	0.0091	0.0434	0.0061
1993	0.0394	0.0003	0.0076	0.0002	0.0035

Table 7. Smolt-to-adult survivals and fishery exploitation rates for Lachmach River and the Toboggan Creek CDP hatchery.

	Lachmach River		Toboggan Creek CDP hatchery	
catch year	smolt-to-adult survival	exploitation rate	smolt-to-adult survival	exploitation rate
1988	–	–	0.010	0.389
1989	0.044	0.621	0.033	0.439
1990	0.113	0.763	0.034	0.685
1991	0.121	0.726	0.049	0.631
1992	0.088	0.754	0.014	0.661
1993	0.061	0.647	0.014	0.558

Figure 1. Fishery officer escapement estimates from 1952 to 1992 for A) the upper Skeena, B) the lower Skeena, and C) for the entire Skeena.

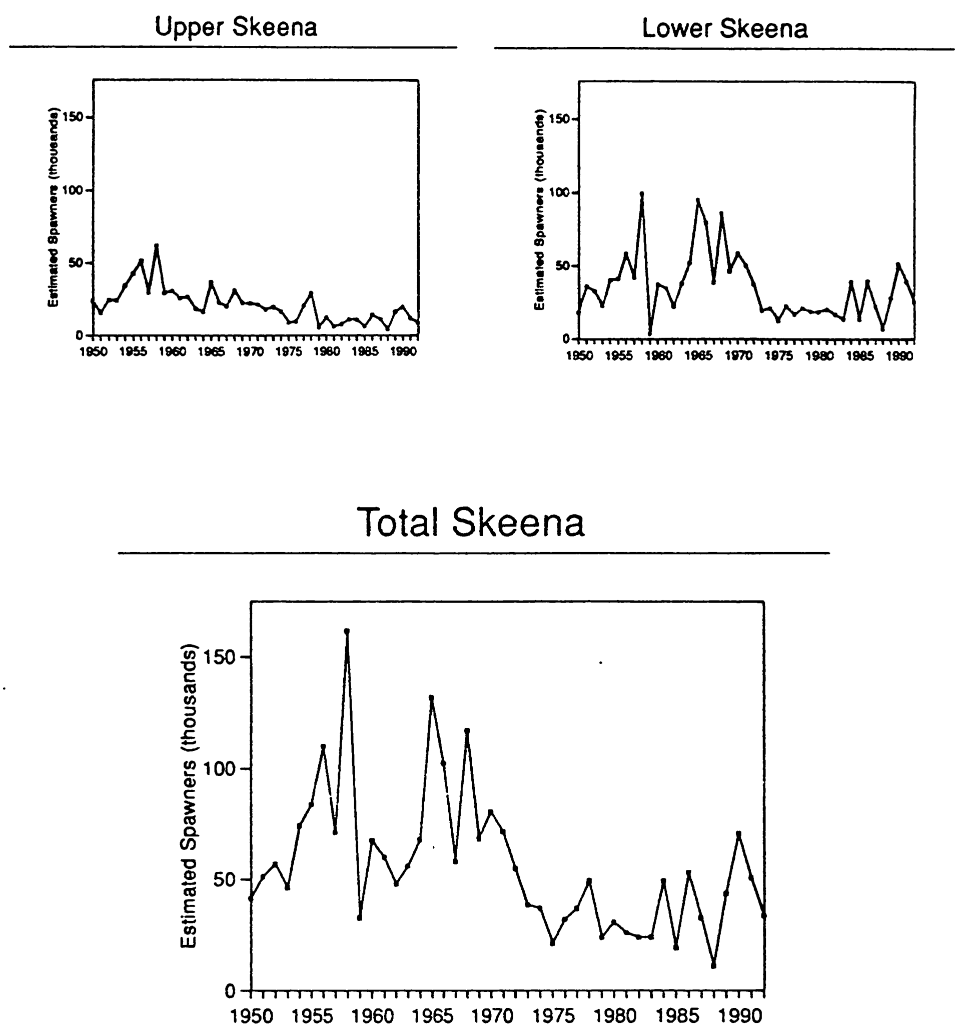

Figure 2. The Babine fence index vs. time, 1950–1993. The index is the cumulative fence count to September 13th. Values are tabulated in Table 2.

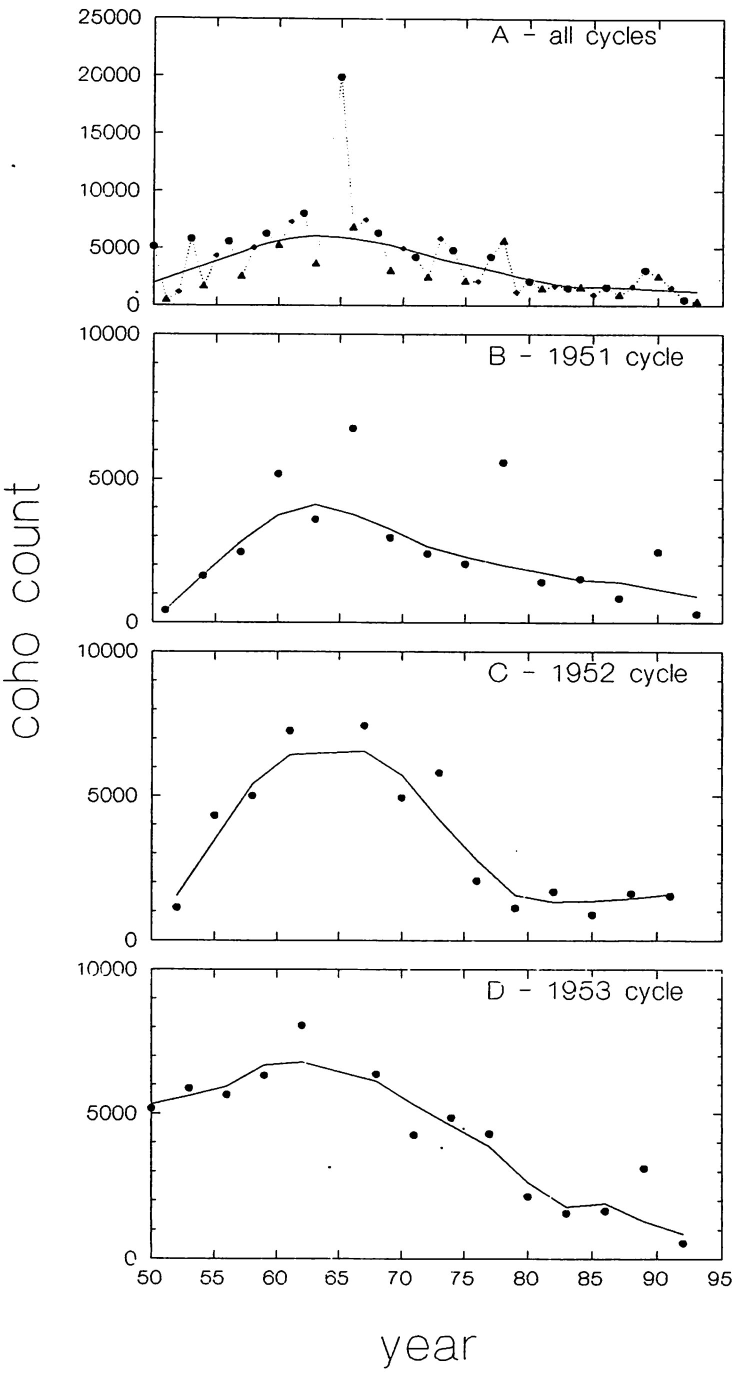

Figure 3. The Babine fence total count vs. time, 1950–1993. The total number of coho counted to the date shown in Table 2.

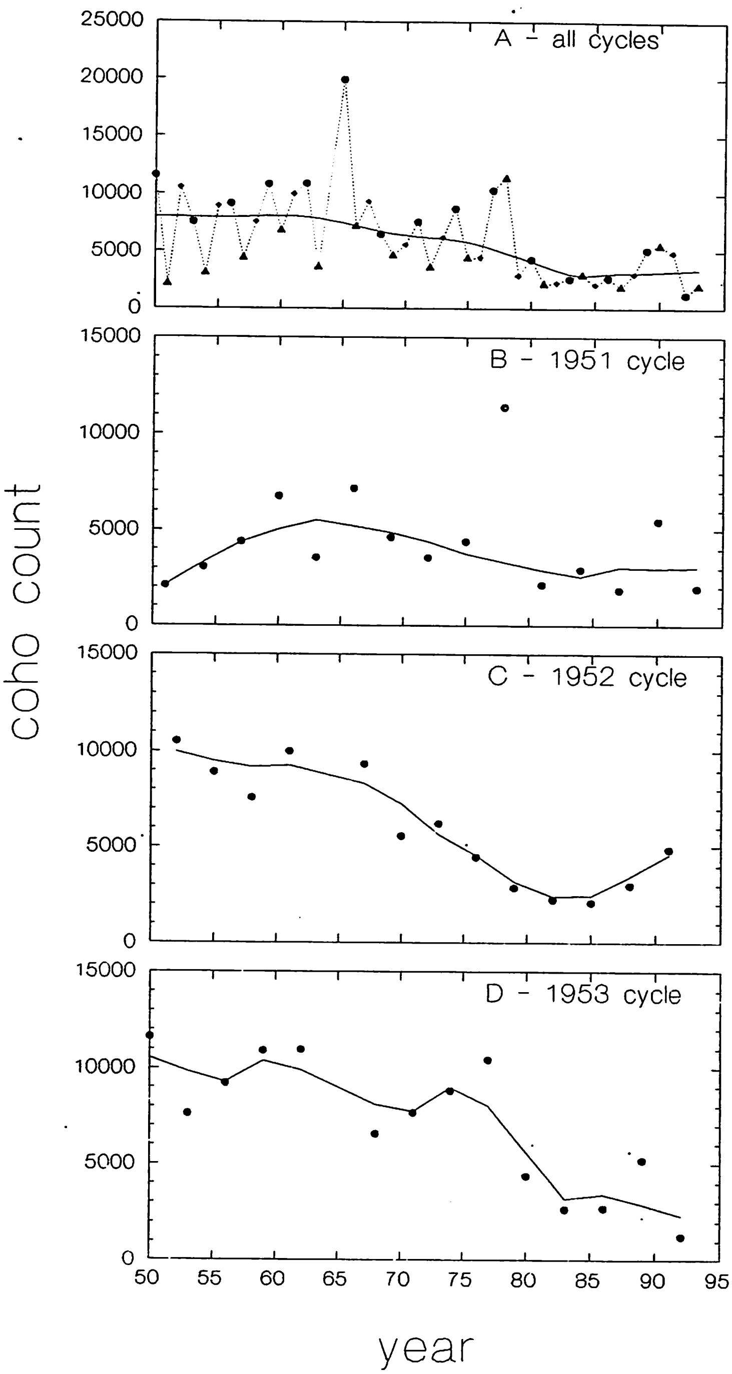

Figure 4. The Skeena test fishery index. The index is the cumulative fishery index to August 24th. Values are tabulated in Table 2. A) all years; B) 1951 cycle; C) 1952 cycle; D) 1953 cycle. The lines shown are LOWESS smooth lines.

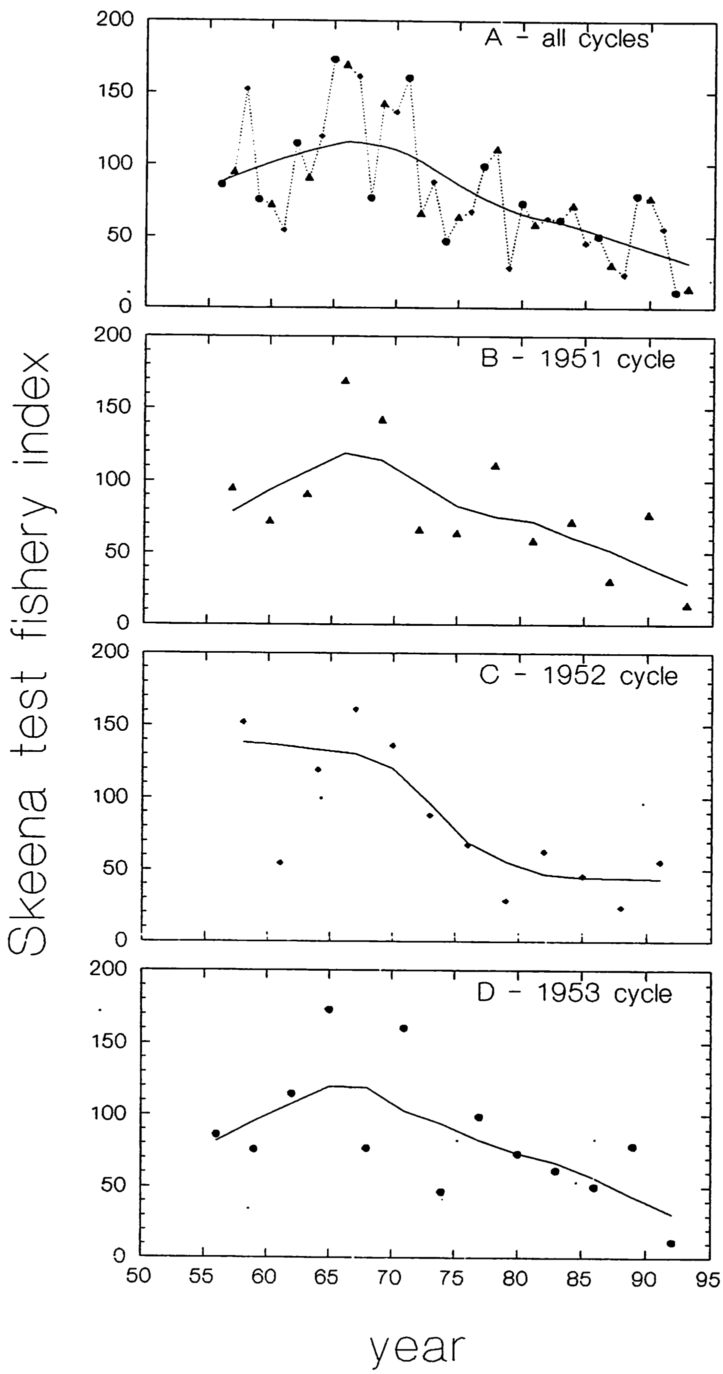

Figure 5. Time series of the constant multiplier and variable multiplier Skeena test fishery indices from 1970 to 1993.

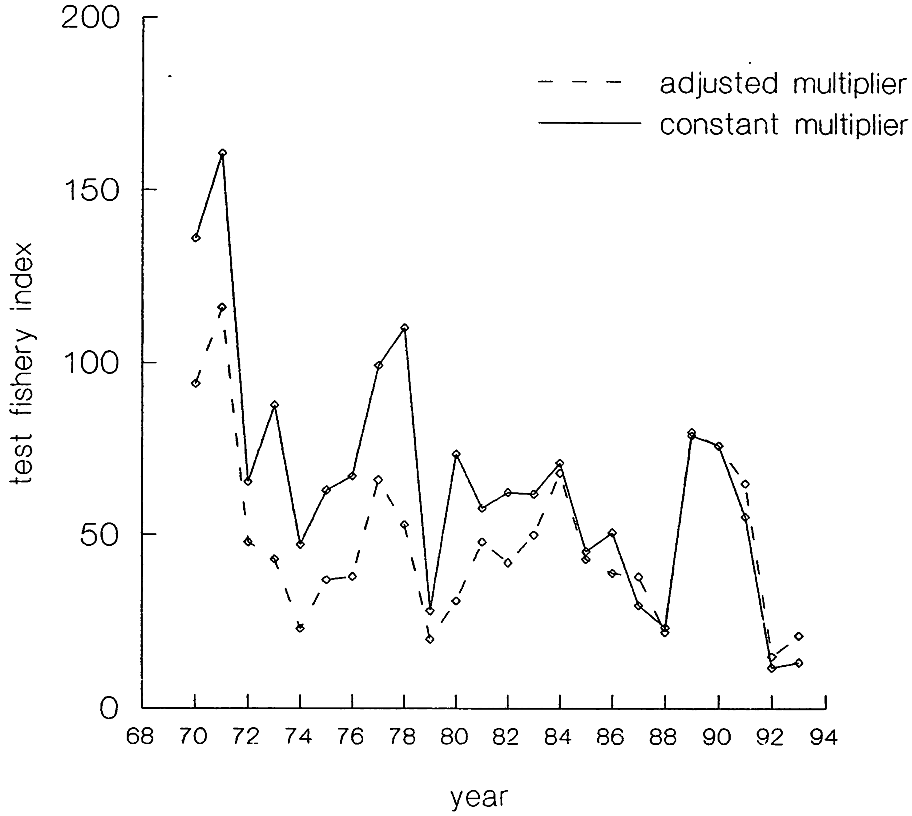

Figure 6. Relationship between Babine fence index and the Skeena test fishery index in two periods, 1956–1976 and 1977–1993. The lines shown are LOWESS smooth lines.

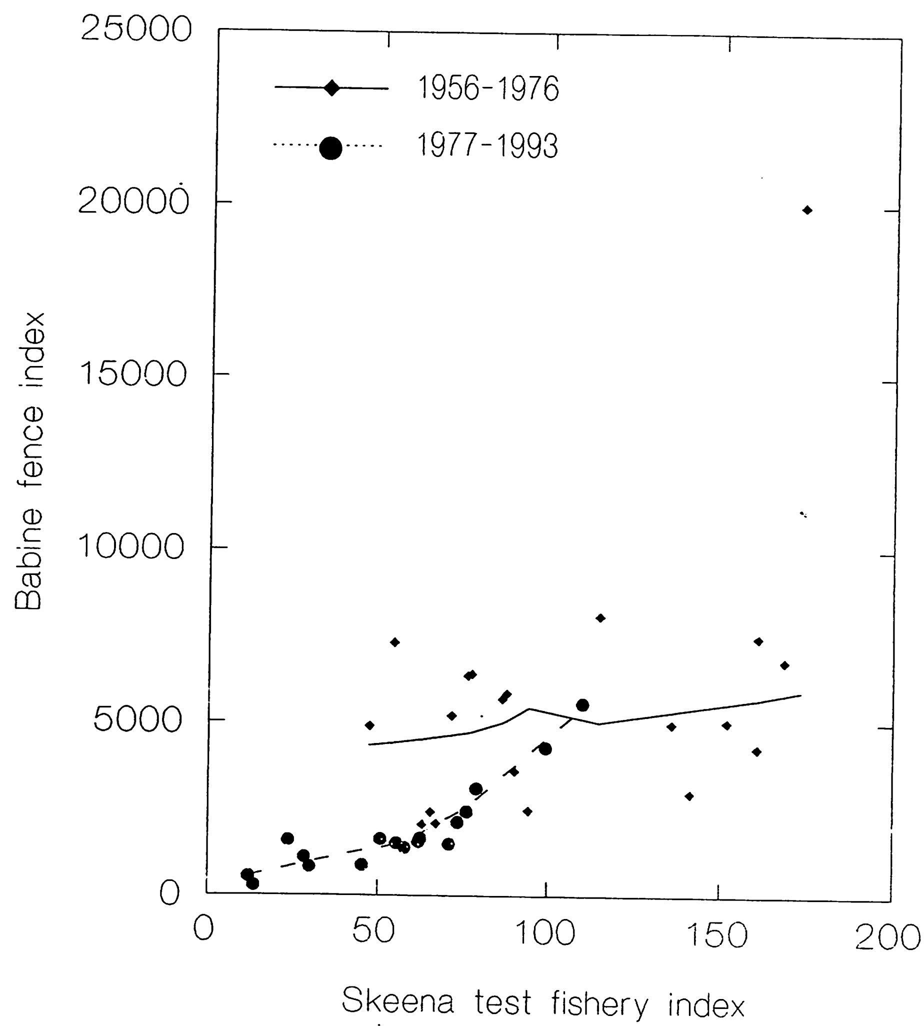

Figure 7. A) sockeye smolt survival vs. the number of sockeye smolts. B) Skeena test fishery index vs. smolt survival of sockeye. C) Skeena coho test fishery index vs. the number of sockeye smolts. All figures are for the period 1961 to 1983 (coho catch year).

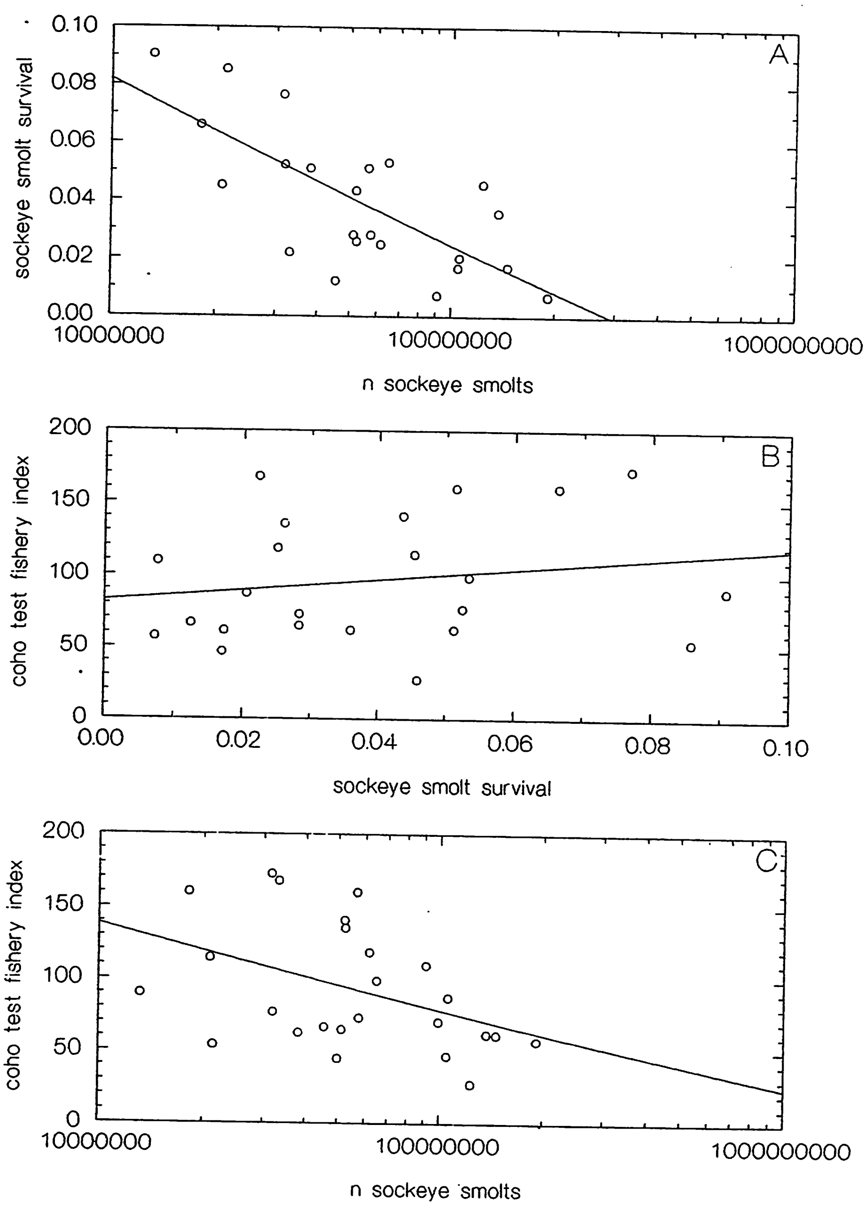

Figure 8. Comparative time series of A) Skeena test fishery index, B) Babine fence index, C) Toboggan wild escapement, D) Telkwa River peak counts, and E) Lachmach River escapements, from 1980 to 1993.

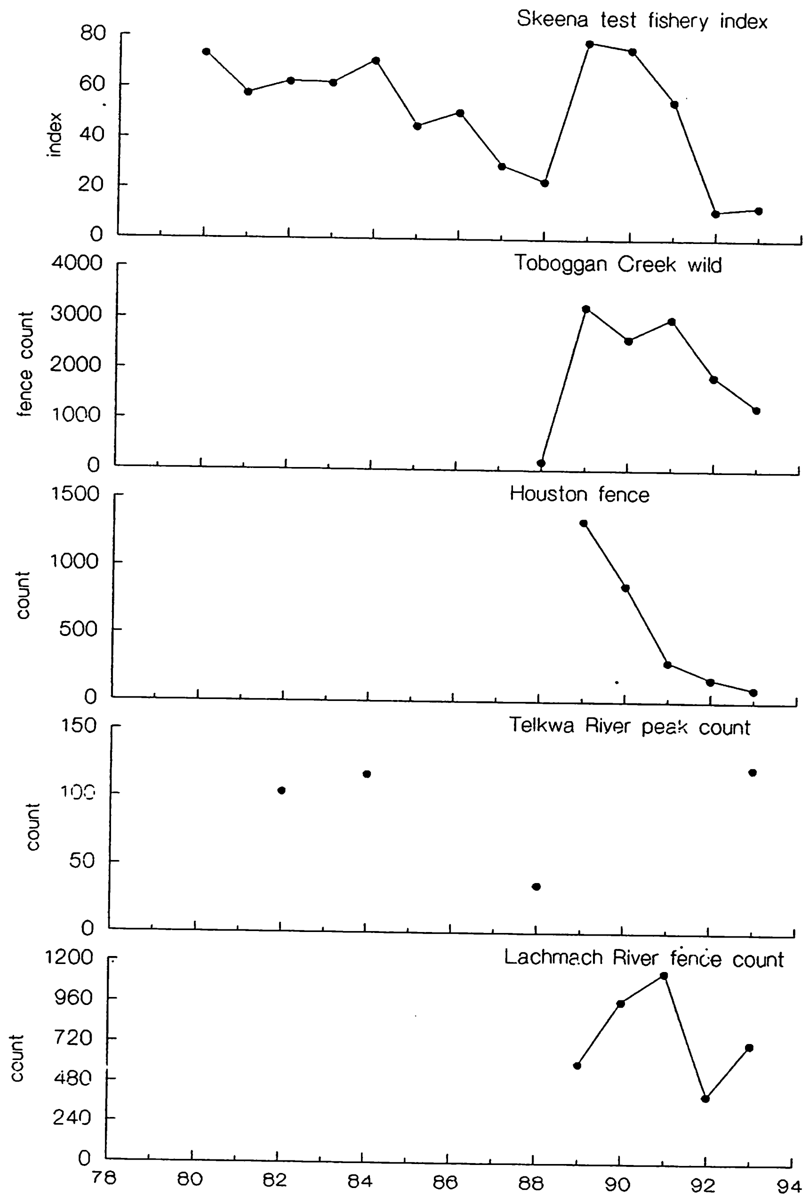

Figure 9. The proportion of streams with age 0^+ coho vs. time for A) the Bulkley River and tributaries and B) the Morice River and tributaries.

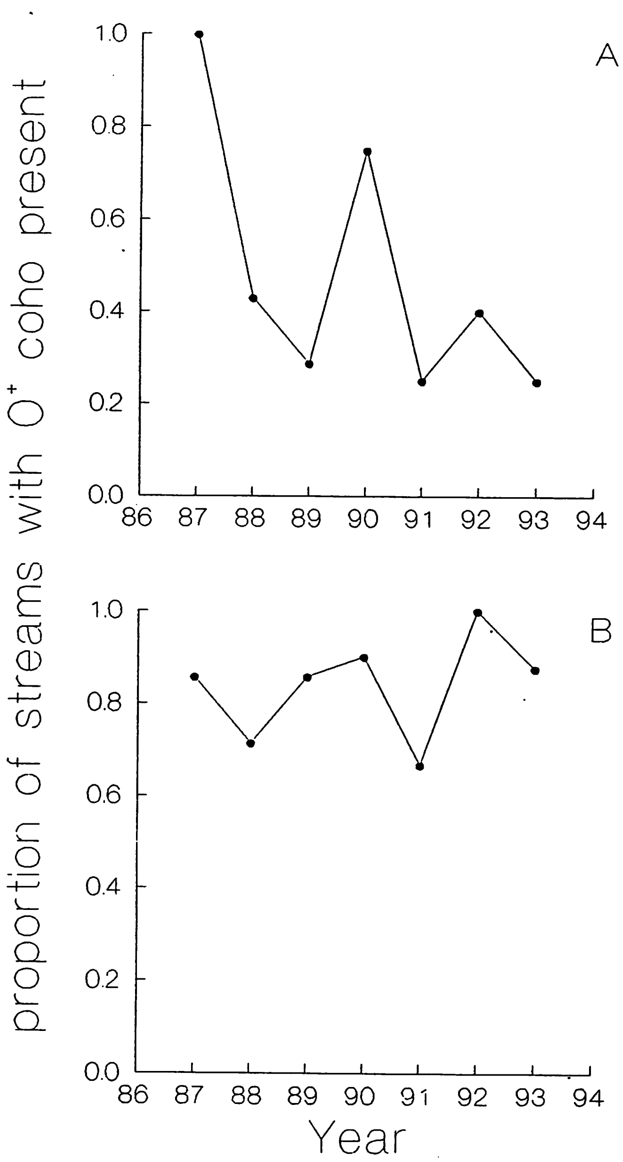

Figure 10. The relationship between the proportion of streams with age 0^+ coho and the Skeena test fishery index for A) streams in the Bulkley valley and B) streams in the Morice valley.

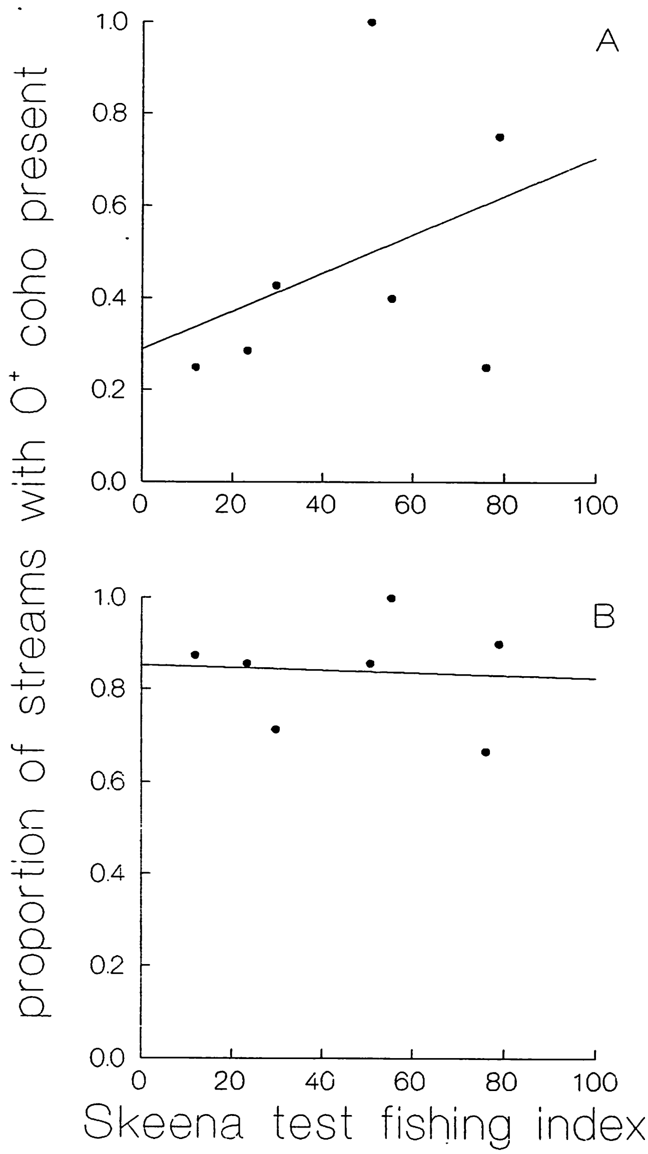

Figure 11. A) The relationship between density and mean FL for A) Owen Creek and B) McBride Creek.

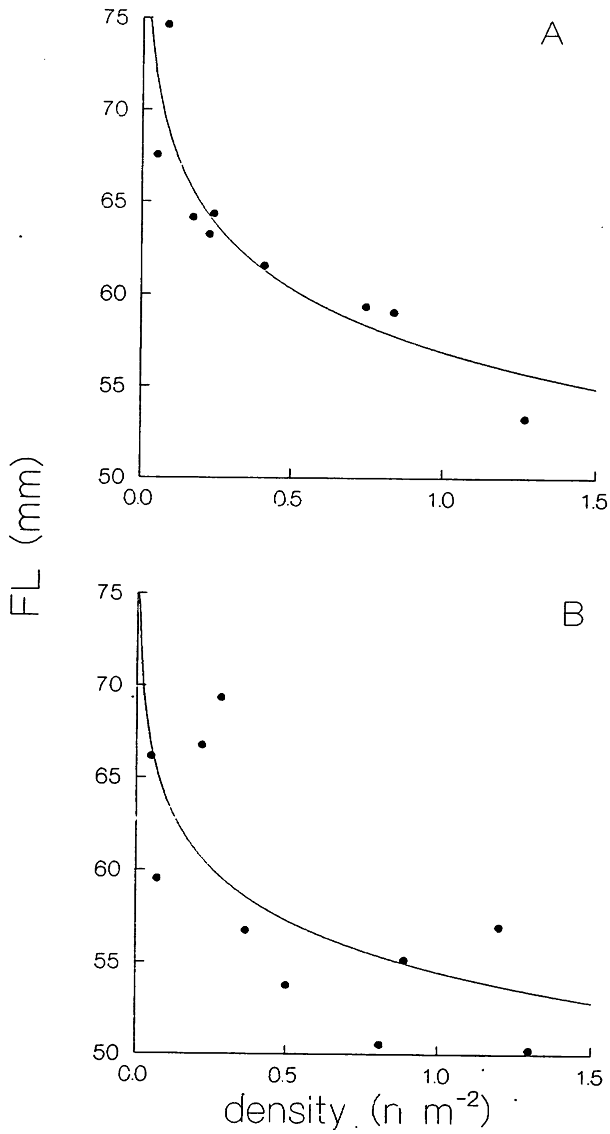

Figure 12. Relationships between the Skeena test fishery index and A) juvenile coho density and B) mean juvenile coho FL for McBride Creek.

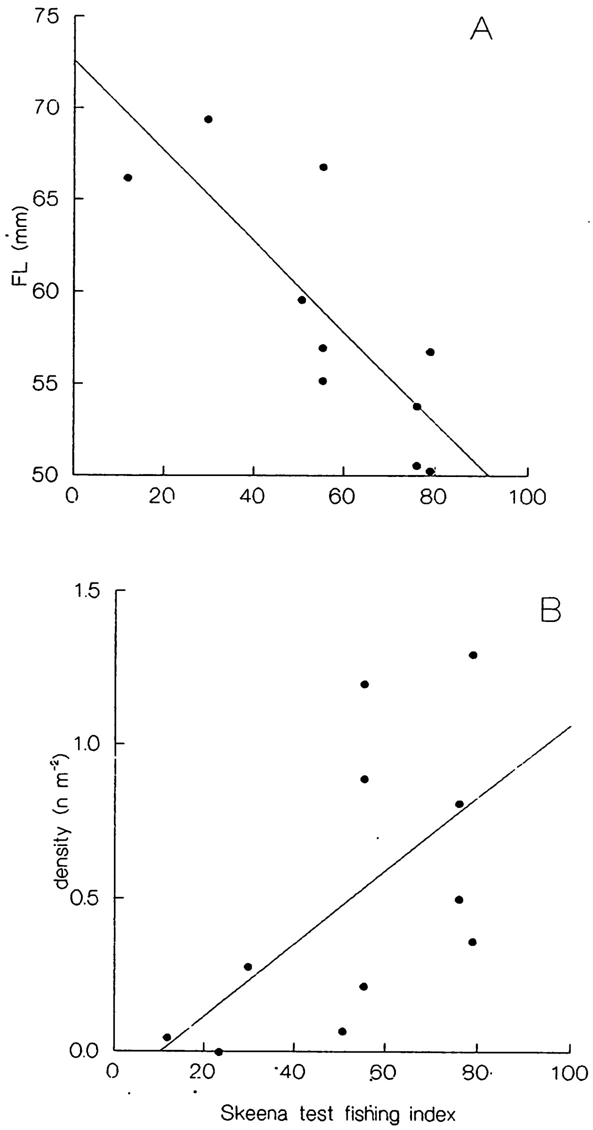

Figure 13. For Morice River juvenile coho: A) relationship between the skewness of the FL distribution and density, and relationships of B) skewness and C) mean FL and the Skeena test fishery index.

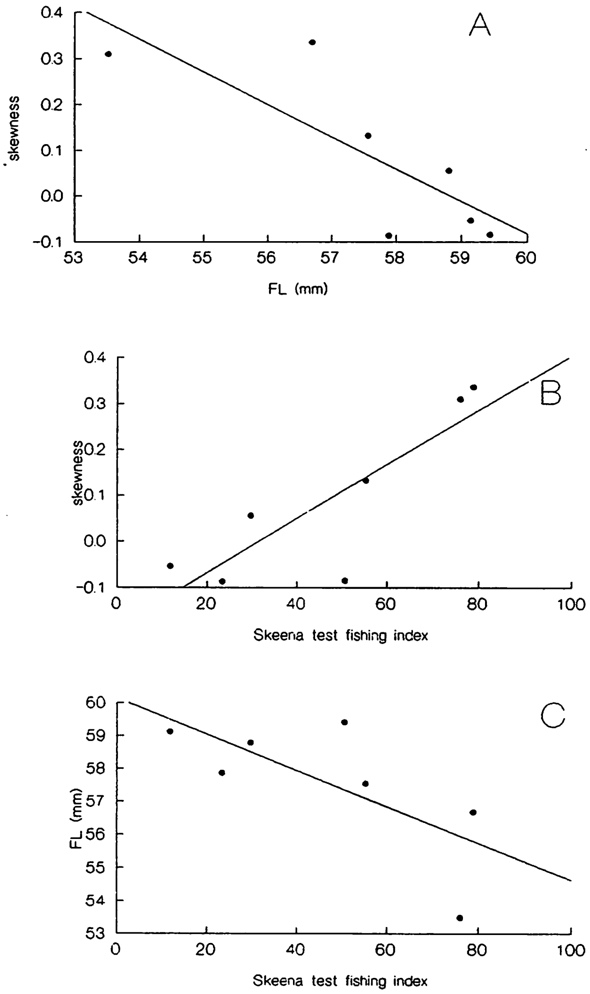

Figure 14. Proportions of catch in ocean fisheries for CWT'd fish from the Lachmach River, Kitimat hatchery, Toboggan Creek CDP, and Fort Babine CDP in 1990. Abbreviations for the fisheries are given in Table 5.

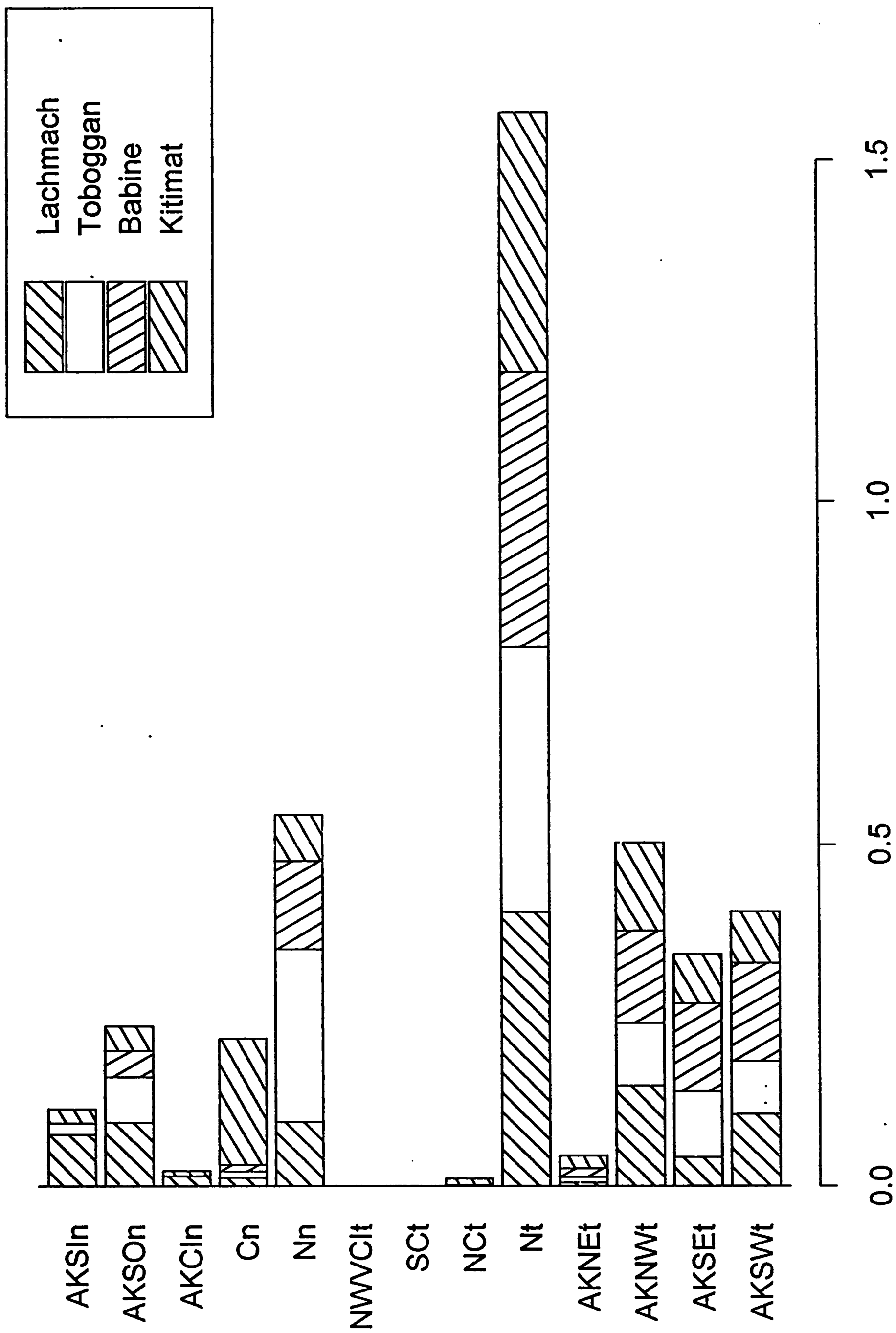

Figure 15. Proportions of catch in ocean fisheries for CWT'd fish from the Lachmach River, Kitimat hatchery, Toboggan Creek CDP, and Fort Babine CDP in 1991. Abbreviations for the fisheries are given in Table 5.

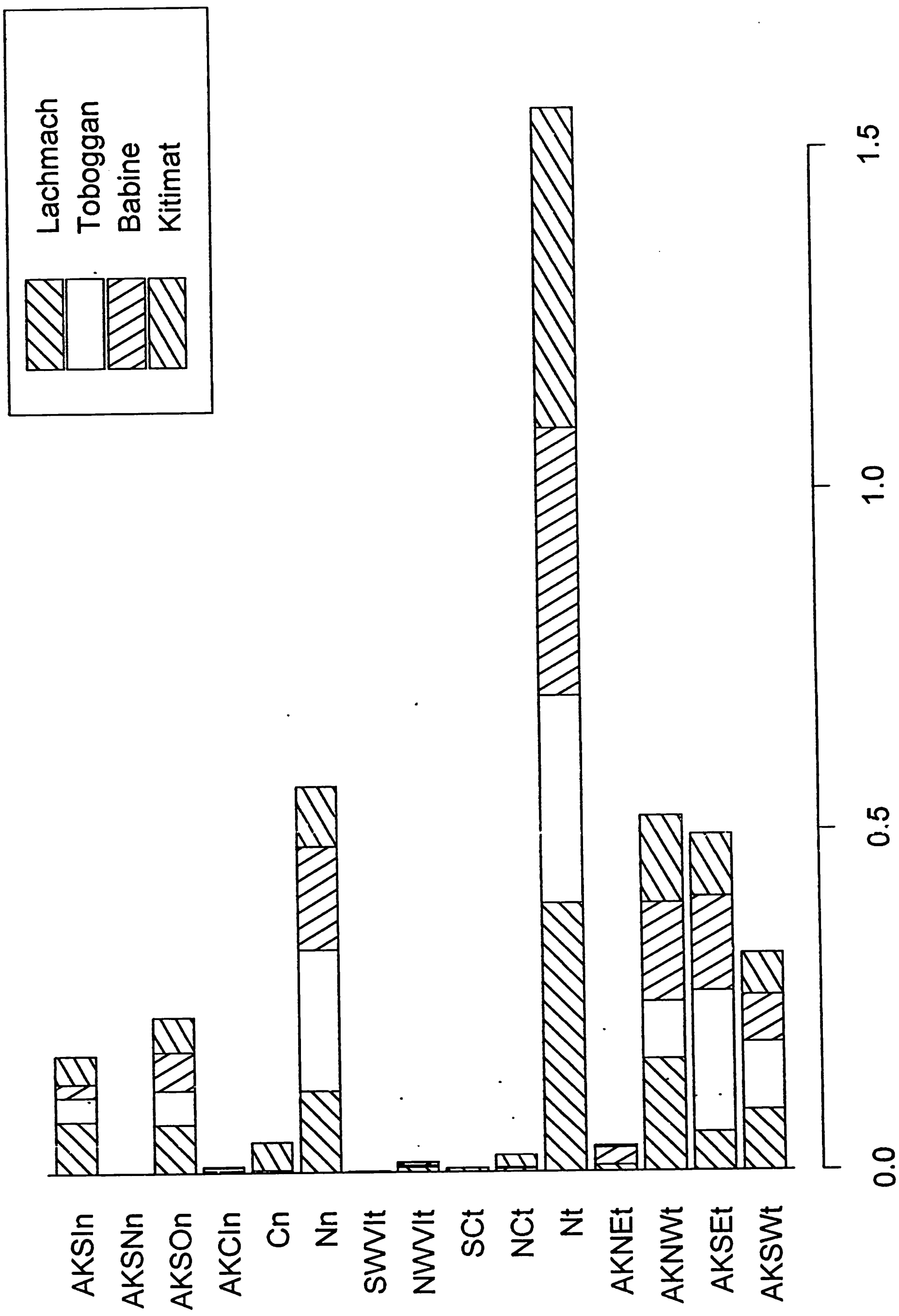

Figure 16. Proportions of catch in ocean fisheries for CWT'd fish from the Lachmach River, Kitimat hatchery, Toboggan Creek CDP, and Fort Babine CDP in 1992. Abbreviations for the fisheries are given in Table 5.

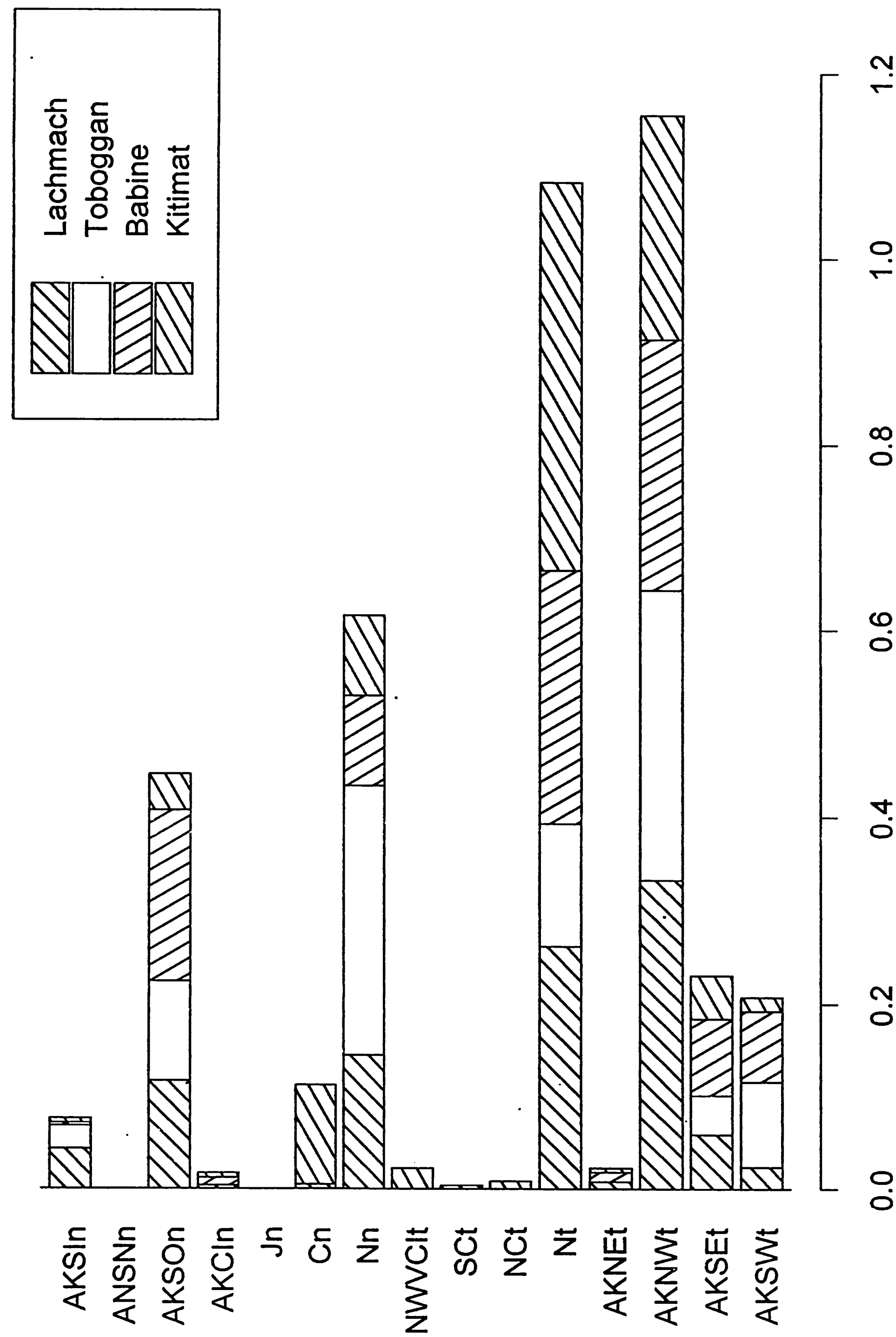

Figure 17. Proportions of catch in ocean fisheries for CWT'd fish from the Lachmach River, Kitimat hatchery, Toboggan Creek CDP, and Fort Babine CDP in 1993. Abbreviations for the fisheries are given in Table 5.

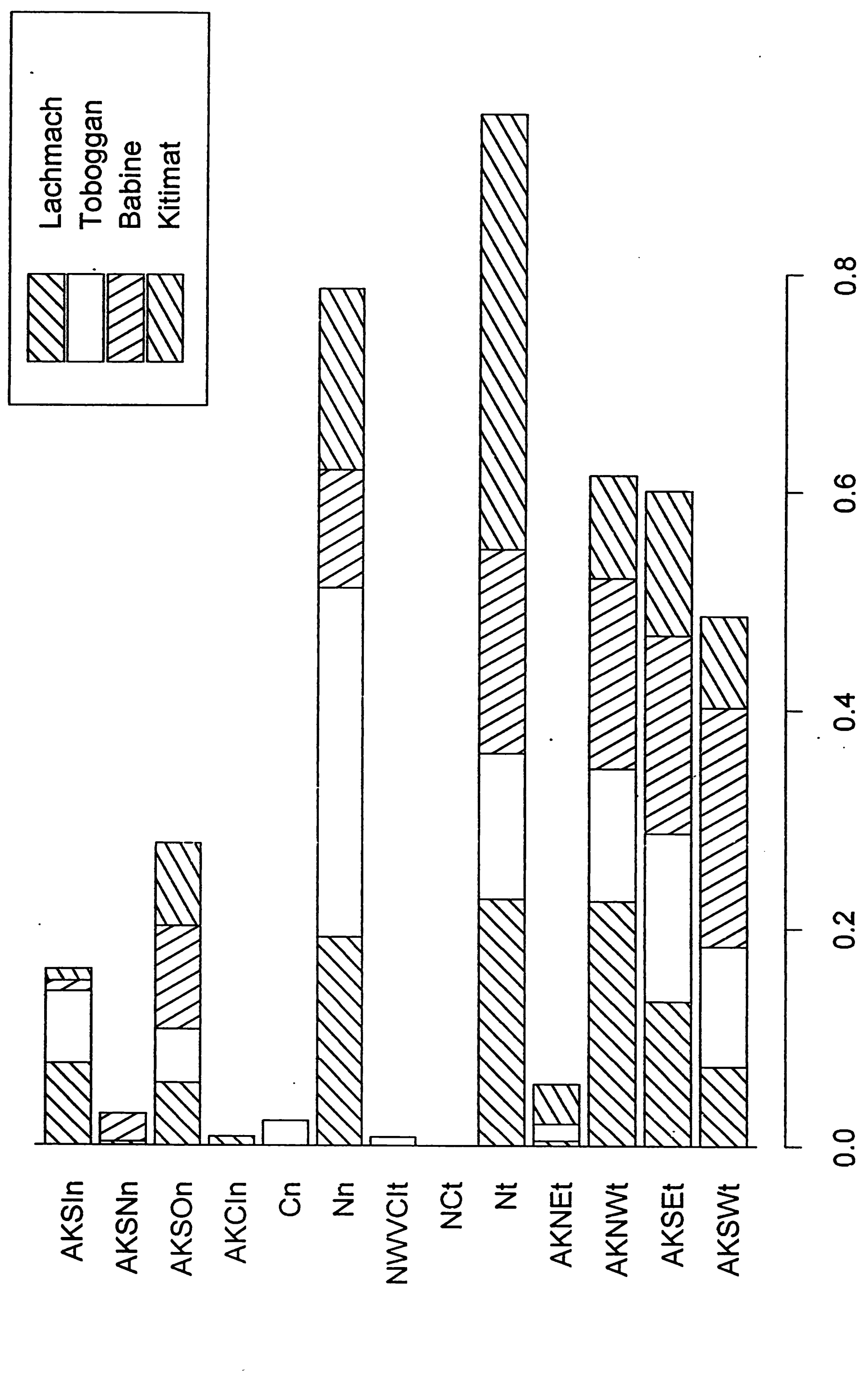

Figure 18. Clustering of release sites in northern B.C. and southern Alaska based on recoveries of CWTs in the 1990 ocean fisheries.

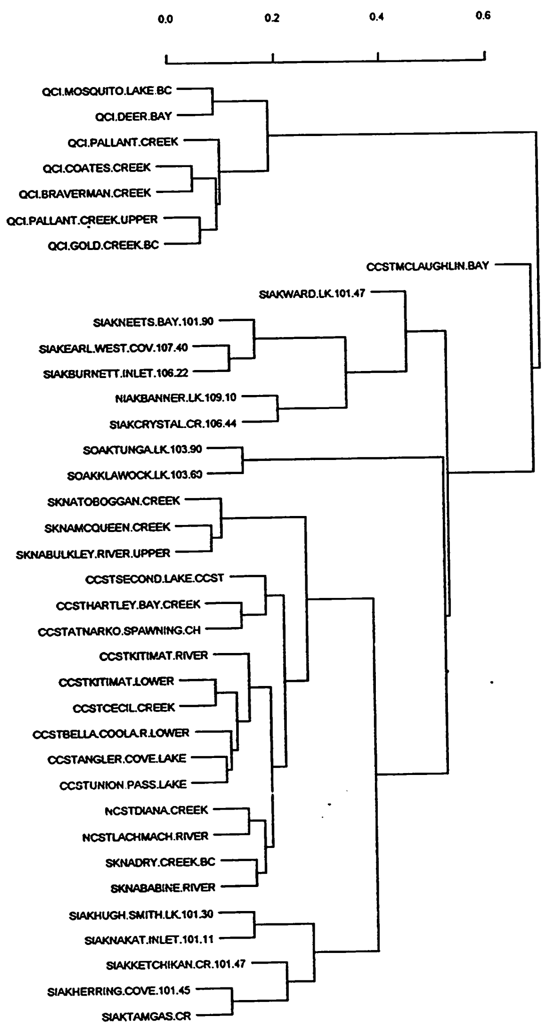

Figure 19. Clustering of release sites in northern B.C. and southern Alaska based on recoveries of CWTs in the 1991 ocean fisheries.

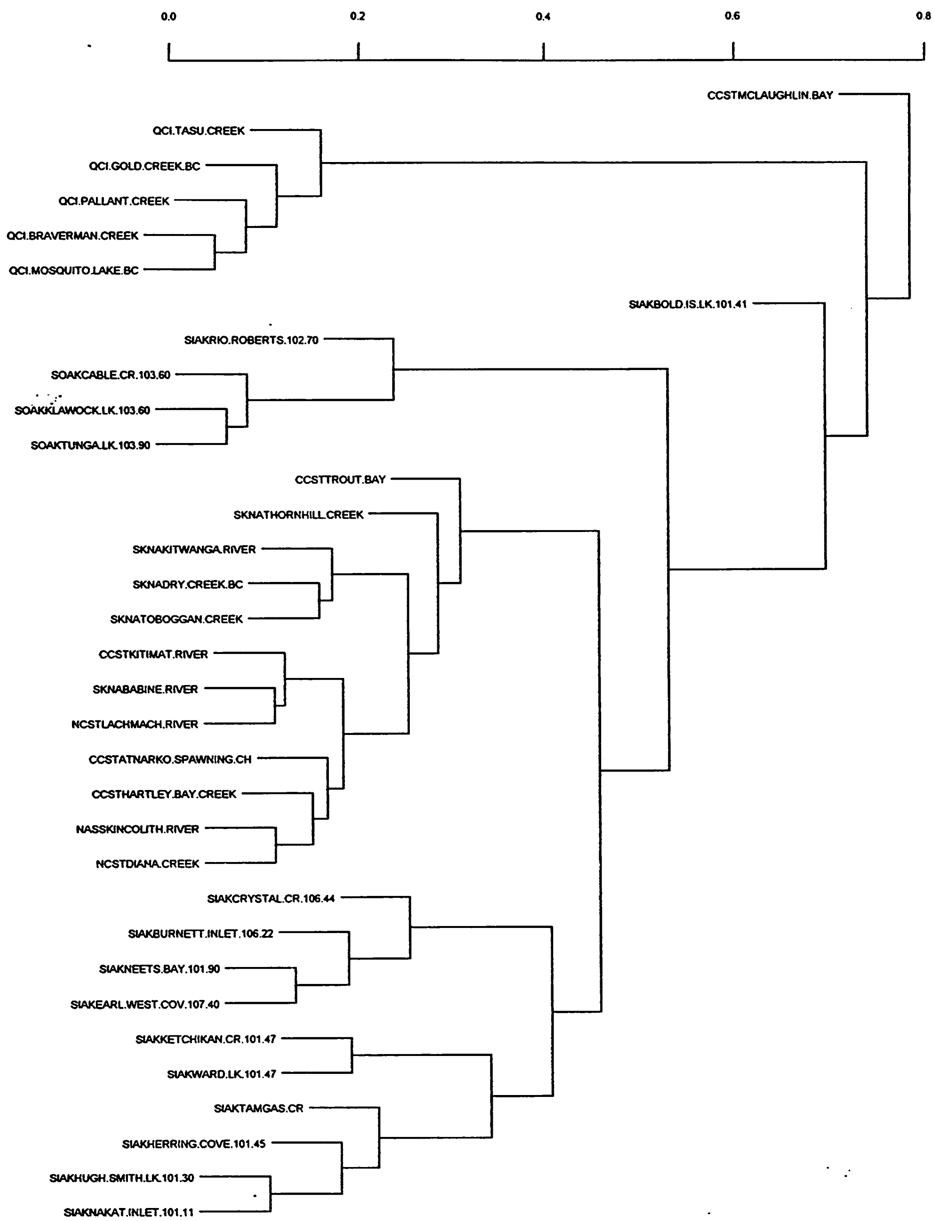

Figure 20. Clustering of release sites in northern B.C. and southern Alaska based on recoveries of CWTs in the 1992 ocean fisheries.

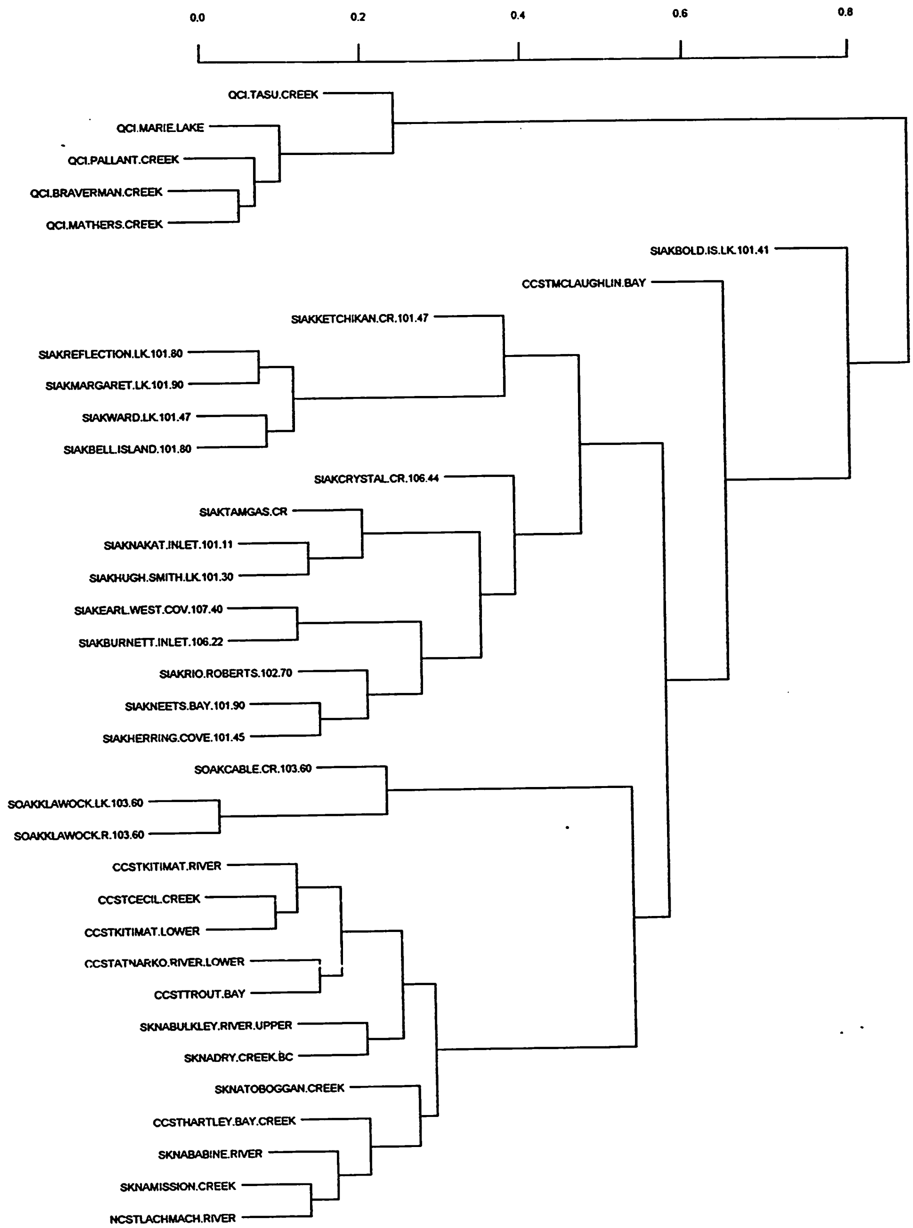

Figure 21. Clustering of release sites in northern B.C. and southern Alaska based on recoveries of CWTs in the 1993 ocean fisheries.

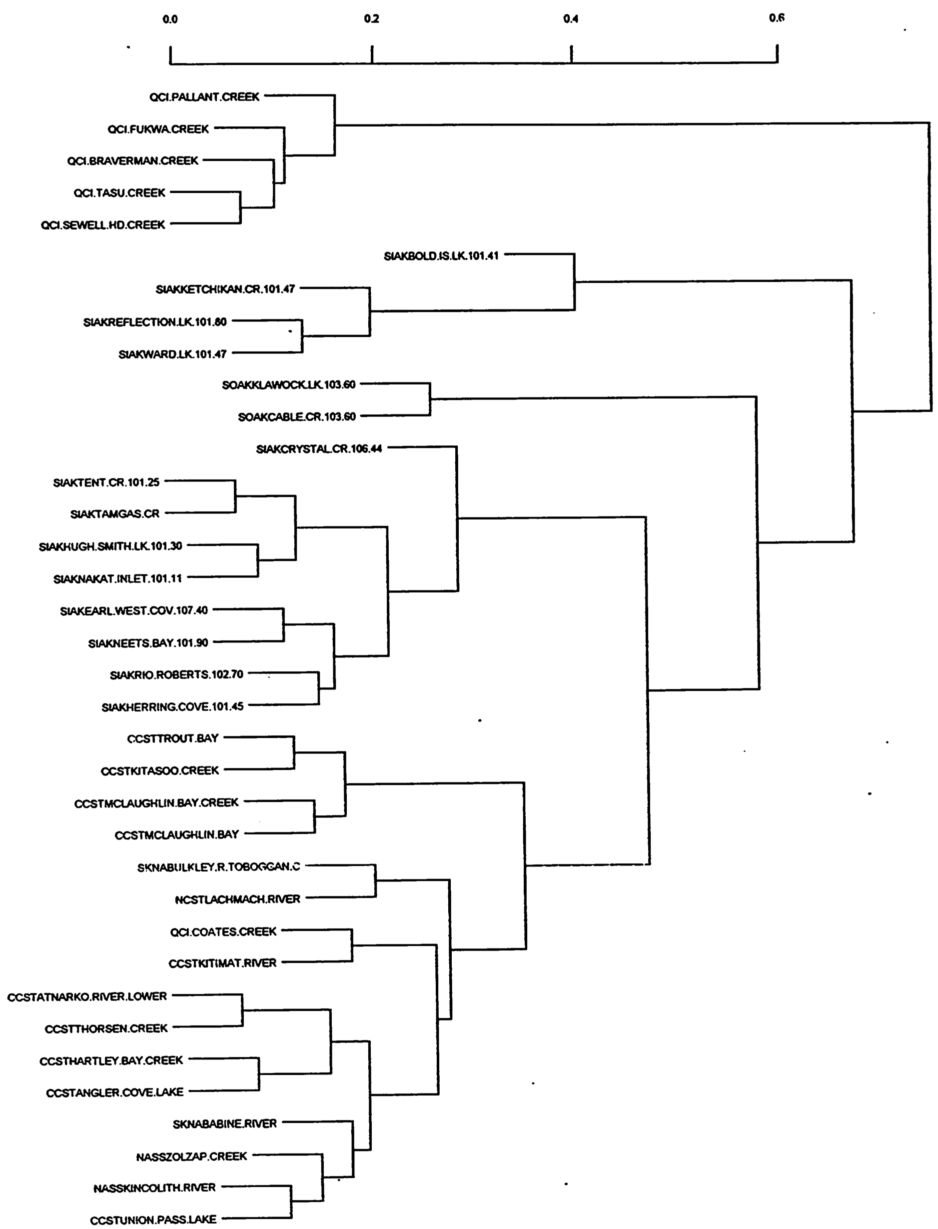

Figure 22. Survivals to the fishery by year for CWT'd fish released from the Lachmach River and upper Skeena sites.

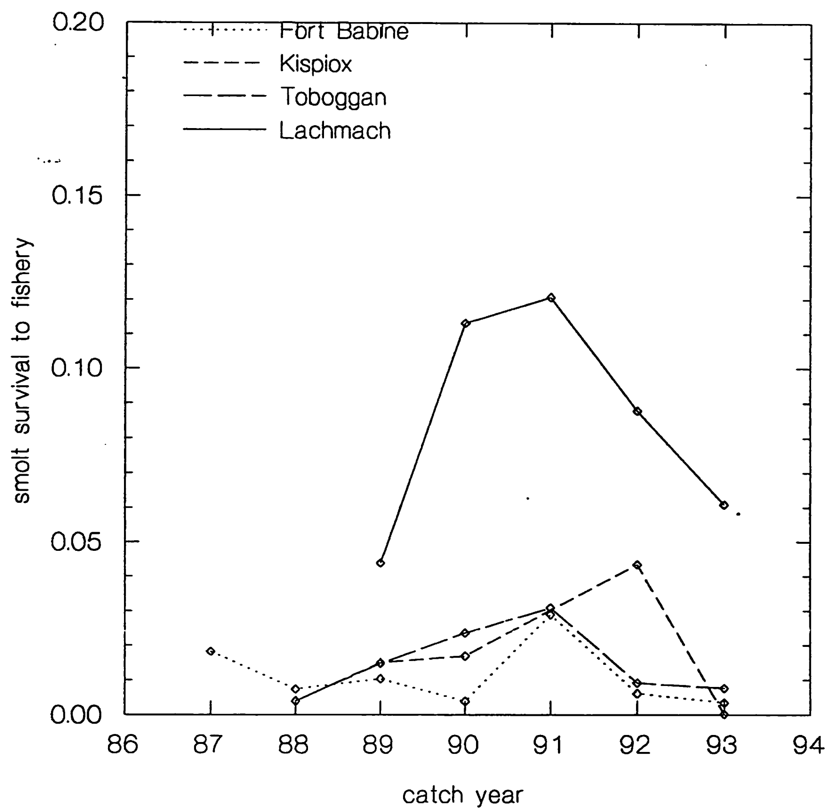

Figure 23. Variation over time of A) survival to the ocean fishery, B) smolt-to-adult survival, and C) exploitation rate, for CWT'd fish released from the Lachmach River and from Toboggan Creek CDP.