CHINOOK AND COHO SALMON

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TABLE OF CONTENTS (S)

LIST OF TABLES AND FIGURES (S)

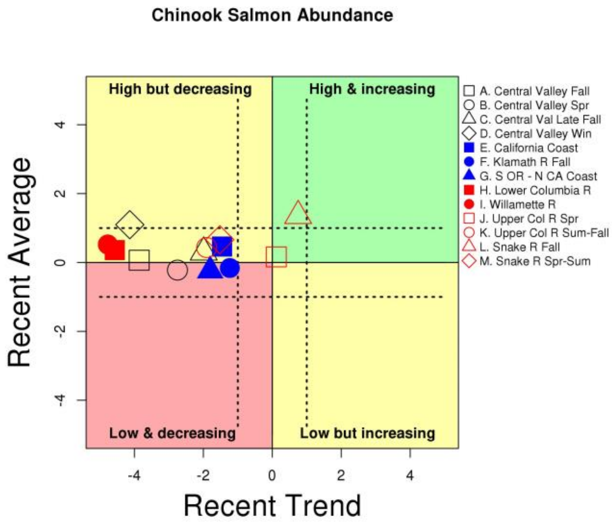
OVERVIEW

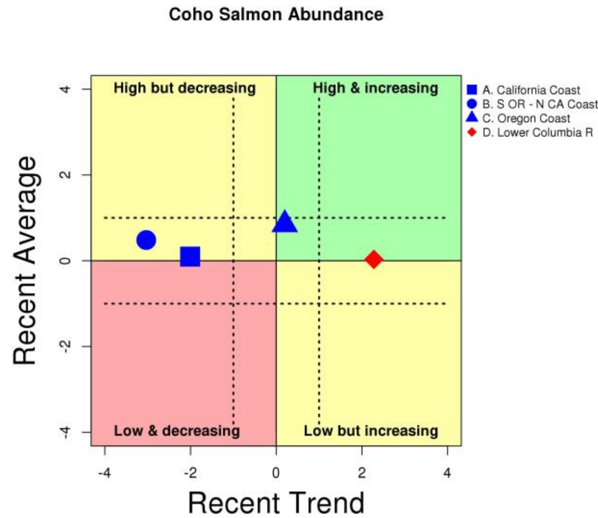
Generally, California Chinook and coho salmon populations are below their historical abundance levels and have continued to decline over the last decade. Most of the Chinook salmon populations from Columbia River Basin (including the Snake and Willamette Rivers) have experienced declines in abundance over the last ten years, with only Snake River Fall-run Chinook salmon populations exhibiting increased abundance. Abundances of coho salmon populations are relatively stable along the Oregon Coast and increasing in the lower Columbia River.

EXECUTIVE SUMMARY

Over the last ten years, there has been a significant decline in abundance of California populations of Chinook and coho calmon. While river Winter-run Chinook salmon had recent increases in abundance in 2002, 2003, and 2006, this population still remains only a fraction of its historical abundance even when compared with abundance levels just 30 years ago. Central Valley Fall and Late Fall-run abundance levels are projected to increase in 2012 following their collapse in 2007-2010, but the high proportion of hatchery-origin fish is a concern. In contrast, the growth rate and proportion of natural fall-run Chinook salmon in the Klamath River (part of the Southern Oregon and Northern California Coast Chinook salmon ESU) are relatively stable and the age structure is becoming more complex. With the exception of the Snake River Fall-run, Chinook salmon populations from the Columbia River Basin have experienced declines in abundance over the last ten years following high abundance levels in the early 2000s. Chinook salmon populations from the Snake River had increases in abundance for the last few years of available data, although the 10-year trends were negative for Snake River Spring/Summer-run Chinook salmon and unchanged for Snake River Fall-run Chinook salmon. With the exception of the Chinook salmon in the Willamette River, Chinook salmon populations in the Columbia River Basin exhibited increases in the proportion of hatchery-origin fish.

California populations of coho salmon have experienced declines in abundance over the past ten years. Coho salmon abundance from the lower Columbia River was variable but increasing over the past 10 years. The abundance of Oregon Coast coho salmon was variable with no significant trend over the past 10 years, although recent abundance levels were greater than that observed during the late-1990s.





Salmon abundance. Quadplot summarizes information from multiple time series of coho and Chinook salmon abundances. Prior to plotting, time series were normalized to place them on the same scale. The short-term trend (x-axis) indicates whether the indicator increased or decreased over the last 10-years. The y-axis indicates whether the mean of the last 10 years is greater or less than the mean of the full time series. Dotted lines show ± 1.0 s.d.

DETAILED REPORT

Pacific salmon (*Oncorhynchus* spp.) are iconic members of North Pacific rim ecosystems, historically ranging from Baja California to Korea (Groot and Margolis 1991). Historically, salmon supported extensive native estuarine and freshwater fisheries along the U.S. West Coast, followed more recently by large commercial marine and recreational marine and freshwater harvest. Because they are anadromous with extensive migrations, salmon connect marine and freshwater ecosystems.

The purpose of this chapter of the CCIEA is to examine trends in available indicators relevant to salmon along the California Current. This is the first step in finding valuable data series that can be used to describe various aspects of the CCE and its salmon community. The analysis is largely qualitative at this early stage of the CCIEA. It is important to recognize that we refer to "status" quite differently than that reported by Pacific Fisheries Management Council (PFMC) and in current Endangered Species Act status reports, therefore, any difference between our status statements and those should not be considered a conflict. We are not using similar models nor benchmarks as those traditionally used. Our purpose is to set the framework for evaluating the salmon community from an ecosystem perspective. This approach starts with a simple selection of indicators and evaluation of the trends. However, in following reports we will use these biological indicators in combination with indicators of environmental and anthropogenic pressures to evaluate potential risk to the salmon community and develop additional assessment tools useful for ecosystem based management. Indicators for various pressures can be found in other chapters of the full CCIEA (e.g., Anthropogenic Drivers and Pressures, Oceanographic and Climatic Drivers and Pressures).

Due to a variety of factors, CCLME salmon populations have experienced substantial declines in abundance (Nehlsen et al. 1991), to the extent that a number of stocks have been listed under the U.S. Endangered Species Act. This has resulted in extensive reviews of salmon population status and recovery efforts (Good et al. 2005, (Ford 2011, Williams et al. 2011). Rather than attempting to summarize the extensive data and literature that has been accumulated regarding West Coast salmon status, we focus on a few key stocks and indicators that relate to the overall condition of the CCLME.

The two most abundant salmon species in the CCLME are Chinook salmon (*O. tshawytscha*) and coho salmon (*O. kisutch*), and these two species have supported large fisheries (PFMC 2012a). For this reason, we focus on these two species, and selected stocks within the species that provide a range of geographic and life-history variation. There are a variety of ways to define 'stock' (for example, (Cushing 1981, Dizon et al. 1992) and Pacific salmon species have complex population structures. Here, we have chosen to use the Evolutionarily Significant Unit (ESU) defined by NOAA for use in Pacific salmon conservation management (Waples 1991). ESUs are defined on the basis of reproductive isolation and their contribution to the evolutionary legacy of the species as a whole, and are often composed of a number of geographically contiguous populations. They do not correspond exactly to the stock delineations that are used for harvest management, in most cases several stocks/populations make up an ESU.

INDICATOR SELECTION PROCESS

INDICATOR EVALUATION

Two underpinning elements of an IEA are data management infrastructure and the ecosystem-modeling infrastructure. The development of the ecosystem-modeling infrastructure requires the development of standard indicators, in our case, indicators useful for assessing the status and trends of Chinook salmon and coho salmon in the CCLME.

Rather than develop a unique suite of indicators for this report, we have relied on the extensive previous work in evaluating the status of salmon populations and ESUs on the Pacific coast (Allendorf et al. 1997, Wainwright and Kope 1999, McElhany et al. 2000, Good et al. 2005, Lindley et al. 2007). In particular, we selected indicators that were not inconsistent with these previous efforts and also the Viable Salmon Population (VSP) characteristics (McElhany et al. 2000) that are the foundation of current conservation and recovery planning efforts for Pacific salmonids; in addition, they are the bases for on-going evaluation of status updates of Pacific salmonid populations. McElhany et al. (2000) described four characteristics of populations that should be considered when assessing viability: abundance, productivity, diversity, and spatial structure. Since a high priority of the IEA effort it to develop frameworks that can expand to include new data and address multiple issues (e.g., protected species, fisheries, and ecosystem health), we felt it most appropriate to use indicators that are used in status reviews and ESA recovery planning documents (Table 1). From this list of potential indicators, we selected those with the most widespread data availability (to allow for comparisons across species and regions) and with most relevance to the state of the marine ecosystem. The following sections describe the indicators we considered as measures of stock abundance and condition.

Table S1. Key indicators for salmon, identified during the ESA listing and recovery planning processes. Indicators categories chosen for this analysis are in ***bold italic*** font.

Indicator	Selection/Deselection Reasoning
Abundance	
Spawning escapement	Widely measured; key measure of reproductive population
Ocean abundance (recruitment)	Requires stock-specific harvest rate estimates; not widely available
Juvenile abundance	Not widely available, but key indicator of reproduction for some ESUs
Population Condition	
Population growth rate (lambda)	Widely available, standard measure of population trend
Natural return ratio (NRR)	A measure of sustainability of the natural component of mixed hatchery-natural stocks; requires both age-structure and natural

Intrinsic rate of increase	Widely available, but depends on a specific formulation of density dependence.
Proportion of natural spawners	Widely available; Indicator of stock genetic integrity and effectiveness of natural production
Genetic diversity	
Age structure diversity	Available for most Chinook salmon stocks; a quantifiable measure of phenotypic diversity; indicator of harvest-related risk
Population spatial structure	Available for few stocks.

POTENTIAL INDICATORS FOR ASSESSING ABUNDANCE (POPULATION SIZE)

Monitoring population size provides information of use both for protected species conservation and for harvest management. We considered three primary indicators of abundance, and chose to focus on one (spawning escapement) as the most widely available and relevant.

1. Spawning escapement–Estimates of spawning escapement are extremely important to salmon management as an indication of the actual reproductive population size. The number of reproducing adults is important in defining population viability, as a measure of both demographic and genetic risks. It is equally important to harvest management, which typically aims at meeting escapement goals such that the population remains viable (for ESA-listed populations) or near the biomass that produces maximum recruitment (for stocks covered by a fisheries management plan). Spawning escapement is the most widely available measure of abundance for West Coast salmon, although these data are often limited to the most commercially important stocks and often stock/population estimates only make up a portion of an ESU.

2. Recruitment–An estimate of the number of adults in the ocean that would be expected to return to spawn in freshwater if not harvested. This is typically estimated as the number of adults that return to spawn divided by the total fishery escapement rate (one minus the total harvest rate). Recruitment is the primary indicator of importance for harvest management, as it determines how much harvest can be tolerated while still meeting escapement goals. It is also the best indicator of overall system capacity for the stock. However, because estimation depends on stock-specific harvest rates, recruitment estimates are not always available.

3. Juvenile abundance–The abundance of juveniles in freshwater or early marine environments is a good measure of reproductive success for a stock. This is monitored for many West Coast salmon stocks, but data series are typically short, and often are made for only a small proportion of an ESU, so are difficult to interpret and compare on a regional basis.

POTENTIAL INDICATORS FOR ASSESSING POPULATION CONDITION

There are a number of potential metrics for assessing the condition of a managed salmon population. These fall into the broad categories of population growth/productivity, diversity, and spatial structure (McElhany et al. 2000). We considered the seven commonly-used metrics, and based on data availability and relevance, chose three of those metrics (population growth rate, hatchery contribution, and age-structure diversity) to reflect a range of assumptions about the effects of various stressors on the populations.

1. Population growth rate–Calculated as the proportional change in abundance between successive generations, population growth rate is an indication of the population's resilience. In addition, growth rate can act as a warning of critical abundance trends that can be used for determining future directions in management. Also, the viability of a population is dependent in part on maintaining life-history diversity in the population. Because of limited information on hatchery fish and natural return ratio (see below) this value includes hatchery origin fish.

2. Natural return ratio (NRR)–NRR is the ratio N/T, where N is naturally produced (i.e., natural-origin) spawning escapement and T is total (hatchery-origin plus natural-origin) spawning escapement in the previous generation. It is a measure of the sustainability of the natural component of mixed hatchery-natural stocks and is an important conservation-oriented measure of stock productivity. However, the calculation requires both age-structure and natural proportion data, and depends on assumptions regarding the relative fitness of hatchery-origin fish in natural environments. This makes it problematic as an ecosystem status indicator.

3. Intrinsic rate of increase–The intrinsic rate of increase is estimated from the statistical fitting of stock-recruit models and is a measure of the rate of population increase when abundance is very low. It is an important parameter in harvest management theory, used in the estimation of optimum yield from a fishery. However, computations require long-term data on both harvest rate and age-structure data, and an assumed theoretical form for the stock-recruit function; therefore it is not easy to use as a status indicator.

4. Hatchery contribution–Defined as the proportion of hatchery-origin fish in naturally-spawning populations. Hatchery fish are relatively homogeneous genetically in comparison to naturally produced populations, typically are not well-adapted to survival in natural habitats, and their presence may reduce the fitness of natural populations (Bisson et al. 2002, Lindley et al. 2007). Thus, this is an important measure of the health of natural populations. Data are available for most West Coast salmon ESUs.

5. Genetic diversity–Genetic diversity is an important conservation consideration for several reasons, particularly in providing adaptive capacity that makes populations resilient to changes in their environment (Waples et al. 2010). Genetic monitoring of salmon populations has become common, and is being used for genetic stock identification as part of harvest management (Beacham et al. 2008). However, there are as yet no time series of genetic data that would allow detection of trends in diversity nor is there an understanding of historical population-specific patterns of genetic diversity to provide context when evaluating contemporary patterns, so this is not a useful status indicator at this time.

6. Age structure diversity–A diverse age structure is important to improve population resilience. Larger, older Chinook salmon produce more and larger eggs (Healey and Heard 1984). Therefore, they produce a brood that may contribute proportionally more to the later spawning population than broods from younger, smaller fish. However, the diversity of ages including younger fish is important to accommodate variability in the environment. If mortality on any given cohort is great, there is benefit to having younger spawners. An individual that produces off spring that return at different adult ages (i.e., overlapping generations) may

increase the likelihood of contributing to future generations when environmental conditions are less than favorable one year to the next. This bet hedging is a critical aspect of Chinook salmon that allow it to naturally mitigate year-to-year environmental variability (Heath et al. 1999). Adult age structure is not an issue for coho salmon, which in our region spawn predominantly at age three (with the exception of a small proportion of younger male 'jacks'). While coho salmon in our region spawn predominantly at a single age, Chinook salmon typically spawn over an age range of 3 or 4 years, and exhibit differences in spawning age both among years and among populations. Data are available for most Chinook salmon populations of commercial importance or of ESA interest ESUs (e.g., Sacramento River Winter-run), although data are typically stock/population specific and might not be representative of an ESU.

7. Spatial structure–The spatial structure of a stock, both among- and within- subpopulations, is important to the long-term stability and adaptation of the stock/population/ESU. A number of methods have been proposed for indexing the structure of both spawning and juvenile salmon (McElhany et al. 2000, Wainwright et al. 2008, Peacock and Holt 2012). Unfortunately, there are not widspread data nor a consistent method used for evaluating spatial structure of West Coast salmon ESUs.

SELECTING APPROPRIATE STOCKS/POPULATIONS FOR EVALUATION OF ABUNDANCE AND CONDITION

Stock selection was based on economic and ecosystem importance, geographic and life-history diversity, and data availability. This resulted in selections consistent with current ESU delineations. Because of regional differences in the availability of data, we considered stocks and data series separately within two regions: California (including southern Oregon south of Cape Blanco) and Oregon-Washington coasts (Cape Blanco to the mouth of the Strait of Juan de Fuca). For each ESU, a variety of data series are available; each series has been used in management documents, status reports, and/or the scientific literature. Any data series that was less than 15 years long was removed; within each ESU, all data series were truncated to match the shortest series. Available data series meeting these criteria for given ESUs are listed in Tables 2-5. It should be noted that in many cases we used data that were not used for recent ESA status updates. Many of the time series available are at the stock or population scale and may not be representative of the whole ESU (the listing unit for ESA efforts) and therefore not appropriate for evaluating the status of an ESU. For our purposes we determined that development of the indicators and ecosystem models using stock/population scale measures was appropriate at this initial stage of development of IEA and we should be able to accommodate ESU representative data as rigorous monitoring programs are established.

For California ESUs (Tables 2 & 3), the data series were compiled from a variety of sources and are presented in Williams et al. (2011), PFMC (2012c), and Spence and Williams (2011). Because of the diversity of data types available, indicators for each stock were selected based on their availability, time series lengths, and scientific support. Data series that were used are highlighted in the tables.

For Oregon and Washington ESUs, data were obtained from the NWFSC's "Salmon Population Summary" database (https://www.webapps.nwfsc.noaa.gov/apex/f?p=238:home:0), with additional data for Oregon Coast coho salmon (Oregon Department of Fish and Wildlife, http://oregonstate.edu/dept/ODFW/spawn/data.htm), and from PFMC (2012c) for the Upper Columbia Summer/Fall-run Chinook Salmon.

When data were only available for a portion of an ESU (e.g., single stream or tributary, but not necessarily representative of the whole ESU) and no ESU-wide estimates were available, we used these data as a proxy for the ESU unless it was not recent enough or was incomplete (Table 2). If data restrictions or reporting required multiple series be used for a given indicator within a single ESU, we computed an ESU-wide average (e.g., Table 2, Central Valley Spring-run). To do this, series were standardized and then averaged across populations within ESUs. These standard scores represent the index for abundance or conditions for that ESU. Data series that represented similar values (e.g., escapements) were weighted by absolute spawning abundance.

APPROPRIATE INDICATORS

We evaluated abundance using the metric of escapement of natural-origin spawners. Selection rationale for assessing only escapement and no other abundance metrics is listed in Table 1. The populations/ESUs that had sufficiently met the criteria for inclusion in the analyses are listed in Tables 2 and 4. When ESU-wide estimates were available and sufficient they were used. If data were only available at the sub-ESU level, escapement values from the component subpopulations were used. As well, we only used data beginning in 1985 so that, when possible, the longer time series could be compared equivalently between populations. Data series for multiple subpopulations were standardized by subtracting the series mean and dividing by the series standard deviation. If a consolidated index for the stock was needed we computed an annual weighted average of the standardized series, with weights proportional to the average abundance for each subpopulation.

To evaluate condition we restricted our analyses to examination of population growth rate, proportion of natural-origin spawners, and age-structure diversity. Selection rationale for assessing only these metrics of condition and no other condition metrics is listed in Table 1. The populations/ESUs that had sufficiently met the criteria for estimation of condition are listed in Tables 3 and 5.

Population growth rate for each subpopulation was estimated as the ratio of the 4-year running mean of spawning escapement in one year to the 4-year running mean for the previous year (Good et al. 2005). Proportion of natural-origin spawners was calculated for those populations where spawning abundance estimates are broken down into hatchery-origin and natural-origin components; the proportion was computed for a single population as the fraction N_N/N_T, where N_N is the number of naturally-origin spawners, and N_T is the total number of spawners. Population fractions were then averaged across the populations within the ESU, weighted by total spawner abundance. Age-structure diversity for Chinook salmon was computed as Shannon's diversity index of spawner age for each population within each year. The indices were then averaged across populations, weighted by total spawner abundance.

Table S2. California ESUs/Stocks and Data available for Abundance Estimates. Those series indicated by ***bold italics*** were used for analyses. Period is the period of availability for the longest series for that population.

Population	Data Available: Escapement	Period
Chinook Salmon		
Central Valley Fall Run	***Escapement to system***	***1983-Present***
	Coleman	1970-Present
	Feather	1970-present
	Nimbus	1970-present
	Mokelumne	1970-present
	Merced	1970-present
Central Valley Late Fall Run	***Escapement to system***	***1971-Present***
Central Valley Winter Run	***Escapement to system***	***1970-2008***
Central Valley Spring Run	Escapement to Sacramento R.	1970-2008
	Escapement Antelope Cr.	***~1982-Present***
	Escapement Battle Cr.	***1989-Present***
	Escapement Big Chico Cr.	***1970-Present***
	Escapement Butte Cr.	***1970-Present***
	Escapement Clear Cr.	***1992-Present***
	Escapement Cottonwood Cr.	***~1973-Present***

Population	Data Available: Escapement	Period
	Escapement Deer Cr.	***1970-Present***
	Escapement FRH	***1970-Present***
	Escapement Mill Cr.	***1970-Present***
Klamath R. Fall Run	***Escapement to system (Klamath+Trinity)***	***1978-Present***
	Shasta	1930-present
	Scott	1978-present
	Salmon	1978-present
SONCC Chinook Fall	***UmpquaEscapement***	***1946 Present***
	Rogues EscapementN+H (Gold Ray Dam)	
Cal Coastal Chinook	Prairie Cr. AUC	1998-Present
	Freshwater Cr. Weir Count	***1994-Present***
	Tomki Cr. (Live/Dead Counts)	***1979-Present***
	Mattole R. Redd Index	1994-Present
	Cannon Cr. (live/Dead Counts)	***1981-Present***
	Sprowl Cr. (Live/Dead Counts)	***1974-Present***
	Eel R. Dam Counts	***~1950-Present***
	Russian R. Video Counts	2000-Present

Population	Data Available: Escapement	Period
Coho salmon		
Coho SONCC	Wild adult abundance	2002-2004, 2006-2008
	Adult density on spawning grounds	2004-2008
	Adult weir counts in Shasta	2001-Present
	Spawning numbers Prairie Cr.	1998-Present
	Spawning numbers	2002-Present
	Abundance of wild coho in Rogue R.	
	Wild adult coho from Gold Ray Dam, OR	
	Spawning numbers Mattole R.	1994-Present
	Freshwater Wier Count	2002-2009
	WB Mill Cr. count	1998-present
	EB Mill Cr. Count	1998-present
	Cannon Count (Mad R.)	1981-present
	Illinois R. Counts	2002-2008 varies
California Coastal Coho	Scott Cr. Weir	2002-present
	Redwood Cr. counts	1997-present
	Lagunitas/Olema coho reddcounts	***1995-present***

Population	Data Available: Escapement	Period
	Caspar Cr. Redd Counts	1999-present
	Little Rvier Redd Counts	1999-present
	Noyo R. Redd countes	2000-present
	Noyo redd Upstream	1999-present
	SF Noyo Weir Count	1998-present
	Pudding Cr. Counts	2000-present
	Sprowl Cr. Escapement	***1978-present***

Table S3. Data series that met the criteria for inclusion in the condition analyses of California ESUs. Period is the period of availability for the longest series for that population.

Population	Series on Condition	Period
Chinook Salmon		
CV Fall Sacramento R. Fall Run	Hatchery contribution	1983 - Present
	Population Growth Rate	1983-present
Klamath R. Fall Run	Klam Age diversity (S-W)	1981-present
	Hatchery contribution	1978 - Present
	Population Growth Rate	1981-present
SONCC Chinook Fall	Rogue Age Diversity	1980-present
	Hatchery Contribution	1972-present

Table S4. Oregon-Washington ESUs/stocks and data available for abundance estimates. Each of these series met the criteria for inclusion in the analyses and was used.

Stock/ESU	Data Available: Escapement	Period
Chinook Salmon		
Lower Columbia R. ESU	Clatskanie R. Fall	1974-2006
	Coweeman R. Fall	1977-2009
	Elochoman R. Fall	1975-2009
	Grays R. Fall	1964-2009
	Kalama R. Fall	1964-2009
	Kalama R. Spring	1980-2008
	Lewis R.	1964-2009
	Lewis R. Fall	1977-2009
	Lower Cowlitz R. Fall	1977-2009
	Mill Cr. Fall	1980-2009
	North Fork Lewis R. Spring	1980-2008
	Sandy R. Fall (Bright)	1981-2006
	Sandy R. Spring	1981-2008
	Toutle R. Fall	1964-2009
	Upper Cowlitz R. Spring	1980-2008

Stock/ESU	Data Available: Escapement	Period
	Upper Gorge Tributaries Fall	1964-2008
	Washougal R. Fall	1977-2009
	White Salmon R. Fall	1976-2009
Snake R. Fall-run ESU	Snake R. Lower Mainstem Fall	1975-2008
Snake R. Spring/Summer-run ESU	Bear Valley Cr.	1960-2008
	Big Cr.	1957-2008
	Camas Cr.	1963-2006
	Catherine Cr. Spring	1955-2009
	Chamberlain Cr.	1985-2008
	East Fork Salmon R.	1960-2008
	East Fork South Fork Salmon R.	1958-2008
	Grande Ronde R. Upper Mainstem	1955-2009
	Imnaha R. Mainstem	1949-2009
	Lemhi R.	1957-2008
	Loon Cr.	1957-2008
	Lostine R. Spring	1959-2009
	Marsh Cr.	1957-2008

Stock/ESU	Data Available: Escapement	Period
	Minam R.	1954-2009
	Pahsimeroi R.	1986-2008
	Salmon R. Lower Mainstem	1957-2008
	Salmon R. Upper Mainstem	1962-2008
	Secesh R.	1957-2008
	South Fork Salmon R. Mainstem	1958-2008
	Sulphur Cr.	1957-2008
	Tucannon R.	1979-2009
	Valley Cr.	1957-2008
	Wenaha R.	1964-2009
	Yankee Fork	1961-2008
Upper Columbia R. Spring-run ESU	Entiat R.	1960-2008
	Methow R.	1960-2008
	Wenatchee R.	1960-2008
Upper Columbia Summer-Fall-run ESU	Escapement estimated at Bonneville	1996-2010
Upper Willamette R. ESU	Clackamas R. Spring	1974-2008
	McKenzie R. Spring	1970-2005

Stock/ESU	Data Available: Escapement	Period
Coho Salmon		
Lower Columbia R. ESU	Clackamas R.	1974-2010
	Sandy R.	1974-2010
Oregon Coast ESU	Alsea R.	1990-2010
	Beaver Cr.	1990-2010
	Coos R.	1990-2010
	Coquille R.	1990-2010
	Floras/New R.	1990-2010
	Lower Umpqua R.	1990-2010
	Middle Umpqua R.	1990-2010
	Necanicum R.	1990-2010
	Nehalem R.	1990-2010
	Nestucca R.	1990-2010
	North Umpqua R.	1990-2010
	Salmon R.	1990-2010
	Siletz R.	1990-2010
	Siltcoos Lk.	1990-2010

Stock/ESU	Data Available: Escapement	Period
	Siuslaw R.	1990-2010
	Sixes R.	1990-2010
	South Umpqua R.	1990-2010
	Tahkenitch Lk.	1990-2010
	Tenmile Lk.	1990-2010
	Tillamook Bay	1990-2010
	Yaquina R.	1990-2010

Table S5. Oregon-Washington ESUs/stocks and data available for condition estimates. These data series met the criteria for inclusion in the condition analyses Data types available are: HC – hatchery contribution to natural spawning; PGR – population growth rate; Age – spawning age structure. Period is the period of availability for the longest series for that population.

Stock/ESU	Population	Data Types	Period
Chinook Salmon			
Lower Columbia R. ESU	Clatskanie R. Fall	HC, PGR, Age	1974-2006
	Coweeman R. Fall	HC, PGR	1980-2009
	Elochoman R. Fall	HC, PGR	1975-2009
	Grays R. Fall	HC, PGR	1964-2009
	Kalama R. Fall	HC, PGR	1964-2009
	Kalama R. Spring	PGR	1980-2008
	Lewis R.	HC, PGR	1978-2009
	Lewis R. Fall	PGR	1964-2009
	Lower Cowlitz R. Fall	HC, PGR	1977-2009
	Mill Cr. Fall	HC, PGR	1980-2009
	North Fork Lewis R. Spring	PGR	1980-2008
	Sandy R. Fall (Bright)	HC, PGR, Age	1981-2006
	Sandy R. Spring	HC, PGR, Age	1981-2008
	Toutle R. Fall	PGR	1964-2009
	Upper Cowlitz R. Spring	PGR	1980-2008

Stock/ESU	Population	Data Types	Period
	Upper Gorge Tributaries Fall	HC, PGR	1964-2008
	Washougal R. Fall	HC, PGR	1977-2009
	White Salmon R. Fall	HC, PGR, Age	1976-2009
Snake R. Fall-run ESU	Snake R. Lower Main. Fall	HC, PGR, Age	1975-2008
Snake R. Spring/Summer-run ESU	Bear Valley Cr.	HC, PGR, Age	1960-2008
	Big Cr.	HC, PGR, Age	1957-2008
	Camas Cr.	HC, PGR, Age	1963-2006
	Catherine Cr. Spring	HC, PGR, Age	1955-2009
	Chamberlain Cr.	HC, PGR, Age	1985-2008
	East Fork Salmon R.	HC, PGR, Age	1960-2008
	E. Fork S. Fork Salmon R.	HC, PGR, Age	1958-2008
	Grande Ronde R. Upper Main.	HC, PGR, Age	1955-2009
	Imnaha R. Mainstem	HC, PGR, Age	1949-2009
	Lemhi R.	HC, PGR, Age	1957-2008
	Loon Cr.	HC, PGR, Age	1957-2008
	Lostine R. Spring	HC, PGR, Age	1959-2009
	Marsh Cr.	HC, PGR, Age	1957-2008

Stock/ESU	Population	Data Types	Period
	Minam R.	HC, PGR, Age	1954-2009
	Pahsimeroi R.	HC, PGR, Age	1986-2008
	Salmon R. Lower Mainstem	HC, PGR, Age	1957-2008
	Salmon R. Upper Mainstem	HC, PGR, Age	1962-2008
	Secesh R.	HC, PGR, Age	1957-2008
	South Fork Salmon R. Mainstem	HC, PGR, Age	1958-2008
	Sulphur Cr.	HC, PGR, Age	1957-2008
	Tucannon R.	HC, PGR, Age	1979-2009
	Valley Cr.	HC, PGR, Age	1957-2008
	Wenaha R.	HC, PGR, Age	1964-2009
	Yankee Fork	HC, PGR, Age	1961-2008
Upper Columbia R. Spring-run ESU	Entiat R.	HC, PGR, Age	1960-2008
	Methow R.	HC, PGR, Age	1960-2008
	Wenatchee R.	HC, PGR, Age	1960-2008
Upper Columbia Summer-Fall-run ESU	Escapement estimated at Bonneville	HC, PGR, Age	1996-2010
Upper Willamette R. ESU	Clackamas R. Spring	HC, PGR, Age	1974-2008
	McKenzie R. Spring	HC, PGR, Age	1970-2005

Stock/ESU	Population	Data Types	Period
Coho Salmon			
Lower Columbia R. ESU	Clackamas R.	HC, PGR	1974-2010
	Sandy R.	HC, PGR	1974-2010
Oregon Coast ESU	Alsea R.	HC, PGR	1990-2010
	Beaver Cr.	HC, PGR	1990-2010
	Coos R.	HC, PGR	1990-2010
	Coquille R.	HC, PGR	1990-2010
	Floras/New R.	HC, PGR	1990-2010
	Lower Umpqua R.	HC, PGR	1990-2010
	Middle Umpqua R.	HC, PGR	1990-2010
	Necanicum R.	HC, PGR	1990-2010
	Nehalem R.	HC, PGR	1990-2010
	Nestucca R.	HC, PGR	1990-2010
	North Umpqua R.	HC, PGR	1990-2010
	Salmon R.	HC, PGR	1990-2010
	Siletz R.	HC, PGR	1990-2010
	Siltcoos Lk.	HC, PGR	1990-2010

Stock/ESU	Population	Data Types	Period
	Siuslaw R.	HC, PGR	1990-2010
	Sixes R.	HC, PGR	1990-2010
	South Umpqua R.	HC, PGR	1990-2010
	Tahkenitch Lk.	HC, PGR	1990-2010
	Tenmile Lk.	HC, PGR	1990-2010
	Tillamook Bay	HC, PGR	1990-2010
	Yaquina R.	HC, PGR	1990-2010

STATUS AND TRENDS

MAJOR FINDINGS

Central Valley Fall and Late Fall-run Chinook salmon and Central Valley Spring-run Chinook salmon escapement has demonstrated declines over the last ten years. Central Valley Fall and Late Fall-run Chinook salmon were near their long-term average of abundance over the past ten years whereas Central Valley Spring-run Chinook salmon were below their long-term average of abundance (although Spring-run data are only available from 1995 to present). Sacramento River Winter-run Chinook salmon had recent increases in abundance in 2002, 2003, and 2006 but still remain only a fraction of their historical abundances of even just 30 years ago. Central Valley Fall and Late Fall-run Chinook salmon population abundances have increased following the collapse of 2007-2010 and 2012 estimates of adult abundance are similar to the long-term average, but the proportion of hatchery-origin fish is a concern. In contrast, Chinook salmon in the Klamath River (part of the Southern Oregon and Northern California Coast Chinook salmon ESU) natural production and growth rate are relatively stable as measured by the indices used and the age structure is becoming more complex. With the exception of the Snake River Fall-run, Chinook salmon populations from the Columbia River Basin have experienced declines in abundance over the last ten years. Chinook salmon populations from the Snake River had increases in abundance for the last few years of available data, although the 10-year trends were negative for Snake River Spring/Summer-run Chinook salmon and unchanged for Snake River Fall-run Chinook salmon. With the exception of the Chinook salmon in the Willamette River, Chinook salmon populations in the Columbia River Basin exhibited increases in the proportion of hatchery-origin fish.

California populations of coho salmon have had declines in abundance over the past ten years with the populations in the California portion of the Southern Oregon/Northern California Coast (SONCC) Coho Salmon ESU having significant declines in the past five years. Coho salmon abundance from lower Columbia River was variable but increasing over the past 10 years whereas Oregon Coast coho salmon abundance was variable with no significant trend over the past 10 years although recent abundances were greater than that observed during the late-1990's.

SUMMARY AND STATUS OF TRENDS

Both short- and long-term trends are reported in this summary. An indicator is considered to have changed over the short-term if the trend over the last 10 years (2002-2011) the series showed a significant increasing or decreasing slope. An indicator is considered to be above or below long-term norms if the mean of the last 10 years of the time series differs from the mean of the full time series by more than 1.0 s.d. of the full time series. A major motivation of presenting long- and short-term trends is to distinguish between stocks/populations that were once very large and suffered historical declines but have stabilized at lower abundances from populations with ongoing declines. This was a particular issue for populations with very long time series of abundance (e.g., certain Columbia River Chinook salmon populations). Such very long time series aren't available for most California populations. In addition, one should be cautious using pre-1980 data from Columbia River stocks/populations (and perhaps other locations) since data collection and methods have significantly improved since the early 1980s. Therefore it should be noted that when references are made to "long-term" abundances, conditions, etc. that this is in the context of the time period going back to 1985. Uncertainty about data prior to 1985 led us to limit data used to this time period. In addition, information on historical values of abundance indicate that for many if not most of these populations current values are now at levels far below historical values – so caution should be used when considering the term "long-term".

CALIFORNIA CHINOOK SALMON: ABUNDANCE

Generally all California stocks, minus Sacramento River Winter-run Chinook salmon were within 1 s.d. of their long term average however, during the last ten years there has been a significant decline in abundance of all the California populations examined (Figs. S1 & S2). Largely, though, this relates to a reduction from series highs during 2002 and a return to, generally, average values (Sacramento River Winter-run Chinook salmon time series, which was above average, stopped in 2008).

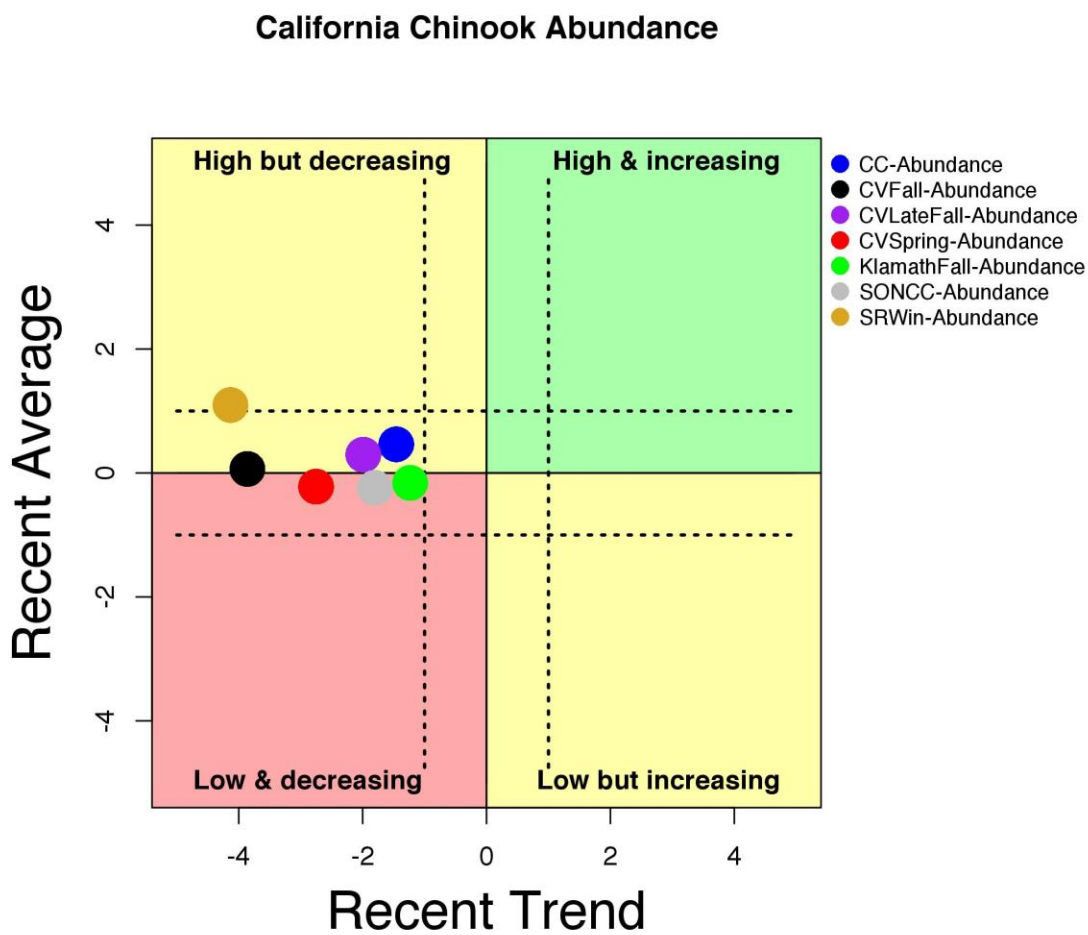
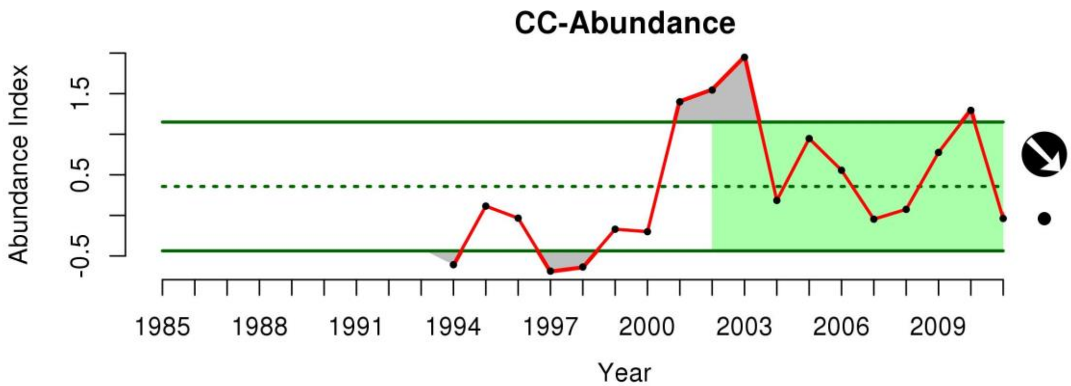
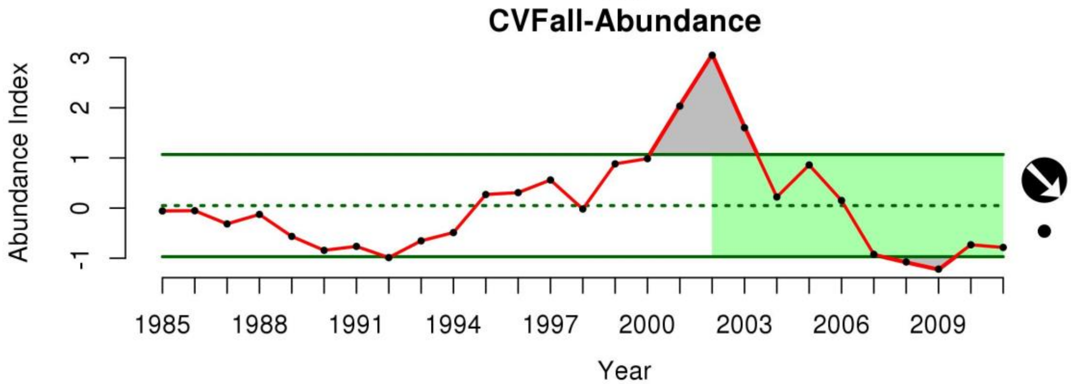
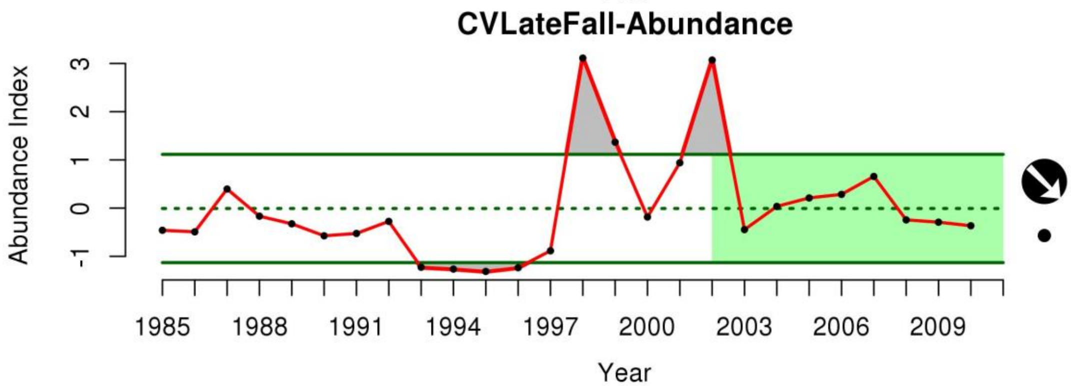
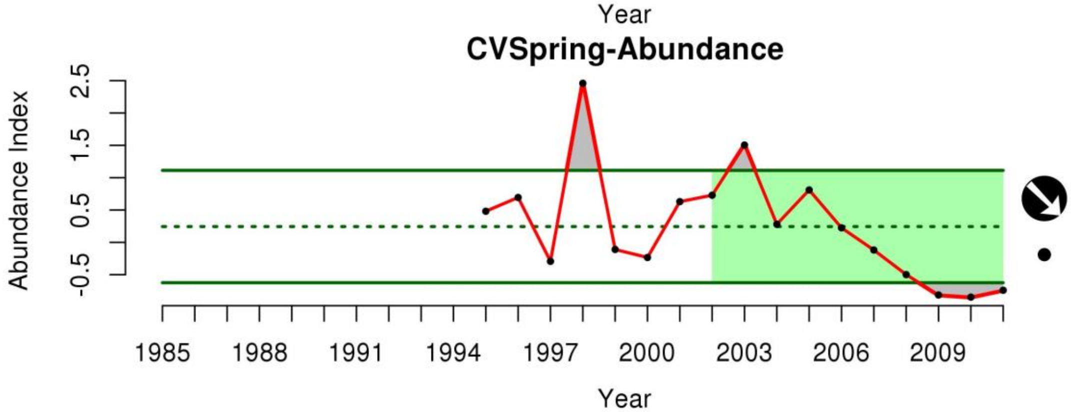


Figure S1. *California Chinook salmon abundance.* Quadplot summarizes information from multiple time series figures. Prior to plotting time series were normalized to place them on the same scale. The short-term trend (x-axis) indicates whether the indicator increased or decreased over the last 10-years. The y-axis indicates whether the mean of the last 10 years is greater or less than the mean of the full time series. Dotted lines show ± 1.0 s.d. Subpopulations listed include: California Coastal (CC), Central Valley (CV) fall, late-fall, and spring, Sacramento River (SR) winter runs, Klamath River fall run, and Sothern Oregon-Northern California (SONCC).


CC-Abundance
Abundance Index
-0.5
0.5
1.5
1985
1988
1991
1994
1997
2000
2003
2006
2009
Year


CVFall-Abundance
Abundance Index
-1
0
1
2
3
1985
1988
1991
1994
1997
2000
2003
2006
2009
Year


CVLateFall-Abundance
Abundance Index
-1
0
1
2
3
1985
1988
1991
1994
1997
2000
2003
2006
2009
Year


CVSpring-Abundance
Abundance Index
-0.5
0.5
1.5
2.5
1985
1988
1991
1994
1997
2000
2003
2006
2009
Year

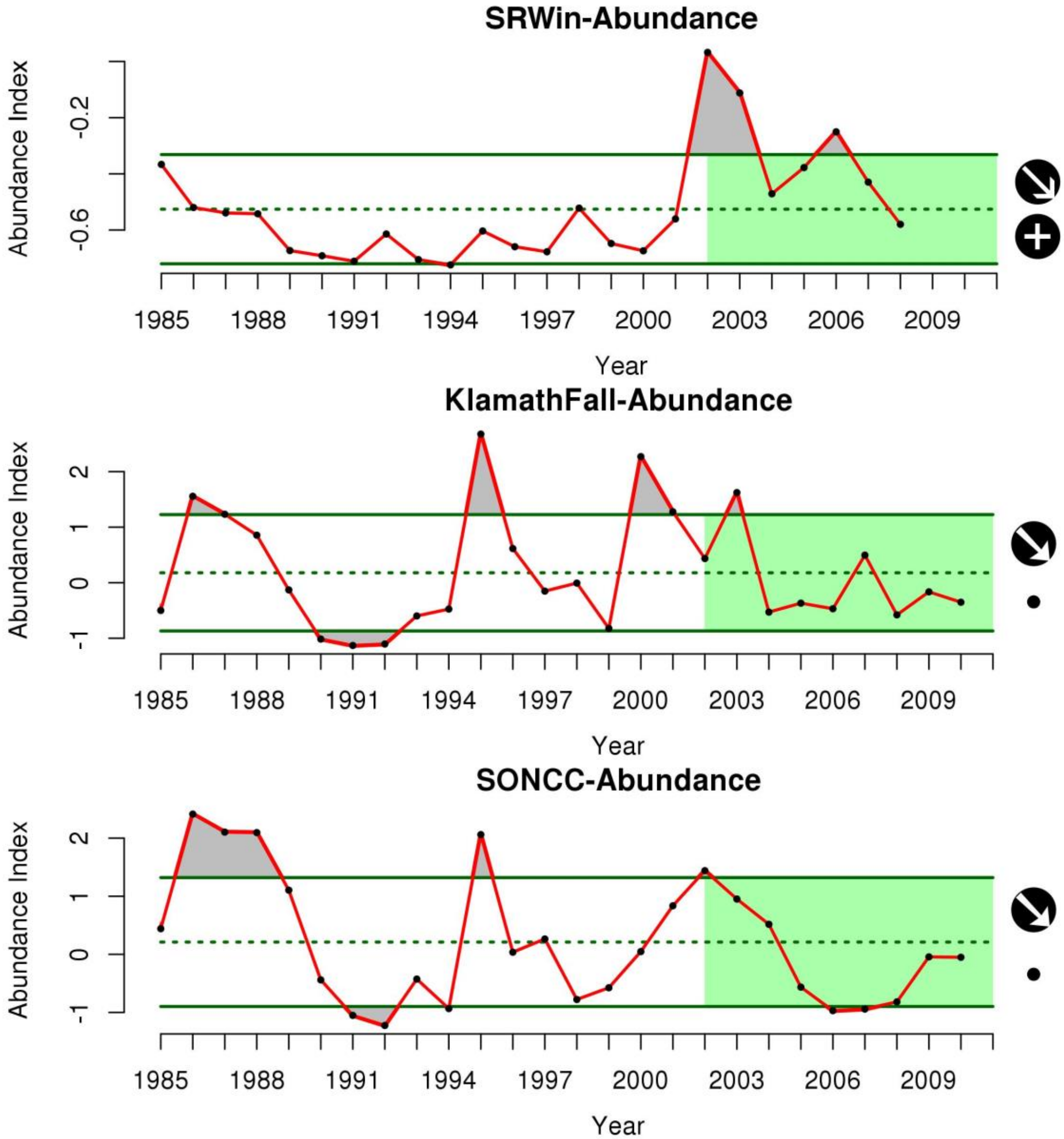


Figure S2. *California Chinook salmon abundance*. Dark green horizontal lines show the mean (dotted) and ± 1.0 s.d. (solid line) of the full time series. The shaded green area is the last 10-years, which is analyzed to produce the symbols to the right of the plot. The upper symbol indicates whether the trend was significant over the last 10-years . The lower symbol indicates whether the mean during the last 10 years was greater or less than or within one s.d. of the long-term mean. Subpopulations listed include: California Coastal (CC), Central Valley (CV) fall, late-fall, and spring, Sacramento River (SR) winter runs, Klamath River fall run, and Sothern Oregon-Northern California (SONCC).

CALIFORNIA CHINOOK SALMON: CONDITION

While there is a recent (last two years) increase in the population growth rate (recovery rate) of the Central Valley Fall and Late Fall-run Chinook salmon, over the last 10 years there has been a decline. In addition, the proportion of the stock that is natural is below the long term average and decreasing. Chinook salmon in the Klamath River (below the confluence of the Klamath and Trinity rivers, part of the SONCC ESU) have, in recent years, had an increase in the diversity of ages and the proportion of wild fish spawning was increasing (Fig. S3, S4).

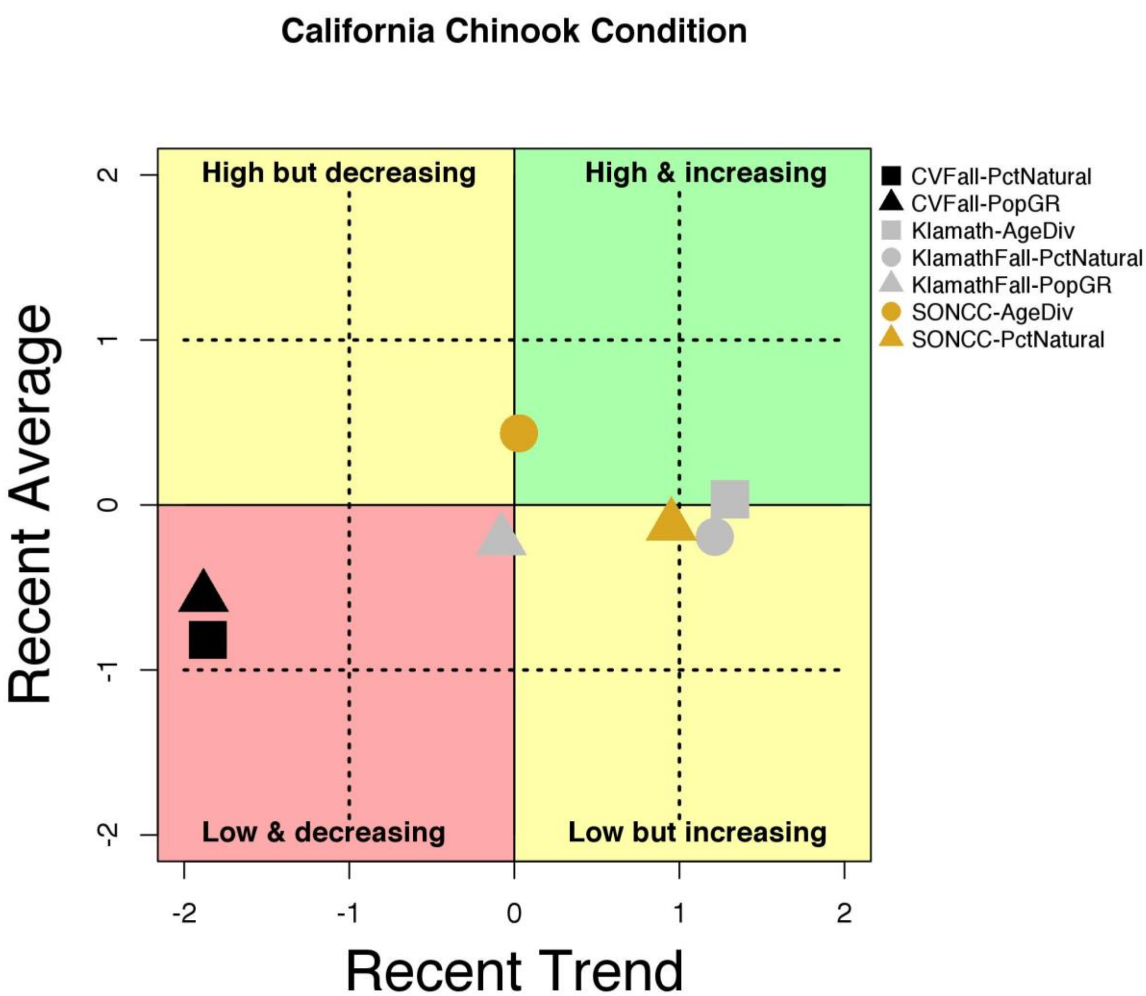
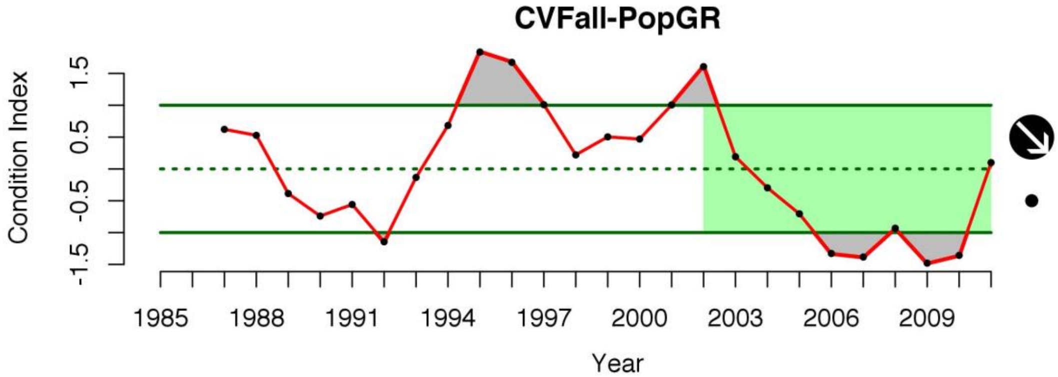
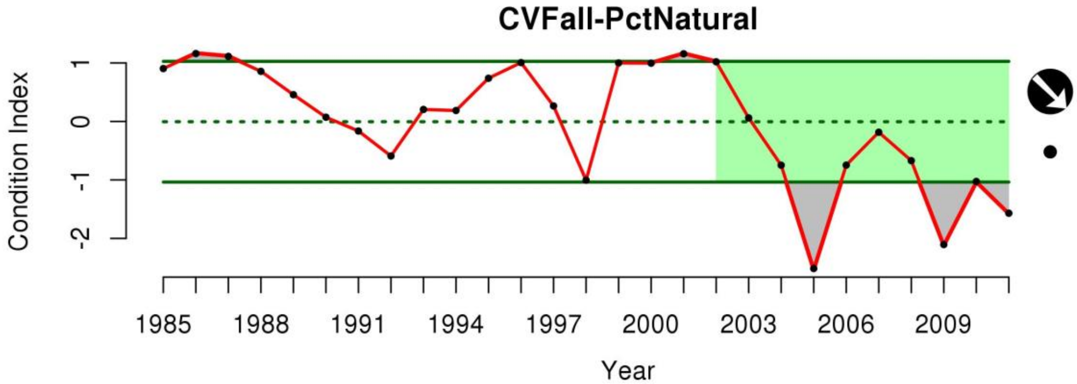
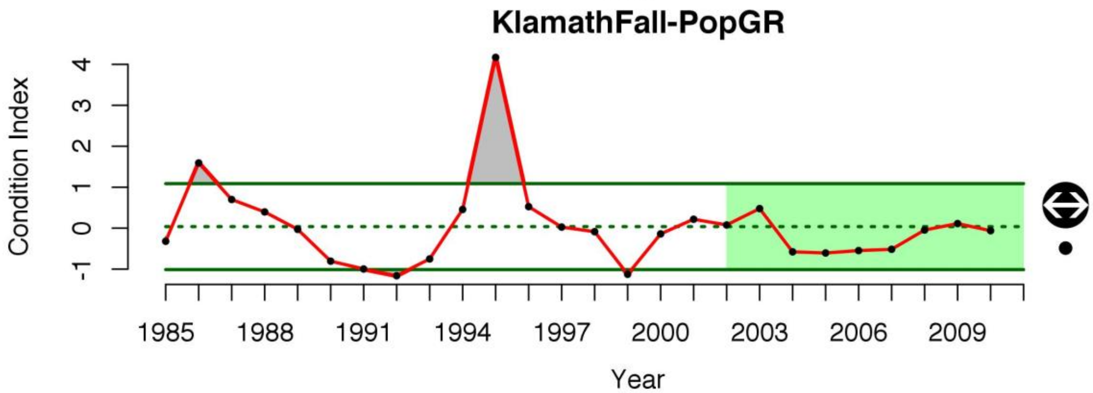
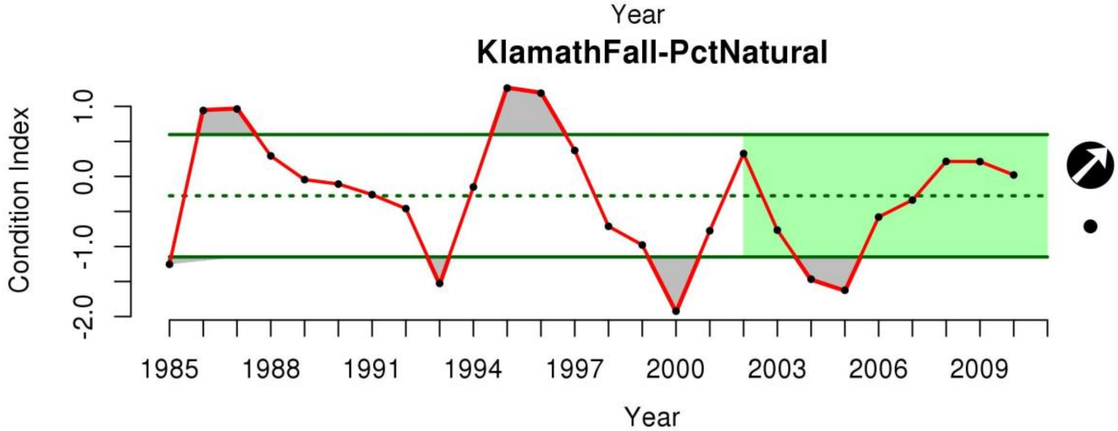


Figure S3. *California Chinook salmon condition.* Quadplot summarizes information from multiple time series figures. Prior to plotting time series were normalized to place them on the same scale. The short-term trend (x-axis) indicates whether the indicator increased or decreased over the last 10-years. The y-axis indicates whether the mean of the last 10 years is greater or less than the mean of the full time series. Dotted lines show ± 1.0 s.d. When possible we evaluated percent natural spawners (PctNatural), age-structure diversity (AgeDiv), and population growth rate (PopGR). Subpopulations listed include: Central Valley (CV) fall run, Klamath River fall-run, and Sothern Oregon-Northern California (SONCC).


CVFall-PopGR
Condition Index
1.5
0.5
-0.5
-1.5
1985
1988
1991
1994
1997
2000
2003
2006
2009
Year


CVFall-PctNatural
Condition Index
1
0
-1
-2
1985
1988
1991
1994
1997
2000
2003
2006
2009
Year


KlamathFall-PopGR
Condition Index
4
3
2
1
0
-1
1985
1988
1991
1994
1997
2000
2003
2006
2009
Year


KlamathFall-PctNatural
Condition Index
1.0
0.0
-1.0
-2.0
1985
1988
1991
1994
1997
2000
2003
2006
2009
Year

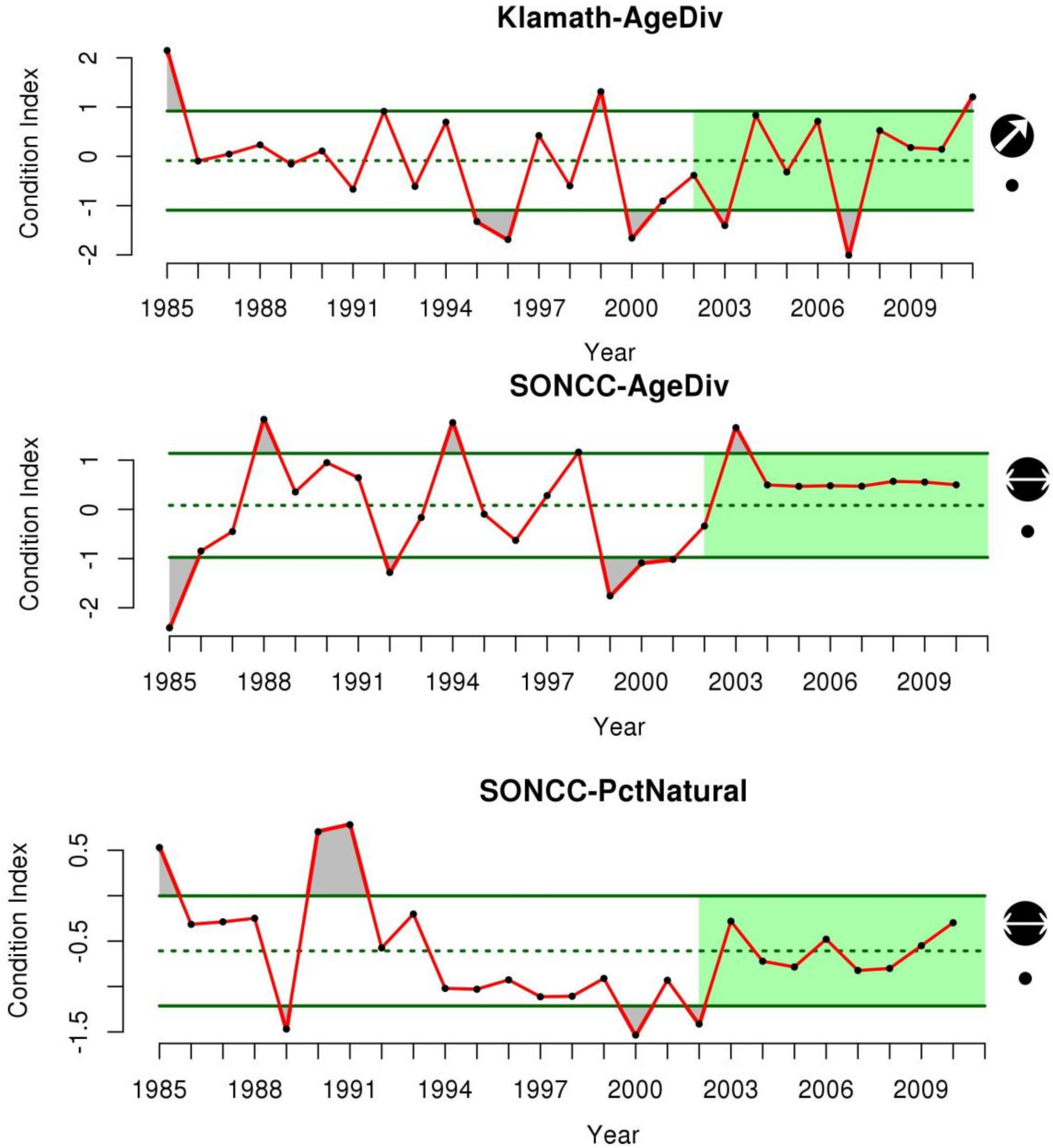


Figure S4. *California Chinook salmon condition*. Dark green horizontal lines show the mean (dotted) and ± 1.0 s.d. (solid line) of the full time series. The shaded green area is the last 10-years, which is analyzed to produce the symbols to the right of the plot. The upper symbol indicates whether the trend was significant over the last 10-years . The lower symbol indicates whether the mean during the last 10 years was greater or less than or within one s.d. of the long-term mean. When possible we evaluated percent natural spawners (PctNatural), age-structure diversity (AgeDiv), and population growth rate (PopGR). Subpopulations listed include: Central Valley (CV) fall run, Klamath River fall-run, and Sothern Oregon-Northern California (SONCC).

CALIFORNIA COHO SALMON: ABUNDANCE

Central California Coast coho salmon abundance has not been within 1 s.d. of the long- and short-term average for only two of the 17 years of data available. From those two high abundance years of 2003 and 2004 the abundance declined over the past ten years (Fig. S6). Abundance of California populations of Southern Oregon/Northern California Coast coho salmon have declined over the past 10 years from high abundance during 2004 (Figs. S5, S6).

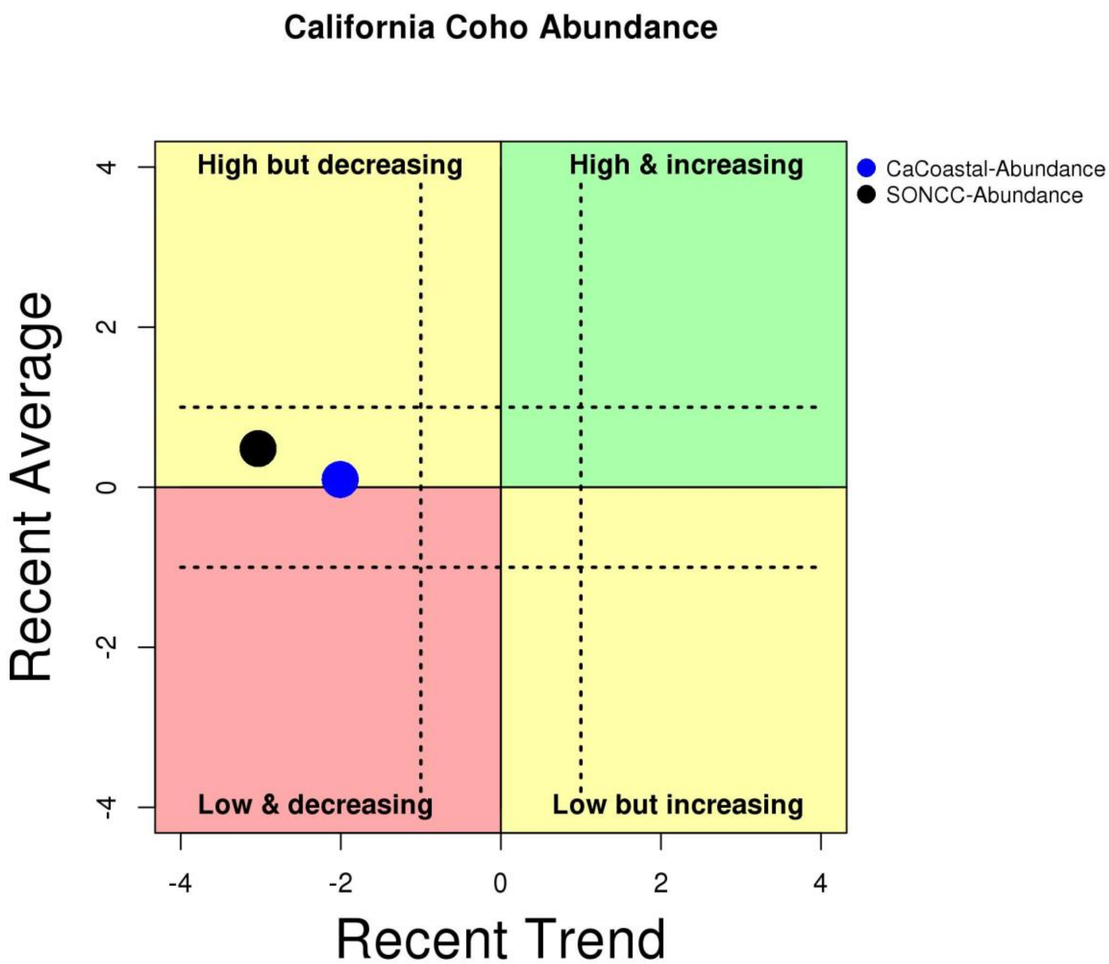


Figure S5. *California coho salmon abundance.* Quadplot summarizes information from multiple time series figures. Prior to plotting time series were normalized to place them on the same scale. The short-term trend (x-axis) indicates whether the indicator increased or decreased over the last 10-years. The y-axis indicates whether the mean of the last 10 years is greater or less than the mean of the full time series. Dotted lines show ± 1.0 s.d. Subpopulations listed include: California coastal (CaCoastal) and Sothern Oregon-Northern California (SONCC).

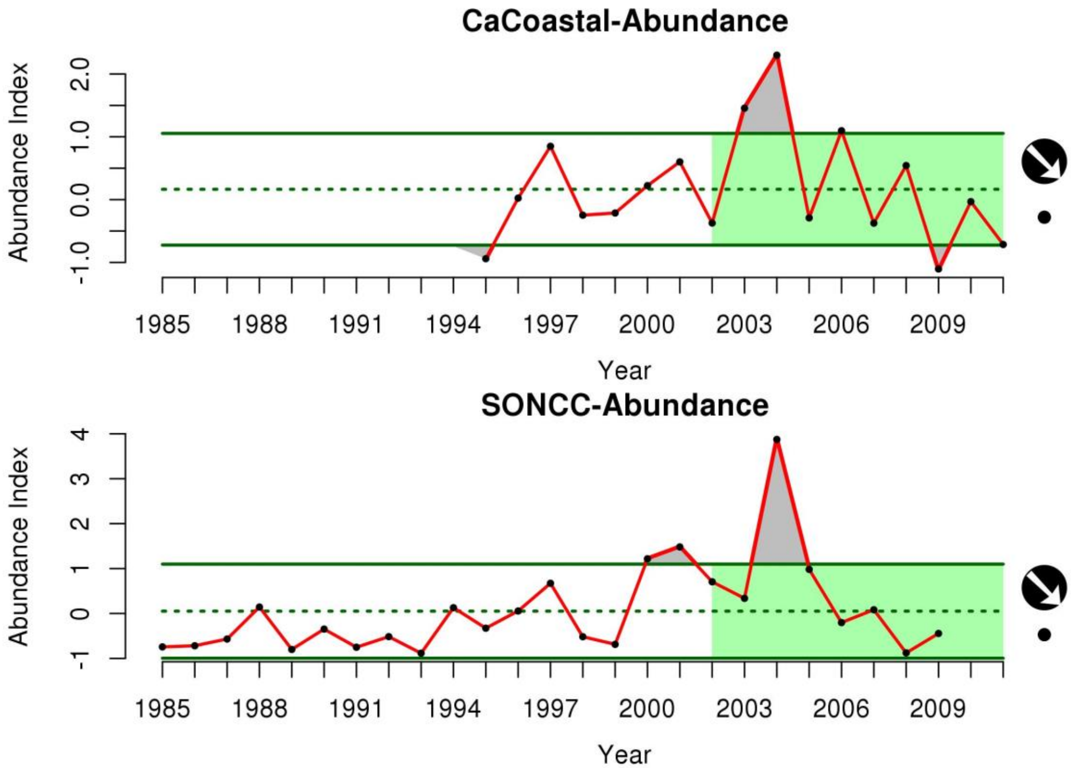


Figure S6. *California Chinook salmon abundance*. Dark green horizontal lines show the mean (dotted) and ± 1.0 s.d. (solid line) of the full time series. The shaded green area is the last 10-years, which is analyzed to produce the symbols to the right of the plot. The upper symbol indicates whether the trend was significant over the last 10-years . The lower symbol indicates whether the mean during the last 10 years was greater or less than or within one s.d. of the long-term mean. Subpopulations listed include: California coastal (CaCoastal) and Sothern Oregon-Northern California (SONCC).

CALIFORNIA COHO SALMON: CONDITION

No data available.

OREGON-WASHINGTON CHINOOK SALMON: ABUNDANCE

Over the long-term, Oregon and Washington Chinook salmon abundances have exhibited substantial variation (Fig. S7) with all but Snake River Fall-run Chinook salmon and Upper Columbia River Spring-run Chinook salmon declining over the past 10 years (Fig. S8). While there has not been a significant trend the Snake River Fall-run Chinook salmon has been above its long term average in the last ten years.

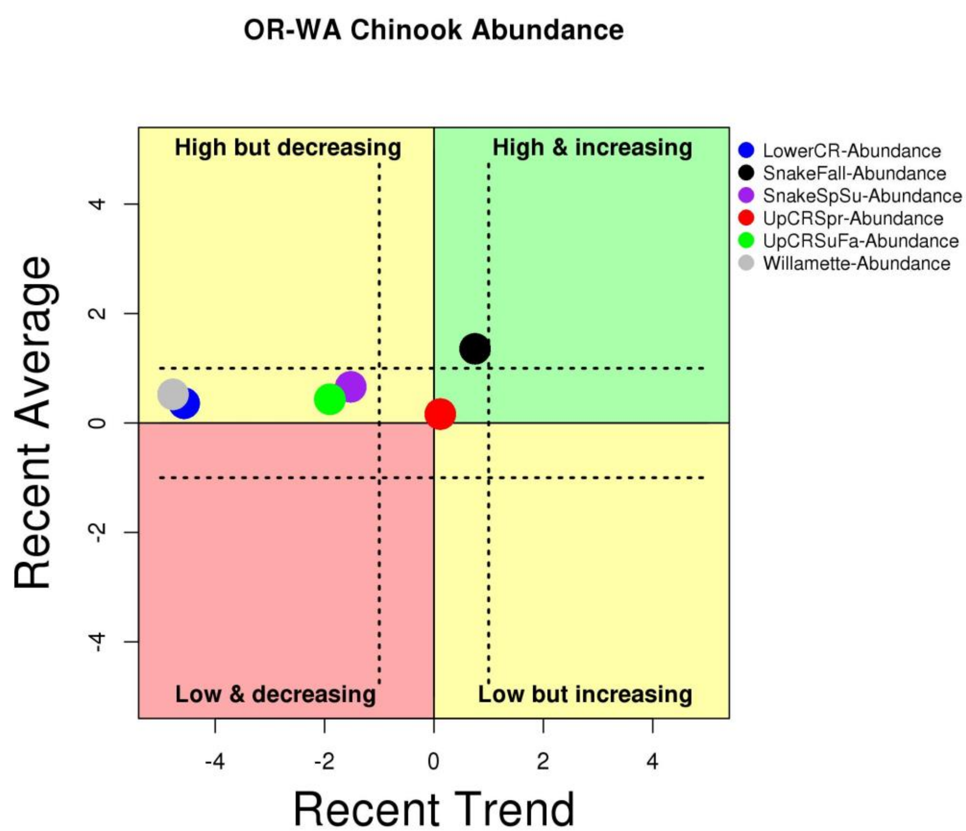
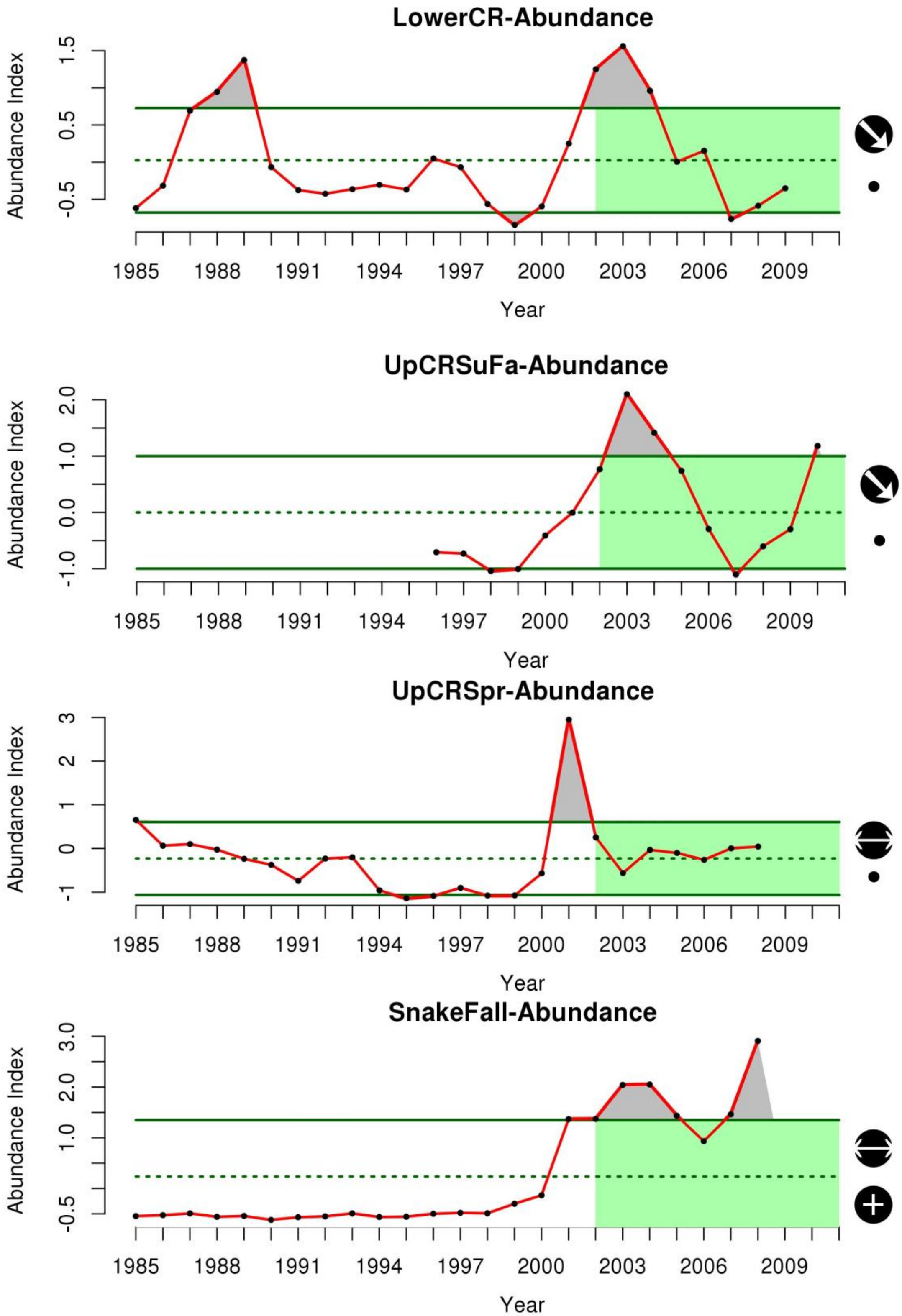


Figure S7. *Oregon-Washington Chinook salmon abundance.* Quadplot summarizes information from multiple time series figures. Prior to plotting time series were normalized to place them on the same scale. The short-term trend (x-axis) indicates whether the indicator increased or decreased over the last 10-years. The y-axis indicates whether the mean of the last 10 years is greater or less than the mean of the full time series. Dotted lines show ± 1.0 s.d. Subpopulations listed include: lower Columbia River (LowerCR), Snake fall, Snake spring-summer (SnakeSpSu), upper Columbia River summer-fall (UpCRSuFa), and Willamette.



LowerCR-Abundance
Abundance Index
Year
UpCRSuFa-Abundance
Abundance Index
Year
UpCRSpr-Abundance
Abundance Index
Year
SnakeFall-Abundance
Abundance Index
Year

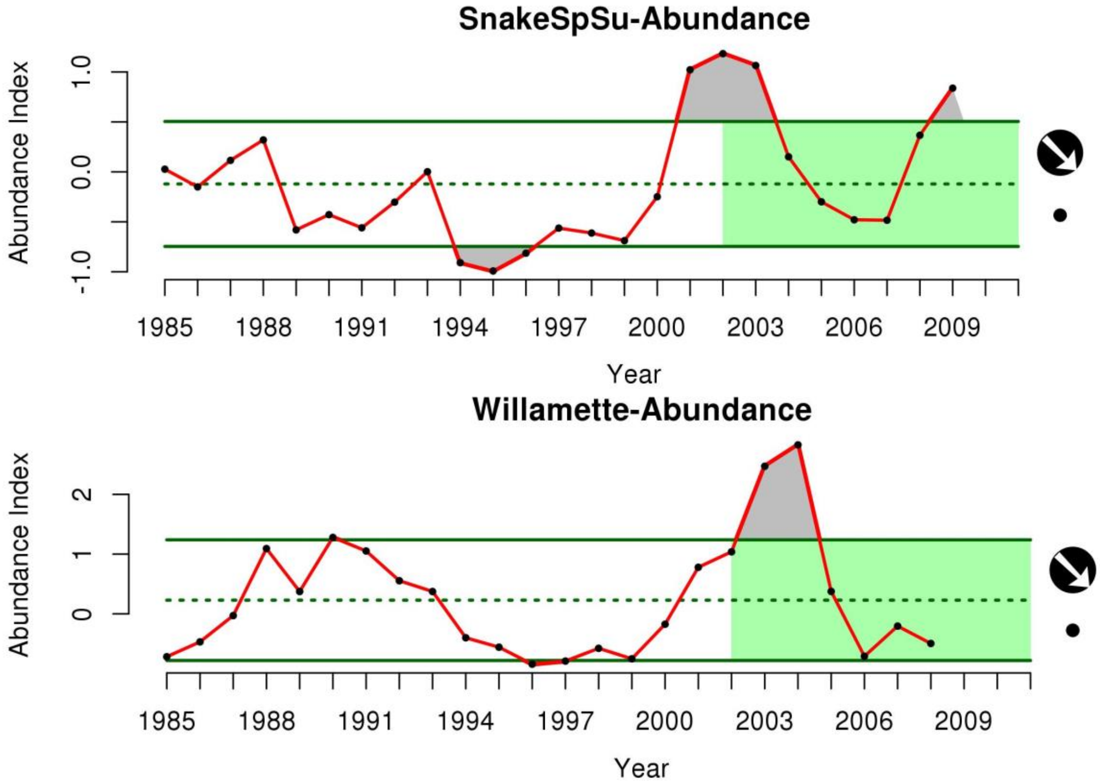


Figure S8. *Oregon-Washington Chinook salmon abundance*. Dark green horizontal lines show the mean (dotted) and ± 1.0 s.d. (solid line) of the full time series. The shaded green area is the last 10-years, which is analyzed to produce the symbols to the right of the plot. The upper symbol indicates whether the trend was significant over the last 10-years . The lower symbol indicates whether the mean during the last 10 years was greater or less than or within one s.d. of the long-term mean. Subpopulations listed include: lower Columbia River (LowerCR), Snake fall, Snake spring-summer (SnakeSpSu), upper Columbia River summer-fall (UpCRSuFa), and Willamette.

OREGON-WASHINGTON CHINOOK SALMON: CONDITION

There are few obvious patterns in the condition indicators for Oregon and Washington Chinook salmon, with a wide mix of positive and negative trends at both time scales (Fig. S9, S10). One apparent pattern is the concentration of points in the “low and decreasing” quadrant for the proportion of natural spawners (“PctNat”), suggesting an increasing overall influence of hatchery production for these stocks. This is likely due to increases in Columbia Basin hatchery production during the 1970s as mitigation for dam construction (long-term trends) and starting in the late 1990s as supplementation for stock rebuilding (short-term trends).

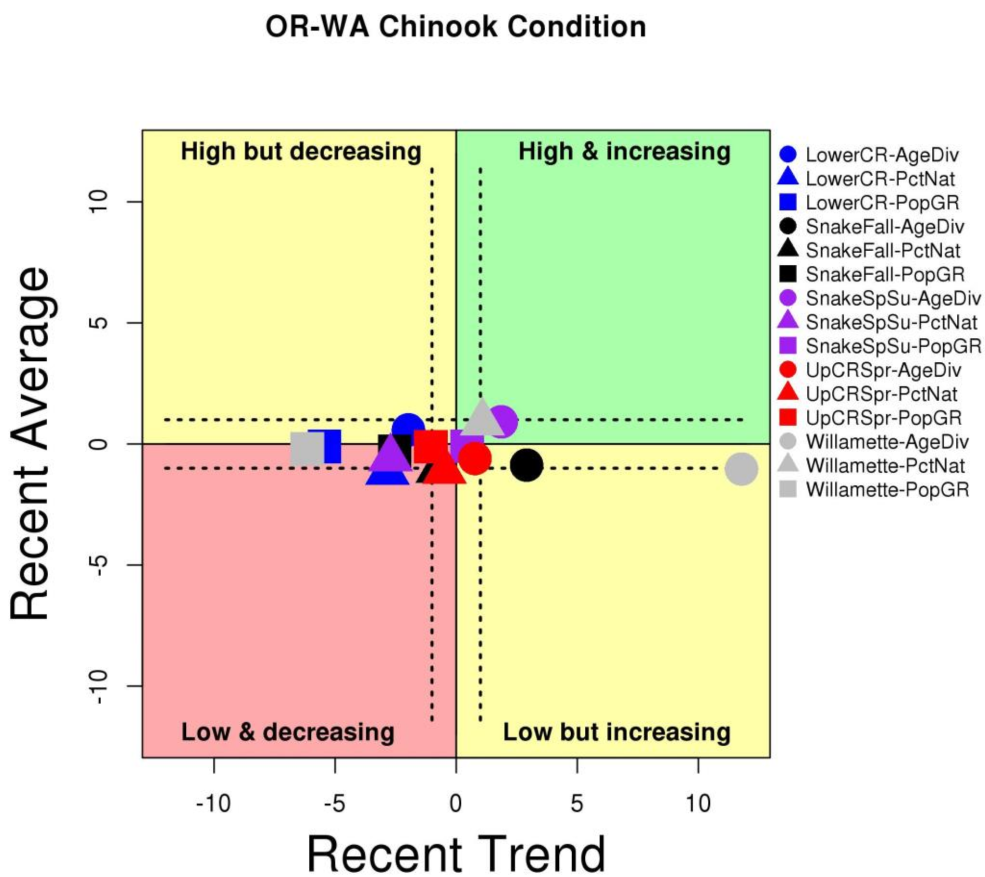
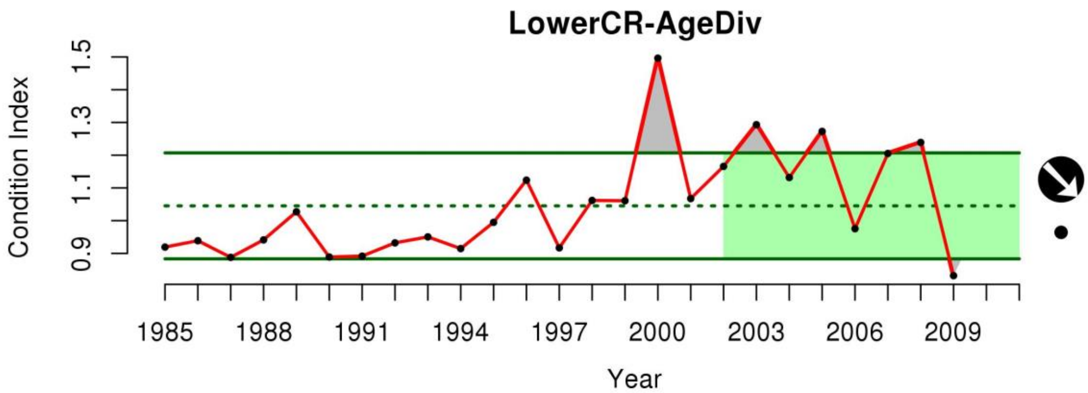
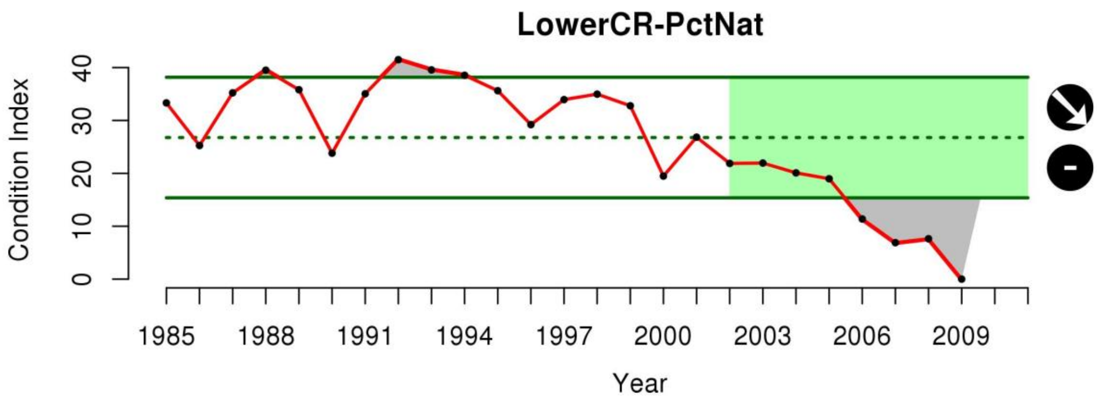
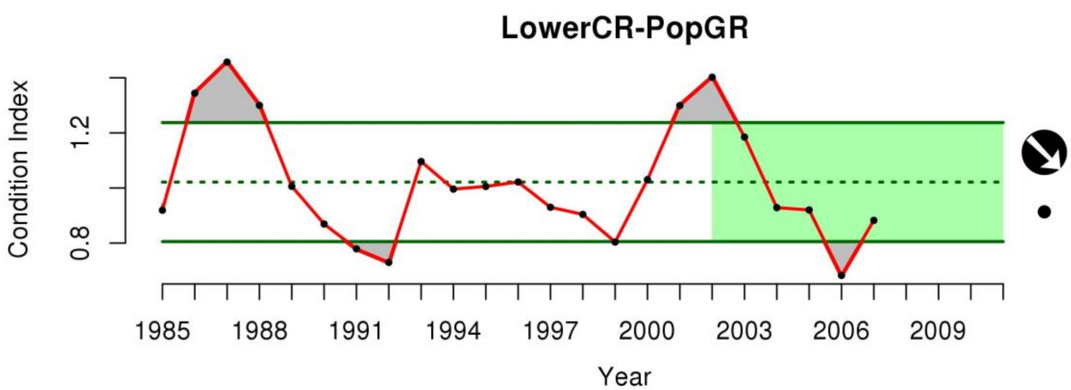
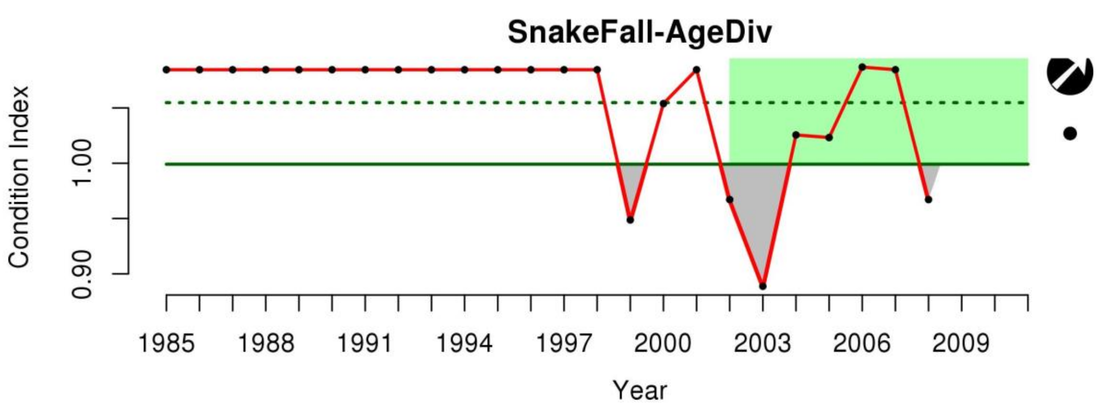


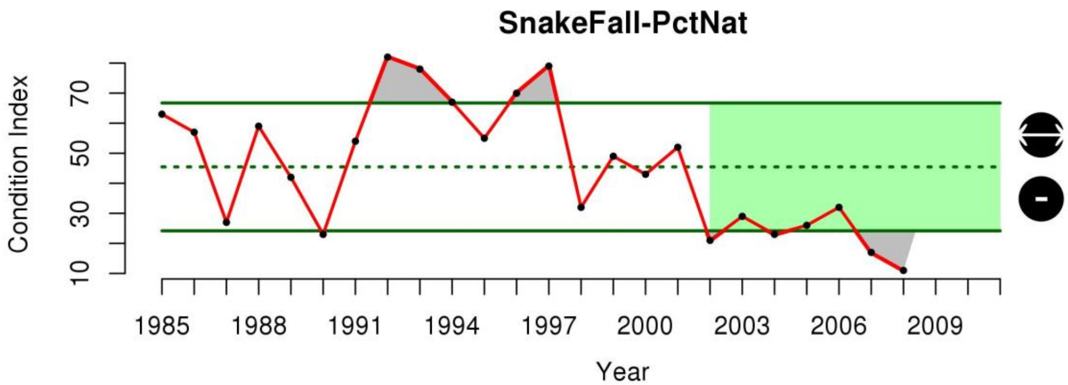
Figure S9. *Oregon-Washington Chinook salmon condition.* Quadplot summarizes information from multiple time series figures. Prior to plotting time series were normalized to place them on the same scale. The short-term trend (x-axis) indicates whether the indicator increased or decreased over the last 10-years. The y-axis indicates whether the mean of the last 10 years is greater or less than the mean of the full time series. Dotted lines show ± 1.0 s.d. When possible we evaluated percent natural spawners (PctNatural), age-structure diversity (AgeDiv), and population growth rate (PopGR). Subpopulations listed include: lower Columbia River (LowerCR), Snake fall, Snake spring-summer (SnakeSpSu), upper Columbia River summer-fall (UpCRSuFa), and Willamette.

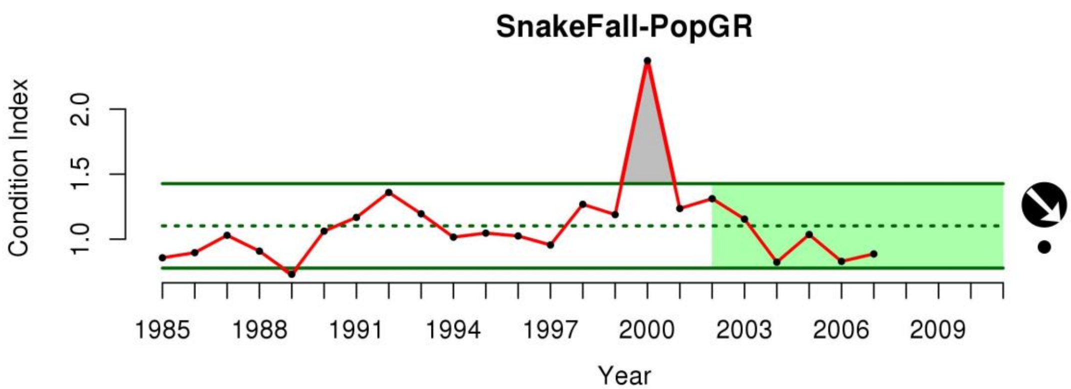

LowerCR-AgeDiv
Condition Index
Year

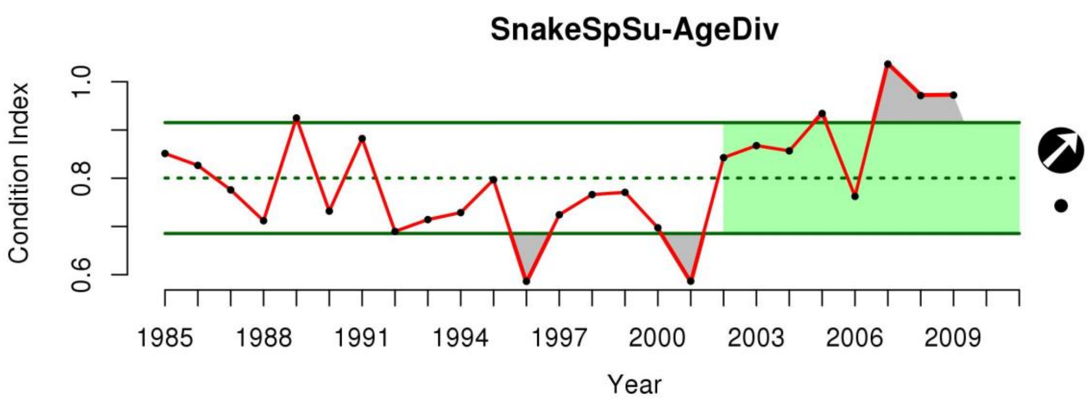

LowerCR-PctNat
Condition Index
Year

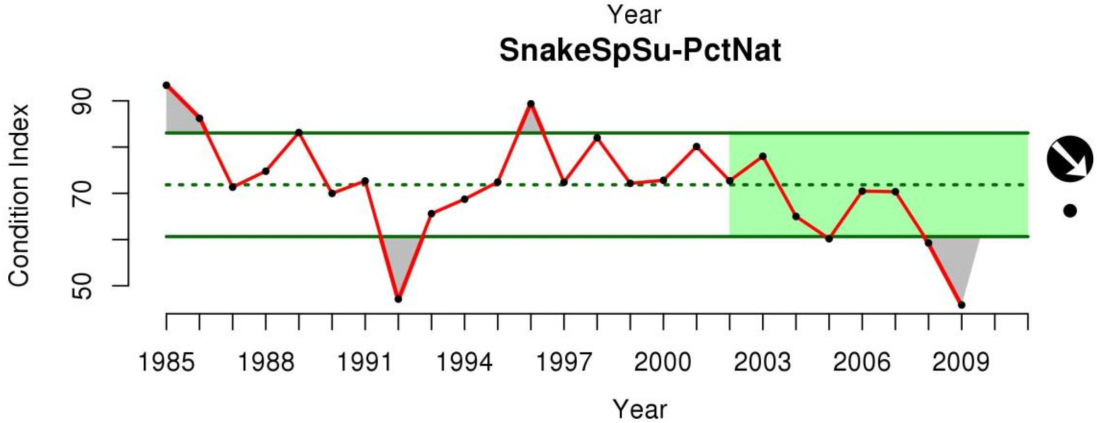

LowerCR-PopGR
Condition Index
Year

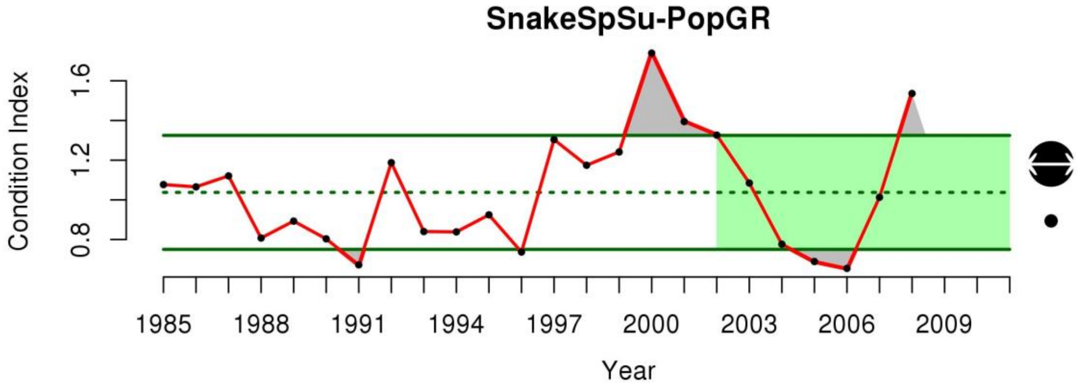

SnakeFall-AgeDiv
Condition Index
Year

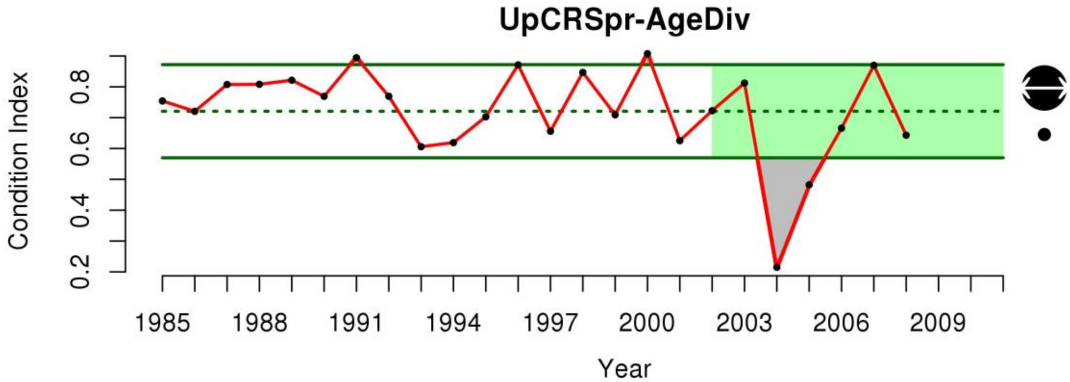

SnakeFall-PctNat
Condition Index
10
30
50
70
1985
1988
1991
1994
1997
2000
2003
2006
2009
Year

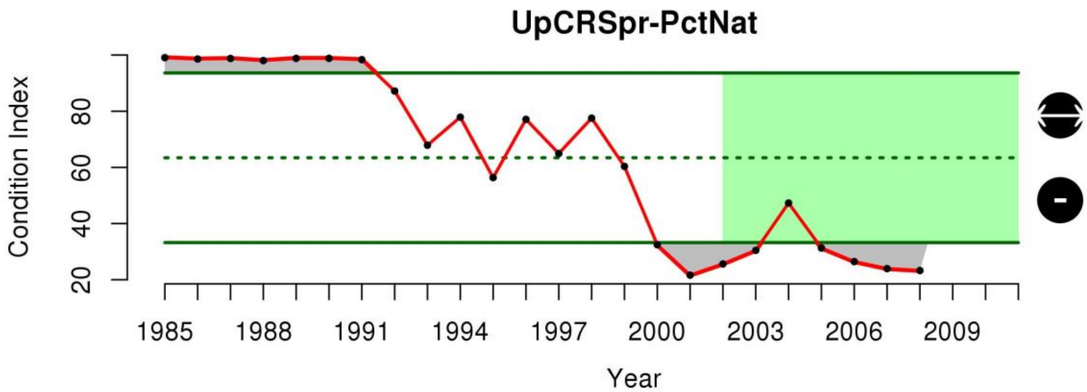

SnakeFall-PopGR
Condition Index
1.0
1.5
2.0
1985
1988
1991
1994
1997
2000
2003
2006
2009
Year

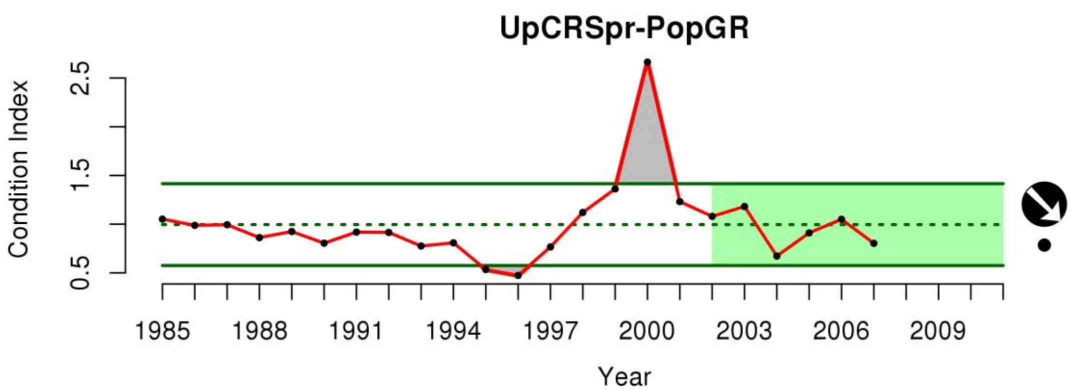

SnakeSpSu-AgeDiv
Condition Index
0.6
0.8
1.0
1985
1988
1991
1994
1997
2000
2003
2006
2009
Year


SnakeSpSu-PctNat
Condition Index
50
70
90
1985
1988
1991
1994
1997
2000
2003
2006
2009
Year


SnakeSpSu-PopGR
Condition Index
Year


UpCRSpr-AgeDiv
Condition Index
Year


UpCRSpr-PctNat
Condition Index
Year


UpCRSpr-PopGR
Condition Index
Year

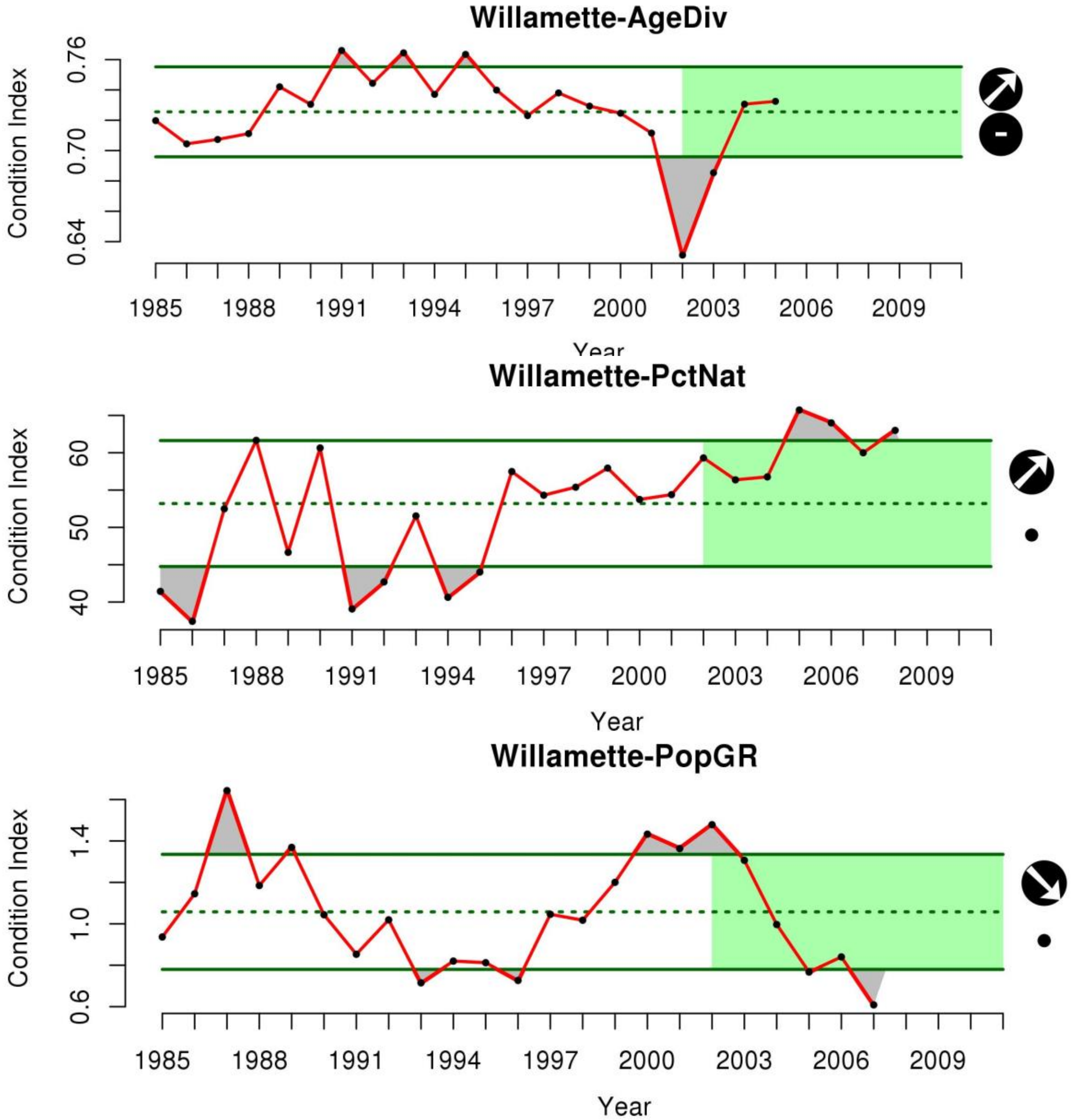


Figure S10 a,b,c. *Oregon-Washington Chinook salmon condition*. Dark green horizontal lines show the mean (dotted) and ± 1.0 s.d. (solid line) of the full time series. The shaded green area is the last 10-years, which is analyzed to produce the symbols to the right of the plot. The upper symbol indicates whether the trend was significant over the last 10-years . The lower symbol indicates whether the mean during the last 10 years was greater or less than or within one s.d. of the long-term mean. When possible we evaluated percent natural spawners (PctNatural), age-structure diversity (AgeDiv), and population growth rate (PopGR). Subpopulations listed include: lower Columbia River (LowerCR), Snake fall, Snake spring-summer (SnakeSpSu), upper Columbia River summer-fall (UpCRSuFa), and Willamette.

OREGON-WASHINGTON COHO SALMON: ABUNDANCE

Coho salmon abundance from lower Columbia River was variable but increasing over the past 10 years whereas Oregon Coast abundance was variable with no significant trend over the past 10 years although recent abundances were greater than that observed during the late-1990's. (Fig. S11, S12).

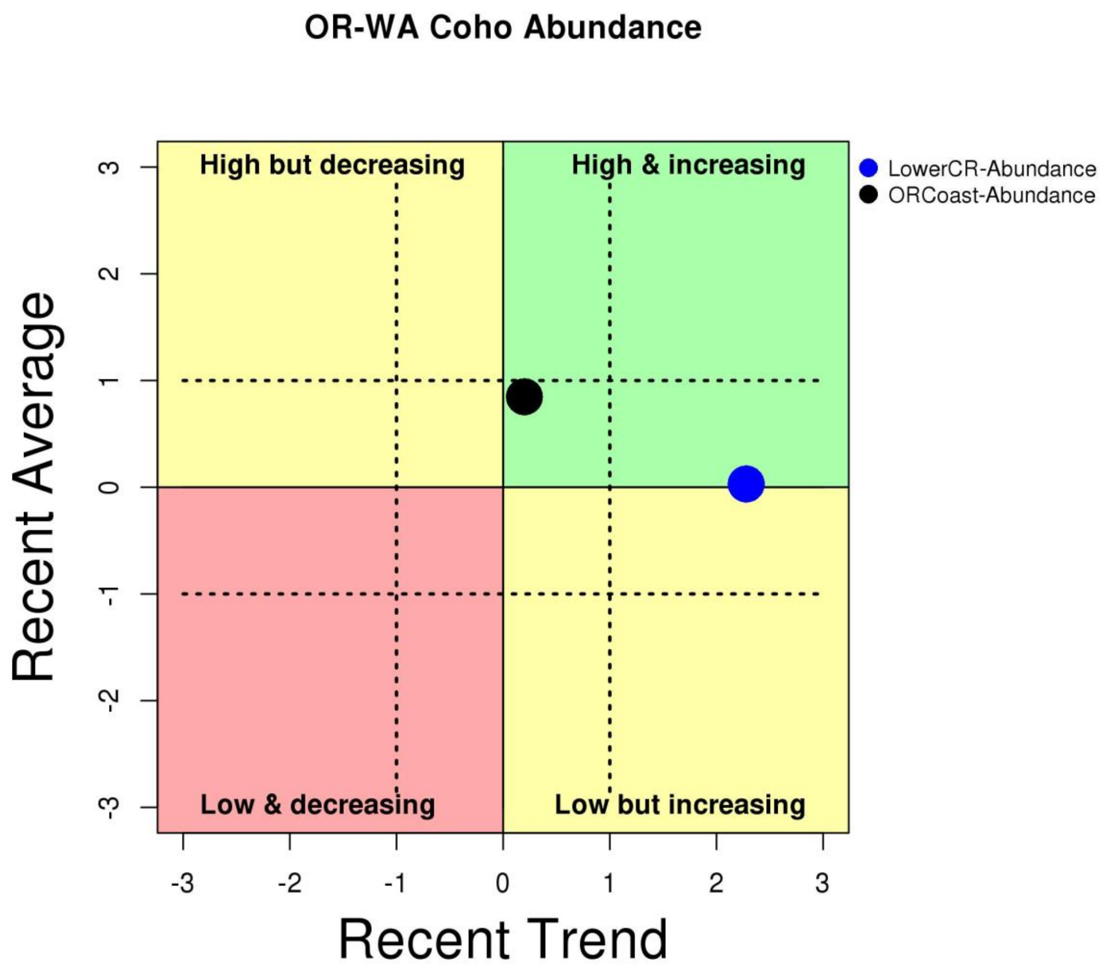


Figure S11. *Oregon-Washington coho salmon abundance.* Quadplot summarizes information from multiple time series figures. Prior to plotting time series were normalized to place them on the same scale. The short-term trend (x-axis) indicates whether the indicator increased or decreased over the last 10-years. The y-axis indicates whether the mean of the last 10 years is greater or less than the mean of the full time series. Dotted lines show ± 1.0 s.d. Subpopulations listed include: lower Columbia River (LowerCR) and Oregon coastal (ORCoast).

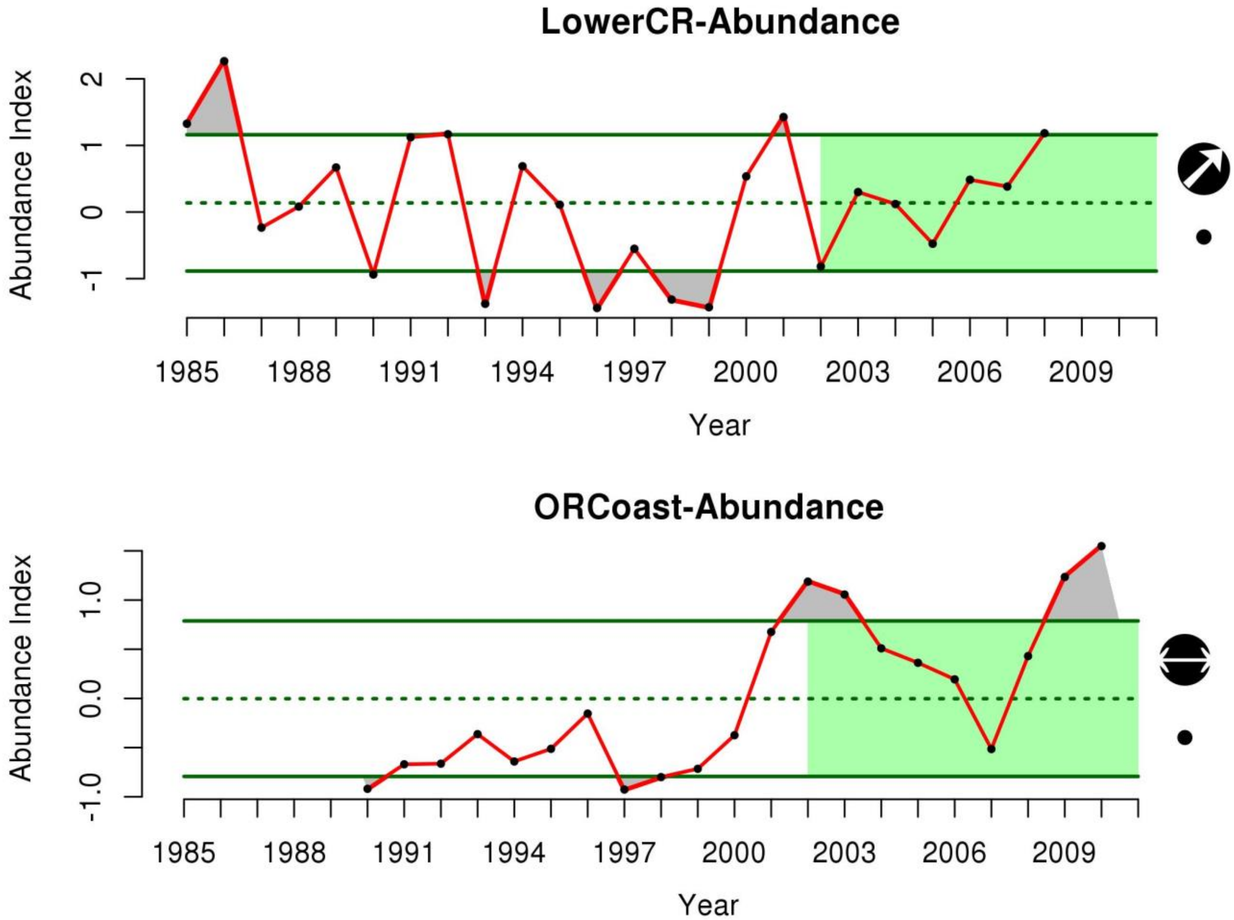


Figure S12. *Oregon-Washington coho salmon abundance*. Dark green horizontal lines show the mean (dotted) and ± 1.0 s.d. (solid line) of the full time series. The shaded green area is the last 10-years, which is analyzed to produce the symbols to the right of the plot. The upper symbol indicates whether the trend was significant over the last 10-years . The lower symbol indicates whether the mean during the last 10 years was greater or less than or within one s.d. of the long-term mean. Subpopulations listed include: lower Columbia River (LowerCR) and Oregon coastal (ORCoast).

OREGON-WASHINGTON COHO SALMON: CONDITION

Trends in proportion of natural spawners (“PctNat”) and population growth rate (“PopGrowth”) for these ESUs are neutral or positive at both time scales (Fig. S13, S14). The long term increase of PctNat for Oregon Coast coho salmon is encouraging.

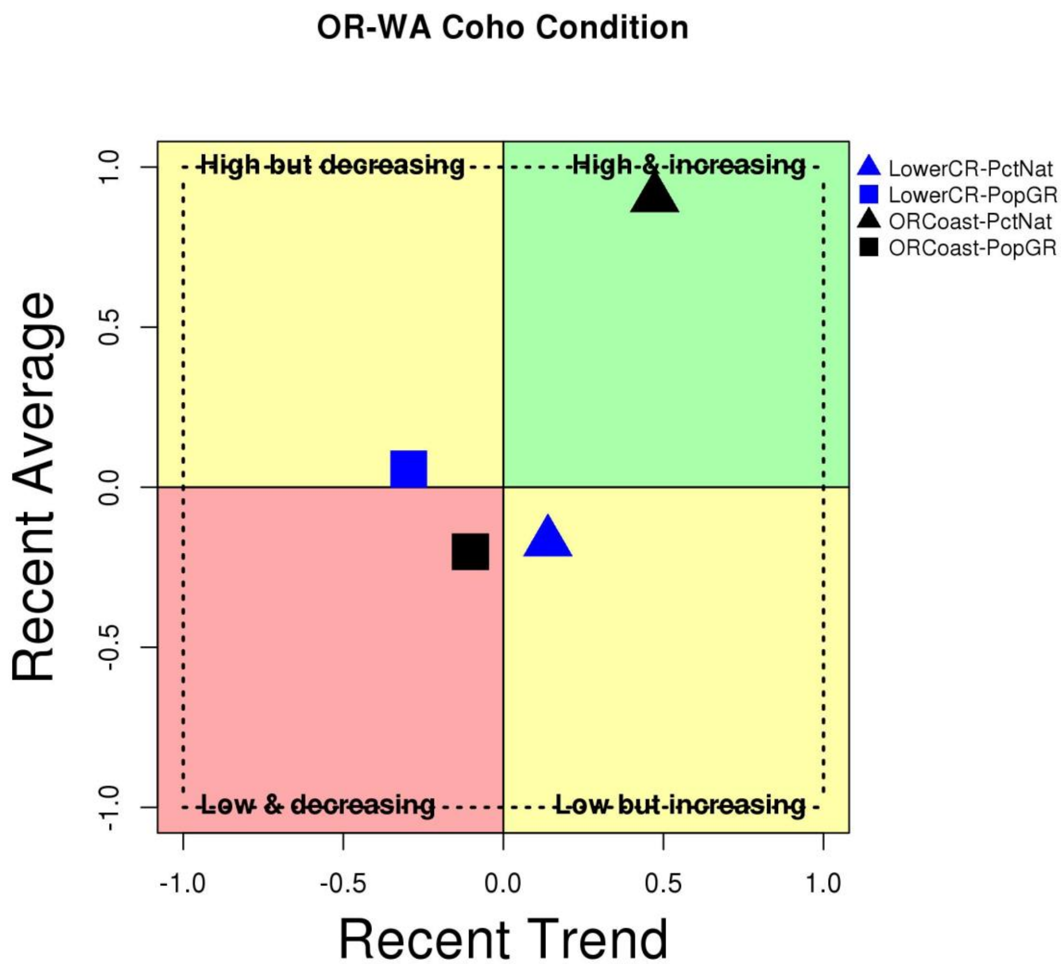


Figure S13. *Oregon-Washington coho salmon condition.* Quadplot summarizes information from multiple time series figures. Prior to plotting time series were normalized to place them on the same scale. The short-term trend (x-axis) indicates whether the indicator increased or decreased over the last 10-years. The y-axis indicates whether the mean of the last 10 years is greater or less than the mean of the full time series. Dotted lines show ± 1.0 s.d. We evaluated percent natural spawners (PctNat) and population growth rate (PopGR). Subpopulations listed include: lower Columbia River (LowerCR) and Oregon coastal (ORCoast).

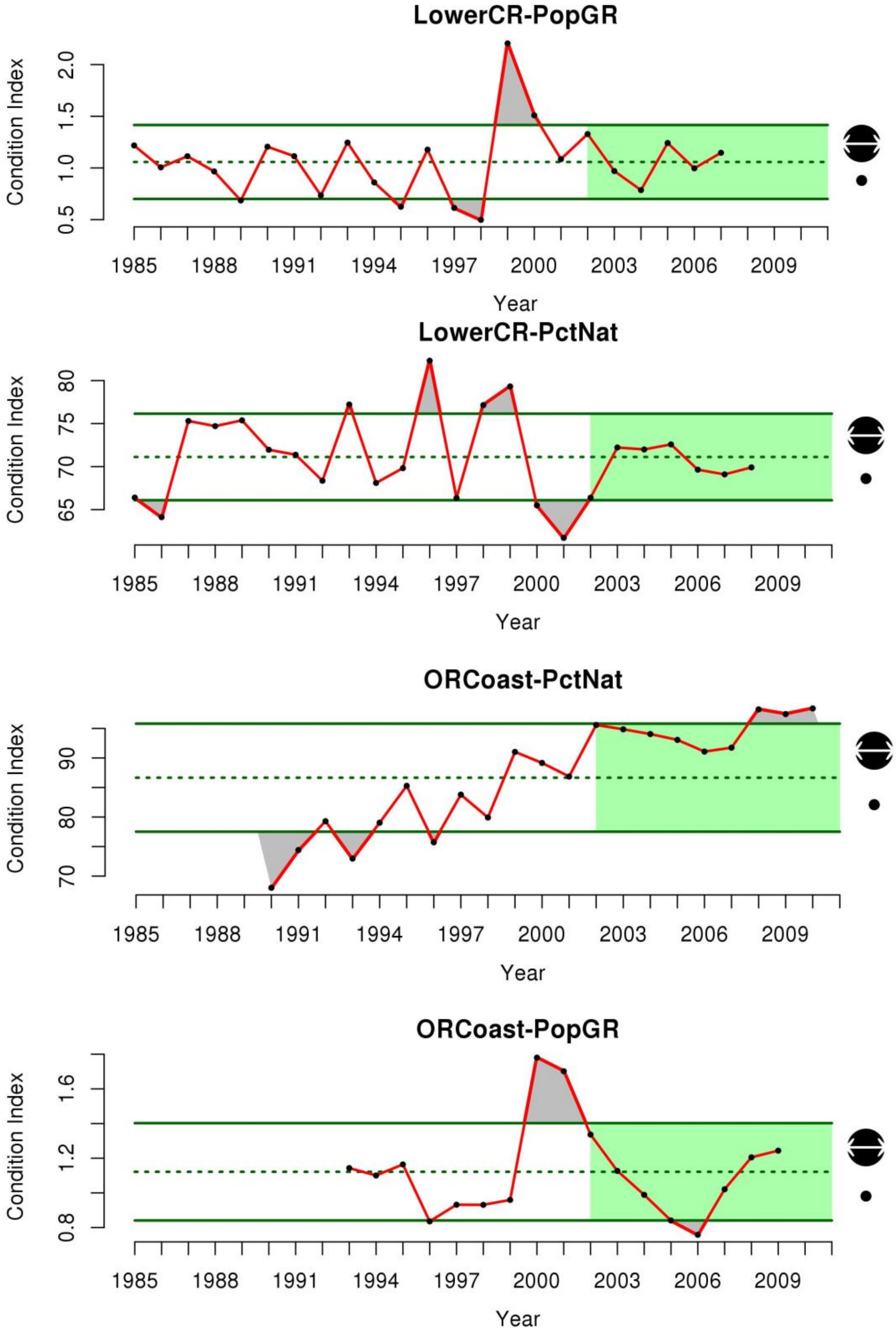


Figure S14. *Oregon-Washington coho salmon condition*. Dark green horizontal lines show the mean (dotted) and ± 1.0 s.d. (solid line) of the full time series. The shaded green area is the last 10-years, which is analyzed to produce the symbols to the right of the plot. The upper symbol indicates whether the trend was significant over the last 10-years . The lower symbol indicates whether the mean during the last 10 years was greater or less than or within one s.d. of the long-term mean. We evaluated percent natural spawners (PctNat) and population growth rate (PopGR). Subpopulations listed include: lower Columbia River (LowerCR) and Oregon coastal (ORCoast).

RISK

We do not evaluate risk in this chapter but are working toward developing metrics of risk that could be helpful for evaluating harvest control rules on the populations. Risk evaluation and forecast will be further developed in subsequent reports.

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Integrated Ecosystem Assessment of the California Current

Phase II Report 2012

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Chapter (example):

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Appendix, example for MS5:

Gray, I.A., I.C. Kaplan, I.G. Taylor, D.S. Holland, and J. Leonard. 2013. Biological and economic effects of catch changes due to the Pacific Coast Groundfish individual quota system, Appendix MS5, Appendix to: Management testing and scenarios in the California Current, In: Levin, P.S., Wells, B.K., and M.B. Sheer (Eds.). California Current Integrated Ecosystem Assessment: Phase II Report. Available from ***http://www.noaa.gov/iea/CCIEA-Report/index***.