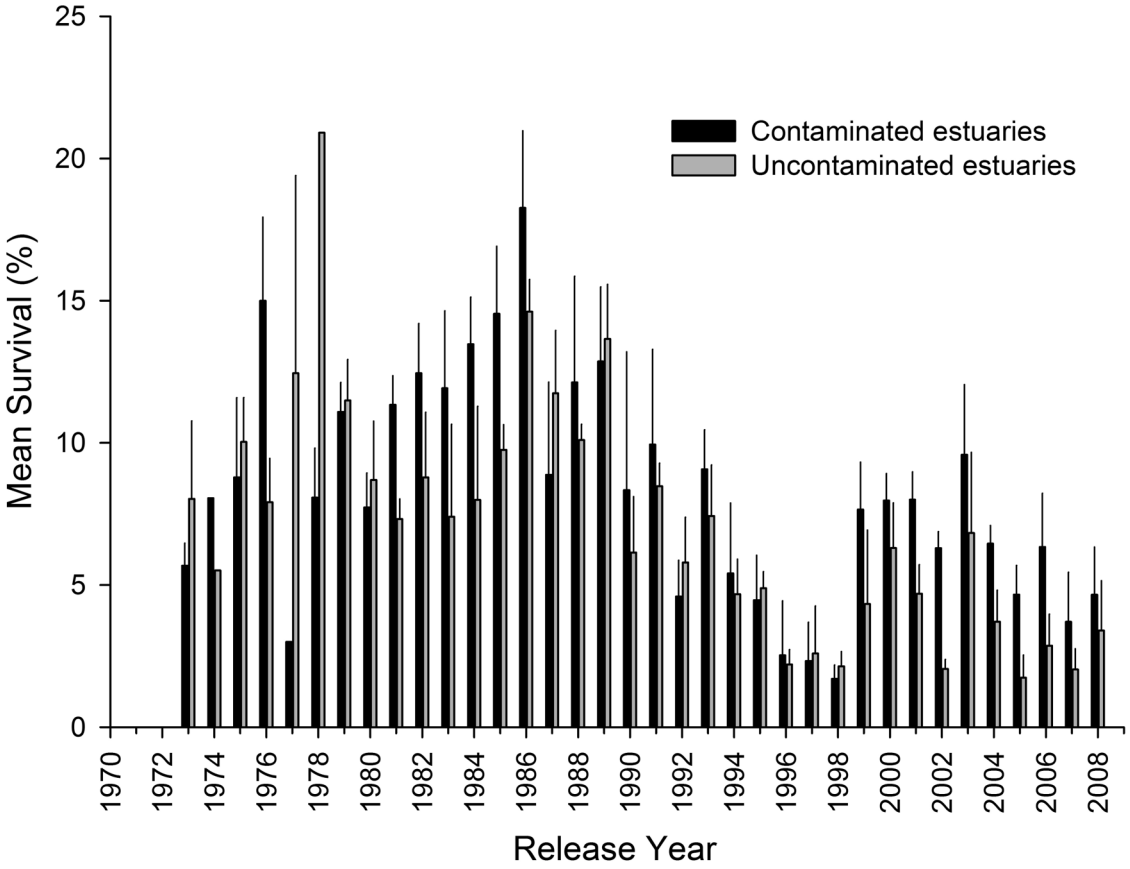
Fig. 3. Mean and standard error smolt-to-adult return rate (SAR) for groups of hatcheries releasing juvenile coho to contaminated and uncontaminated estuaries.



expected. It is important to note that these results held even when blocking by time, estuary size, release mass, and geographic location. The Wilcoxon test allowed for a year-by-year comparison that provided even stronger patterns compared with the analysis of all years together. Also, a focused evaluation for the last 10 years revealed essentially identical results as that for the overall analysis. Estuary size may affect the residence time for Chinook and limit their exposure to contaminants if they move through quickly; however, this factor was found to be unimportant in this analysis, as the results were the same when only large estuaries (>2.5 km^2) were considered. Also noteworthy is the absence of a pattern for high and low SAR values in the four geographic regions and the lack of correlation with distance from hatchery to estuary.

The observation of a substantially higher rate of survival for Chinook from uncontaminated estuaries over all years and the lack of such a strong difference for coho supports the hypotheses that contaminated estuaries decrease the probability of a successful life cycle. Outmigrating coho experience relatively similar freshwater and oceanic conditions as Chinook, but spend little time in the local estuaries and generally move quickly to marine waters. Surprisingly, the data show that survival is slightly higher for coho transiting contaminated estuaries, which is mostly due to the Wallace River hatchery, as shown in the Results section. For Chinook, the aggregate data often appear contradictory, in that mean SAR values for some hatcheries releasing fish to uncontaminated estuaries are comparable to or even lower than those for hatcheries releasing to contaminated systems (Table 3), which is due in part to relatively high SARs in the 1970s and 1980s for some hatcheries. Even though the overall pattern does show some important correlations, it is more appropriate to conduct such an analysis year by year to mitigate the high interannual variability in survival. For example, even though Soos Creek fish exhibited a relatively high overall SAR value (Table 3), survival was higher than the mean value for fish from hatcheries transiting uncontaminated estuaries for only 7 of 29 years examined, and 4 of the 7 years were less than 20% higher.

Non-contaminant factors potentially affecting smolt-to-adult survival

A number of authors have addressed the importance of estuarine residence for salmonids, especially juvenile Chinook. The crucial factors that are commonly listed include refuge from predation, freshwater–seawater transitional areas, and productive foraging allowing increased growth (Simenstad et al. 1982; Healey 1982; Macdonald et al. 1988; Thorpe 1994). Adjunct to these are such factors as flow rate, water temperature, intraspecific and interspecific competition, hatchery practices and husbandry, fish stock (genetic differences), contamination, habitat quality (e.g., sediment type, prey availability, cover, predator densities), and numerous minor attributes. Hatchery practices are multifaceted and include a number of factors such as age of the hatchery, disease accumulation, and genetic changes, all of which were ruled out as important by Coronado and Hilborn (1998) in their analysis of Chinook and coho survival in the Pacific Northwest. Often an estuary is considered in terms of its natural or "pristine" state, which encompasses many of the factors listed above. As acknowledged by Magnusson and Hilborn (2003), factors that covary with the degree of pristine habitat may be important in determining survival for outmigrating Chinook. Some of the more important factors that could potentially affect the success of juvenile Chinook reaching the adult phase are addressed below, such as fish density, migration distance to the estuary, availability of prey, and growth rate. The conclusion here is that contamination

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