Survival Rates of Coho (*Oncorhynchus kisutch*) and Chinook Salmon (*O. shawytscha*) Released from Coastal Washington and Oregon Hatcheries ..... Chapter 6

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Introduction

Coho (*Oncorhynchus kisutch*) and chinook (*Oncorhynchus tshawytscha*) salmon have been released from hatcheries on the U.S. and Canadian Pacific coast since the late 1800s, but it was not until the 1960s and 1970s that the number of hatcheries and their release output increased dramatically. This was in response to dwindling spawner returns, and today more than half of the salmon catches in the Pacific Northwest are of hatchery origin. However, in Alaska the opposite is true, where most runs consist of wild spawners in pristine watersheds (NRC 1996).

The number of returning spawners, wild and hatchery-reared, fluctuates considerably between years and the dynamics behind those changes are often far from understood. Due to the complex salmon life cycle their survival can be impacted by a multitude of physical and biological factors in local watersheds and the ocean. Macdonald et al. (1988) approached this problem with a direct experiment and found that chinook smolts are subject to considerable mortalities in estuaries and in the ocean just outside estuaries, but in recent years much of the research effort has been directed towards coho survival rate and its relationship with oceanic conditions (Ryding and Skalski 1999; Cole 2000; Hobday and Boehlert 2001). In this paper, temporal patterns of coho and chinook survival rate are compared between regions in an attempt to separate watershed-specific changes from interregional trends. If regions separated by hundreds of kilometers show similar fluctuations of survival rate it seems likely that large-scale effects such as climate play a dominant role in determining salmon survival rate. If the temporal patterns of coho and chinook survival rates look similar within a region, it seems likely that the two species are subject to the same kind of mortalities.

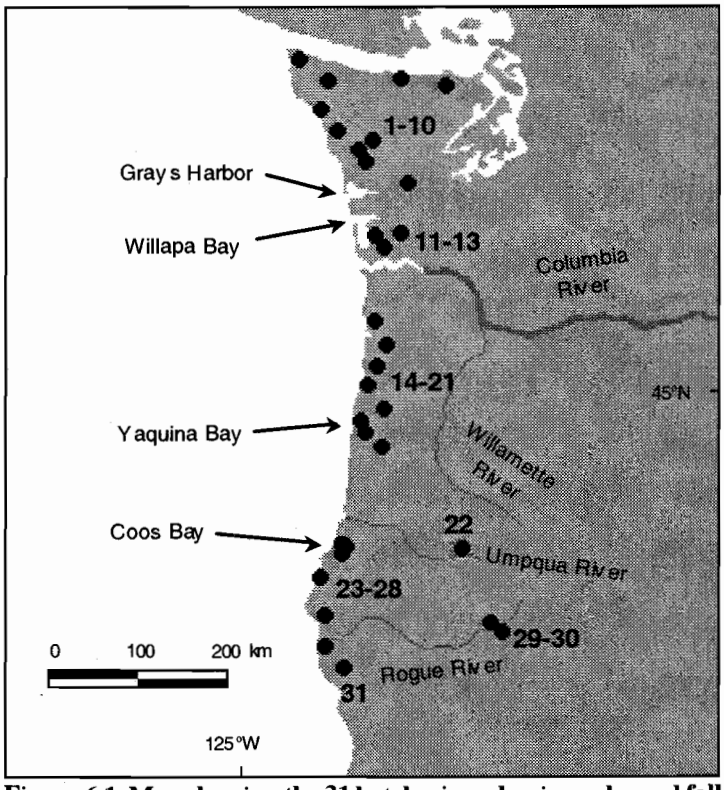

Figure 6.1. Map showing the 31 hatcheries releasing coho and fall chinook in coastal Washington and Oregon. The Columbia River divides coastal Washington and Oregon.

Methods

Survival rate, defined as the proportion of individuals surviving from smolt release to adulthood, was estimated from coded-wire-tag (CWT, Jefferts et al. 1963; Johnson 1990) recoveries obtained from the CWT database of the Pacific States Marine Fisheries Commission (Gladstone, Oregon). The analysis included 15,136 coho and fall chinook CWT groups, tagged and released from 189 hatcheries in Alaska in the north to California in the south. The coho groups were released in the years 1972–1998 and the fall chinook groups were released 1972–1996. Survival rates of spring chinook (Magnusson 2002) are not reported here, as relatively few of them are released from coastal hatcheries in Washington and Oregon.

Coho are released at age two and fall chinook during the first year following their brood year. Both species generally return at age three, but the age distribution at recovery varies between regions, and because of this variation, standardization of the number of fish recovered (Coronado and Hilborn 1998) was necessary to compare survival rates between regions:

$$N_3^* = C_2 s_2 + C_3 + \frac{C_4}{s_3} + \frac{C_5}{s_3 s_4} + \frac{C_6}{s_3 s_4 s_5}$$

where N^*_3 is the number of 3-year-olds from a particular release group that would be alive if none were recovered at an age different from age three, C_a is the number of fish recovered at age a, and s_a is the adult ocean survival rate from age a to $a+1$. For coho, s_a=0.5 across all ages, but for chinook s_2=0.6, s_3=0.7, s_4=0.8, s_5=0.9 (Argue et al. 1983). This assumed adult ocean survival rate plays a minor role in the computations, since most individuals are recovered at age three, and should not be confused with the estimated smolt-to-adult survival rate which depends primarily on the first few months after release. Survival rate of each CWT release group was estimated as:

$$\text{Survival} = \frac{N_3^*}{\text{No. released}}$$

Table 6.1. List of the 31 hatcheries releasing coho and fall chinook in coastal Washington, Oregon and California. "Label" refers to the map labels, "Grps" stands for number of CWT groups released and "Surv" stands for average survival rate.

				Coho		Fall chinook	
Label	Hatchery	State	Estuary	Grps	Surv	Grps	Surv
01	Dungeness	WA	Dungeness Bay	50	4.19%		
02	Lower Elwha	WA	Freshwater Bay	28	1.28%	31	0.31%
03	Makah	WA	Mukkaw Bay	43	3.66%	46	0.26%
04	Solduc	WA	Quillayute River	115	1.42%	25	0.37%
05	Chalaat Creek	WA	Hoh River	13	1.03%		
06	Salmon River (WA)	WA	Queets River	46	1.00%	11	0.70%
07	Quinault	WA	Quinault River	54	1.30%	55	0.81%
08	Quinault Lake	WA	Quinault River	53	1.15%	43	0.71%
09	Humptulips	WA	Grays Harbor	62	2.20%	10	1.23%
10	Bingham Creek	WA	Grays Harbor	61	1.55%	14	0.51%
11	Forks Creek	WA	Willapa Bay	26	2.87%	17	1.13%
12	Nemah	WA	Willapa Bay			18	1.06%
13	Naselle	WA	Willapa Bay	10	5.96%		
14	Nehalem	OR	Nehalem Bay	52	1.26%		
15	Trask	OR	Tillamook Bay	53	1.31%	139	0.75%
16	Cedar Creek	OR	Nestucca Bay			17	0.62%
17	Salmon River (OR)	OR	Salmon River	50	0.81%	59	2.28%
18	Siletz	OR	Siletz River	30	1.27%		
19	Yaquina Bay	OR	Yaquina Bay	628	0.75%	85	1.14%
20	Wright Creek	OR	Yaquina Bay	59	0.38%		
21	Fall Creek	OR	Alsea Bay	122	1.09%	14	0.90%
22	Rock Creek	OR	Umpqua River	37	1.47%	33	0.56%
23	Coos Bay (Anad Inc)	OR	Coos Bay	239	1.91%	135	1.07%
24	Domsea Farms	OR	Coos Bay	13	0.95%	10	0.35%
25	Coos Bay (Oreg Aqua)	OR	Coos Bay	22	0.73%		
26	Bandon	OR	Coquille Bay	12	0.72%	10	0.25%
27	Elk River	OR	Elk River			146	1.82%
28	Indian Creek	OR	Rogue River			14	0.53%
29	Cole Rivers	OR	Rogue River	59	2.77%	280	2.23%
30	Butte Falls	OR	Rogue River	54	1.76%	15	0.99%
31	Burnt Hill Creek	OR	Chetco Bay			19	0.92%

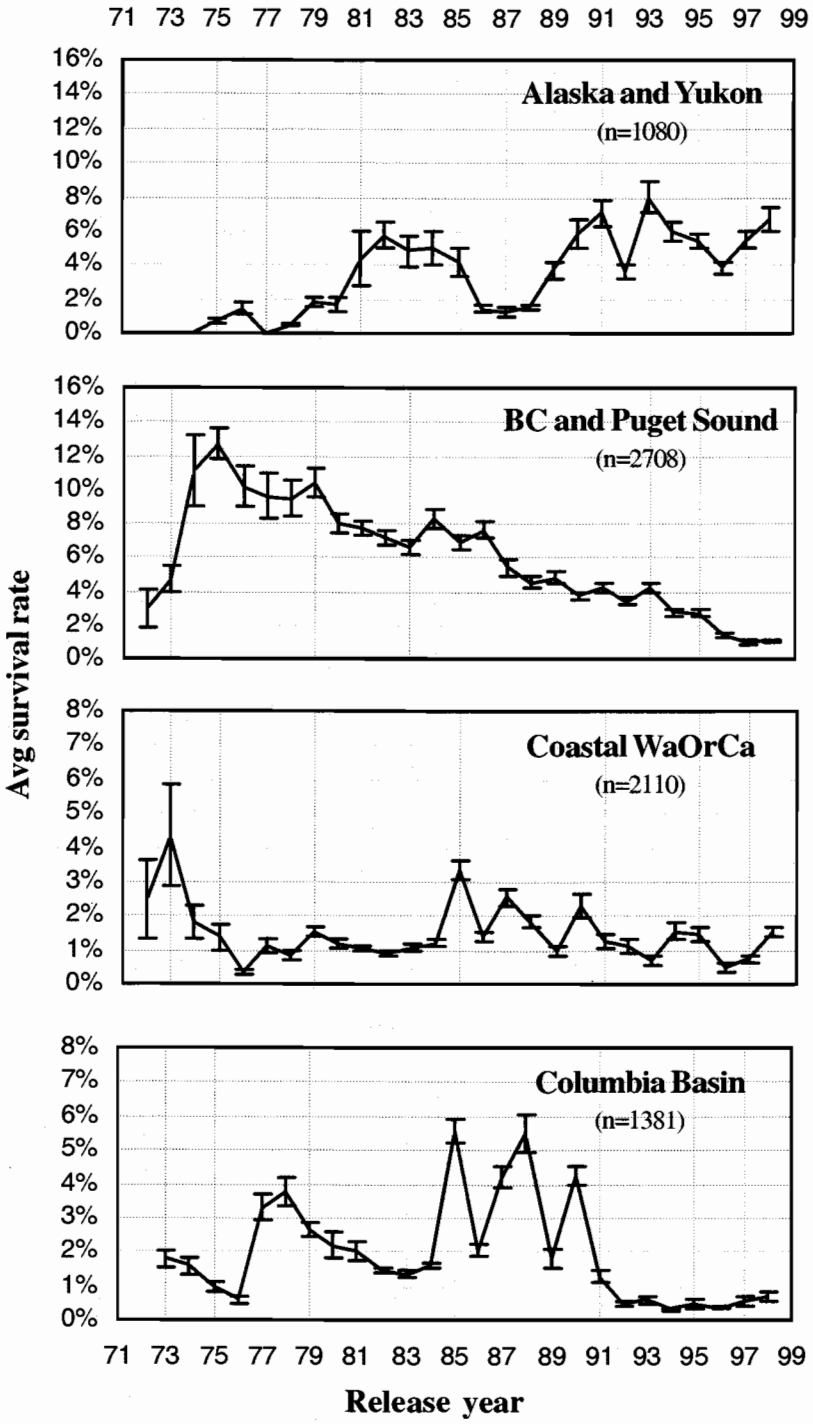

Figure 6.2. Coho survival rates by release year in each geographical domain. The number of CWT groups released is shown within parenthesis and the error bars show the standard error of the mean.

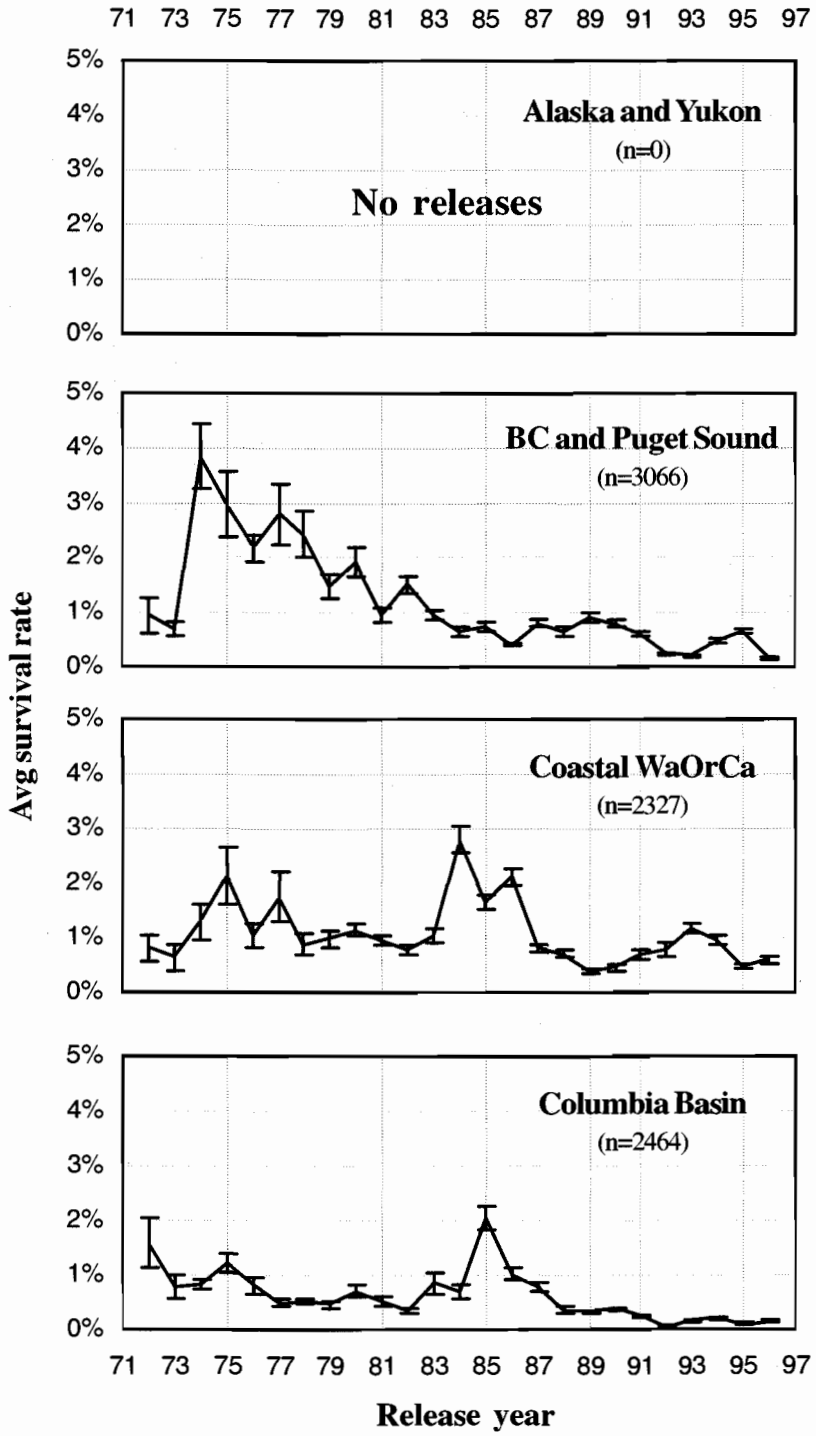

Figure 6.3. Fall chinook survival rates by release year in each geographical domain. The number of CWT groups released is shown within parenthesis and the error bars show the standard error of the mean.

All recoveries are treated the same, be they from ocean catches, freshwater catches, or hatchery escapement, which makes the survival rate a robust statistic under varying fishing intensity. Average survival was calculated as the arithmetic mean of survival for individual tag codes, grouped by hatchery location and release year, and the standard deviation of the mean is included in the charts as a measure of variability of the average survival.

The 189 hatcheries are grouped into four geographic domains on the basis of similar survival rate trends: (1) Alaska and Yukon; (2) British Columbia and Puget Sound; (3) Coastal Washington, Oregon and California; and (4) Columbia Basin. The 31 hatcheries in coastal Washington and coastal Oregon (Figure 6.1, Table 6.1) release coho and fall chinook into 22 different estuaries, and four key estuaries were analyzed in further detail: Grays Harbor, Willapa Bay, Yaquina Bay and Coos Bay. The wetted area of each estuary is 252 km^2, 347 km^2, 17 km^2 and 50 km^2, respectively (Simenstad 1984).

Apart from release and recovery data of hatchery-reared salmon, the CWT database contains a small amount of data from wild smolt tagging studies. When nearby hatcheries were releasing groups of the same species in the same year, these data allow a comparison of survival rates of hatchery and wild fish. The longest comparative time series are presented, with 85 wild groups of coho tagged in northern Washington and 34 wild groups of fall chinook tagged in northern California.

Results

All regions

The average survival rate of all 7279 coho CWT groups is 3.4%. In British Columbia and Puget Sound the survival rates have declined steadily from around 11% in the mid 1970s down to around 2% in the mid 1990s (Figure 6.2). During the same time period, the survival rates in Alaska have been increasing from around 1% to 6%, except for a sharp temporary decline in 1986–1988. The coho survival rate patterns in Columbia Basin are characterized by large fluctuations (between 1.3% and 5.6%) during the 1980s, followed by very low survival rates in the 1990s, around 0.5%.

Fall chinook are only released in regions south of Alaska, and the average survival rate of all 7857 CWT groups is 0.8%. The temporal patterns (Figure 6.3) are not unlike those found for coho, being a steady decline in British Columbia and Puget Sound, from around 3% in the mid 1970s down to around 0.5% in the mid 1990s. Another similarity is the consistent low survival rate in Columbia Basin during the later years, around 0.2% on average in the 1990s.

Coastal Washington and Oregon

The average survival rate of coho released from hatcheries in coastal Washington is 2.0%, somewhat higher than 1.2% in coastal Oregon (Figure 6.4). In Oregon, the highest coho survival rates are during the mid 1980s, but the fluctuations in Washington are less regular. Fall chinook survival rates average 0.6% in coastal Wash-

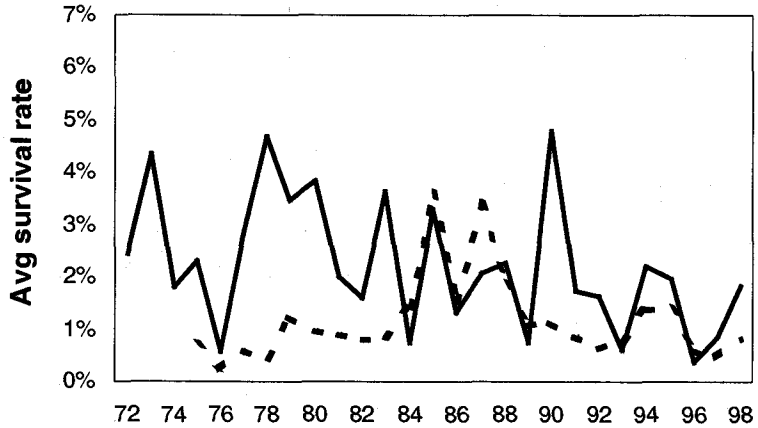

Figure 6.4. Coho survival rates by release year in coastal Washington (solid line, 561 CWT groups) and coastal Oregon (dotted line, 1430 CWT groups).

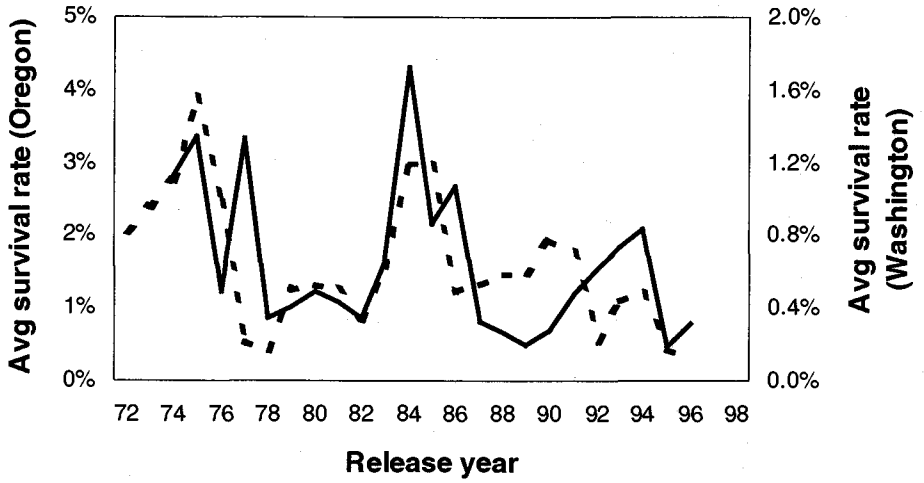

Figure 6.5. Fall chinook survival rates by release year in coastal Washington (solid line, 270 CWT groups) and coastal Oregon (dotted line, 976 CWT groups).

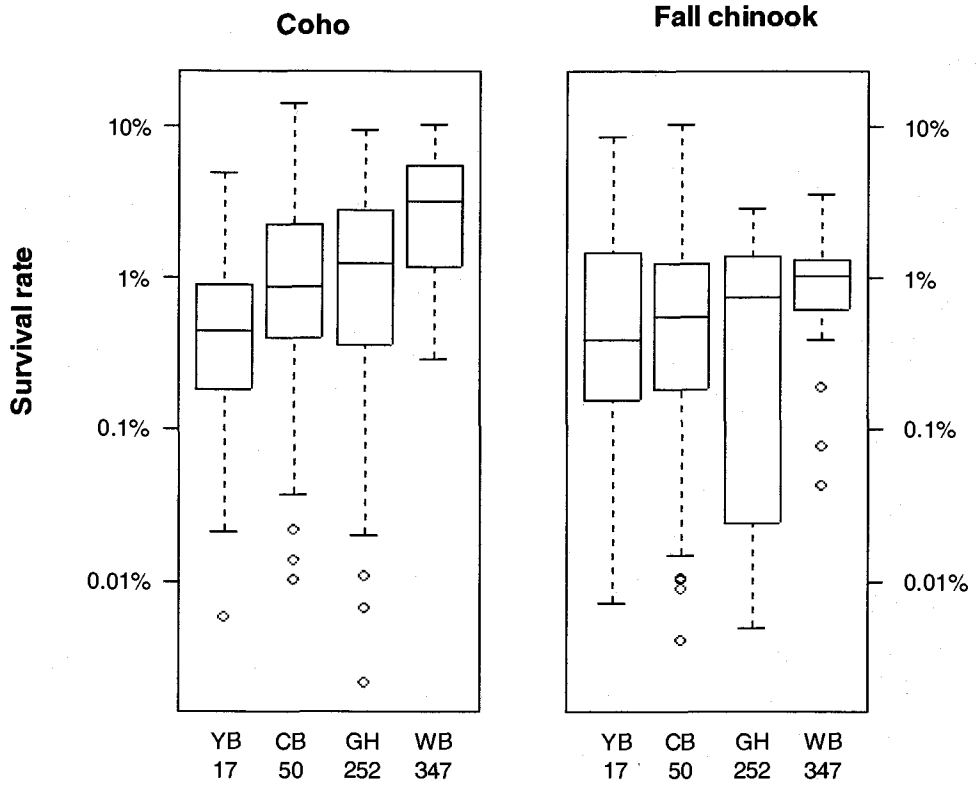

Figure 6.6. Boxplots of coho and fall chinook survival rates in Yaquina Bay (YB), Coos Bay (CB), Grays Harbor (GH), and Willamette Bay (WB). The survival rates are graphed on log-scale and the numerical labels show the size of each estuary in km^2.

ington, which is considerably lower than 1.5% in coastal Oregon (Figure 6.5), but in proportional terms the trends are quite similar. In both regions the highest survival rates are in the mid 1970s and mid 1980s.

The three hatcheries that have released most coho CWT groups are all in Oregon, (Yaquina Bay, Coos Bay/ Anadromous Inc., and Fall Creek), but the hatcheries with the highest coho survival rates are all in Washing-

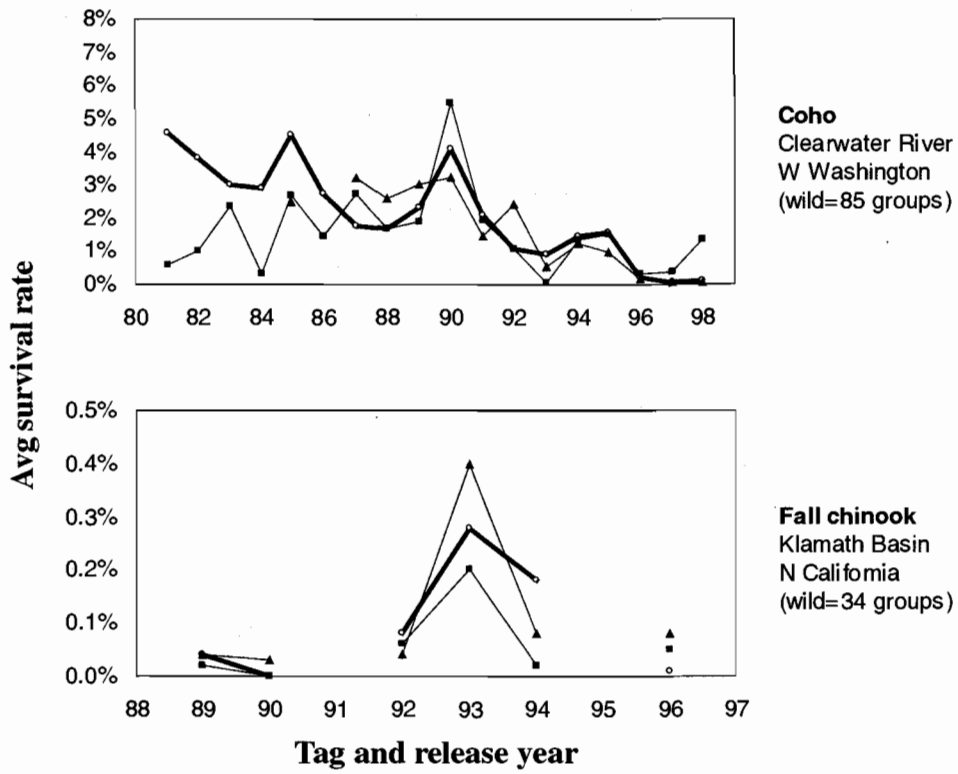

Figure 6.7. Survival rates of tagged wild (W) smolts compared with those released from nearby hatcheries (H). For the purposes of comparison, datapoints are only displayed in years when tagging was conducted both at hatcheries and in the wild.

ton: Naselle, Dungeness, and Makah (Table 6.1). For fall chinook, on the other hand, the hatcheries with the most releases (Cole Rivers, Elk River, and Trask) and the highest survival rates (Salmon River, Cole Rivers, and Elk River) are all in Oregon.

Estuary size

Looking at Grays Harbor, Willapa Bay, Yaquina Bay and Coos Bay with respect to estuary size, coho survival rates tend to be higher in the larger estuaries (Figure 6.6), but such a relationship is not apparent from the fall chinook data.

Wild and hatchery salmon

Survival rates of wild coho tagged in Clearwater River, western Washington, follow the same fluctuations as the survival rates of hatchery fish released from nearby hatcheries (Figure 6.7). The same is true for wild fall chinook tagged in Klamath Basin, northern California, although there are fewer years of data for the comparison.

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Applications

Publications:

Magnusson, A. 2002. Survival rates of coho (*Oncorhynchus kisutch*) and chinook salmon (*O. tshawytscha*) released from hatcheries on the U.S. and Canadian Pacific coast 1972–1998, with respect to climate and habitat effects. M.S. thesis, School of Aquatic and Fishery Sciences, University of Washington, Seattle, WA.

Presentations:

Arni Magnusson. "Survival rates of coho and chinook salmon with respect to climate and habitat effects." M.S. defense, Jan 11, 2002, School of Aquatic and Fishery Sciences, University of Washington, Seattle, WA.

Arni Magnusson. "Climate and habitat effects on smolt survival rates." Northwest Salmonid Recovery Conference, Oct 24, 2002, Mountaineers Club, Seattle, WA.

Workshops:

None.

Partnerships:

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