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STATUS OF COHO SALMON STOCKS AND FISHERIES IN THE NORTHERN BOUNDARY AREA

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STATUS OF COHO SALMON STOCKS

IN THE NORTHERN BOUNDARY AREA

THROUGH 1998

by

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EXECUTIVE SUMMARY

We examined information on the status of coho salmon stocks in Southeast Alaska and northern British Columbia, with emphasis on stocks in the upper Skeena River drainage. The data and analysis support several conclusions:

1. The Tyee test fishery index of early coho salmon escapement to the Skeena River is most closely correlated with Babine River escapement when the coho salmon index is adjusted to account for sockeye salmon catchability. The fit is best using a five-year-moving average, suggesting that while sockeye salmon catchability may differ from coho salmon within a given year, the long-term trend in test fishery efficiency probably holds closely for both species. The adjusted coho salmon index has shown no significant trend in early escapement to the Skeena River since 1972 (Spearman rho = -0.008, p=0.975). The downward trend in the unadjusted index since 1980 was probably caused by declining test fishery efficiency rather than a decline in abundance, assuming that the Babine stock was representative of other early Skeena stocks during that period.

2. The Babine stock declined abruptly in total abundance by 62%–66% in one generation (1975–1978 brood years), and the stock's estimated contribution to total early Skeena escapement declined markedly from about 18%, on average, in 1956–1980, to only 7% after 1980. Synchrony with non-Babine stocks increased dramatically following the decline.

3. Following the 1975 brood year, the Babine stock has under-performed compared with the pre-1976 Ricker spawner-recruit relationship on a relatively consistent basis. Intrinsic productivity has not changed significantly from pre-1975 levels, but return-per-spawner has dropped sharply at higher escapement levels suggesting that carrying capacity has decreased by 60%-75%, a decrease that is sufficient to account for the decline in the stock.

4. We examined several hypotheses for the apparent decline in carrying capacity including: loss of habitat, reduced marine survival, loss of isolated subpopulations, competition for forage by sockeye, and a habitat-specific predator response to sockeye salmon enhancement. The "predator response" hypothesis appears most consistent with the body of evidence surrounding the decline: (1) abrupt decrease (one generation); (2) coincident timing with major sockeye salmon enhancement; (3) significant decline in carrying capacity ($p<0.01$), but not intrinsic productivity ($p=0.38$); (4) divergent abundance history between Babine and non-Babine coho salmon stocks; (5) increased stability and synchrony with other Skeena coho salmon stocks, and (6) decline in freshwater survival of wild Babine River sockeye salmon that rear in the lower system.

5. Ricker analysis of marine survival-adjusted returns from the 1984–1995 brood years indicates that escapement levels at MSY and maximum stock size for the Babine stock are about 1,900 and 2,500 spawners, respectively. The 20–year average escapement was 3,219 spawners, with only two brood years below 1,900 spawners. Pending returns from recent extreme escapements (453 spawners in 1997 and 14,907 in 1999), we recommend an interim goal range of 1,900–4,000 spawners (returns averaged 30% lower for four escapements over 4,000 compared with eight escapements under 4,000).

6. MSY escapement for the Toboggan Creek stock is about 1,200 spawners, compared with a 1988–1998 average escapement of 1,592 spawners (wild only). We recommend a Toboggan Creek goal range of 950–1,900 spawners, representing 0.8–1.6 times estimated MSY escapement. During 1988–1999 the number of wild spawners has been within the proposed range in over half of the years (7), above in four years, and below only in 1997 (321 spawners).

7. A similar pattern of low spawner and smolt densities in interior Taku River tributaries, compared with nearby coastal streams, suggests that low coho salmon densities in the upper Skeena drainage may be characteristic of interior habitats, rather than evidence of chronic under-seeding by spawners. Average spawner densities in two interior Taku tributaries ranged from 5-6 females per km while four coastal streams ranged from 34–176 females per km. Interior Taku smolt densities ranged from 213–420 per km compared with 1,917–4,140 per km in coastal streams. These estimates, combined with observations of different ecological conditions in interior and coastal habitats, suggest that consistently low coho salmon density in interior tributaries is an indicator of lower habitat productivity for coho salmon, rather than inadequate escapement. Direct measurement of production from interior systems at different escapement levels is needed to reliably determine habitat capability and the number of spawners needed to seed available habitat.

8. Abundance estimates derived from the Tyee test fishery index indicate that total adult abundance of non-Babine stocks has not followed a significant long-term trend since 1956 (Spearman rho = 0.179, p = 0.257) and that escapement, while lower on average than 1950s and 1960s levels, has shown no trend since 1972 (Spearman rho = -0.015, p = 0.940). However, our discussions with biologists knowledgeable of habitat conditions in the Skeena drainage indicate that substantial habitat losses have probably occurred in some areas in recent decades, most notably in the upper Bulkley River.

9. The geographic pattern of marine survival since the early 1980s shows higher survival in more northern systems. This latitudinal gradient has intensified in 1992–1998 as survival increased in Southeast Alaska but remained stable or declined slightly for northern B.C. indicators. Survival rates for major producers (Taku, Nass, and Skeena Rivers) have been consistently lower compared with nearby smaller coastal indicator stocks. We recommend that major mainland stocks be given a high priority for assessment because of their typically lower survival rates and intensive exploitation.

10. Although historical indicator coverage is limited, the escapement status of Southeast Alaska and transboundary stocks appears to be good. Marine survival has generally been high for these stocks in the past two decades, and biological escapement goals have been met or exceeded in most years. We found the information on Canadian stocks outside of the Skeena drainage to be insufficient in quality and quantity to assess spawning escapements relative to biological parameters, or to be conclusive about status. In particular, improved stock assessment programs are needed in the central coast area.

11. Although we have found no evidence of a chronic shortage of spawners in the upper Skeena system or other northern boundary systems, the 1997 escapement of upper Skeena indicators and possibly other north coast systems appears to have been far below the historical range of observations and probably below requirements for MSY in at least some locations. Although unlikely, recurrent escapements at that level could lead to serious stock declines.

12. Indicator stocks in Southeast Alaska and in the upper Skeena system are closely correlated with fishery indicators of overall coho salmon abundance in their respective geographic areas. Several inseason indicators of aggregate abundance and marine survival for specific stocks show promise in providing timely stock assessments that are needed to support inseason escapement-based fishery management, and to help insure extremely low escapement events like 1997 are not repeated. We recommend that biological escapement goals be established for key indicator stocks and that inseason management capability be developed to estimate and respond to varying levels of abundance.

INTRODUCTION

In February 1996, the Pacific Salmon Commission Northern Panel requested that the Northern Boundary Technical Committee (NBTC) conduct a joint review of the status of northern boundary area coho salmon stocks. This effort has taken a substantial period of time, partly because of differences in interpretation of existing data for Skeena stocks.

The NBTC developed joint data sets on upper Skeena coho salmon stocks including comparable Tyee test fishery indexes through September 4 and total escapement estimates past the Babine Fence. An agreed methodology was also developed to reconstruct historical exploitation rates. A wide variety of other data were shared and discussed among committee members, but disagreement remained over interpretation of the status of upper Skeena coho salmon stocks. Therefore, the NBTC elected to produce separate U.S. and Canadian agency reports, specifically on the status of northern boundary coho salmon stocks, and a joint report on the fisheries and their management. The respective agency reports are based on the same basic data, but analysis and interpretation differs substantially in some cases. This report includes only the U.S. analysis, while Holtby (1999) provides the Canadian analysis.

Although this report encompasses stocks throughout Southeast Alaska and northern British Columbia (Figure 1), its focus is primarily on upper Skeena River stocks which have been a source of concern and debate for over a decade. Beginning in 1988, several reports have been published on the status of coho salmon populations in the Skeena system, particularly earlier migrating stocks in the interior portion of the drainage (Kadowaki 1988, Kadowaki et al. 1992, Holtby et al. 1994, Holtby and Finnegan 1997, DFO 1999, and Holtby et al. 1999). In earlier works, concerns were raised about declines in the Skeena test fishery index for coho salmon and in the Babine River fence count, as well as a drop in aggregate visual estimates of escapement. More recently, low juvenile densities have been reported as added evidence of not only an overall decline in the upper Skeena aggregate but a decrease to levels that are in some cases perilous to continued existence of the stocks (Holtby and Finnegan 1997). Concerns about the status of upper Skeena stocks were brought to the forefront following an extraordinarily poor return in 1997. These concerns were compounded by ongoing deterioration in coho salmon returns to southern British Columbia where marine survival trended downward sharply in the 1990s (Holtby et al. 2000).

As a result of concerns raised in these reports, localized conservation measures were undertaken in both net and troll fisheries in northern B.C., followed by initiation of non-retention of coho salmon, and major fishery restructuring beginning in 1998. The Canadian Minister of Fisheries announced that severe restrictions on fisheries affecting upper Skeena coho salmon stocks would be maintained for at least two cycles (six to eight years). In addition to the severe measures undertaken in Canada, Holtby and Finnegan (1997) proposed reductions in Alaska fisheries in which a substantial proportion of the harvest of Skeena stocks has been taken.

However, Shaul et al. (1998) examined historical escapement data for the upper Skeena system and concluded that, with the exception of 1997, the trend in escapement has been stable since the early 1970s for the aggregate of populations and since the late-1970s for the Babine stock. This conclusion was based primarily on a stable, neutral trend since 1971 in the Tyee test fishery index since 1971 (adjusted for changing efficiency on sockeye salmon), supported by an analysis of aggregate visual fishery officer estimates from throughout the system. They suggested that the decline in escapement to the Babine system may have been related to the major sockeye salmon enhancement program (Babine Development Project) that greatly increased the density of rearing sockeye salmon and, therefore, potential competition with coho salmon for food. With the exception of the 1997 brood year, Shaul et al. (1998) disagreed with the conclusion that upper Skeena coho salmon stocks were in need of rebuilding. However, they recommended inseason abundance-based management be developed to identify and protect weak returns of northern British Columbia stocks in general.

Detailed stock assessment information on northern boundary coho salmon stocks is available only for recent years and is limited to a very small fraction of total regional abundance. Indicator stock programs were initiated in Southeast Alaska in the early 1980s (Shaul 1998) and in northern B.C. in the late 1980s. Long-term indicator stocks in Southeast Alaska with associated data series on adult abundance extending from 1982 include Auke Creek, Berners River, Ford Arm Lake, and Hugh Smith Lake (Figure 1). Run reconstruction estimates for the transboundary Taku River are available from 1992 onward. Indicator stock programs were initiated in the Lachmach River and two upper Skeena tributaries in the late 1980s. Zolzap Creek, a lower Nass River tributary, has been studied as an indicator stock since 1993. These programs cover only a tiny fraction of total production but provide the highest level of information on stock status. In order to evaluate stock status over the longer term it is necessary to examine fishery performance (catch and effort) supplemented where available by escapement indicators that are of limited coverage and often of very questionable quality.

Coho salmon production in the northern boundary region is distributed among thousands of small streams on both islands and mainland. Mainland Rivers are very important to overall production, and a few that appear to typically produce 100,000 or more adults include the Chilkat, Taku, Nass, and Skeena Rivers. Coho salmon are most abundant in coastal streams and the lower portions of mainland rivers. However, a few major river systems that penetrate the coast range contain apparently unique stocks that are adapted to the very different interior environment of headwater tributaries. Of the northern boundary systems, the Skeena River likely contains the greatest relative proportion of interior stocks.

Upper Skeena coho salmon stocks include a myriad of populations and subpopulations throughout a broad area of the interior Skeena River drainage (Figure 2). These stocks fall into three distinctive geographic areas that include Bulkley/Morice, Babine, and High Interior (or Upper Skeena/Sustut). The Kispiox River was categorized as an upper Skeena tributary by Koski et al. (1995) but as a middle Skeena system by Holtby and Finnegan (1997), and will be treated as a middle tributary in this report.

The Bulkley-Morice system is largely road accessible and several communities are located within the drainage as well as substantial agriculture, forestry, and mining development. This system has an indicator stock based on both wild and hatchery production at Toboggan Creek, near the town of Smithers.

The Babine drainage is dominated by Babine Lake, which is a large body of freshwater that supports substantial sockeye salmon production. Coho salmon spawn in tributaries of Babine Lake and in the Babine River and its tributaries below the lake (Figure 3). An adult salmon enumeration fence has been operated in the Babine River since 1948, and has enumerated varying proportions of the coho salmon escapement depending on the operational ending date. Coded-wire tagged smolts from the Fort Babine hatchery have been used to represent the stock in the fisheries since 1987.

The High Interior or Upper Skeena/Sustut area includes the upper reaches of the Skeena River proper and its tributaries (Sustut, Bear, Kluatantan, and Slamgeesh), some of which are at relatively high altitude (>1,000 m) in a subalpine environment. Very little is known of coho salmon populations in this remote area except for limited juvenile surveys and occasional fence counts incidental to other species (Holtby et al. 1999).

Upper Skeena stocks typically enter the lower system earlier than most stocks in the lower and middle Skeena, although a 1994 radio-telemetry study (Koski et al. 1995) indicates that there is substantial overlap in timing. Early authors (Kadowaki 1988, Kadowaki et al 1992, and Holtby et al. 1994) referred to interior stocks as “early” Skeena stocks which were thought to have largely passed the Tyee test fishery before August 25. However, this designation evolved into “upper” Skeena with the finding that coded wire tagged fish from the Toboggan Creek and Fort Babine hatcheries were recovered in marine fisheries through the second week of September (Spilsted and Hudson 1994).

Despite evidence of protracted and overlapping timing with middle and lower river stocks, the early Tyee test fishery index has been a primary measure of the aggregate status of upper Skeena stocks, and we will include it in this analysis. We will explore alternative hypotheses regarding the trend in efficiency of the test fishery index, and its effect on interpretation of the status of escapements.

We will also present available data on abundance and other parameters for Babine and Bulkley-Morice stocks in order to explore population trends and to estimate stock productivity and MSY escapement. For the Babine stock, we will examine the trend in the population relative to other Skeena stocks and explore alternative hypotheses for a major downward shift in abundance during 1978–1981.

We will also examine recent information on juvenile densities in the Skeena drainage to examine the conclusion of Holtby and Finnegan 1997 and Holtby et al. 1999 that low juvenile densities (compared with established standards from coastal systems) are evidence of widespread depletion of upper Skeena stocks through over-exploitation. We will present comparative population density estimates for Alaska coastal systems and interior Taku River tributaries, and explore an alternative hypothesis that low coho salmon density in interior systems reflects lower habitat capability for that species, compared with coastal systems.

We will not examine visual estimates of spawning escapement in the Skeena system, as these data have been evaluated recently (Shaul et al. 1998 and Holtby et al. 1999). Also, while in aggregate, the visual estimates have followed a similar trend to the adjusted Tyee test fishery index (Shaul et al. 1998), they are poorly documented and of questionable reliability, and are therefore of only very limited use in a detailed assessment.

Finally, while the central focus of this report is on upper Skeena stocks, we will also present information on the status of Southeast Alaska and northern B.C. stocks from outside of the Skeena drainage, but in less detail.

DATA SOURCES

All counts and estimates within the Skeena system and catch estimates for northern B.C. were made by the Canada Department of Fisheries and Oceans (DFO) and provided to the Northern Boundary Technical Committee (NBTC) of the Pacific Salmon Commission. The unadjusted Tyee test fishery index and Babine escapement estimates were standardized jointly by the NBTC to account for varying ending dates. Also, reconstruction of historical exploitation rates from fishing effort data was undertaken jointly within the NBTC. However, this report contains some differences from Holtby (1999) in the methods used to reconstruct the historical catch of Babine River coho salmon (see section on Babine River Stock — Run Reconstruction).

Also, there are some differences (mostly minor) from Holtby et al. (1999) in the estimated marine harvest of tagged Babine and Toboggan coho salmon stocks. Marine coded wire tag (CWT) information in this report was downloaded from the Pacific States Fisheries Commission data base in December 2000. However, for 1997 and 1998 we used estimates from Holtby et al. (1999) for Canadian commercial fisheries, which include alternative mortality estimates for net fisheries. For marine sport and freshwater fisheries, we used harvest rate estimates that were made by Dave Peacock (DFO, Prince Rupert) based on 1994 radio-telemetry estimates by Koski et al. (1995), and also used by Holtby et al. (1999). CWT estimates for spawning escapements are from Holtby et al. (1999).

Juvenile coho salmon density estimates for the Skeena drainage and nearby coastal streams were provided by Blair Holtby (DFO, Nanaimo). Juvenile and spawner abundance estimates for two sites in the upper Taku drainage used for comparison were obtained from reports by Shaul (1987, 1988, 1989, 1990, and 1992). Pre-smolt, smolt, and spawner abundance and marine survival estimates for four Southeast Alaska systems were updated from those reported by Shaul (1998). Taku River smolt production, survival, and run estimates are reported in Yanusz et al. (1999).

Nass River escapement estimates based on marking at lower river fishwheels and recovery at the Meziadin fishway were provided by Richard Alexander (LGL Ltd., New Aiyansh, B.C.). Meziadin fishway counts were obtained from the DFO North Coast salmon website. Estimates for the Zolzap Creek indicator stock in the lower Nass River drainage were reported by Nass (1996a, 1996b, 1996c, 1997a, 1997b, 2001), Nass and Frith (2001) and Baxter et al. (2001). Data for the Lachmach River indicator stock were reported in Holtby et al. (1999). Data on Southeast Alaska indicator stocks through 1997 were reported by Shaul (1998) and are updated here through 1998.

TYEE TEST-FISHERY INDEX

The Tyee test fishery has indexed the number of salmon entering the lower Skeena River since 1956. The test fishery is the only available measurement of the total aggregate abundance of coho salmon stocks entering the Skeena River. However, despite efforts to maintain constant efficiency, substantial variations and trends in efficiency have raised questions about the consistency and reliability of the Tyee Index (Cox-Rogers and Jantz 1993). A comparison between the Tyee index for sockeye salmon and independent upriver estimates of sockeye salmon abundance indicates the efficiency of the index for that species has not only been variable but has followed a substantial trend over time (Figure 4). However, test fishery efficiency has not been independently assessed for coho salmon, leaving an unresolved technical question about how to interpret the coho salmon index.

Another problem concerning use of the Tyee Index to evaluate abundance of upper river coho salmon stocks is that there is substantial intermixing with middle and lower Skeena stocks that could partially mask a change in escapement to a specific portion of the system. Upper Skeena stocks tend to migrate early in the season with middle and lower river stocks becoming more prevalent as the season progresses. However, there are exceptions that include a substantial early-run stock in the Kitsumkalum River, a lower Skeena tributary (Koski et al. 1995).

In our analysis of the Tyee index, we evaluated available information on run timing from a 1994 radio telemetry study (Koski et al. 1995) as an aid in selecting an optimal ending date for the coho salmon index that best represents abundance of upper river stocks. We also compared the index with escapements to the Babine River as a guide in selecting both an ending date and a preferred method for incorporating varying efficiency for sockeye into the index.

Ending Date

The test fishery has consistently been placed in operation well before the coho salmon run but the ending date has varied from August 24 to October 7. Therefore, only the early portion of the coho salmon run has been indexed in many years.

The test fishery has been operated through September 4 in 40% of the years during its history and in over half of the years in the more recent period from 1981–1998. Operation has been much less frequent after September 4. In order to develop the most complete and comparable index from available data, we filled in incomplete data for test fishery ending dates up to September 4 using values from other years and other weeks (Table 1). Missing values were filled in under the assumption that the expected value is determined by a given week and year in a multiplicative way (i.e., values across weeks for a given year are multiples of values for other years, and values across years for a week are multiples of values for other weeks). The estimated expected value for a given week in a given year is then equal to the sum of all values for the year times the sum of all values for the week divided by the sum of all values over all weeks and years. If there is more than one missing value, an iterative procedure, as described by Brown (1974), must be used since the sums change as missing values are filled in at each step.

We evaluated the index through ending dates ranging from August 24 to September 4. There were several issues to consider in choosing an index ending date for the assessment. An index that continues farther into the run reduces the effect of variability in run timing which may be substantial for the August 24 ending date because upper Skeena stocks are known to continue entering the river until after mid-September. However, a late ending date may be less specific to upper Skeena stocks for which there has been the greatest concern. Radio telemetry research (Koski et al. 1995) indicates late-run lower Skeena stocks begin to enter the river in late August and comprise the majority of the run by mid-September. Also, seal predation in the test fishery gillnet becomes a more important potential source of bias in September following the pink salmon run when overall salmon abundance declines dramatically relative to the number of predators (Dave Peacock, DFO, Prince Rupert, personal communication). Finally, filling in for missing data in later weeks adds a varying degree of statistical uncertainty in some years.

Two factors were considered in selecting a standard ending date for the analysis. First, we examined available radio telemetry data to determine ending dates that encompassed much of the run to the upper system while avoiding the period when lower river stocks were predominant. Second, we examined the statistical fit between the test fishery index and the estimated escapement to the Babine River (Table 2), the only long-term reliable indicator of escapement specific to the upper system.

Radio Telemetry Results

Only 74 radio-tagged fish were tracked to spawning areas in the Skeena River in a single annual study in 1994 (Koski et al. 1995). Therefore, radio telemetry results can provide only a rough indication of stock composition of the escapement. Unfortunately, while tagging was conducted in marine waters near the river mouth, there was no radio receiving station at Tyee with which to directly calibrate stock composition at the test fishery. However, the average period between tagging in the ocean and passage at the Exchamsiks station upstream of Tyee was 11.4 d. The average inriver travel rate between Exchamsiks and the next mainstem station at Zymoetz (17.1 km/d) was applied to the distance from Tyee to Exchamsiks (68 km) to estimate the travel time from Tyee to Exchamsiks (4.0 d). Subtraction of the

Tyee-Exchamsiks estimate from the Tagging-Exchamsiks estimate resulted in an average period of 7.4 d between tagging and passage at Tyee. Therefore, a period of 7 d was used to adjust tagging dates to the test fishery.

Upper river stocks accounted for 38% of cumulative fish marked from August 5–August 25 (corresponding to August 12–September 1 at Tyee) that were tracked to spawning destinations in the Skeena drainage. Small sample sizes and the narrow range of percentages makes it impossible to determine with any precision whether upper Skeena stocks were more prevalent for any particular ending date within this range. Kitsumkalum and middle Skeena stocks accounted for most tags within this period that were not destined for the upper system. A total of 40 radio tags applied through August 25 were tracked to spawning destinations within the Skeena drainage of which 15 (37.5%) went to the upper system including: three (7.5%) to the Babine River, four (10%) to high interior areas of the upper Skeena River including the Sustut River, and eight (20%) to the Bulkley drainage. Five tags (12.5%) were tracked to the Kispiox River and six (15%) to other locations in the middle Skeena drainage above Terrace. The remaining 14 tags (35%) applied through August 25 were tracked to locations in the lower Skeena drainage, of which the Kitsumkalum River accounted for 10 tags (25%). The proportion of tags entering the Skeena River that were destined for the upper system is probably an under-estimate as the authors reported that between six and 11 tagged fish were harvested within the system at locations and times that suggested most were bound for the upper drainage.

Later migrating lower Skeena stocks began to account for the majority of tags released after August 24 and the percentage of cumulative recoveries that were tracked to the upper system fell sharply after August 25. Of the 34 tags applied after August 25 that were tracked to spawning destinations in the Skeena drainage, 29 (85%) went to lower Skeena locations while the remaining five tags were distributed as follows: Kispiox River (2), other middle Skeena tributaries (2), and Babine River (1). Most of these later fish were tagged during September 2–8, while there were only five recoveries from tagging during August 26–September 1.

In conclusion, the radio telemetry results suggest an August 31 or September 1 test fishery ending date (corresponding to ocean tagging through approximately August 24–25) offers about the best possible compromise for indexing upper Skeena stocks.

Test Fishery-Babine Fence Comparison

In selecting a test fishery ending date, we also considered the relationship between the index (through various ending dates) and escapement to the Babine River. The Babine River stock is thought to account for only a small component of the upper Skeena run, and its representiveness is unclear. Never-the-less, the Babine escapement is the only potentially reliable long-term index of escapement in the upper drainage.

Both adjusted and unadjusted indexes show a sharp decline in the Babine escapement relative to the test fishery index between 1978 and 1981 (Figure 5). Because of the abrupt change in the test fishery-Babine relationship, we elected to evaluate test fishery ending dates using the later period beginning in 1981. R^2 values were computed for linear relationships using four different adjustment methods and different ending dates including August 15 and August 24–September 4 (Table 3). The September 1 ending date showed the best fit regardless of adjustment method with R^2 values ranging from 0.64 for the unadjusted index to 0.87 using a five-year symmetrical average sockeye salmon catchability adjustment. However, while the fit was optimal for September 1, it was nearly as good (R^2 = 0.83 or higher) over a range of ending dates from August 24 to September 4.

We chose September 1 as a standard ending date for analysis of the test fishery index because it fit best with the Babine escapement and because it was a reasonable compromise date for the most complete and concise coverage of upper system stocks.

Accounting for Catchability

The test fishery index is the only available indicator of aggregate escapement of early migrating stocks into the Skeena system since 1956 and is, therefore, critical to an assessment of the run. Whether or not to adjust the Tyee test fishery coho salmon index for sockeye salmon catchability is a critical issue for assessment of historical escapement and most importantly, the recent trend. The decision about which index to use has relatively little consequence until the most recent two decades when the unadjusted index shows a steep linear decline at an average annual rate of 3.3% per year, increasing from 2.5% to 4.6% per year during the period (Figure 5). At the same time, the unadjusted index shows a stable trend with a slope not significantly different from zero. Because of its importance to the entire assessment, it is necessary to first evaluate the question of catchability before continuing with an assessment of the test fishery index.

The sockeye salmon run past the Tyee site is estimated independently of the test fishery so that an annual post-season calibration can be done for that species. Results of this calibration show catchability (the proportion of the run censused by a unit of test fishery effort) has varied substantially and declined markedly from the 1970s to early 1990s (Figure 4). Average efficiency of the test fishery in indexing the sockeye salmon run declined by 60% from 1977–1981 to 1992–1996. Unfortunately, there is no comparable information with which to directly compute catchability for other species, including coho salmon. Although it seems highly probable that catchability for other species has changed as well, fluctuations in efficiency and the magnitude of the decreasing trend may have differed among species. The only available method to account for changing efficiency for coho salmon is to correct directly for sockeye salmon catchability. We made this adjustment by dividing the annual unadjusted coho salmon index by the corresponding sockeye salmon catchability factor and multiplying the result by the 1994 (lowest observed) sockeye salmon catchability factor (Table 1).

The causes of variability in sockeye salmon catchability are poorly understood. However, Cox-Rogers and Jantz (1993) identified gear saturation, size selectivity, and accessibility to the gear as three of the most important factors. Within the category of accessibility they identified river hydrology, net design, fish behavior, and seal predation as probable important factors. Another potential problem results from the possibility of inaccurate or incomplete accounting for non-Babine sockeye salmon stocks. Escapement estimates for non-Babine stocks are visual estimates from the spawning grounds which may substantially underestimate their proportional contribution to the total system escapement compared with Babine stocks that are enumerated at the fence. An increasing trend in escapement estimates for aggregate non-Babine sockeye salmon stocks (Wood et al. 1998) shows nearly an opposite pattern from declining Tyee Index catchability estimates (Figure 4), suggesting that if under-estimation has been a problem it has actually moderated the recent decline in efficiency.

Unfortunately, it is impossible from existing data to accurately assess catchability within the period of a seasonal migration. However, depending on flow and turbidity conditions, we suspect catchability may vary substantially within the period of the sockeye salmon run and may change substantially by the time the main coho salmon run occurs. Other factors that affect sockeye salmon catchability (such as varying fish size with ocean age) may not apply at all to the coho salmon migration in the same year. With that in mind, we developed and evaluated test fishery indices that incorporated three and five-year symmetrical moving average sockeye salmon catchability factors. The intent was to account for the trend in sockeye salmon catchability, which may apply to coho salmon as well, while reducing potential variability introduced by factors such as fish size, short-term river conditions, and gear saturation that may be more specific to sockeye salmon within a given year.

In evaluating adjustment methods, we examined relationships with the Babine escapement over the entire data series and within limited periods. We selected an early period (1956–1978) before the decline in Babine escapement relative to the Tyee index, a later period (1981–1998) after the decline, a 1970–1998 period used by Holtby et al. (1999) that transited the decline, and the most recent 10-year period (1989–1998).

Over the complete period from 1956–1998, R^2 was the same (0.48) for the unadjusted and annually adjusted indexes (Table 4). The unadjusted index fits substantially better compared with adjusted indices when the extreme 1965 point is removed from the relationship (R^2 = 0.43 compared with 0.18). The difference in fit between the adjusted and unadjusted methods is greatest in the 1970–1998 period when the R^2 value for the unadjusted index is 0.51 compared with 0.17 for the annual adjustment and 0.22 for the moving average adjustments.

The degree of fit between the test fishery index and the Babine escapement varies greatly between the periods before and after the relative decline in Babine escapement. During the early period (1956–1978), the fit is poor with R^2 values ranging up to 0.44 for the annual adjustment. However, there is no significant relationship in any case when the data point for the exceptional 1965 run is excluded. Without 1965, R^2 values ranged from 0.01 to 0.04.

In contrast, the fit improved dramatically following the decline in the Babine escapement relative to the Tyee index. During this later period (1981–1998), the annual catchability adjustment improved the fit substantially over the unadjusted index (R^2 = 0.79 versus 0.64). In addition, the slope was substantially greater and the Y intercept lower for the adjusted index. However, the best fits were obtained for the average catchability adjustment, with the three and five-year adjustments having R^2 values of 0.87.

Finally, the relationship between the test fishery index and the Babine escapement has remained remarkably strong in the most recent 10-year period with R^2 values ranging from 0.91 for the unadjusted index to 0.96 for the three-year adjustment.

Regardless of the adjustment method used, the Babine escapement clearly underwent an abrupt decline relative to the test fishery between 1979 and 1981. The Babine component then stabilized while the unadjusted index declined after 1981 (Figure 5), coincident with declining sockeye salmon catchability (Figure 4). Adjusted indices show a similarly poor fit before the decline and a far closer fit with Babine escapement afterward. Therefore, an overall decline in both indicators during the period appears to explain the closer fit with the unadjusted index over periods beginning in 1956 and 1970 (Holtby et al. 1999), even though the timing and probable cause of the decline was different for Babine escapement compared with the adjusted Tyee index. All adjustment methods point to an actual abrupt decline in Babine escapement relative to the rest of the system during 1979–1981. However, the decline in the unadjusted index relative to the Babine escapement after the early 1980s probably occurred because test fishery catchability declined for coho salmon as it has for sockeye salmon. The later decline in the unadjusted Tyee index, while probably not indicative of actual abundance, increased the overall downward slope of the index to more closely match the Babine escapement over the entire 29-year period (hence higher correlation coefficients for periods that transited the Babine decline).

We selected a five-year average catchability adjustment using the September 1 ending date for further analysis because that combination was most closely correlated with the Babine escapement in recent years (1981–1998). The abrupt decline in Babine escapement concurrent with dramatic improvement in the fit with the Tyee index after 1980 is an interesting feature that is discussed in further detail the "Babine River Stock" section.

Test Fishery Trends

The Tyee five-year adjusted index showed a high and increasing trend (although not significant: Spearman rho = 0.459, p=0.074) trend from 1956 through 1971. However, the index decreased abruptly beginning in 1972 and has shown no significant trend during the most recent 20-year period from 1979 through 1998 (Spearman rho = -0.008, p=0.975) (Figure 6). Over the entire period from 1956–1998, the index has shown a decline that was not significant by a small margin (Spearman rho = -0.419, p=0.005). The index has averaged 28.9 during 1972–1998, a decrease of 42% from 1956–1971 (average 49.2). During the most recent 10-year period from 1989–1998, the average index (32.5) was 66% of the 1956–1971 level and 121% of the 1972–1988 level (average 26.9).

The 10-year coefficient of variation for the test fishery index increased during the period spanning the drop in the index in 1972, before decreasing again to 0.27–0.32 for periods ending in 1981 through 1988 (Table 5 and Figure 7). However, despite a continued stable index trend, variation has increased since 1986 from 0.32 in 1979–1988 to 0.56 in 1989–1998. The recent 10-year period from 1989–1998 has included three of the ten highest observed test fish indexes (1989–1991) as well as three of the four lowest (1992, 1993, and 1997). The 1997 test fishery index was one-third or less of the previous lowest indexes (33% of 1979 and 27% of 1993).

The trend in the coefficient of variation of the Babine escapement differed substantially from the Tyee Index until the most recent 20 years. Both indexes have since shown a parallel increase in variability since the 10-year period ending in 1988 (Figure 7). Overall, the Tyee Index has become more variable since the post-1978 decline in Babine abundance (coefficient of variation increased from 0.382 to 0.504) while Babine escapement has been less variable (coefficient of variation decreased from 0.666 to 0.403) (Table 5).

Non-Babine Component

There was an abrupt decline in the Babine fence escapement both in absolute terms and relative to the Tyee test fishery index during 1979–1981. Because of this change, it is necessary to remove the Babine component from the Tyee index in order to evaluate escapement of other early migrating stocks throughout the full historical period of the Tyee index. Information from the 1994 radio telemetry project (Koski et al. 1995) provides a potential basis for separation of non-Babine and Babine components.

As described above, three (7.5%) out of 40 radio tagged fish estimated to have passed Tyee through September 1 were tracked to the upper Babine River. For other years, the proportional contribution of Babine River coho salmon ($P_{Bab.i}$) to the September 1 adjusted test fishery index was estimated as follows:

where:

$$P_{Bab.i} = P_{Bab.94}(B_i/B_{94})/(T_i/T_{94})$$

- i : year,
- $P_{Bab.94}$: estimated Babine proportion of the Tyee test fishery index in 1994 (0.075),
- B_i : Babine escapement in year i,
- B_{94} : Babine escapement in 1994 (4,053),
- T_i : Tyee test fishery index in year i,
- T_{94} : Tyee test fishery index in 1994 (35.32).

As expected, the estimated contribution of the Babine stock to the Tyee index shows an abrupt decrease to a lower, more stable proportion after 1980 (Figure 8 and Table 2). The estimated average contribution of the Babine component fell from 18% in 1956–1980 to only 7% in 1981–1998. At the same time, the coefficient of variation of the estimated Babine proportion decreased from 0.53 to 0.25.

Abundance trends in both Babine and non-Babine components of the escapement peaked in the 1960s (Figure 9). The non-Babine component followed a lower, but relatively stable trend after 1971 with an average index during 1972–1998 (25.9) that was 63% of the 1956–1971 average (41.3). The average non-Babine index for the most recent 10-year period from 1989 to 1998 (30.3) was 73% of the 1956–1971 average and 130% of the 1972–1988 level (23.4). In comparison, the average Babine escapement in 1989–1998 (3,350) was only 27% of the 1956–1971 average (12,594) and 61% of the 1972–1988 average (5,487).

While the number of tags tracked to the Babine River and other locations in the Skeena drainage in 1994 is small, the relative decline in the Babine percentage remains the same regardless of the 1994 calibration. Also, the effect of uncertainty about the Babine fraction on the larger non-Babine component is not great since the point estimate of the non-Babine proportion in 1994 was large (92.5%) with 90% confidence limits ranging from 81.7–97.9%. Based on these confidence bounds, the 1989–1998 average non-Babine index was between 68% and 82% of the 1956–1971 average (point estimate 73%) and between 122% and 150% (point estimate 130%) of the 1972–1988 average.

While the overall trend in the non-Babine component has been relatively stable with no significant trend since 1972 (Spearman rho = 0.100, p = 0.622) or even since 1956 (Spearman rho = 0.297, p = 0.056), escapement of both the non-Babine and Babine components has been highly variable in recent years. The most recent 10-year period included proportionately more years when the non-Babine index was over 40 (three out of 10) compared with earlier years (eight out of 32), but also included three of the five lowest escapements. Since 1981, both the Babine and early non-Babine components of the Skeena escapement have been highly variable but have tracked closely together with no significant positive or negative trend. Escapement of both components was very low in 1997 at approximately one-third of the previous lowest observed level.

Test Fishery Technical Issues

Although it is impossible to conclusively determine whether the adjusted (for sockeye salmon catchability) or unadjusted index more accurately reflects aggregate upper Skeena coho salmon escapement, the collective evidence strongly favors the adjusted index. While year-to-year variation in sockeye salmon catchability is somewhat predictable from average sockeye salmon length (Cox-Rogers and Jantz 1993), the cause of the downward trend in sockeye salmon catchability since the late-1970s remains a mystery. Since the trend cannot be explained by any factor specific to the sockeye salmon run, we conclude that test fishery catchability for coho salmon has most likely also followed a downward trend over the same period. While it seems very unlikely that coho salmon have not been affected to some extent, it is impossible to determine whether the slope of the trend for the two species differed, and therefore, the accuracy of directly applying of the sockeye salmon catchability adjustment directly to the coho index. The conclusion that the long-term trend in catchability probably holds closely for coho salmon (while year-to-year variations may differ substantially between the two species) is supported by the close fit between the Tyee index and the Babine fence escapement when using three and five-year moving average catchability adjustments.

The abrupt 1979–1981 decline in the number of Babine spawners relative to the aggregate early Skeena escapement is evident in a comparison of the Babine fence escapement with either the adjusted and unadjusted index. Therefore, we conclude that a decline in the Babine escapement (relative to the remainder of the aggregate) did in fact occur during this period and was probably related to a drop in smolt production. However, it makes little sense to us that the Babine escapement then followed a lower but stable trend beginning in 1981 while escapement in the remainder of the system then began declining for decades relative to the Babine run (on a slope that coincidentally tracked declining sockeye salmon catchability).

The conclusion in favor of the unadjusted index by Holtby et al. (1999) hinges on their selection of a particular base period (1970–1998). Using the same criteria (i.e. synchrony with Babine escapement), but comparison periods before and after the Babine decline, we conclude just the opposite — that the adjusted index is substantially more synchronous with Babine escapement, and therefore, a more appropriate indicator of upper Skeena escapement. Their conclusion that early-run aggregate escapement has declined since 1980 is probably attributed entirely or in large part to a decline in coho salmon catchability, similar to that demonstrated for sockeye salmon. We conclude that there has likely been no trend in aggregate escapement since 1981 (as indicated by the adjusted index shown in Figures 5 and 6), while total non-Babine escapement has shown no obvious trend since the early 1970s (Figure 9).

However, despite the preponderance of evidence in favor of incorporating a sockeye salmon catchability adjustment into the coho salmon index, the lack of an explanation for changing sockeye salmon efficiency, or consensus on whether or not to apply it to coho salmon, points to the need for more specific and direct measures of escapement. Low resolution in the Tyee index, because of overlapping run timing between upper Skeena stocks and stocks from the lower and middle Skeena, is further evidence of the need for more specific measures of escapement.

BABINE RIVER STOCK

Babine Lake is a large water body in the upper Skeena drainage that drains through the upper Babine River, Nilkitkwa Lake, and the lower Babine River (Figure 3). The Babine system is a major producer of sockeye salmon and a counting fence has been operated on the lower Babine River nearly every year since 1946.

Nilkitkwa Lake and the North Arm of Babine Lake have historically been important rearing areas for a late sockeye salmon run that spawns in the Babine River both above and below Nilkitkwa Lake. However, natural spawning habitat around the main Basin of Babine Lake is very limited relative to the capacity of the lake to rear sockeye salmon juveniles. Recognition of this fact led to construction of major spawning channels beginning in the late-1960s, one at Fulton River and a second a Pinkut River (West and Mason 1987). These projects have quadrupled sockeye smolt production from the main basin of Babine Lake and have resulted in a dramatic increase in the middle-timing portion of the sockeye salmon run in the Skeena River system (Wood et al. 1998).

The Babine River system is also important for coho salmon, although historical coho abundance is a small fraction of the number of sockeye salmon produced in the system. The fence operation was established primarily to assess the sockeye salmon escapement, and the fence has often been removed well before the end of the coho salmon run. However, despite this limitation, escapement counts and age samples from the Babine Fence provide the only data series of sufficient duration and reliability to evaluate the productivity and abundance long-term abundance trends for a specific coho salmon population in the upper Skeena system.

Available Data Sets

Since 1946, the Babine fence has been operated at least partially through the coho salmon run every year, except 1948 and 1964. The latest date for which there is a count every year is September 13. Incomplete counts were expanded to a total season estimate using the average cumulative proportion of the total count from years with complete escapement counts (Holtby et al. 1999). A change in timing was noted in the early 1990s, so incomplete years were estimated using two separate base groups with one from 1948–1991 and a second beginning in 1992. Cumulative counts through September 13, final season counts (regardless of ending date), and total season escapement estimates are shown in Table 2 and Figure 10.

Our escapement numbers are identical to Holtby (1999) with four exceptions. Although we did not attempt to estimate Babine escapement for the two years when the fence was not operated (1948 and 1964), Holtby estimated the 1948 escapement from the catch per hook in the Alaska troll fishery and the 1964 escapement from the unadjusted Tyee test fishery index through September 4. Also, we included the extremely high 1965 escapement estimate of 42,985 spawners based on the September 13 count of 20,000 expanded for average run timing. However, Holtby rejected the extremely large 1965 estimate as ”inconsistent with other returns that year” and instead used a figure of 22,985. We excluded the exceptional 1965 estimate from some parts of our analysis because it had a large effect on estimated population parameters. Also, while Holtby (1999) used Alaska troll catch-per-hook to estimate what the 1951 escapement would have been had the Babine slide not occurred (20,427), we used the average escapement for 1949, 1950, 1953 and 1954 (10,706). We used the "without slide" estimate only to estimate recruitment of the minor age class (age 4) for the 1947 brood year and used the actual above-slide estimate of 2,276 as the escapement for the 1951 brood year. Holtby (1999) did likewise, but also used the "without slide" estimate to compute age 3 returns for the 1948 brood year for which we made no escapement estimate.

Age data is relatively incomplete (Table 2). A relationship between the number of age-3 fish in brood year + 3 and the brood year escapement was used to estimate age composition for return years with inadequate age data. On average, 66% of Babine coho salmon from all brood years returned at age 3, however, an average of 71% returned at age 3 for the most recent ten complete brood years (1985–1994).

Escapement History

The history of Babine coho salmon escapements shows several features of interest (Figure 10 and Table 2). With the exception of an extremely large escapement in 1965 (September 13 count 20,000; total season estimate 42,985), early escapements followed a relatively stable trend near 10,000 spawners annually through 1978. The average escapement then dropped abruptly to a much lower but stable trend (Spearman rho = 0.135, p = 0.570) averaging just over 3,200 spawners for the most recent 20 years (1979–1998). Within the recent period, there occurred an exceptionally low 1997 escapement of 453 spawners which was only 26% of the lowest escapement recorded in the 49 previous years. The average escapement (3,219 spawners) in the most recent 20 years was only 30% of the average of 10,767 for the previous 31 years (35% if the exceptional 1965 and 1997 escapements are excluded).

Run Reconstruction

Fishery exploitation rate estimates are available for the Babine stock beginning in 1994 and for Toboggan Creek beginning in 1988. Exploitation rates for prior years, were estimated from historical fishing effort and a recent proportional relationship between effort and exploitation rate.

Holtby et al. (1999) describe the process used to reconstruct effort and exploitation rates in the Canadian fisheries. A similar method was used for Alaska fisheries, where a profile was developed of the relative catch per boat day (CPUE) of coded wire tagged upper Skeena coho salmon in the primary fisheries that harvested those stocks. The estimates were stratified by area (six areas) and time (statistical week) for the Alaska troll fishery, and by week only for the purse seine fisheries in Districts 101 and 104. The Tree Point gillnet fishery (District 101) was the only other single fishery in Alaska that harvested a substantial number of tagged upper Skeena coho salmon. However, the Tree Point fishery showed a very stable effort history and therefore a recent average exploitation rate was used for earlier years. The recent combined exploitation rate by more minor harvesting fisheries was also averaged to reconstruct earlier values.

An annual profile of the CPUE of upper Skeena tags was developed for each year when adequate data was available. Then each year was standardized to a mean-average value of 1 for all areas and times so that all years were given equal weight in the average. This was done by dividing each weekly value by the global average for all areas and times. The standardized values were then averaged across years to develop a profile of the average relative availability of upper Skeena coho salmon (A) by area and time (Table 6).

For the troll fishery, the number of landings from fish tickets in each area and time period was multiplied by the average number of days fished per landing from interviews to estimate the total number of boat-days fished by area and week. Hand troll effort was standardized to a power troll equivalent based on catch.

Total effort in the Alaska troll fishery has declined since 1978 while the average troll exploitation rate for three Alaska indicator stocks has followed a stable trend since 1982 when estimates were first available (Figure 11). Therefore, it is evident that efficiency of a unit of power troll effort has increased since at least the early 1980s. In order to compensate for this increase in efficiency, effort levels during 1985–

1998 were standardized to the average relationship between effort and exploitation rate that existed during 1982–1984. Effort levels in 1985–1998 (*E'*) adjusted for efficiency were estimated as follows.

$$E_i' = \frac{U_i \sum_{j=1982}^{1984} \left(\frac{E_j}{U_j} \right)}{3}. \tag{1}$$

Where:

$$EA_i = U_i(\overline{EA_j/U_j})$$

i : year from 1985 to 1998,
j : base year from 1982 to 1984,
U : average troll fishery exploitation rate for three Alaska indicator stocks,
E : unadjusted troll effort,
E' : troll effort adjusted for efficiency.

The standardized value for availability of upper Skeena coho salmon (*A*) was multiplied by efficiency-adjusted effort (*E'*) in each area and week. The products (*A E')* were summed across areas and weeks to estimate total effective effort (ΣE^*) on upper Skeena coho salmon.

The same process of computing effective effort was used for the seine fisheries in Districts 101 and 104, except that ΣE^* was computed only across weeks within a single fishing district.

For more recent years when direct exploitation rates were available, the total troll fishery exploitation rate on upper Skeena coho salmon was divided by ΣE^* and the result was averaged across years to establish an effort-to-exploitation rate conversion for prior years beginning in 1969 when only ΣE^* was available. Exploitation rate estimates were summed over all Alaska fisheries to estimate the total for the stock. The average exploitation rate for the period from 1969–1971 was used to estimate prior years back to 1946. Estimates of Alaska exploitation rates were then combined with estimates for Canadian fisheries to estimate the total for the stock.

Although the effort-exploitation rate calibration methods employed were largely the same, we arrived at substantially different historical exploitation rate estimates for the Babine stock compared with Holtby (1999). Holtby calibrated the relationship between effort and exploitation rate based on direct measures of the exploitation rate for the Babine stock during 1994-1998. However, we reconstructed Babine exploitation rates using estimates for the Toboggan Creek stock (Tables 8 and 9). We found that reconstructed estimates calibrated directly to the Babine stock were very high, resulting in some cases in reconstructed values as high as 95% with five-year averages as high as 87% (Figure 12). Also, direct Babine estimates did not track well with Toboggan Creek estimates (Holtby and Finnegan 1997). The Babine stock has a slightly more northern, later distribution in the marine fisheries compared with the Toboggan Creek stock in most years, which may result in higher exploitation rates for the Babine stock in Alaska fisheries. However, the combined Alaska-Canada totals still seemed improbably high.

Because of the slightly later, more-northward migration of Babine River coho salmon, one might expect that run to be exploited at a lower rate in Canadian marine waters compared with the Toboggan Creek stock. However, a comparison of removal rate estimates for Canadian marine fisheries during 1994–1997 revealed just the opposite. The estimated Canadian marine harvest of Babine coho salmon averaged 43% of the available stock (minus Alaska harvest) in Canadian waters, compared with 29% for Toboggan Creek. We find it improbable that one stock (Babine) would be more vulnerable to both fisheries, and therefore surmise that the most likely cause of this pattern was incomplete or inconsistent accounting of Babine CWTs that survived the fisheries.

We are unaware of any specific problems in accounting for Babine tags at the fence that would lead us to suspect the completeness of the data, however, there have been several recoveries of tagged Babine adults in freshwater locations outside of the Skeena system, including the Nass River (Bruce Baxter, LGL Ltd., personal communication) and Hugh Smith Lake, while one Toboggan Creek fish was also reported from the Nass drainage. While there has been less evidence of straying by tagged Toboggan Creek fish, it appears that accounting for escapement and returning tags at Toboggan Creek was very systematic. Each fish was closely examined as it was sampled at the fence, and a careful count and expansion was made for fish that were not sampled at the fence (Mike O'Neil, CDFO, Toboggan Creek Hatchery, personal communication). Furthermore, while there have been tagged returns to Fort Babine hatchery since 1987, exploitation rate estimates are unavailable before 1994. Toboggan Creek exploitation rate estimates since 1988 provide a more extensive baseline for calibration with fishing effort. Therefore, in the face of inconsistent and improbable estimates, we elected to base the Babine exploitation rate on estimates for Toboggan Creek, with an adjustment for different harvest distributions.

We generated estimates of the Babine River exploitation rate using two different assumptions: (1) the removal rate by commercial marine fisheries in Canada was the same for the two stocks, and (2) the exploitation rate by Alaska fisheries was the same for both stocks. In applying both assumptions, we accounted for different harvest distributions of the two stocks as indicated by coded wire tags. On average during 1988–1997, 28.7% more of the marine harvest of Babine River coho salmon occurred in Alaska compared with Toboggan Creek. Therefore, Toboggan Creek exploitation rate estimates for Alaska fisheries were multiplied by an annual adjustment to account for the observed difference in fishery distribution in 1988–1998. A standard (1988–1998) average multiplier of 1.287 was applied in 1998 (when Canadian fisheries were curtailed) and prior to 1988 before tagged coho salmon returned to both sites.

In applying the first assumption, we adjusted the Toboggan Creek exploitation rate to account for a different proportion of the catch taken in Alaska fisheries while holding the Canadian commercial marine removal rate constant. In the second assumption, we held the Alaska exploitation rate constant while setting the Canadian commercial marine exploitation rate according to the estimated catch distribution from CWTs. In considering the two assumptions, we find that assumption 1 probably results in estimates that are high because if the Babine stock is more available in Alaska waters, it is probably less available to Canadian fisheries. However, assumption 2 probably results in low estimates because a higher proportionate harvest in Alaska for the Babine stock likely indicates that it is more available in Alaska waters and, therefore, probably accrues a higher exploitation rate there. In view of these probable biases in opposite directions, we elected to average the estimates derived using assumptions 1 and 2 (Figure 12).

Our reconstructed Babine exploitation rates were steady at 55% during 1946–1962, before effort statistics were available in either Alaska or Canada, and continued to maintain a steady trend until the late-1970s when the five-year trend rose above 60% (Figure 12). Effort in several fisheries on both sides of the boundary increased in the late-1970s and early 1980s, resulting in an increase to a peak five-year average of 67% in the mid-1980s. Following the peak annual estimate of 72% in 1986, exploitation rate estimates during 1987–1996 were highly variable (31%–65%) and averaged only 55%, with a drop to only 24% following closure of Canadian fisheries to retention of coho salmon in 1998. The decrease in the trend during 1987–1997 apparently resulted in part from increasing restrictions in Canadian fisheries to reduce harvest of Skeena coho salmon stocks, as well as a slight decline in effective effort on those stocks in the Alaska troll fishery. While effective troll effort calibrated to Alaska indicator stocks has remained relatively constant (Figure 11), effective effort on upper Skeena stocks has declined in the 1990s with a shift in effort away from areas of higher availability near the boundary in southern Southeast, particularly Area 6 (Table 6).

Our reconstructed exploitation rates are similar to those of Holtby (1999) through 1976, but are substantially lower on average after 1976. The differences result primarily from two sources: (1) a different method for generating direct estimates described above (accounts for differences in 1988-1998), and (2) use of different statistics for effective effort by commercial marine fisheries in Canada. The first difference contributes to Holtby's substantially higher exploitation rate estimates for 1988-1998. The second major difference results from our use of revised estimates of effective fishing effort for upper Skeena stocks that were provided by DFO (Dave Peacock, Prince Rupert) in January 2000. For years before 1977, the revised effort estimates are within 3% of those used by Holtby (1999), but range from 6-20% lower (average 12%) during 1977-1997. Our use of the revised effective effort statistics contributes to substantially lower exploitation rate estimates during 1977-1987 compared with Holtby (1999). In addition to these more substantial differences, Holtby (1999) appeared to use a lower value for the inriver harvest rate before 1994 while we employed a constant 15% inriver harvest rate for years prior to 1994, based on results of the 1994 radio telemetry study (Koski et al. 1995).

The difference between our approach and that of Holtby (1999) had little effect on exploitation rate estimates for the Babine stock in earlier years, with no annual differences of over 5% occurring before 1980. However, our estimates are lower on average and track poorly with Holtby (1999) in the 1980s and 1990s. Our estimates averaged only 59% in 1980-1997 and peaked at 72% in 1986 while estimates by Holtby (1999) averaged 72% in 1980-1997 and peaked at 87% in 1995. These differences in later years have had a substantial effect on our respective analyses of stock trends, productivity and carrying capacity.

Trends in Abundance

Reconstructed total abundance of Babine River coho salmon (Figure 13 and Table 2) has been highly variable, but followed a relatively stable trend from 1946–1978 (Spearman rho = 0.055, p = 0.770) with a sharp drop in 1979 to a much lower average level in the most recent 20-year period. The average total run size in the early period is estimated at 24,300 but dropped to only 8,200 in 1979–1998, a decline of 66%. Even when the extreme 1965 and 1997 data points are excluded, the average run declined by 62% from 22,200 to 8,500. Despite the abrupt and dramatic drop in production two decades ago and the recent extremely poor 1997 escapement, there was not a significant continued downward trend in the population from 1979 through 1998 (Spearman rho = 0.417, p = 0.068). (In fact, preliminary data puts the 1999 run at over 20,000 fish, with 14,907 spawners counted at the Babine fence).

Spawner-Recruit Analysis

Escapements and estimated brood year returns for the Babine coho salmon stock were compiled (Table 7). We performed a Ricker spawner-recruit analysis using the total data set and subsets grouped in different time periods. The first analysis included the entire data series from the 1946–1995 brood years. The second analysis examined the relationships for a more recent period following the decline (1978–1995 brood years) and the period preceding the decline (1946–1975 brood years), separately.

Finally, in order to remove the highly variable effect of marine survival on returns, we standardized returns from the most recent brood years for mean-average marine survival of smolts released from the Toboggan Creek and Fort Babine hatcheries during 1986–1997 and returning in 1987–1998 (Table 10). Marine survivals for the two hatcheries were averaged with the 1987 value for Toboggan Creek interpolated using the same procedure employed earlier for missing values in the Tyee test fishery index. Estimated returns were multiplied by the average marine survival rate for 1988–1996 returns and divided by the survival rate in the appropriate return year to standardize returns to average survival. We were able to estimate survival-adjusted returns for 12 brood years (1984–1995) using this procedure. The age-4 component for the 1995 brood year was estimated from the age-3 return and the recent 10-year average proportion returning at age 3 (75.6% for Babine; 51.1% for Toboggan Creek).

The results of the spawner-recruit analysis (Table 11) present widely divergent perspectives on the productivity and status of the Babine coho salmon stock.

Long-term Production

The long-term relationship between spawners and returns (Figure 14) suggests that the Babine stock has been substantially over exploited for the past two decades. MSY escapement is estimated by the 1946–1995 Ricker model at 9,012 spawners (Table 11), a level never attained during the recent 20-year period (1979–1998). Even the maximum observed escapement of 5,619 spawners during this latter period was below the range predicted to produce 90% or more of MSY on the long-term Ricker model.

However, more recent relationships indicate that the stock is stabilized at its recent lower level and shows no tendency to increase with increasing escapement. The trend in residuals around the Ricker relationship declined beginning in about the 1976 brood year (Figure 15) and recent returns have typically under-performed the model. Returns from the 18 brood years (1978–1995) following the decline are very poorly correlated with escapement, but suggest there was an abrupt decrease in carrying capacity (*K*) after the 1975 brood year. The 1976 and 1977 escapements both produced only 65% of predicted production, while the large 1978 escapement of 11,930 spawners produced only 14% of the predicted adult return, based on the pre-1976 model (Figure 14). Escapements and returns during 1979–1998 have remained near the lower limit of earlier historical observations before the decline. The Ricker relationship for the recent period indicates that post-1977 carrying capacity is 6,540 fish or only 29% of the pre-1976 level of 22,525 fish.

The apparent loss of carrying capacity is evident in a significant ($p < 0.01$) steepening of the relationship between spawning escapement and Log(return/spawner) after the decline (Figure 16). The reduction in carrying capacity is estimated at 60% (71% if the 1962 and 1965 data points are included). While carrying capacity appears to have decreased, the characteristics of the shift suggest that intrinsic productivity of the stock (i.e. the ability to produce returns from very low escapements) has not declined significantly ($p=0.38$). When two outlying points (1962 and 1965) are excluded, ln(alpha) decreased from 1.97 to 1.69 from 1946–1975 to 1978–1995 (with 1962 and 1965 included, ln(alpha) was actually lower in the earlier period at 1.50). Although post-1975 escapements of under 4,000 fish (12 brood years) have produced returns averaging 86% of the level predicted by the 1946–1975 Ricker relationship, escapements above 4,000 spawners (8 brood years) have produced returns averaging only 45% of the level predicted by the early model. In other words, the eight recent escapements above 4,000 spawners have consistently produced less than predictions based on the 1946–1975 model, and have done so by an average of over 50%. The estimated average return of 7,836 fish from escapements of over 4,000 spawners (average 6,474 spawners) was actually lower than the average return of 8,327 fish from escapements under 4,000 spawners (average 2,674).

In 1951, a landslide in the Babine River canyon restricted the escapement to only 2,276 spawners compared with an average for other years (excluding 1965) of 10,062 spawners. However, the return estimate of 14,655 fish for the 1951 brood year was 67% of the average of 21,770 for other pre-1976 brood years (71% if the outlying 1962 brood year is excluded). Three low brood year escapements in the early to mid-1950s (1951, 1954, and 1957) that were all under 4,500 spawners (average 3,352; range 2,276–4,421) outperformed 1946–1975 Ricker model predictions by an average of 51% (range 23–66%) (Figure 14) and resulted in average returns of about 18,000 fish, which was not far below the period average of about 21,000. The comparatively high performance of these early low escapements within the range of recent levels, casts doubt on the hypothesis that the abrupt decline in coho salmon production from the Babine system after 1978 resulted from reduced spawning escapement.

Recent Survival-Adjusted Production

Survival-adjusted returns from the 1984–1995 brood years (Table 7) show a negative relationship (not significant, p=0.05) between escapements and returns within the range of relatively low spawning escapements that have been observed in recent years (Figure 17). The four largest escapements ranging from 4,053–5,619 (average 4,960) all apparently resulted in below-average smolt production with survival-adjusted adult returns averaging only 6,547 fish (range 5,946–6,970). On the other hand, smaller escapements from 1,714 to 3,671 spawners (average 2,577) produced survival-adjusted returns that averaged 9,320 adults (range 5,299–12,950).

This relationship stands in stark contrast with predicted production based on the pre-1976 and long-term Ricker relationships. The recent survival-adjusted relationship indicates that MSY escapement is only 1,937 adults (90% range 1,220–2,809), a dramatic reduction from 8,941 (90% range 5,768–12,550) during the mid-1940s through the mid-1970s (Table 11). Estimated carrying capacity is about 75% lower than before the mid-1970s (65% if the 1962 and 1965 brood years are excluded). The recent survival-adjusted relationship predicts a maximum return of 9,136 adults from an escapement of only 2,478 spawners.

The different data sets also point to very different conclusions about the appropriateness of recent exploitation rates. Inclusion of all years, or only the 1946–1975 brood years, in the analysis leads to the conclusion that there has been on average no surplus above the MSY escapement goal for the past 20 years (Table 11). On the other hand, the most recent relationship based on survival-adjusted data indicates that exploitation rates have on average been below the optimum level and, with the exception of 1997, never below the 90% range. The average exploitation rate in 1979–1997 was estimated at 57%, while the predicted MSY exploitation rate on a 1979–1998 average return of 8,155 fish is 76%.

The survival-adjusted relationship predicts the return from the 1997 escapement at two-times MSY escapement (Table 11). It is difficult to imagine how all of the coho salmon rearing habitat in the immense Babine system could have been adequately seeded by only 453 spawners in the 1997 brood year. However, the fact that sampled juvenile densities in 1998 were slightly above average (Figure 23 and Table 14) suggests that at least some habitats were fully seeded. The observed response to the 1997 escapement in 2000 and 2001 will be particularly useful in determining a lower bound for a biological escapement goal.

Loss of Carrying Capacity

The evidence presented thus far is consistent with a substantial reduction in the carrying capacity (K) for the Babine coho salmon stock. Estimates of the decrease in K (60%–75%) appear sufficient to completely account for the 62%–66% decline in average stock size between 1946–1978 and 1979–1998 (Figure 13). The apparent effect occurred abruptly between the 1975 and 1978 brood years. The current population, while much smaller, appears relatively stable and productive. The mechanism for this change is not completely clear but some hypotheses have more supporting evidence than others.

Five hypotheses that could potentially account for an apparent reduction in K include: (1) loss of physical habitat; (2) downward shift in marine survival; (3) loss of sub-populations specific and exclusive to certain habitats; (4) competition for forage by enhanced sockeye; and (5) a predator response to sockeye enhancement that has resulted in an increase in freshwater mortality in specific habitats.

Loss of Physical Habitat

Some habitat changes have been noted within the Babine system in the past 30 years. Increased beaver dam construction and possible loss of access to spawning areas has been noted in Tahlo Creek in the Morrison system while timber harvesting has occurred in some tributaries (Doug Lofthouse, DFO, personal communication). However, it appears unlikely that collective habitat losses in the Babine drainage have been substantial enough or have occurred over a broad enough area to account for a decline in total production of over 60% (Tom Pendray, DFO Habitat Branch, Smithers, personal communication).

Reduction in Marine Survival

Theoretically, an apparent decline in carrying capacity (as measured by returning adults) could be explained entirely by a decrease in natural marine survival (i.e. a reduction in adult returns with little or no change in smolt production). However, available evidence suggests that a long-term downward shift in marine survival has not occurred. A comparison with the Tyee test fishery shows no synchronous decline in aggregate coho salmon returns to the remainder of the Skeena system. If there was a general decrease in overall Skeena and northern B.C. coho salmon production that might be attributable to marine survival, it appears to have occurred in the early 1970s followed by a rebound in the 1980s (Figures 27 and 28) just when the Babine stock declined.

Otherwise, salmon abundance and marine survival indicators for the northern Boundary area suggest the trend in marine survival for stocks in the Skeena River vicinity has been relatively stable or has increased (for some species) in recent years. Marine survival of Babine sockeye salmon smolts has not shown a downward trend (Wood et al. 1998). Pink salmon catch and escapement (NBTC 1999) and chinook salmon returns to the Skeena River (CTC 1999) have increased, on average, from the 1960s and 1970s to the 1980s and 1990s, suggesting that marine conditions have been favorable for those species.

From this evidence, we conclude that a reduction in marine survival is an unlikely cause of an apparent reduction in K for the Babine coho salmon stock.

Loss of Sub-populations

Another possible explanation for the drop in carrying capacity is a sudden loss of a spawning sub-population that had specific and nearly exclusive use of specific rearing habitat. The loss of such a sub-population could be caused by reduced spawner abundance, or by an increase in density-independent freshwater mortality in either spawning or rearing habitat.

In order for this hypothesis to hold, there would need to be substantial habitat (more than half of total system capability) that was once occupied but is now largely unutilized by remaining sub-populations. The hypothesis requires a strong linkage between a specific spawning sub-population and specific use of rearing habitat. It implies that a genetic component may be nearly or completely lost. Otherwise, if a specific sub-population were reduced or lost, fish from other sub-populations may fill in and the run would be able to rebuild with increases in escapement (which has not occurred in this case).

Reliable information on the coho salmon escapement to specific locations within the Babine system is very limited. However, recent fence counts indicate that viable spawning populations still exist in the Morrison and Fulton Rivers. In 1998, 15% of the entire escapement count into the Babine system was documented in the Fulton River (652 out of 4,291 spawners). On average, the Fulton River has likely accounted for 10% or more of the system escapement based on prior counts, which suggests this main-basin tributary is still an important component of total coho salmon production and is well-occupied relative to available instream rearing habitat (Colin Harrison, DFO, personal communication). Also in 1998, 265 coho salmon (6%) were documented in the Morrision River in a relatively complete census that included a lower-river fence count and downstream survey (Doug Lofthouse, DFO, personal communication). Although this modest count indicates a viable spawning population, it appears smaller than might be expected based on substantial available rearing habitat within the Morrison River system (including Tahlo Creek) as well as around the perimeter of Morrison Arm (Holtby et al. 1999).

Visual estimates of escapement to specific spawning areas are sporadic and probably unreliable for historical comparative purposes. However, the distribution of management goals in the system reflects the best guess about the historical distribution of coho salmon escapement. Of the total Babine "management goal" of 18,175 spawners (DFO unpublished data), 6,500 are assigned to spawning areas below the fence. Of the remaining goal of 11,675 spawners for spawning areas above the fence, 70% (8,150) are assigned to the Babine River and tributaries between the fence and the North Arm of Babine Lake while the Morrison system accounts for 17% (1,500). Tributaries of the main basin account for only 13% of the goal (2,025 fish) of which the Fulton River is nearly half (1,000 fish). A goal of zero for the Sutherland River proper suggests that coho salmon were not well known in that system, although a small goal of 250 spawners is designated for one tributary, Shass Creek. Overall, the vast majority of coho salmon production in the Babine system was thought to have occurred in the lower system. This suggests that a major portion of the decline occurred in that area and, therefore, cannot be attributed entirely to loss of isolated sub-populations from main-basin tributaries. Aside from the Fulton River, which still hosts a significant population, escapement goals were assigned to only four other main basin tributaries that had combined management goals of 1,025 fish (9% of the above-fence goal).

In addition to the distribution of production implied by the management goals, juvenile sampling work has provided some information on the distribution of coho salmon in the Babine system. Bustard (1990) sampled rearing juvenile densities in tributaries to Babine Lake in 1988. He observed both age-0 juveniles from the relatively low 1987 escapement of 2,101 spawners and age-1 juveniles from the 1986 escapement of 3,671 spawners. Therefore his observations reflect conditions well after the 1978–1981 decline. He found juvenile coho salmon in 36 of 57 tributary streams that were sampled, including streams on both shores all the way to the Sutherland River at the upper end of Babine Lake.

Bustard estimated that tributary streams to Babine Lake accounted for a relatively small proportion of overall coho salmon rearing in the system, which is consistent with the management goals for escapement. He estimated total abundance in the sampled streams at only 31,068 fry and 10,794 yearlings, and most of those occurred near the north end of the Lake. He surmised from the results that "The bulk of the juvenile coho that are spawned in the inlet tributaries to Babine Lake move into Babine Lake by late summer and rear in the lake until smolt migration the following spring." He suggested that some of this movement may have been due to high water temperatures. He assumed that the juveniles were rearing in the shallow marginal areas along the lake shoreline and listed several extensively vegetated areas including Morrison Arm, the Smithers Landing area, Nilkitkwa Lake, and an area near the mouth of the Sutherland River.

However, despite his favorable opinions on the suitability of the Sutherland River and the lakeshore in its vicinity, Bustard caught only a single juvenile coho salmon in the lower Sutherland system and cited another account of an absence of coho salmon rearing in that area. He speculated that the Sutherland and tributaries could provide up to an additional 78 km of accessible stream. A more recent aerial examination of the Sutherland River (Barry Finnegan, DFO, Nanaimo, personal communication) indicates it is barrier-free to the upper reaches and contains what appear to be many kilometers of excellent rearing habitat, including some far-upper sections. According to estimates by Holtby et al. (1999), the Sutherland River contains nearly half (46%) of potential stream rearing habitat upstream from the Babine fence.

From these accounts it appears the Sutherland River could contain extensive habitat that is under-utilized. If this is the case, a reduction in use from historical levels could conceivably account for the decline in overall Babine coho salmon abundance. However, while rearing densities in the lower portion of the Sutherland River appear to be very low, there is no direct historical evidence that the system once supported higher densities. Bustard (1990) cites evidence that Shass Creek, a lower Sutherland tributary, received a coho salmon escapement of up to 500 spawners in 1987 but he found only one juvenile in eight sample sites in Shass Creek and the lower Sutherland the following fall. This observation suggests that the lower Sutherland drainage may not be favorable coho salmon habitat, despite its appearance.

Closer monitoring of the Sutherland system is warranted to determine if rearing densities are sensitive to parent escapement, or if the drainage is for some reason less productive as coho salmon habitat than its appearance would suggest. Information on the escapement status of this tributary relative to its use by juvenile coho salmon would aid in establishing an escapement goal for the aggregate Babine run, that maintains an adequate abundance of all components. However, for now it's unclear whether or not coho salmon abundance in the Sutherland River has declined, and if it has, whether the decline has been driven by a decline in escapement or some other cause.

Aside from the Sutherland River, the shoreline of Babine Lake is another area where a decrease in use of available rearing habitat by coho salmon could have reduced smolt production enough to account for the observed decline. However, in either case, it's difficult to explain from the circumstances how a sudden and permanent decline could have been driven by a decrease in spawning escapement, independent of another strong influence. The fact that two of the three primary brood year escapements leading into the decline were strong, plus evidence of resilience from earlier low escapements in the 1950s, suggests loss of a major sub-population due to lack of escapement was not the controlling factor in the decline.

Competition From Enhanced Sockeye

The dramatic success of sockeye salmon enhancement in Babine Lake is largely a result of the fact that the zooplankton community in the main basin was greatly underutilized by planktivores prior to enhancement. Development of spawning channels resulted in a several-fold increase in the input of sockeye salmon fry into the lake, which has in turn produced an even more than proportionate increase in the number of smolts, with little change in average growth (Wood et al. 1998). Numerous examples exist of effective use of zooplankton by coho salmon in cases where zooplankters occur in sufficient body size and density (Kyle 1990, Crone 1981, and Crone and Koenings 1985). These factors led us to examine the hypothesis put forward by Shaul et al. (1998) that the limnetic zone of Babine Lake was once an important rearing area for coho salmon, but increased competition for plankton by sockeye salmon following enhancement has resulted in a reduction in the size and density of zooplankters to the point where coho salmon can no longer utilize them efficiently. Coho salmon are substantially less efficient as planktivores, and a decrease in density or average body size of zooplankters could conceivably eliminate limnetic foraging by coho salmon even though sockeye salmon continue to thrive. The decline in brood-year coho salmon production did in fact occur at about the time sockeye salmon fry output from the spawning channels achieved full capacity (Figure 18).

However, despite the plausibility of this hypothesis, extensive sampling of Babine Lake during the early stages of enhancement (when sockeye salmon fry production was still very low) failed to document extensive use of the limnetic zone by juvenile coho salmon. Extensive seining with a small-mesh 150 fathom x 10 fathom seine was conducted in waters greater than 18 m in depth throughout the lake in 1966–1968 (Scarsbrook and McDonald 1970). Relatively few fish other than young sockeye salmon were caught. A total of 41 coho salmon were captured, however, 24 of those were captured in protected northern portions of the lake including North, Morrison, and Hagan Arms in locations relatively near to shore. Samples from these areas are of less interest because most were taken in areas adjacent to more typical lakeshore coho salmon habitat while these northern arms also appear to be less frequented by enhanced sockeye salmon juveniles. The remaining 17 fish were captured in 631 sets made beginning on June 1 in the main basin of the lake, and all but two were captured 0.5 km or more from shore. Several were captured roughly midway between the shores.

We made a rough projection of the number of adult coho salmon spawners that may have accounted for this level of catch by making assumptions from juvenile sockeye salmon catches in the same seine sets. During the three years, a total of 99,045 underyearling sockeye salmon were captured by the same fishing effort in the main-basin that accounted for 17 juvenile coho salmon. During these years estimated natural and wild anadromous sockeye salmon fry input into the main basin was relatively stable at an average of 65.6 (range 57.2-75.3) million fry per year (Wood et al. 1998). A substantial proportion of underyearling sockeye salmon rearing in the main basin were probably progeny of kokanee, a resident form of sockeye salmon. Based on spawning ground observations, Johnson (1958) estimated the proportions of age-0 sockeye salmon in the main basin that were kokanee at approximately 0% in 1955, 70% in 1956, and 39% in 1957. Application of Johnson’s average estimate of the kokanee contribution (36%) to the total age-0 sockeye salmon catch in 1966–1968 (99,000) results in an estimated seine catch of 63,000 anadromous sockeye salmon in the main basin during the three years. In order to approximate the number of coho salmon fry that may have reared in limnetic waters we divided the average number of sockeye salmon fry entering the main basin (65.6 million) by the number caught (63,000) and multiplied the result by the number of juvenile coho salmon caught (17). This calculation results in an estimate of about 17,700 coho salmon fry from the incidence of juveniles observed in the limnetic zone.

Application of the same fry per spawner conversion (233) used to estimate the number of naturally-produced sockeye salmon fry in the main basin (Wood et al. 1998) results in an estimate of only 76 coho salmon spawners. The average estimated Babine return (excluding 1965 and 1997) dropped by 62% between 1946–1978 and 1979–1998 from 22,191 to 8,537 fish. Average escapement during 1946–1978 (excluding 1965) was 9,693 spawners. Therefore, if the entire decrease in the total Babine return resulted from the complete loss of rearing in limnetic waters of the main basin, it should have accounted for nearly 6,000 spawners. However, according to our calculations, coho salmon abundance in offshore waters of the main basin in 1966–1968 accounted for only about 1.3% of that number of spawners. Furthermore, we lack information demonstrating earlier use of these waters has completely ceased.

In conclusion, the results of the 1966–1968 sampling suggest use of the offshore limnetic waters was magnitudes less than needed to account for the decline in overall Babine coho salmon abundance. Although offshore sampling failed to support the hypothesis of increased competition with sockeye salmon, it is still possible that increased competition has occurred in the nearshore littoral area of the lake. However, direct competition within the nearshore environment also seems unlikely because sockeye salmon fry remain in nearshore areas of Babine Lake for only a short period of time and disperse rapidly into the main lake (McDonald 1969), so the effect would likely be very limited (i.e. occurring only in limited time periods and in areas adjacent to sources of enhanced fry from the Fulton and Pinkut Rivers.

Predator Response to Sockeye Salmon Enhancement

The fifth hypothesis links the decline in the Babine coho salmon run to increased predation within the Babine drainage. The most probable catalyst for an increase in predation is a response by predator populations to the increase in availability of sockeye salmon as forage, following enhancement.

At full capacity, the Babine Development Project has nearly quadrupled the estimated number of sockeye salmon fry entering the main basin of Babine Lake (Wood et al. 1998). The resultant increase in smolts was even more than proportional to fry input. Average smolt production quintupled from a pre-enhancement level of 19.6 million smolts in 1961–1967 to 97.6 million smolts in 1978–1992 following full development of the Fulton and Pinkut spawning channels (Figure 18).

The dramatic increase in sockeye salmon production has increased the density of prey available to predatory fish in the main basin. It has also resulted in an increased opportunity for predators in the long, narrow outlet area to forage on smolts as they depart the system through the North Arm of Babine Lake, the upper Babine River, Nilkitkwa Lake, and the lower Babine River.

Several predatory fish species exist in the system including: rainbow trout, cutthroat trout, burbot, lake trout, Dolly Varden and northern squawfish (Withler et al. 1949 and McMahon 1948). All of these species are present in the outlet area while rainbow trout, lake trout, and burbot are also found elsewhere in the system. Information is lacking on abundance trends of any of these populations, although angler reports on recreational fishing in the upper Babine River suggest that the rainbow trout population has remained abundant (Bob Hooton, B.C. Ministry of Environment, Lands and Parks, personal communication).

If increased predation is responsible for the decline in coho salmon abundance, it has likely acted in an uneven fashion across available rearing habitat in the system. This would account for the appearance of a reduction in carrying capacity caused by a sharp drop in survival in some habitats, while survival in others remains high. Increased predator populations could have reduced use of rearing habitat in either the main basin area where enhanced sockeye salmon rear, or in the outlet area where prey availability increases dramatically when sockeye salmon smolts depart in May and early June. Large aggregations of predatory fish have been documented feeding intensively on smolts in outlet areas of other major sockeye salmon producing systems (Nelson 1966 and Rogers et al. 1972).

The outlet of Babine Lake follows a long, narrow, convoluted path through the North Arm, the upper Babine River, Nilkitkwa Lake, and the lower Babine River. Nilkitkwa Lake and the North Arm of Babine Lake comprise the rearing area for a late-run sockeye salmon population that spawns in the upper and lower Babine River. This subpopulation supported the majority of Babine sockeye salmon production before enhancement and, therefore, the density of yearling sockeye salmon rearing sockeye salmon in Nilkitkwa Lake and the North Arm was historically several times higher than in the main basin, based on 1955–1957 tow-netting estimates (Johnson 1958).

Total smolt migration estimates are available for the Babine River sockeye salmon subpopulation, separate from combined main basin subpopulations (Wood et al. 1998). There was a sharp decline in smolt production from Babine River spawners after the 1980 brood year (Figure 19). At only 3.2 million fish, estimated smolt migrations during 1983–1997 averaged just over one quarter of the 1961–1983 average of 11.9 million. Data from Wood et al. (1998) show the estimated number of smolts and smolts-per-spawner from the late Babine sockeye salmon stock declined substantially in the 1980s and 1990s over the entire range of observed escapements (Figure 20). Smolt production appears to have remained positively related with spawner abundance both before and after the decline, but very large escapements in 1985, 1992, and 1993 produced smolt runs that were far lower than expected.

These relationships indicate that there has been a dramatic increase in freshwater mortality, resulting in reduced productivity for the Babine River sockeye salmon stock. We were unable to find any information suggesting that a major change has occurred in the spawning area. Therefore, the agent responsible for increased mortality has most likely operated between fry emergence and smolt migration. Two possible agents are disease and increased predation. While disease outbreaks have occurred in the Fulton spawning channel on occasion (Wood et al. 1998) there is no evidence of a consistent disease problem in the outlet (Babine River) population (Chris Wood, DFO, Nanaimo, personal communication). Therefore, we suspect increased predation as a probable cause of the apparent decline in wild sockeye salmon survival.

It seems likely that if increased predation is the causative agent in reduced wild sockeye salmon smolt production, it may also have had an effect on juvenile coho salmon that rear in the same general areas. Therefore, there could be a common element in the decline of runs of both species. The lake portions of the outlet area have historically supported high densities of rearing sockeye salmon that migrate from the system as smolts primarily in mid-May. Immediately following this migration and partially overlapping it was a smaller migration of late-run smolts from the main basin from late-May until mid-June (Wood et al. 1998). This later migration has increased approximately four-fold as a result of enhancement. The concentrated migration of a larger number of smolts over a longer period has substantially increased opportunities for fish predators in the long, spatially limited outlet area. Although this concentrated food source provides a tremendous opportunity for feeding and growth during a limited time period, predators must pursue other food sources during the remainder of the year. One primary food source when smolts are not migrating through the outlet area is presumably juvenile salmon. Therefore, there may be a common effect on both the Babine River sockeye salmon run and that portion of the Babine coho salmon stock, which rears near the migration corridor of sockeye salmon smolts from the main basin.

The data suggests a difference in the nature of the decline in the late Babine River sockeye run and the Babine coho run. The wild sockeye salmon population appears to have lost productivity with a decline in smolts per spawner across the range of escapements, while the coho salmon stock, although reduced in size, still appears very productive. There is no significant difference in the slope of the relationship between sockeye spawners and smolts per spawner for any combination of split periods, suggesting that carrying capacity for the sockeye population did not change. However, there is a significant change in intrinsic productivity when the series were split beginning in brood years 1982 ($p = 0.018$) or 1983 ($p = 0.011$), which follows by about 5-years the decline in the coho return per spawner (1976-1978). When the periods are divided between 1959-1977 and 1978-1995, the change in intrinsic productivity was not significant ($p = 0.151$).

The difference in the declines of the two species in relation to brood year escapement suggests predation may be acting on the coho and sockeye populations in different ways. Sockeye salmon rear mainly in exposed open bodies of water where they typically travel and feed in schools. Coho salmon on the other hand tend to be territorial in structured stream and shoreline habitats that provide both opportunities to feed and concealment from predators. However, coho salmon are also highly opportunistic and will inhabit open shoreline areas and even offshore areas of lakes when they can find sufficient food and survive predation (Kyle 1990 and Crone and Koenings 1985). While the chances for survival and growth for juvenile sockeye salmon in the open lake may be relatively even among individual fish, juvenile coho salmon likely face highly variable odds depending on the specific features of their home territory. Individuals that inhabit and defend the most favorable locations for food and cover have a substantial advantage over those inhabiting less-desirable locations.

Therefore, unless forage is limiting survival (which is not evident) predation on sockeye salmon may act to merely reduce the productivity (alpha parameter) of the population. Consumption by predators may occur at a relatively constant amount or at a constant proportion of the rearing sockeye salmon population. Under either model, production is proportionately greater from larger spawning escapements. However, a typical coho salmon population responds to a decrease in density with increased growth and survival. Therefore, it may remain highly productive under reduced spawner densities and even under increased predation levels as long as enough juveniles survive to fully occupy the limited preferred habitat. This is consistent with the survival-adjusted Ricker relationship, which indicates relatively low MSY escapement.

The “predator response” hypothesis is consistent with the increase in synchrony between the Babine coho salmon escapement and the Tyee test fishery index (also noted by Holtby et al. 1994) that accompanied the abrupt decline in the Babine stock. It suggests that in the late 1970s the factors determining abundance of the Babine stock became more similar to those for the entire aggregate of coho salmon populations entering the Skeena River early in the season. This feature is consistent with a change in habitat use within the Babine system. It suggests a substantial expanse of marginal rearing habitat (where survival was low on average and variable) was used by coho salmon before the decline but is no longer productive for that purpose. Use of this extensive marginal habitat such as open shoreline areas may have resulted in larger, more-variable smolt runs than have occurred in recent years, assuming recent smolt production has been restricted to limited core habitat types typically used by coho salmon. Restriction of rearing to more limited, highly structured habitats would result in a lower but more stable level of smolt production that is typical of most coho salmon populations, hence the increase in synchrony with other Skeena coho salmon populations represented in the Tyee index.

Increased predation pressure may have had a disproportionate effect on juvenile coho salmon that cruise and forage away from secure, highly structured habitat. Following a response by predator populations to main-basin sockeye enhancement, juvenile coho salmon that pursued that strategy may have incurred a mortality rate so high that few have survived to smolt-hood. If this is the case, loss of production from extensive exposed shoreline area may be sufficient to explain the observed decline. Increased predation within the system may also have restricted movement of juveniles between spawning areas and isolated “islands” of suitable rearing habitat that lack adequate nearby spawning habitat. If predator populations have expanded in response to main basin sockeye enhancement they may have eliminated use by coho of a large expanse of marginal habitat (such as exposed lakeshore areas), resulting in far lower average abundance, increased stability and increased synchrony with other Skeena coho populations. Expansion of predator populations could be either a system-wide response to increased prey abundance within and migrating from the main basin, or may have occurred primarily in portions of the system near the outlet (i.e. North Arm, Morrison Arm, Nilkitkwa Lake) where enhanced smolts are concentrated as they migrate to sea.

The apparent 5-year lag in the decline of freshwater survival estimates for wild Babine River sockeye salmon compared with the reduction in carrying capacity for coho salmon would appear to shed doubt on a direct linkage involving predation. However, we see two reasons why the apparent mismatch in timing of the declines is not inconsistent with the predator response hypothesis: (1) error is likely high in the models used to separate early and late-run sockeye smolts (Chris Wood, DFO, Nanaimo, personal communication), which may reduce the ability to detect and pinpoint a significant change, and (2) a lag in the decline in estimated sockeye survival compared with the coho population may be indicative of progressive expansion of predator populations (possibly involving different species) into different habitats.

Information Needs for the Babine Stock

The "predator response" hypothesis appears most consistent with the body of evidence surrounding the decline in Babine coho salmon production, including the following features: (1) abrupt decline (one generation); (2) coincident timing with sockeye salmon enhancement; (3) significant decline in carrying capacity, but not intrinsic productivity; (4) divergent abundance between Babine and non-Babine coho salmon stocks; (5) increased stability and synchrony with other Skeena coho salmon stocks, and (6) decline in spawner-smolt survival for wild Babine River sockeye salmon.

However, despite the preponderance of evidence in this direction, current information is still insufficient to clearly pinpoint the mechanism or its area of effect in the system. It is apparent that a substantial component of smolt production in the system was abruptly disrupted during the period between the 1977 and 1980 smolt years. Isolated changes in the physical habitat have occurred, including logging and increased beaver dams (Tom Pendray, CDFO, personal communication), but do not appear to have been on a large enough scale to account for a loss of over half of habitat capability of the system. Abundance and survival rate estimates for other species suggest that marine survival rates for Skeena coho salmon were most likely stable or increasing at the time of the decline.

A drop in parent escapement seems an unlikely catalyst, because aggregate parent escapements were within the normal historical range right up to the decline in returns. A decline in carrying capacity is evident in an increased slope in the relationship between spawners and Log(return/spawner), a decline in Ricker spawner-recruit residuals after 1975, and in far lower estimates of carrying capacity for Ricker models that include only post-1975 brood years.

However, there remains a possibility that apparent low rearing densities in the lower Sutherland River are suppressed by lack of sufficient spawning escapement to seed available habitat, or are indicative of some other limitation. If the decline were attributable specifically to a Sutherland River subpopulation, it would have to represent nearly a total collapse in production in order to explain the apparent increase in synchrony between the Babine Run and other Skeena populations. In that case, there should be a strong response within the Sutherland to the very large 1999 escapement of 14,907 spawners (third largest on record), assuming there was a proportional increase in upper system spawning areas. Close monitoring of juvenile and adult abundance from the 1999 brood year would help test this hypothesis.

Meanwhile, the combined evidence leads us to strongly suspect one or more freshwater factors specific to the Babine system. The timing of declines in both coho and wild sockeye salmon populations has lead us suspect that the Babine Development Project is indirectly the responsible agent. If this is the case, increased predation in response to enhanced prey abundance appears to be the most likely responsible mechanism, but increased competition for forage cannot be completely ruled out.

Filling several important information gaps would substantially improve our ability to isolate and evaluate cause of the decline as well as to determine an appropriate course of action. Improved information on the distribution of spawners in the system combined with a more complete evaluation of rearing habitat and its current use would aid in isolating areas in the system where the stock has been most affected by the decline. This in turn may lend support to one hypothesis or another. A radio-telemetry project with tags applied at the fence and tracked to spawning locations in the drainage would likely provide the most thorough and cost-effective estimates of spawner distribution. Similarly, marking and tracking fry within the system would help link spawning subpopulations with specific rearing habitat. The exceptional 1999 escapement provides an opportunity to test the effect of increased spawning escapement on the abundance and distribution of larger rearing juveniles.

Also, a baseline assessment of resident fish populations in the lower system including dietary monitoring during the smolt run and at other times of year would help evaluate the "predator response" hypothesis with compatible or competing hypotheses.

The Ricker relationship for the survival-adjusted returns probably provides the most reliable indication of the current optimal escapement level, although returns have not yet been observed from escapements that appear limiting of production. The predicted MSY escapement of 1,937 spawners (90% range 1,220–2,809) is well below the 20-year average of 3,219 and above only two prior years (1,714 in 1992 and 453 in 1997). Production estimates from recent extreme escapements (453 in 1997 and 14,907 in 1999) will be available after November 2003 and should substantially improve our confidence in an appropriate escapement range specific to the current Babine stock.

TOBOGGAN CREEK STOCK

The other primary upper Skeena coho salmon indicator stock resides at Toboggan Creek, a tributary of the Bulkley-Morice system. The wild Toboggan Creek stock is represented by tagged fish from the Toboggan Creek hatchery. Although the available data series is short compared with the Babine stock, estimates of wild smolt abundance and marine survival at Toboggan Creek (Holtby et al. 1999) help define the relationship between escapement and resultant production. A total of 11 years of return estimates are available, while production estimates are completed for eight brood years with parent escapements (Table 12 and Figure 21).

We examined the relationship between escapement and return for eight brood years using returns calibrated to average marine survival for Toboggan Creek wild smolts. Returns were estimated to be the product of smolt production estimates by brood year and the average marine survival rate for the 1988–1996 return years.

The results of the Ricker analysis (Table 13 and Figure 22) predict MSY escapement at 1,188 spawners (90% range 748–1,723). Recent wild escapement levels have averaged 1,520 and fallen below the 90% range only in 1997 (321). Production from 1997 wild spawners is projected at 22,200 smolts and 2,600 returning adults, assuming average marine survival (11.7%). The MSY exploitation rate on the predicted return is 54% (90% range 34%–71%). The average exploitation rate in 1988–1997 was estimated at 60%.

Under average marine survival, an average (1988–1997) fishing pattern with a resulting 60% exploitation rate on the projected 1997 brood year return would likely result in escapement that is under the point estimate for MSY, but within the range predicted to achieve 90% of MSY. Similar to the Babine stock, widely diverging wild escapements in 1997 (321 spawners) and 1999 (6,266 spawners) should substantially improve our ability to establish a realistic biological goal, after estimates of resulting production are available in 2003

Juvenile Density

Juvenile coho salmon densities have been sampled in nine geographic areas within and near the Skeena watershed since 1994 (Holtby and Finnegan 1997 and Table 14). Surveys were conducted in late summer and early fall. Juveniles sampled during this period were primarily the offspring of spawning adults from the previous fall but also included a component from the previous brood year.

Sampling was conducted during a period in late summer when substantial compensatory mortality commonly occurs in coho salmon populations (Crone and Bond 1976). Therefore, the resultant density estimates may reflect neither parent escapement nor potential smolt output in entirety, but both to some extent. Whether or not a system is fully seeded, we would expect fry densities in early to mid-summer to reflect to a large extent the level of spawning escapement. However, in a fully seeded system we would expect no correlation between escapement and resultant smolt production. A positive relationship between escapement and smolt production would only be expected if the system were not fully seeded (i.e. the compensatory mechanism saturated). In such a population, a decrease in escapement would be expected to result in nearly a commensurate decrease in smolt production.

The extremely low 1997 escapement throughout most of northern B.C. including the Skeena drainage provides a test of the response of different rearing populations to a dramatic reduction in escapement. Smolt production is a more definitive measure of freshwater production. However, lacking smolt estimates, juvenile densities provide some insight.

The Babine River is the only system within the upper Skeena drainage where both escapement and juvenile density estimates are available. Babine escapement and juvenile density have both been highly variable during the five years of comparable observations, but there is no positive correlation (Figure 23). The sampled juvenile density estimate following the 1997 spawning escapement was actually 11% above the 1993–1996 average (even though escapement was 84% below average).

Based on a very limited series of observations (five years for most areas), late-summer juvenile density was positively correlated with the Tyee Index of aggregate Skeena escapement in three out of eight Skeena areas (upper Bulkley, Kispiox, and Terrace), but not in five others (Figure 24). A significant negative correlation was found in the lower Skeena ($p<0.01$). P values for the three positively correlated locations ranged from 0.06 to 0.09.

Following the tiny 1997 escapement, sampled juvenile densities were well below average in most middle and upper Skeena areas, with the primary exception being the Babine system. On the other hand, densities in the lower Skeena and coastal areas were average or higher. The Tyee Index decreased by 85% compared with the 1993–1996 average (Table 14). Despite the dramatic decrease in escapement, Coastal and Lower Skeena juvenile densities actually increased. Middle Skeena locations (Kispiox and Terrace) and the Morice River (Bulkley River System) decreased by 43 to 69%. Only the upper Bulkley and High

Interior locations showed declines that were roughly equal to the 86% decline in the system-wide index (the High Interior declined by 81% while no juveniles were captured in the upper Bulkley River). This regional pattern of response supports the concept that interior stocks may be less productive in general (Holtby et al. 1999) and, therefore, more sensitive to restricted spawning escapement compared with lower river and coastal stocks.

Juvenile density sampling in the Skeena drainage has occurred near or within the period when maximum freshwater mortality typically takes place. For example, Crone and Bond (1976) found that during a one-month period (mid-July to mid-August) mortality of coho salmon fry in Sashin Creek, Southeast Alaska averaged 70% (range 62%–78%), over a three-year study period. In most cases we would expect the density of newly emerged fry to be positively correlated with the density of parent spawners. However, as the summer progresses the rearing population undergoes a dramatic reduction that is in most cases heavily density-dependent so that production of age-1 smolts the following year would not be expected to be positively correlated with escapement unless spawner density is so low that the system is under-seeded.

In the case of these late summer density estimates for the Skeena River drainage, the fact that escapement and resultant juvenile density appears to be positively correlated in some systems offers the possibility they were not fully seeded at low spawner densities. Those locations that show no positive relationship or a negative relationship were probably fully seeded. However, estimates of actual smolt production (following complete density-dependent interaction) would be needed to conclude that the positively correlated systems are in fact under-seeded in years of low escapement. Suitable over-wintering habitat for coho salmon in the upper Bulkley River is reportedly extremely limited (Brenda Donas, DFO, personal communication) suggesting that higher sampled late-summer densities following larger escapements may not be indicative of greater smolt production. Conversely, juvenile density samples are taken in areas that appear to be suitable habitat and may be more indicative of core rather than marginal habitats. Therefore, it is possible that densities in the sampled habitats, particularly in a large system like the Babine, do not represent the level of seeding in the entire system.

Upper Bulkley River

Juvenile densities have been very low and highly variable in the upper Bulkley River where average density was only 0.02 per m^2, an order of magnitude below any other areas (range 0.20–1.27). Also, the coefficient of variation was the highest observed at 1.17 compared with 0.41 to 0.75 for other areas (Table 14). In contrast, densities in sampled areas of the nearby Morice River averaged 0.76 per m^2.

Low and variable rearing coho salmon densities in the upper Bulkley may reflect the poor quality of the habitat which has been extensively degraded by agriculture and other human development (Brenda Donas, CDFO, Habitat Division, Smithers, personal communication). Spawning habitat in the upper Bulkley could be of poor quality, resulting in low egg-to-fry survival, or the number of spawners too low, but we might still expect higher rearing densities simply from immigration of juveniles from other areas in the Bulkley drainage, including the Morice River. Other potential factors that could account for low juvenile densities and apparent low productivity of the upper Bulkley coho salmon run include high predation or unsuitable physical conditions in the rearing environment. Observations of high late-summer water temperatures suggest there may be thermal limits to juvenile coho salmon abundance in the upper Bulkley (Mike O'Neil, DFO, Toboggan Creek Hatchery, personal communication).

The following observations were related to us by Brenda Donas (DFO Habitat Division, Smithers), who has studied habitat and rearing salmon populations in the upper Bulkley drainage. The habitat in the upper Bulkley River and its tributaries has been heavily altered by human activity, including primarily agriculture in the lower reaches and extensive timber harvesting in the upper drainage (and to some extent mining). Lower system habitat appears to be generally of poor quality for rearing salmonids, particularly coho salmon. There is apparently very little remaining woody debris and pools are generally unstable. Many banks are eroded and heavy siltation has been observed in spawning areas. Water temperatures up to 18^{o} C have been recorded as early as mid-July and up to 22^{o} C in late summer. High ammonia levels from agriculture have been noted early in the spring runoff period. Coho over-wintering survival appears very poor. She noted that coho salmon juveniles sampled during the winter appeared to be in generally poor condition and over-wintering sites were very limited. Approximately 10% of the escapement has been taken as broodstock at Toboggan Creek hatchery for back-planting as smolts in the upper Bulkley River. Back-planted hatchery-reared smolts have contributed the vast majority of the escapement into the upper Bulkley in recent years, indicating natural survival rates are very low. Juvenile steelhead which are less dependent on pool habitat and woody debris, are apparently much more abundant compared with rearing coho salmon. Juvenile chinook salmon appear to leave the upper Bulkley in the fall and probably overwinter in the mainstem Bulkley below the junction with the Morice River or in the main Skeena River.

Of the salmonid species inhabiting the upper Bulkley River, coho salmon are most dependent on large woody debris and associated pool habitat, and therefore have likely been the most affected by land use practices that have removed wood and changed the characteristics of stream channels. Many side channels have apparently been cut off from the river by road and railroad construction (Tom Pendray, DFO Habitat Division, Smithers, personal communication). Coho salmon escapement records for the upper Bulkley River are sporadic and derived from a mixture of visual estimates and fence counts, and are therefore of questionable reliability. However, the history of visual estimates beginning in 1950 (Holtby et al. 1999) suggests average production has declined dramatically beginning at least by the early 1960s, with the upper Bulkley proper declining more than its tributaries. The average visual estimate for the 1950s was 3,835 spawners (range 825–7,650). Visual estimates are largely unavailable after 1978, while more recent counts at a broodstock collection fence at Houston since 1989 have often been incomplete. Holtby et al. (1999) categorized counts in 1991 and 1996–1998 as "good" counts of both wild and enhanced fish. The 1990 wild count was 587 spawners (378 wild) while the 1996–1998 counts averaged only 192 total (73 wild) spawners. On average during 1996–1998, only 33% (range 22%–44%) of returning spawners were wild fish.

Given the marginal condition of upper Bulkley habitat, it is likely that survival and subsequent abundance have been highly sensitive to annual weather and climate conditions that affect the hydrological cycle and solar radiation. Extreme water temperatures observed in some years have probably resulted from extensive canopy removal and may have been exacerbated by a recent warming trend in weather. Timing of the spring freshet in the Bulkley system has apparently been advanced in some recent years (Mike O'Neil, DFO, Toboggan Creek Hatchery, personal communication).

Access by spawners to the upper reaches, where good rearing habitat still exists, has apparently become blocked by extensive beaver dams since the early 1990s (Tom Pendray, DFO Habitat Division, Smithers, personal communication). DFO has recently shifted its restoration effort from backplanting of smolts in the lower system to reseeding the upper reaches with fry and improving access for returning adults past the beaver dams (Barry Finnegan, DFO, Nanaimo, personal communication).

Holtby and Finnegan (1997) describe the status of natural coho salmon production in the upper Bulkley River as "desperate." We agree that recent production has been very poor, however, based on information shared by individuals knowledgeable about the system, we disagree with the inference that this condition is caused by poor and declining escapement levels, or that it can be reversed in a meaningful way by increasing escapement. Short of a large investment in habitat restoration in the lower drainage, the fry backplanting effort in the upper drainage (combined with re-opening spawner access) appears to be the best prospect for restoring natural coho salmon production in the upper Bulkley drainage.

Density Comparisons

Based on studies of coastal populations, densities in excess of 0.75 to 1 juvenile per square meter are considered by DFO (1999) to indicate of full seeding (i.e. enough spawners to produce a near-maximum number of smolts). The finding of lower juvenile densities in interior tributaries of the Skeena River has raised concerns that interior populations may be in trouble (i.e. substantially under-seeded) (Holtby and Finnegan 1997 and DFO 1999). However, an alternative hypothesis is that interior habitats typically have a lower carrying capacity per area unit of habitat compared with coastal systems. We examined information on the density of smolts and spawners in other northern coho salmon systems to test these competing hypotheses for low densities in interior tributaries of the Skeena (i.e. under-seeding versus lower habitat capability).

Southeast Alaska and Interior Taku River Populations

Adult and smolt production estimates are available for four coastal systems in Southeast Alaska and for two interior tributaries of the Taku River. We measured the total length of accessible stream and lakeshore habitat in these systems (Table 15) in order to estimate average female spawner abundance and smolt output per kilometer of habitat (Table 16 and Figure 25). These are system-wide estimates and are, therefore, not directly comparable with the juvenile density estimates for the Skeena drainage which are generated from sampling specific habitats. However, they are comparable between the interior Taku tributaries and coastal systems in Southeast Alaska, and with estimates for the Babine system by Holtby et al. (1999).

The coastal systems represent a range of habitat types and production levels. The Berners River is a typical coastal mainland river system with a glacial mainstem and with most preferred rearing habitat concentrated in sloughs and beaver ponds. The Ford Arm system is a very compact island system with high-quality stream and lakeshore habitat found in roughly equal proportions. Rearing habitat in Auke Lake near Juneau is dominated by the shoreline of Auke Lake. The Hugh Smith system, southeast of Ketchikan, also consists primarily of lakeshore habitat. Tatsamenie River in the upper Taku drainage is dominated by Tatsamenie and Little Tatsamenie Lakes, located at about 740 m elevation on the interior margin of the Coast Range. The upper Nahlin River, the most interior Taku tributary, flows across a plateau at about 900 m elevation. The majority of the upper Nahlin River is low gradient and highly convoluted. It has extensive high quality habitat in the main channel as well as in off-channel ponds, tributary streams, and sloughs. Both of these interior systems are separated from habitats in the lower Taku system by hundreds of kilometers of swift water canyons.

The density of female spawners in the coastal systems ranged from 33.5 per km for Hugh Smith Lake to 176.5 per km for the Ford Arm system (Table 16). The Berners River was intermediate at 74.8 per km. Smolt output was also variable, from 1,148 smolts per km for Auke Creek to 4,140 for Ford Arm Lake. Again, the Berners River was intermediate at 2,649 smolts per km.

Both female spawner and smolt densities were far lower in the interior Taku tributaries. Female spawner densities averaged only 5.0 per km for the upper Nahlin River and 6.3 per km for the Tatsamenie River. Smolt production averaged 213 smolts per km in the upper Nahlin and 420 per km in the Tatsamenie River.

The results are consistent with results in and around the Skeena drainage where sampled densities are generally higher in middle river, lower-river, and coastal habitats compared with the interior. Also, using the range given by Holtby et al. (1999) for habitat length in the Babine system, spawner densities range from 3.1–7.3 females per km and 155–369 smolts per km (assuming 10% marine survival). These densities may be low because the escapement count represents only spawners above the fence while Holtby et al. (1999) included substantial rearing habitat below the fence (including the Nilkitkwa River). When below-fence habitat is excluded, the density estimates increase to 3.6–11.6 females per km and 183–587 smolts per km. These densities are very similar to the estimates for the two interior Taku tributaries. The similarity in patterns between the Taku and Skeena drainages supports the idea that interior habitats may not typically support coho salmon population densities as high as those found on the coast, regardless of parent escapement levels. The question then is: “Why are interior populations less dense?”

Our field observations in the upper Taku system (Shaul 1987, 1988, 1989, 1990, and 1992) suggest several possible reasons. The upper Nahlin and Tatsamenie Rivers appear to be highly productive systems and we suspect that overall aquatic productivity (including production of suitable forage for coho salmon) is, if anything, higher compared with the coastal systems. For example, Shaul (1987) noted a high density of large juvenile coho salmon (60 to 100 in one pool) in small lake outlet stream near the headwaters of the Nahlin River. Despite the high-localized density, these fish exhibited exceptional growth, having already achieved smolt size less than two months after emergence (snout-fork length ranged from 98–105 mm for five age-0 juveniles sampled on July 18).

While forage may be more abundant in many interior systems, we note the overall fish community is often very different. In the upper Taku system, there was both a broader range of competitive species and a far more formidable predator assemblage compared with coastal systems. Despite the tremendous conditions for growth in the location noted above, Shaul (1987) found no evidence of use by coho salmon of vegetated lakeshore rearing locations in the lake from which the sampled stream flowed. The lake was occupied by a dense population of northern pike, which were found congregated in aquatic vegetation in the littoral zone, the same type of structured habitat preferred by rearing coho salmon. It was clear that the prospects of survival for rearing coho salmon in the lakeshore area were very poor. Although pike are unknown in the Skeena drainage or in the other sampled Taku tributary (Tatsamenie River), other predators including burbot, lake trout, and rainbow trout are common in the upper reaches of both the Taku and Skeena Rivers, but are rare or absent in most coastal systems.

While coho salmon are typically the dominant rearing species in coastal systems, interior systems have a broad range of potential competitors that could reduce the niche available to coho salmon. Some of these species include: lake chubs, arctic grayling, whitefish, and chinook salmon. One competitor found in most coastal systems (three-spine stickleback) is absent from interior tributaries. In the upper Nahlin River, however, this latter species is largely replaced by juvenile sockeye salmon in the warm, shallow slough habitats dominated by sticklebacks on the coast.

Chubs and Dolly Varden appeared to dominate some interior pond and lake habitats in the upper Taku drainage. However, chinook salmon appeared to be the most serious potential competitor because they were found in high densities in most main channel habitat and, in some years, in the littoral zone of Little Tatsamenie Lake. Rearing juveniles of both coho and chinook salmon feed primarily on aquatic and terrestrial insects, so they likely compete in habitats where they coexist.

Greater interspecies competition and more intensive predation in interior systems may, in combination, explain the lower observed coho salmon densities. Although high densities of rearing coho salmon may be found in specific locations (e.g. the highly structured margin of little Tatsamenie Lake), features of the overall fish community appear to limit the range of habitats used and therefore the overall density of coho salmon in interior Taku tributaries.

In addition to the fish community, physical factors in the environment may also limit coho populations in interior tributaries with their continental climate. In Southeast Alaska systems, minnow trap catches of juvenile coho salmon are typically optimum in the range of 14–19 ^{o}C while extreme temperatures are uncommon. However, Shaul (1987) recorded summer temperatures in upper Nahlin River habitats ranging widely from 6.7–20.5^{o} C during August 1986.

We conclude that an estimate of rearing density is, without a very specific standard for comparison, an inadequate measure of the adequacy of parent spawning escapement. Before juvenile density information can be reliably applied as an indicator of spawning escapement relative to full seeding, we recommend that it be compared with measured escapement over a period of years and calibrated with smolt production.

Survival is another interesting area of comparison between interior Taku tributaries and coastal populations. Survival rates from summer pre-smolt (>60 mm in length) to returning adult stages are available for two of the coastal systems (Berners River and Ford Arm Lake) and for the Nahlin and Tatsamenie Rivers (Table 17 and Figure 26). Estimates for the coastal systems were consistently higher, averaging 6.2% for the Berners River (1986–1988) and 10.6% for Ford Arm Lake (1986–1989) compared with only 1.5% for the upper Nahlin River in 1988 and 2.7% for the Tatsamenie River (1986–1989). The higher mortality rate on large juveniles in the interior systems supports the idea that density independent mortality is higher and intrinsic productivity therefore lower for the interior stocks (as concluded by Holtby et al. 1999).

Trends in Aggregate Abundance

We reconstructed an index of historical aggregate abundance of predominantly upper Skeena coho salmon stocks, based the five-year adjusted Tyee Index and the historical exploitation rate for Toboggan Creek (Table 18). We removed the estimated Babine component from analyses that spanned the period of decline in the Babine population in order to evaluate aggregate abundance of non-Babine populations represented by the early Tyee Index. The resulting index of total abundance of non-Babine Skeena stocks (represented by the test fishery through September 1) has been highly variable with no significant long-term trend (Spearman rho = -0.179, p = 0.257). Periods of peak abundance occurred in 1965–1971 and 1983–1991 with low points in the mid-1970s and mid to late-1990s (Figure 27). Inter-annual variability has been very high, particularly in the 1990s when the index varied by as much as 20 fold from a record high level in 1990 to a record low in 1997. The expanded non-Babine Tyee index has trended closely with the total troll catch in northern British Columbia since 1956 (Table 19 and Figure 28). The 10-year trends in both indicators show peaks in the late-1960s and late-1980s with a trough in the mid-1970s.

Data from more recent years, shows the expanded Tyee index (including Babine) was closely correlated with the commercial catch in Canadian Areas 1, 3, and 4 in 1980–1997 (Figure 29), suggesting that common factors have influenced early migrating Skeena stocks and other stocks on the northern B.C. coast. However, Skeena stocks have not tracked closely with Southeast Alaska indicator stocks during the 1990s (Table 20 and Figure 30). While Southeast Alaska indicator stocks reached peak levels in the mid-1990s, Skeena stocks represented by the Babine run and the Tyee test fishery index declined in 1992–1995 from a 1989–1991 peak. The drop in production in 1997 was much more severe on the northern B.C. coast than in Southeast Alaska.

The same trend shown in the indicator stocks is evident in the historical troll catch in the respective areas, and can be tracked over a longer period (Figure 31). While the wild troll catch in Southeast Alaska has shown varying trends in different periods, with peaks in the 1940s and 1990s, the Canadian north coast troll catch has followed a more stable historical trend before it dropped to a record low level in 1997. The Canadian troll fishery was closed to retention of coho salmon in 1998.

These data do not indicate that abundance of upper Skeena coho salmon has changed relative to the aggregate of all of northern B.C. stocks, including those in coastal streams and mainland rivers like the lower Skeena. However, while northern B.C. stocks represented in boundary area fisheries appear to have fluctuated in relative synchrony, a steep gradient in marine survival developed near the northern boundary during 1992–1998. While the northern B.C. troll coho salmon catch has followed a stable long-term trend from the first records in 1953 through the mid-1990s, the Alaska wild coho salmon troll catch, which had remained depressed but similarly stable for 25 years, began to recover following the 1977 oceanic regime shift. During the late-1970s to early 1990s, harvests in the two fisheries were in relative synchrony although the wild Alaska catch was consistently larger. However, there was a dramatic divergence in catch trends beginning in 1992 when the Alaska harvest continued to increase further while the trend in northern B.C. remained level or declined. The divergence coincided with a steep decline in marine survival for coho salmon stocks in Georgia Strait in southern British Columbia (Holtby et al. 2000).

While the array of indicators (Figure 32) shows no apparent evidence of a decline specific to coho populations in the upper Skeena watershed, the indicators are highly correlated. For example, R^2 values for linear relationships with the Babine total run size during 1981–1998 are 0.72 for Tree Point CPUE (n=18) and 0.83 for the commercial catch in Canadian areas 1, 3, and 4 (n=17). Based on coded wire tag recoveries, the Canadian catch and early Tree Point CPUE measure approximately the same aggregate of predominantly mainland stocks in northern British Columbia. R^2 values for the linear relationship between the two indicators are 0.80 during 1981–1997 (n=17) and 0.92 during 1988–1997 (n=10). During 1988–1998, R^2 values for linear relationships between the Toboggan Creek total run and other indicators are: Canadian commercial catch 0.88 (n=10), Tree Point CPUE 0.73 (n=11), and Babine total run 0.76 (n=11). R^2 values for the Babine run size during 1988–1998 are 0.89 with Tree Point CPUE (n=11) and 0.84 with the Canadian commercial catch (n=10). The Tyee index expanded to total run was strongly correlated with other indicators (R^2 values: Tree Point CPUE 0.71, Areas 1, 3, and 4 commercial catch 0.69, and Babine total run 0.92).

The apparent synchrony among both stocks and fishery performance indicators within both Southeast Alaska (Shaul 1998) and northern B.C. suggests that it is feasible to employ indicator stocks to establish management objectives for mixed stock fisheries and to manage stocks in the respective areas inseason based on fishery performance. Two areas in which inseason stock assessment information may be useful for management based on escapement goals for indicator stocks include: (1) the use of inseason fishery performance indicators of aggregate stock abundance, like early Tree Point and boundary area troll CPUE; and (2) estimation of marine survival for specific stocks based on the inseason accumulation of tag recoveries from mixed-stock fisheries like the Alaska troll fishery. Inseason survival rate estimates, in combination with real-time estimates of smolt production, can be used to estimate adult abundance for specific indicator stocks. Based on the above relationships, it is evident that specific indicator stocks can have broad applicability in fishery management.

Stock Productivity

Estimates of intrinsic productivity for the Babine and Toboggan stocks are very similar, with an estimated ln(alpha) value of 2.3 for both stocks based on recent brood year production standardized to average marine survival (Tables 11 and 13). Composite and individual Ricker relationships for the two stocks predict MSY yield from escapements that are well below the 1988–1995 average number of spawners (53% of average for Babine and 56% for Toboggan Creek, Figure 33).

Confidence in productivity estimates for these stocks will be substantially improved with the addition of production estimates for the extreme 1997 and 1999 brood year escapements. In particular, returns from the extremely low 1997 escapement of 453 spawners in the Babine River and 359 in Toboggan Creek promise to substantially improve our estimates of intrinsic productivity. Observations are very limited for both stocks and, therefore, current estimates of productivity should be considered very preliminary.

However, the fact that in both cases the linear relationship between escapement and return is negative (although not significant) over the observed range indicates these stocks have not been routinely over-exploited. Both populations appear relatively productive and capable of sustaining average fishery exploitation rates that are substantially above the 1988–1995 average, given similar marine survival. The exploitation rate that would result in MSY is estimated at 78% for both stocks, assuming average marine survival, while exploitation rate estimates during 1988–1997 averaged 60% (range 41%–71%) for Toboggan Creek and 54% (range 31%–65%) for the Babine River.

Escapement Objectives

The 1999 PST agreement states that “the Northern Boundary Technical Committee shall develop a work plan to develop MSY escapement goals for Skeena and Nass River coho salmon, to improve stock assessment programs, to develop inseason and post-season abundance determinations and to improve fishery performance data.” Establishing agreed escapement objectives is particularly important in order to begin building an improved system of cooperative management. Development of common goals requires first that a method for estimating MSY escapement be selected (i.e. spawner-recruit or habitat capability), and second that a target range be specified based on the results.

We prefer spawner-recruit analysis over habitat capability modeling as a method of establishing escapement goals. Spawner-recruit analysis uses a direct measurement approach of inputs and results for the specific stock in question. In contrast, habitat-based models rely on the assumption that habitat capability can be accurately predicted from measures of available rearing habitat and standards (i.e. density estimates at habitat saturation) based on observations in other locations. Standards used by Holtby et al. (1999) to develop escapement targets for the Babine coho salmon stock were developed for Oregon coastal rivers and Carnation Creek, a small coastal stream in southern B.C. Habitat capability per km may be very different in the Babine River, which is a more northern interior lake system.

However, spawner-recruit analysis also has limitations when applied to a system like the upper Skeena, or even within the Babine drainage where spawning and rearing occur over a large geographic area. First of all, it requires intensive monitoring over a period of years. Another drawback is that it can under-estimate MSY escapement for an mixture of populations with varying productivity and a history of over-exploitation of some run components (Hilborn 1985). On the other hand, trends in marine survival and measurement error can result in underestimates of productivity and overestimates of carrying capacity (Geiger 2001). In the case of a widely dispersed species like coho salmon, spawner-recruit analysis requires extrapolation of results from one or more indicator stocks to a larger aggregate, with the assumption of equal productivity.

Although we favor spawner-recruit analysis for establishment of the relationship between spawning escapement and production, it is prudent in some cases to apply the results conservatively in setting escapement goals for indicator stocks. This is particularly true in cases where there are likely to be stocks in a management unit that are less productive than the indicator stocks. Interior Skeena stocks are probably less intrinsically productive, on average, than the coastal stocks that contribute the majority of northern B.C. production, and therefore, goals that are conservative enough for upper Skeena indicators are probably more than conservative enough for coastal stocks. However, there is currently no independent information on productivity of stocks in one major geographic region of the upper Skeena drainage (i.e. high interior or upper Skeena-Sustut).

Babine River Escapement Goal

There is no doubt the Babine population has been depressed in recent years compared with pre-1980 levels. However, it is unlikely that low parent escapement levels are the reason for this depressed condition. The evidence indicates to us that the carrying capacity of the system for coho salmon has declined substantially and that recent escapements have not limited smolt production. However, Holtby et al. (1999) conclude otherwise based on low spawner densities relative to measurements of available rearing habitat and from a spawner-recruit analysis that pools the entire time series of escapements and returns. Research to better document the distribution of spawners in the system and the distribution, movements, and sources of food and mortality of juveniles would help resolve this technical question. Close monitoring of the response of the population to the large 1999 escapement of nearly 14,907 spawners (third highest in 52 years) will also be useful in that regard.

For Babine coho salmon, Holtby et al. (1999) proposed a Limit Reference Point (LRP) or absolute escapement floor and a Target Reference Point (TRP) or minimum target level (defined in DFO 2000a, Figure 34). Their recommended LRP of 1,200 spawners is close to our estimate of the lower escapement level expected to produce 90% of MSY (1,220 spawners). They recommended a TRP of 11,500 spawners based on average estimates using four methods. The averaged estimates included two habitat-based goals derived from a southern B.C. coastal stream (Carnation Creek) and the target spawner density for the Oregon coast as well as spawner-recruit estimates of escapement at MSY and maximum recruitment (R_{max}) using the pooled historical data series. The two habitat-density estimates were very high at 13,702 based on the Carnation Creek standard, and 13,426 based on the Oregon coastal standard. Their Ricker estimates of MSY escapement and escapement at (R_{max}) were 7,561 and 11,285 spawners, respectively.

We view a goal of 11,500 spawners as unrealistic, given the recent relationship between spawners and returns, and the fact that our estimates of total run size have averaged only 8,200 fish and exceeded 11,500 in only six years out of twenty during 1979–1998 (Figure 34). While Holtby et al. (1999) predict that their proposed goal will be achieved at an exploitation rate of about 46% under average marine survival, our analysis of recent survival-adjusted spawner-recruit data predicts it would not be achievable under average survival, even in the absence of any fishing mortality. We estimate maximum stock size under average survival conditions at only 9,100 fish. While escapement exceeded 11,500 spawners less than half of the time even before 1979, our estimate of MSY escapement from the spawner-recruit relationship that existed prior to the 1976 brood year at about 8,900 spawners (Table 11). However, the stock has recently shown no sign of responding in a positive way to escapements above 4,000 spawners. There is no evidence that escapements over that level are beneficial to future production as they have, in the recent past, actually produced smaller average returns than have escapements in the range of 1,700–3,700 spawners.

Our best estimates of MSY escapement and the escapement that produces maximum return are about 1,900 spawners and 2,500 spawners, respectively, based on Ricker analysis of the survival adjusted data for the 1984–1995 brood years. Based on the spawner-recruit relationship and these considerations, we recommend a goal range with the lower bound set at the predicted MSY escapement (rounded to 1,900) and the upper bound set at 4,000 spawners, a level above which there appears to be no benefit to future returns. We view this as a management target range rather than a critical level (LRP) or a minimum target (TRP) as defined in DFO's Wild Salmon Policy (DFO 2000a).

Given run sizes that occurred in 1979–1998 (excluding 1997), our recommended goal range would have corresponded to a total exploitation rate of 44%–73%, on average. The proposed goal range was not achievable in 1997 when the run totaled only 902 fish. However, the range could have been achieved in the second poorest return year (1995 — total run 4,160 fish) under an exploitation rate between 4%–54%. Escapement was lower than the proposed range in only two years (or 10%) out of the past 20 (1,714 spawners in 1992 and 453 spawners in 1993), above the range in six years (30%) and within the range in 12 years (60%).

Escapements at the low end of the range appear adequate to sustain production at its recent level and are actually predicted to produce larger returns (and certainly larger harvestable surpluses) than escapements near the upper bound. If changes in the system related to the concurrent sockeye salmon enhancement program are in fact responsible for the decline, a higher escapement goal commensurate with pre-1979 returns would be non-productive.

Toboggan Creek Escapement Goal

For Toboggan Creek, we estimate escapement levels at MSY and maximum stock size to be approximately 1,200 and 1,500 spawners, respectively (Table 13). Escapements ranging from approximately 750–1,700 spawners are predicted to produce 90% or more of MSY.

Holtby et al. (1999) estimated MSY escapement at 1,369 spawners from smolt estimates and a standard marine survival rate of 10%. Their data series included a preliminary estimate of smolt production for the 1996 brood year. Escapements producing 90% of MSY based on their Ricker parameter estimates range from 880 to 1,950, while maximum return is predicted at an escapement of about 2,000 spawners.

We propose an escapement goal range of 950–1,900 spawners for Toboggan Creek, based on a range of 0.8 to 1.6 times our estimate of MSY escapement (Figure 35). This proportionate range was suggested by Eggers (1993), based on simulation results, as a more conservative alternative to the 90% range for management of mixed stocks. During 1988–1998 (excluding 1997), this goal range would have corresponded to a total exploitation rate of 47%–73%, on average. The proposed goal range was not achievable in 1997 when the wild run totaled only 666 fish. However, the range could have been achieved in the second poorest return year (1988 — total run 1,688 wild fish) under an exploitation rate of anywhere from 0%–44%. We estimate the MSY exploitation rate under average marine survival at 78%, compared with an estimate of 68% by Holtby et al. (1999). During 1988–1997 the exploitation rate averaged 60% (range 41%–71%).

During the 11-year period, wild escapement was lower than the proposed goal range in only one year (321 spawners in 1997), above the range in three years, and within the range in seven years (64%). The 1988–1998 average escapement of 1,592 wild spawners was well within the range.

Eventually, a biological goal should also be established for the Moricetown mark-recapture estimate of which the Toboggan Creek escapement is one component. Based on total mark-recapture estimates to date (Holtby et al. 1999), a preliminary goal range for the Bulkley-Morice system would likely be about 10,000–21,000 fish if calibrated with the proposed goal for Toboggan Creek.

OTHER NORTHERN BOUNDARY STOCKS

Holtby (1999) presented an analysis of the status of other northern boundary coho salmon stocks outside the Skeena drainage. In northern B.C., data on stocks outside of the Skeena River is very limited. Detailed assessments are possible only for recent years and for Area 3 indicator stocks in the Nass and Lachmach Rivers. Information on the status of Southeast Alaska stocks through 1997 was presented by Shaul (1998), and data presented here consists of an update of basic components of that assessment (smolt abundance, run size, and marine survival) through 1998.

Smolt Production

Shaul (1998) estimated that on average, since the early 1980s, freshwater production accounted for 38% of the variability in adult abundance for four Southeast Alaska wild coho salmon indicator stocks, while marine survival accounted for 62%. Although fishery and land-use managers cannot control marine survival, smolt production is influenced by both spawner abundance and freshwater habitat quality, in addition to other influences including weather. Smolt production is, therefore, an appropriate indicator of the health of a stock and the success of management and habitat protection programs. Unfortunately, smolt estimates are available for relatively few streams in Southeast Alaska and northern B.C. (Table 21) and for too short a period to effectively evaluate long-term trends. None of the indicators show a significant trend in smolt production (p=0.05) during the period of observation.

Marine Survival Patterns

The intrinsic productivity of a stock is directly related to marine survival, a parameter that is often assumed to be density independent. Although marine survival rates for northern mainland coho salmon indicator stocks have fluctuated with some degree of synchrony over a 10-year period (1989–1998), average marine survival rates have varied greatly among stocks (Figure 36 and Table 22). For example, survival estimates during 1993–1998 varied by over five-fold among wild stocks, from as low as 4.4% for the Nass River (Zolzap Creek indicator) to as high as 22.8% for Auke Creek.

Latitudinal Survival Gradient

There appears to have been a latitudinal effect, with the mean-average 1993–1998 survival rate estimate for northern Southeast Alaska stocks of 17.6% being 2.5 times the mean-average rate for the two wild indicator stocks (Lachmach River and Zolzap Creek) in Canadian Area 3 (6.9%). The difference increased to over three-fold when upper Skeena hatchery smolts (2.5%) were included in the average for northern B.C. (5.4%). Hugh Smith Lake in southern Southeast Alaska was intermediate in both geography and average survival rate (13.9%). This apparent latitudinal gradient is consistent with the oceanic regime during this period that was associated with substantially lower survival rates for stocks in Oregon through southern B.C. (Hare et al. 1999 and Holtby et al. 2000a). Overall, fishery and indicator stock trends suggest stocks in Canadian Areas 3 and 4 have experienced the most level trend in survival across the steps in marine survival that have been associated with ocean regime shifts, while areas to the north and south have trended upward and downward.

System Characteristics and Survival

In addition to a latitudinal effect, there is substantial variability in survival among systems in close geographic proximity. The pattern of this variability suggests that it may be associated with system size or productive capacity, with larger smolt producers having lower average survival rates (Table 22). Within northern Southeast Alaska, marine survival rate estimates are strongly ranked by the inverse of system size with Auke Creek which produces fewer than 10,000 smolts having the highest average survival rate (22.7%) and the Taku River, producing well over 1 million smolts on average having the lowest (13.2%). The Berners River was intermediate in average production at slightly under 200,000 smolts and in marine survival with an average rate of 16.8%.

In the international boundary area to the south the average marine survival estimate for the Nass River, a major producer of likely well over 1 million smolts, was only 4.4%, based on the Zolzap Creek indicator. The very low estimate for this large producer located in upper Portland Inlet stands in contrast with two closely situated small producers that have averaged only 30–35 thousand smolts. The average survival rate for the Lachmach River stock located in Work Channel near the southern entrance to Portland Inlet was 9.3%, or over double the Nass average. The average survival rate for Hugh Smith Lake located on Boca de Quadra north of Portland Inlet was 13.9%, or over triple the Nass average. Therefore, survival patterns in the boundary area are consistent with northern Southeast Alaska where coho salmon smolts from a large-producing river system suffered substantially higher mortality than smolts from nearby smaller producers.

These observations support two hypotheses about marine survival. First, the large variation in the scale of marine survival among systems in close proximity suggests the most important factors determining marine survival operate very early in the sea-migration period. Second, while the factors causing marine mortality may be common over a broad area (suggested by synchrony among inside stocks), they appear to operate much more intensely in the close proximity to larger river systems like the Taku, Nass, and Skeena, which produce far more smolts of all species. We hypothesize that lower survival for major producers is the result of concentrated predation near major point sources where smolts enter confined inlets in high densities, and that this affect may also be promoted by greater competition for food in these areas. Smolts of all species are far more concentrated near the mouths of major producers, compared with smaller, more isolated systems that broadcast smolts into marine waters from hundreds or thousands of widely distributed points. In order for this predation hypothesis to hold, predator concentrations would have to be dense enough near large salmon producers like the Taku, Nass, and Skeena so that the predator field remains unsaturated, despite greater prey abundance. A compounding effect may be a decrease in early-marine growth at higher smolt densities that could leave smolts from larger point sources vulnerable to predation for a longer period. It is also possible that there are differences in marine productivity that limit food abundance in glacial inlets near large rivers. However, because coho salmon smolts are fairly large and mobile at sea-entry, we find it most probable that predation is the primary direct cause of mortality rather than inadequate nutrition.

There are other possible explanations, including disease, parasitism, and smolt size, that cannot be ruled out. Although not investigated here, it is likely that average smolt size and the jack return rate also affect marine survival. Auke Creek smolts are very large, on average, which may give them a marine survival advantage. On the other hand, a high proportion of Auke Creek smolts return as jacks (thereby reducing survival through age .1), while very few jacks are evident in the glacial mainland rivers (Berners, Taku, Nass, and Skeena). The survival rate of 1985 Hugh Smith Lake smolts to age .1 was estimated by size range (Shaul et al. 1991), providing some indication of the survival advantage attributed to larger smolts. While the overall survival rate was 19.1% for smolts averaging 105 mm, survival rates by size class were as follows: 16.1% for small smolts (80–99 mm; average 93 mm); 20.4% for medium smolts (100–120 mm; average 109 mm); and 21.5% for large smolts (121–151 mm; average 128 mm). Although survival in this particular study was related to smolt size, the observed effect was insufficient to explain a three-fold lower survival rate for smolts from nearby Zolzap Creek where average length over five years ranged from 97–101 mm (Nass 1996c, 1997a, 1997b, 2001; Nass and Frith 2001) for a mean-average of 99 mm.

Canadian Non-Skeena Stocks

The historical assessment database for northern B.C. coho salmon stocks outside of the Skeena drainage is sparse and includes very little detailed information, with the exception of recent programs in Area 3 (Nass River and Lachmach River). Data sets for the remainder of northern B.C. consist almost entirely of questionable visual estimates by fishery officers, extrapolated to total annual escapement. There is very little documentation associated with the historical records (Dave Peacock, DFO, personal communication) and it is not clear that all of the streams with estimates were even visited during the coho salmon spawning season.

While visual estimates of salmon escapement are often suspect under the best of conditions, coho salmon surveys in northern B.C. and Southeast Alaska occur under some of the most difficult conditions of remoteness, high water, and poor visibility. For example, escapement estimates for Area 6 were qualified on the DFO website (April 19, 2001): "Escapement enumeration is difficult mainly because of the long spawning period (early August to January) and high, tea colored water conditions that are often experienced during the fall and early winter months. For this reason, recorded escapement levels are suspect." Furthermore, the recorded numbers are not merely attempted "peak counts" but are the responsible fishery officer's estimate of the total season escapement, with little or no specific documentation as to how the estimate was made. Therefore, given variability in observers, conditions, and coverage over time, the estimates are influenced not only by variability in counting efficiency within and among observers, but also by varying mental expansions used to estimate total seasonal abundance.

Given these limitations, we have not attempted an in-depth analysis of the visual data but will review other applicable analyses (Holtby 1999 and Holtby et al. 2000). We will include a brief summary of recent indicator stock data from Area 3 (Lachmach River and Zolzap Creek) as well as mark-recapture estimates in the Nass River, and will compare Area 3 data with estimates for the upper Skeena River and Southeast Alaska.

Canadian Area 3 Stocks

Wild indicator stock programs have been operated on the Lachmach River in Work Channel since the 1989 return year (Holtby 1999), and in Zolzap Creek (lower Nass drainage) since the 1992 return year (Nass 1996a, 1996b, 1996c, 1997a, 1997b, and 2001; Nass and Frith 2001; Baxter et al. 2001). In addition, improved escapement estimation programs have been operated in the Nass drainage in recent years. Since 1994, the Nisga'a Nation and LGL Ltd. have estimated the majority of the coho salmon escapement that enters the lower river using a mark-recapture technique (Richard Alexander, LGL Ltd, personal Communication). In addition, the Meziadin fishway has been operated throughout most of the coho salmon migration since 1994.

The fact that detailed assessment programs were only recently developed in Area 3 precludes a reliable assessment of longer-term stock status. However, Holtby (1999) presents a summary of visual escapement estimates for Area 3, and concludes that they "indicate no discernable temporal trend" since 1950.

During the five-year period (1993–1997) prior to implementation of non-retention in most Canadian fisheries, exploitation rate estimates averaged 66.8% (range 56.1%–71.9%) for Lachmach River and 66.1% (range 56.2%–73.7%) for Zolzap Creek, but dropped to 46.4% and 51.3%, respectively, when non-retention was instituted in Canada in 1998 (Table 23). For comparison, 1993–1997 exploitation rate estimates for Hugh Smith Lake, located north of the Nass River in Southeast Alaska (Table 31), averaged 76.7% and ranged from 72.4% to 81.4%. Due to the location of its natal system and its later, more northward migration, the Hugh Smith stock is substantially more available to both troll and net fisheries in Southeast Alaska compared with nearby stocks in Canadian Area 3.

Other Northern British Columbia Stocks

Holtby (1999) presented visual estimates for 1950–1998, with the streams in each area given equal weight. Estimates were reported as a proportion of the maximum observed. He described three patterns of abundance with the upper Skeena, Central Coast (Areas 5 and 6), and the Queen Charlotte Islands showing "a pattern of prolonged depression." He found no discernable trend in the lower Skeena and Area 3, while Southeast Alaska showed an increase since the 1970s. He then estimated a finite rate of change for the period 1970–1996, showing a significant increase in Southeast Alaska and significant decreases (15%–18% per generation) in the upper Skeena, eastern Queen Charlottes and in Area 6 (Central Coast).

When taken at face value, the geographic trends in the data shown by Holtby (1999) are generally consistent with the recent trend in ocean conditions and salmon survivals in the eastern Pacific (Hare et al. 1999). Marine survival has increased in the north and fallen in more southern areas, with increasing intensification in the early to mid-1990s. Based on the overall body of evidence, it appears that the pivotal (i.e. most stable) point in the shifting gradient of marine survival along the Pacific coast is located in the Portland Canal/Skeena River area. The decline in visual estimates of coho salmon escapement in the Central Coast and Queen Charlotte areas to the south of the Skeena River described by Holtby (1999) is, therefore, generally consistent with the apparent coast-wide trend in marine survival. Unfortunately, outside of Areas 3 and 4, there are no direct estimates of marine survival or exploitation rates for northern B.C. coho salmon stocks, as coded wire tagging has been largely limited to a few hatchery releases without estimation of tagged fish returning in the escapement.

While the decline in escapement estimates in the southern areas is of concern (assuming they are accurate), the measure of status of primary interest is smolt production. Unfortunately, available information from the Central Coast and Queen Charlotte areas is wholly insufficient to determine if there has likely been a decline in smolt production (possibly related to lower escapement levels and/or reduced habitat capability) or if the escapement trends, if they are accurate, merely reflect a trend in marine survival and exploitation.

<u>Spawner-recruit Analysis Using Visual Estimates</u>

Holtby (1999) used the visual estimates pooled by area as the basis for spawner-recruit analysis. He then compared the results with recent escapement levels to estimate the status of the stocks relative to MSY. Holtby et al. (2000b) used the resulting spawner-recruit models to forecast returns to these areas in 2000. The resulting estimates and predictions require assumptions be made about several critical parameters that cannot be directly estimated: marine survival, age composition, and exploitation rate. Also required is a questionable assumption of constant efficiency of escapement estimation among years and observers.

There may be no alternative basis for such estimates, but Holtby's (1999) results have a high probability of error because of questionable assumptions about critical unmeasured parameters. For example, estimates for three Alaska indicator stocks after the 1977 regime shift indicate marine survival has accounted for 62% of observed variability in return abundance compared with only 38% for freshwater factors including spawning escapement (Shaul 1998). Therefore, marine survival was clearly the most important determining factor even within this limited period when ocean conditions were generally favorable for salmon in Southeast Alaska. The record of visual estimates since 1950 that are presented by Holtby (1999) transcends major changes in ocean survival, and therefore, is probably affected more by variable marine survival than are the Alaska estimates.

Therefore, spawner-recruit relationships based on the visual estimates were probably influenced far more by the history of marine conditions than by spawning escapement, which accounts for only a fraction of the freshwater component of production. For example, while it is well documented that marine survival along the coast has followed distinct trends, Holtby's (1999) Ricker relationship for Area 6 (Figure 37) is based on highly clustered data. This clustering may have resulted not only from "steps" in marine survival but quite likely also from differing counting rates and mental expansions used to estimate escapement over time.

The effect of clustering data that spans decadal-scale steps in marine survival and observer bias causes the stock to appear less productive, but with a higher carrying capacity. Geiger (2001) demonstrated how shifts between environmental states have likely had a common effect on both spawning escapement and survival of progeny in Prince William Sound pink salmon, resulting in data clustering similar to the Canadian Area 6 coho salmon estimates. When the data was examined in stock-recruit analysis, Geiger concluded that it "substantially understates the stock's *average* yield potential at low stock sizes, overstates the *average* yield potential at high stock sizes, and greatly misstates the stock's average response to very high stock sizes." Failure to account for steps in marine survival (and observer bias) can result in spurious spawner-recruit relationships and "can lead to poor management advice when the environment undergoes switches between states."

It may be instructive to consider a case where there is no underlying relationship between escapement and smolt production above some minimum level that produces full recruitment (i.e. level "hockey stick" spawner-recruit model proposed for coho salmon by Bradford et al. 2000). In this case, decadal-scale trends in marine survival tend to cluster estimates based on adult returns closer to the replacement line simply because progeny of lower escapements tend to experience lower marine survival and progeny of larger escapements tend to experience higher marine survival. This is the case regardless of whether survival increased or decreased during stepped changes, and gives an appearance of low productivity, high carrying capacity, and an escapement limitation for a stock for which returns were actually unaffected by spawning escapement within the observed range. Estimation error is likely to have an effect similar to environmental states because estimation efficiency is somewhat specific to an observer who estimates escapement within an area for a period of years, before replacement by another observer.

In either case, an assessment program that is subject to "states" in marine survival or estimation efficiency produces an appearance of lower stock productivity. These influences have likely resulted in downward bias in estimates of intrinsic productivity for Area 6 stocks and may have led to a false conclusion that the stock has been over-exploited. Holtby (1999) estimated average escapement in Area 6 in 1992–1998 to be only 31% of MSY and log (alpha) to be only 1.394.

While we have serious concerns about the use of the visual estimates to estimate spawner-recruit relationships for northern B.C. coho salmon stocks, we find the data to be insufficient to recommend an alternative analytical approach. Stock assessments need to account for and respond to the most important factor influencing abundance; marine survival. Although we cannot significantly affect marine survival, an inability to assess it obscures the role of more controllable factors, including spawning escapement and habitat quality. A high priority for stock assessment should be placed on development of wild indicator stocks with routine estimates of escapement, smolt production and marine survival for stocks in the

Central Coast and other areas. Until such programs are implemented, we have to agree with conclusion of the Pacific Fisheries Resource Conservation Council (PFRCC 2001) that there is a serious lack of credible measures of stock status for the Central Coast.

Exploitation Rates

Exploitation rates are largely unknown for Central Coast and Queen Charlotte Island stocks. However, coded-wire tag information on the timing and distribution of the harvest (Coho Technical Committee 1991 and 1994) indicates that Central Coast stocks are similar in migratory patterns to upper Skeena stocks and are harvested to a significant extent in boundary area and outer coastal fisheries in Southeast Alaska. Still, their greater distance from intensive Alaska and Canadian fisheries, and their early timing, suggests that exploitation rates (particularly in Alaska) are likely somewhat lower than for Skeena stocks (estimated marine exploitation rates for Toboggan Creek in the upper Skeena drainage averaged only 48% in 1993–1997 and declined to 19% in 1998). Also, there has been relatively little harvest of coho salmon by net fisheries on the Central coast since the mid-1970s when directed coho salmon net fisheries were closed, suggesting most of the exploitation rate on Central Coast stocks has occurred in the same mixed stock fisheries that harvest Skeena stocks.

The Queen Charlotte Islands support major wild coho salmon production (Coho Technical Committee 1991). However, tag recovery information indicates Queen Charlotte stocks have a very localized migratory pattern and are largely unavailable to Alaska fisheries, even near the boundary (Coho Technical Committee 1991 and 1994). Therefore, given restrictions on coho salmon retention in Canadian fisheries, recent exploitation rates on Queen Charlotte stocks have probably been very low compared with other stocks in northern B.C. and Southeast Alaska.

Fishery Performance

Along with Skeena stocks, Central Coast stocks likely contribute the majority of the early coho salmon harvest in the Dixon Entrance area including southern Districts 101 and 102 in Southeast Alaska and in Canadian Areas 1, 3, and 4 (Coho Technical Committee 1994). The fact that abundance of upper Skeena indicator stocks has been closely correlated with fishery performance in these areas suggests Central Coast and Skeena stocks not only have a similar migratory pattern but have been highly synchronized in adult abundance.

Status of Central Coast and Queen Charlotte Stocks

In summary, without direct measures, we conclude that marine survival rates on Central Coast and Queen Charlotte stocks have likely declined in the mid-1990s, while exploitation rates have likely been lower compared with most northern coho salmon stocks. Most systems in this area are coastal in nature, so the stocks likely have relatively high freshwater productivity, similar to other coastal stocks in Southeast Alaska and northern B.C. On balance, although we find it unlikely stocks in these areas have been systematically over-exploited, contrary to the conclusions of Holtby (1999), it is difficult to conclude much of anything about stock status from available data. We are in basic agreement with the following statement by PFRCC (2001) regarding Central Coast stocks: "The basic monitoring of spawners and/or juveniles has not been adequate to be confident about stock status and therefore, about conservation and wise management." However, while we find it very difficult to develop any kind of objective management goals from available stock assessment data, we are more optimistic than the PFRCC (2001) about the probable status of Central Coast stocks relative to escapement needs. That optimism is based on what is known of stock migration and fishing patterns in northern B.C. and Southeast Alaska, and of intrinsic productivity of northern coho salmon indicator stocks.

We suggest that a high priority be given to the establishment of wild indicator stocks and a more systematic and documented (even if more limited) escapement assessment program on the Central Coast so that more informed stock assessments and management decisions can be made in the future.

Southeast Alaska and Transboundary River Stocks

The status of Southeast Alaska stocks through 1997 was reported by Shaul (1998). Therefore, we will limit coverage in this report to an update of run reconstruction estimates for the long-term indicator stocks (Tables 24–31 and Figure 38) and a summary of escapement data for the boundary area (Table 39). Four indicator stock projects have been operated since the early 1980s including two in inside waters of northern Southeast (Auke Creek and Berners River), one on the outer coast (Ford Arm Lake), and one in the inside area of southern Southeast (Hugh Smith Lake). A full run reconstruction program was initiated on the Taku River at the international border in 1992 (Tables 32 and 33 and Figure 39).

Indicator Stocks

Total adult abundance for the primary indicator stocks has shown a similar long-term pattern for the inside stocks (Auke Creek, Berners River, and Hugh Smith Lake) with the most prominent feature being generally strong runs in the early-to-mid 1990s including a peak in 1994 (Figure 38 and Tables 24–31). Despite an intervening distance of 490 km between their natal streams, Berners River and Hugh Smith Lake stocks have been closely correlated (Figure 30) and have also tracked closely with regional fishery performance indicators (Shaul 1998). However, the outer coastal stock, Ford Arm Lake, shows a substantially different abundance pattern. All of the inside indicator stocks peaked in 1994, had a relatively weak return in 1997, and returned at about average abundance in 1998. In contrast, the Ford Arm Lake stock peaked in 1993 instead of 1994, returned in well above-average abundance in 1997, and had a record return in 1998. Broad differences in marine survival and abundance between inside and outside stocks are also evident in southern B.C. (Holtby et al. 2000a), and provide further evidence that the most important processes affecting marine survival typically operate in very nearshore waters, as opposed to waters off the outer coast.

Based on estimates by Yanusz et al. (1999) the transboundary Taku River stock (Tables 32 and 33 and Figure 39) has tracked closely in abundance with the Berners River stock since 1992. This is not surprising since, although the stocks are exploited in separate near-terminal gillnet fisheries, they are situated in close proximity in northern inside waters and most of their smolt production originates in similar lower mainland river habitat.

Biological escapement goals were established for the four long-term indicator stocks, based on Ricker analysis of returns that were adjusted to average marine survival (Clark et al. 1994). The goal ranges were established within the range estimated to produce 90% or more of MSY. Over the duration of the indicator stock programs, escapements have been within or above the goal range with relatively few exceptions (Berners River 1984 and 1986–1988 and Hugh Smith Lake 1989). The Berners River stock was historically subjected to a very intensive fall gillnet fishery in Lynn Canal that was managed primarily for the Chilkat fall chum salmon run. However, a decline in Chilkat chum abundance combined with increased coho salmon fishing opportunities in other districts has resulted in a dramatic change in gillnet effort and fishing patterns in the 1990s. The number of boats fishing in Lynn Canal declined dramatically after 1988 and the fishery has more recently been managed in both area and time to achieve the coho escapement goal in the Berners River, while conserving the Chilkat chum run. During the most recent 10-year period (1989–1998), the escapement goal range for the Berners River has been met in four years and exceeded in six years.

During the same period, the goal for the Hugh Smith Lake stock was not achieved in the first year, but has been achieved or exceeded every year since (achieved in five years and exceeded in four years). Despite larger run sizes in the 1990s, escapement to Hugh Smith Lake has followed a relatively level trend since the early 1980s (Figure 38). The exploitation rate on this stock (Table 31) has been relatively high in recent years at an average of 76% (range 68%–82%) during 1989–1998, compared with an average of only 62% (range 52%–66%) during 1982–1998. The most significant component of the increase occurred in gillnet fisheries in Districts 101 and 106 followed by the Alaska troll fishery, primarily in northern Southeast (Shaul 1998).

The Auke Creek and Ford Arm Lake stocks are more typical of stocks that are harvested at moderate rates in hook-and-line fisheries but are not subjected to intensive net fisheries. Productivity estimates for these two stocks were lower than for the more heavily exploited Berners River and Hugh Smith Lake stocks (Clark et al. 1994) and, therefore, the escapement goal ranges are higher relative to average abundance. However, we suspect the narrow range of escapement observations may be partly responsible for their lower productivity estimates. Because of generally high marine survival rates and low to moderate exploitation rates (40%–60% on average), the escapement observations at Ford Arm Lake and Auke Creek may have been too high and within too narrow of a range to adequately test intrinsic productivity, and to accurately define the relationship between spawners and production. Over the full 19-year period from 1980–1998, the current escapement goal for Auke Creek (200–500 spawners) was exceeded in all but three years when it was near the upper bound (Figure 38). The escapement to Ford Arm Lake was within the goal range in 10 years and above in six years out of 16.

Escapement in Southern Southeast Alaska

Escapement survey programs in Southeast Alaska typically cover fewer than 50 systems per year and have only been developed within the past 20 years. Regionwide results through 1997 are presented in Shaul (1998). Results presented here include only streams in the Ketchikan area near the international boundary.

Methods and Problems

Obtaining a reliable index of coho salmon escapement from surveys in remote areas of Southeast Alaska is at best a marginal proposition. Inside mainland stocks near Ketchikan have been identified as being probably the most vulnerable stocks to potential over-fishing, because of lower average marine survival rates, combined with relatively high exploitation rates that occur mostly in highly mixed-stock fisheries. Therefore, the most concerted effort to obtain a comparable spawner index has been undertaken in that area, where an escapement index is available for 15 surveyed streams, plus the total escapement to Hugh Smith Lake dating from 1987 (Table 34).

The stream surveys in this area are all conducted by helicopter, with efforts made to maintain consistency among the two observers who are long-term local management staff. Each biologist has an individual circuit of streams to cover when there is a break from the typical rainy, high flow conditions that prevail in the fall. Streams were chosen to include those where visibility conditions are typically the best and where spawners can be observed regardless of their distribution within the system. Surveys are only conducted when weather and stream conditions are suitable, and two surveys are scheduled per year. A late September or early October pre-peak survey is conducted, when possible, because weather and visibility conditions often deteriorate for several weeks throughout the period of peak spawner abundance, which typically occurs in mid to late October. Surveys conducted after the peak of spawning are not useful for indexing seasonal spawner abundance because spawning, predation and flushing rates are highly variable. It is essential to view the fish during the window when most have entered freshwater, but before substantial spawning has occurred. Only the highest annual survey count under acceptable conditions is used. When a survey is not conducted that meets standards for timing and visibility, the count for that stream is not used in the overall index. However, an interpolation is made based on counts on other systems in the same year and counts in the same system across years, using a method described in Shaul (1998) in order to obtain a comparable overall escapement index for stocks in the area.

Escapement Index

Despite efforts at consistency and quality control, the annual values are clearly affected by the particular fall weather conditions that prevail each season, affecting fish behavior as well as the timing and effectiveness of surveys. Therefore, the index provides at best only a rough comparison between particular years, but is probably useful for evaluating trends. The total index (Table 34) shows a peak in the mid-1990s when wild coho salmon catches in southern Southeast and throughout the region were also at peak levels. In 1997, the total index and the Hugh Smith weir count alone were well below average, but still far higher than the extremely low escapement values for upper Skeena systems in the same year (Tables 2 and 12). The 1998 index of 8,126 spawners was slightly above the 1987–1997 average of 7,732. Unfortunately, data on longer-term trends are unavailable.

All of the systems in the index are mainland streams in District 101. Based on observations in other areas, we suspect escapements may vary substantially on nearby Islands, particularly on the outer coast, where no suitable escapement indicator has yet been established.

Southeast Alaska Stock Status

Southeast Alaska stocks have experienced generally favorable conditions for marine survival since the early 1980s, while smolt production from indicator stocks has shown no significant trends. Stocks in much of the region are not subjected to intensive near-terminal net fisheries nor to the full gauntlet of mixed-stock fisheries. If Auke Creek and Ford Arm Lake are suitable examples of this type of stock, it appears unlikely that escapements in these systems have fallen low enough to limit smolt production even in years when returns have been weakest. Indicators for the more heavily exploited inside stocks that are more likely to have been escapement-limited (Berners River and Hugh Smith Lake) have met or exceeded their biological goals in recent years. In addition, the escapement index for southern Southeast stocks that have been most heavily exploited by mixed-stocks fisheries have shown no trend since the mid-1980s.

Based on these observations and on recent wild-stock fishery performance that has been strong on average, we conclude that the escapement status of wild coho salmon stocks in Southeast Alaska is very good.

Habitat quality was discussed by Shaul (1998) and will not be reviewed in detail here. However, we expect that habitat loss will be a long-term concern as the full effect of historical timber harvesting practices are manifested on streams where recruitment of wood into stream channels has been interrupted. We expect that streamside protection guidelines adopted in the past decade will significantly slow the amount of habitat that enters into a long-term period of decline in the future. Total wild smolt production within the region will probably decline in small increments for many decades as a result of past forest management practices on smaller stream systems within timber harvest units, but many important habitats have not been degraded to any extent.

CONCLUSIONS AND RECOMMENDATIONS

Southeast Alaska and transboundary river coho salmon stocks have benefited from favorable marine conditions within the past two decades, and appear to be in excellent condition relative to escapement needs. Northern B.C. stocks have clearly diverged from Southeast Alaska stocks in the mid-1990s as a result of a shift in marine survival between the regions. However, while abundance of northern B.C. stocks has not followed the increase seen in Southeast Alaska, we find no evidence of chronic inadequacy in spawning escapement nor any direct indication that escapements have limited smolt production, with the possible exception of the 1997 brood year. However, there is insufficient information to make any definitive assessment for many stocks, including those on the B.C. central coast and the Queen Charlotte Islands. Detailed stock assessment programs in Portland Inlet (Area 3) were initiated too recently to draw conclusions about long-term stock status, but it appears likely that recent marine survival rates in that area have been intermediate between high levels in Southeast Alaska and lower rates to the south.

We conclude that improvements in stock assessment in northern B.C. should be concentrated on the central coast where information is lacking, and on the larger mainland systems where marine survival appears to be chronically lower and exploitation potentially greater.

The history of abundance of upper Skeena River coho salmon, reconstructed from the Tyee index, shows a relatively stable long-term trend in total abundance that appears similar to the trend for the overall aggregate of northern B.C. mainland stocks (as indicated by fishery performance). While average runs in recent years appear to have been little changed from 1950s and 1960s levels, aggregate escapement declined in the early 1970s and has since followed a stable trend through recent times. The drop in average escapement after 1971 likely resulted first from a decline in natural survival in the mid-1970s followed by increased exploitation as total abundance recovered in the late-1970s and 1980s. Although the long-term escapement trend has been stable for nearly 30 years, recent escapements have been highly variable, ranging from an exceptionally low level (about one-third of the previous low) in 1997 to some of the largest recorded escapements in 1999 (fence counts at Toboggan Creek and the Babine River were 6,316 and 14,907, respectively).

Despite the apparent stable trend in aggregate production, there are at least two exceptions in which specific components of the upper Skeena run appear to have declined. The best-documented exception is the sharp decline in Babine coho salmon abundance between 1978–1981, but the Babine stock has since followed a stable trend accompanied by greater synchrony with other Skeena and northern B.C. stocks. We estimate that the contribution by the Babine stock to the migration of coho salmon into the Skeena River through early September declined from an average of 18% during 1956–1980 to only 7% after 1980 and that the Babine fraction of upper Skeena abundance has become much more stable. The cause of the decline in Babine production remains at least partially a mystery, but was probably not caused by reduced parent escapement levels. Related circumstances suggest an indirect effect of Babine sockeye salmon enhancement (most likely a predation response in specific habitats) as the most probable cause. The Ricker analysis indicates that carrying capacity of the Babine stock declined abruptly by between 60%–75% (i.e. enough to account for the decrease in average adult abundance of 62%–66% between 1946–1978 and 1979–1998). Of several hypotheses that we examined to explain the decline, the most credible appears to be a predator response to Babine Lake sockeye salmon enhancement that may have disproportionately affected coho salmon rearing in specific habitats.

The other evident exception to stable long-term production is the upper Bulkley River. This tributary has undergone habitat changes in the lower drainage as a result of human development, while spawner access to the upper drainage has apparently been restricted in recent years. Partial restoration of this subpopulation may be possible by re-seeding the upper system and restoring spawner access. These measures have recently been initiated by DFO.

While aggregate upper Skeena and northern B.C. coastal coho salmon abundance has followed a relatively stable trend since the mid-1950s, wild coho salmon abundance in Southeast Alaska followed an increasing trend since the late-1970s. The increasing trend in Alaska production is coincidental with a decline from southern B.C. southward (Holtby et al. 2000). Over the long-term, the trend in marine survival on the north coast of B.C. has apparently varied less compared with areas to the south and north because of its location near the pivotal point of north-south oscillations in marine survival, that are apparently related to shifting oceanic regimes (Pearcy 1997). Although variability in the total abundance of upper Skeena coho salmon populations has increased as the latitudinal gradient in survival has become steeper in the 1990s, we see no evidence that the levelness of the long-term trend has changed. Known cases in which subpopulations appear to be below 1950s to mid-1970s levels (i.e. Babine and Upper Bulkley) appear to have been caused by factors other than reduced parent escapement or lower marine survival.

Given these circumstances, the most effective policy for balancing risk and yield is to develop a management strategy that is responsive to large inter-annual fluctuations in abundance, without presuming a trend. Evidence indicating that production from upper Skeena stocks has been sustainable for decades with only limited active management suggests that fishing at a pre-1998 average level of about 60% under a more responsive escapement-based management program would pose little risk to the stocks in the future. A strategy that accurately and precisely responds to annual abundance could be effective, even if the runs were to abandon their long-term stability and trend downward for a period of years.

An important step in developing a responsive management program is to establish biological escapement goals. We favor spawner-recruit analysis as the basis for escapement goals, as habitat-based goals are subject to large potential errors compared with direct measurement (i.e. spawner-recruit analysis), especially in the case of the upper Skeena system where adequate standards are lacking for interior habitats. The density disparity between interior Taku River tributaries and coastal streams suggests the lower rearing densities observed in the Skeena system may be somewhat typical of interior systems, rather than evidence of a chronic shortfall in escapement.

The current "best" point estimates of MSY escapement are about 1,900 and 1,200 spawners for Babine and Toboggan stocks, respectively, based on spawner-recruit analysis of recent marine survival-adjusted returns. We recommend escapement target ranges that are centered well above these levels because of the following factors: (1) there are still substantial limitations in the data, (2) Babine production is distributed over a large geographic area among habitats that may be somewhat isolated, and (3) there remains lack of reliable information on the other major upper Skeena production area (high interior). Also, the Babine run has included a small hatchery component since 1987 that has not been separated from wild production in this analysis or by Holtby et al. (1999). We recommend initial escapement target ranges of 1,900–4,000 spawners for the Babine stock and 950–1900 wild spawners for Toboggan Creek.

We anticipate returns through 2003, from widely varying escapements in 1997 and 1999 (20 fold in Toboggan Creek and 33 fold in the Babine River), will better define the relationship between the number of spawners and returns for these populations. This will, in turn, provide an improved basis for setting biological goals, which should be re-evaluated in 2004. Resolution of the technical issues around the Babine goal is a particularly important objective. The LRP of 1,200 spawners and the TRP of 11,500 spawners proposed by Holtby et al. (1999) would place the Babine stock in a "rebuilding" classification (between LRP and TRP) at all escapement levels observed within the 20-year period from 1979-1998 (except for 1997 when the total run was below the proposed LRP escapement). The run would have been classified as rebuilding in all of those years even if there had been no fishing mortality in Canadian waters (or even in Alaska waters in thirteen out of 19 years). Since rebuilding status typically restricts harvest to incidental mortality (DFO 2000a), future directed fishing under the proposed TRP is contingent on the Babine stock rebuilding substantially toward pre-1979 levels. Therefore, the technical question about whether average stock size can be restored to earlier abundance by increasing escapement is critical.

Our analysis suggests the Babine run has likely declined from factors other than reduced escapement, and we have uncovered no evidence that increasing escapement above recent levels has had or will have a rebuilding effect. Furthermore, even if larger escapements could eventually restore former abundance, our proposed goal is clearly adequate to insure the security of the Babine population while allowing for a greater harvest opportunity on other more abundant northern B.C. coho salmon stocks that are intermingled in the fisheries. Our analysis indicates that even if the Babine stock could be rebuilt to pre-1979 abundance by increasing escapement, and then managed precisely for MSY under the long-term Ricker relationship, total yield to the fisheries would increase by only 4,481 fish over the 1988–1997 average harvest. Holtby's (1999) run reconstructions and Ricker estimates would put that figure somewhat lower, at about 3,339 fish.

Another top priority is to develop a coordinated inseason system of run-strength assessment (as stated in the 1999 PST Agreement, Attachment B) and to actively apply inseason information to achieve escapement goals. Early-season performance in fisheries in which Skeena and nearby northern B.C. stocks are the major component of the coho salmon catch should be evaluated for their potential utility as inseason run strength indicators. In addition, coded wire tag recoveries cumulated in mixed-stock fisheries have proven useful as inseason indicators of marine survival. Timely marine survival estimates, combined with real-time smolt abundance estimates, would be highly useful for inseason stock assessment and management of northern B.C. coho salmon stocks. Further stock assessment work in the upper Skeena system would also be useful to determine how well indicator stocks in the Bulkley and Babine tributaries represent those in the other major geographic area (high interior) in abundance patterns and productivity. To date, however, a comparison of escapements with test fishery and commercial fishery indicators suggests a high level of synchrony in abundance exists among stocks within the Skeena system and probably along the mainland coast of northern B.C. as well. This suggests that it is feasible to manage upper Skeena coho salmon stocks in mixed stock fisheries based primarily on indicator stocks and fishery performance.

Holtby and Finnegan (1997) raised serious concerns about the sustainability of upper Skeena coho salmon stocks under mixed-stock fishery management and cautioned that any exploitation "poses a serious risk to the viability of coho populations in the area." A substantial part of their concern was centered on a poor ability to predict abundance (using the Lachmach jack indicator), and therefore, to adjust exploitation to an appropriate level based on annual abundance. Reliable real-time stock assessment appears to be a key requirement in order to demonstrate to broad satisfaction that upper Skeena coho salmon stocks can be sustained under a substantial average rate of exploitation.

Aside from the extremely weak 1997 run, our results run counter to the conclusion by Holtby and Finnegan (1997) that exploitation rates averaging 60%–65% in the early to mid-1990s were unsustainable. We agree that interior coho salmon stocks are probably less productive on average than those on the coast, as evidenced by a number of factors, including the differential response of juvenile densities following the 1997 escapement and lower smolt survival rates from large river indicator stocks. However, while interior stocks are probably less productive and should therefore be more closely monitored, the preponderance of evidence suggests interior Skeena stocks have been productive enough to sustain historical levels of fishing. The "mismatch between exploitation rate and productivity" described by Holtby and Finnegan (1997) appears to have existed only in infrequent years like 1997 when natural survival was very poor. The key to avoiding or minimizing future shortfalls in spawning escapement while achieving substantial fishery yield over time, will be to identify runs that are weak compared with biological escapement objectives, and to respond with fishery restrictions in a timely and appropriate manner.

While our conclusions differ from Holtby and Finnegan (1997) and Holtby et al. (1999) regarding the current status of upper Skeena stocks and the historical level of risk posed by fisheries, it is clear that recent and ongoing changes in the structure and management of Canadian fisheries will further reduce risk in the future. License buyouts and area licensing have substantially reduced the capacity of the northern B.C. troll fleet, the primary Canadian harvester of upper Skeena coho salmon, from as many as 600–700 vessels fishing on the North Coast before area licensing to approximately 150 eligible licenses in 2000 (DFO 2000b). In addition to a reduced capacity to exploit the stocks, other recent developments that will further reduce risk to upper Skeena stocks include: (1) a provision for joint abundance-based management with Alaska in the 1999 PST agreement, (2) promising technical progress toward inseason stock assessment, and (3) increased investment in stock assessment (recently by DFO and potentially expanded in the future with earnings from the PST endowment fund).

In conclusion, the primary challenge facing fishery managers lies not in insuring that weaker stocks like those in the upper Skeena River continue to persist, but rather in developing strong stock assessment capability and an escapement-based management program that provides sustainable fishery benefits comparable to historical levels, but at lower risk.

LITERATURE CITED

Baxter, B. E., Cy Stephens, and B. L. Nass. 2001. Adult and juvenile coho salmon enumeration and coded-wire tag recovery analysis for Zolzap Creek, B.C., 1998. Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 2566. Canada Department of Fisheries and Oceans, Prince Rupert, B.C., Canada.

Bradford, M. J., R. A. Myers, and J. R. Irvine. Reference points for coho salmon (*Oncorhynchus kisutch*) harvest rates and escapement goals based on freshwater production. Can. J. Fish. Aquat. Sci. 57:677-686.

Brown, M. B. 1974. Identification of sources of significance in two-way contingency tables. Appl. Statist. 23:405-413.

Bustard, D. 1990. Assessment of coho salmon recruitment from streams tributary to Babine Lake. Report prepared for Dept. of Fisheries and Oceans, Habitat Management Section, Prince Rupert, B.C. by David Bustard and Associates, Smithers, British Columbia, Canada.

Clark, J. E., J. H. Clark, and L. D. Shaul. 1994. Escapement goals for coho salmon stocks returning to Berners River, Auke Creek, Ford Arm Lake, and Hugh Smith Lake in Southeast Alaska. Alaska Department of Fish and Game, Commercial Fisheries Division, Regional Information Report No. 1J94-26. Douglas, Alaska.

Coho Technical Committee. 1991. Northern panel area coho salmon status report. Pacific Salmon Commission Coho Technical Committee Report TCCOHO (91)-1. Vancouver, British Columbia, Canada.

Coho Technical Committee. 1994. Interim estimates of coho stock composition for 1984–1991 southern area fisheries and for 1987–1991 northern panel area fisheries. Pacific Salmon Commission Coho Technical Committee Report TCCOHO (94)-1. Vancouver, British Columbia, Canada.

Cox-Rogers, S. and L. Jantz. 1993. Recent trends in the catchability of sockeye salmon in the Skeena River gillnet test fishery and impacts on escapement estimation. Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 2219. Canada Department of Fisheries and Oceans. Prince Rupert, British Columbia, Canada.

Clark, J. E., J. H. Clark, and L. D. Shaul. 1994. Escapement goals for coho salmon stocks returning to Berners River, Auke Creek, Ford Arm Lake, and Hugh Smith Lake in Southeast Alaska. Alaska Department of Fish and Game, Commercial Fisheries Division, Regional Information Report No. 1J94-26. Douglas, Alaska.

Crone, R. A. 1981. Potential for production of coho salmon, *Oncorhynchus kisutch*, in lakes with outlet barrier falls in Southeast Alaska. Ph.D. thesis. University of Michigan.

Crone, R. A. and C. E. Bond. 1976. Life history of coho salmon, *Oncorhynchus kisutch*, in Sashin Creek, Southeastern Alaska. Fish. Bull. 74(4):897-923.

Crone, R. A. and J. P. Koenings. 1985. Limnological and fisheries evidence for rearing limitation of coho salmon, *Oncorhynchus kisutch*, production from Sea Lion Cove Lake, Northern Southeast Alaska (1980–1983). Alaska Department of Fish and Game, FRED Division. Technical Data Report Series No. 54. Juneau, Alaska.

CTC (Chinook Technical Committee). 1999. 1995 and 1996 annual report. Pacific Salmon Commission, Report TCCHINOOK (99)-2. Vancouver, British Columbia, Canada.

DFO (Department of Fisheries and Oceans). 1999. Stock status of Skeena River coho salmon. DFO Science Stock Status Report D6-02 (1999). Canada Department of Fisheries and Oceans, Nanaimo, British Columbia, Canada.

DFO (Department of Fisheries and Oceans). 2000a. Wild Salmon Policy Discussion Paper. Canada Department of Fisheries and Oceans, Canada.

DFO (Department of Fisheries and Oceans). 2000b. 2000 salmon licence area selection results. Unpublished report. Canada Department of Fisheries and Oceans, Nanaimo, British Columbia, Canada.

Eggers, D. M. 1993. Robust harvest policies for Pacific salmon fisheries. Proceedings of the International Symposium on Management Strategies for Exploited Fish Populations. Alaska Sea Grant College Program, AK-SG-93-02:85-106.

Geiger, H. J. 2001. Spurious stock-recruit relationships. In: Proceedings of the 7th Alaska Salmon Workshop – Escapement and the Realities of the New Salmon Management, February 21–23, 2001, Anchorage, Alaska. Alaska Department of Fish and Game, Commercial Fisheries Division, Juneau, Alaska.

Hare, S. R., N. J. Mantua, and R. C. Francis. 1999. Inverse production regimes: Alaska and West Coast Salmon. Fisheries 24 (1):6-14.

Hilborn, R. 1985. Apparent stock recruitment relationships in mixed stock fisheries. Can. J. Fish. Aquat. Sci. 42:718-723.

Holtby, B. 1999. Stock status of northern boundary coho. Canadian Report to the Northern Boundary Technical Committee of the Pacific Salmon Commission. Canada Department of Fisheries and Oceans, Nanaimo, British Columbia, Canada.

Holtby, B., R. Kadowaki, and L. Jantz. 1994. Update of stock status for early run Skeena River coho salmon (through the 1993 return year). PSARC Working Paper S94-4. Canada Department of Fisheries and Oceans, Nanaimo, British Columbia, Canada.

Holtby, B. and B. Finnegan. 1997. Biological assessment of Skeena River coho salmon. PSARC Working Paper S99-12. Canada Department of Fisheries and Oceans, Nanaimo, British Columbia, Canada.

Holtby, B., B. Finnegan, D. Chen, and D. Peacock. 1999. Biological assessment of Skeena River coho salmon. Canadian Stock Assessment Secretariat Research Document 99/140. Canada Department of Fisheries and Oceans, Ottawa, Canada.

Holtby, B., K. Simpson, R. Tansichuk, and J. R. Irvine. 2000a. Forecast for southern British Columbia coho salmon in 2000. PSARC Working Paper S00-3. Canada Department of Fisheries and Oceans, Nanaimo, British Columbia, Canada.

Holtby, B., K. Simpson, B. Finnegan, and B. Spilsted. 2000b. Forecast for northern British Columbia coho salmon in 2000. Canadian Stock Assessment Secretariat Research Document 2000/128. Canada Department of Fisheries and Oceans, Ottawa, Canada.

Joint Coho Technical Committee. 1991. Northern Panel area coho salmon status report. TCCOHO (91)-1. Pacific Salmon Commission, Vancouver, B.C., Canada.

Joint Coho Technical Committee. 1994. Interim estimates of coho stock composition for 1984–1991 southern area fisheries and for 1987–1991 northern panel area fisheries. TCCOHO (94)-1. Pacific Salmon Commission, Vancouver, B.C., Canada.

Johnson, W. E. 1958. Density and distribution of young sockeye salmon (*Oncorhynchus nerka*) throughout a multibasin lake system. J. Fish. Res. Bd. Canada. 15(5):961-982.

Kadowaki, R. 1988. Stock assessment of early run Skeena River coho salmon and recommendations for management. Can. Tech. Rep. Fish. Aquat. Sci. 1638. Nanaimo, B.C.

Kadowaki, R., T. Pendray, and L. Jantz. 1992. Stock assessment of early run Skeena River coho salmon (through the 1991 return year). PSARC Working Paper S96-9. Canada Department of Fisheries and Oceans, Nanaimo, British Columbia, Canada.

Koski, W. R., R. F. Alexander, and K. K. English. 1995. Distribution, timing and numbers of coho salmon and steelhead returning to the Skeena watershed in 1994. Report prepared by LGL Limited Environmental Research Associates for Fisheries Branch, B.C. Ministry of Environment, Lands and Parks. Sidney B.C., Canada.

Kyle, G. B. 1990. Aspects of the food habits and rearing behavior of underyearling coho salmon (*Oncorhynchus kisutch*) in Bear Lake, Kenai Peninsula, Alaska. Alaska Department of Fish and Game, FRED Division. Technical Data Report Series No. 105. Juneau, Alaska.

McDonald, J. G. 1969. Distribution, growth and survival of sockeye fry (*Oncorhynchus kisutch*) produced in natural and artificial stream environments. J. Fish Res. Bd. Canada 26:229-267.

McMahon, V. H. 1948. Lakes of the Skeena River drainage. VII. Morrison Lake. Fish Res. Bd. Canada, Pacific Prog. Rept. No. 74. Nanaimo, British Columbia, Canada.

Nass, B. L. 1996a. Escapement enumeration studies of adult coho salmon at Zolzap Creek, B.C., 1993. Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 2373. Canada Department of Fisheries and Oceans, Prince Rupert, B.C., Canada.

Nass, B. L. 1996b. Escapement enumeration studies of adult coho salmon at Zolzap Creek, B.C., 1992. Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 2374. Canada Department of Fisheries and Oceans, Prince Rupert, B.C., Canada.

Nass, B. L. 1996c. Escapement enumeration and coded-wire tagging of coho salmon smolts at Zolzap Creek, and enumeration of coho salmon smolts at Seaskinnish and Ginluluk Creeks, 1992. Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 2376. Canada Department of Fisheries and Oceans, Prince Rupert, B.C., Canada.

Nass, B. L. 1997a. Adult and juvenile coho salmon enumeration and coded-wire tag recovery analysis for Zolzap Creek, B.C., 1994. Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 2420. Canada Department of Fisheries and Oceans, Prince Rupert, B.C., Canada.

Nass, B. L. 1997b. Adult and juvenile coho salmon enumeration and coded-wire tag recovery analysis for Zolzap Creek, B.C., 1995. Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 2423. Canada Department of Fisheries and Oceans, Prince Rupert, B.C., Canada.

Nass, B. L. 2001. Adult and juvenile coho salmon enumeration and coded-wire tag recovery analysis for Zolzap Creek, B.C., 1996. Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 2564. Canada Department of Fisheries and Oceans, Prince Rupert, B.C., Canada.

Nass, B. L. and H. R. Frith. 2001. Adult and juvenile coho salmon enumeration and coded-wire tag recovery analysis for Zolzap Creek, B.C., 1997. Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 2565. Canada Department of Fisheries and Oceans, Prince Rupert, B.C., Canada.

NBTC (Northern Boundary Technical Committee). 1999. U.S./Canada northern boundary area 1998 salmon fisheries management report and 1999 preliminary expectations. Pacific Salmon Commission, Report TCNB (99)-1. Vancouver, British Columbia, Canada.

Nelson, M. O. 1966. Food and distribution of Arctic char in Lake Aleknagik, Alaska, during the summer of 1962. M.S. Thesis, University of Washington.

Pearcy, W. G. 1977. Salmon production in changing ocean domains. pp. 331-352. *In* D.S. Stouder, P. A. Bisson and R. J. Naiman, eds. Pacific salmon and their ecosystems. Chapman and Hall, Inc. New York, N.Y.

PFRCC (Pacific Fisheries Resource Conservation Council). 2001. Salmon conservation in the Central Coast. Pacific Fisheries Resource Conservation Council, Advisory Report. Vancouver, B.C., Canada.

Rogers, D. E., L. Gilbertson, and D. Eggers. 1972. Predator-prey relationship between Arctic char and sockeye salmon smolts at the Agulowak River, Lake Aleknagik, in 1971. University of Washington, Fish. Res. Inst. Circ. No. 727. Seattle, Washington.

Scarsbrook, J. R. and J. McDonald. 1970. Purse seine catches of sockeye salmon and other species of fish at Babine Lake, 1966–1968. Fish. Res. Bd. Can. Man. Report No. 1075. Nanaimo, British Columbia, Canada.

Shaul, L. D. 1987. Taku and Stikine River coho salmon (*Oncorhynchus kisutch*) adult escapement and juvenile tagging investigations, 1986. Alaska Department of Fish and Game, Division of Commercial Fisheries, Completion Report for National Marine Fisheries Service Cooperative Agreement No. NA-85-ABH-00050, Juneau, Alaska.

Shaul, L. D. 1988. Taku River coho salmon (*Oncorhynchus kisutch*) adult escapement and juvenile tagging investigations, 1987. Alaska Department of Fish and Game, Division of Commercial Fisheries, Completion Report for National Marine Fisheries Service Cooperative Agreement No. NA-87-ABH-00025, Juneau, Alaska.

Shaul, L. D. 1989. Taku River coho salmon investigations, 1988. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 1J89-33, Juneau, Alaska.

Shaul, L. D. 1990. Taku River coho salmon investigations, 1989. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 1J90-19, Juneau, Alaska.

Shaul, L. D. 1992. Taku River coho salmon investigations, 1990. Alaska Department of Fish and Game, Division of Commercial Fisheries, Manuscript Report, Juneau, Alaska.

Shaul, L. D. 1998. Status of coho salmon stocks and fisheries in Southeast Alaska through 1997. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 1J98-26, Juneau, Alaska.

Shaul, L. D., P. L. Gray, and J. F. Koerner. 1991. Coded-wire tag estimates of abundance, harvest, and survival rates of coho salmon stocks in Southeast Alaska, 1981–1986. Alaska Department of Fish and Game, Division of Commercial Fisheries, Fishery Research Bulletin 91-05, Juneau, Alaska.

Shaul, L. D., J. P. Koenings, B. W. Van Alen, and G. T. Oliver. 1998. Status of coho salmon stocks and fisheries in the Northern Boundary Area. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 1J98-12, Juneau, Alaska.

Spilsted, B. P. and G. Hudson. 1994. A summary of coded wire tag recovery information from northern B.C. and Alaska's commercial fisheries for the years 1987 to 1992 for coho tagged within the Skeena River watershed. Canadian Data Report of Fisheries and Aquatic Sciences No. 944. Prince Rupert, B.C., Canada.

Taylor, J. A. 1999. An estimate of the coho escapement above Moricetown Falls, Bulkley River, B.C. Contractor's Report to DFO, Nanaimo. B.C.

West, C. J. and J.C. Mason. 1987. Evaluation of sockeye salmon (*Oncorhynchus nerka*) production from the Babine Lake Development Project. pp. 176-190 *in* H. D. Smith, L. Margolis, and C.C. Wood (ed.) Sockeye salmon (*Oncorhynchus nerka*) population biology and future management. Can. Spec. Publ. Fish. Aquat. Sci. 96.

Withler. F. C., J. A. McConnell, and V. H. McMahon. 1949. Lakes of the Skeena River drainage. IX. Babine Lake. Fish Res. Bd. Canada, Pacific Prog. Rept. No. 78. Nanaimo, British Columbia, Canada.

Wood, C. C., D. T. Rutherford, D. Bailey, and M. Jakubowski. 1998. Assessment of sockeye salmon production in Babine Lake, British Columbia with forecast for 1998. Can. Tech. Rep. Fish. Aquat. Sci. 2241. Nanaimo, B.C.

Yanusz, R. J., S. A. McPherson, and D. R. Bernard. 1999. Production of coho salmon from the Taku River, 1997–1998. Alaska Department of Fish and Game, Division of Sport Fish, Fishery Data Series No. 99-34.

Table 1. Tyee test fishery annual sockeye salmon catchability adjustment factor and unadjusted coho salmon index by test fishery ending date, 1956–1998.[a]

	Sockeye Catchability	Unadjusted Index												
Year	Adj. Factor	15-Aug	24-Aug	25-Aug	26-Aug	27-Aug	28-Aug	29-Aug	30-Aug	31-Aug	1-Sep	2-Sep	3-Sep	4-Sep
1956	3.98	58.70	86.49	91.39	94.68	97.64	103.28	106.79	109.74	111.10	111.10	118.01	123.75	127.32
1957	2.83	62.87	94.27	97.07	101.34	104.57	106.01	107.90	108.38	109.57	111.36	112.32	113.24	115.12
1958	2.53	111.89	151.98	155.99	161.43	167.50	171.58	173.44	175.38	178.02	184.65	192.51	206.86	212.98
1959	2.56	64.01	76.20	76.20	76.20	76.49	76.80	79.94	79.94	81.70	83.33	83.97	85.34	89.18
1960	2.79	60.27	71.51	71.51	71.51	72.49	72.49	73.70	74.95	76.20	76.20	76.20	76.20	77.53
1961	2.27	42.24	54.38	56.18	60.32	64.41	65.82	70.05	71.98	81.32	84.17	85.74	85.74	92.89
1962	2.47	77.06	115.01	119.25	122.11	124.23	127.20	128.14	128.14	128.14	128.14	128.59	129.55	131.43
1963	2.55	74.95	90.23	90.23	90.23	90.23	90.23	90.23	90.23	91.17	92.45	94.33	96.68	102.38
1964	2.63	83.84	119.09	119.58	122.87	122.87	123.81	124.75	126.00	128.46	131.85	133.73	133.73	139.75
1965	2.08	150.28	173.33	175.53	176.18	180.94	183.79	221.87	226.18	232.63	238.76	245.18	252.03	263.39
1966	3.95	151.49	168.46	168.46	168.46	168.46	172.68	178.90	182.38	187.57	192.52	197.69	203.22	212.37
1967	3.24	117.68	160.89	163.29	164.18	164.86	165.77	165.77	168.99	173.81	178.39	183.18	188.31	196.79
1968	3.01	59.95	77.37	79.49	81.48	83.36	85.45	88.53	90.25	92.82	95.27	97.83	100.56	105.09
1969	2.96	81.24	141.43	146.49	146.49	149.03	151.35	152.80	155.40	159.83	164.04	168.45	173.16	180.96
1970	2.70	90.19	136.01	136.94	147.01	150.40	154.17	159.72	162.83	167.47	171.88	176.50	181.43	189.61
1971	2.68	98.47	160.78	168.30	173.09	176.59	181.01	187.53	191.18	196.63	201.81	207.23	213.02	222.62
1972	2.91	49.33	65.43	75.93	77.84	79.63	81.63	84.57	86.21	88.67	91.00	93.45	96.06	100.39
1973	3.93	60.86	87.77	91.41	91.87	92.31	96.09	99.55	101.49	104.38	107.13	110.01	113.09	118.18
1974	3.81	27.50	47.27	47.71	48.16	52.64	54.44	56.40	57.50	59.14	60.70	62.33	64.07	66.96
1975	3.20	51.71	63.04	63.51	65.86	67.38	69.07	71.55	72.95	75.03	77.00	79.07	81.28	84.94
1976	3.30	36.12	67.13	68.04	71.34	72.26	74.07	76.74	78.23	80.46	82.58	84.80	87.17	91.10
1977	2.95	61.38	99.30	103.53	106.77	109.23	111.97	116.00	118.26	121.63	124.83	128.19	131.77	137.71
1978	3.93	73.85	110.10	111.55	111.55	114.75	117.62	121.86	124.23	127.77	131.14	134.66	138.43	144.66
1979	2.60	19.81	28.16	28.16	29.55	30.23	30.99	32.10	32.73	33.66	34.55	35.48	36.47	38.11
1980	4.25	51.68	73.50	75.51	77.41	79.19	81.18	84.10	85.74	88.18	90.50	92.93	95.53	99.84
1981	2.23	48.69	57.81	57.81	58.76	60.12	61.62	63.84	65.08	66.94	68.70	70.55	72.52	75.79
1982	2.79	46.43	62.46	63.60	64.07	65.55	67.19	69.61	70.96	72.99	74.91	76.92	79.07	82.63
1983	2.36	41.12	61.97	64.29	67.02	68.33	69.26	71.76	73.15	75.24	77.22	79.29	81.51	85.18
1984	2.05	58.46	70.98	74.78	76.90	78.67	80.64	83.55	85.17	87.60	89.91	92.33	94.91	99.18
1985	2.08	30.39	45.29	48.07	48.07	49.77	51.21	53.27	53.27	54.79	56.23	57.74	59.36	62.03
1986	2.48	36.93	50.70	52.49	53.81	55.05	56.43	58.46	59.60	61.30	62.91	64.60	66.41	69.40
1987	1.46	22.93	29.71	30.63	32.46	32.46	32.46	32.46	32.46	32.46	32.46	39.71	44.19	59.77
1988	2.00	21.29	23.37	23.67	23.97	24.85	26.17	27.49	28.83	30.61	32.34	32.34	32.94	33.88
1989	1.86	43.60	78.94	81.30	87.06	89.09	93.36	95.56	100.69	103.42	104.77	105.24	108.05	108.98
1990	1.86	51.29	76.09	77.79	80.16	83.14	85.20	85.53	86.41	89.23	95.84	97.03	100.09	104.12
1991	1.69	35.00	55.36	59.37	61.66	67.29	70.72	72.72	77.53	83.14	83.14	87.22	89.53	92.30
1992	1.25	9.91	11.81	12.12	12.72	12.72	13.68	14.58	16.80	18.63	21.37	21.83	22.46	24.35
1993	1.24	8.23	13.33	14.23	15.15	16.05	16.66	17.26	17.58	18.20	18.20	19.13	19.13	20.05
1994	1.00	21.28	35.77	37.17	37.48	39.35	39.99	39.99	42.20	44.97	46.15	47.39	48.72	50.92
1995	1.68	20.07	26.55	27.90	30.16	31.95	32.83	33.27	34.13	35.39	37.51	39.59	40.82	42.56
1996	1.53	16.68	25.67	27.44	29.23	29.23	31.39	33.17	33.63	34.59	37.60	38.47	39.40	39.40
1997	1.76	3.91	5.21	5.21	5.34	5.46	5.60	5.80	5.92	6.08	6.24	6.41	6.59	6.89
1998	2.04	27.40	50.87	52.26	54.58	55.96	62.88	65.86	67.87	69.40	73.81	75.71	78.20	85.15

[a] Interpolated values are shaded.

Table 2. Coho salmon escapement counts at the Babine fence and estimates of annual total escapement, catch, and total return of Babine River coho salmon with the Babine contribution to the adjusted Tyee Index of aggregate lower Skeena escapement through September 1.

	Escapement								
Year	Count Through Sept. 13	Total Observed	Ending Date	Estimated Season Total	Prop. Age 3	Exploitation Rate (%)	Total Catch	Total Annual Return	Estimated Percent of the Tyee Index[a]
1946	8,687	12,489	Oct. 4	13,411	0.62	55.2	16,491	29,902	
1947	4,983	10,252	Oct. 7	10,815	0.62	55.2	13,299	24,114	
1948		Fence Not Operated				55.2			
1949	6,044	11,938	Oct. 3	12,961	0.52	55.2	15,937	28,898	
1950	5,205	11,654	Oct. 15	11,654	0.59	55.2	14,331	25,985	
1951	444	2,120	Oct. 4	2,276	0.51	55.2	2,799	5,076	
1952	1,157	10,550	Nov. 6	10,554	0.53	55.2	12,978	23,532	
1953	5,904	7,648	Oct. 28	7,655	0.57	55.2	9,414	17,069	
1954	1,644	3,094	Oct. 3	3,359	0.80	55.2	4,131	7,490	
1955	4,339	8,947	Oct. 3	9,714	0.60	55.2	11,944	21,658	
1956	5,675	9,250	Sept. 30	9,857	0.67	55.2	12,121	21,978	17.6
1957	2,475	4,421	Oct. 29	4,421	0.78	55.2	5,436	9,857	7.5
1958	5,026	7,606	Oct. 1	8,438	0.62	55.2	10,375	18,813	8.6
1959	6,347	10,947	Oct. 2	12,004	0.62	55.2	14,761	26,765	23.8
1960	5,191	6,794	Sept. 28	7,942	0.75	55.2	9,766	17,708	16.8
1961	7,297	10,024	Sept. 21	14,416	0.65	55.2	17,727	32,144	27.6
1962	8,088	11,000	Sept. 22	15,183	0.56	55.2	18,670	33,853	19.2
1963	3,600	3,600	Sept. 13	7,737	0.67	51.6	8,253	15,990	12.8
1964		Fence Not Operated				61.0			
1965	20,000	20,000	Sept. 13	42,985	0.47	50.4	43,716	86,701	33.2
1966	6,784	7,200	Sept. 15	13,377	0.67	58.3	18,732	32,109	13.2
1967	7,469	9,378	Sept. 23	12,487	0.59	49.6	12,291	24,778	13.6
1968	6,393	6,600	Sept. 14	13,054	0.27	57.9	17,974	31,028	27.7
1969	2,978	4,660	Sept. 21	6,702	0.52	51.8	7,191	13,893	7.6
1970	4,968	5,600	Sept. 15	10,404	0.55	56.8	13,656	24,060	11.0
1971	4,284	7,700	Sept. 24	9,909	0.53	56.8	13,004	22,913	9.5
1972	2,415	3,598	Sept. 20	5,381	0.70	63.2	9,245	14,626	12.1
1973	5,836	6,247	Sept. 15	11,606	0.60	52.5	12,851	24,457	22.8

[a] Proportional contribution estimated from the results of a 1994 radio telemetry study (Koski et al. 1995).

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Table 2. (page 2 of 2)

Year	Escapement: Count Through Sept. 13	Escapement: Total Observed	Escapement: Ending Date	Escapement: Estimated Season Total	Prop. Age 3	Exploitation Rate (%)	Total Catch	Total Annual Return	Estimated Percent of the Tyee Index[a]
1974	4,886	8,853	Sept. 19	13,661	0.71	56.4	17,668	31,329	49.2
1975	2,059	4,429	Oct. 1	4,913	0.60	48.9	4,698	9,611	14.0
1976	2,085	4,499	Oct. 28	4,499	0.60	48.5	4,243	8,742	11.9
1977	4,324	10,474	Oct. 20	10,474	0.46	57.0	13,882	24,356	17.1
1978	5,600	11,446	Oct. 10	11,930	0.78	65.5	22,634	34,564	19.7
1979	1,144	2,909	Oct. 31	2,909	0.77	65.8	5,587	8,496	17.1
1980	2,172	4,399	Sept. 29	5,046	0.78	65.3	9,480	14,526	11.2
1981	1,426	2,167	Sept. 29	2,486	0.36	58.1	3,448	5,934	6.6
1982	1,704	2,287	Sept. 28	2,673	0.79	56.8	3,519	6,192	6.2
1983	1,598	2,704	Sept. 25	3,402	0.74	72.0	8,759	12,162	6.5
1984	1,539	2,956	Oct. 2	3,241	0.54	65.5	6,149	9,390	5.4
1985	914	2,129	Oct. 24	2,129	0.85	67.0	4,313	6,442	5.0
1986	1,673	2,757	Sept. 23	3,671	0.81	72.5	9,673	13,345	7.5
1987	867	1,894	Oct. 1	2,101	0.90	56.0	2,669	4,770	8.2
1988	1,639	3,026	Oct. 5	3,225	0.81	30.8	1,437	4,661	12.3
1989	3,140	5,228	Oct. 25	5,228	0.77	57.2	6,977	12,205	5.6
1990	2,477	5,512	Oct. 14	5,619	0.81	60.8	8,718	14,338	6.5
1991	1,558	4,904	Oct. 19	4,941	0.78	60.9	7,698	12,638	6.0
1992	584	1,302	Sept. 29	1,714	0.73	63.6	2,999	4,713	7.2
1993	322	1,974	Oct. 11	2,186	0.72	49.4	2,135	4,321	10.5
1994	695	3,930	Nov. 1	4,053	0.74	62.1	6,646	10,699	7.5
1995	510	2,345	Nov. 6	2,345	0.81	43.6	1,815	4,160	5.7
1996	640	2,669	Nov. 4	2,669	0.80	64.7	4,882	7,551	7.2
1997	100	453	Oct. 19	453	0.76	49.8	449	902	8.1
1998	1,279	4,291	Nov. 15	4,291	0.80	24.2	1,372	5,663	6.6

[a] Proportional contribution estimated from the results of a 1994 radio telemetry study (Koski et al. 1995).

Table 3. R^2 values for the linear relationship between the Tyee test fishery coho salmon index and escapement past the Babine fence by test fishery ending date and catchability adjustment method, 1981–1998.[a] The percent of years when statistical fill-ins were not required to reach the ending date are shown for 1956–1998 and 1981–1998.

Ending Date	R^2 Values by Sockeye Catchability Adjustment Method: Unadjusted	Annual	3-Year Average	5-Year Average	Percent of Years with Complete Data: 1956-1998	1981-1998
August 15	0.337	0.523	0.637	0.701	100	100
August 24	0.543	0.719	0.825	0.837	100	100
August 25	0.549	0.719	0.821	0.836	95	89
August 26	0.563	0.728	0.824	0.835	88	72
August 27	0.583	0.740	0.830	0.842	72	72
August 28	0.604	0.763	0.846	0.853	63	67
August 29	0.592	0.764	0.842	0.850	56	67
August 30	0.611	0.770	0.849	0.855	51	61
August 31	0.626	0.774	0.853	0.860	47	56
September 1	0.638	0.789	0.866	0.871	44	56
September 2	0.630	0.772	0.858	0.865	44	56
September 3	0.627	0.762	0.855	0.862	44	56
September 4	0.599	0.706	0.835	0.843	40	56
Aug. 24-Sept. 4 Average	0.597	0.751	0.842	0.851		

[a] Best fits by ending date and adjustment method are shaded.

Table 4. R^2, slope, and y intercept values for linear relationships between the Tyee test fish index of coho salmon abundance in the lower Skeena River through September 1 and the Babine River coho escapement by period, 1956–1998.

Years	Exceptions	Catchability Adjustment	Slope	Intercept	R^2
1956-1998 (complete period)	none	None	90.9	998	0.484
		Annual	238.5	1286	0.475
		3-Year	235.1	996	0.353
		5-Year	243.2	1288	0.366
1956-1998 (complete period)	without 1965	None	56.5	1,559	0.429
		Annual	111.2	2,756	0.182
		3-Year	125.0	2,267	0.230
		5-Year	131.0	2,057	0.244
1956-1978 (pre-decline)	none	None	80.7	1,191	0.263
		Annual	230.3	1,275	0.441
		3-Year	217.4	2,079	0.255
		5-Year	244.8	943	0.291
1956-1978 (pre-decline)	without 1965	None	11.5	8,520	0.022
		Annual	19.2	9,140	0.009
		3-Year	33.8	8,533	0.026
		5-Year	43.6	8,134	0.038
1970-1998	none	None	56.9	770	0.512
		Annual	89.8	2,223	0.173
		3-Year	102.9	1,831	0.218
		5-Year	104.3	1,790	0.218
1981-1998 (post-decline)	none	None	36.8	1,052	0.638
		Annual	82.2	636	0.789
		3-Year	86.5	559	0.866
		5-Year	81.9	682	0.871
1989-1998 (ten most recent years)	none	None	47.4	862	0.915
		Annual	92.0	391	0.949
		3-Year	93.7	367	0.963
		5-Year	86.8	531	0.954

Table 5. Ten-year running coefficient of variation of the Babine coho salmon escapement and the September 1 Tyee test fishery (five-year sockeye salmon adjustment), 1956–1998.

	Adjusted Tyee Index		Babine Escapement	
Year	Annual Index	10-Year Coefficient of Variation	Number of Spawners	10-Year Coefficient of Variation
1956	35.7		9,857	
1957	37.5		4,421	
1958	62.9		8,438	
1959	32.1		12,004	
1960	30.2		7,942	
1961	33.3		14,416	
1962	50.4		15,183	
1963	38.5		7,737	
1964	48.2			
1965	82.6	0.349	42,985	0.794
1966	64.6	0.341	13,377	0.766
1967	58.5	0.324	12,487	0.686
1968	30.1	0.356	13,054	0.649
1969	56.2	0.327	6,702	0.697
1970	60.3	0.287	10,404	0.674
1971	66.5	0.254	9,909	0.706
1972	28.4	0.305	5,381	0.792
1973	32.4	0.321	11,606	0.756
1974	17.7	0.401	13,661	0.719
1975	22.4	0.415	4,913	0.313
1976	24.0	0.442	4,499	0.365
1977	39.0	0.434	10,474	0.358
1978	38.5	0.420	11,930	0.348
1979	10.8	0.498	2,909	0.416
1980	28.6	0.470	5,046	0.454
1981	24.1	0.314	2,486	0.540
1982	27.4	0.314	2,673	0.591
1983	33.6	0.316	3,402	0.639
1984	38.3	0.296	3,241	0.610
1985	27.0	0.284	2,129	0.672
1986	31.2	0.271	3,671	0.687
1987	16.4	0.303	2,101	0.699
1988	16.7	0.318	3,225	0.267
1989	59.1	0.383	5,228	0.313
1990	55.3	0.418	5,619	0.338
1991	52.6	0.408	4,941	0.328
1992	15.2	0.454	1,714	0.367
1993	13.3	0.521	2,186	0.398
1994	34.4	0.525	4,053	0.392
1995	26.0	0.527	2,345	0.384
1996	23.5	0.547	2,669	0.402
1997	3.6	0.620	453	0.492
1998	41.6	0.564	4,291	0.486
Period	Average	Coeff. Var.	Average	Coeff. Var.
1956-1978	43.0	0.382	11,426	0.666
1979-1998	28.9	0.504	3,219	0.403

Table 6. Relative availability of upper Skeena coho salmon tags in the Alaska troll fishery by area and statistical week, 1987–1998 (excluding 1997), based on average power troll CPUE. The value for each time-area stratum is expressed as a proportion of the average annual CPUE of upper Skeena tags for all 90 strata.

Week	Area						Combined Areas
	1	2	3	4	5	6	
25	0.00	0.11	0.52	0.00	0.11	1.81	0.25
26	0.00	0.35	0.59	0.00	0.23	2.65	0.61
27	0.00	0.84	0.99	0.00	0.63	5.89	1.22
28	0.31	0.76	1.68	0.13	0.72	7.98	1.94
29	0.82	1.08	2.38	0.31	1.62	8.93	2.49
30	1.04	1.00	3.21	0.22	0.50	8.05	2.50
31	0.55	0.75	1.70	1.38	0.56	6.80	1.77
32	0.14	0.66	0.80	0.00	0.73	6.30	1.24
33	0.27	0.43	1.28	0.00	0.34	4.73	1.08
34	0.18	0.58	0.68	0.00	0.20	1.98	0.90
35	0.13	0.59	0.70	0.00	0.10	0.86	0.48
36	0.00	0.44	0.23	0.00	0.13	0.25	0.30
37	0.00	0.04	0.00	0.00	0.00	0.07	0.01
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00
39	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Average	0.23	0.51	0.98	0.14	0.39	3.75	1.00

Table 7. Stock-recruitment data for Babine River coho salmon.

Brood Year	Total Escapement	Return at Age 3	Return at Age 4	Total Brood Year Recruitment	Recruits Per Spawner	Marine Survival[a] Age 3	Marine Survival[a] Age 4	Survival Adjusted Return
1946	13,411	15,072	10,760	25,832	1.93			
1947	10,815	15,224	6,618	21,842	2.02			
1948		6,888	11,060	17,948				
1949	12,961	12,472	7,340	19,812	1.53			
1950	11,654	9,729	1,498	11,227	0.96			
1951	2,276	5,992	8,663	14,655	6.44			
1952	10,554	12,995	7,253	20,248	1.92			
1953	7,655	14,725	2,169	16,894	2.21			
1954	3,359	7,689	7,149	14,838	4.42			
1955	9,714	11,664	10,171	21,835	2.25			
1956	9,857	16,594	4,427	21,021	2.13			
1957	4,421	13,281	11,250	24,531	5.55			
1958	8,438	20,893	14,895	35,789	4.24			
1959	12,004	18,958	5,277	24,235	2.02			
1960	7,942	10,713						
1961	14,416		45,951					
1962	15,183	40,749	10,596	51,345	3.38			
1963	7,737	21,513	10,159	31,672	4.09			
1964		14,619	22,650	37,269				
1965	42,985	8,378	6,669	15,046	0.35			
1966	13,377	7,224	10,827	18,051	1.35			
1967	12,487	13,233	10,769	24,002	1.92			
1968	13,054	12,144	4,388	16,531	1.27			
1969	6,702	10,238	9,783	20,021	2.99			
1970	10,404	14,674	9,085	23,760	2.28			
1971	9,909	22,243	3,845	26,088	2.63			
1972	5,381	5,767	3,497	9,263	1.72			
1973	11,606	5,245	13,152	18,397	1.59			

[a] Marine survival is the average of estimates for smolts from the Fort Babine and Toboggan Creek hatcheries.

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Table 7. (page 2 of 2)

Brood Year	Total Escapement	Return at Age 3	Return at Age 4	Total Brood Year Recruitment	Recruits Per Spawner	Marine Survival[a] Age 3	Marine Survival[a] Age 4	Survival Adjusted Return[c]
1974	13,661	11,204	7,604	18,808	1.38			
1975	4,913	26,960	1,954	28,914	5.88			
1976	4,499	6,542	3,196	9,737	2.16			
1977	10,474	11,330	3,798	15,128	1.44			
1978	11,930	2,136	1,300	3,437	0.29			
1979	2,909	4,892	3,162	8,054	2.77			
1980	5,046	9,000	4,319	13,319	2.64			
1981	2,486	5,071	966	6,037	2.43			
1982	2,673	5,476	2,535	8,011	3.00			
1983	3,402	10,809	477	11,286	3.32			
1984	3,241	4,293	886	5,179	1.60	3.54	3.15	5,299
1985	2,129	3,776	2,807	6,583	3.09	3.15	3.48	7,110
1986	3,671	9,398	2,724	12,122	3.30	3.48	3.89	12,059
1987	2,101	11,613	2,780	14,394	6.85	3.89	5.91	12,261
1988	3,225	9,858	1,272	11,130	3.45	5.91	2.40	7,797
1989	5,228	3,440	1,210	4,650	0.89	2.40	2.28	6,970
1990	5,619	3,111	2,782	5,893	1.05	2.28	6.04	6,478
1991	4,941	7,917	790	8,708	1.76	6.04	2.12	5,976
1992	1,714	3,370	1,510	4,880	2.85	2.12	2.66	7,661
1993	2,186	6,041	216	6,257	2.86	2.66	0.56	9,421
1994	4,053	685	1,133	1,818	0.45	0.56	1.64	6,762
1995	2,345	4,530	***1,338*** [b]	5,868	2.50	1.64		12,950
1996	2,669							
1997	453							
1998	4,291							
1999	14,907							

[a] Marine survival is the average of estimates for smolts from the Fort Babine and Toboggan Creek hatcheries.

[b] The age-4 return for the 1995 brood year is predicted from the average proportion of age at return.

[c] Survival adjustment is made by multiplying the age class return by the 1988–1996 average survival rate and dividing by the annual survival rate.

Table 8. Toboggan Creek coho salmon exploitation rate estimates.[a]

	Alaska					Canada		
		D. 104	D. 101					
Year	Troll	Seine	Seine	Other	Total	Marine	Inriver	Total
Pre-1963					16.2	31.4	13.6	61.2
1963					16.2	26.5	14.9	57.6
1964					16.2	39.3	11.6	67.1
1965					16.2	24.9	15.3	56.4
1966					16.2	35.7	12.5	64.4
1967					16.2	23.8	15.6	55.5
1968					16.2	35.2	12.7	64.0
1969	11.4	1.2	0.0	2.4	15.0	28.2	14.8	58.0
1970	13.6	0.7	1.1	2.7	18.2	30.9	13.2	62.3
1971	12.4	0.5	0.1	2.4	15.3	34.7	13.0	63.0
1972	16.1	1.8	1.2	3.2	22.3	34.4	11.3	67.9
1973	16.8	1.9	0.1	3.1	21.9	19.9	15.1	56.9
1974	19.9	2.0	0.4	3.6	25.9	19.8	14.1	59.8
1975	16.0	1.6	0.0	3.0	20.6	16.6	16.3	53.5
1976	15.0	2.6	0.0	3.0	20.6	16.2	16.4	53.2
1977	15.9	2.4	0.3	3.1	21.7	26.4	13.5	61.6
1978	24.1	5.9	1.6	4.7	36.3	18.0	11.9	66.2
1979	23.1	6.9	0.1	4.5	34.7	21.0	11.5	67.2
1980	18.5	8.6	0.5	4.2	31.8	24.3	11.4	67.5
1981	17.6	3.3	0.2	3.4	24.4	24.3	13.3	62.0
1982	16.5	4.8	0.5	3.5	25.3	21.3	13.9	60.4
1983	20.9	5.3	0.4	4.1	30.7	35.9	8.7	75.3
1984	14.3	4.0	0.8	3.2	22.3	37.6	10.4	70.3
1985	19.1	3.3	0.5	3.6	26.6	34.0	10.2	70.8
1986	19.4	5.8	0.8	4.0	29.9	37.6	8.4	76.0
1987	14.5	1.7	0.2	2.8	19.2	32.9	12.4	64.6
1988	3.7	1.2	0.6	0.6	6.1	13.5	20.9	40.5
1989	14.7	0.9	0.0	3.7	19.2	35.2	11.8	66.3
1990	15.4	4.0	0.2	0.1	19.7	38.8	10.8	69.3
1991	20.0	2.6	1.0	2.0	25.7	27.5	12.2	65.4
1992	24.1	5.8	0.0	2.2	32.1	26.2	10.9	69.1
1993	10.7	1.3	0.6	7.8	20.4	19.2	15.7	55.3
1994	23.3	7.0	0.0	1.1	31.3	24.2	11.6	67.1
1995	11.1	4.0	0.0	0.5	15.6	15.4	15.2	46.2
1996	21.3	4.3	0.5	2.9	29.0	36.3	5.6	70.9
1997	28.8	3.5	0.0	1.4	33.7	13.9	4.2	51.8
1998	11.1	1.6	2.5	2.6	17.9	1.1	0.8	19.8

[a] Marine fishery estimates for 1988–1998 are direct CWT estimates. Marine fishery estimates are reconstructed from the amount and distribution of fishing effort by area and time compared with the mean-average CPUE of tagged upper Skeena coho salmon Alaska fisheries (1969–1987). Estimates of effective effort on upper Skeena coho salmon stocks by Canadian marine fisheries and harvest rate estimates for inriver fisheries were made by Holtby et al. (1999). For Alaska fisheries, pre-1969 estimates are averages for 1969–1971. For Canadian fisheries, pre-1963 estimates are averages for 1963–1972.

Table 9. Toboggan Creek and Babine River coho salmon estimated exploitation rate estimates.[a]

	Toboggan Creek				Babine River			
		Canada				Canada		
Year	Alaska	Marine	Inriver	Total	Alaska	Marine	Inriver	Total
Pre-1963	16.2	31.4	13.6	61.2	20.2	27.0	7.9	55.2
1963	16.2	26.5	14.9	57.6	20.2	22.8	8.5	51.6
1964	16.2	39.3	11.6	67.1	20.2	33.8	6.9	61.0
1965	16.2	24.9	15.3	56.4	20.2	21.4	8.7	50.4
1966	16.2	35.7	12.5	64.4	20.2	30.8	7.4	58.3
1967	16.2	23.8	15.6	55.5	20.2	20.5	8.9	49.6
1968	16.2	35.2	12.7	64.0	20.2	30.3	7.4	57.9
1969	15.0	28.2	14.8	58.0	18.8	24.4	8.5	51.8
1970	18.2	30.9	13.2	62.3	22.7	26.4	7.6	56.8
1971	15.3	34.7	13.0	63.0	19.2	30.0	7.6	56.8
1972	22.3	34.4	11.3	67.9	27.9	28.8	6.5	63.2
1973	21.9	19.9	15.1	56.9	27.5	16.7	8.4	52.5
1974	25.9	19.8	14.1	59.8	32.4	16.3	7.7	56.4
1975	20.6	16.6	16.3	53.5	25.8	14.0	9.0	48.9
1976	20.6	16.2	16.4	53.2	25.8	13.7	9.1	48.5
1977	21.7	26.4	13.5	61.6	27.2	22.2	7.6	57.0
1978	36.3	18.0	11.9	66.2	45.5	13.9	6.1	65.5
1979	34.7	21.0	11.5	67.2	43.4	16.3	6.0	65.8
1980	31.8	24.3	11.4	67.5	39.8	19.3	6.1	65.3
1981	24.4	24.3	13.3	62.0	30.6	20.1	7.4	58.1
1982	25.3	21.3	13.9	60.4	31.6	17.6	7.6	56.8
1983	30.7	35.9	8.7	75.3	38.4	28.7	4.9	72.0
1984	22.3	37.6	10.4	70.3	27.9	31.5	6.1	65.5
1985	26.6	34.0	10.2	70.8	33.3	27.9	5.8	67.0
1986	29.9	37.6	8.4	76.0	37.5	30.2	4.9	72.5
1987	19.2	32.9	12.4	64.6	24.5	23.7	7.8	56.0
1988	6.1	13.5	20.9	40.5	8.2	10.4	12.2	30.8
1989	19.2	35.2	11.8	66.3	32.7	16.9	7.6	57.2
1990	19.7	38.8	10.8	69.3	23.4	30.4	6.9	60.8
1991	25.7	27.5	12.2	65.4	24.7	29.3	6.9	60.9
1992	32.1	26.2	10.9	69.1	35.1	22.1	6.4	63.6
1993	20.4	19.2	15.7	55.3	27.3	13.2	8.9	49.4
1994	31.3	24.2	11.6	67.1	31.7	23.8	6.7	62.1
1995	15.6	15.4	15.2	46.2	26.0	9.2	8.4	43.6
1996	29.0	36.3	5.6	70.9	37.7	23.0	3.9	64.7
1997	33.7	13.9	4.2	51.8	30.7	16.4	2.6	49.8
1998	17.9	1.1	0.8	19.8	22.4	1.0	0.8	24.2

[a] The harvest rate by Canadian fisheries was assumed to be the same for Toboggan and Babine. The exploitation rate in Alaska in 1994–1997 was based on the proportion of Babine tags taken in Alaska compared with Canada and the Toboggan harvest rate in Canadian marine fisheries. The average of these tag distribution estimates was used to estimate the Alaska exploitation rate for 1998 and years prior to 1994.

Table 10. Marine survival estimates for Toboggan Creek and Babine River coho salmon smolts.

	Wild	Hatchery		
Return Year	Toboggan Creek	Toboggan Creek	Babine River	Average
1987		***3.2*** [a]	3.9	3.5
1988	8.0	2.1	4.2	3.2
1989	10.4	2.7	4.2	3.5
1990	13.9	4.0	3.8	3.9
1991	22.2	6.0	5.8	5.9
1992	6.4	1.7	3.1	2.4
1993	7.6	2.1	2.5	2.3
1994	21.7	6.0	6.1	6.0
1995	6.7	1.8	2.4	2.1
1996	8.7	2.3	3.0	2.7
1997	1.9	0.5	0.6	0.6
1998	6.0	1.6	1.6	1.6
Average	10.3	2.8	3.4	3.1

[a] Marine survival for Toboggan Creek hatchery smolts in the 1987 return year is interpolated from the estimate for Babine hatchery smolts.

Table 11. Ricker statistics for Babine River coho salmon.

	Method (Period)			
	Unadjusted			
Parameter	All Years 1946-1995	Early 1946-1975	Late 1978-1995	Survival-Adjusted 1984-1995
<u>Maximum Sustained Yield (MSY)</u>				
MSY Escapement	9,012	8,941	2,506	1,937
MSY Return	17,870	22,084	7,107	8,885
MSY	8,858	13,143	4,601	6,947
<u>MSY Escapement Range (90% of Optimum)</u>				
Lower	5,881	5,768	1,606	1,220
Upper	12,474	12,550	3,546	2,809
Carrying Capacity (K)	21,458	22,525	6,540	5,711
Maximum Stock Size	21,772	24,753	7,715	9,136
Escapement at Maximum Stock Size	18,182	15,024	3,870	2,478
Theoretical MSY Exploitation Rate	50%	60%	65%	78%
MSY Exploitation Rate on 1979-1998 Average Return	0%	0%	69%	76%
<u>Return from the 1997 Escapement of 453 Spawners</u>				
Predicted Return	1,438	1,969	2,184	3,782
Percent of MSY Escapement	16%	22%	87%	195%
Predicted MSY Exploitation Rate	0%	0%	0%	49%
<u>Ricker Parameters</u>				
ln(alpha)	1.180	1.499	1.690	2.305
beta	-0.0000550	-0.0000666	-0.0002584	-0.0004036
ln(alpha) (without 1962 and 1965)	1.277	1.966		
beta (without 1962 and 1965)	-0.0000719	-0.0001208		

Table 12. Toboggan Creek coho salmon spawning escapement, wild run size, age composition, marine survival, and estimated return by brood year (adjusted to an average marine survival rate of 11.7%).

Year	Spawners in Wild	Wild Run			Prop. Age 3	Marine Survival Rate (%)	Brood Year Return (Adjusted to Average Marine Survival)		
		Catch	Escapement	Total			Age 3	Age 4	Total
1988	1,284	684	1,004	1,688	0.687	8.0	1,905	3,927	5,832
1989	2,301	3,648	1,853	5,501	0.881	10.4	6,862	1,759	8,621
1990	2,775	5,443	2,414	7,857	0.447	13.9	2,203	1,318	3,521
1991	3,280	5,148	2,722	7,870	0.459	22.2	1,637	2,280	3,917
1992	1,974	4,071	1,819	5,890	0.636	6.4	2,412	2,184	4,595
1993	1,387	1,410	1,140	2,550	0.556	7.6	2,291	2,393	4,685
1994	2,362	3,659	1,793	5,452	0.554	21.7	1,712	2,584	4,296
1995	1,723	1,245	1,449	2,694	0.514	6.7	2,395	***3,817*** [a]	6,212
1996	1,124	2,346	965	3,311	0.512	8.7			
1997	359	345	321	666	0.417	1.9			
1998	2,415	500	2,027	2,527	0.481	6.0			

[a] The age-4 return for the 1995 brood year was projected from the 1999 wild smolt estimate (66,565), an average marine survival rate of 11.7%, and the average proportion returning at age 4 for the 1988–1994 brood years (0.489).

Table 13. Ricker statistics for wild Toboggan Creek coho salmon.

Parameter			Value
Maximum Sustained Yield (MSY)			
MSY Escapement			1,188
MSY Return			5,446
MSY			4,258
MSY Escapement Range (90% of Optimum)			
Lower			748
Upper			1,723
Carrying Capacity (K)			3,502
Maximum Wild Stock Size			5,601
Escapement at Maximum Wild Stock Size			1,520
MSY Exploitation Rate at 1988-1996 Average Marine Survival			78%
MSY Exploitation Rate on 1979-1998 Average Return			72%
	Lowest	Highest	Average
1988-1997 Exploitation Rates	41%	71%	60%
Return from the 1997 Wild Escapement of 321 Spawners			
Predicted Return			2,603
Percent of MSY Escapement			219%
Predicted MSY Exploitation Rate			54%
Ricker Parameters			
ln(alpha)			2.304
beta			-0.0006580

Table 14. Tyee test fishery index of coho salmon escapement and juvenile coho salmon density estimates for habitats sampled within and near the Skeena River drainage in late summer of the following year.

Year	Tyee Index[a] Year (i-1)	Area (Juveniles per Meter^2) High Interior	Babine	Upper Bulkley	Morice	Kispiox	Terrace	Lower Skeena	Lachmach	Coast
1986	31.2				0.097				0.783	
1987	16.4				0.060					
1988	16.7									
1989	59.1				0.832					
1990	55.3				0.748				0.504	
1991	52.6				0.530				0.911	
1992	15.2				0.345				0.669	
1993	13.3	0.243	0.430	0.002	0.599	0.746	0.652	0.770	0.447	0.566
1994	34.4	0.131	0.031	0.047	0.958	2.236	1.230	0.230	1.384	0.950
1995	26.0	0.300	0.141	0.037	1.447	2.131	0.622	0.398	2.272	1.898
1996	23.5	0.417	0.165	0.007	0.483	0.777	0.661	0.503	0.810	0.715
1997	3.6	0.052	0.213	0.000	0.325	0.456	0.451	0.879	1.376	1.159
1986-92 Avg.	35.2				0.435				0.717	
1993-97 Avg.	20.2	0.229	0.196	0.019	0.762	1.269	0.723	0.556	1.258	1.058
1993-96 Avg.	24.3	0.273	0.192	0.023	0.872	1.473	0.791	0.475	1.228	1.032
1997	3.6	0.052	0.213	0.000	0.325	0.456	0.451	0.879	1.376	1.159
% Change	-85	-81	11	-100	-63	-69	-43	85	12	12
1993-97 Coeff. Var.	0.59	0.62	0.75	1.17	0.59	0.67	0.41	0.48	0.55	0.49

[a] September 1 test fishery index adjusted for five-year average sockeye salmon catchability.

Table 15. Length in kilometers of habitat accessible to coho salmon in two interior tributaries of the Taku River system (Upper Nahlin and Tatsamenie Rivers) and four coastal systems in Southeast Alaska.

Upper Nahlin River	Length (km)	Tatsamenie River	Length (km)
Mainstem	69.2	Inlet to Tatsamenie Lake	5.9
Tributaries	77.4	Interlake stream	7.5
Stream (subtotal)	146.5	Outlet to Tatsatua Cr.	2.8
Lakeshore	25.1	Stream (subtotal)	16.1
		Tatsamenie Lake shore	41.6
Total	171.6	Little Tatsamenie Lake shore	4.1
		Lakeshore (subtotal)	45.7
		Total	61.8

Berners River	Length (km)	Ford Arm Lake	Length (km)
Main channel	38.5	Outlet stream	1.7
Tributaries and side channels	17.2	Inlet streams	2.1
Stream (subtotal)	55.7	Stream (subtotal)	3.8
Lakeshore	16.6	Lakeshore	4.8
Total	72.3	Total	8.6

Auke Creek	Length (km)	Hugh Smith Lake	Length (km)
Outlet stream	0.5	Outlet stream	0.1
Inlet streams	1.4	Inlet streams	3.9
Stream (subtotal)	1.9	Stream (subtotal)	4.0
Lakeshore	4.0	Lakeshore	13.2
Total	5.9	Total	17.2

Table 16. Estimated number of female spawners and smolts produced per kilometer of habitat in two interior tributaries of the Taku River (Tatsamenie and Upper Nahlin Rivers) and four coastal systems in Southeast Alaska.

	Return		Total	Marine		Habitat Length (km)				
System	Year	Escapement	Adults	Survival (%)	Smolts	Streams	Lakeshore	Total	Females/km	Smolts/km
Tatsamenie R.	1988	663	2,191	7.6 [b]	29,020	16.1	45.7	61.8	5.4	470
Tatsamenie R.	1989	712	3,195	9.5 [b]	33,806	16.1	45.7	61.8	5.8	547
Tatsamenie R.	1990	648	3,197	13.1 [b]	24,494	16.1	45.7	61.8	5.2	397
Tatsamenie R.	1991	1,070	2,556	15.5 [b]	16,532	16.1	45.7	61.8	8.7	268
	Average	773	2,785	11.4	25,963	16.1	45.7	61.8	6.3	420
Upper Nahlin R.	1988	1,322	3,083	7.6 [b]	40,834	146.5	25.1	171.6	3.9	238
Upper Nahlin R.	1994	2,112	7,446 [a]	23.0 [b]	32,356	146.5	25.1	171.6	6.2	189
	Average	1,717	5,265	15.3	36,595	146.5	25.1	171.6	5.0	213
Berners River	1990-98 Avg.	10,813	36,665	19.2	191,544	55.7	16.6	72.3	74.8	2,649
Ford Arm Lake	1982-98 Avg.	3,035	7,476	21.0 [c]	35,600	3.8	4.8	8.6	176.5	4,140
Auke Creek	1980-98 Avg.	722	1,283	19.3	6,775	1.9	4.0	5.9	61.2	1,148
Hugh Smith Lake	1984-98 Avg.	1,154	4,252	10.6	32,966	4.0	13.2	17.2	33.5	1,917

[a] Total return to the Upper Nahlin River in 1994 was estimated from the weir count and the exploitation rate estimate for the entire drainage above Canyon Island.

[b] Marine survival rate estimates for the lower Taku River were applied to the Upper Nahlin and Tatsamenie Rivers. The survival rate in 1991 was projected from the 1990 and 1992–1998 relationship between the Taku River estimate and the average for Auke Creek and Berners River.

[c] The average marine survival rate for Auke Creek in 1982–1983 and 1985–1998 was applied to Ford Arm Lake.

Table 17. Survival rates of juvenile coho salmon (>60 mm in length) tagged in interior tributaries of the Taku River (Upper Nahlin and Tatsamenie Rivers) and in two coastal systems (Berners River and Ford Arm Lake) during 1986–1989.

System	Tagging Year	Month(s)	Number Tagged	Survival to Adult (Years After Marking) 2 Years	3 Years	Total
Upper Nahlin River	1986	August	4,872	1.5	0.0	1.5
Tatsamenie River	1986	September	13,328	2.0	0.1	2.1
	1987	July-Aug.	11,426	2.9	0.0	2.9
	1988	July-Aug.	10,823	2.7	0.1	2.8
	1989	July-Aug.	10,672	2.9	0.0	2.9
	Average		11,562	2.6	0.1	2.7
Berners River	1986	Late June	8,740	5.2	0.0	5.2
	1987	Late June	10,349	4.3	0.0	4.3
	1988	Late June	9,926	9.0	0.0	9.0
	Average		9,672	6.2	0.0	6.2
Ford Arm Lake	1986	Mid-July	10,392	6.7	0.4	7.1
	1987	Mid-July	10,138	13.3	0.5	13.8
	1988	Mid-July	12,567	9.4	1.0	10.4
	1989	Mid-July	11,300	10.8	0.2	11.0
	Average		11,099	10.1	0.5	10.6

Table 18. Run reconstruction of the non-Babine component of the Tyee test fishery index.[a]

	Tyee Index of Escapement			Exploitation Rate (% of Total Run)			Non-Babine Run	
Year	Total Index	Babine Estimate	Non-Babine Estimate	Alaska	Canada Marine	Total	Marine Catch	Total Run
1956	35.7	6.3	29.4	16.2	31.4	47.5	26.6	56.0
1957	37.5	2.8	34.6	16.2	31.4	47.5	31.4	66.0
1958	62.9	5.4	57.5	16.2	31.4	47.5	52.1	109.6
1959	32.1	7.7	24.5	16.2	31.4	47.5	22.1	46.6
1960	30.2	5.1	25.1	16.2	31.4	47.5	22.7	47.9
1961	33.3	9.2	24.1	16.2	31.4	47.5	21.8	45.9
1962	50.4	9.7	40.7	16.2	31.4	47.5	36.9	77.5
1963	38.5	4.9	33.6	16.2	26.5	42.7	25.0	58.5
1964	48.2			16.2	39.3	55.5		
1965	82.6	27.4	55.2	16.2	24.9	41.0	38.4	93.6
1966	64.6	8.5	56.0	16.2	35.7	51.9	60.4	116.5
1967	58.5	8.0	50.6	16.2	23.8	39.9	33.6	84.2
1968	30.1	8.3	21.7	16.2	35.2	51.3	22.9	44.6
1969	56.2	4.3	52.0	15.0	28.2	43.3	39.6	91.6
1970	60.3	6.6	53.7	18.2	30.9	49.1	51.7	105.4
1971	66.5	6.3	60.2	15.3	34.7	50.0	60.1	120.3
1972	28.4	3.4	25.0	22.3	34.4	56.7	32.7	57.6
1973	32.4	7.4	25.0	21.9	19.9	41.8	18.0	43.0
1974	17.7	8.7	9.0	25.9	19.8	45.7	7.5	16.5
1975	22.4	3.1	19.3	20.6	16.6	37.2	11.4	30.7
1976	24.0	2.9	21.1	20.6	16.2	36.7	12.3	33.4
1977	39.0	6.7	32.4	21.7	26.4	48.2	30.1	62.4
1978	38.5	7.6	30.9	36.3	18.0	54.4	36.8	67.8
1979	10.8	1.9	9.0	34.7	21.0	55.6	11.2	20.2
1980	28.6	3.2	25.4	31.8	24.3	56.1	32.5	57.9
1981	24.1	1.6	22.6	24.4	24.3	48.7	21.4	44.0
1982	27.4	1.7	25.7	25.3	21.3	46.5	22.3	48.0
1983	33.6	2.2	31.4	30.7	35.9	66.6	62.6	94.0
1984	38.3	2.1	36.2	22.3	37.6	59.9	54.1	90.3
1985	27.0	1.4	25.6	26.6	34.0	60.6	39.4	65.0
1986	31.2	2.3	28.9	29.9	37.6	67.5	60.1	89.0
1987	16.4	1.3	15.1	19.2	32.9	52.1	16.4	31.5
1988	16.7	2.1	14.7	6.1	13.5	19.6	3.6	18.3
1989	59.1	3.3	55.7	19.2	35.2	54.5	66.7	122.4
1990	55.3	3.6	51.7	19.7	38.8	58.5	72.9	124.6
1991	52.6	3.1	49.5	25.7	27.5	53.2	56.3	105.8
1992	15.2	1.1	14.1	32.1	26.2	58.3	19.7	33.8
1993	13.3	1.4	11.9	20.4	19.2	39.6	7.8	19.6
1994	34.4	2.6	31.9	31.3	24.2	55.6	39.8	71.7
1995	26.0	1.5	24.5	15.6	15.4	31.0	11.0	35.6
1996	23.5	1.7	21.8	29.0	36.3	65.3	41.0	62.8
1997	3.6	0.3	3.3	33.7	13.9	47.6	3.0	6.3
1998	41.6	2.7	38.8	17.9	1.1	19.0	9.1	47.9

[a] The Tyee Index is based on a September 1 ending date and a five-year average sockeye salmon catchability adjustment. Marine exploitation rates are estimates for Toboggan Creek.

Table 19. Fishery Performance indicators for northern British Columbia coho salmon stocks and total abundance of coho salmon returning to Toboggan Creek and the Babine River.

	Tree Pt. Gillnet Fishery			Canadian Com. Catch		Tyee Index		Babine R.		Toboggan Cr.	
	Cumulative CPUE			N. Coast	Areas 1,3,4	Escape-	Total	Escape-	Total	Escape-	Total
Year	Wild	Hatchery	Total	Troll	All-Gear	ment	Run	ment	Run	ment	Run
1953				567,173				7,655	17,069		
1954				535,520				3,359	7,490		
1955				760,160				9,714	21,658		
1956				615,494		35.7	67.8	9,857	21,978		
1957				759,827		37.5	71.2	4,421	9,857		
1958				574,065		62.9	119.5	8,438	18,813		
1959				436,650		32.1	61.0	12,004	26,765		
1960				432,545		30.2	57.4	7,942	17,708		
1961				521,444		33.3	63.3	14,416	32,144		
1962				820,853		50.4	95.7	15,183	33,853		
1963				801,464		38.5	67.4	7,737	15,990		
1964				1,022,804		48.2	106.5				
1965				632,669		82.6	140.8	42,985	86,701		
1966				1,093,477		64.6	133.0	13,377	32,109		
1967				491,130		58.5	98.1	12,487	24,778		
1968				1,190,424		30.1	61.2	13,054	31,028		
1969			5.13	456,120		56.2	99.1	6,702	13,893		
1970			8.01	651,786		60.3	118.5	10,404	24,060		
1971			2.49	720,150		66.5	131.8	9,909	22,913		
1972			15.6	967,419		28.4	65.6	5,381	14,626		
1973			8.63	611,255	244,131	32.4	56.8	11,606	24,457		
1974			9.94	534,651	254,689	17.7	33.5	13,661	31,329		
1975			11.1	289,607	227,287	22.4	36.4	4,913	9,611		
1976			16.5	606,747	159,905	24.0	38.8	4,499	8,742		
1977			2.71	318,636	234,238	39.0	76.2	10,474	24,356		
1978			36.2	687,225	475,083	38.5	89.2	11,930	34,564		
1979			10.8	588,261	405,569	10.8	25.5	2,909	8,496		
1980			10.5	647,929	431,608	28.6	67.6	5,046	14,526		
1981			4.76	467,642	319,185	24.1	48.0	2,486	5,934		
1982			12.49	466,207	400,330	27.4	52.5	2,673	6,192		
1983			19.18	919,602	780,995	33.6	101.2	3,402	12,162		
1984			11.33	672,360	592,560	38.3	94.8	3,241	9,390		
1985			17.52	582,012	567,174	27.0	68.9	2,129	6,442		
1986			17.64	1,293,820	1,019,388	31.2	96.3	3,671	13,345		
1987			9.90	680,143	474,327	16.4	33.0	2,101	4,770		
1988			7.12	391,078	310,002	16.7	20.7	3,225	4,661	1,004	1,688
1989	13.94	0.51	14.45	606,926	565,606	59.1	123.2	5,228	12,205	1,853	5,501
1990	18.85	1.05	19.90	1,092,068	914,581	55.3	126.3	5,619	14,338	2,414	7,857
1991	16.17	3.44	19.62	1,052,121	997,912	52.6	113.5	4,941	12,638	2,722	7,870
1992	8.23	0.36	8.59	596,534	494,619	15.2	35.9	1,714	4,713	1,819	5,890
1993	8.74	0.22	8.97	354,375	384,461	13.3	22.1	2,186	4,321	1,140	2,550
1994	13.01	0.84	13.85	766,853	783,481	34.4	77.4	4,053	10,699	1,793	5,452
1995	7.37	0.22	7.58	310,125	340,937	26.0	38.9	2,345	4,160	1,449	2,694
1996	11.46	0.95	12.41	435,841	490,909	23.5	63.5	2,669	7,551	965	3,311
1997	2.86	0.23	3.09	172,295	156,546	3.6	6.8	453	902	321	666
1998	12.08	1.14	13.22			41.6	52.8	4,291	5,663	2,027	2,527

Table 20. Estimated coho salmon return to the Babine River and two coastal indicator systems in Southeast Alaska (Berners River and Hugh Smith Lake) compared with the Tyee test fishery index expanded to total run size, 1982–1998.

	Indicator Stock Size (Number of Fish)			Sept. 1 Adjusted Tyee Test Fishery Index		
Year	Berners River[a]	Hugh Smith Lake[a]	Babine River	Escapement Index[b]	Marine Catch[c]	Total Abundance
1982	30,960	6,096	6,192	27.38	25.14	52.52
1983	34,036	3,875	12,162	33.57	67.66	101.23
1984		4,010	9,390	38.27	56.55	94.81
1985	24,247	2,412	6,442	26.97	41.93	68.91
1986	24,635	4,474	13,345	31.24	65.11	96.35
1987	14,057	2,344	4,770	16.43	16.53	32.97
1988	14,972	1,530	4,661	16.74	3.96	20.70
1989	19,688	2,424	12,205	59.06	64.10	123.16
1990	33,814	4,593	14,338	55.32	70.95	126.27
1991	35,162	5,731	12,638	52.63	60.82	113.45
1992	45,850	4,890	4,713	15.18	20.75	35.93
1993	49,594	4,268	4,321	13.26	8.85	22.11
1994	73,728	9,450	10,699	34.45	42.95	77.40
1995	28,800	6,753	4,160	26.02	12.89	38.91
1996	23,800	3,915	7,551	23.47	40.00	63.47
1997	15,442	2,652	902	3.56	3.21	6.77
1998	23,760	4,319	5,663	41.56	11.19	52.75

[a] Total adult abundance estimates for the Berners River and Hugh Smith Lake are updated from Shaul (1998).
[b] The cumulative Tyee coho salmon index is adjusted based on five-year symmetrical average sockeye salmon catchability.
[c] The marine exploitation rate used to estimate catch represented by the Tyee index was estimated is average for Toboggan Creek and the Babine River.

Table 21. Total coho salmon smolt and pre-smolt production estimates for wild coho salmon indicator stocks in Southeast Alaska and northern British Columbia, 1980–1998.

	Number of Fish							
Migration Year	Auke Creek Smolts	Berners River Smolts	Taku River Smolts[a]	Ford Arm Lake Pre-smolts	Hugh Smith Lake Smolts	Lachmach River Smolts[b]	Zolzap Creek Smolts[c]	Toboggan Creek Smolts[d]
1979	8,789							
1980	10,714							
1981	6,967			78,682				
1982	6,849			65,186				
1983	6,901				51,789			
1984	6,838			38,509	32,104			
1985	5,852			46,422	23,499			
1986	5,617			73,272	21,878			
1987	7,014			88,649	36,218			21,106
1988	7,685			43,354	23,336	35,789		52,961
1989	7,011	164,356		55,803	26,620	34,864		56,355
1990	5,137	141,154		56,284	32,925	34,789		35,374
1991	5,690	187,715	743,164	61,724	23,326	18,628		91,950
1992	6,596	326,126	1,510,032	57,401	32,853	33,026	53,000	33,768
1993	8,647	255,431	1,475,874	83,686	48,433	25,521	51,000	25,179
1994	7,495	181,503	1,525,330	134,640	49,288	38,966	41,000	39,990
1995	4,884	194,019	986,489	91,843	22,413	38,339	13,000	38,137
1996	3,934	133,629	759,763	66,528	32,294	43,035	23,000	34,989
1997	6,111	139,959	853,662	80,567	37,898	21,619	18,000	42,429
1998	7,420	252,199	1,184,195	132,607	29,830	21,160	19,000	66,565
Average	6,808	197,609	1,129,814	73,833	32,794	31,431	31,143	44,900

[a] Taku River smolt estimates are from Yanusz et al. (1999) and include only the portion of the drainage upstream from Canyon Island near the international border.
[b] Lachmach River smolt estimates are Peterson estimates based on the number of smolts marked and the proportion marked for adult returns (data provided by Barry Finnegan, CDFO, personal communication).
[c] Zolzap Creek smolt estimates are real-time estimates provided by Bruce Baxter, LGL Ltd. (personal communication).
[d] Toboggan Creek smolt estimates are from Holtby (1999).

Table 22. Marine survival rate for coho salmon smolts from indicator stocks in Southeast Alaska and northern British Columbia by return year, 1989–1998.

Stream:	Auke Creek	Berners River	Taku River[a]	Hugh Smith Lake	Lachmach River[b]	Nass River[c]	Skeena River (Hatchery)
Geographic Area:	N.S.E. Alaska	N.S.E. Alaska	N.S.E. Alaska	S.S.E. Alaska	Northern B.C.	Northern B.C.	Northern B.C.
Size:	Small	Medium	Large	Small	Small	Large	Large
Average Smolt Production:	6,300	191,500	1,438,500	32,900	32,500	>1,000,000	>1,000,000
Year	Survival Rate						
1989	14.4			10.4	4.4		3.5
1990	21.1	20.6		17.3	11.8		3.9
1991	23.0	24.9		17.4	12.1		5.9
1992	33.0	24.4	25.1	21.0	9.0		2.4
1993	24.1	15.1	14.0	13.0	6.3	2.1	2.3
1994	35.3	28.9	23.0	19.4	17.9	8.9	6.0
1995	10.9	15.9	11.9	13.7	8.3	3.6	2.1
1996	23.4	12.4	9.6	17.9	10.2	6.6	2.7
1997	19.2	11.6	6.7	8.2	4.0	2.4	0.6
1998	23.1	17.0	14.0	11.4	9.4	2.9	1.6
1989-1998 Average	22.8	19.0	14.9	15.0	9.3	4.4	3.1
1993-1998 Average	22.7	16.8	13.2	13.9	9.3	4.4	2.5

[a] Estimates for the Taku River are from Yanusz et al. (1999).
[b] Estimates for the Lachmach River were based on tagging and recovery data provided by Barry Finnegan, Canada Department of Fisheries and Oceans, Nanaimo, B.C.
[c] Nass River marine survival estimates are based on an indicator stock project at Zolzap Creek, a lower system tributary (Nass 1996a, 1996b, 1996c, 1997a, and 1997b; preliminary unpublished data for 1996–1998 provided by Bruce Baxter, LGL Ltd., personal communication).

Table 23. Canadian Area 3 coho salmon escapement and total abundance indicators for the Nass and Lachmach Rivers.

	Lachmach River[a]					Nass River: Zolzap Creek[b]					Nass River: Meziadin[c]	Nass River: Main Nass[d]
	Catch		Escapement		Total	Catch		Escapement		Total	Fishway	Escapement
Year	Fish	%	Fish	%	Run	Fish	%	Fish	%	Run	Sept. 27	Estimate
1989	991	62.3	599	37.7	1,590							
1990	3,145	76.4	971	23.6	4,116							
1991	3,053	72.8	1,141	27.2	4,194							
1992	1,270	75.6	409	24.4	1,679			1,561				
1993	1,345	65.1	720	34.9	2,065	1,784	63.0	1,048	37.0	2,832		
1994	3,253	71.2	1,317	28.8	4,570	7,109	73.7	2,536	26.3	9,645	3,521	160,237
1995	2,248	69.7	975	30.3	3,223	2,149	70.3	908	29.7	3,057	1,708	25,253
1996	2,818	71.9	1,102	28.1	3,920	2,120	67.1	1,039	32.9	3,159	1,957	48,202
1997	970	56.1	758	43.9	1,728	602	56.2	470	43.8	1,072	633	13,830
1998	939	46.4	1,086	53.6	2,025	1,019	51.3	967	48.7	1,986	1,659	42,320
Avg.	2,003	66.8	908	33.2	2,911	2,464	63.6	1,218	36.4	3,625	1,896	57,968

[a] Lachmach River estimates are from Holtby (1999).
[b] Zolzap Creek estimates for 1992–1995 are from Nass (1996a, 1996b, 1997a, and 1997b). Preliminary estimates for 1996–1998 were provided by Bruce Baxter, LGL Ltd., Sidney B.C.
[c] Meziadin fishway counts are from the Canada Department of Fisheries and Oceans web database.
[d] Nass River escapement estimates were provided by Richard Alexander, LGL Ltd., New Aiyansh, B.C.

Table 24. Estimated harvest by gear type, escapement, and total run of coho salmon returning to Auke Creek, 1980–1998.

		Number of Fish						
Year	Fishery Sample Size	Troll	Seine	Drift Gillnet	Sport	Total Catch	Escapement	Total Return
1980	15	117	0	29	24	170	698	868
1981	70	280	0	31	19	330	646	976
1982	45	149	117	24	2	292	447	739
1983	129	385	10	28	122	545	694	1,239
1984	124	372	8	13	51	444	651	1,095
1985	177	594	3	71	73	741	942	1,683
1986	110	421	2	60	37	520	454	974
1987	145	438	2	48	23	511	668	1,179
1988	145	306	12	72	55	445	756	1,201
1989	182	533	7	15	49	604	502	1,106
1990	168	635	15	57	78	785	697	1,482
1991	47	200	8	152	11	371	808	1,179
1992	53	603	10	196	46	855	1020	1,875
1993	169	611	8	92	19	730	859	1,589
1994	330	1064	224	218	112	1618	1437	3,055
1995	82	264	5	65	26	360	460	820
1996	160	446	11	133	36	626	515	1,141
1997	43	94	4	0	50	148	609	757
1998	157	437	17	43	54	551	862	1,413
Average		418	24	71	47	560	722	1,283

Table 25. Estimated percent harvest by gear type, escapement, and total run of coho salmon returning to Auke Creek, 1980–1998.

Year	Fishery Sample Size	Percent of Total Run: Troll	Seine	Drift Gillnet	Sport	Total Catch	Escapement	Total Return
1980	15	13.5	0.0	3.3	2.8	19.6	80.4	100.0
1981	70	28.7	0.0	3.2	1.9	33.8	66.2	100.0
1982	45	20.2	15.8	3.2	0.3	39.5	60.5	100.0
1983	129	31.1	0.8	2.3	9.8	44.0	56.0	100.0
1984	124	34.0	0.7	1.2	4.7	40.6	59.4	100.0
1985	177	35.3	0.2	4.2	4.3	44.0	56.0	100.0
1986	110	43.2	0.2	6.2	3.8	53.4	46.6	100.0
1987	145	37.2	0.2	4.1	2.0	43.5	56.5	100.0
1988	145	25.5	1.0	6.0	4.6	37.1	62.9	100.0
1989	182	48.2	0.6	1.4	4.4	54.6	45.4	100.0
1990	168	42.8	1.0	3.8	5.3	52.9	47.1	100.0
1991	47	17.0	0.7	12.9	0.9	31.5	68.5	100.0
1992	53	32.2	0.5	10.5	2.5	45.7	54.3	100.0
1993	169	38.5	0.5	5.8	1.2	46.0	54.0	100.0
1994	330	34.8	7.3	7.1	3.7	52.9	47.1	100.0
1995	82	32.2	0.6	7.9	3.2	43.9	56.1	100.0
1996	160	39.1	1.0	11.7	3.2	55.0	45.0	100.0
1997	43	12.4	0.5	0.0	6.6	19.5	80.5	100.0
1998	157	30.9	1.4	3.0	3.8	39.0	61.0	100.0
Average		31.4	1.7	5.1	3.6	41.9	58.1	100.0

Table 26. Estimated harvest by gear type, escapement and total run of coho salmon returning to the Berners River, 1982–1998.

		Number of Fish								
Year	Fishery Sample Size	Troll	Seine	Drift Gillnet	Sport	B.C. Net	Cost Recovery	Total Catch	Escapement	Total Run
1982	48	12,887	0	10,568	0	0	0	23,455	7,505	30,960
1983	125	17,153	0	6,978	65	0	0	24,196	9,840	34,036
1984									2,825	
1985	93	10,865	198	7,015	0	0	0	18,078	6,169	24,247
1986	157	13,560	0	8,928	395	0	0	22,883	1,752	24,635
1987	53	7,448	0	3,301	48	0	0	10,797	3,260	14,057
1988	102	5,926	181	6,141	0	0	0	12,248	2,724	14,972
1989	58	10,515	0	1,664	0	0	0	12,179	7,509	19,688
1990	470	14,751	149	7,339	525	0	0	22,764	11,050	33,814
1991	1,025	6,417	579	16,519	117	0	0	23,632	11,530	35,162
1992	701	15,337	344	14,677	192	0	0	30,550	15,300	45,850
1993	1,496	19,353	192	14,239	140	0	0	33,924	15,670	49,594
1994	2,647	27,319	1,686	27,907	891	5	0	57,808	15,920	73,728
1995	1,384	8,847	22	14,869	117	0	0	23,855	4,945	28,800
1996	601	10,524	380	6,434	412	0	0	17,750	6,050	23,800
1997	312	2,454	282	2,477	179	0	0	5,392	10,050	15,442
1998	613	10,427	435	5,716	380	0	0	16,958	6,802	23,760
Average		12,111	278	9,673	216	0	0	22,279	8,171	30,784

Table 27. Estimated percent harvest by gear type, escapement, and total run of coho salmon returning to the Berners River, 1982–1998.

		Percent of Total Run								
Year	Fishery Sample Size	Troll	Seine	Drift Gillnet	Sport	B.C. Net	Cost Recovery	Total Catch	Escapement	Total Run
1982	48	41.6	0.0	34.1	0.0	0.0	0.0	75.8	24.2	100.0
1983	125	50.4	0.0	20.5	0.2	0.0	0.0	71.1	28.9	100.0
1984										
1985	93	44.8	0.8	28.9	0.0	0.0	0.0	74.6	25.4	100.0
1986	157	55.0	0.0	36.2	1.6	0.0	0.0	92.9	7.1	100.0
1987	53	53.0	0.0	23.5	0.3	0.0	0.0	76.8	23.2	100.0
1988	102	39.6	1.2	41.0	0.0	0.0	0.0	81.8	18.2	100.0
1989	58	53.4	0.0	8.5	0.0	0.0	0.0	61.9	38.1	100.0
1990	470	43.6	0.4	21.7	1.6	0.0	0.0	67.3	32.7	100.0
1991	1,025	18.2	1.6	47.0	0.3	0.0	0.0	67.2	32.8	100.0
1992	701	33.5	0.8	32.0	0.4	0.0	0.0	66.6	33.4	100.0
1993	1,496	39.0	0.4	28.7	0.3	0.0	0.0	68.4	31.6	100.0
1994	2,647	37.1	2.3	37.9	1.2	0.0	0.0	78.4	21.6	100.0
1995	1,384	30.7	0.1	51.6	0.4	0.0	0.0	82.8	17.2	100.0
1996	601	44.2	1.6	27.0	1.7	0.0	0.0	74.6	25.4	100.0
1997	312	15.9	1.8	16.0	1.2	0.0	0.0	34.9	65.1	100.0
1998	613	43.9	1.8	24.1	1.6	0.0	0.0	71.4	28.6	100.0
Average		40.2	0.8	29.9	0.7	0.0	0.0	71.7	28.3	100.0

Table 28. Estimated harvest by gear type, escapement, and total run of coho salmon returning to Ford Arm Lake, 1982–1998.

		Number of Fish							
Year	Fishery Sample Size	Alaska Troll	Seine	Drift Gillnet	Sport	Canadian Troll	Total Catch	Escapement	Total Run
1982	38	1,948	106	0	0	0	2,054	2,662	4,716
1983	93	3,344	912	0	0	0	4,256	1,938	6,194
1984									
1985	49	2,438	0	0	0	0	2,438	2,324	4,762
1986	87	2,500	62	0	0	0	2,562	1,546	4,108
1987	71	1,456	79	0	0	0	1,535	1,694	3,229
1988	151	2,857	46	0	0	30	2,933	3,028	5,961
1989	221	3,777	185	0	0	0	3,962	2,177	6,139
1990	174	2,979	108	0	0	0	3,087	2,190	5,277
1991	193	3,208	44	10	0	0	3,262	2,761	6,023
1992	199	5,252	208	0	0	0	5,460	3,847	9,307
1993	349	7,847	443	0	201	0	8,491	4,202	12,693
1994	236	6,918	1,234	0	112	0	8,264	3,228	11,492
1995	91	3,577	1,468	0	0	0	5,045	2,445	7,490
1996	64	3,148	0	0	332	0	3,480	2,500	5,980
1997	241	4,883	0	0	373	0	5,256	4,965	10,221
1998	315	7,835	435	20	679	0	8,969	7,049	16,018
Average		3,998	333	2	106	2	4,441	3,035	7,476

Table 29. Estimated percent harvest by gear type, escapement, and total run of coho salmon returning to Ford Arm Lake, 1982–1998.

		Percent of Total Run							
Year	Fishery Sample Size	Alaska Troll	Seine	Drift Gillnet	Sport	Canadian Troll	Total Catch	Escapement	Total Run
1982	38	41.3	2.2	0.0	0.0	0.0	43.6	56.4	100.0
1983	93	54.0	14.7	0.0	0.0	0.0	68.7	31.3	100.0
1984									
1985	49	51.2	0.0	0.0	0.0	0.0	51.2	48.8	100.0
1986	87	60.9	1.5	0.0	0.0	0.0	62.4	37.6	100.0
1987	71	45.1	2.4	0.0	0.0	0.0	47.5	52.5	100.0
1988	151	47.9	0.8	0.0	0.0	0.5	49.2	50.8	100.0
1989	221	61.5	3.0	0.0	0.0	0.0	64.5	35.5	100.0
1990	174	56.5	2.0	0.0	0.0	0.0	58.5	41.5	100.0
1991	193	53.3	0.7	0.2	0.0	0.0	54.2	45.8	100.0
1992	199	56.4	2.2	0.0	0.0	0.0	58.7	41.3	100.0
1993	349	61.8	3.5	0.0	1.6	0.0	66.9	33.1	100.0
1994	236	60.2	10.7	0.0	1.0	0.0	71.9	28.1	100.0
1995	91	47.8	19.6	0.0	0.0	0.0	67.4	32.6	100.0
1996	64	52.6	0.0	0.0	5.6	0.0	58.2	41.8	100.0
1997	241	47.8	0.0	0.0	3.6	0.0	51.4	48.6	100.0
1998	315	48.9	2.7	0.1	4.3	0.0	56.0	44.0	100.0
Average		52.9	4.1	0.0	1.0	0.0	58.1	41.9	100.0

Table 30. Estimated harvest by gear type, escapement, and total run of coho salmon returning to Hugh Smith Lake, 1982–1998.

		Number of Fish										
Year	Fishery Sample Size	Alaska Troll	Alaska Seine	Alaska Gillnet	Alaska Trap	Alaska Sport	B.C. Troll	B.C. Net	B.C. Sport	Total Catch	Escapement	Total Return
1982	91	2,780	627	203	0	0	264	78	0	3,952	2,144	6,096
1983	189	1,373	424	277	49	0	211	51	0	2,385	1,490	3,875
1984	151	1,260	501	470	18	0	325	28	0	2,602	1,408	4,010
1985	212	868	287	137	5	0	199	13	0	1,509	903	2,412
1986	257	1,585	515	315	2	14	234	26	0	2,691	1,783	4,474
1987	100	656	95	249	0	23	153	50	0	1,226	1,118	2,344
1988	42	408	230	122	0	0	234	23	0	1,017	513	1,530
1989	91	1,213	375	237	0	41	105	20	0	1,991	433	2,424
1990	263	1,810	538	504	24	0	794	53	0	3,723	870	4,593
1991	408	2,102	195	881	0	54	630	43	0	3,905	1,826	5,731
1992	497	1,852	674	601	0	42	286	9	0	3,464	1,426	4,890
1993	162	2,259	262	677	0	0	197	43	0	3,438	830	4,268
1994	846	4,339	1,125	1,424	0	59	684	53	13	7,697	1,753	9,450
1995	433	2,030	908	1,651	0	101	241	28	13	4,972	1,781	6,753
1996	496	1,581	640	478	0	104	126	36	0	2,965	950	3,915
1997	481	1,286	121	397	0	27	89	0	0	1,920	732	2,652
1998	666	1,772	471	980	0	113	0	0	0	3,336	983	4,319
Average		1,716	470	565	6	34	281	33	2	3,105	1,232	4,337

Table 31. Estimated percent harvest by gear type, escapement, and total run of coho salmon returning to Hugh Smith Lake, 1982–1998.

		Percent of Total Run										
Year	Fishery Sample Size	Alaska Troll	Alaska Seine	Alaska Gillnet	Alaska Trap	Alaska Sport	B.C. Troll	B.C. Net	B.C. Sport	Total Catch	Escapement	Total Return
1982	91	45.6	10.3	3.3	0.0	0.0	4.3	1.3	0.0	64.8	35.2	100
1983	189	35.4	10.9	7.1	1.3	0.0	5.4	1.3	0.0	61.5	38.5	100
1984	151	31.4	12.5	11.7	0.4	0.0	8.1	0.7	0.0	64.9	35.1	100
1985	212	36.0	11.9	5.7	0.2	0.0	8.3	0.5	0.0	62.6	37.4	100
1986	257	35.4	11.5	7.0	0.0	0.3	5.2	0.6	0.0	60.1	39.9	100
1987	100	28.0	4.1	10.6	0.0	1.0	6.5	2.1	0.0	52.3	47.7	100
1988	42	26.7	15.0	8.0	0.0	0.0	15.3	1.5	0.0	66.5	33.5	100
1989	91	50.0	15.5	9.8	0.0	1.7	4.3	0.8	0.0	82.1	17.9	100
1990	263	39.4	11.7	11.0	0.5	0.0	17.3	1.2	0.0	81.1	18.9	100
1991	408	36.7	3.4	15.4	0.0	0.9	11.0	0.8	0.0	68.1	31.9	100
1992	497	37.9	13.8	12.3	0.0	0.9	5.8	0.2	0.0	70.8	29.2	100
1993	162	52.9	6.1	15.9	0.0	0.0	4.6	1.0	0.0	80.6	19.4	100
1994	846	45.9	11.9	15.1	0.0	0.6	7.2	0.6	0.1	81.4	18.6	100
1995	433	30.1	13.4	24.4	0.0	1.5	3.6	0.4	0.2	73.6	26.4	100
1996	496	40.4	16.3	12.2	0.0	2.7	3.2	0.9	0.0	75.7	24.3	100
1997	481	48.5	4.6	15.0	0.0	1.0	3.4	0.0	0.0	72.4	27.6	100
1998	666	41.0	10.9	22.7	0.0	2.6	0.0	0.0	0.0	77.2	22.8	100
Average		38.9	10.8	12.2	0.1	0.8	6.7	0.8	0.0	70.3	29.7	100.0

Table 32. Estimated catch and escapement of coho salmon bound for the Taku River above Canyon Island, 1987–1998.

		Number of Fish							
Year	Fishery Sample Size	Troll	Seine	Gillnet	Marine Sport	Canadian Inriver	Total Catch	Escapement	Total Return
1987						6,519		55,457	
1988						3,643		39,450	
1989						4,033		56,808	
1990						3,685		72,196	
1991						5,439		127,484	
1992	129	41,713	2,283	79,013	431	5,541	128,981	84,853	213,834
1993	121	78,371	3,430	40,308	3,222	4,634	129,965	109,457	239,422
1994	178	97,039	26,352	86,198	19,018	14,693	243,300	96,343	339,643
1995	201	45,041	1,853	56,820	7,857	13,738	125,309	55,710	181,019
1996	136	24,779	220	17,069	2,461	5,052	49,581	44,635	94,216
1997	66	8,822	550	1,490	4,963	2,690	18,515	32,345	50,860
1998	230	28,372	740	21,951	4,428	5,090	60,581	41,449	102,030
1992-98 Average		46,305	5,061	43,264	6,054	7,348	108,033	66,399	174,432
1987-97 Average		-	-	-	-	6,230	-	68,016	-

Table 33. Estimated percent of harvest by gear type, escapement, and total run of coho salmon returning to the Taku River above Canyon Island, 1992-1998.

Year	Fishery Sample Size	Number of Fish							
		Troll	Seine	Gillnet	Marine Sport	Canadian Inriver	Total Catch	Escapement	Total Return
1992	129	19.5	1.1	37.0	0.2	2.6	60.3	39.7	100.0
1993	121	32.7	1.4	16.8	1.3	1.9	54.3	45.7	100.0
1994	178	28.6	7.8	25.4	5.6	4.3	71.6	28.4	100.0
1995	201	24.9	1.0	31.4	4.3	7.6	69.2	30.8	100.0
1996	136	26.3	0.2	18.1	2.6	5.4	52.6	47.4	100.0
1997	66	26.3	0.2	18.1	2.6	5.4	52.6	47.4	100.0
1998	230	27.8	0.7	21.5	4.4	5.0	59.4	40.6	100.0
1992-98 Average		26.6	1.8	24.0	3.0	4.6	60.0	40.0	100.0

Table 34. Southern inside area coho salmon escapement index (number of spawners), 1987–1998.[a]

Year	Herman Creek	Grant Creek	Eulachon River	Klahini River	Indian River	Barrier Creek	Humpy Creek	King Creek	Choca Creek
1987	92	***97***	154	***70***	***372***	***123***	***72***	***244***	***149***
1988	72	150	205	20	300	50	20	175	150
1989	75	101	290	15	925	450	10	510	200
1990	150	30	235	150	***274***	***90***	***53***	35	***110***
1991	245	50	285	50	550	100	75	300	220
1992	115	270	860	90	675	100	90	250	150
1993	90	175	460	50	475	325	190	110	300
1994	265	220	755	200	560	175	155	325	225
1995	250	94	435	165	600	220	185	415	180
1996	94	92	383	40	570	230	80	457	220
1997	75	***93***	420	60	***355***	***117***	***68***	***233***	175
1998	94	130	460	120	220	50	***95***	411	190
87-98 Average	135	125	412	86	490	169	91	289	189

Year	Carroll River	Blossum River	Keta River	Marten River	Hugh Smith L. (Weir)	Humpback Creek	Tombstone River	Total Index
1987	180	700	800	740	1,118	650	532	6,092
1988	193	790	850	600	513	52	1,400	5,540
1989	70	1,000	650	1,175	433	350	950	7,204
1990	***159***	800	550	575	870	135	275	4,490
1991	375	725	800	575	1,826	671	775	7,622
1992	360	650	627	1,285	1,426	550	1,035	8,533
1993	310	850	725	1,525	830	600	1,275	8,290
1994	475	775	1,100	2,205	1,753	560	850	10,598
1995	400	800	1,155	1,385	1,781	82	2,446	10,593
1996	240	829	1,506	1,924	958	440	1,806	9,869
1997	140	1,143	571	759	732	35	847	5,824
1998	***287***	1,004	1,169	1,961	983	285	666	8,126
87-98 Average	266	839	875	1,226	1,102	368	1,071	7,732

[a] Total index is the sum of counts and interpolated values. Interpolated values are shown in bold italic print.

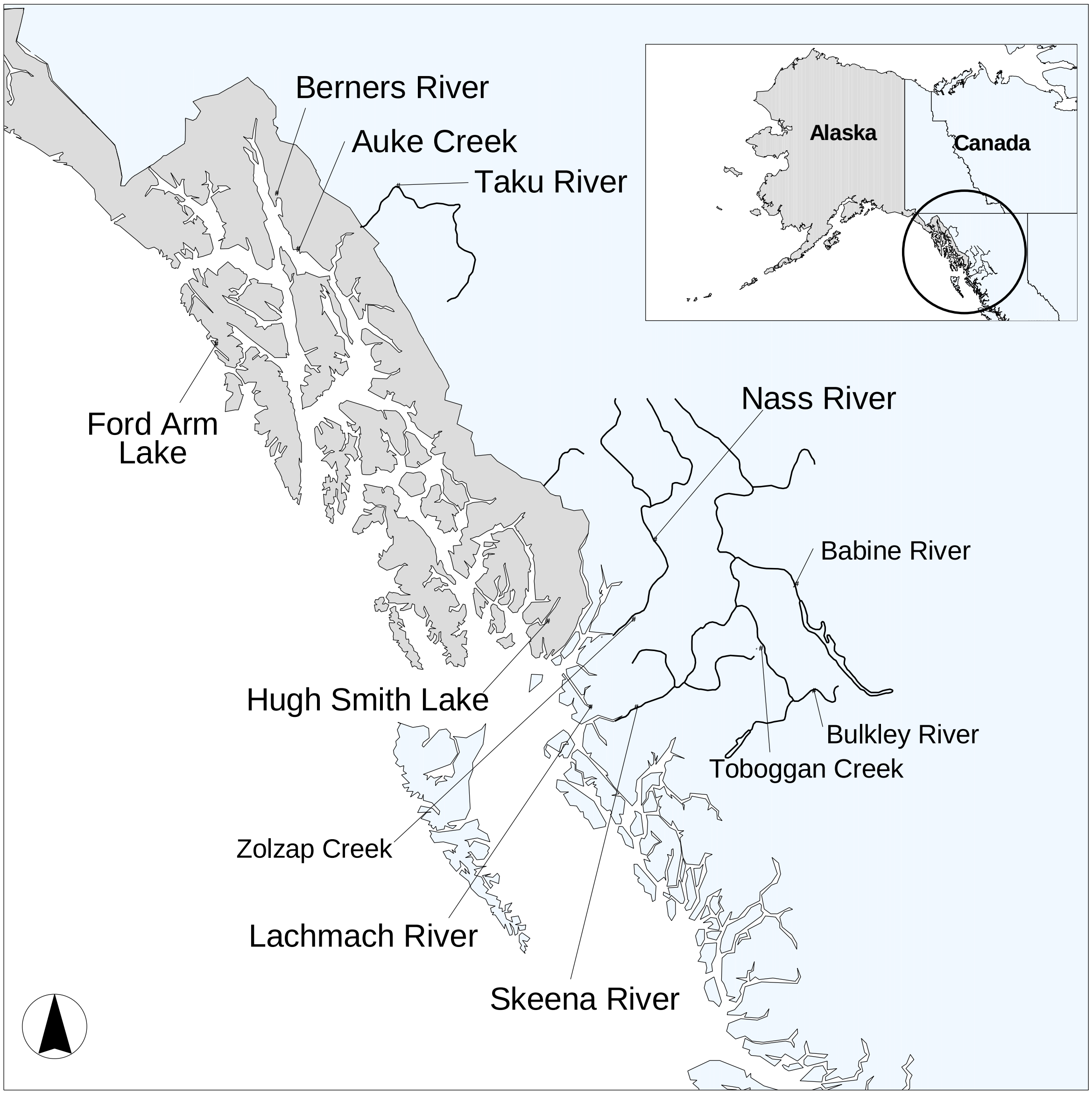

Figure 1. Map of Southeast Alaska and northern British Columbia, showing the locations of long-term coho salmon stock assessment projects.

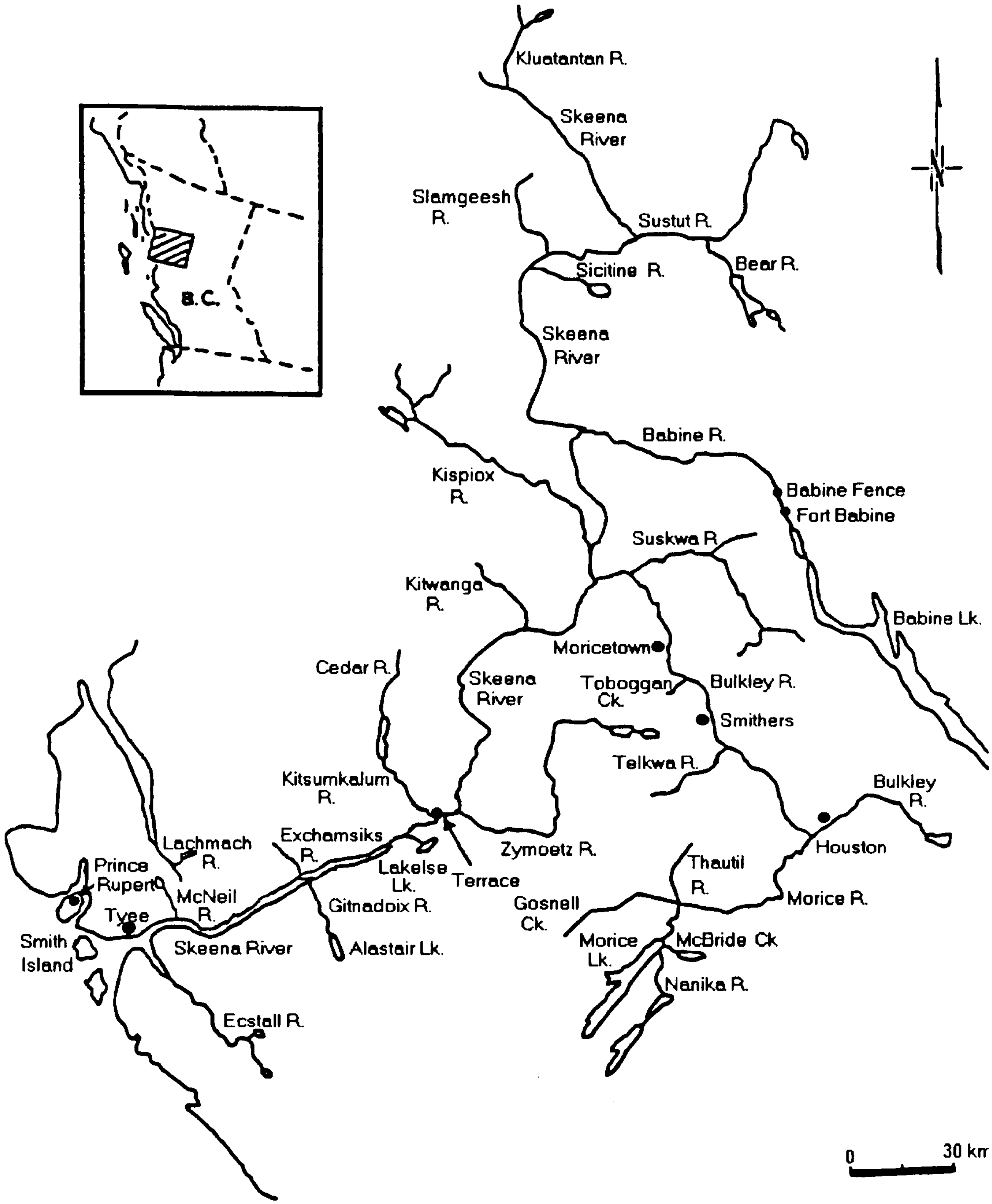

Figure 2. Map of the Skeena River drainage (from DFO 1999).

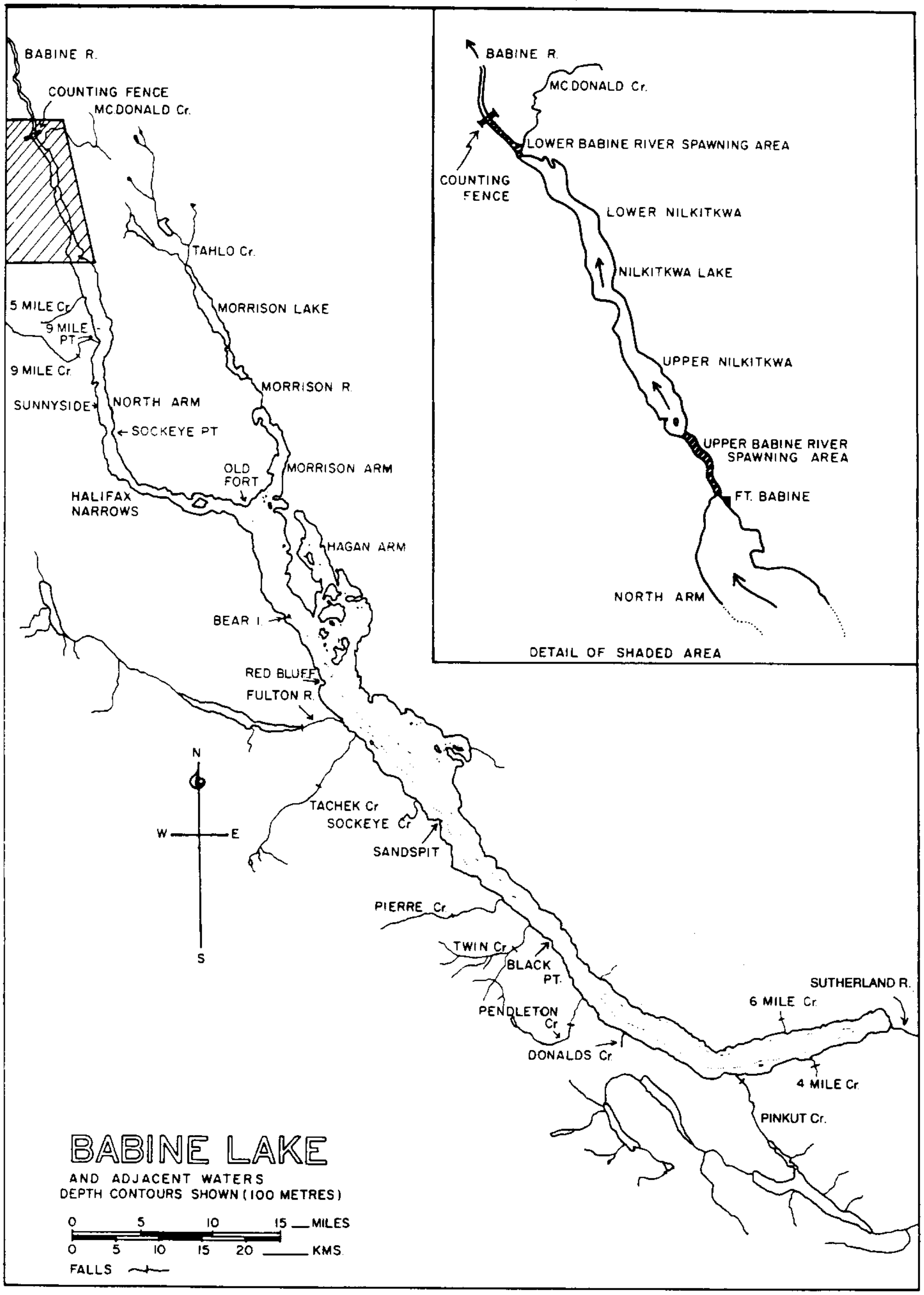

Figure 3. Map of the Babine-Nilkitkwa Lake system (from Johnson 1958).

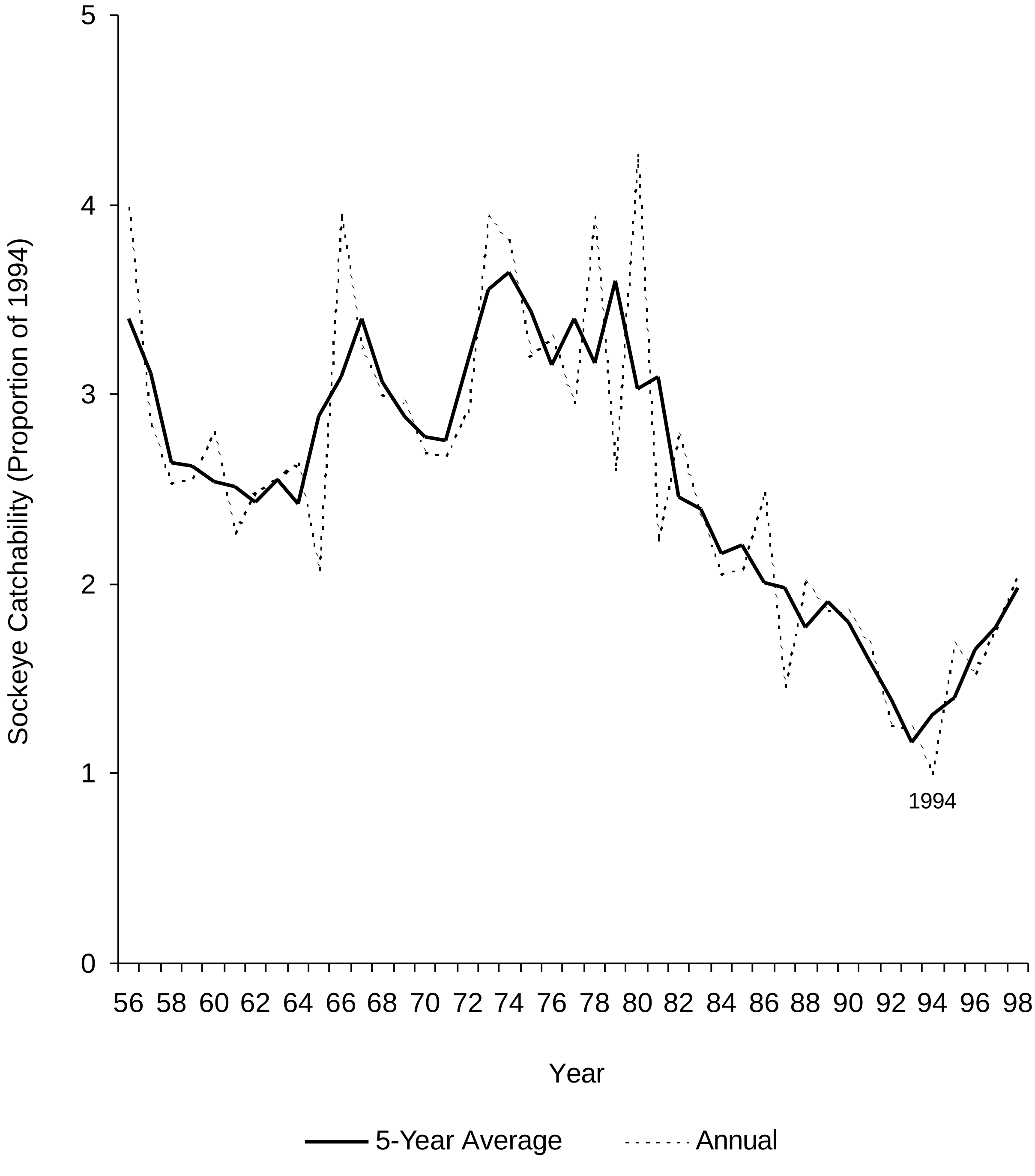

Figure 4. Tyee test fishery sockeye salmon catchability, 1956–1998, as a proportion of 1994.

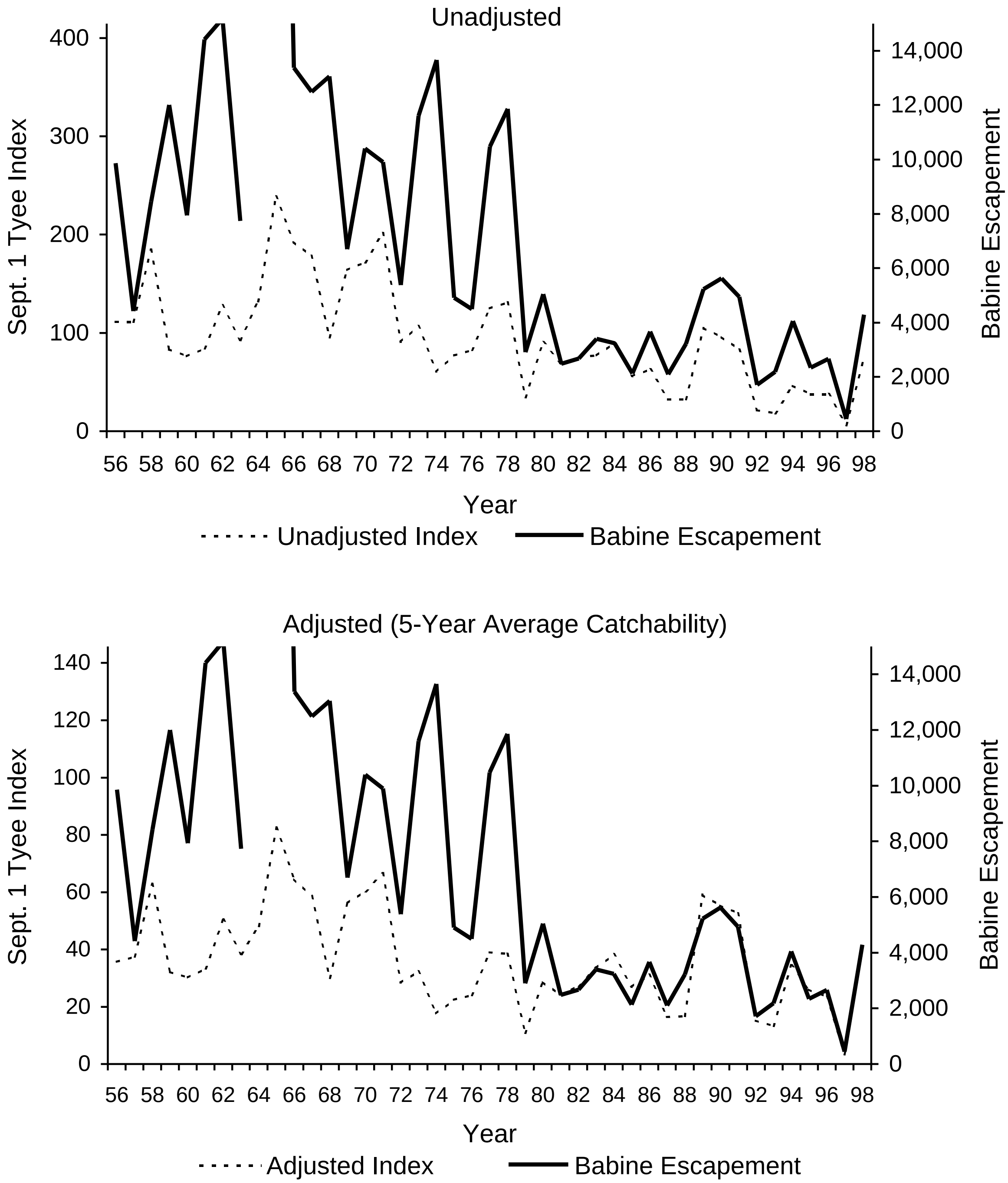

Figure 5. A comparison between the estimated coho salmon escapement to the Babine River and the Tyee test fishery index of coho salmon escapement into the lower Skeena River through September 1 showing the index in its unadjusted form (top graph) and adjusted for five-year average sockeye salmon catchability (bottom graph). In both graphs, the Y axes are scaled so that the 1981 data points coincide.

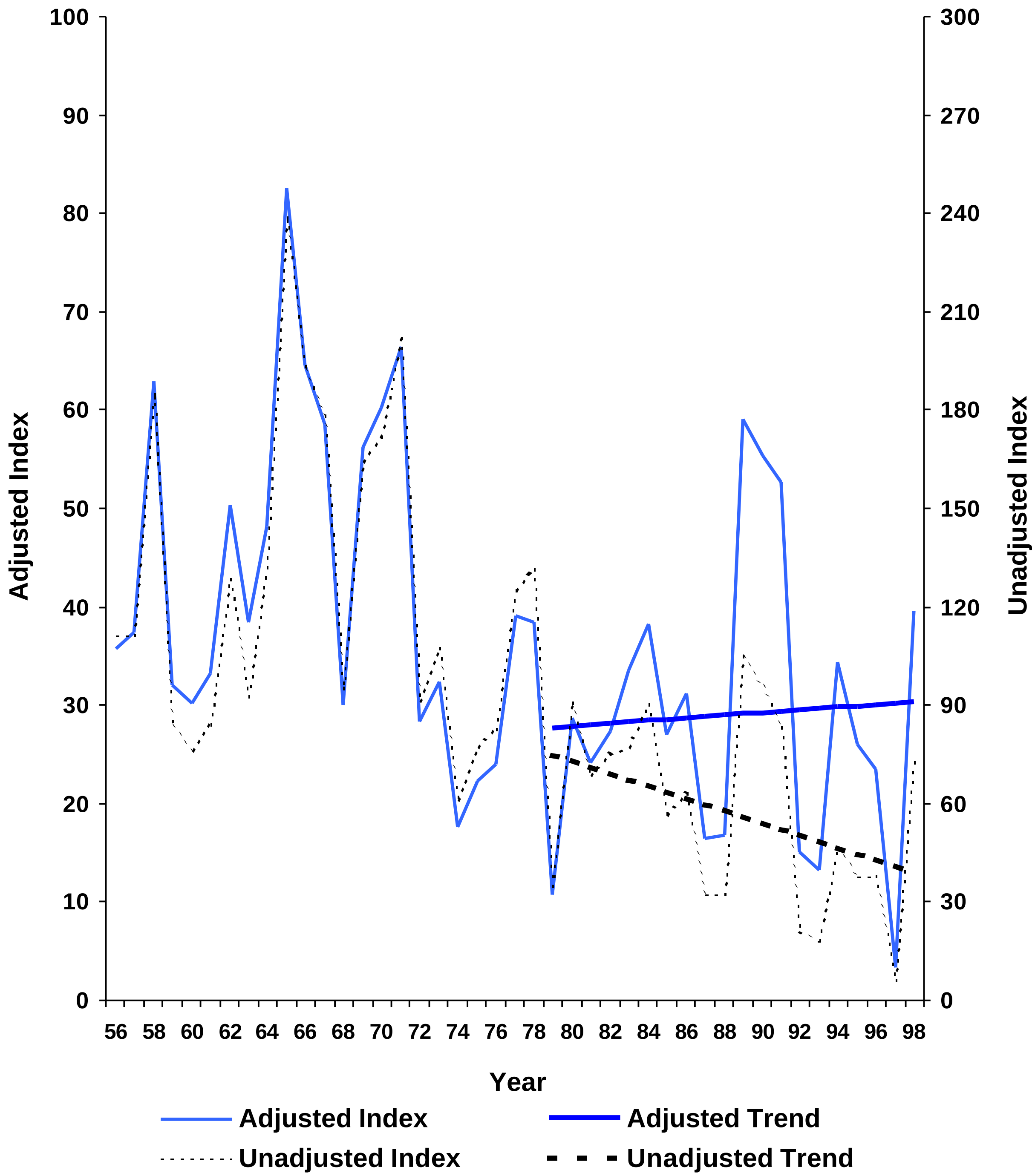

Figure 6. September 1 Tyee test fishery index of coho salmon escapement showing the unadjusted index and the same index adjusted for five-year average sockeye salmon catchability. Also shown are linear trends for the most recent 20-year period (1979–1998).

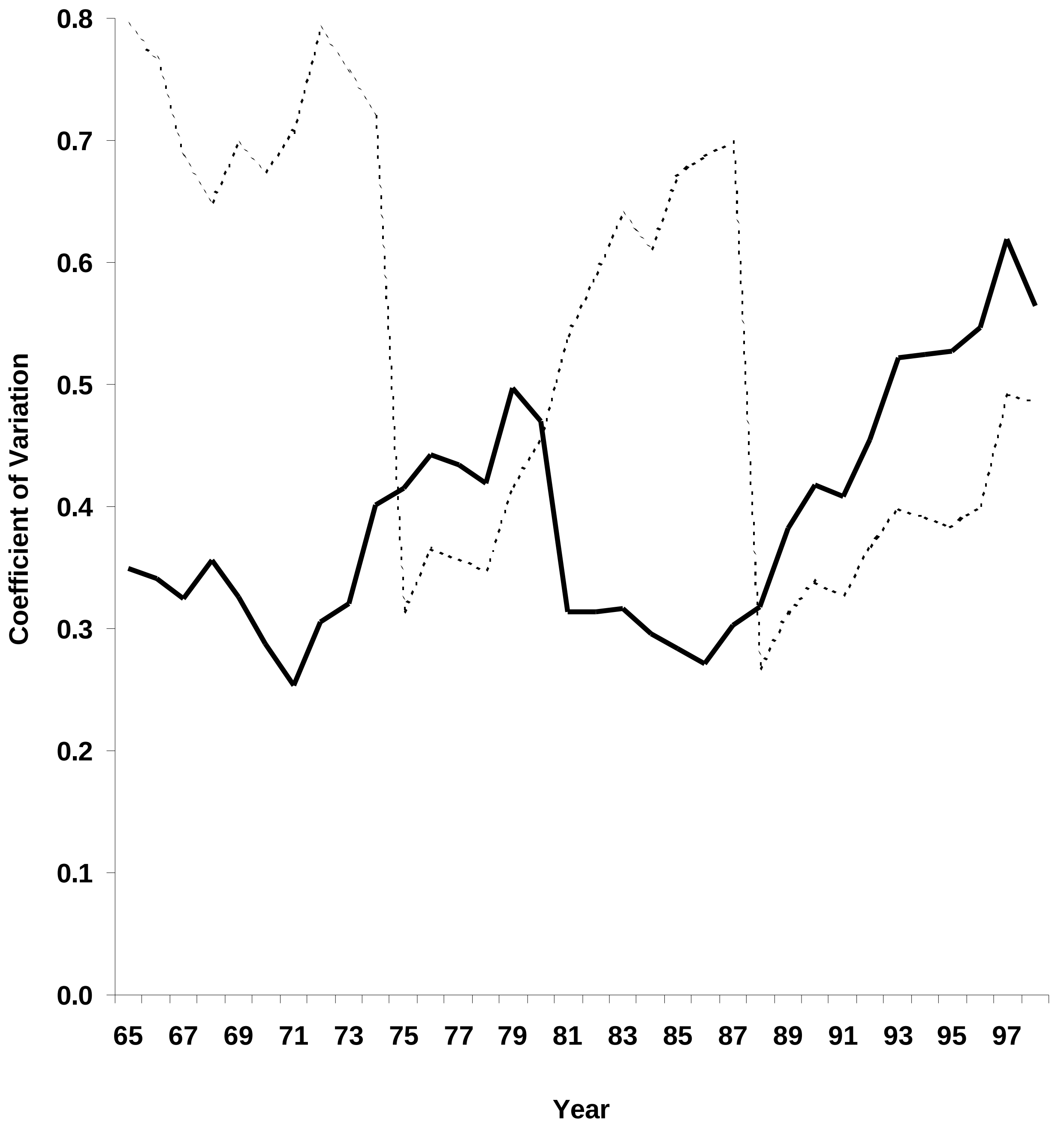

Figure 7. Coefficient of variation in the September 1 Tyee test fishery index of coho salmon escapement (adjusted for five-year average sockeye salmon catchability) and the Babine River escapement over a moving 10-year period by ending date, 1956–1998.

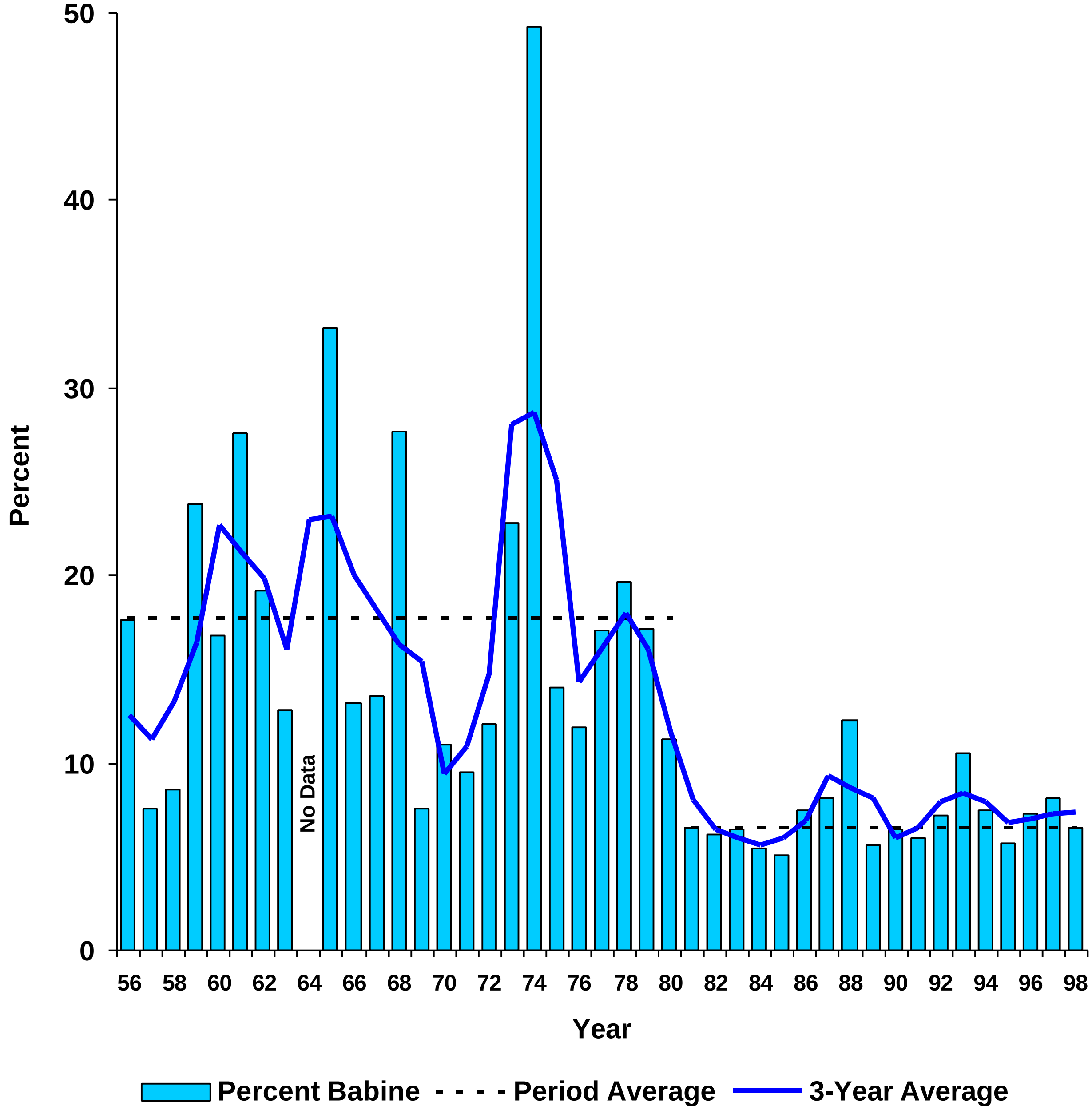

Figure 8. Estimated percent contribution of Babine River coho salmon to the Tyee test fishery index of coho salmon escapement through September 1 (adjusted for five-year average sockeye salmon catchability) based on escapement at the Babine fence and 1994 radio telemetry results (Koski et al. 1995).

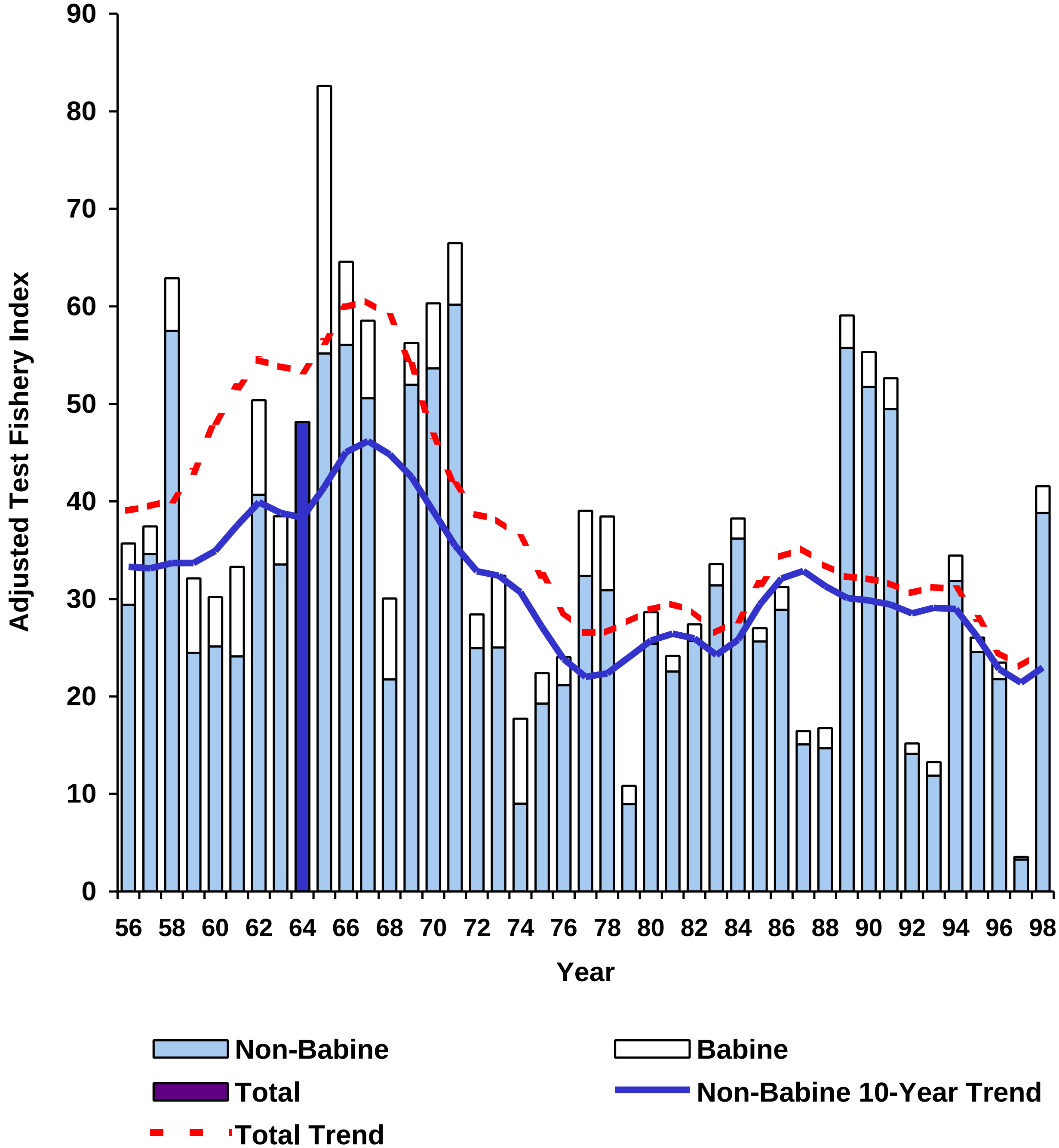

Figure 9. September 1 Tyee test fishery index of coho salmon escapement (adjusted for five-year average sockeye salmon catchability) showing the Babine and non-Babine components estimated from 1994 radio telemetry results (Koski et al. 1995).

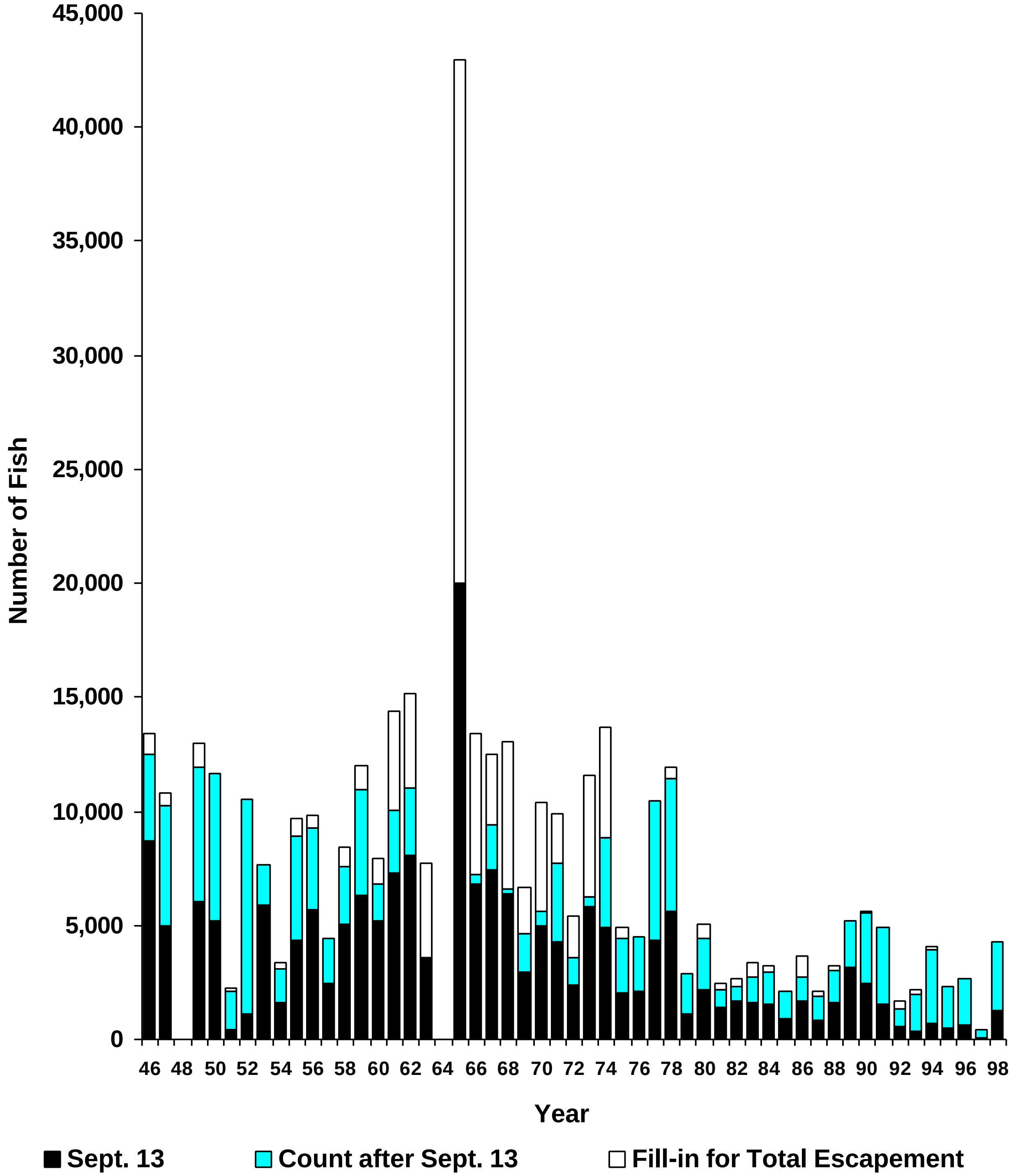

Figure 10. Estimated total coho salmon escapement above the fence on the Babine River showing the count through September 13, the count after September 13 and the statistical extrapolation from the end of the fence operation to the total escapement.

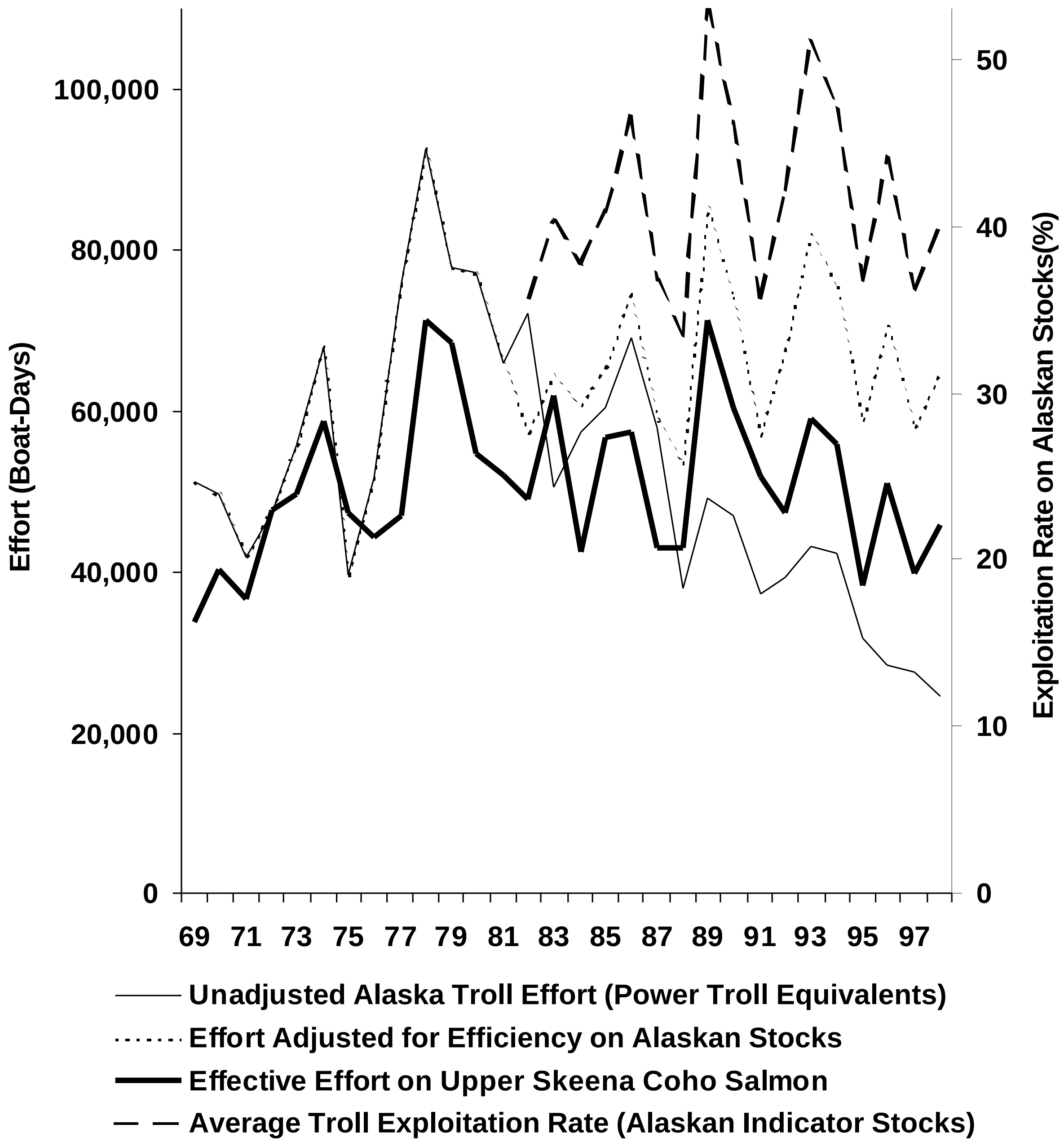

Figure 11. Alaska troll fishery total effort, effort adjusted for changing efficiency during 1982–1998 and estimated effective effort used to reconstruct exploitation rates on upper Skeena coho stocks. Also shown is the estimated average Alaska troll exploitation rate on the Auke Creek, Ford Arm Lake, and Hugh Smith Lake indicator stocks during 1982–1998.

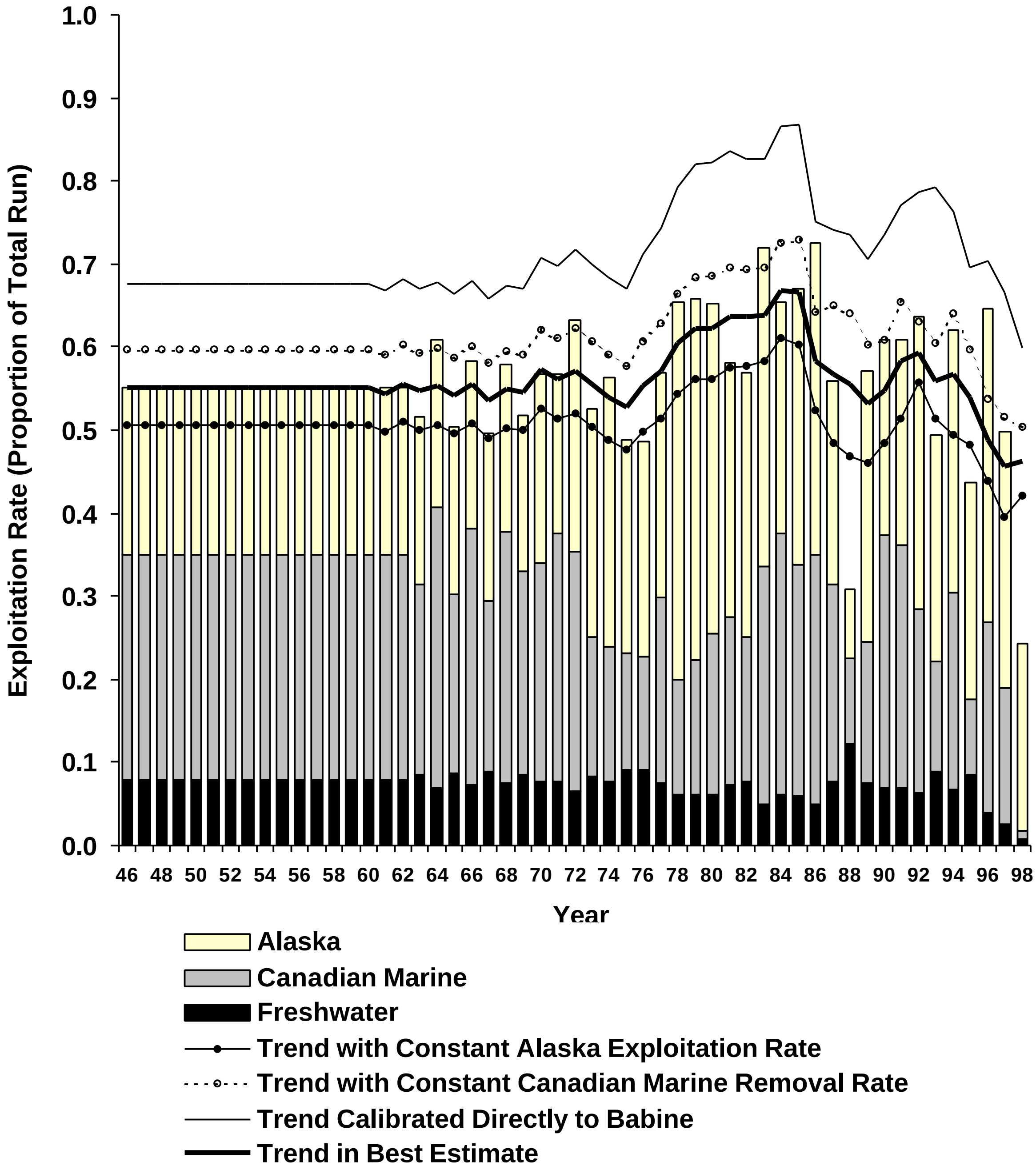

Figure 12. Best annual exploitation rate estimates for Babine River Coho salmon, 1946–1998 (bar graph), computed from Toboggan Creek exploitation rate estimates and adjusted to reflect a different harvest distribution for the Babine stock. Also shown are five-year trends in: (1) estimates that assume an Alaska exploitation rate equal to Toboggan Creek; (2) estimates that assume a removal rate by Canadian marine commercial fisheries that is equal to Toboggan Creek; (3) a "best" estimate that averages 1 and 2; and (4) estimates based directly on 1994–1997 CWT exploitation rate estimates for the Babine stock.

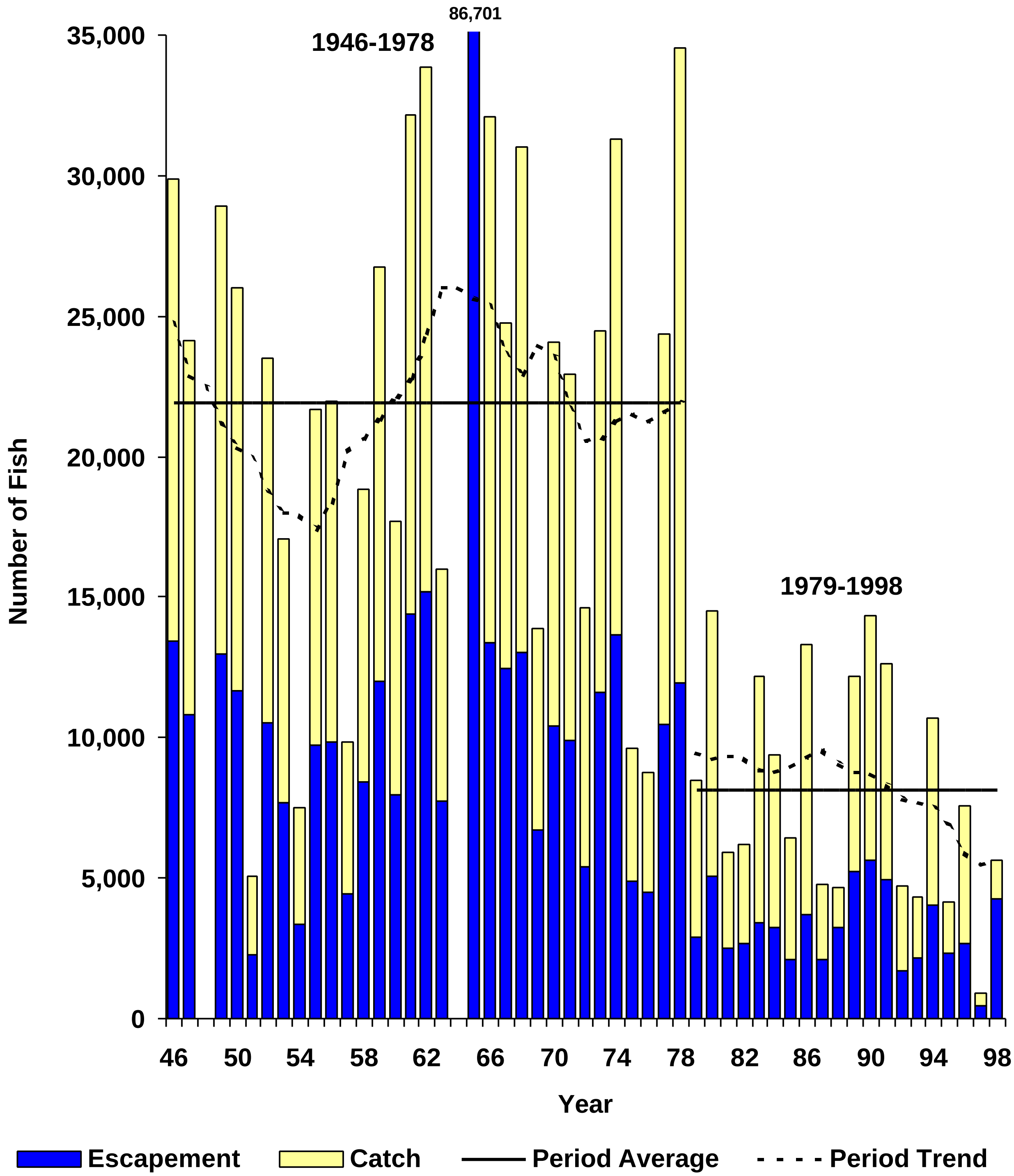

Figure 13. Estimated escapement and catch of Babine River coho salmon showing averages and 10-year trends in total run size for two periods (1946–1978 excluding 1965 and 1979–1998).

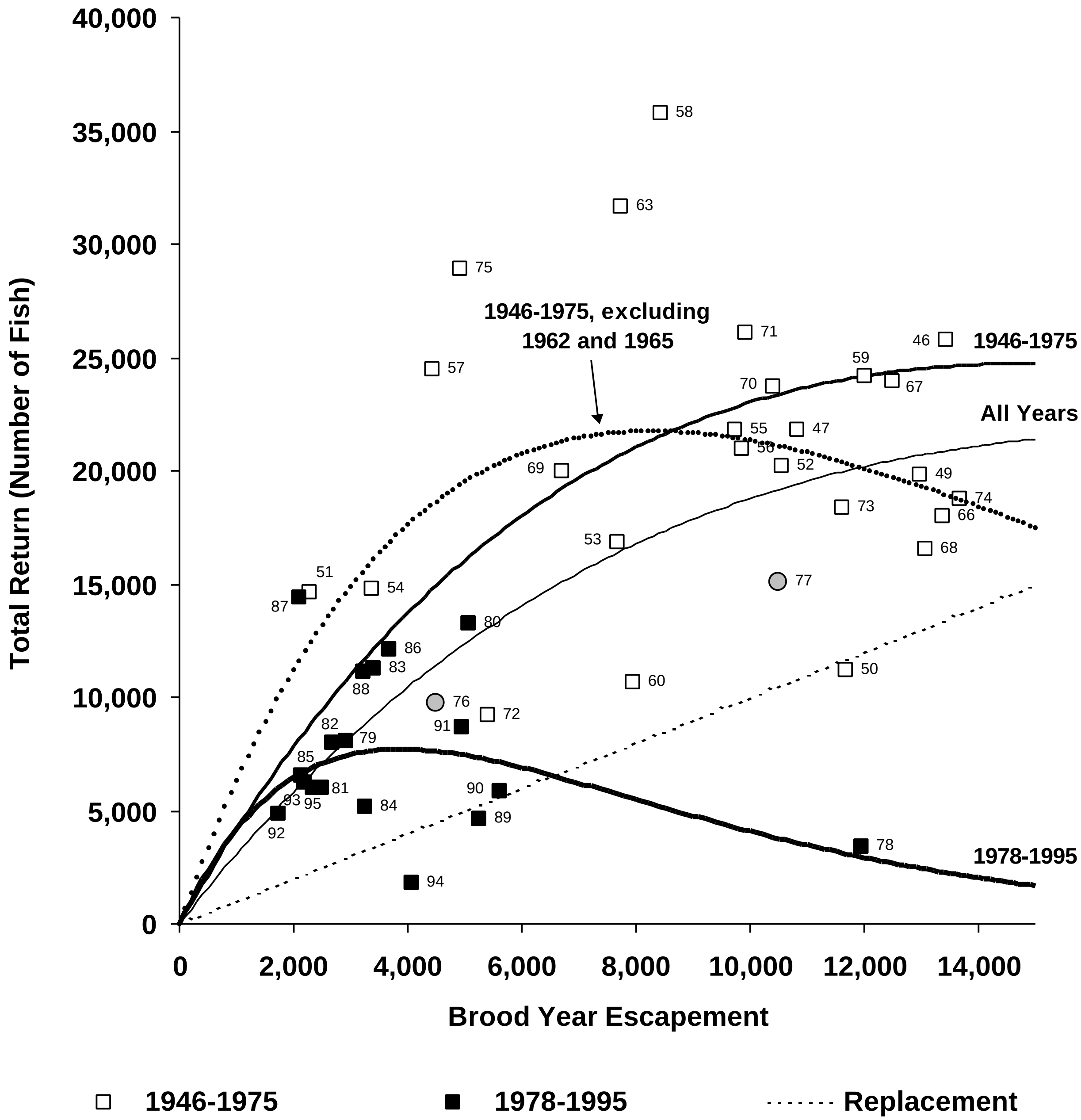

Figure 14. Escapement and total return of Babine River coho salmon by brood year, 1946–1995. The 1962 and 1965 data points are off scale and not shown but are included in the analysis.

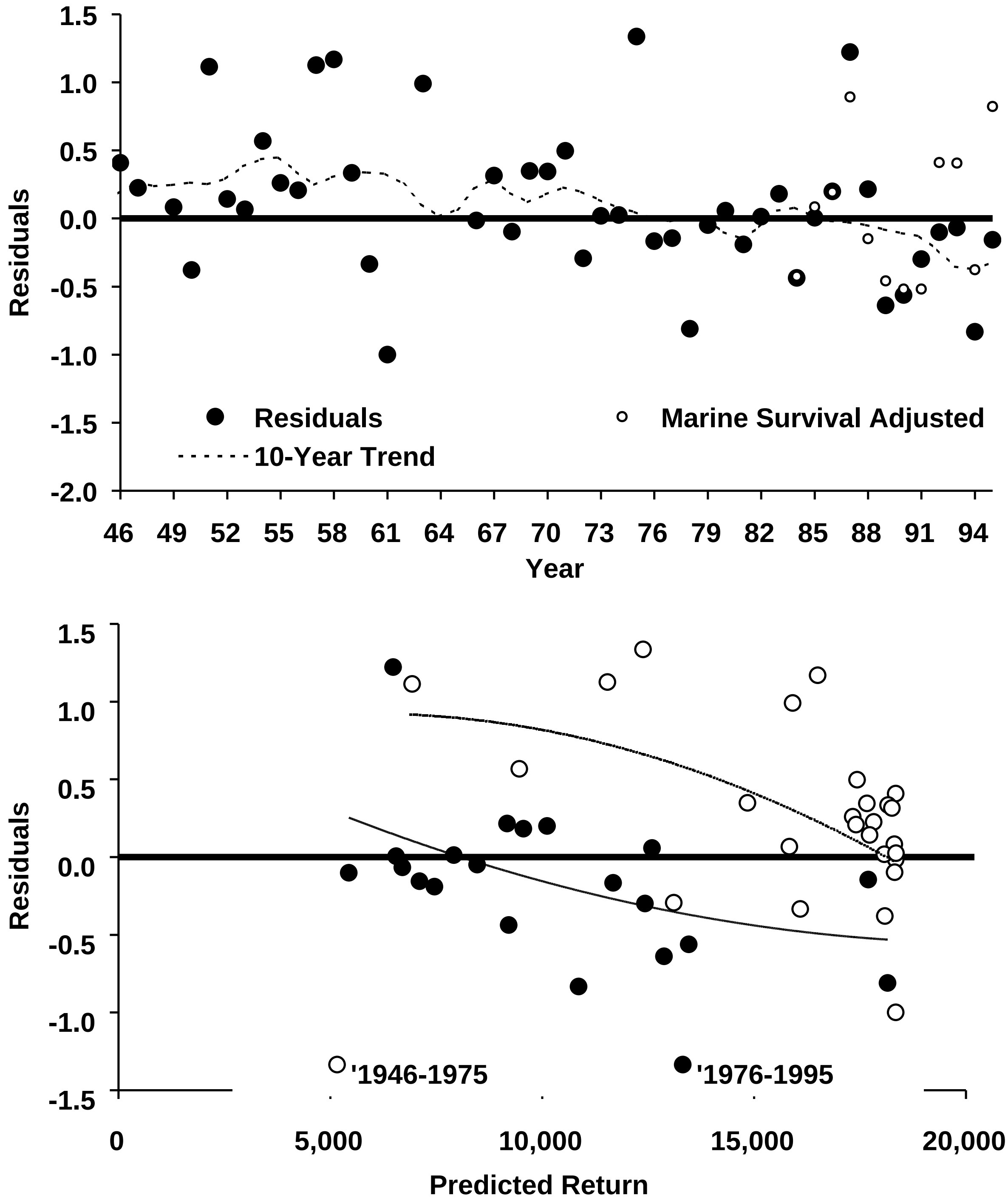

Figure 15. Residuals in the Ricker spawner-recruit relationship for Babine coho salmon (1946–1995, excluding 1962 and 1965) with 10-year trend (top figure) and shown in relation to predicted return (bottom figure). Estimates adjusted for marine survival in the 1984–1995 brood years are shown in the top figure.

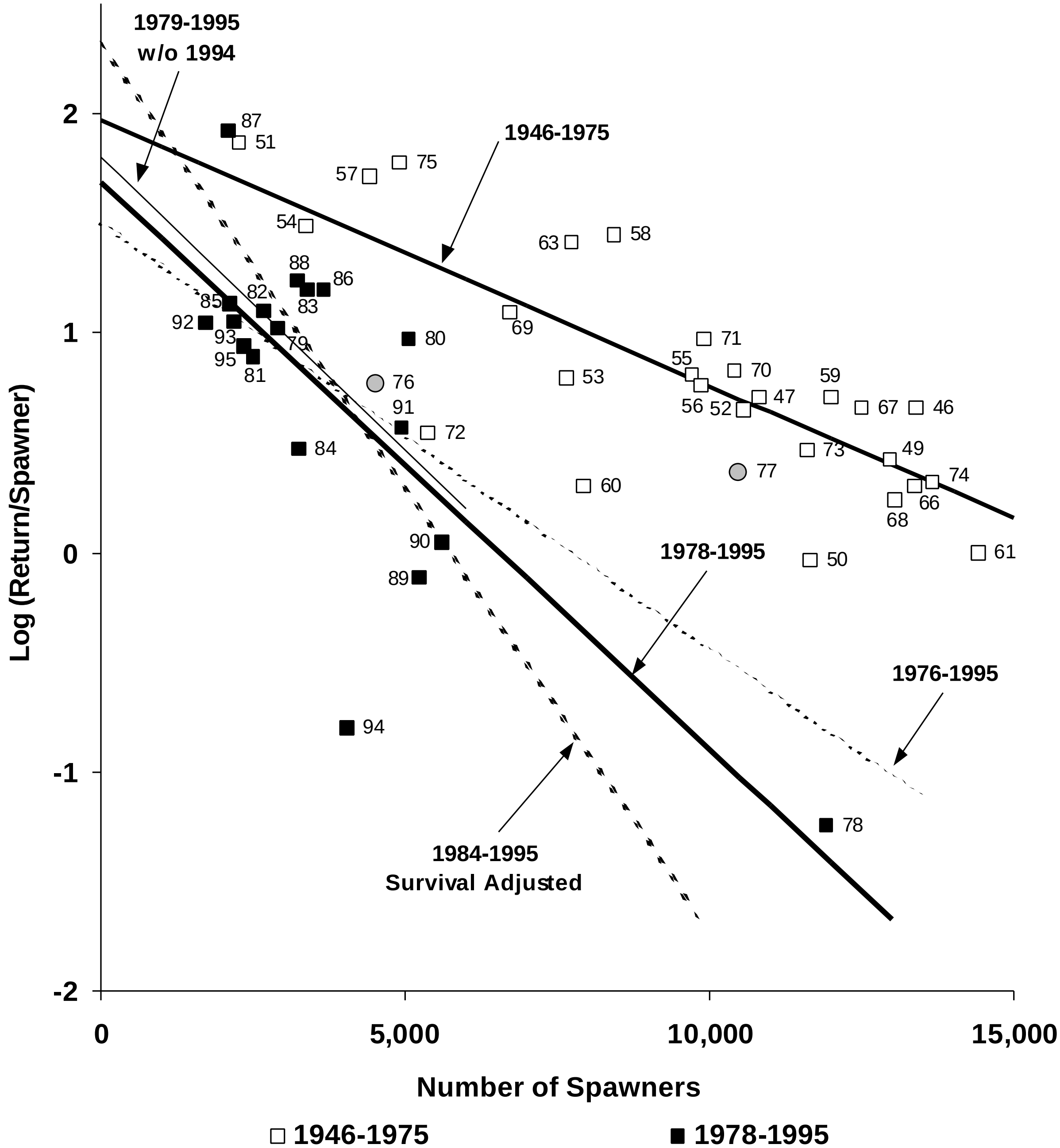

Figure 16. Relationship between the estimated number of spawners and return-per-spawner for Babine River coho salmon during the 1946–1975 and 1978–1995 brood years, excluding years with missing data (1948, 1961 and 1964) and major outlyers (1962 and 1965). The linear relationship for the 1984–1995 brood years with returns adjusted to 1988–1996 average marine survival (see Table 7 and Figure 15) is shown for comparison.

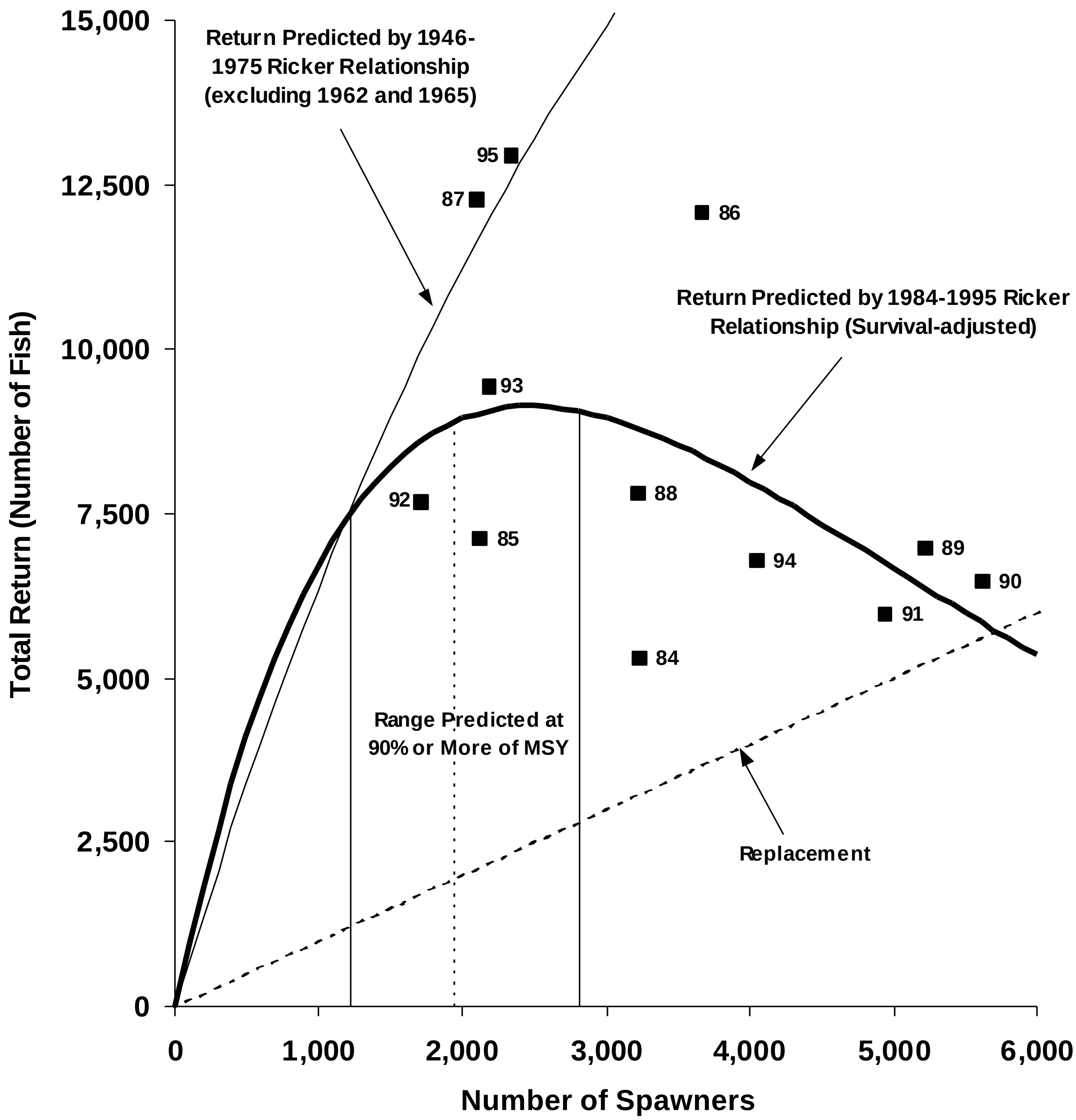

Figure 17. Ricker spawner-recruit relationship for Babine River coho salmon, 1984–1995 (with returns adjusted to remove the effect of variable marine survival) compared with the Ricker relationship for unadjusted returns in the period from 1946–1975 (excluding 1962 and 1965 outlyers). Annual Babine coho returns were normalized to an 1988–1996 average marine survival rate using average survival estimates for Toboggan Creek and Fort Babine hatchery smolts.

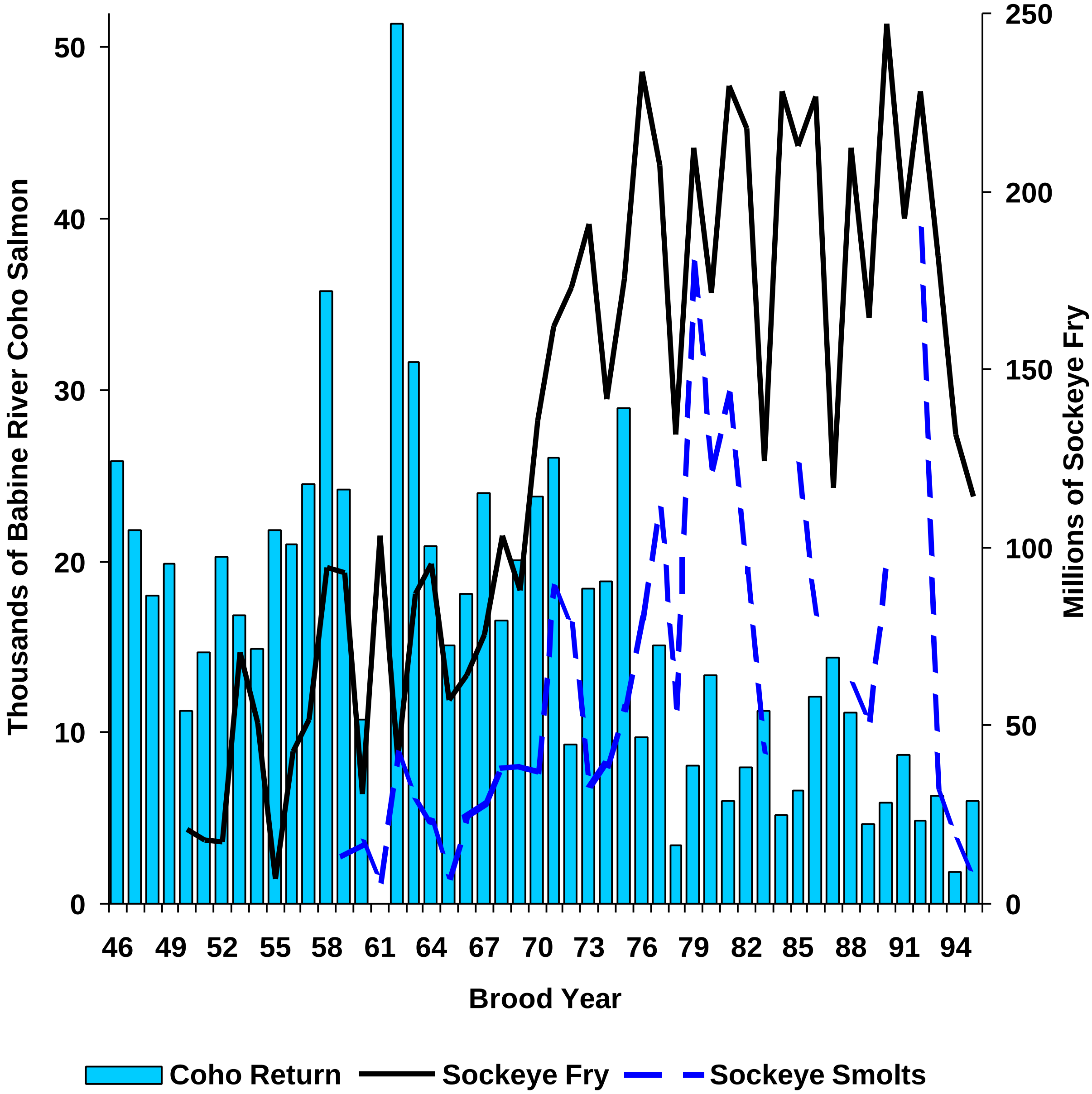

Figure 18. Babine River coho salmon estimated total return by brood year (1950–1995) and estimated number of sockeye salmon fry entering and smolts leaving the main basin of Babine Lake by brood year (1946–1995). Sockeye salmon data are from Wood et al. (1998).

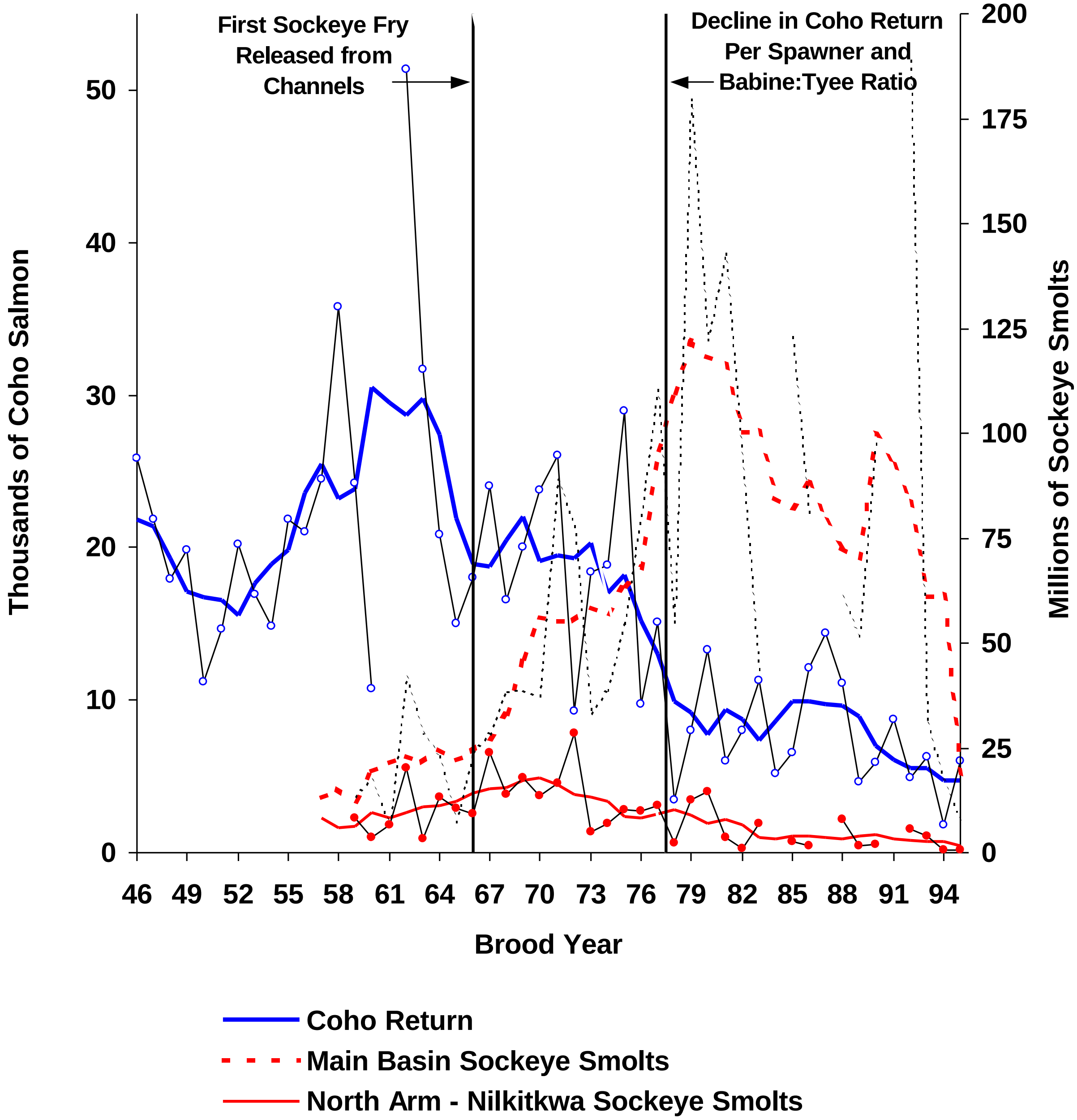

Figure 19. Estimated return of coho salmon to the Babine River system compared with production of sockeye salmon smolts from the main basin of Babine Lake and from the North Arm of Babine Lake and Nilkitkwa Lake with five-year symmetrical moving averages. Sockeye salmon smolt data are from Wood et al. (1998).

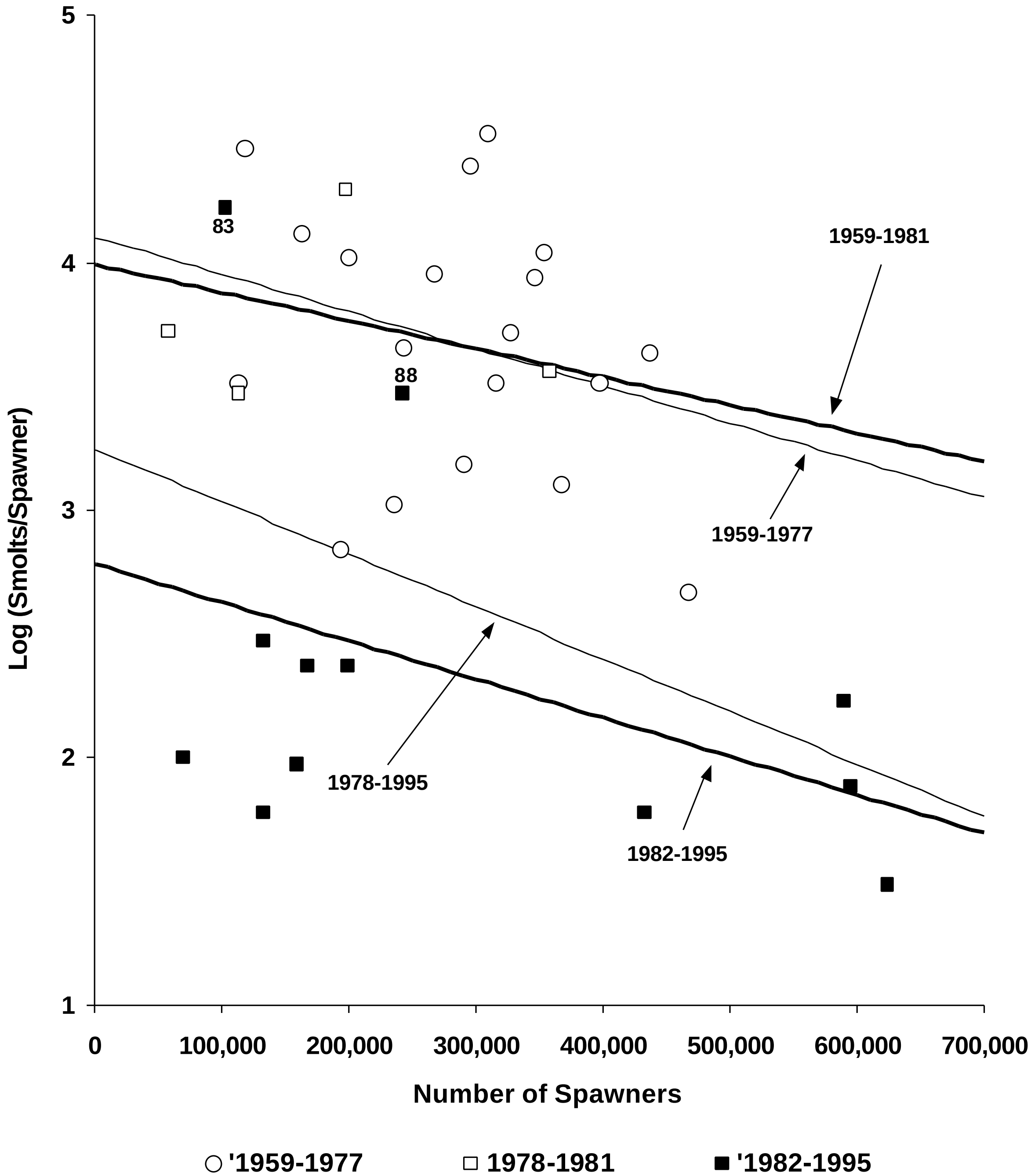

Figure 20. Relationship between the estimated number of spawners and smolts-per-spawner for sockeye salmon spawning in the Babine River by period, 1959–1995 (data are from Wood et al. 1998).

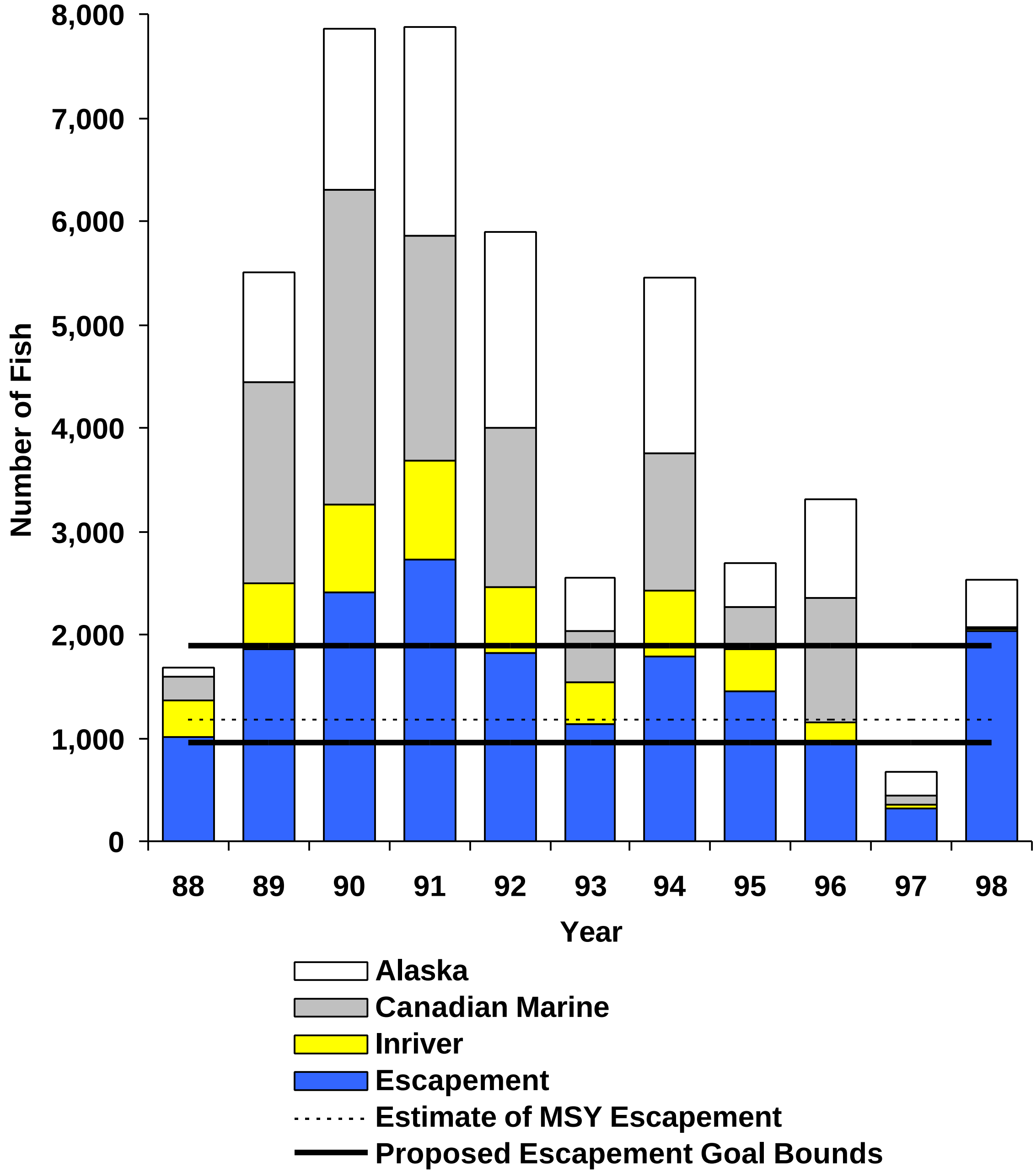

Figure 21. Estimated catch, escapement and MSY escapement for wild Toboggan Creek coho salmon, 1988–1998, and proposed escapement goal range.

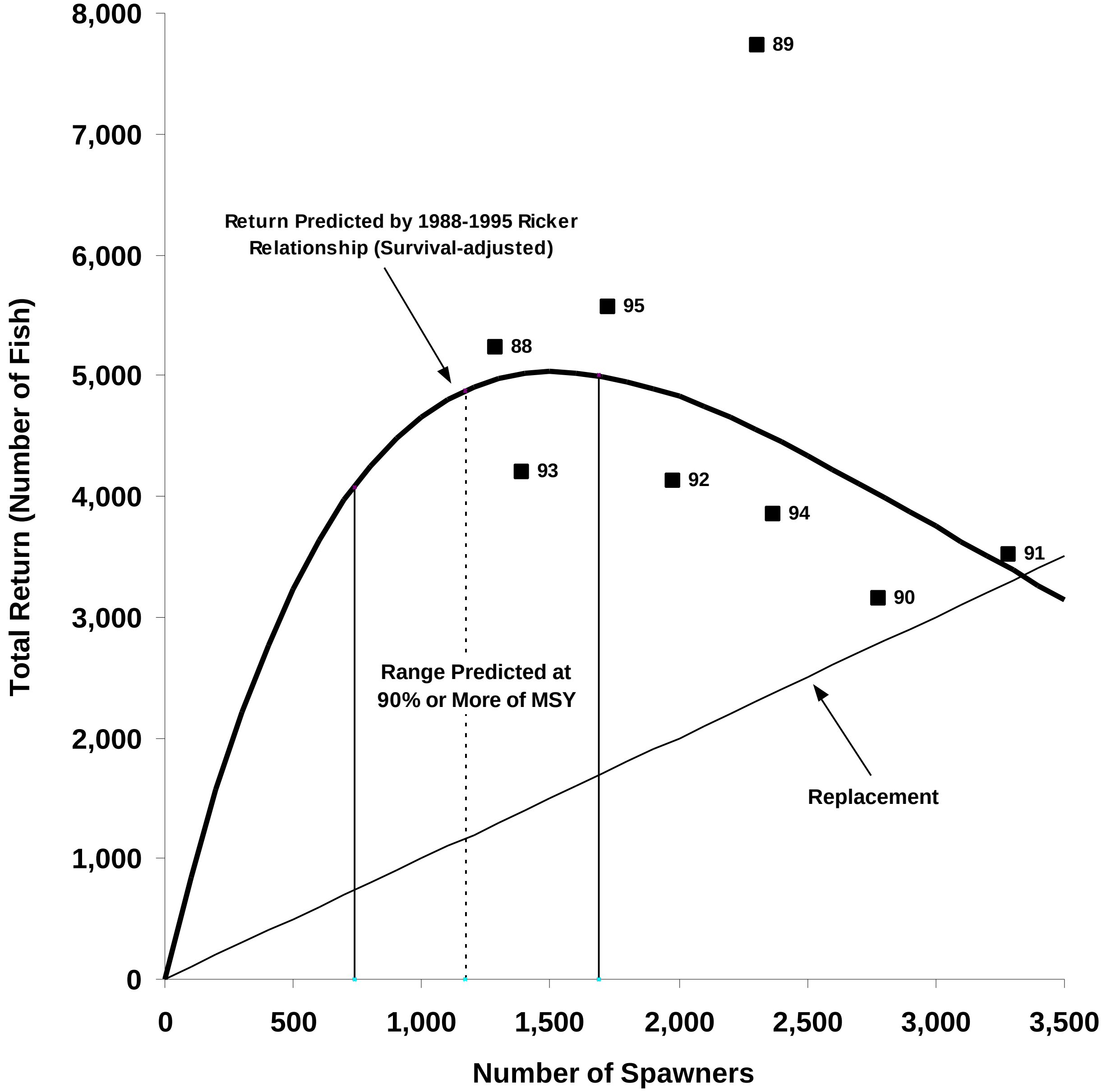

Figure 22. Ricker relationship for wild Toboggan Creek coho salmon showing the escapement range predicted to result in 90% or more of maximum sustained yield. Returns were adjusted to average marine survival.

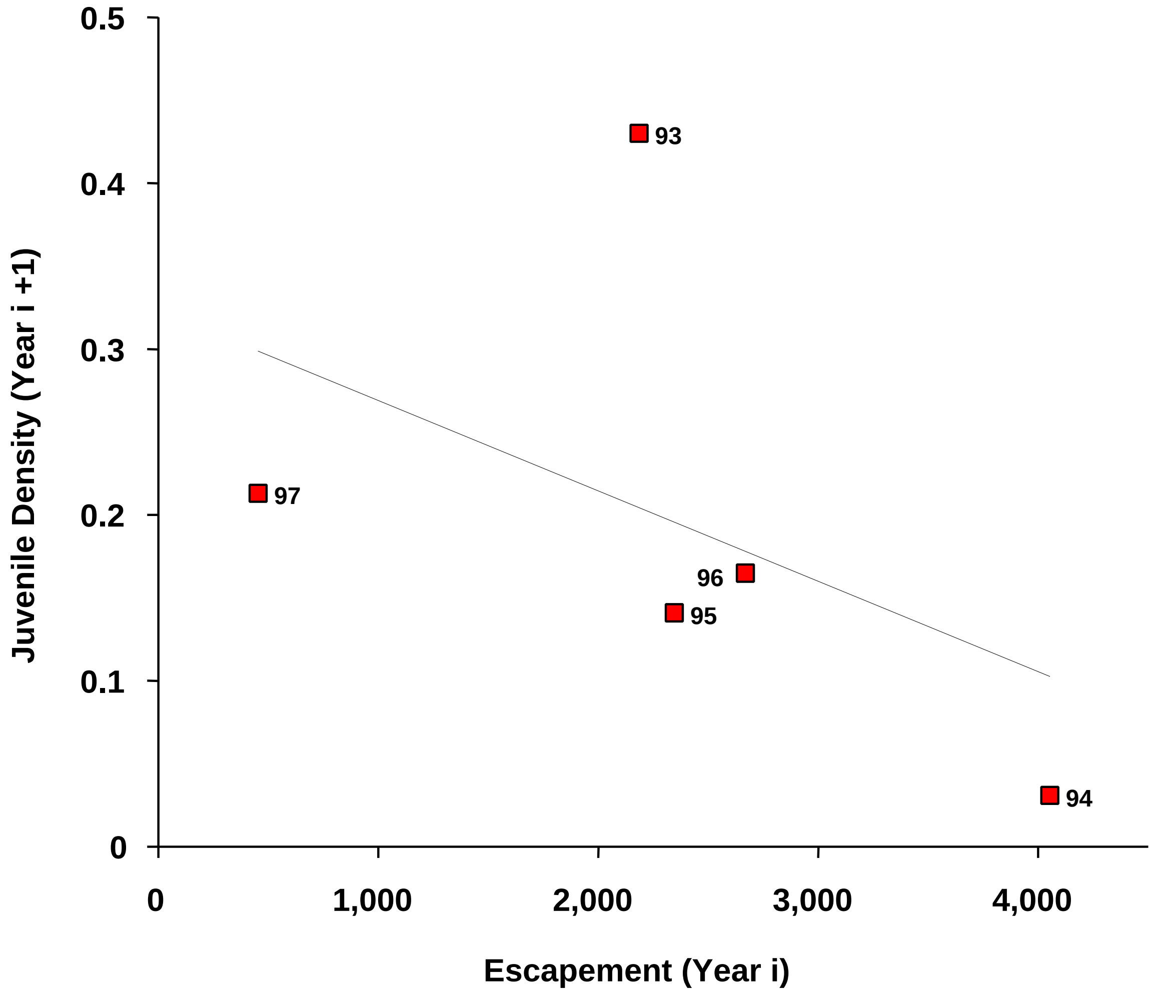

Figure 23. Relationship between Babine coho salmon escapement, 1993–1997, and sampled juvenile abundance the following year.

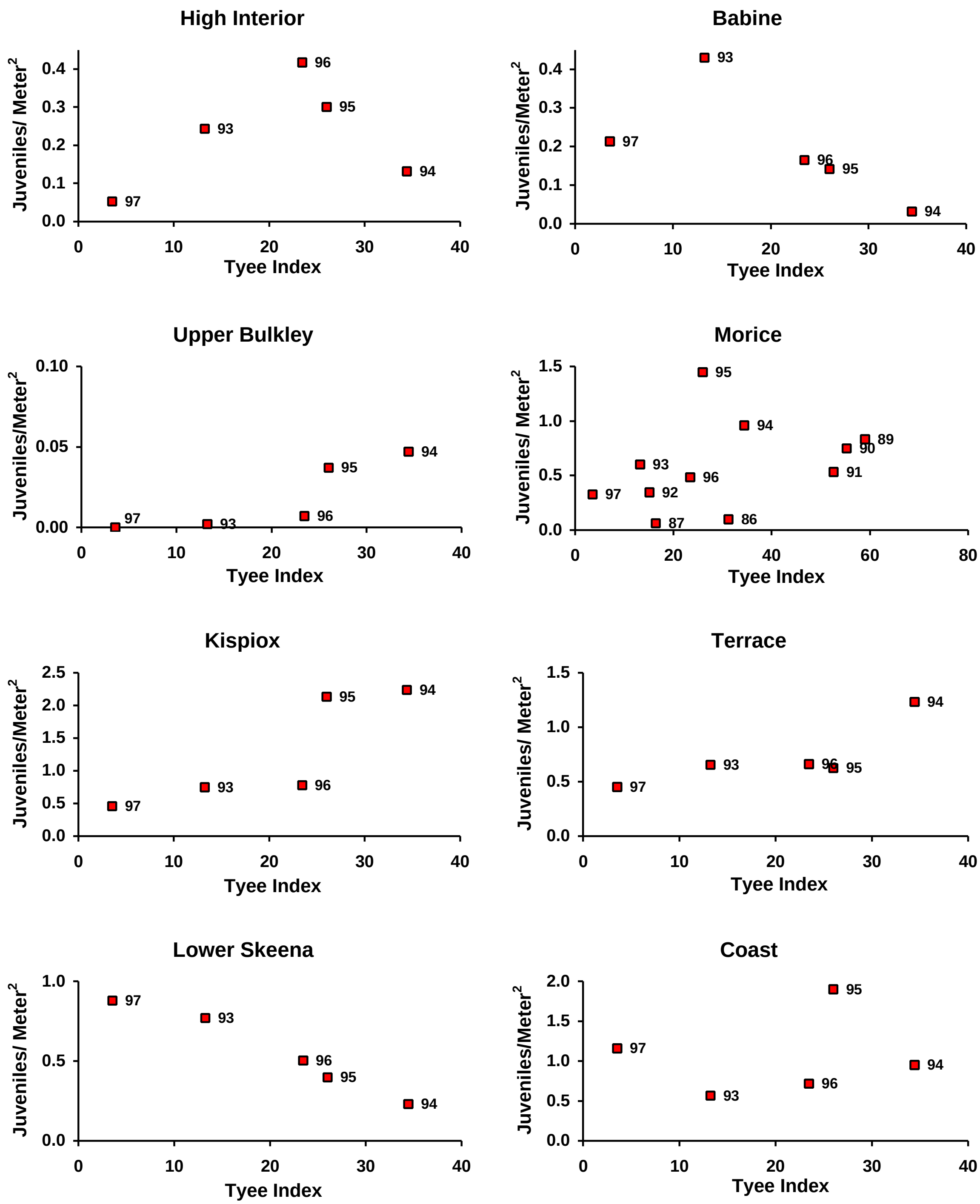

Figure 24. Relationship between the September 1 Tyee Index of coho salmon escapement to the Skeena River and sampled juvenile density in selected areas late in the following summer.

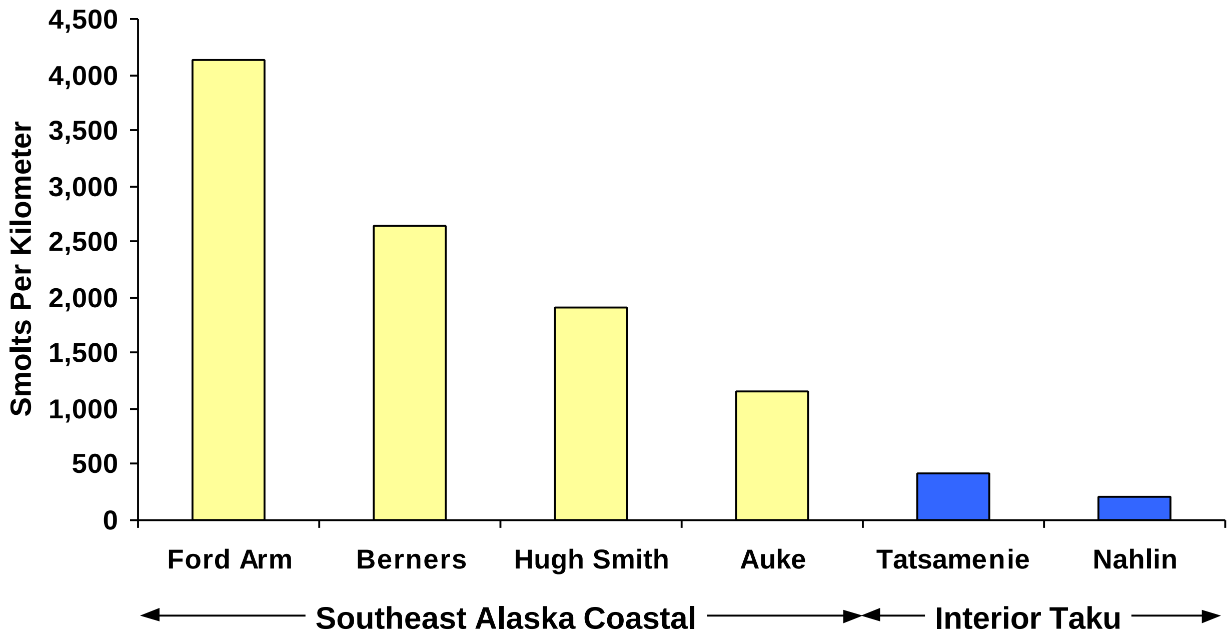

Figure 25. Estimated average number of coho salmon smolts produced per kilometer of habitat in four Southeast Alaska coastal systems and two interior tributaries of the Taku River.

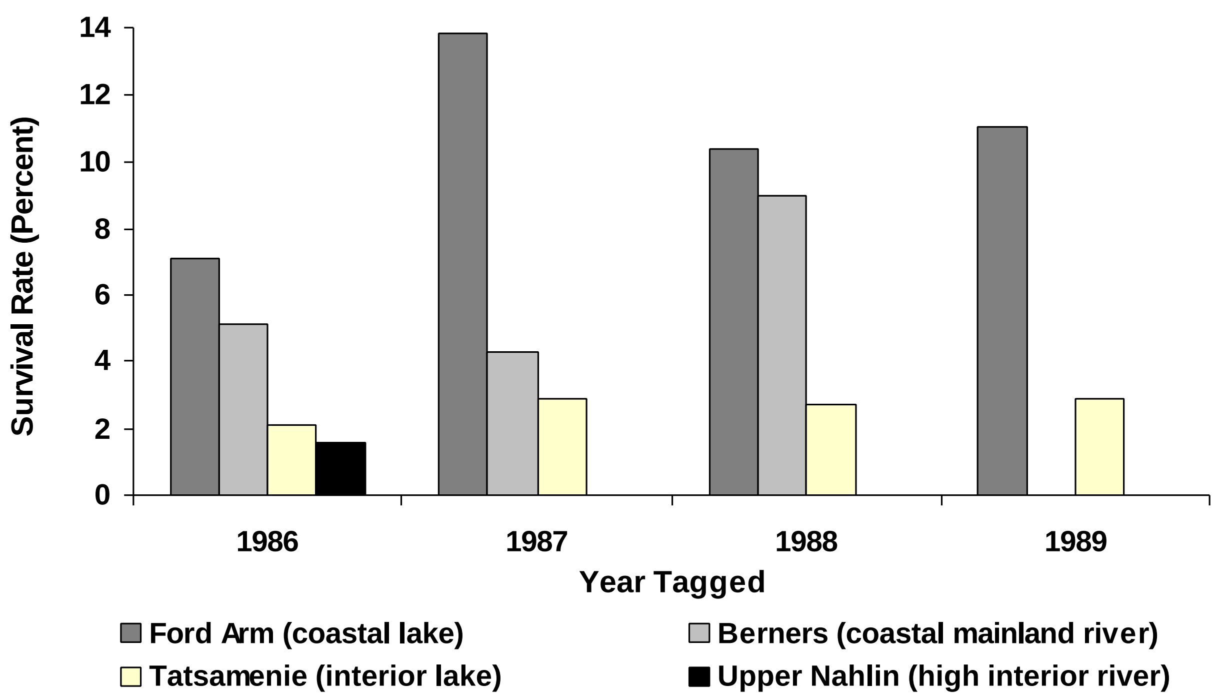

Figure 26. Survival rate estimates for coded wire tagged coho pre-smolts (>60 mm mideye-fork length) from the time of marking to adult return (two or three years later) for two coastal systems in Southeast Alaska and two interior tributaries of the Taku River.

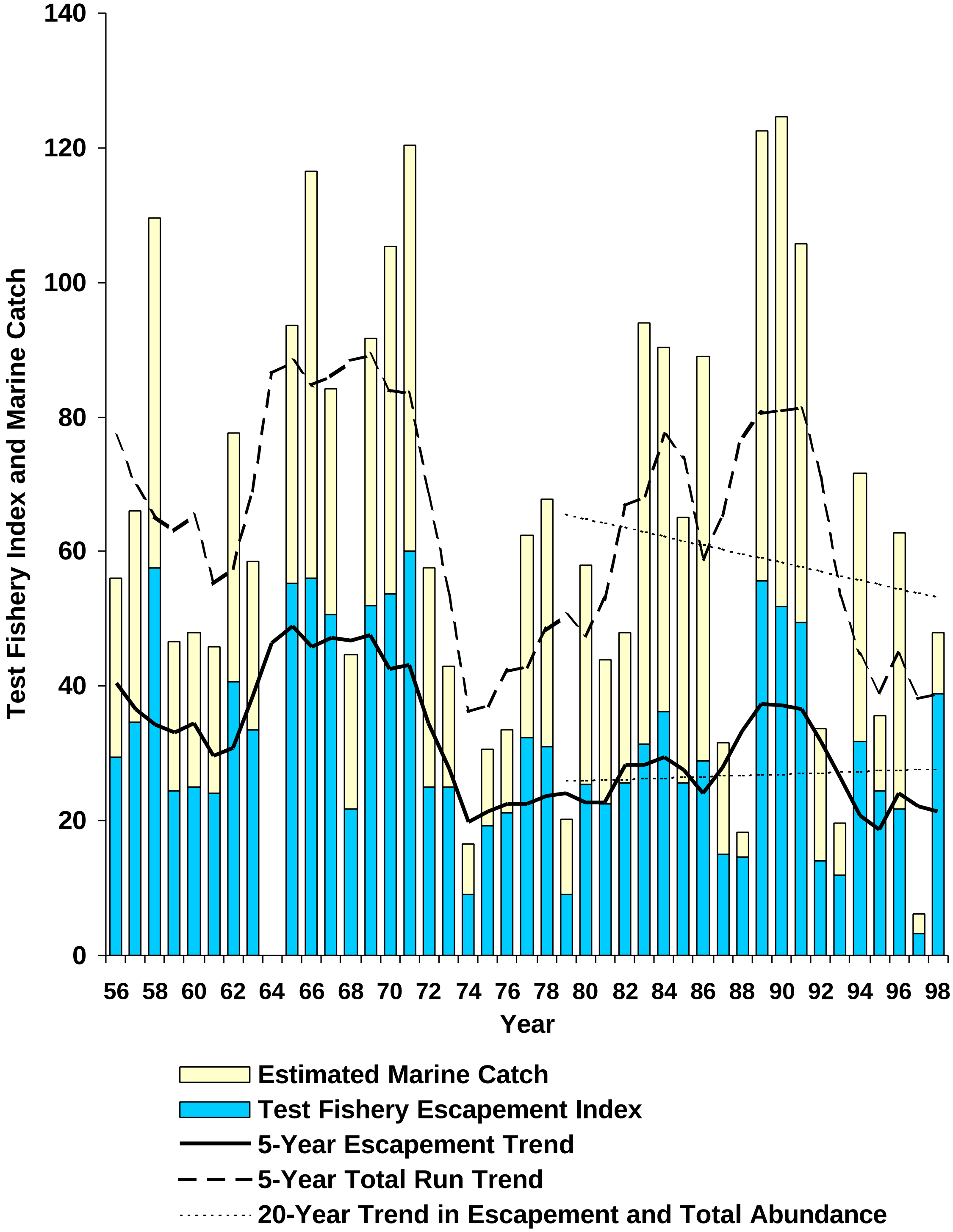

Figure 27. Tyee test fishery coho salmon index through September 1 adjusted by five-year average sockeye salmon catchability and with the estimated Babine contribution removed. Marine exploitation rates in 1988–1998 are coded wire tag estimates for the Toboggan Creek indicator stock while exploitation rates for previous years are estimated from fishing effort.

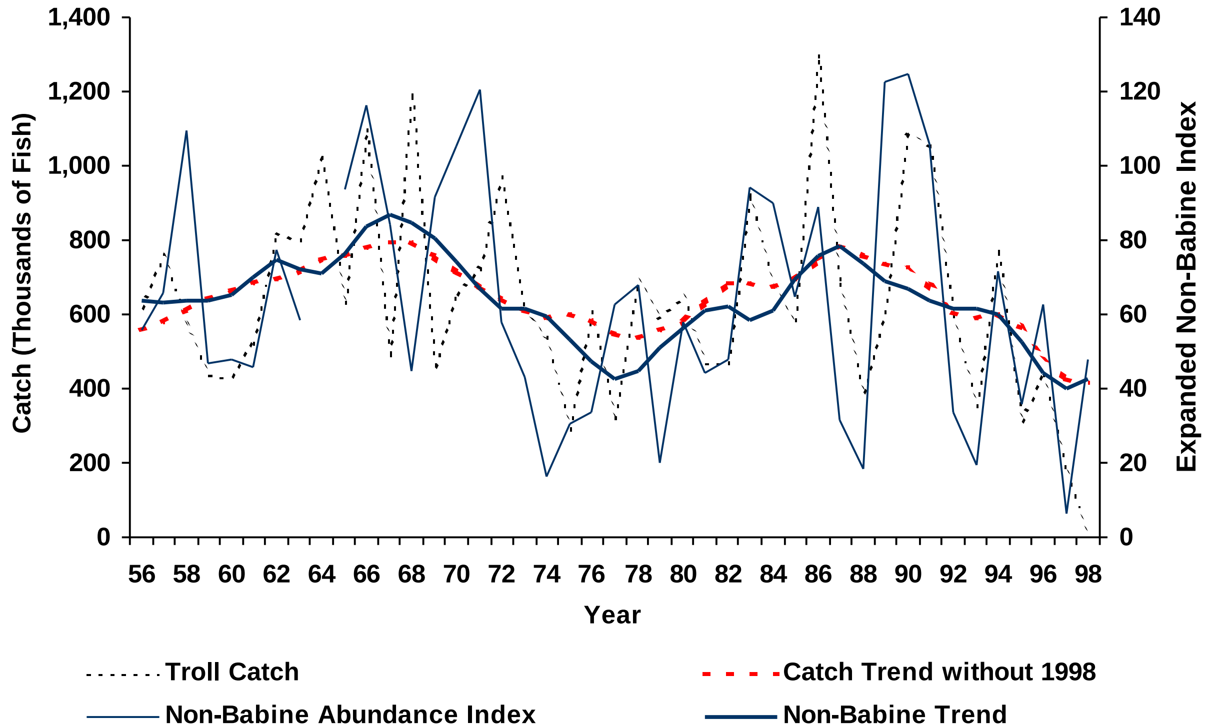

Figure 28. Tyee test fishery index of non-Babine coho salmon escapement to the Skeena River through September 1 adjusted for five-year sockeye salmon catchability and expanded to total run compared with the Canadian north coast troll coho catch, with 10-year average trends.

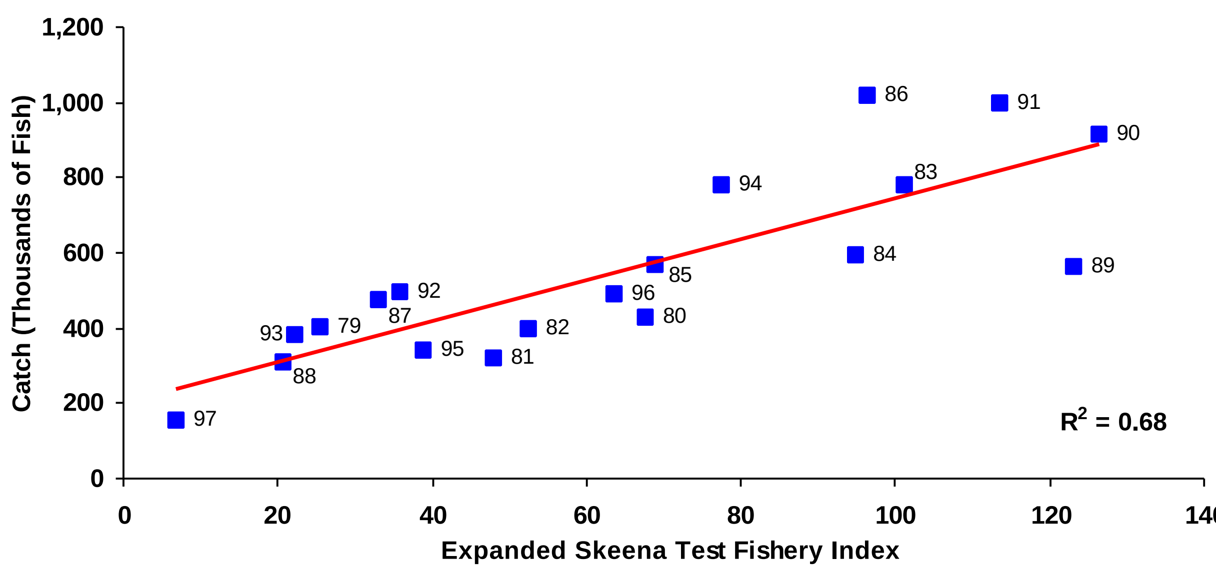

Figure 29. Linear relationship between the September 1 Skeena test fishery coho salmon index expanded to total abundance (including catch) and the commercial catch in Canadian areas 1, 3, and 4, 1979–1997.

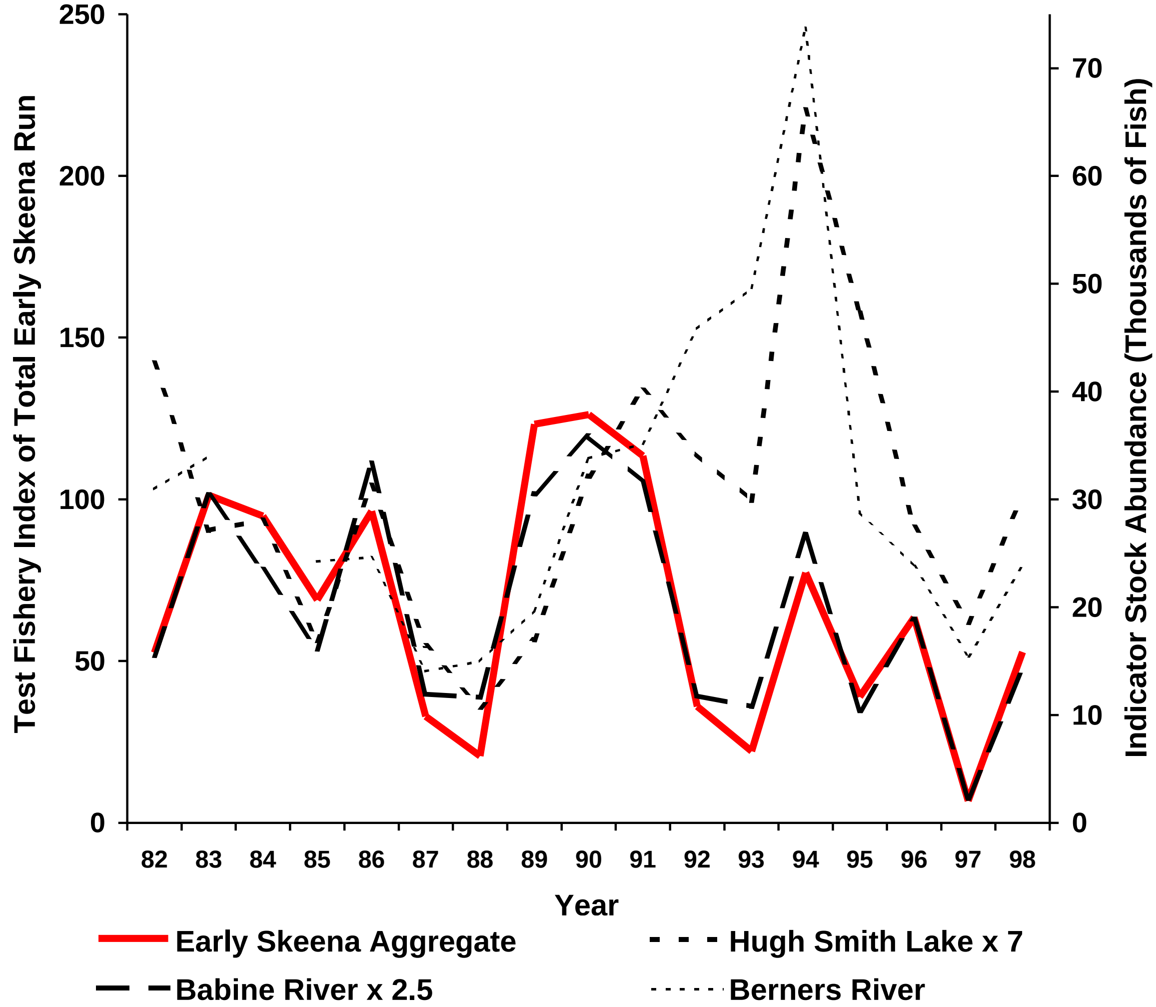

Figure 30. Two indicators of total abundance of upper Skeena coho salmon (Babine total run and Tyee index expanded to total catch) compared with total run size for two Southeast Alaska indicator stocks (Berners River and Hugh Smith Lake), 1982–1998.

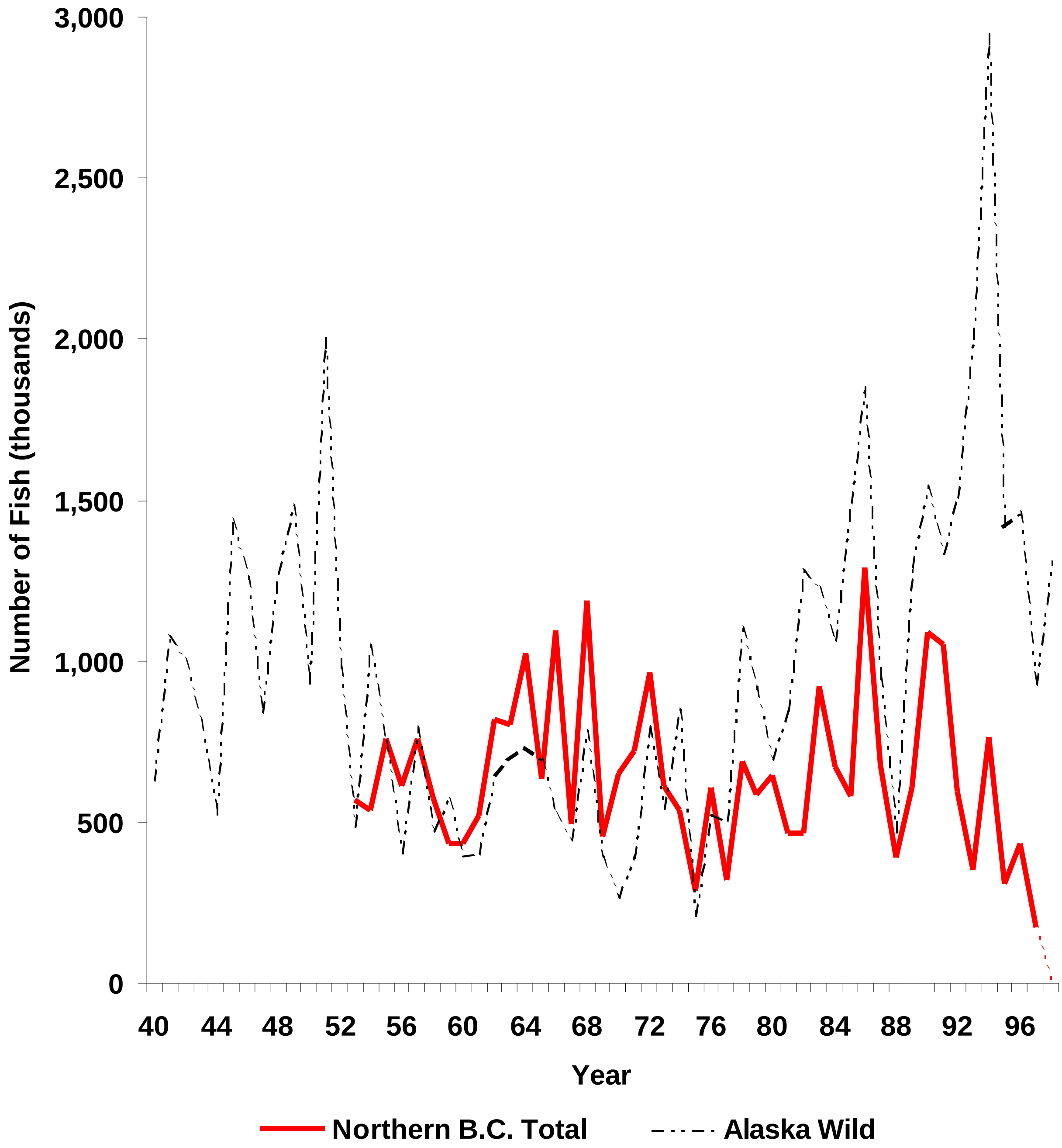

Figure 31. Troll catch of wild coho salmon in Southeast Alaska (1940–1998) and all coho salmon (including a small hatchery component) in northern British Columbia, 1953–1998.

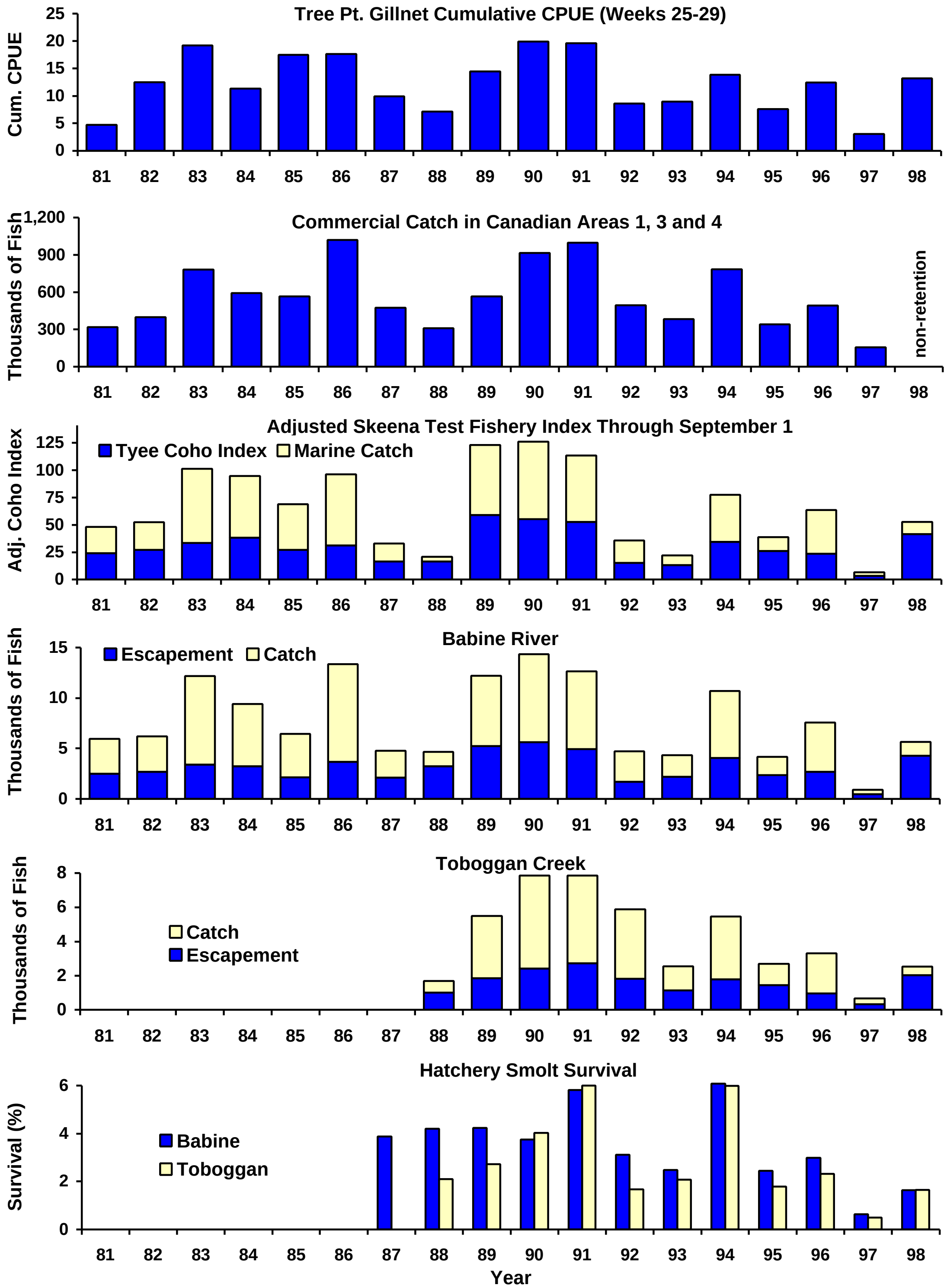

Figure 32. Six indicators of abundance of coho salmon stocks on the northern B.C. coast, 1981-1998.

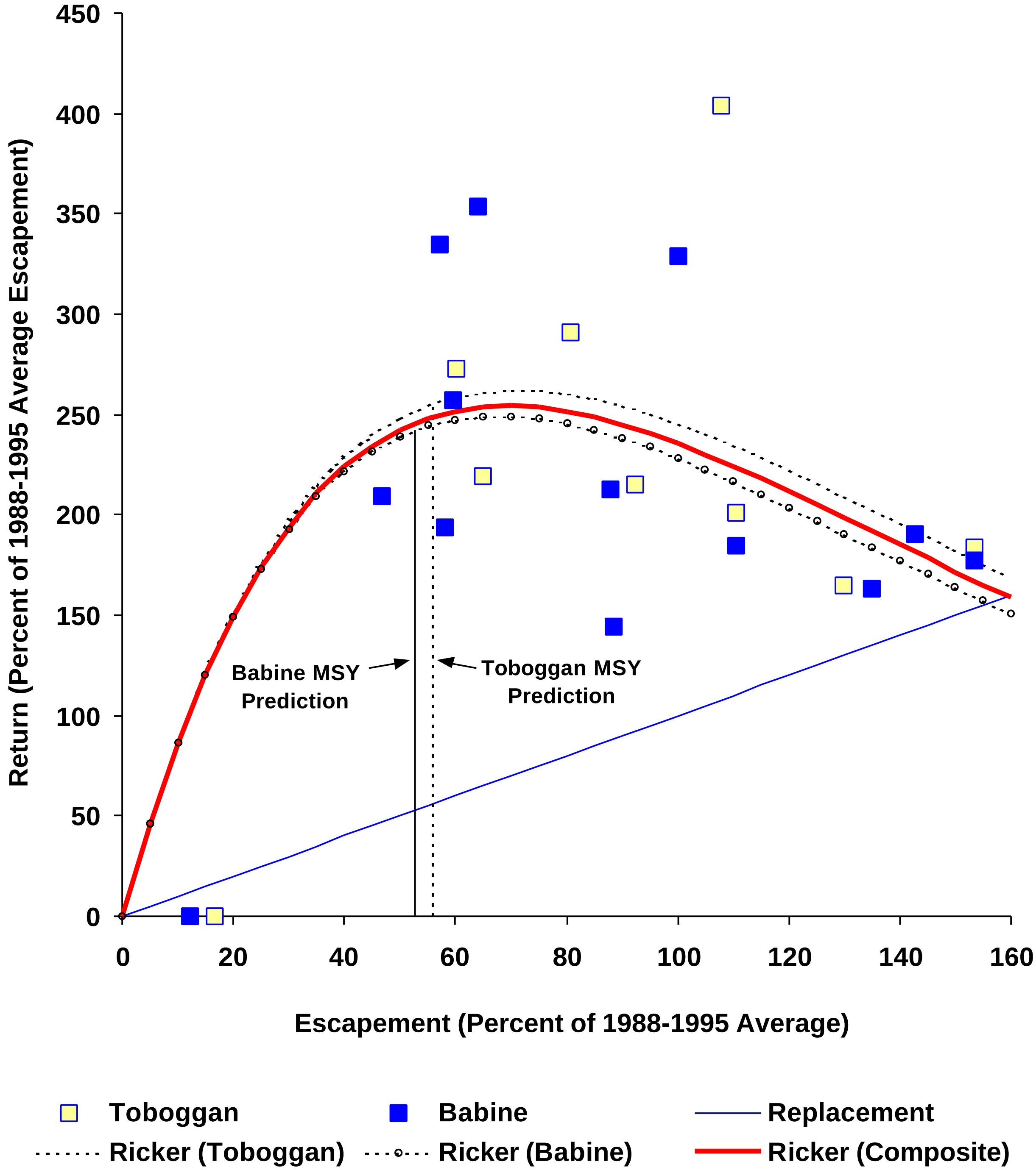

Figure 33. Ricker spawner-recruit relationships for Babine River (1984–1995) and Toboggan Creek (1988–1995) coho salmon scaled for comparability to the 1988–1995 average escapement to each system. Returns are adjusted to average marine survival based on local wild smolts for Toboggan Creek and average upper Skeena hatchery smolt survival for the Babine River. Escapements in 1997 are shown for comparison with return estimates pending until 2001.

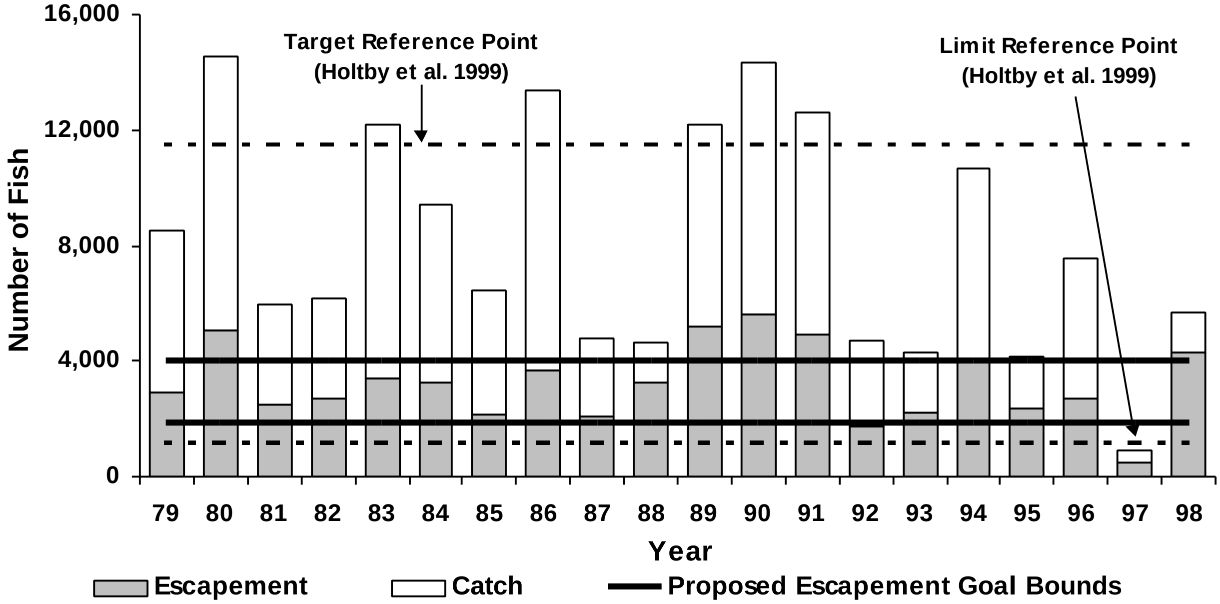

Figure 34. Proposed escapement goal range for Babine coho salmon compared with estimated returns and escapements, 1979–1998. The lower bound of 1,900 spawners is rounded from the estimated MSY escapement of 1,937 spawners. Also shown for comparison are the limit reference point (conservation floor) and target reference point (minimum management target escapement) proposed by Holtby et al. (1999).

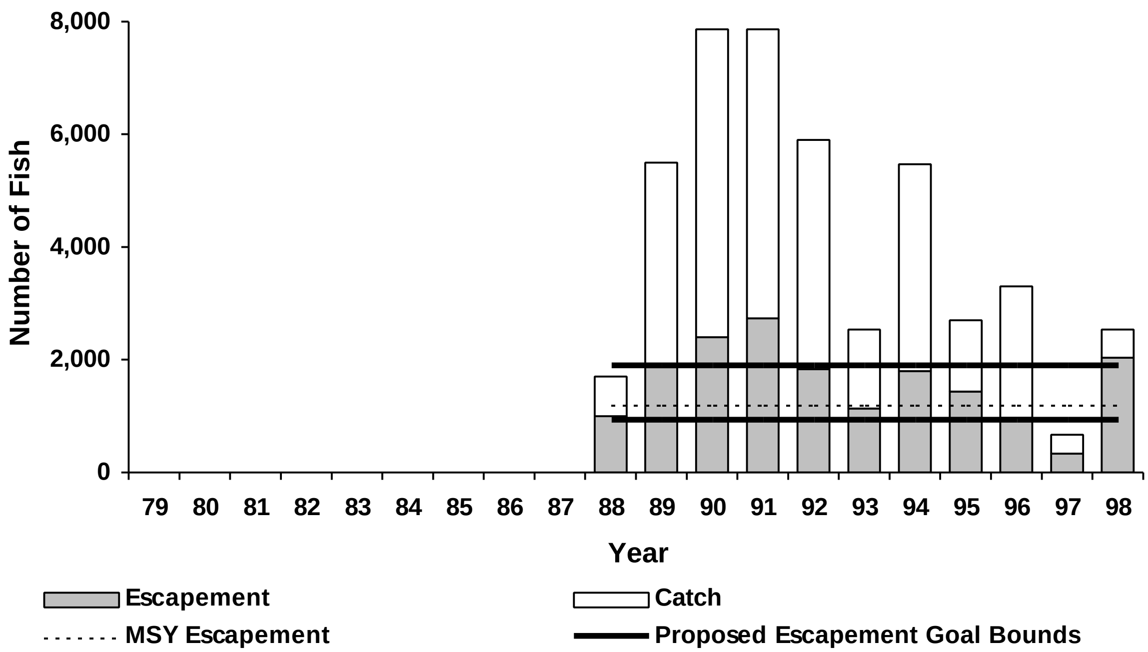

Figure 35. Proposed escapement goal range and estimated MSY escapement for Toboggan Creek coho salmon compared 1988–1998 returns of wild fish only. The proposed escapement goal range is 80%–160% of the estimated MSY level (1,188).

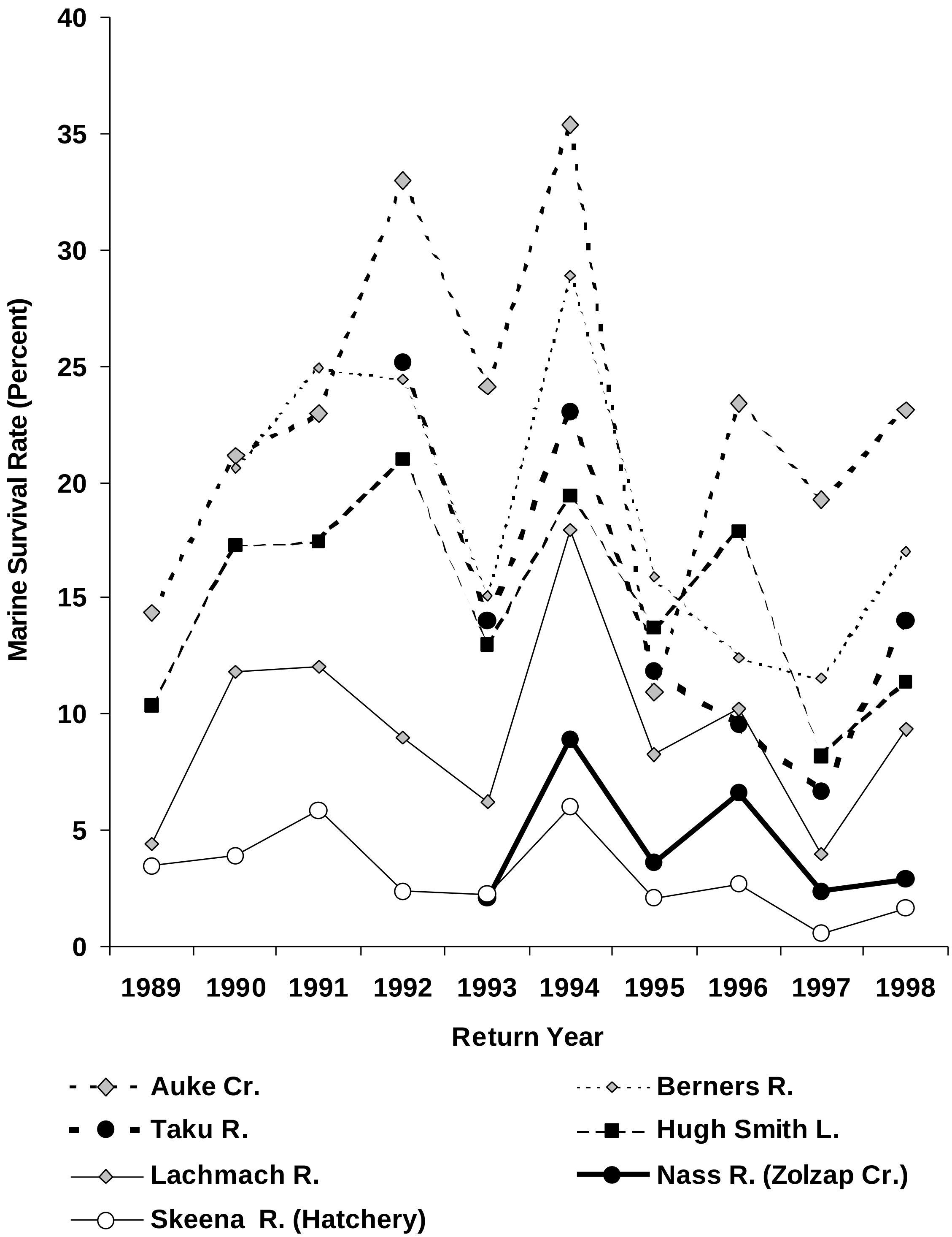

Figure 36. Estimated marine survival rate for coho salmon smolts from seven indicator stocks in Southeast Alaska and northern British Columbia, 1989–1998.

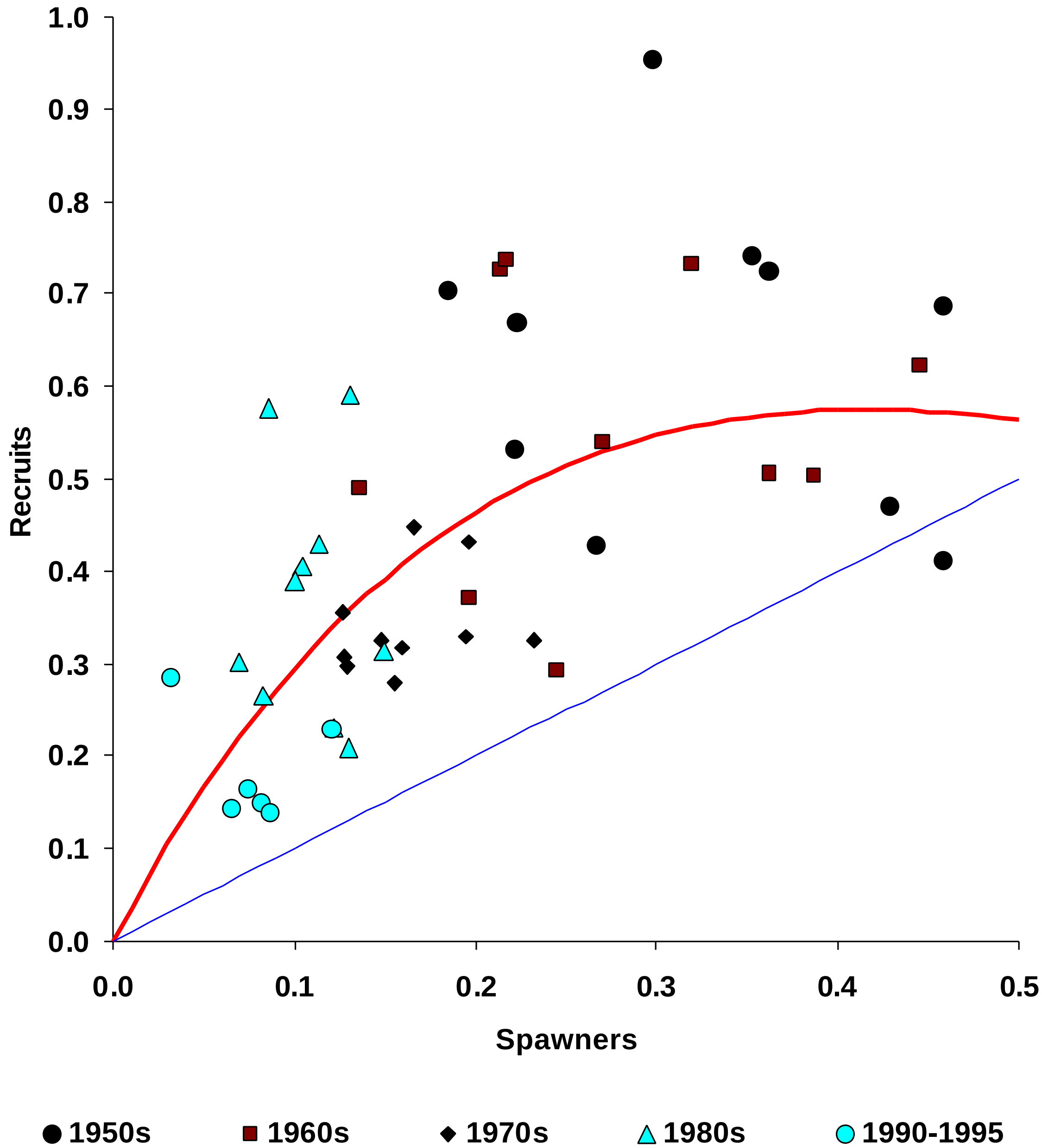

Figure 37. Ricker spawner-recruit relationship for Canadian Area 6 coho stocks from data presented by Holtby (1999). Symbols show the data segregated by decade.

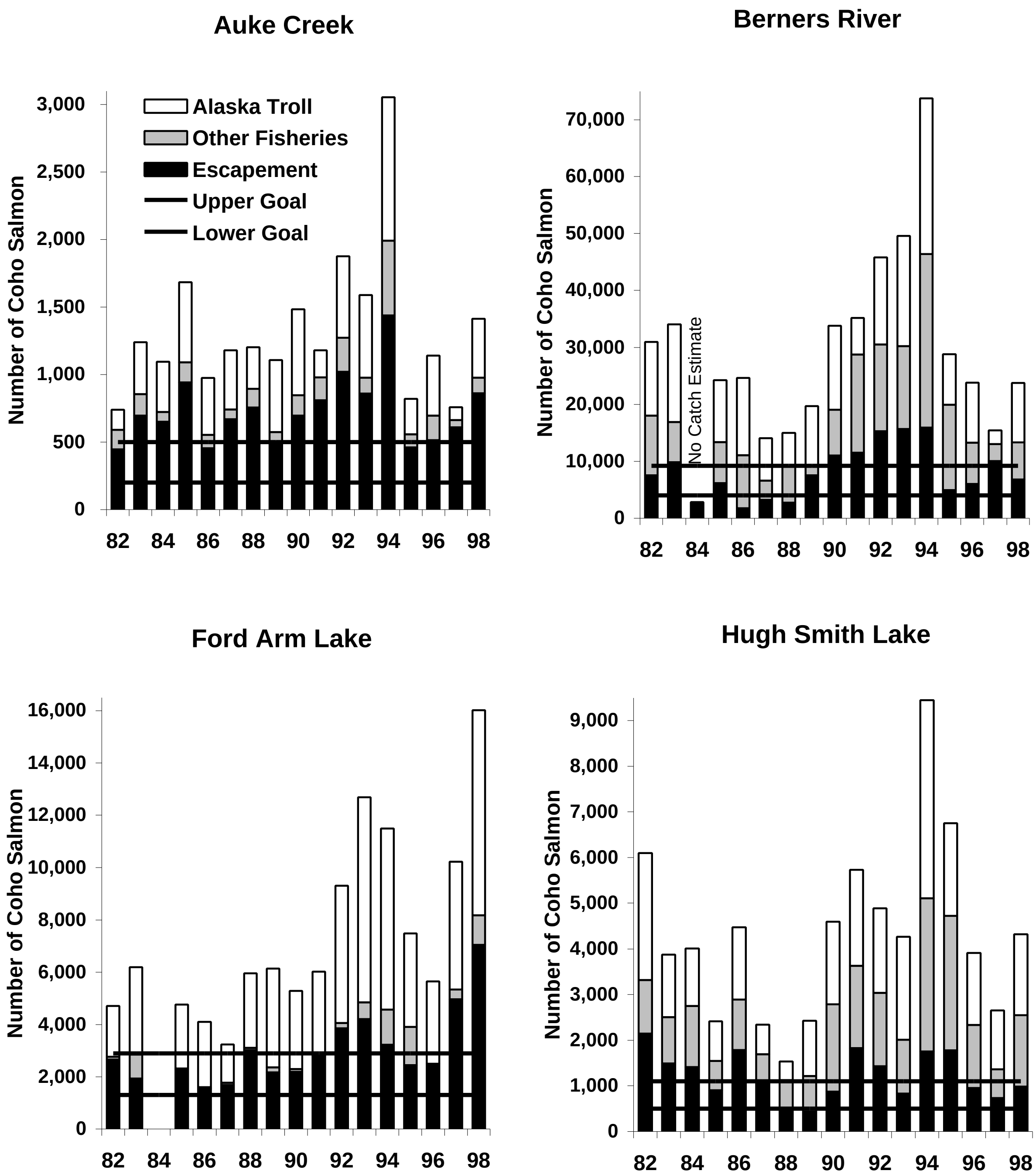

Figure 38. Total run size, catch, escapement and escapement goal range for four wild Southeast Alaska coho salmon indicator stocks, 1982–1998.

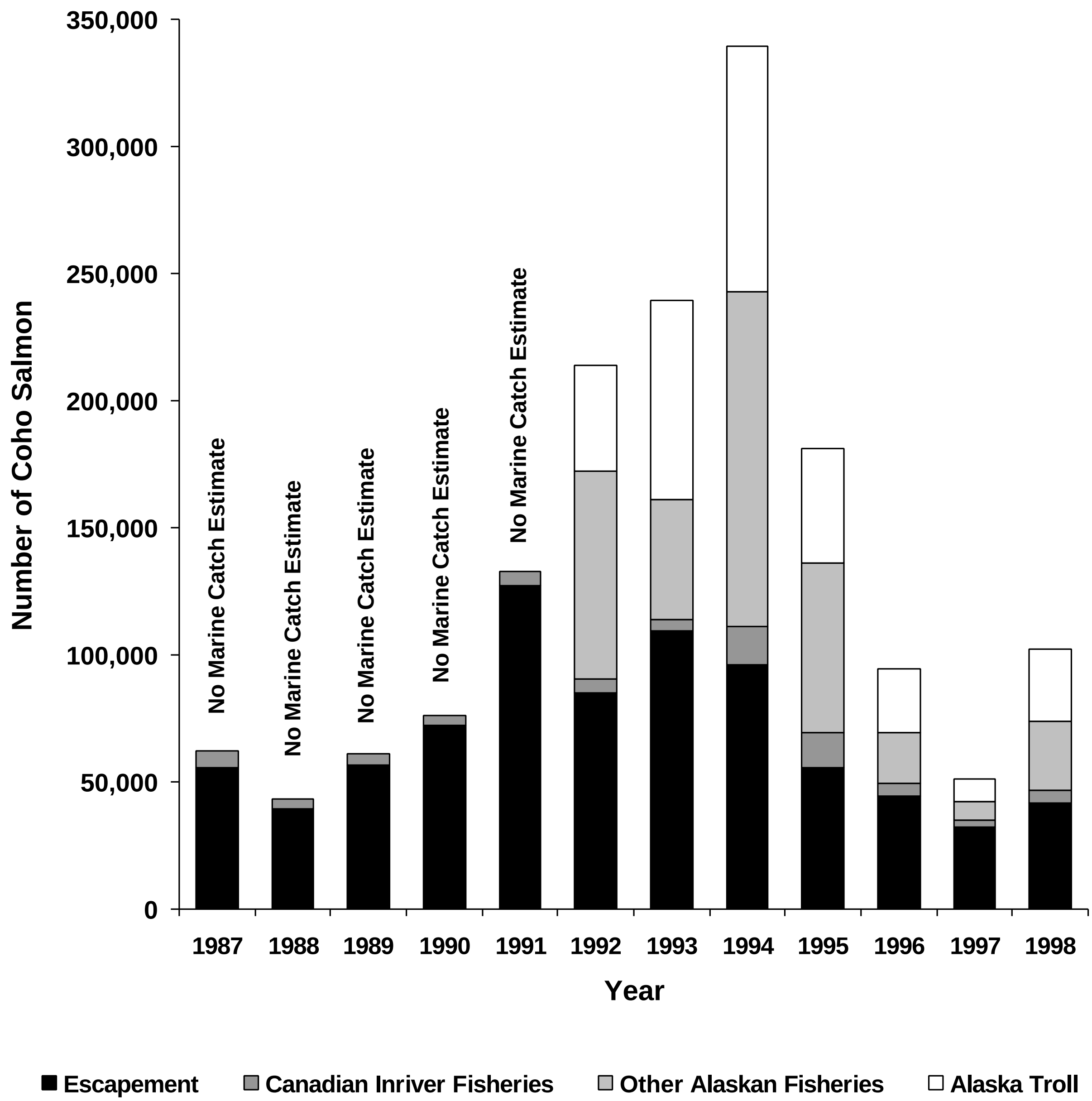

Figure 39. Catch and escapement estimates for transboundary Taku River coho salmon, 1987–1998.