Trends in the Status of Pacific Salmon Populations in Washington, Oregon, California, and Idaho

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Over the past 3 years, the National Marine Fisheries Service, Northwest Fisheries Science Center has conducted coastwide status reviews of Pacific salmon in Washington, Oregon, California, and Idaho. Patterns of stock health have emerged that relate to life history, and freshwater and marine distribution. For most species, the health of natural populations declines from north to south. The health of natural populations also declines from west to east as the length of freshwater migration increases. Across species and life history strategies, declines in natural populations generally increase with the length of freshwater residence. Populations of pink salmon and chum salmon are doing relatively well, while populations of chinook, coho, and sockeye salmon have experienced greater declines. Trends in the abundance of natural populations of steelhead, and chinook and coho salmon are obscured to some degree by extensive hatchery programs. These patterns implicate the availability and quality of freshwater habitat as a primary factor in observed declines in abundance.

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INTRODUCTION

The National Marine Fisheries Service (NMFS) has responsibility for administering the United States Endangered Species Act (ESA) for marine and anadromous species. The ESA recognizes the importance of variability within vertebrate species by allowing the listing of "distinct population segments". NMFS has adopted a policy defining distinct population segments as evolutionarily significant units (ESU), then further defining ESUs (Waples 1991).

After receiving several petitions to list individual runs of Pacific salmon as endangered species, the NMFS initiated coastwide status reviews for all species of Pacific salmon. Status reviews have been completed for coho salmon (Weitkamp et al. 1995), pink salmon (Hard et al. 1995), and steelhead trout (Busby et al. 1996), and status reviews for chum salmon, sockeye salmon, chinook salmon, and cutthroat trout are in various stages of completion. Because the ESA is concerned specifically with the health of natural populations and the ecosystems they depend on, these status reviews have focused on natural populations and have included consideration of the demographic and genetic impacts of artificial propagation on natural production.

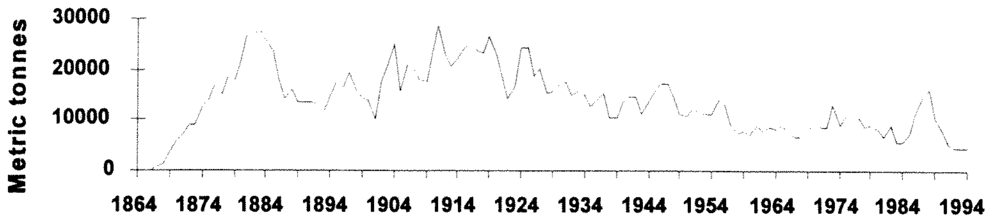
The process that NMFS has adopted for status reviews consists of two steps; the first is defining the ESUs comprising a biological species, and the second is evaluating the risk of extinction faced by each ESU. These evaluations are carried out by a team of knowledgeable scientists after considering a variety of information. Factors considered in defining ESUs include: genetic similarity, life history patterns, freshwater and marine distribution, behavior, ecology, habitat types, and biogeography. Factors considered in evaluating the risk of extinction include: total abundance, current abundance relative to historic abundance, trends in abundance, demographic and genetic effects of artificial propagation, habitat condition, harvest, and other risk factors. Not all of these status reviews have been concluded, so rather than trying to summarize conclusions of the status reviews, we will summarize some of the information considered by the review team. Information summarized here will be limited to harvest, previous status reviews, and spawning escapement, and limited in geographic scope to Washington, Oregon, California and Idaho.

TOTAL HARVEST

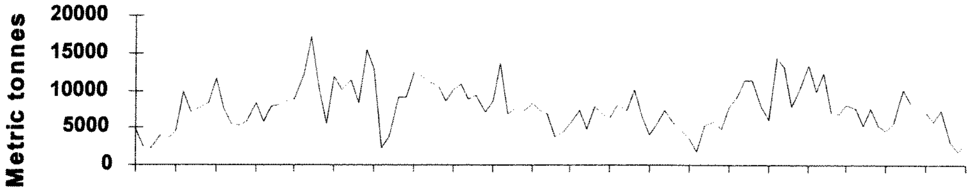
Perhaps the most readily available measure of stock health is landed commercial catch (Fig. 1). Landings of most species peaked prior to 1920, and landings of chinook, coho, and pink salmon have varied considerably, but declined since then. Landings of sockeye salmon have varied widely, but

Fig. 1 Total commercial landings of salmon from California, Oregon, and Washington in metric tonnes.

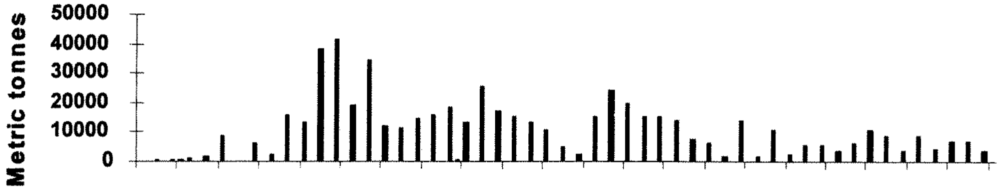
Chinook salmon



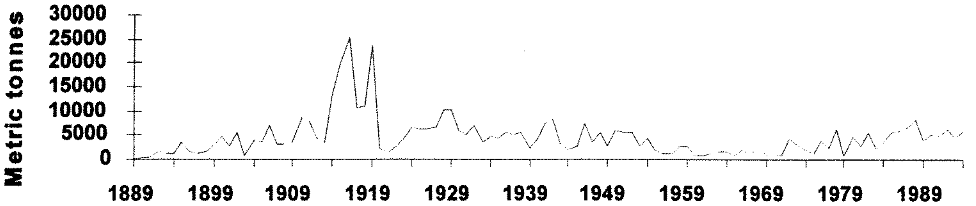
Coho salmon



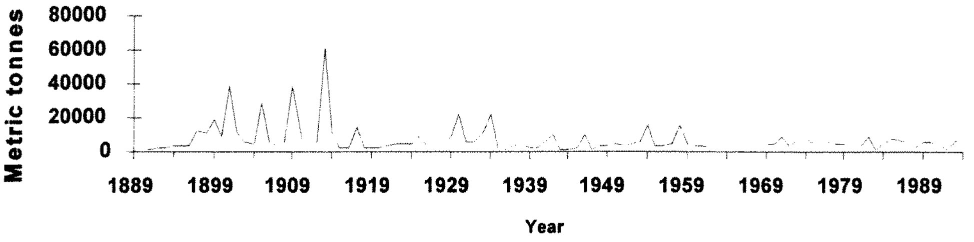
Pink salmon



Chum salmon



Sockeye salmon



have not had any clear trend since the 1920s, and chum salmon landings declined sharply until the late 1950s and have been increasing since then.

There are several reasons why landings for all species do not accurately reflect stock health. Harvest of chinook and coho salmon initially occurred in freshwater where only mature fish were taken. Most harvest of these species now occurs at sea where immature fish are taken, so numbers of fish harvested have not declined to the extent that the weight of landings has. Much of the harvest of Washington and Oregon stocks of these two species occurs in Canadian and Alaskan waters. This harvest is not included in domestic landings. In addition, much of the natural production reflected in the early landings has been replaced by hatchery production.

Most harvest of pink, chum, and sockeye salmon occurs in Puget Sound, but the landed catch of pink and sockeye salmon is dominated by Canadian stocks returning to the Fraser River. The declines in chum salmon landings in the early part of the century reflect the loss of many large stocks of chum salmon in the Columbia River and large declines in coastal Oregon stocks. The increase in landings since about 1960 is due to increases in the abundance of Puget Sound stocks.

PREVIOUS STATUS REVIEWS

Among the data considered in the course of the status reviews were prior population status assessments. Several reviews of stock status have recently been conducted. Nehlsen et al. (1991) examined a wide variety of risk factors and compiled a list of stocks from California, Oregon, Washington, and Idaho that they considered at risk of extinction. They classified stocks as extinct, possibly extinct, at high risk of extinction, at moderate risk of extinction, and of special concern. The categories of high and moderate risk of extinction were intended to roughly correspond to ESA categories of endangered and threatened respectively. Higgins et al. (1992) considered stocks on a finer scale than Nehlsen et al. (1991) and compiled a more detailed list for northern California.

Because Nehlsen et al. (1991) only considered stocks at risk, Huntington et al. (1996) compiled a coastwide list of healthy native stocks to complement Nehlsen et al. (1991). Again a wide variety of risk factors were considered, but their final criteria were based on abundance. They considered stocks to be healthy (Level II) if recent abundance was between 1/3 and 2/3 of what they estimated it would be in the absence of human impacts, and healthy (Level I) if recent abundance was at least 2/3 of what it would be in the absence of human impacts.

Status reviews analogous to Nehlsen et al. (1991) and Huntington et al (1996) have also been compiled for British Columbia (Slaney et al. 1996) and southeast Alaska (Baker et al. 1996), but they are outside the geographic scope of this summary.

Stock inventories were also compiled for salmonid stocks in Washington state (WDF et al. 1993), and for coastal basins in Oregon (Nickelson et al. 1992). WDF et al. (1993) evaluated stock status, but the criteria used depended primarily on level of recent production relative to the current potential. They did not consider the effects of hatchery production and stock transfers on the health of natural, native populations. Nickelson et al. (1992) did consider the effect of hatchery production and hatchery stock origin, but used numeric criteria that are not consistent with the other reviews.

Because only Nehlsen et al. (1991), and Huntington et al. (1996) applied uniform standards of stock status to the entire coast, only the lists they developed are summarized below. It should be noted that these lists are not comprehensive. There are many stocks that fail to meet the criteria for healthy stocks or for stocks at risk. The majority of stocks probably fall somewhere between these two broad categories.

When all stocks are considered, there is a tendency for a higher proportion of stocks in the extinct and high risk categories to occur in species with greater dependence on freshwater habitat as measured by the fraction of their lives spent in freshwater (Fig. 2, Appendix Table 1). Sockeye salmon have the greatest proportion of stocks in the extinct category, and pink and chum salmon have the highest proportion in the healthy categories. Steelhead are an exception to this pattern, with a higher proportion of stocks in lower risk categories than coho salmon or chinook salmon. This may be because they are more opportunistic, and their iteroparous life history and ability to residualize in freshwater may serve as a buffer against poor environmental conditions.

Confounding the relationship between degree of risk and life history is a tendency for more extinctions and greater risk for stocks with longer spawning migrations (Fig. 3, Appendix Table 1). Stocks with the longest migration corridors also have the greatest opportunity to encounter impassible dams and be excluded from their historic spawning habitat. In general, chinook, inland steelhead, and sockeye salmon have the longest spawning migrations.

When only coastal populations are considered, there is also a clear tendency for northern stocks to be in better health than southern stocks (Fig. 3, Appendix Table 1). Again, this pattern is confounded somewhat by the species composition in individual states. Only steelhead, chinook and coho salmon occur in all three states. Extant sockeye salmon populations only occur in Washington, and Idaho, pink salmon only occur in

Fig. 2 **Proportion of stocks in each risk category from Nehlsen et al. (1991) and Huntington et al. (1996) by species. Species are arranged from front to back in decreasing order of the proportion of total life history spent in freshwater.**

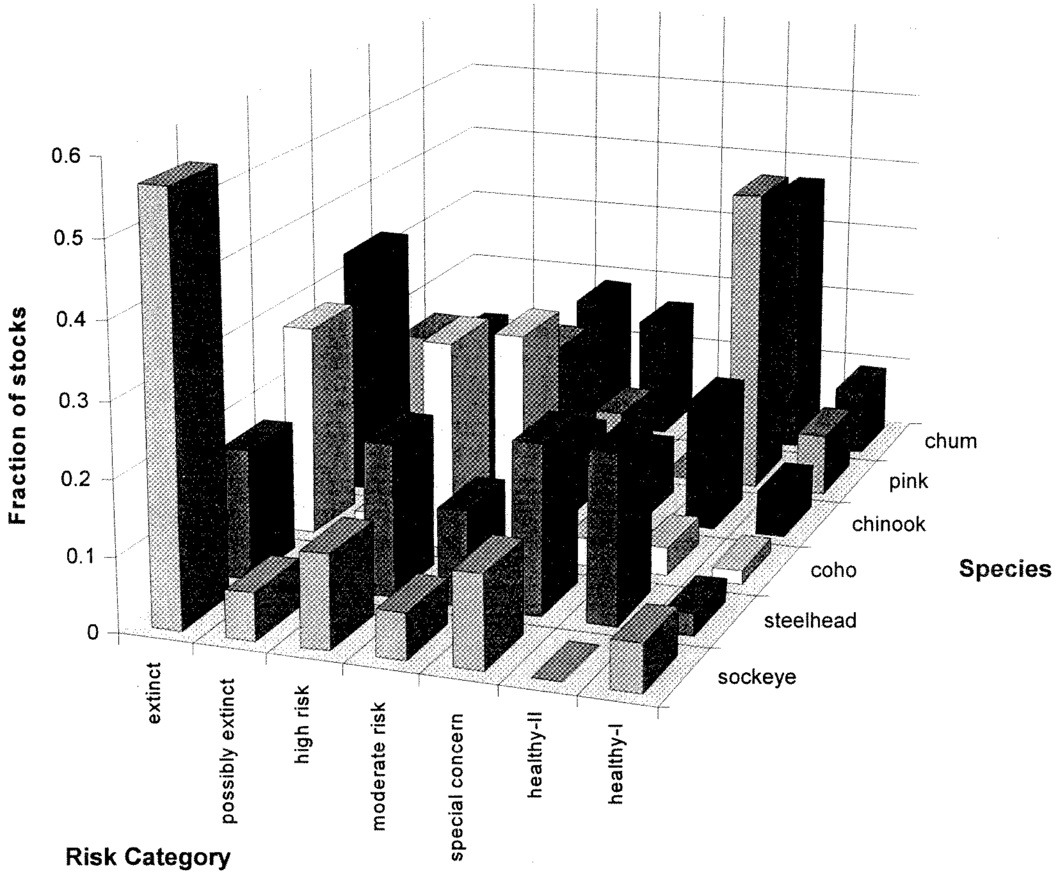
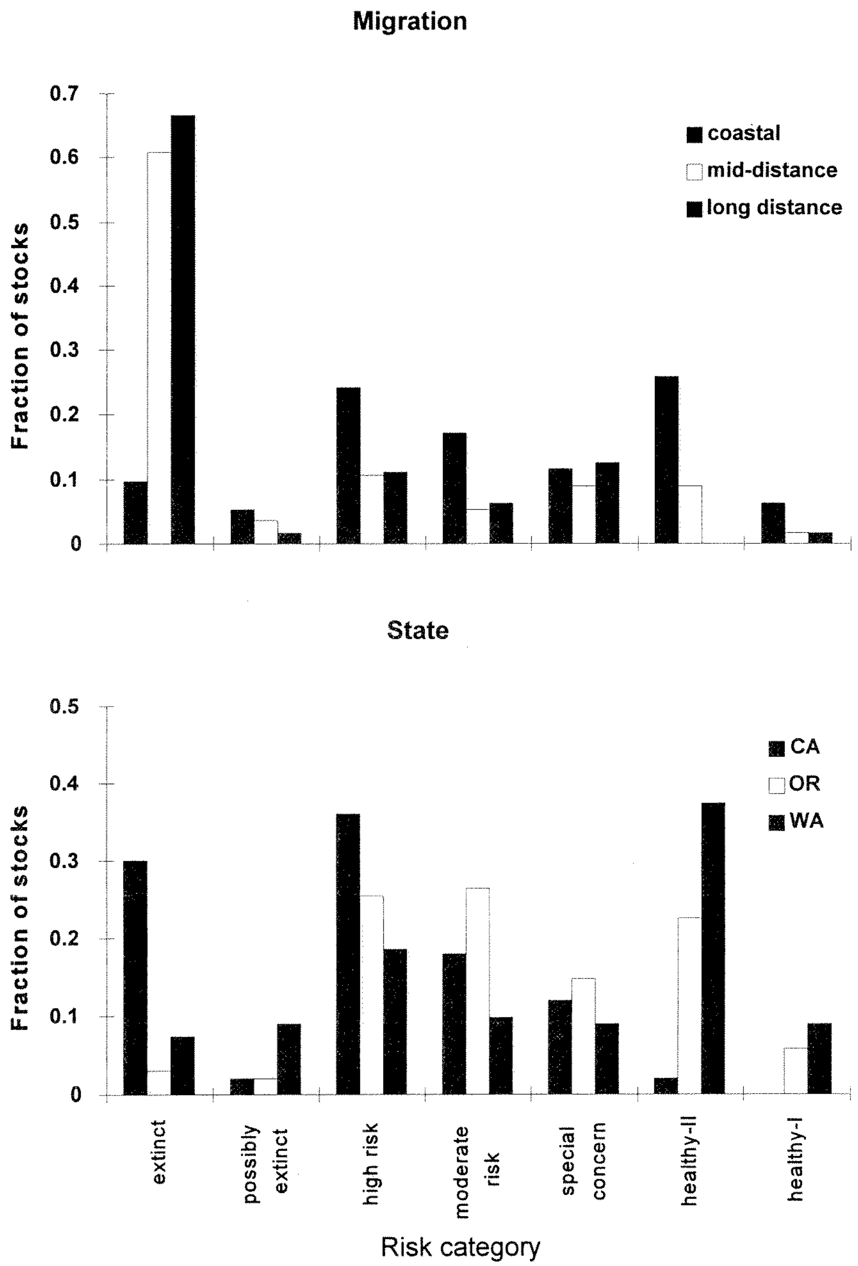


Fig. 3 **Proportion of stocks in each rish category from Nehlsen et al. (1991) and Huntington et al. (1996) by migration distance (upper panel) and by state for coastal stocks (lower panel). Long distance migrations includes stocks from rivers draining the west slope of the Rocky Mountains. Mid-distance migrations include stock from rivers draining the east slope of the Cascade Mountains or basins east of the crest of the Coast Range in California and Oregon. All stocks from rivers draining the west slope of the Cascade Mountains or Coast Range were classified as coastal.**



Washington, and chum salmon occur primarily in Washington with a few populations in coastal Oregon. If coastal stocks of the three species with coastwide distributions are considered individually (Fig. 4, Appendix Table 1), the same general pattern persists, though it is somewhat obscured by small sample sizes.

ESCAPEMENT TRENDS

Another primary data type considered by NMFS in the status reviews was abundance of natural stocks. The most readily available stock-specific information is spawning escapement. The availability, type, and quality of escapement data vary depending on locality and species, and range from fishway counts at dams to carcass estimates for index areas. Escapement data summarized here are compiled in the NMFS database of salmon catch, escapement, and historical abundance (available from the Pacific States Marine Fisheries Commission, 2501 SW First Ave., Suite 200, Portland, OR 97201, USA). For some species in some locations, total escapement estimates and harvest rate information can be used to calculate recruitment and estimate stock productivity. However, escapement data often only encompass a portion of the stock and cannot be used to estimate total spawning escapement, much less total stock production. In order to provide the broadest and most consistent geographic coverage, we have only summarized escapement trend data here. Exponential trends were fitted to spawning escapement or escapement index data wherever such data were available. The trends summarized here were fitted to entire time series of escapement data.

In general, trends in escapement data show patterns similar to those for the risk categories of Nehlsen et al. (1991) and Huntington et al. (1996). Though the majority of trends in escapement are small in magnitude, there is a tendency for a higher proportion of negative trends for species spending a greater proportion of their lives in freshwater (Fig. 5, Appendix Table 2). There is also a tendency for the proportion of negative trends to increase from north to south, and as the length of the spawning migration increases (Fig. 6, Appendix Table 2).

DISCUSSION AND CONCLUSIONS

In the course of reviewing a variety of salmon stock information, patterns of abundance and stock health have emerged. Abundance of all species harvested commercially, as measured by total landings, has declined since the early part of the century. Declines for chinook and coho salmon have occurred despite large hatchery programs intended to mitigate losses of freshwater habitat and enhance fisheries. More integrated measures of stock health demonstrate patterns relative to the latitudinal distribution of stocks, the distance of spawning migration, and the degree of dependence on freshwater habitat. In general, the health of salmonid stocks in California, Oregon, Washington, and Idaho declines from north to south, with the length of the spawning migration, and with the proportion of life history spent in freshwater.

In recent years much attention has focused on the relationship between marine climatic regimes and abundance of salmon in the eastern north Pacific and the Gulf of Alaska (Beamish and Bouillon 1993; Lawson 1993; Francis and Hare 1994; Hare and Francis 1995). Climatic regime shifts apparently occurred in the late 1940s and late 1970s. The change that occurred in the late 1970s was associated with an increase in abundance of stocks that rear primarily in the Gulf of Alaska (Beamish and Bouillon 1993; Hare and Francis 1995) and a decrease in abundance of stocks that reside off the coast of California, Oregon, Washington, and British Columbia (Lawson 1993) . While it might be expected that stocks with similar freshwater origins would be subject to similar marine conditions, different species have very different marine distributions and life-histories (Beamish and Bouillon 1993; Groot and Margolis 1991). Similarly, conspecific stocks with proximate freshwater habitats can have different life-histories and marine distributions (Weitkamp et al. 1995; Nicholas and Hankin 1988). Though ocean conditions clearly affect marine growth and survival, the consistency of relationships between stock health and freshwater life history argue that freshwater conditions are a primary causal factor in current trends stock status.

Fig. 4 Proportion of coastal stocks in each risk category from Nehlsen et al. (1991) and Huntington et al. (1996) plotted by state for each of the three species with coastwide distributions.

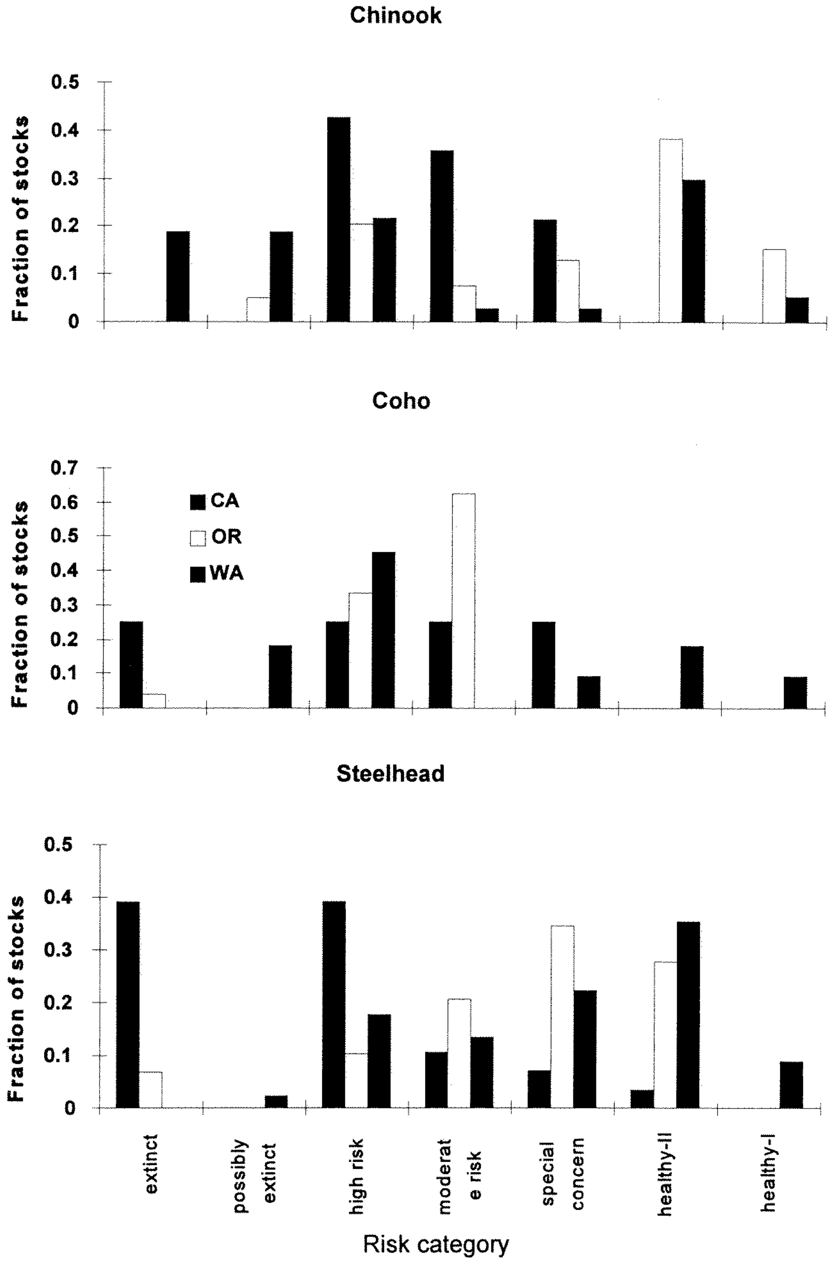


Fig. 5 Distribution of trends in spawning escapement for each species. Species are arranged from front to back in order of decreasing proportion of life history spent in freshwater. Trends were calculated as exponential trends fitted to the entire data series. Series length, data types, and data quality vary.

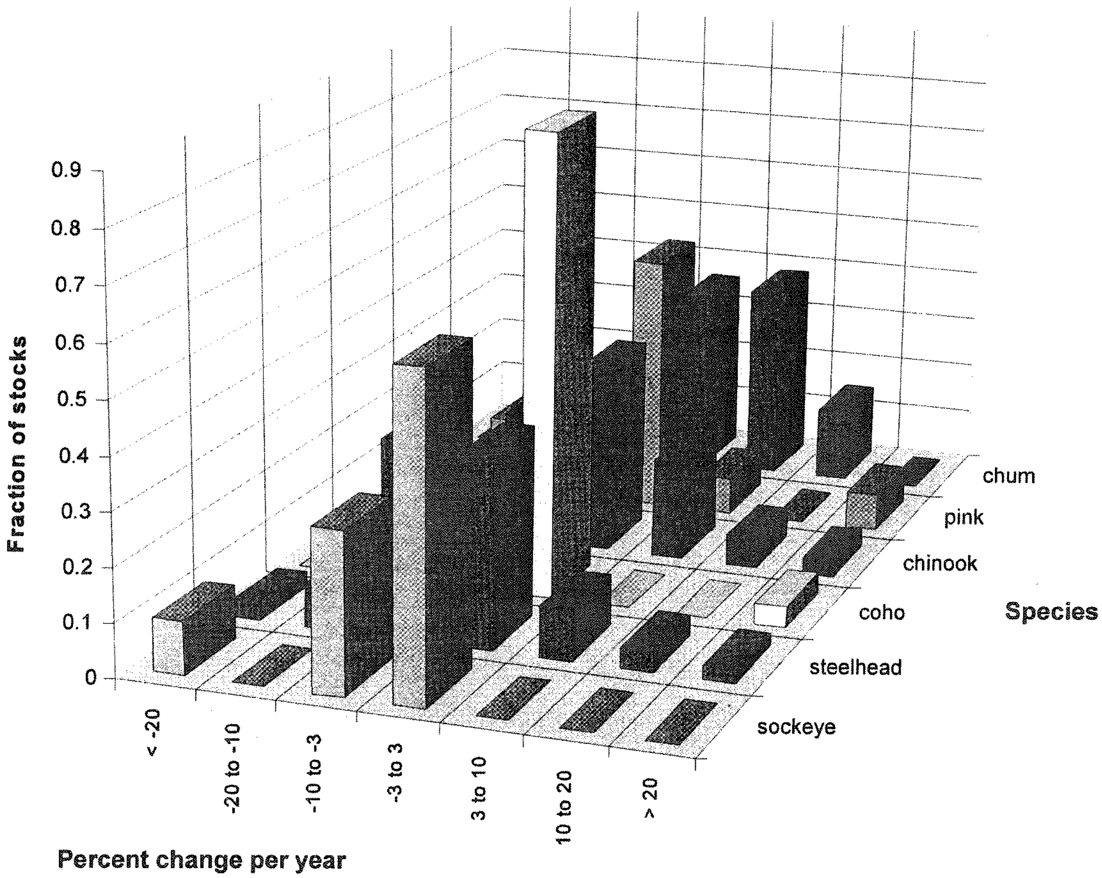
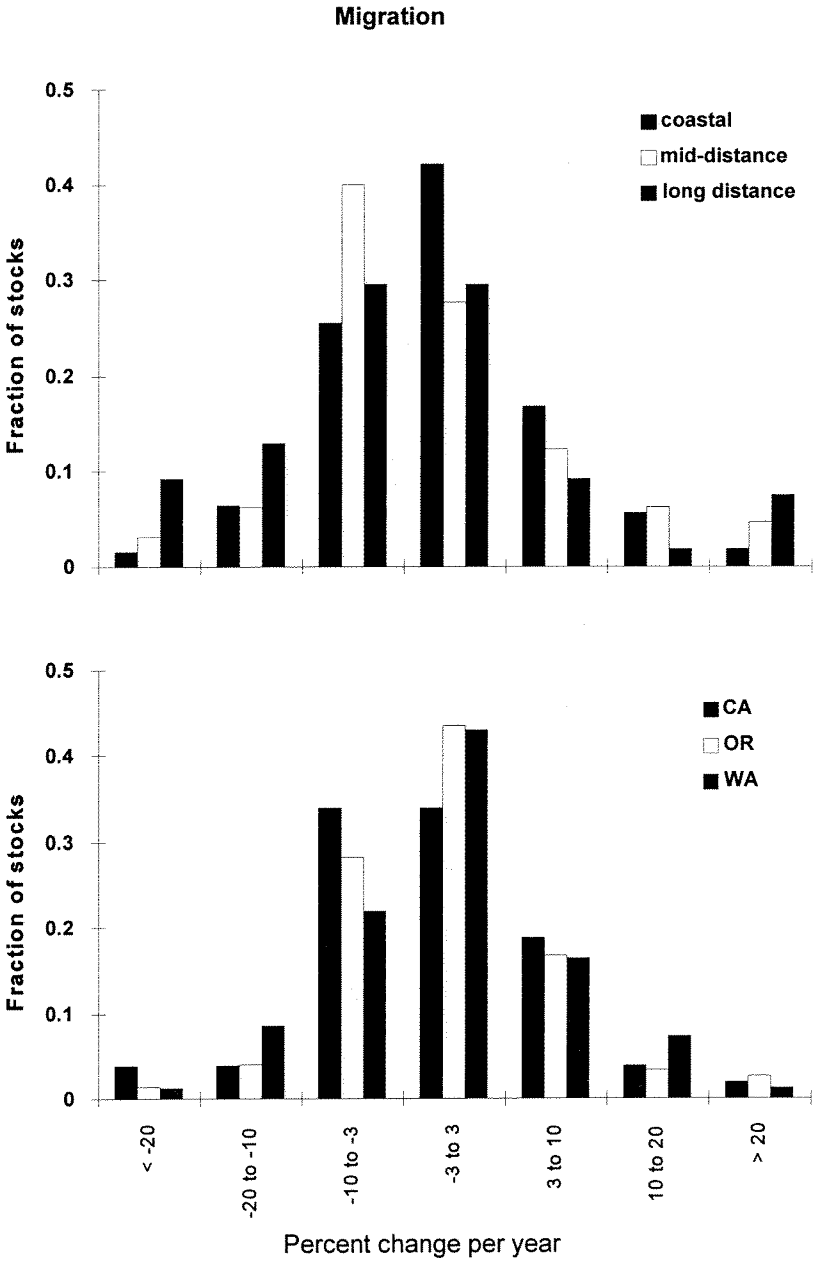


Fig. 6 **Distribution of trends in spawning escapement by length of freshwater spawning migration (upper panel), and by state for coastal stocks (lower panel).**



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Appendix

Table 1. Number of stocks assigned to each rish category by Nehlson et al. (1991), and Huntington et al. (1996).

		Risk category*							
		X	A+	A	B	C	H-II	H-I	Total
Species									
chum		5	3	8	7	0	16	4	43
pink		2	1	2	1	0	5	1	12
chinook		50	10	28	14	12	26	9	149
coho		15	2	15	16	2	2	1	53
steelhead		23	1	27	17	30	30	4	132
sockeye		16	1	2	1	2	0	1	23
Total		111	18	82	56	46	79	20	412
Freshwater spawning migration									
coastal		28	15	69	49	33	74	18	286
mid-distance		34	2	6	3	5	5	1	56
long distance		49	1	7	4	8	0	1	70
Total		111	18	82	56	46	79	20	412
Stocks with coastal freshwater spawning migrations									
Species	**State**								
chinook	**CA**	0.00	0	6	5	3	0	0	14
	OR	0	2	8	3	5	15	6	39
	WA	7	7	8	1	1	11	2	37
coho	**CA**	1	0	1	1	1	0	0	4
	OR	1	0	8	15	0	0	0	24
	WA	0	2	5	0	1	2	1	11
steelhead	**CA**	11	0	11	3	2	1	0	28
	OR	2	0	3	6	10	8	0	29
	WA	0	1	8	6	10	16	4	45
All species	**CA**	15	1	18	9	6	1	0	50
	OR	3	2	26	27	15	23	6	102
	WA	10	12	25	13	12	50	12	134
Total		28	15	69	49	33	74	18	286

* Risk categories: X, extinct; A+, possibly extinct; A, high risk; B, moderate risk; C, special concern; H-II, between 1/3 and 2/3 of pristine abundance; H-I greater than 2/3 pristine abundance.

Appendix (continued)

Table 2. Stocks grouped by the annual rate of change in abundance. Annual rates of change were estimated as geometric trends by linear regression of the log transforms of non-zero values of abundance indices against year.

		Annual percent change in abundance							
Species		**< -20**	**-20 to -10**	**-10 to -3**	**-3 to 3**	**3 to 10**	**10 to 20**	**> 20**	**Total**
chum		0	1	4	15	16	6	0	42
pink		0	2	3	7	1	0	1	14
chinook		7	19	64	92	49	15	8	254
coho		0	0	2	22	0	0	1	25
steelhead		6	17	77	75	20	8	5	208
sockeye		1	0	3	6	0	0	0	10
Total		14	39	153	217	86	29	15	553
Migration	**State**								
coastal	CA	2	2	18	18	10	2	1	53
	OR	2	6	42	65	25	5	4	149
	WA	3	20	51	100	38	17	3	232
coastal total		7	28	111	183	73	24	8	434
mid distance total		2	4	26	18	8	4	3	65
long distance total		5	7	16	16	5	1	4	54
Grand Total		14	39	153	217	86	29	15	553