Agenda Item C.1
Situation Summary
March 2014

CALIFORNIA CURRENT ECOSYSTEM REPORT INCLUDING INTEGRATED ECOSYSTEM ASSESSMENT

The National Marine Fisheries Service (NMFS) will report on three topics under this agenda item: 1) the State of the California Current Ecosystem Report, 2) the California Current Integrated Ecosystem Assessment (IEA) Phase II Report, and 3) current IEA work. Additionally, under this agenda item, the Council is scheduled to review and discuss the status of ecosystem initiatives under the Fishery Ecosystem Plan (FEP).

State of the California Current Ecosystem Report

The FEP calls for an annual report to the Council on status and trends in the California Current Large Marine Ecosystem (CCLME). The Integrated Ecosystem Assessment Team (convened by the National Oceanic and Atmospheric Administration, or NOAA) has produced a second State of the California Current Ecosystem report, following past Council guidance on indicators and report content (Agenda Item C.1.a, Attachments 1 and Attachment 2). The purpose of this report is to bring ecosystem information for the CCLME into the Council process in a succinct, straightforward format to inform decision-making through the consideration of ecosystem variability. The report includes a synthesis of 22 key environmental, biological, and socio-economic indicators. The goal of the report is to present trends in physical and biological components of the ecosystem - alongside fisheries, ecosystem impacts from other human activities, and socio-economic factors.

IEA Phase II Report

The California Current Integrated Ecosystem Assessment Phase II Report (Agenda Item C.1.a, Attachments 3 and 4) is a web-based, interactive report that synthesizes status, trends, and risks facing the U.S. West Coast marine ecosystem. This is a peer-reviewed report of 2011-2012 research based on contributions of the California Current Integrated Ecosystem Assessment Team authors and affiliates (57 authors and 15 affiliations). This interactive report is an evolving product that will be updated annually and is completed as part of NOAA's National IEA program. It is organized around three questions:

- What are the status and trends of key indicators of ecosystem health in the U.S. West Coast marine ecosystem?
- What are the status and trends of drivers and pressures affecting the health of the U.S. West Coast marine ecosystem?
- How might potential future management options influence the health of the U.S. West Coast marine ecosystem?

Current IEA Work

NMFS will brief the Council on planned IEA work for 2014. Focus areas include:

- Conceptual models for human well-being, salmon, forage fish, groundfish, marine mammals, and seabirds;
- human dimensions, specifically the identification of measures that reflect vulnerability of fishing communities and measures of human well-being; and
- habitat considerations, the identification of key habitats and the development of potential indicators of habitat quantity, quality, and relative pressures.

The FEP states that each year at the Council's March meeting, the Council and its advisory bodies will:

- review progress to date on any ecosystem initiatives the Council already has underway;
- review the list of potential initiatives and determine whether any merit Council attention in the coming year and, if so, request background materials from the appropriate entities;
- in March 2015 and in each subsequent odd-numbered year, assess whether there are new ecosystem initiative proposals that could be added to the appendix; and
- in March 2018, assess whether to initiate a review and update of the FEP.

<u>The Fishery Ecosystem Plan and Ecosystem-Based Fisheries Management Initiatives</u>
(detailed descriptions can be found in the Ecosystem Initiatives Appendix of the FEP, posted on the Council's web page):
Ongoing Initiatives:

- FEP Initiative 1, Protection for Unfished and Unmanaged Forage Fish – Scheduled for Council consideration at the April 2014 meeting in Vancouver, Washington.

Potential Future FEP Initiatives:

- Initiative on the Potential Long-Term Effects of Council Harvest Policies on Age- and Size- Distribution in Managed Stocks
- Bio-Geographic Region Identification and Assessment Initiative
- Cross-FMP Bycatch and Catch Monitoring Policy Initiative
- Cross-FMP EFH Initiative
- Cross-FMP Safety Initiative
- Human Recruitment to the Fisheries Initiative
- Cross-FMP Socio-Economic Effects of Fisheries Management Initiative
- Cross-FMP Effects of Climate Shift Initiative
- Indicators for Analyses of Council Actions Initiative

<u>Council Action:</u>

1. **Discuss the State of the California Current Ecosystem and IEA reports.**
2. **Review progress on ecosystem initiatives and provide guidance.**

<u>Reference Materials</u>:

1. Agenda Item C.1.a, Attachment 1: Annual State of the California Current Ecosystem Report.
2. Agenda Item C.1.a, Attachment 2: Annual State of the California Current Ecosystem Report Supplement (**electronic format only**).
3. Agenda Item C.1.a, Attachment 3: Integrated Ecosystem Assessment Summary Report.
4. Agenda Item C.1.a, Attachment 4: *California Current Integrated Ecosystem Assessment Report* (**available only on the web at**: *www.noaa.gov/iea/CCIEA-Report/index.html*).

<u>Agenda Order</u>:

a. Agenda Item Overview — Mike Burner
b. Reports and Comments of Advisory Bodies and Management Entities
c. Public Comment
d. **Council Action:** Council Discussion

PFMC
02/13/14

Annual State of the California Current Ecosystem Report

A report of the NMFS Northwest and Southwest Fisheries Science Centers

1 Introduction

The Pacific Fishery Management Council (Council) adopted a Fishery Ecosystem Plan (FEP) in 2013. Section 1.4 of the FEP outlines an annual reporting process, where the Council requests that NMFS provide yearly updates on the state of the California Current Ecosystem (CCE). The report should summarize and synthesize environmental, biological and socio-economic indicators relevant to the state of the CCE. NOAA's Integrated Ecosystem Assessment (IEA) team, in collaboration with the Council's Ecosystem Plan Development Team (EPDT), produced a thorough report on conditions in the CCE for the Council's November 2011 meeting (Agenda Item H.1). At the Council's November 2012 meeting (Agenda Item K.3), the IEA team and EPDT presented a streamlined, updated report of the state of the CCE. The present document is the second iteration state-of-the-CCE report and provides an annual update of IEA results, taking into account comments received from the Council and the public.

The highlights of this report are summarized in Box 1.1. Sections below provide greater detail. In addition, NMFS has submitted electronic copies of supplemental materials for this report to Council staff, at the request of the Scientific and Statistical Committee. A list of supplemental materials is provided at the end of this document.

This report is still developmental, and needs further evaluation of the indices and information that might best meet the Council's needs. However, this report continues progress toward the greater objective of bringing ecosystem information into the Council process, so that the Council can continue to consider ecosystem status, trends and indicators in its decision-making.

Box 1.1: Highlights of this report

- From late 2010 to 2012, the tropical Pacific transitioned from weak La Niña to ENSO-neutral conditions.
- Strong upwelling occurred in 2012 for southern and central California and in 2013 for the whole coast, indicating higher primary productivity.
- Copepod biomass and diversity indicate generally average to favorable conditions for secondary production in the CCE.
- Survey catches indicate that Northern anchovy abundance is reduced along much of the coast recently; however, a number of other forage fish populations have responded positively to productive conditions.
- Most salmon populations examined are near their average escapement, but trends are mixed: 3 populations show increasing trends, 6 show downward trends, and 3 show no trends.
- The mean trophic level of groundfish exhibited a declining trend south of Cape Mendocino, but has been largely stable since 2009 throughout the CCE.
- In response to the poor condition of sea lion pups at rookeries and a high level of strandings, NMFS declared an Unusual Mortality Event (UME) of California sea lion pups in March 2013
- Non-fisheries human activities in the CCE that may negatively impact the ecosystem are generally low with stable or declining trends. Nutrient input is an exception: it is elevated, although it shows a declining trend at the coast-wide scale.

Throughout this report, many figures describing recent and long-term trends follow a common format, demonstrated in Figure 1.1, which is described here for ease of interpretation; see the figure caption for details. The data in the most recent five years of the time series (indicated by the green shaded area) show no trend (symbolized at right by ←→), and the mean of the most recent five years is more than 1 standard deviation less than the long-term mean (symbolized at right by −). For example, if Figure 1.1 represented a fish population, we would conclude that the population has been stable for the most recent five years, but that it is below the long-term average for that population.

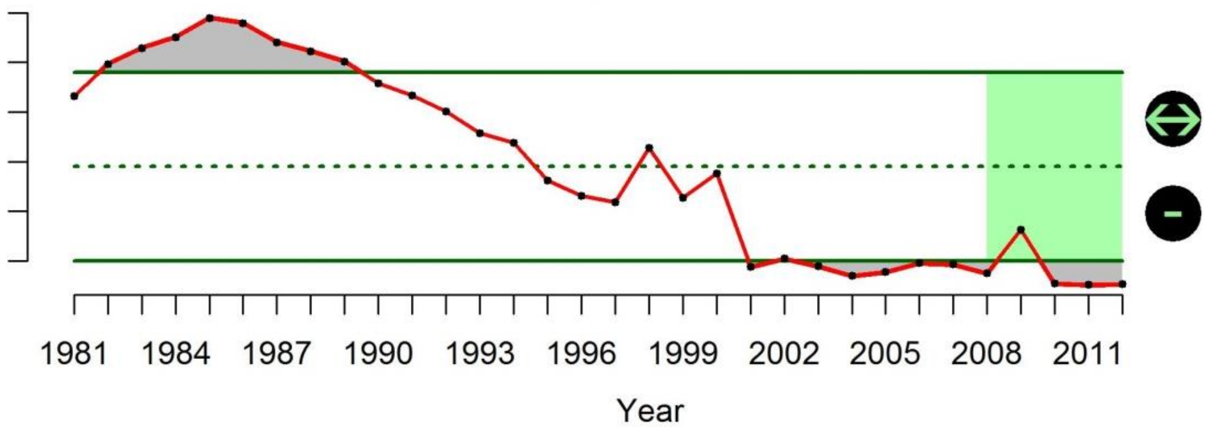


Figure 1.1: Sample figure to demonstrate status trend plots in this document. Dark green horizontal lines show the mean (dashed line) ± 1.0 s.d. (solid lines) of the full time series. The shaded green area represents the last five years of the time series, which are analyzed to produce the symbols to the right of the plot. The upper symbol at the right indicates whether data over the last five years had a positive trend (↗), a negative trend (↘), or no trend (←→). The lower symbol at the right indicates whether the mean over the past 5 years was greater than (+), less than (–), or within 1 s.d. (•) of the full time mean series.

2 Climate and Ocean Drivers

2.1 Basin-Scale Climate Indicators

The CCE comprises a major eastern boundary current, the California Current, which is dominated by strong coastal upwelling, and is characterized by fluctuations in physical conditions and productivity over multiple time scales. Many of these fluctuations have been shown to be a consequence of larger scale changes in ocean conditions throughout the Pacific, including changes observed in the tropics (the El Niño/Southern Oscillation) and changes in the North Pacific and subarctic (including the Pacific Decadal Oscillation and the North Pacific Gyre Oscillation). Although a suite of additional potential indices exist, and the science behind both the mechanisms and the consequences of each continues to evolve, a great deal has been learned about how these indicators represent variability in the physical and biological conditions experienced throughout the CCE.

The El Niño/Southern Oscillation (ENSO) is the dominant mode of interannual variability in the equatorial Pacific, with impacts throughout the Pacific basin and CCE. There are several means of assessing the state of the ENSO cycle; in this report, we use the Multivariate ENSO Index (MEI), which is based on a set of physical variables measured in the equatorial Pacific. Positive values of the MEI represent El Niño conditions, while negative values represent La Niña conditions. El Niño conditions in the CCE are associated with warmer surface water and weaker upwelling winds. From late 2009 to early

2010, the CCE experienced a short duration El Niño associated with stronger than average downwelling-favorable winds. The El Niño was followed La Niña conditions in the summer of 2010 (Fig. 2.1). From late 2010 to 2012, the MEI went from negative to weakly positive, indicating that the tropical Pacific had transitioned back to ENSO-neutral conditions. However, the effects of any given El Niño or La Niña event are highly variable – some events lead to major impacts throughout the CCE, while others may lead to major impacts in the tropics, but relatively modest impacts at higher latitudes.

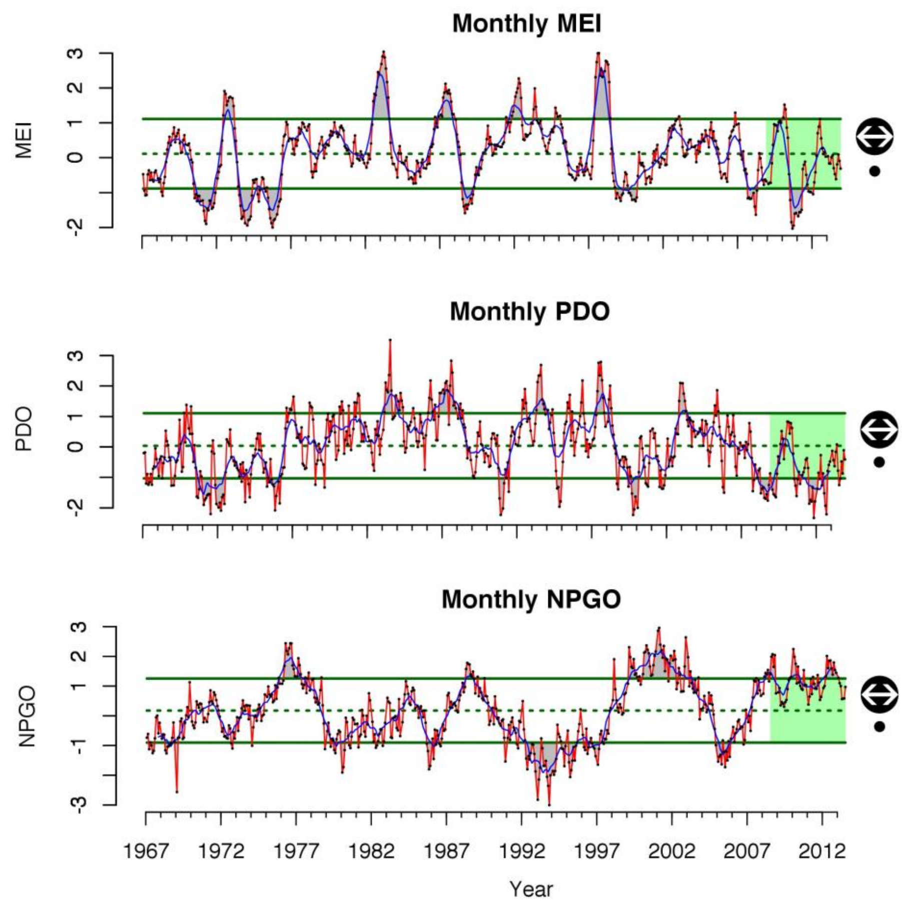


Figure 2.1. Monthly values of basin-scale climate indicators used to assess environmental variability impacts in the California Current ecosystem. The three time series are Multivariate ENSO Index (MEI), Pacific Decadal Oscillation (PDO), and North Pacific Gyre Oscillation (NPGO). Lines, colors and symbols are as in Figure 1.1; the blue line shows the 12-month running average.

The Pacific Decadal Oscillation (PDO) is a low frequency signal in North Pacific sea surface temperatures that affects biological productivity in the Northeast Pacific. The "low frequency" refers to the observation that the average conditions over multi-decadal periods tend to be cooler or warmer, although year-to-year values continue to vary. These multidecadal periods are often referred to as "regimes." Cold regimes (negative values of the PDO) are associated with enhanced productivity in the CCE and vice versa. Such conditions were observed from the mid-1940s through the late 1970s, and in most years since 1999. During positive PDO regimes, which were observed from the late 1970s through the late 1990s, and for several years in the mid-2000s, coastal sea surface temperatures in both the Gulf of Alaska and the CCE tend to be higher, while those in the North Pacific Subtropical Gyre tend to be lower. The PDO has remained negative since 2011 (Fig. 2.1), indicating a cooler regime associated with higher upwelling and enhanced productivity in the CCE.

The North Pacific Gyre Oscillation (NPGO) represents the low frequency signal in sea surface height over the Northeast Pacific. The variability in sea surface height is a driver of variations in the circulation of the North Pacific Subtropical Gyre and Alaskan Gyre, which in turn relate to the source waters for the California Current. Positive values of the NPGO are linked with increased equatorward flow in the California Current, which in turn is associated with increased surface salinities, nutrients, and chlorophyll-a values in the CCE. Negative values of the NPGO are associated with decreases in such values, inferring less subarctic source waters for the California Current and generally lower productivity;

for example the NPGO was strongly negative during the 2005 and 2006 years, which in turn were associated with record low levels of juvenile groundfish productivity and seabird reproductive success in some parts of the CCE. The NPGO has been positive from 2011 through 2013 (Fig. 2.1), indicating strong circulation in the North Pacific Subtropical Gyre.

In summary, over the last 5 years (2009-2013), there have been no significant trends or mean values > 1 s.d. from the long-term mean for these large-scale indices. However, ocean conditions from 2010 to late 2013 all point to a cooler and more productive CCE, which may provide better conditions for recruitment, particularly of cooler-water species.

2.2 Regional Climate Indicators

Upwelling is critically important to productivity and ecosystem health in the CCE, as local wind fields that drive coastal upwelling ultimately drive primary production at the base of the food web. The most common metric of upwelling is the Bakun Upwelling Index, which is a measure of the magnitude of coastal upwelling anywhere along the coast. The timing, strength, and duration of upwelling in the CCE are highly variable, and are forced by large-scale atmospheric pressure systems. While this report includes only a basic upwelling anomaly, the full IEA and other reports often include variables on onset, length, and strength of the upwelling season. Any or all of these indices may relate more appropriately to the productivity of any particular region or population, although as with any climate index, such relationships can be complex.

Figure 2.2 shows monthly upwelling anomalies for three locations within the CCE (monthly anomalies reflect the relative amount of upwelled water in a given month after subtracting the long-term mean). Over the past five years, the upwelling anomalies for the three locations have no significant trends or means greater than 1 s.d. from the data-set means. However, from early 2011 to mid 2013, there has been increased upwelling persisting from southern California to Washington, with some of the highest upwelling anomalies ever recorded at 39° N in 2012. The cumulative upwelling for 2012 south of 42°N was extreme, while the cumulative upwelling for 2013 included the highest recorded values since 1967.

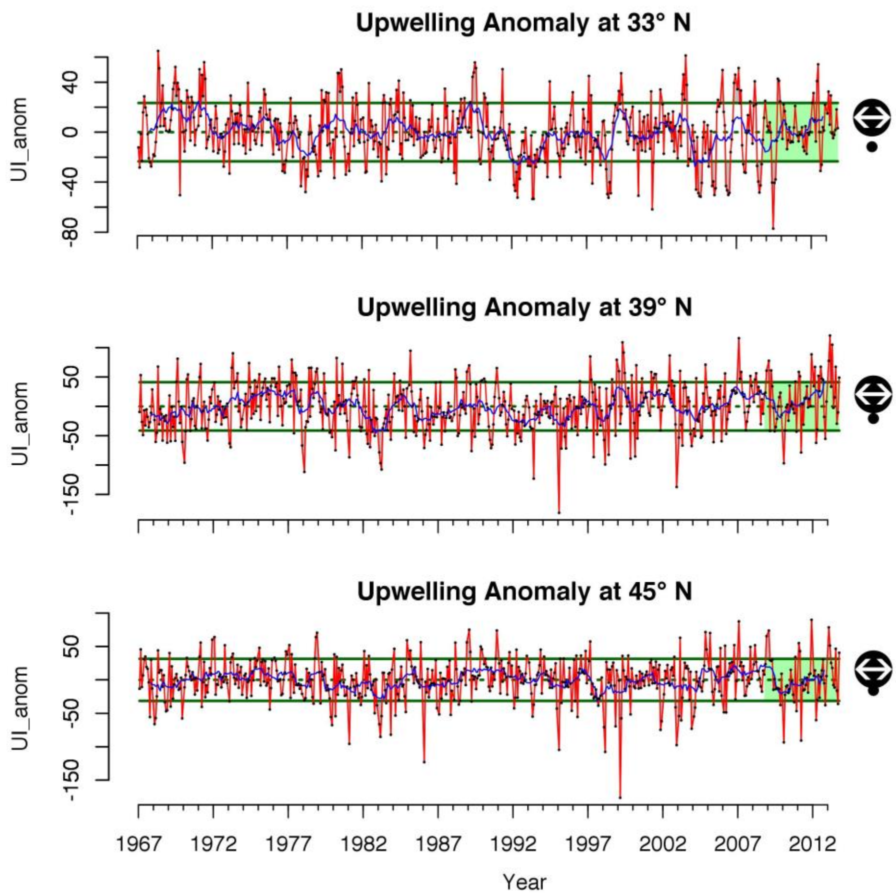


Figure 2.2. Monthly upwelling anomalies (m^3/s/100 km) calculated at three locations along the California Current (labeled by latitude North) with seasonal means removed from the Bakun Upwelling Index. Lines, colors and symbols are as in Figure 1.1; the blue line shows the 12-month running avg.

Low dissolved oxygen concentrations in CCE coastal and shelf waters are an emerging concern. When dissolved oxygen (DO) concentrations fall below 1.4 ml L^{-1} (2 mg L^{-1}; 64 μM), the waters are considered to be 'hypoxic' with limited oxygen available to organisms. DO concentrations in the ocean are dependent on a number of physical and biological processes, including circulation, ventilation, air-sea exchange, production and respiration. Off Oregon, upwelling transports offshore hypoxic waters onto productive continental shelves, where respiration can reduce water-column DO and thus subject coastal ecosystems to hypoxic or anoxic conditions. Declining DO is a concern for the CCE as it can result in habitat compression for pelagic species, more severe hypoxic events on the shelf, and resultant physiological stress or even die-offs for less mobile species. Off southern California, the boundary between oxygenated and hypoxic waters has shoaled in recent years.

Although hypoxia in the CCE is the result of different mechanisms from Gulf of Mexico or Chesapeake Bay dead zones, there still is evidence of increased stress and mortality due to hypoxia – particularly off the Oregon coast. DO values have been declining over the past 14 years for Central California and 28 years for Southern California, evident through 2013. Between NOAA, state and tribal agencies, and West Coast academic institutions, there are a variety of oceanographic monitoring stations off the U.S. West Coast, including several where oceanographic data (like DO levels) are collected.

Figure 2.3 shows DO trends derived from offshore sampling station data at several locations. In the past 5 years, higher oxygen values have been observed at the offshore California stations (90.90), on top of a long-term declining trend. Nearshore DO values are almost always lower than those offshore (93.30 vs. 90.90). The two inshore stations in Oregon and Southern California had mean values of approximately 2.3 ml L^{-1} at 150 m. The DO time series presented above are from shelf and offshore waters (50 to 300 km from shore) and may not adequately correlate with nearshore hypoxic events, where Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) datasets may be more informative.

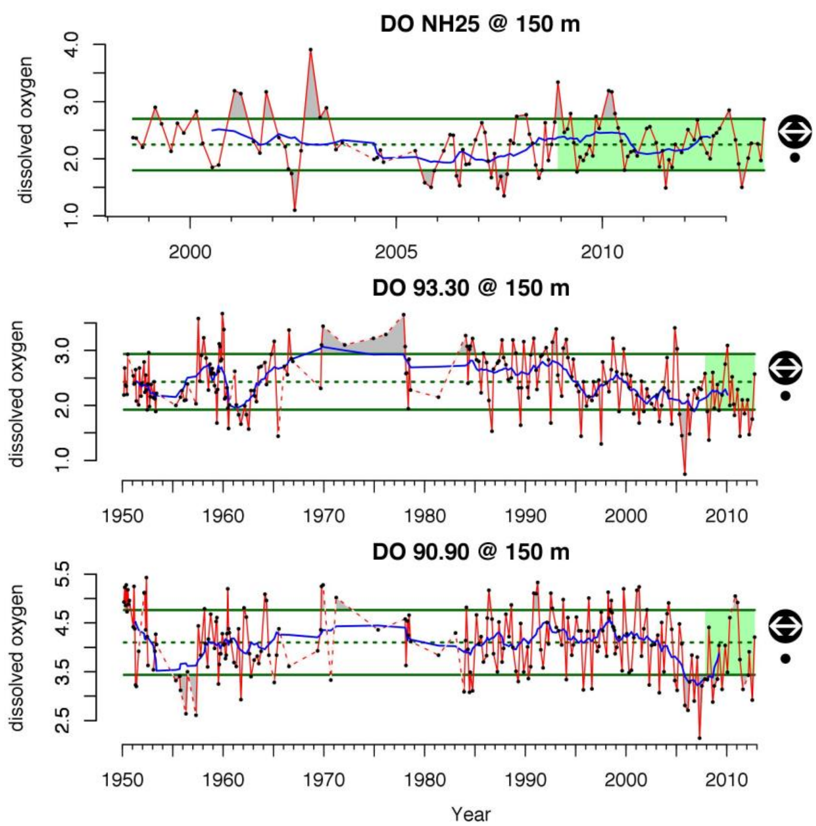


Figure 2.3. Dissolved Oxygen (in ml L^{-1}) in the CCE, 1983-2013. Dissolved oxygen was measured at 150 m depth off of Oregon (Newport Line station NH25) and southern California (CalCOFI stations 93.30 and 90.90). Stations 93.30 and NH25 are located within 50 km from the shore, while station 90.90 is located over 300 km from shore. Dashed lines show areas with a gap greater than 6 months. Lines, colors and symbols are as in Figure 1.1; the blue line shows the 12-month running average.

Ocean acidification is caused by increased concentration of carbon dioxide (CO_2) in seawater which changes in parallel with atmospheric concentrations. For seawater, an increase in CO_2 leads to a decrease in pH (increased acidification) and carbonate concentration $[CO_3^{2-}]$. Lower pH and reduced availability of carbonate negatively affect organisms that rely on calcium carbonate ($CaCO_3$) for structures or shells (i.e. corals, oysters, urchins, etc.) and internal protein synthesis for many other organisms. It is not easy to measure pH directly; sensors suitable for measurement of pH in the ocean are still under development. Fortunately chemists have developed algorithms that can estimate the "aragonite saturation state," an indicator of how corrosive seawater is to organisms that have aragonite shells (a mixture of calcium and magnesium carbonate). Values near or <1 indicate acidic conditions for at least two key animals, the larvae of oysters and the pelagic snail *Limacina helicina* which is an important food source for pink salmon and herring and to a lesser degree for other salmonids.

At sampling station NH05 off of Newport, OR, aragonite saturations <1 are seen throughout the upwelling season, with values <1 seen commonly in July and August (Fig. 2.4). High values are seen in winter, when the water column tends to be mixed top to bottom by winter storms. Conversely, at station NH25, aragonite saturation is always <1 at a depth of 150 m. It is noteworthy that water from this depth upwells onto the continental shelf in summer, thus it is the acidity of these source waters that contribute to low aragonite saturation on the continental shelf in summer. There is no clear temporal trend in aragonite saturation; however, we are already seeing seasonal pulses of acidified water off Oregon and believe that this is of natural origin, caused by the decomposition of organic matter and CO_2 release as it sinks toward the seafloor.

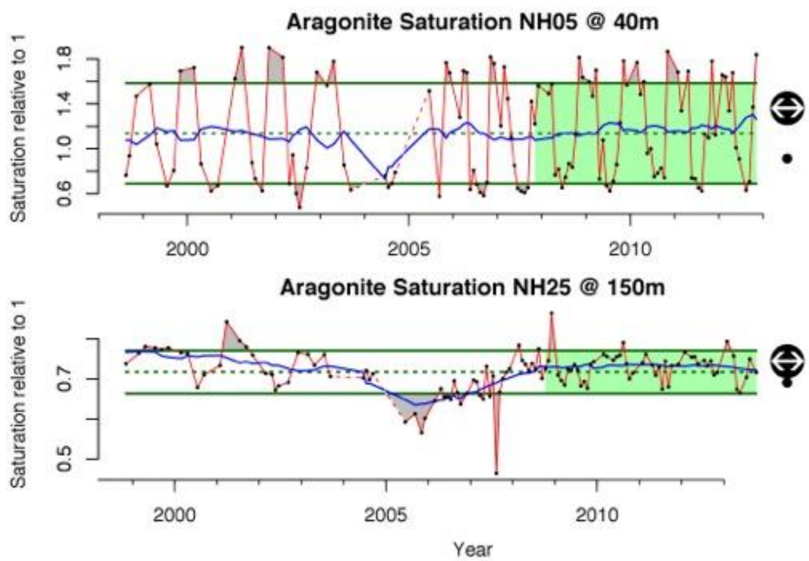


Figure 2.4. Aragonite saturation trends in the northern CCE, 1998-2013 (see text for explanation). Lines, colors and symbols are as in Figure 1.1; the blue line shows the 12-month running average. The time series is similar to the oxygen data shown in Figure 2.2 because aragonite saturation is calculated in part from oxygen data.

3 Focal Components of Ecological Integrity

Indicators of ecological integrity can be empirical or model based, and should relate either directly or indirectly to the productivity or condition of ecologically important, managed, or protected species and assemblages. Ideally, they should offer some perspective on the relative condition of species, species assemblages or communities that might not necessarily be reflected by species-specific metrics.

3.1 Northern Copepod Biomass Anomaly

The northern copepod biomass anomaly time series represents interannual variations in the biomass of three "cold–water copepod" species, two of which (*Calanus marshallae* and *Pseudocalanus mimus*) are lipid-rich, thus the index represents the amount of lipid (wax-esters and fatty acids) available to pelagic fishes for whom these fatty compounds appear to be essential.

The northern copepod anomaly fluctuated from 1996-2013 (Fig. 3.1). Current values for both the winter and summer are relatively high—approximately 1.0 s.d. above the mean of the full time series. There were no short-term trends in either case. Threshold values for the anomaly have not been set. However, positive values in the summer period are correlated with stronger returns of fall and spring ocean-type Chinook to Bonneville dam, and values greater than 0.2 are associated with better survival of coho. Overall the high anomalies in recent years, especially for the summer data, suggest that ocean conditions are in a generally productive state. See http://www.nwfsc.noaa.gov/research/divisions/fed/oeip/eb-copepod-anomalies.cfm for further detail.

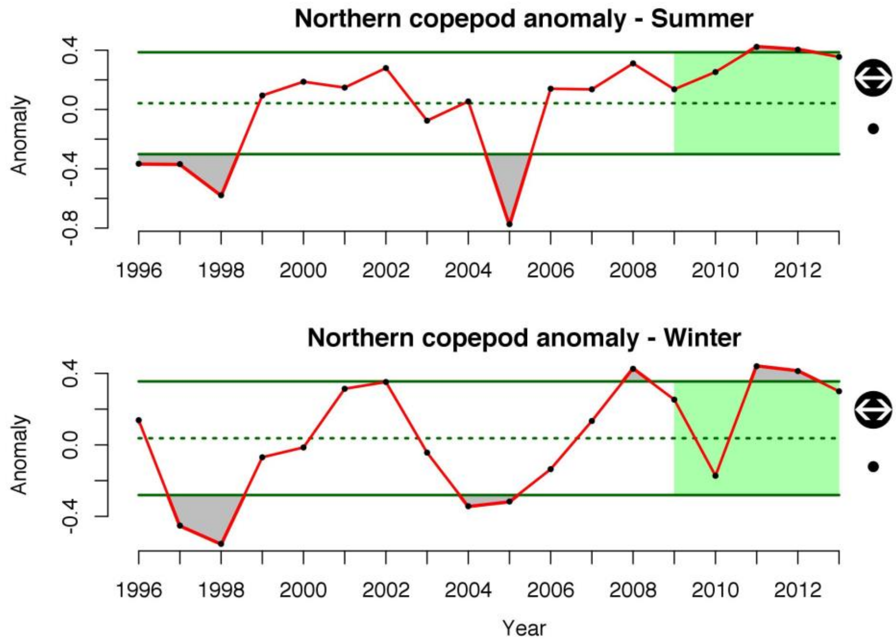


Figure 3.1. Northern copepod biomass anomaly for 1996-2012 in the waters off of Oregon during the winter (Oct-April) and summer (May-Sept). Lines, colors and symbols are as in Figure 1.1. Data courtesy of Bill Peterson.

3.2 Copepod Species Richness off Washington and Oregon

Copepod species richness has been tied to food chain structure and survival of coho salmon in the CCE. Low species richness is correlated with southward transport of sub-Arctic waters, high abundance of lipid-rich northern copepods, and increased growth and survival of some species.

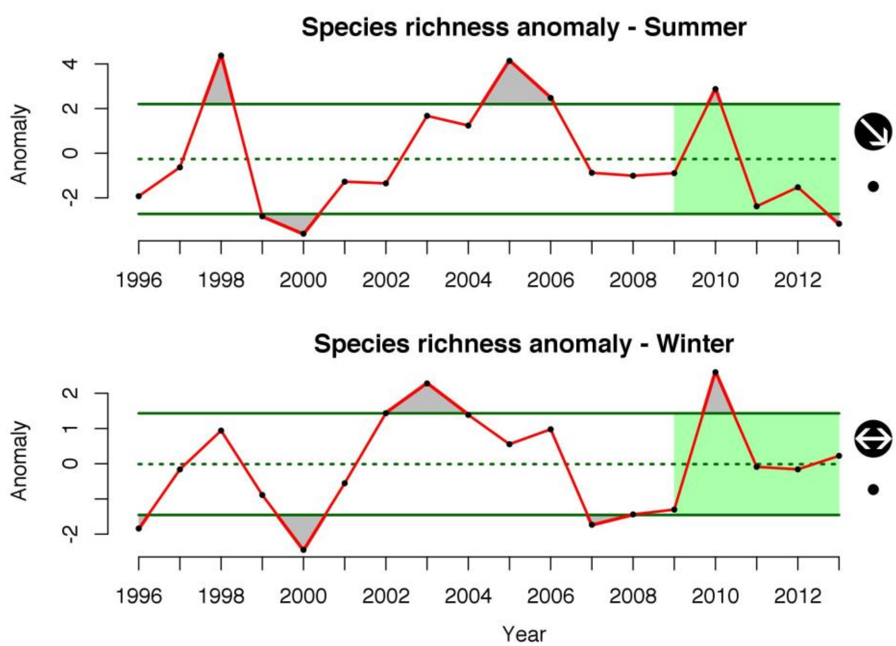


Figure 3.2. Copepod species richness in waters off Oregon from 1997-2012. Lines, colors and symbols are as in Figure 1.1. Data courtesy of Bill Peterson.

The species richness anomaly for copepods has been highly variable over time (Fig. 3.2). Species richness for the winter assemblage showed no short-term trend, and the mean of the last five years was within 1.0 s.d. of the long-term mean. Copepod species richness in the summer declined over the last five years of the data series suggesting generally good feeding conditions for copepod predators. However, the mean of the last five years was within 1.0 s.d. of the full time series.

3.3 Coastal Pelagic Species: Anchovy, Sardine, and Forage Diversity

Figure 3.3 presents trends in Northern anchovy and Pacific sardine based on the full length of the respective time series of NMFS research cruises off Southern California Bight, central California, and Oregon and Washington. While many species were collected, Northern anchovy and Pacific sardine were the only forage species that were enumerated in all three regions and can be used to compare patterns along the coast. However, each time series represents very different survey methodologies, different selectivities, and often different survey objectives. Thus, none should be considered accurate reflections of the abundance of these species throughout the entire CCE, for which stock assessments provide the most accurate synthesis of information. Largely for this reason we rely on the anomalies.

In recent years (2006-2011) the abundance of larval anchovy was below average and declining in CalCOFI surveys off southern California, following a 20-year decline. Anchovy juveniles and adults (not larvae) continue to be low (but within 1 s.d.) in central California, and remain average in the northern CCE. In the southern regions, sardine larvae remain near to above average in recent years. Off central California juvenile and adult (not larval) sardine abundance remains low (but mostly within 1 s.d.), and in the northern CCE juvenile and adult sardine abundance has been variable between average to below average.

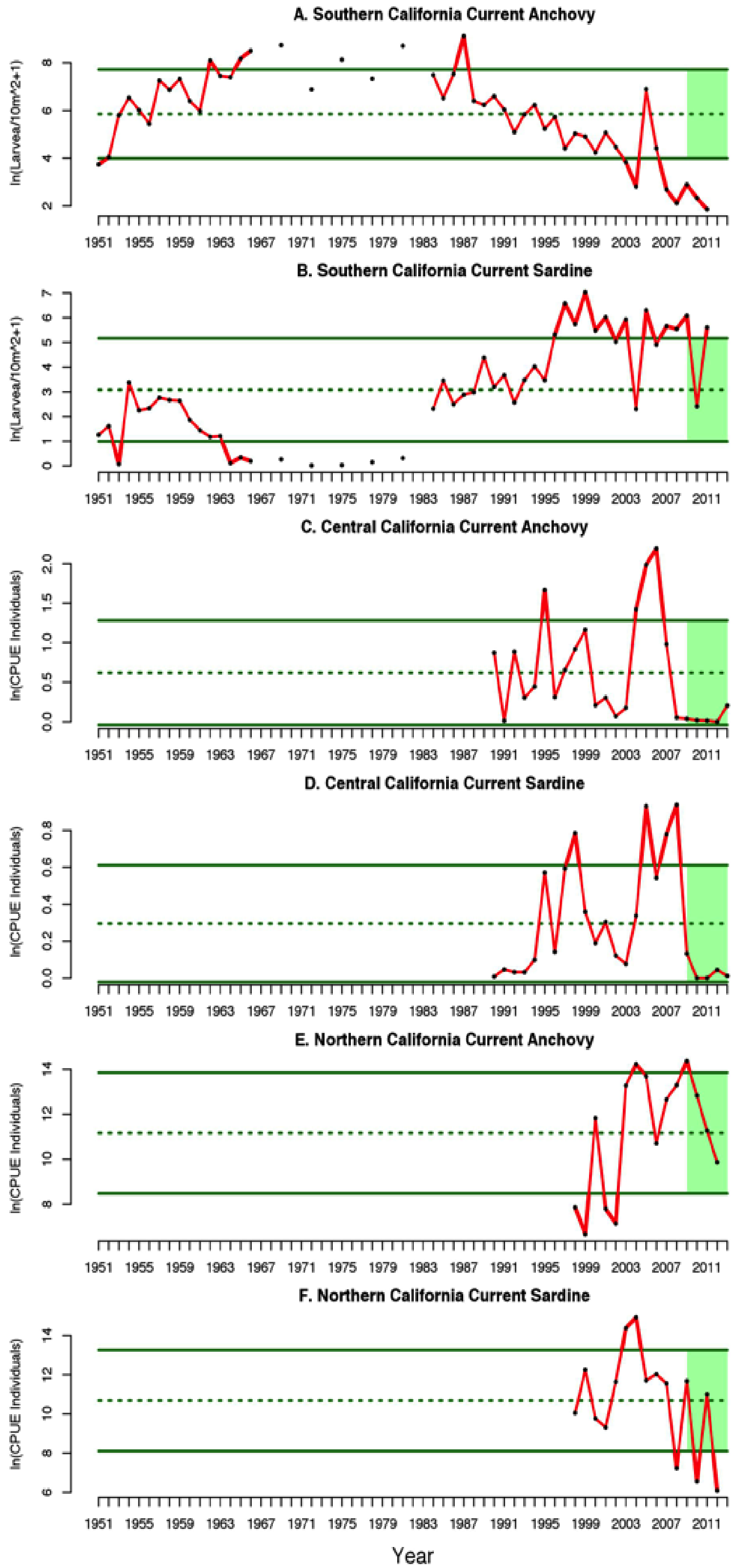


Figure 3.3. Abundance of anchovy and Pacific sardine in surveys. Lines and colors are as in Figure 1.1. Symbols indicating recent trends and means were not used in this figure, due to the life history characteristics of these populations.

The most common species enumerated in the three regions are quite different, but examining the community structure can provide a broad sense of the relative change in the forage base within each region. Forage species can vary greatly and any recent trends or changes in community structure should be interpreted cautiously because some of the time series are too short to make definitive statements. Similarly, there is not an estimate of total forage abundance or biomass, and these results should not be interpreted as such; this is a subset of species and there is not an estimated catchability for them.

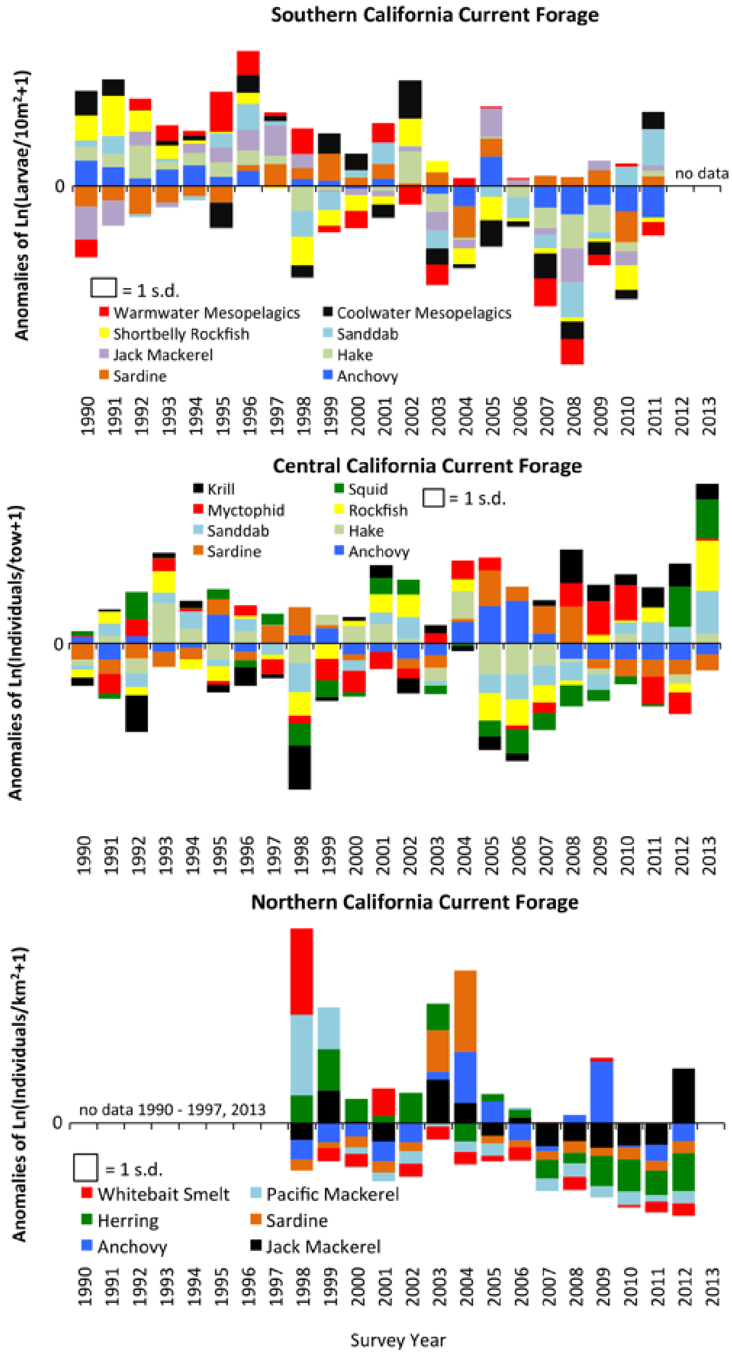


Figure 3.4. Stacked anomalies of the most common species caught in each larval fish survey. Zero reference indicates average; above the line indicates above average for that year. Also shown is a scale for 1 standard deviation (s.d.), indicating the degree to which any given species is above or below average demonstrated by the height of its portion of the column.

CalCOFI larval fish data off southern California are only available to 2011 due to sorting backlogs (Fig. 3.4 top). Off southern California warm-water associated mesopelagics and anchovies were below the 1990 – 2011 average (i.e., below the 0 line in Fig. 3.4, top). At the same time, in 2011 there was an increase in cool-water mesopelagics and sanddabs. Off Central California, in a midwater trawl survey for young-of-the-year (YOY) rockfish, the total abundance varied dramatically and a number of species often do not appear in substantial numbers (e.g., anchovy and Pacific sardine, Fig. 3.4 middle). The most recent cruise of 2013 (other regional data not yet available for 2013) indicates a dramatic increase of YOY shelf rockfish and sanddabs, with YOY rockfish being observed at the greatest abundance levels since the survey began in 1983. Krill and market squid have also been in higher abundance in recent years. In contrast to the central region, in the northern CCE has had a reduction in the abundance of a number of forage fishes since 2006 (Fig. 3.4, bottom). Variability in the community structure in the northern region was largely determined by the abundances of anchovy, jack mackerel, herring and whitebait smelt (bearing in mind the limitations of a short time series, 1998-2012).

3.4 Salmon: Chinook Salmon Abundance

Chinook salmon are iconic members of North Pacific rim ecosystems. Salmon are of cultural significance in the region as well as support large commercial and recreational marine and freshwater harvest. Because they are anadromous with extensive migrations, salmon connect marine and freshwater ecosystems. Here, we compare the trends in spawning escapement (which incorporates the cumulative effect of natural and anthropogenic pressures) along the CCE to evaluate the coherence in production dynamics, and also to get a more complete perspective of their health across the greater portion of their ranges. When available we used the full time series back to 1985 to allow for comparability. However, some populations only had available data for a shorter time frame (Central Valley Spring starts 1995, Central Valley Winter starts 2001, and Coastal California starts 1991).

Figure 3.5 summarizes information from multiple time series. Before plotting, time series were normalized to place them on the same scale. The recent trend (x-axis) indicates whether the escapement increased or decreased significantly over the last 10-years of the time series. The y-axis indicates whether the mean escapement of the last 10 years is greater or less than the mean of the full time series. Dotted lines show ± 1.0 s.d. The legend lists the stocks that we examined.

In California, all of the examined populations are near their average escapement and Coastal California, Central Valley Late-Fall, and Klamath Fall do not demonstrate a significant trend. Central Valley Fall, Central Valley Spring, Central Valley Winter (fairly short time series), and Southern Oregon-North California populations demonstrate a negative trend.

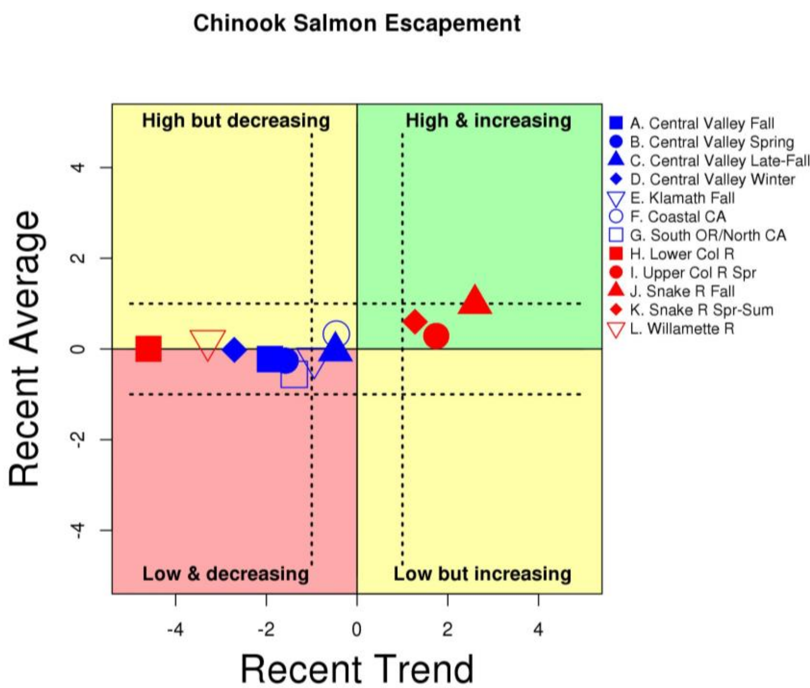


Figure 3.5. West Coast salmon escapement trends.

In Oregon and Washington all of the assessed populations are near average escapement for their series (although Snake River Fall is above average for the last four years). Snake River Spring-Summer and Fall runs, and upper Columbia River Spring run are increasing escapement and Willamette River and lower Columbia River are trending down in the last ten years.

3.5 Groundfish: Stock Status Relative to Biological Reference Points

Most assessed groundfishes are above the biomass limit reference point, and are thus not overfished (Fig. 3.6). The four assessed stocks currently in an overfished state are all rockfishes. Cowcod status has changed significantly since the last report and is nearing a rebuilt status. Several new stocks have been added since the last assessment cycle. Approximately 1/3 of the managed groundfish species within the groundfish FMP have been evaluated (either recently or historically) for the overfished threshold based on stock assessment results. Results for those assessments conducted over the most recent four assessment cycles are reflected in Figure 3.6. For species that have not undergone stock assessments, data from the NWFSC annual trawl survey (or other surveys) are not sufficient for evaluating whether or not a stock is below the overfished threshold. Although methods have been developed to estimate allowable catches for unassessed species, formal status determinations for such species are not currently feasible.

In general, results suggest that most groundfish populations that have been formally assessed in the CCE are at or above their target biomass levels, and most are at or below half of the total allowable catch or mortality level. Individual trajectories for each stock are available in the stock assessments. The vast majority (albeit not all) of these species demonstrate stable or increasing abundance trends.

In Figure 3.6, stock status is plotted relative to being overfished (x-axis) and whether overfishing is occurring (y-axis) for all species assessed since 2007. For example, sablefish biomass in 2010 was below the target biomass (left of the black vertical broken line), but above the biomass limit (right of the red vertical solid line); thus, sablefish were not considered overfished. Mortality of sablefish in 2010 was below the allowable biological catch (below the horizontal solid line), indicating that overfishing was not occurring.

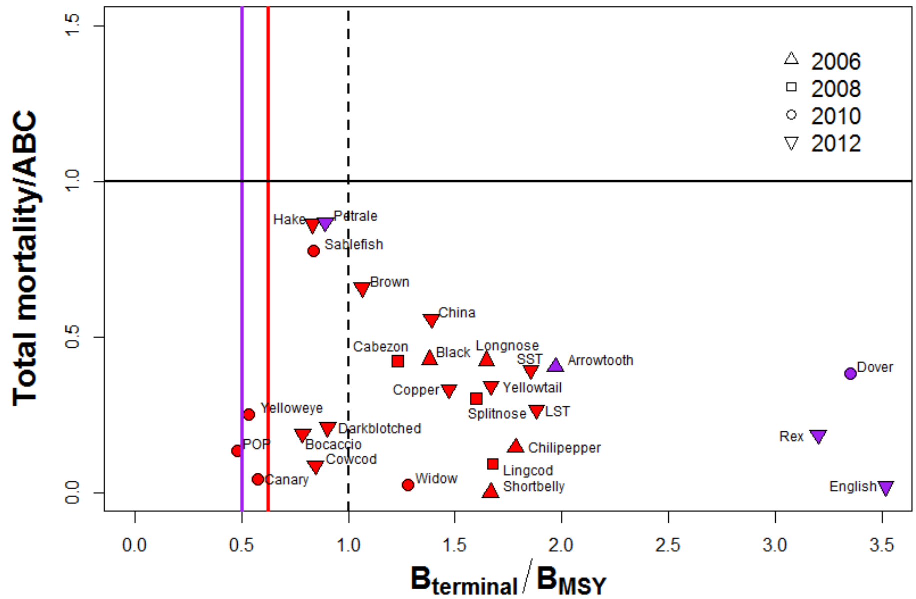


Figure 3.6. Stock status of all California Current groundfish assessed since 2007. The vertical broken line indicates the target biomass reference point. The vertical solid lines indicate the limit reference point showing an overfished status (red for elasmobranchs, rockfishes, and roundfishes; purple for flatfishes). The horizontal line indicates overfishing threshold wherein total mortality exceeds the allowable biological catch (ABC). Symbols indicate the terminal year of the assessment in which the reference points are determined.

3.6 Mean Trophic Level of West Coast Groundfishes

Mean trophic level (MTL) is the biomass weighted average of the trophic levels of the species in a sample. It is widely used as an indicator of change in trophic structure. Conceptually, a decrease in the abundance of higher trophic level predators (whether absolute or relative to lower trophic level taxa) influences the strength of trophic cascades and top-down forcing in the ecosystem. MTL comes in two forms. 'Catch MTL' is calculated from fisheries dependent data and reflects both changing fishing practices and the availability of target species. 'Ecosystem MTL' is calculated from fisheries independent data and tracks changes in the ecosystem.

Here, we report Ecosystem MTL calculated from the West Coast Groundfish Bottom Trawl Survey. Trends are presented for northern and southern regions, separated by Cape Mendocino (40.4°N). In the region north of Mendocino, MTL declined steadily from 2003 to 2010 from approximately 3.76 to 3.66 in

2010 (Figure 3.7). However over the last five years, MTL has remained low but fairly stable with no short-term trend. The mean of the last five years was also within 1.0 s.d. of the long-term mean. South of Cape Mendocino, groundfish MTL increased from 2003 to 2006 but then declined to 2012, with the last five years showing a significant decline (Figure 3.7). However, the mean of the last five years was within 1.0 s.d. of the long-term mean and the value in 2012 was similar to that in 2003. Most of the decline occurred from 2008 to 2009 and MTL has largely been low but stable since.

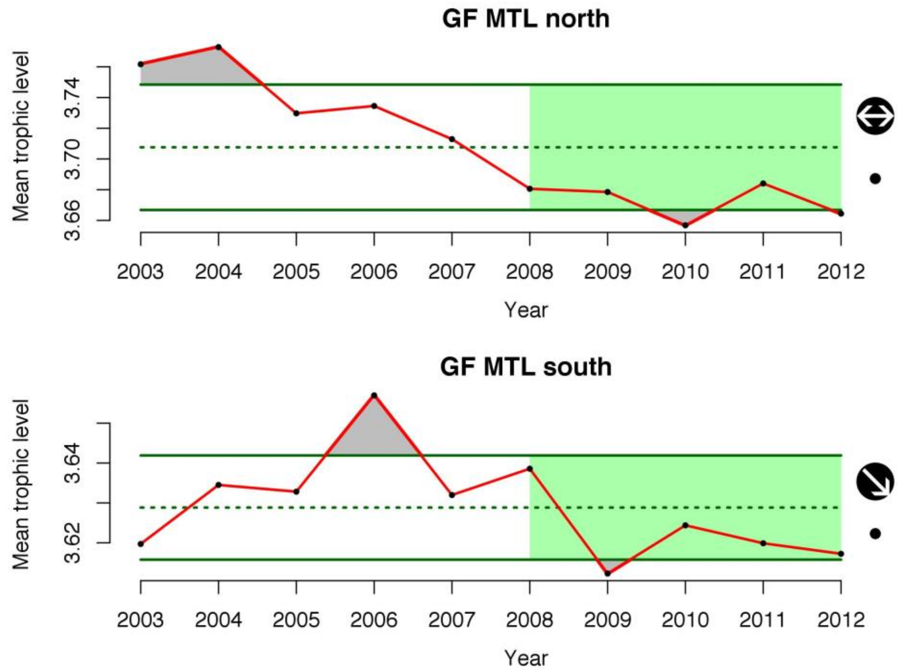


Figure 3.7. Area-weighted mean trophic level (MTL) for West Coast groundfishes north (upper) and south (lower) of Cape Mendocino from 2003 – 2012. Colors, lines and symbols are as in Fig. 1.1. Data are from the West Coast Groundfish Bottom Trawl Survey, courtesy of Beth Horness (Beth.Horness@noaa.gov).

Previous work suggests that the changes in MTL are strongly driven by the abundance of Pacific hake, spiny dogfish and sablefish—relatively high TL, high biomass species that have all declined in abundance in the trawl survey since 2003. Low groundfish MTL probably indicates good conditions for competitors of groundfishes. Many predators in the CCE eat krill and forage fishes. Food web modeling suggests that a drop in groundfish MTL due to a loss of higher TL species lowers predation pressure on the forage species and makes these prey available to other taxa such as squid, salmon, tuna and seabirds leading to positive population forcing for these taxa. Therefore, setting targets for groundfish MTL entails making trade-offs with these other species.

3.7 Mammals: California Sea Lion pup production

California sea lions are permanent residents of the CCE, breeding on the California Channel Islands and feeding throughout the CCE in coastal and offshore habitats. They are also sensitive to changes in the CCE on different temporal and spatial scales and so provide a good indicator species for the status of the CCE at the upper trophic level. Two indices are particularly sensitive measures of prey availability to California sea lions, pup births and pup growth. Pup production in any year is an indicator of prey availability and nutritional status of adult females from October of the previous year to the following June when pups are born. Pup growth is an index energy transfer from the mother to the pup and is related to prey availability to adult females during the 11-month lactation period and to survival of pups after weaning.

The population size of the U.S. stock of California sea lions in the CCE is estimated from the number of live pups counted from aerial surveys or ground counts conducted in July by SWFSC and AFSC. Because at no time are all the animals ashore, pup births are used as an index of the population size and trends. The average annual growth rate of the US stock of California sea lions during 1975-2011 was 5.3% with the population estimated at 309,000 in 2011. The highest pup counts since 1975 at San Miguel Island, one of the largest colonies, occurred in 2011 and 2012 (Fig. 3.8, top). The high live pup count in 2012 for San Miguel Island suggests that pregnant females experienced good foraging conditions from October 2011 to June 2012.

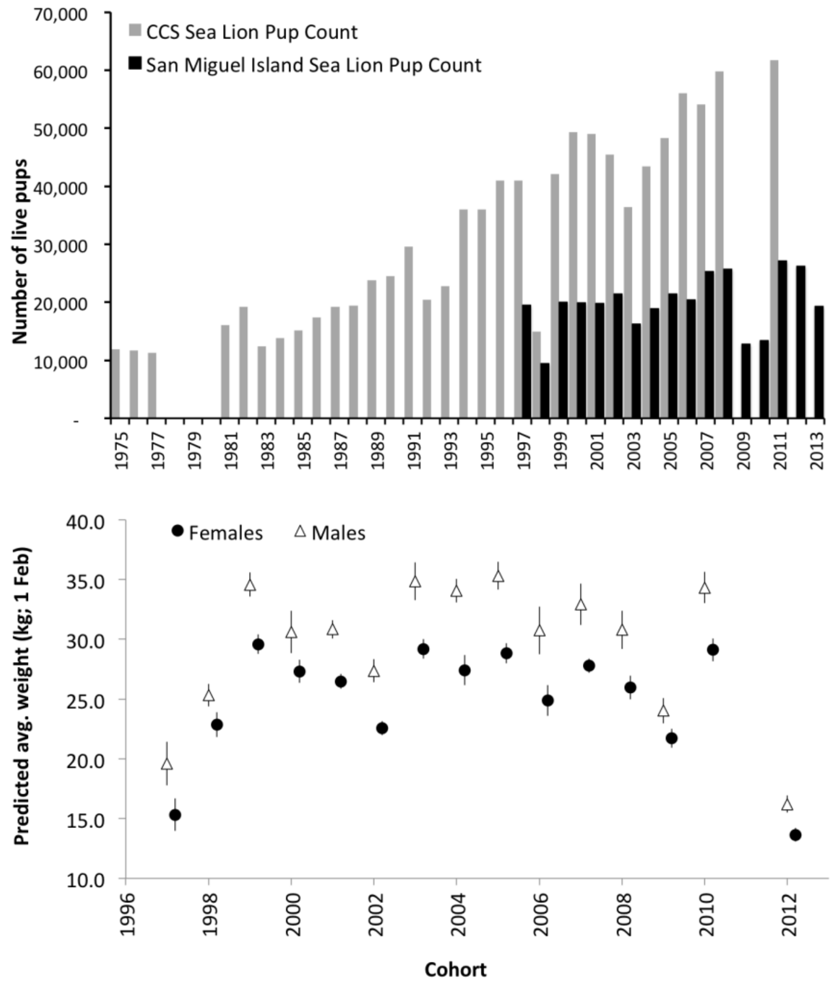


Figure 3.8. Top: California sea lion pup production, 1975 – 2011 across the CCE and at San Miguel Island (1997-2013). Lower: Predicted average daily growth rate of female (circle) and male (triangle) California sea lion pups between 4 and 7 months old at San Miguel Island, California, 1997-2012. Error bars are ± 1 standard error.

However, the pup growth index for California sea lions at San Miguel Island in 2012 indicated that dependent pups were in poor condition throughout the year. By February 2013, at 7 months of age, pups were significantly underweight, about 40-45% below the average weights of the past 14 cohorts (Fig. 3.8, bottom).

In addition to pups in poor condition on the rookery at San Miguel Island, pup mortality was higher than normal and high numbers of emaciated pups began stranding on southern California beaches in January 2013, indicating that pups were weaning up to three months earlier than normal. High levels of strandings continued into April with three times the normal level of strandings during the four-month period (http://www.nmfs.noaa.gov/pr/health/mmume/californiasealions2013.htm). In response to the poor condition of pups at the rookeries and the high level of strandings, NMFS declared an Unusual Mortality Event (UME) of California sea lion pups in March 2013. Two lines of investigation were initiated to explain the UME, one focusing on disease in pups or their mothers and the other on a shortage of food available to lactating females. The population response was very similar to that observed during strong El Niño events when the availability of sea lion prey is diminished in the CCE, and the unusual mortality event in 2013 may be related to the reduced availability of forage fish during late 2012 and early 2013. The unusual morality event is currently under investigation and the potential role of both forage community dynamics and disease are being considered.

4 Human Activities

These indicators can be empirical or model based, and should either directly or indirectly relate to the productivity or condition of managed or protected species or assemblages. Ideally, they should offer some perspective on the relative condition of species, species assemblages or communities that might not necessarily be reflected by species-specific metrics. The status of each indicator below was evaluated against two criteria: recent short-term trend and status relative to the long-term mean—reported as short-term status and long-term status, respectively.

4.1 Total Landings by Major Fisheries

The best source for information on stock-specific fishery removals is typically stock assessments that report landings, estimate amount of discard, and evaluate discard mortality, but these are only available for assessed species. For non-assessed stocks, fishery removal data are best summarized in the Pacific Fisheries Information Network (http://pacfin.psmfc.org). Landings provide the best long-term indicator of fisheries removals. Landings of coastal pelagic species increased and were above historic levels over the last five years; shrimp landings increased over the short-term but were still within historic levels; and landings of salmon and groundfish species (excluding hake) were at historically low levels for the last five years (Fig. 4.1). Landings of Pacific hake and crab varied within historic landing levels. Total removals from commercial and recreational fisheries varied within historical ranges and were highly dependent on the trends of Pacific hake landings. Landings and ex-vessel values of these fisheries are summarized by region in the Supplemental Materials.

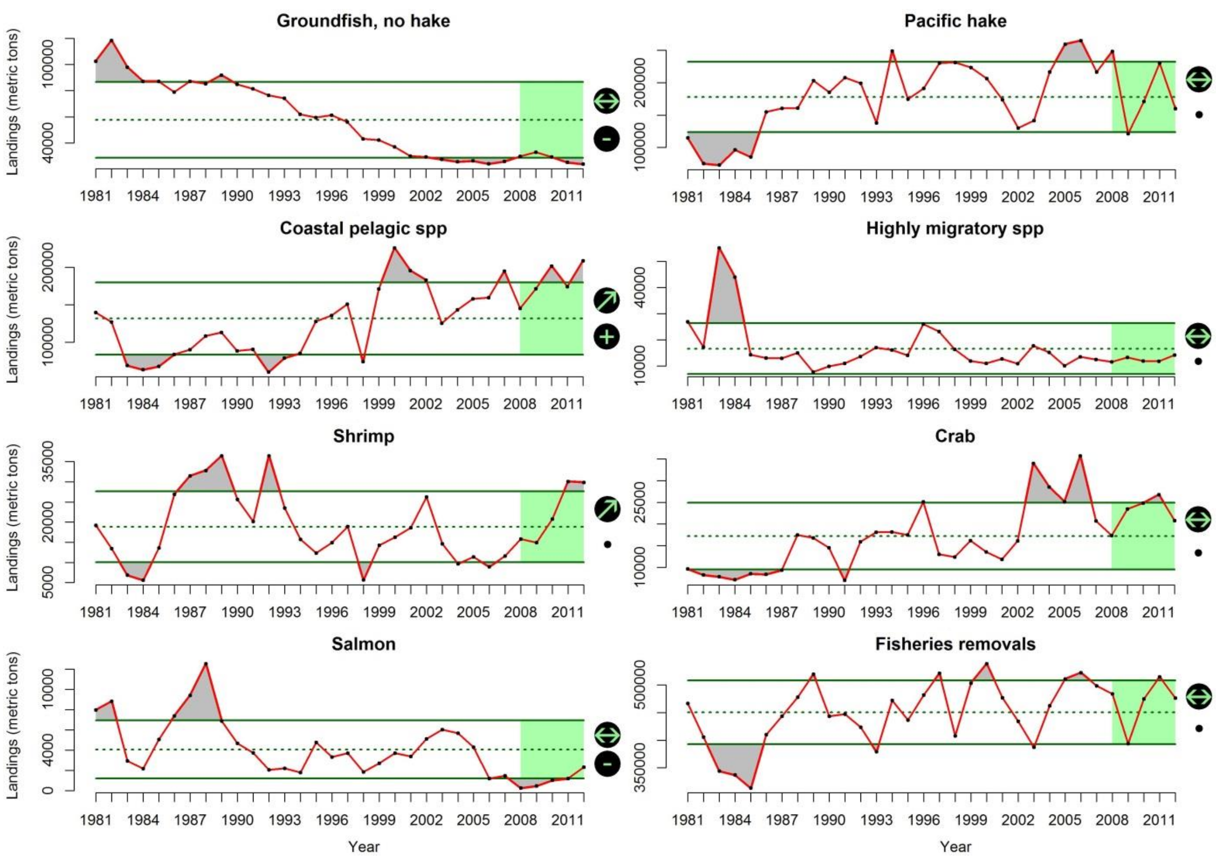


Figure 4.1. Annual landings of seven major West Coast commercial fisheries and total landings from all commercial and recreational fishing. Colors, lines and symbols are as in Fig. 1.1.

4.2 Aquaculture Production

Shellfish aquaculture production in the CCE increased over the last five years, and was more than 1 s.d. above the long-term historic average (Fig. 4.2). Shellfish aquaculture has risen dramatically over recent years as demand for seafood products is increasingly being met through aquaculture practices.

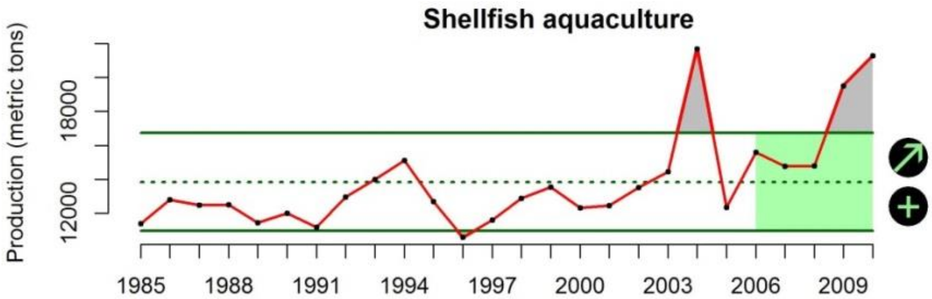


Figure 4.2. U.S. production of shellfish (clams, mussels and oysters) in marine waters of the CCE. Colors, lines and symbols are as in Fig. 1.1.

Shellfish aquaculture data were acquired from the California Department of Fish and Game and the Oregon Department of Agriculture. Washington State does not have good production estimates, so data from NOAA's Fisheries of the United States annual reports were used to estimate production in Washington State.

4.3 Trends in Benthic Structures, Shipping, Nutrient Input and Offshore Oil and Gas Activity

The effects of benthic structures, such as oil rigs, wells and associated anchorings, on managed species will be initially destructive with the loss or modification of habitat, but these risks may dissipate in the long term by potential enhanced productivity brought about by colonization of novel habitats by structure-associated fishes and invertebrates (e.g., rockfish, encrusting organisms, etc.). However, activities associated with oil & gas extraction can disturb the associated epifaunal communities, which may provide feeding or shelter habitat for species of interest. Benthic organisms, especially prey species, may recolonize disturbed areas, but this may not occur if the composition of the substrate is drastically changed or if facilities are left in place after production ends. Benthic structures associated with oil and gas activities have been relatively unchanged over the last five years and are at historically low levels (Fig. 4.3).

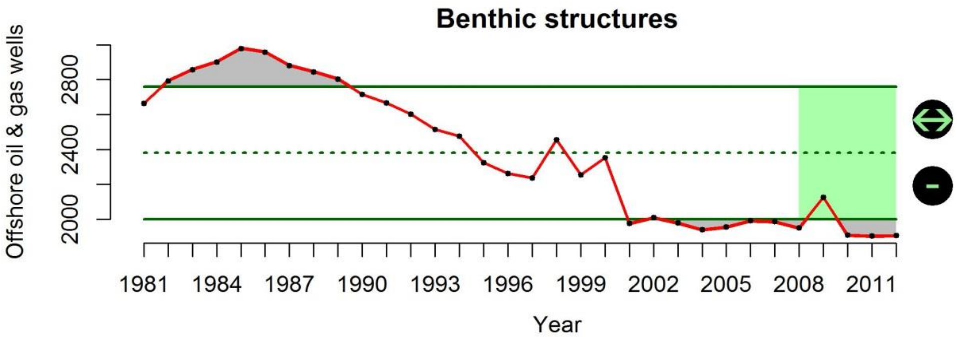


Figure 4.3. The number of offshore oil and gas wells in production or shut-in within the CCE. Colors, lines and symbols are as in Fig. 1.1.

Approximately 90% of world trade is carried by the international shipping industry and the volume of cargo moved through U.S. ports is expected to double (as compared to 2001 volume) by 2020. Fisheries impacts associated with increased commercial shipping include interactions between fishing and shipping vessels; ship strikes of protected species; underwater noise levels that impact fish spawning, migration, communicative, and recruitment behaviors.

Commercial shipping activity in the CCE decreased over the last five years (Fig. 4.4), potentially reflecting economic conditions; a slight rebound has occurred over the last two years. Data come from the U.S. Army Corps of Engineers and integrate distance traveled and draft and breadth of all port-to-port coastwise traffic for foreign and domestic vessels.

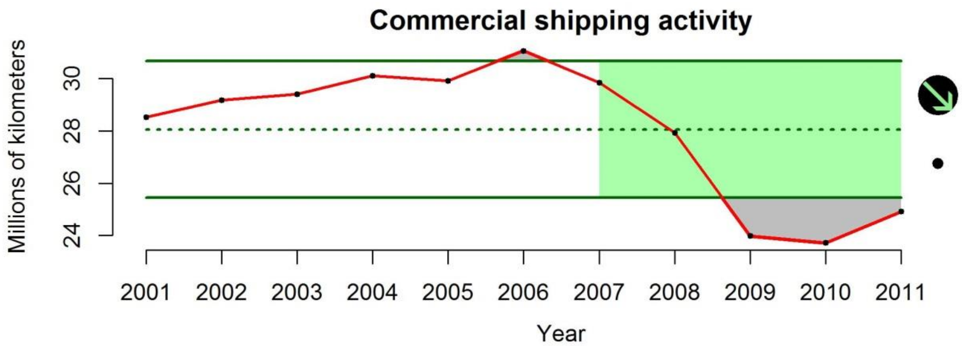


Figure 4.4. Distance transited by commercial shipping vessels along the coast of the CCE. Colors, lines and symbols are as in Fig. 1.1.

Elevated nutrient concentrations are a leading cause of contamination in streams, lakes, wetlands, estuaries, and groundwater of the United States. Excessive nutrients accelerate eutrophication, which produces a wide range of other impacts on aquatic ecosystems and fisheries, including: algae blooms; declines in aquatic vegetation; mass mortality of fish and invertebrates through poor water quality (e.g., via oxygen depletion and elevated ammonia levels); and alterations in long-term natural community dynamics.

Nutrient input declined over the last five years of the dataset (2005- 2010) but the short-term average was greater than 1 s.d. above the long-term average of the time series (Fig. 4.5). Overall, steep increases in the application of nitrogen and phosphorus occurred at the beginning of this time series until 1980 followed by a relatively sharp stepped increase in the 2000's. However a large decrease occurred in 2009 leading to the short-term decline. Data consist of county-level inputs of nitrogen and phosphorus via fertilizers in Washington, Oregon and California (http://pubs.usgs.gov/sir/2006/5012/).

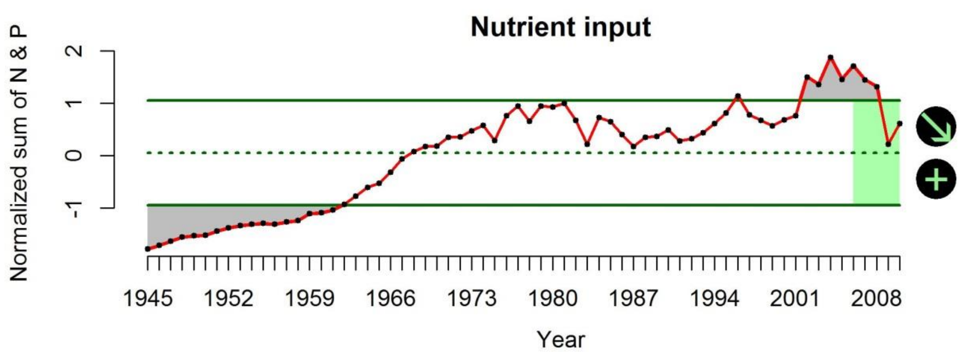


Figure 4.5. Normalized index of the sum of nitrogen and phosphorus applied as fertilizers in WA, OR and CA. Colors, lines and symbols are as in Fig. 1.1.

The environmental risks posed by offshore exploration and production of oil and gas are well known. They include the loss of hydrocarbons to the environment, smothering of benthos, sediment anoxia, destruction of benthic habitat, and the use of explosives. Petroleum products, including polycyclic aromatic hydrocarbons (PAHs), consist of thousands of chemical compounds which can be particularly damaging to marine fishes. Effects of exposure to PAH in benthic species of fish include liver lesions, inhibited gonadal growth, inhibited spawning, reduced egg viability and reduced growth. The effects of oil rigs on fish stocks are less conclusive, as there may be some benefits associated with the structure associated with rigs.

Offshore oil and gas activity in the CCE has been constant over the last five years, but the short-term average was more than 1 s.d. below the long-term average (Fig. 4.6). A rather steady decrease in oil and gas production has occurred over the last 15 years, but that appears to be leveling off. Data were retrieved from annual and monthly reports of the California State Department of Conservation's Division of Oil, Gas, and Geothermal Resources and from the U.S. Energy Information Administration.

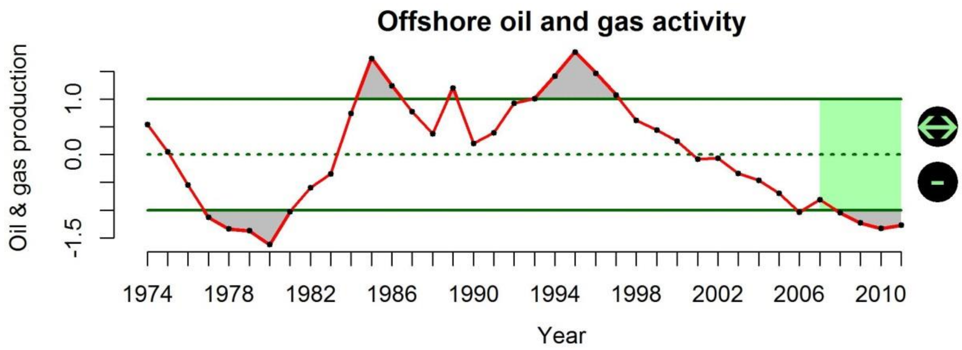


Figure 4.6. Normalized index of the sum of oil and gas production from offshore wells in CA. Colors, lines and symbols are as in Fig. 1.1.

5 Human Wellbeing

These indicators can be empirical or model based, and should either directly or indirectly relate to the productivity or condition of managed or protected species or assemblages. Ideally, they should offer some perspective on the relative condition of species, species assemblages or communities that might not necessarily be reflected by species-specific metrics. The status of each indicator below was evaluated against two criteria: recent short-term trend and status relative to the long-term mean—reported as short-term status and long-term status, respectively.

5.1 Fleet Diversity Indices

Catches and prices from many fisheries exhibit high inter-annual variability leading to high variability in fishermen's income. Kasperski (AFSC) and Holland (NWFSC) recently examined > 28,000 vessels fishing off the West Coast and Alaska over the last 32 years (Fig. 5.1). This work shows that variability of annual revenue can be reduced by diversifying fishing activities across multiple fisheries or regions. Diversification can be measured with the Herfindahl-Hirschman Index (HHI) which ranges from a high of 10,000 for a vessel that derives all its income from a single fishery and declines toward zero as revenues are spread more evenly across more fisheries.

Levels of diversification for groupings of vessels vary greatly and exhibit different trends over time. The current fleet of vessels fishing on the US West Coast and in Alaska (those that fished in 2010) is less diverse than at any point in the past 32 years, except for 2011 when it was slightly less diverse. Trends for vessels with landings in West Coast states are similar to those for the larger fleet of vessels fishing the West Coast and/or Alaska. The trends over time are due both to entry and exit of vessels and changes for individual vessels. Over time less diversified vessels have been more likely to exit, which increases the average diversification level (decreases HHI). However vessels that remain in the fishery have become less diversified, at least since the mid 1990s, and newer entrants have generally been less diversified than earlier entrants. The overall result is a moderate decline in average diversification (increase in HHI) since the mid 1990s or earlier for most vessel groupings. Notwithstanding these trends in average diversification, there are wide range of diversification levels and strategies within as well as across vessel classes and some vessels remain highly diversified.

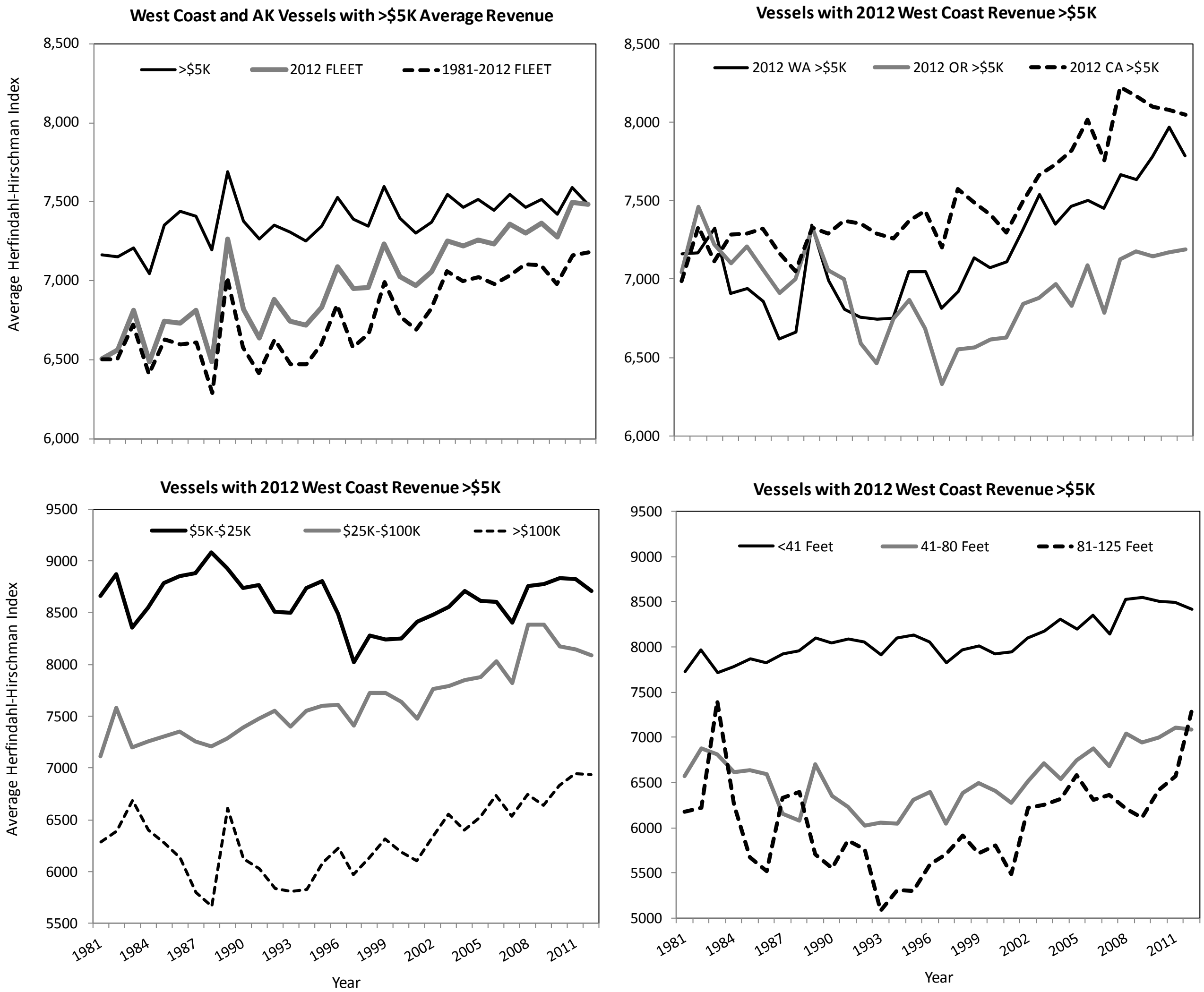


Figure 5.1. Trends in average diversification for US West Coast and Alaskan fishing vessels with over $5K in average revenues (top left) and for vessels in the 2012 West Coast Fleet with over $5K in average revenues, broken out by state (top right), by average gross revenue classes (bottom left) and by vessel length classes (bottom right).

5.2. Personal Use: Subsistence and Informal Economic Practices Among Commercial Fisheries

This section documents the volume of fish and shellfish kept for personal use from commercial vessels in Washington (WA) and California (CA). Between 1990 and 2010, over 37.5 million pounds of seafood were kept for "personal use," a category used as a proxy for subsistence food and informal economic share systems. These 37.5 million pounds of personal use constitute a fraction (0.2%) of the total catch (16.3 billion pounds) landed during that same period. Nearly 85% (31.8 million pounds) of the personal use removals are from tribal participants in WA (Fig. 5.2), while the remaining personal use removals are from nontribal participants from both WA and CA. The majority of personal use (over 30.4 million pounds or 81.3%) was landed in Puget Sound.

Roughly 96% of catch retained by tribal participants is salmonids. The other top species retained by tribes include geoduck, Dungeness crab, and Pacific halibut. Nontribal participants retain a wider diversity of species than their tribal counterparts; top species include market squid, albacore, Pacific sardine, Dungeness crab, Pacific halibut, bait shrimp, and salmonids. CA ports record less personal use than WA ports, but the species breadth in CA is greater: in CA, 229 species were kept for personal use, compared to 93 in WA.

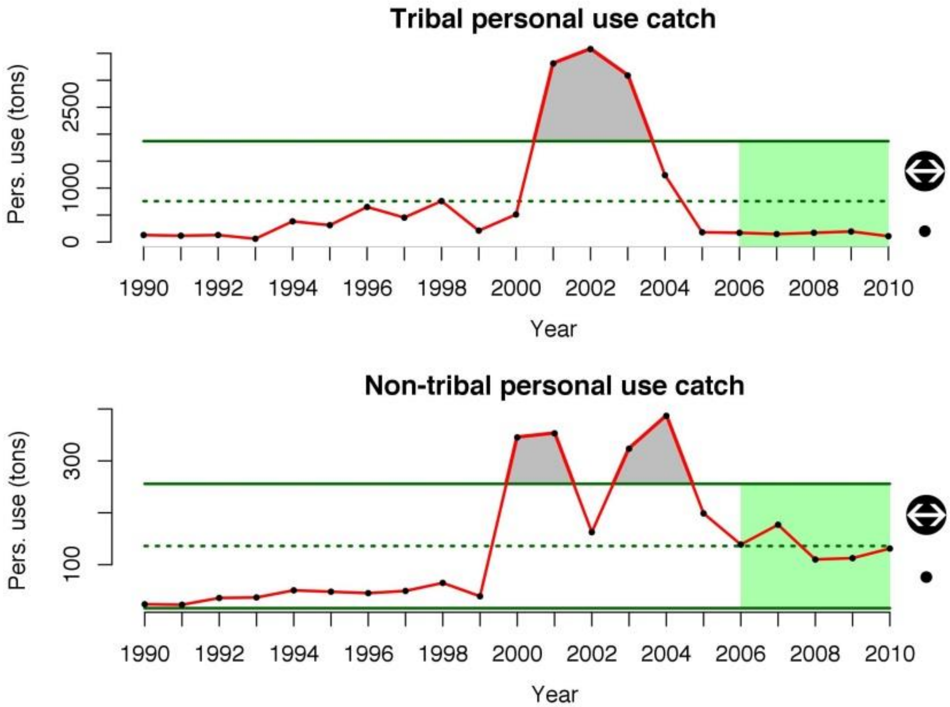


Figure 5.2. Catch retained for personal use from 1990 - 2010 in tons (2000 lbs). Colors, lines and symbols are as in Fig. 1.1. Data source: Pacific Fisheries Information Network (PacFIN), 1990-2010. Data are from landings in 139 of 350 ports in WA and CA; data not collected/reported from OR.

The recent trends for personal use catch are stable in both the tribal and non-tribal sectors, and both sectors' recent 5-year averages fall within ±1.0 s.d. of the long-term means (Fig. 5.2).

6 Supplemental Materials List

Detailed information on each of the above sections is available in the Supplementary Materials that will be provided with the Briefing Book. A list of supplementary materials is provided below; additional information can be found in the most recent full California Current IEA report, which is available online at http://www.noaa.gov/iea/CCIEA-Report/index.html.

2104 State of the California Current Report Supplement

Section 2 Report	Wells, B.K., I.D. Schroeder, J.A. Santora, E.L. Hazen, S.J. Bograd, E.P. Bjorkstedt, V.J. Loeb, S. McClatchie, E.D. Weber, ……2013. State of the California Current 2012-2013: No such thing as normal. CalCOFI Reports, 54:37-71.
Section 3 Papers	Copepod Biomass Anomaly, Copepod species richness off Washington and Oregon (Papers):
	Peterson, W. T., J. E. Keister. 2003. Interannual variability in copepod community composition at a coastal station in the northern California Current: a multivariate approach. Deep Sea Research Part II: Topical Studies in Oceanography, 50:2499-2517. Peterson, W. T. 2009. Copepod species richness as an indicator of long–term changes in the coastal ecosystem of the northern California Current. California Cooperative Oceanic Fisheries Investigations (CalCOFI) Report 50:73-81.

Narrative	Coastal Pelagic Species: Anchovy, Sardine, and Forage Diversity - Narrative
Narrative	Salmon: Chinook Salmon Abundance – Narrative
Paper	Mean Trophic Level of West Coast Groundfish – Paper: Tolimieri, N., J. F. Samhouri, V. Simon, B. E. Feist, P. S. Levin. 2013. Linking the trophic fingerprint of groundfishes to ecosystem structure and function in the California Current.. Ecosystems 16:1216-1229
Narrative	Mammals: California Sea Lion pup production – Narrative
Section 4	Total Landings by Major Fisheries - Commercial landings and price per pound by state – Narrative
Section 5 Paper,Narrative	Fleet Diversity Indices – Narrative and paper: Kasperski, S. and D.S. Holland (2013). Income Diversification and Risk for Fishermen. Proc. Nat. Acad. Sci. 100(6):2076-2081. doi: 10.1073/pnas.1212278110
Narrative	Personal Use: Subsistence and informal economic practices among commercial fisheries in Washington and California – Narrative

Agenda Item C.1.a
Attachment 2 (Electronic Only)
March 2014

2014 STATE OF THE CALIFORNIA CURRENT REPORT

CALIFORNIA CURRENT INTEGRATED ECOSYSTEM ASSESSMENT

SECTION 2 – CLIMATE AND OCEAN DRIVERS

STATE OF THE CALIFORNIA CURRENT 2012–13: NO SUCH THING AS AN "AVERAGE" YEAR

BRIAN K. WELLS, ISAAC D. SCHROEDER, JARROD A. SANTORA
Fisheries Ecology Division
Southwest Fisheries Science Center
National Marine Fisheries Service
110 Shaffer Road
Santa Cruz, CA 95060

ELLIOTT L. HAZEN[1], STEVEN J. BOGRAD
Environmental Research Division
Southwest Fisheries Science Center
National Marine Fisheries Service
1352 Lighthouse Avenue
Pacific Grove, CA 93950-2020

ERIC P. BJORKSTEDT
Fisheries Ecology Division
Southwest Fisheries Science Center
National Marine Fisheries Service
110 Shaffer Road
Santa Cruz, CA 95060
and
Department of Fisheries Biology
Humboldt State University
1 Harpst Street
Arcata, CA 95521

VALERIE J. LOEB
Moss Landing Marine Laboratories
8272 Moss Landing Road
Moss Landing, CA 95039

SAM MCCLATCHIE, EDWARD D. WEBER, WILLIAM WATSON, ANDREW R. THOMPSON
Fisheries Research Division
Southwest Fisheries Science Center
National Marine Fisheries Service
8901 La Jolla Shores Drive
La Jolla, CA 92037-1508

WILLIAM T. PETERSON, RICHARD D. BRODEUR
Northwest Fisheries Science Center
National Marine Fisheries Service
Hatfield Marine Science Center
Newport, OR 97365

JEFF HARDING, JOHN FIELD, KEITH SAKUMA, SEAN HAYES, NATHAN MANTUA
Fisheries Ecology Division
Southwest Fisheries Science Center
National Marine Fisheries Service
110 Shaffer Road
Santa Cruz, CA 95060

WILLIAM J. SYDEMAN, MARCEL LOSEKOOT, SARAH ANN THOMPSON
Farallon Institute for
Advanced Ecosystem Research
Petaluma, CA 94952

JOHN LARGIER
Bodega Marine Laboratory
University of California, Davis
P.O. Box 247
Bodega Bay, CA 94923

SUNG YONG KIM
Division of Ocean Systems Engineering
Korea Advanced Institute
of Science and Technology
Yuseong-gu, Daejeon 305-701
Republic of Korea

FRANCISCO P. CHAVEZ
Monterey Bay Aquarium Research Institute
7700 Sandholdt Road
Moss Landing, CA 95039

CAREN BARCELÓ
College of Earth, Ocean and
Atmospheric Sciences
Oregon State University
Corvalis, OR 97331-5503

PETE WARZYBOK, RUSSEL BRADLEY, JAIME JAHNCKE
PRBO Conservation Science
3820 Cypress Drive #1
Petaluma, CA 94954

RALF GOERICKE, GREGORY S. CAMPBELL, JOHN A. HILDEBRAND
Scripps Institute of Oceanography
University of California, San Diego
9500 Gilman Drive
La Jolla, CA 92093-0205

SHARON R. MELIN, ROBERT L. DELONG
National Marine Fisheries Service
Alaska Fisheries Science Center
National Marine Mammal Laboratory
NOAA
7600 Sand Point Way N. E.
Seattle, WA 98115

JOSE GOMEZ-VALDES, BERTHA LAVANIEGOS, GILBERTO GAXIOLA-CASTRO
Centro de Investigación Científica y de
Educación Superior de Ensenada (CICESE)
División de Oceanología
Carretera Ensenada Tijuana No. 3918
Zona Playitas, Ensenada
Baja California, México C.P. 22860

RICHARD T. GOLIGHTLY, STEPHANIE R. SCHNEIDER
Department of Wildlife
Humboldt State University
1 Harpst Street
Arcata, CA 95521

NANCY LO
Ocean Associates, Inc. and
Fisheries Research Division
Southwest Fisheries Science Center
National Marine Fisheries Service
8901 La Jolla Shores Drive
La Jolla, CA 92037-1508

ROBERT M. SURYAN, AMANDA J. GLADICS, CHERYL A. HORTON
Department of Fisheries and Wildlife
Oregon State University
Hatfield Marine Science Center
Newport, OR 97365

JENNIFER FISHER, CHERYL MORGAN, JAY PETERSON, ELIZABETH A. DALY
Cooperative Institute for
Marine Resources Studies
Oregon State University
Hatfield Marine Science Center
Newport, OR 97365

TOBY D. AUTH
Pacific States Marine Fisheries Commission
Hatfield Marine Science Center
2030 Marine Science Drive
Newport, OR 97365

JEFFREY ABELL
Department of Oceanography
Humboldt State University
1 Harpst Street
Arcata, CA 95521

ABSTRACT

This report reviews the state of the California Current System (CCS) between winter 2012 and spring 2013, and includes observations from Washington State to Baja California. During 2012, large-scale climate modes indicated the CCS remained in a cool, productive phase present since 2007. The upwelling season was delayed north of 42˚N, but regions to the south, especially 33˚ to 36˚N, experienced average to above average upwelling that persisted throughout the summer. Contrary to the indication of high production suggested by

[1]The first four authors represent members of the SWFSC California Current Integrated Ecosystem Assessment group and worked in equal collaboration on preparation of this report.

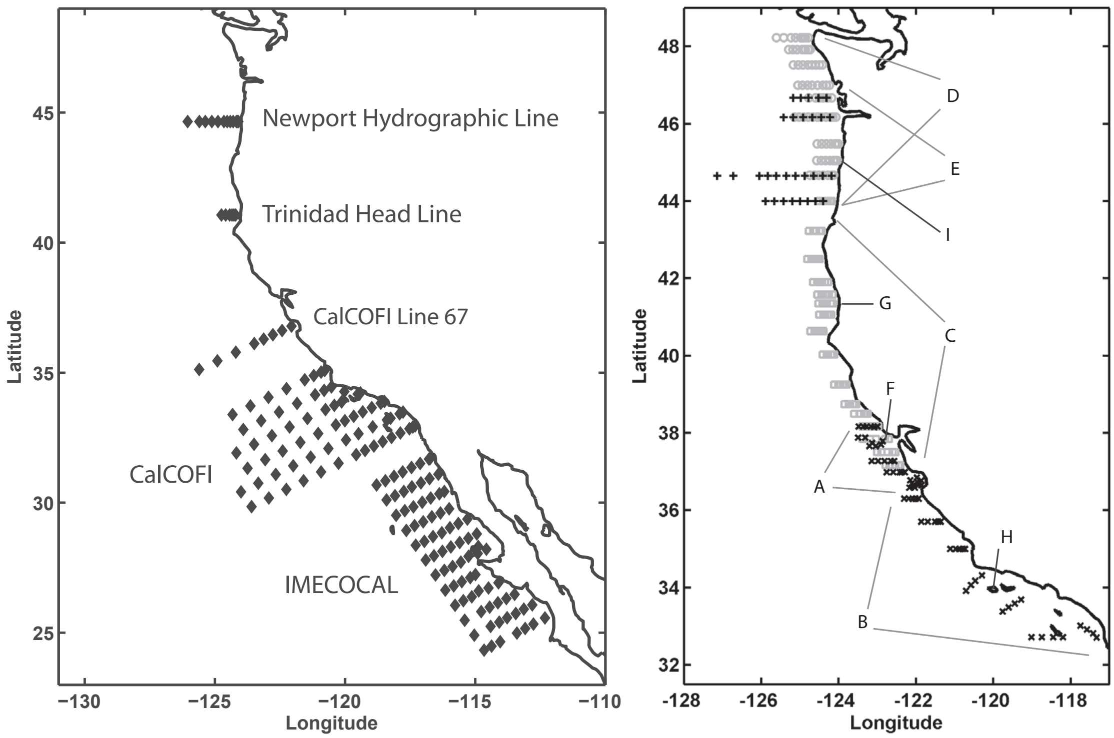


Figure 1. Left: Station maps for surveys that were conducted multiple times per year during different seasons to provide year-round observations in the California Current System. The CalCOFI survey (including CalCOFI Line 67) were occupied quarterly; the spring CalCOFI survey grid extends just north of San Francisco. The IMECOCAL survey is conducted quarterly or semiannually. The Newport Hydrographic Line was occupied biweekly. The Trinidad Head Line was occupied at biweekly to monthly intervals. Right: Location of annual or seasonal surveys, including locations of studies on higher trophic levels, from which data was included in this report. Different symbols are used to help differentiate the extent of overlapping surveys. A. SWFSC FED midwater trawl survey core region (May–June) B. SWFSC FED midwater trawl survey south region (May–June). C. SWFSC FED salmon survey (June and September) (grey squares). D. NWFSC salmon survey (May, June, and September). E. NOAA/BPA pelagic rope trawl survey (May through September). F. Southeast Farallon Island. G. Castle Rock. H. San Miguel Island. I. Yaquina Head Outstanding Natural Area.

the climate indices, chlorophyll observed from surveys and remote sensing was below average along much of the coast. As well, some members of the forage assemblages along the coast experienced low abundances in 2012 surveys. Specifically, the concentrations of all life-stages observed directly or from egg densities of Pacific sardine, *Sardinops sagax*, and northern anchovy, *Engraulis mordax*, were less than previous years' survey estimates. However, 2013 surveys and observations indicate an increase in abundance of northern anchovy. During winter 2011/2012, the increased presence of northern copepod species off northern California was consistent with stronger southward transport. Krill and small-fraction zooplankton abundances, where examined, were generally above average. North of 42°N, salps returned to typical abundances in 2012 after greater observed concentrations in 2010 and 2011. In contrast, salp abundance off central and southern California increased after a period of southward transport during winter 2011/2012. Reproductive success of piscivorous Brandt's cormorant, *Phalacrocorax penicillatus*, was reduced while planktivorous Cassin's auklet, *Ptychoramphus aleuticus* was elevated. Differences between the productivity of these two seabirds may be related to the available forage assemblage observed in the surveys. California sea lion pups from San Miguel Island were undernourished resulting in a pup mortality event perhaps in response to changes in forage availability. Limited biological data were available for spring 2013, but strong winter upwelling coastwide indicated an early spring transition, with the strong upwelling persisting into early summer.

INTRODUCTION

This report reviews the oceanographic and ecosystem responses of the California Current System (CCS) between winter 2012 and spring of 2013. Biological and hydrographic data from a number of academic, private, and government institutions have been consolidated and described in the context of historical data (fig. 1). The various institutions have provided data and explanation of the data after an open solicitation for contributions; these contributions are acknowledged in the author list. These data are synthesized here, in the spirit of providing a broader description of the present condition of the CCS. All data are distilled from complex sampling programs covering multiple spatial and temporal scales into a simple figure(s) that might not convey the full complexity of the region being studied. As a consequence, we

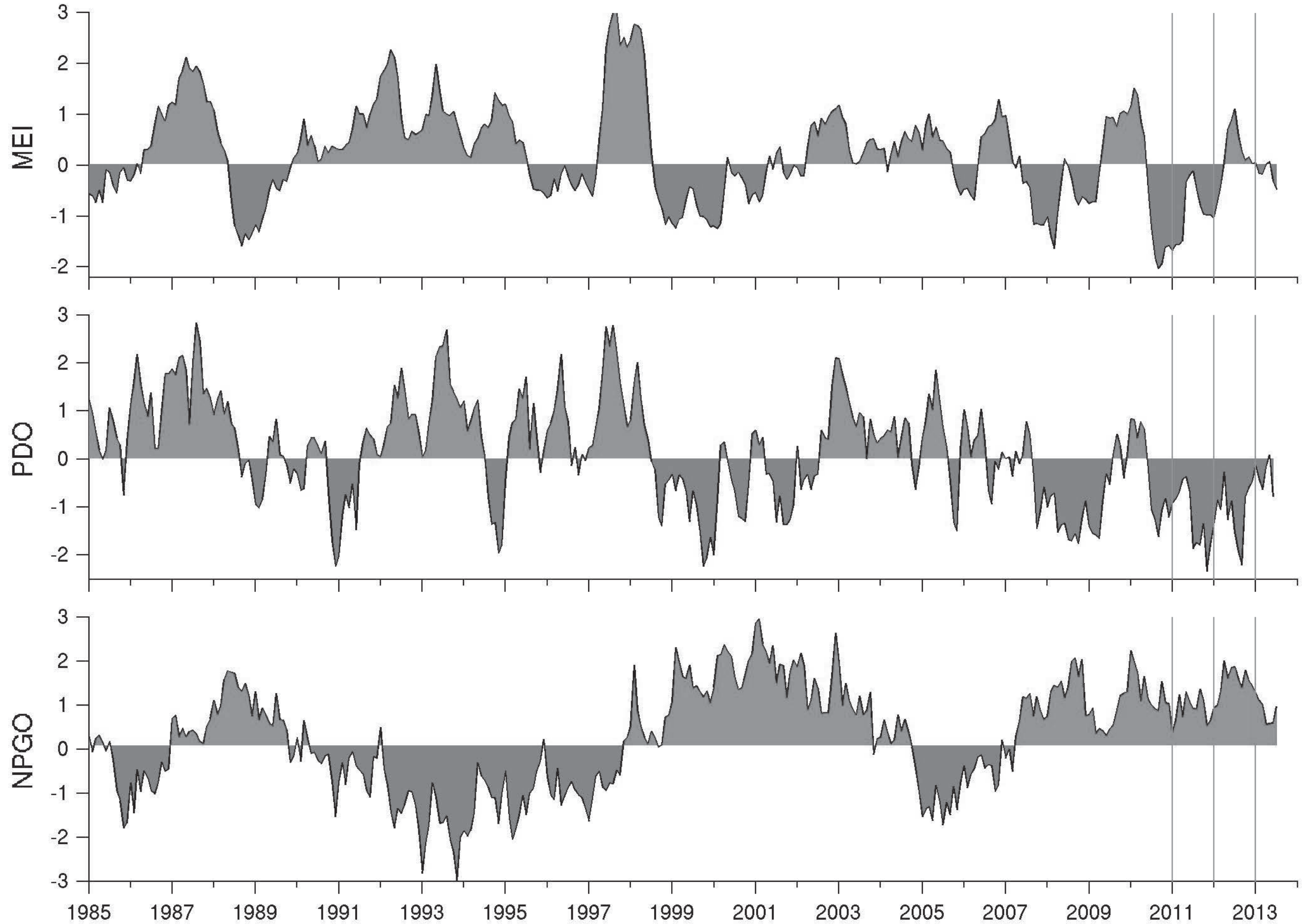


Figure 2. Time series of monthly mean values for three ocean climate indices especially relevant to the California Current: the multivariate ENSO index (MEI), the Pacific Decadal Oscillation (PDO), and the North Pacific Gyre Oscillation (NPGO) for January 1985–June 2013. Vertical lines mark January 2011, 2012, and 2013.

focus on the findings of the data and limit our descriptions of the methodology to only that which is required for interpretation. More complete descriptions of the data and methodologies can be found in the supplement. Can be found in the supplement (http://calcofi.org/publications/ccreports/568-vol-54-2013.html)

In 1949, the California Cooperative Oceanic Fisheries Investigations program (CalCOFI) was formed to study the environmental causes and ecological consequences of Pacific sardine, *Sardinops sagax*, variability. Consideration of the broader forage communities has been invigorated by recent fluctuations in the abundance of sardine and another important forage fish, the northern anchovy, *Engraulis mordax* (Cury et al. 2011; Pikitch et al. 2012). Specifically, there has been a decline in the observed catches of larval, juvenile, and adult northern anchovy reported by the various sampling programs along the CCS (Bjorkstedt et al. 2012). While not unprecedented, with two similar examples since 1993, the estimated Pacific sardine biomass declined from 1,370,000 MT in 2006 to 659,539 MT in July 2012 (http://www.pcouncil.org/wp-content/uploads/MAIN_DOC_G3b_ASSMNT_RPT2_WEB_ONLY_NOV2012BB.pdf). Here, we return to an initial focus of the CalCOFI program and consider physical and biological signals related to coastal pelagic species. Importantly, the survey designs that we examine are dissimilar and each has unique limitations restricting a common interpretation along the CCLME. Therefore, this report should be considered a first examination for instigating more focused exploration of potential drivers of the forage community's dynamics.

This report will focus on data highlighting variability in the forage community with additional (supporting) data provided in the supplement. Some information in the supplement are data that have been presented in previous reports and are included as a reference to an aspect of the "state of the CCS," which might be of interest beyond the focus here. As in past reports, we begin with an analysis of large-scale climate modes and upwelling conditions in the California Current. Following, the various observational data sampling programs are reviewed to highlight the links between ecosystem structure, processes, and climate.

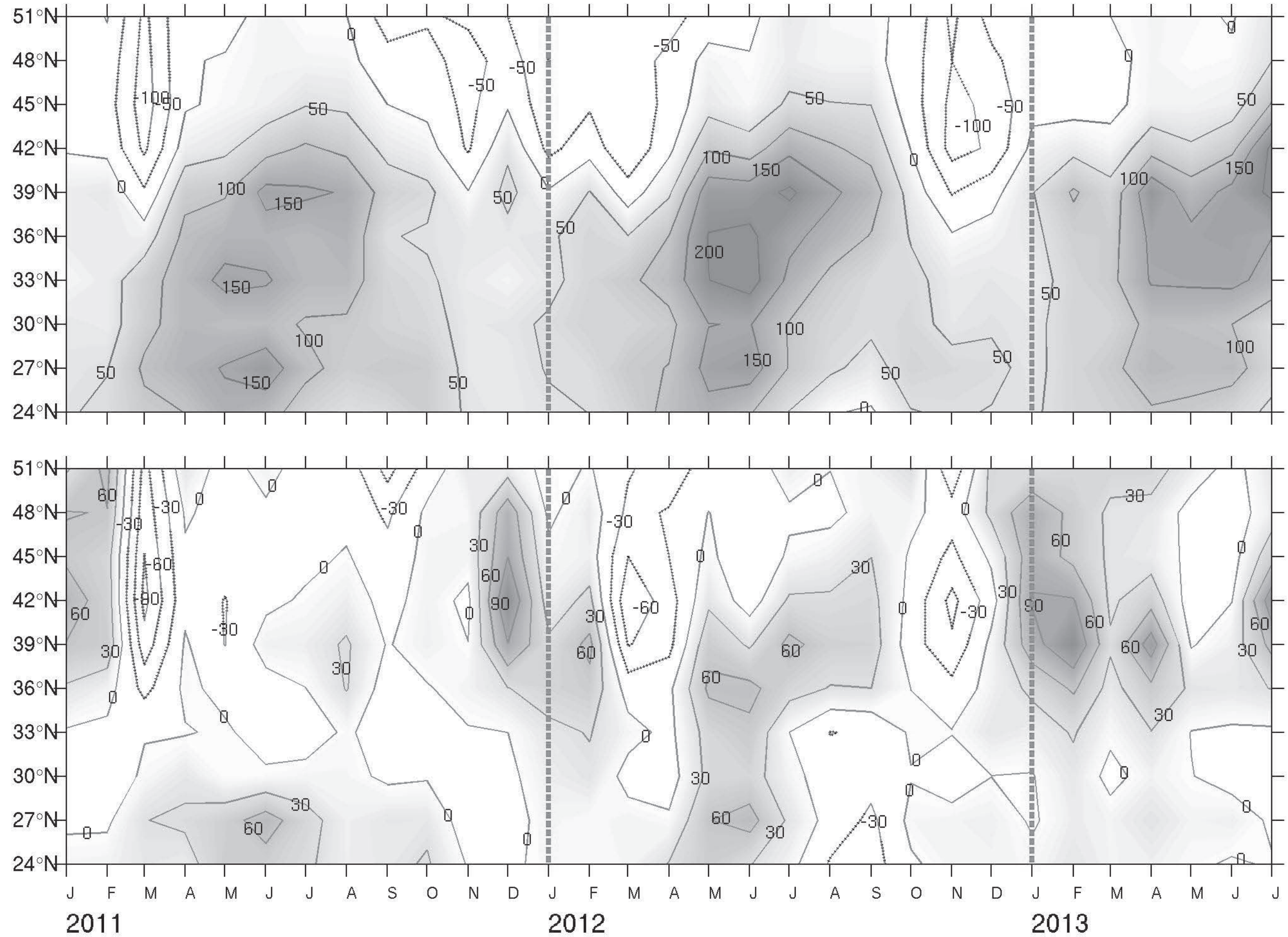


Figure 3. Monthly upwelling index (top) and upwelling index anomaly (bottom) for January 2011–May 2013. Shaded areas denote positive (upwelling-favorable) values in upper panel, and positive anomalies (generally greater than normal upwelling) in lower panel. Anomalies are relative to 1967–2013 monthly means. Units are in m³ s–1 per 100 km of coastline.

NORTH PACIFIC CLIMATE INDICES

The multivariate El Niño Southern Oscillation (ENSO) index (MEI) (Wolter and Timlin 1998) transitioned from La Niña conditions in summer of 2010 through January 2012 (fig. 2). In the summer of 2012, MEI increased but the values were too low and short-lived to be classified as an ENSO event; the values returned to neutral conditions in the spring of 2013. The Pacific Decadal Oscillation index (PDO) (Mantua and Hare 2002) has been negative (cool in the CCS) coinciding with the start of the La Niña in the summer of 2010 (fig. 2). The PDO continued in a negative phase through the summer of 2012, with a minimum in August. After October 2012, the PDO increased to slightly negative values in the winter and spring of 2013. The May 2013 value of the PDO was +0.08 but dropped to a value of –0.78 in June. The North Pacific Gyre Oscillation index (NPGO) (Di Lorenzo et al. 2008) was positive from the summer of 2007 to the spring 2013 with a peak value in July 2012 (fig. 2).

NORTH PACIFIC CLIMATE PATTERNS

A basin-scale examination of SST allows for the interpretation of the spatial evolution of climate patterns and wind forcing over the North Pacific related to trends in the basin-scale indices (fig. 2). In the summer of 2012, predominately negative SST anomalies over the western Pacific coincided with anticyclonic wind anomalies. Warmer than normal SST (+1.0˚C) in the central and eastern north Pacific occurred during a period of anomalous eastward winds in October of 2012. For 2013 the northeast Pacific experienced winter SST anomalies that were slightly cooler than normal (< –0.5˚C), followed by slightly warmer anomalies (< +0.5˚C) in the spring. SST anomalies across the North Pacific in 2013 (January to June) were positive and were simultaneous with a rise in PDO values from the extreme negative values experienced in 2012. However, SST anomalies along the CCS remained slightly negative (< –0.5˚C) forced by equatorward meridional wind anomalies (fig. S1).

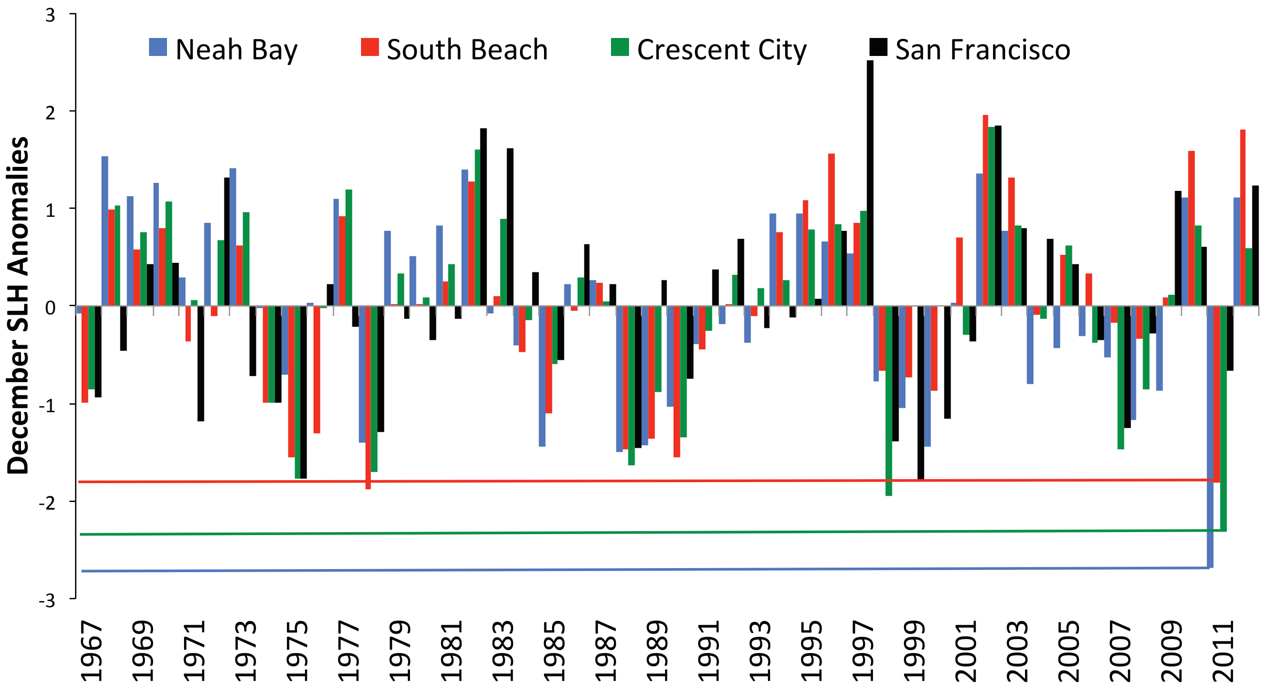


Figure 4. Sea level height anomalies measured by tidal gauges during December for the following four locations along the CCS: Neah Bay, WA, South Beach, OR, Crescent City, CA and San Francisco, CA. Horizontal lines mark the values observed in December 2011.

Upwelling in the California Current

December 2011 was marked by anomalously strong upwelling between 36˚N and 45˚N and substantially weaker downwelling north of 45˚N (fig. 3). This resulted in anomalously low coastal sea levels, as measured by tidal gauges, in December at Neah Bay, WA, South Beach, OR, and Crescent City, CA (fig. 4). Such low coastal sea levels suggests southward transport in winter 2011/2012.

By March 2012, upwelling winds north of 39˚N were anomalously low while winds south of 39˚N remained near the climatological mean. Upwelling north of 39˚N did not resume again until May and for summer and fall remained at close to climatological values. In contrast, south of 39˚N average upwelling prevailed from winter 2011 to April 2012, after which it intensified. Strong upwelling continued off central California until fall. North of 36˚N, high upwelling persisted through winter 2012 and into January–February 2013 (fig. 3).

The cumulative upwelling index (CUI) gives an indication of how upwelling influences ecosystem structure and productivity over the course of the year (Bograd et al. 2009). In the north from 42˚ to 48˚N, the upwelling season in 2012 began early (fig. S2) resulting in average CUI values from January 1 to the beginning of March, but dropped to below long-term average over the spring and summer. The upwelling season also began early in southern and central California (33˚–36˚N) during 2012, with highest levels of the CUI at the end of February since record highs experienced in 2007. Strong upwelling continued into the summer off southern California (33˚N) with CUI estimates at the end of July being the highest since 1999. At 36˚N, the 2012 CUI values at the end of the year were the second highest on record, falling just below the high in 1999. Through mid-2013, CUI values are greater than previously observed records throughout the CCS. While there were significant regional differences in upwelling in 2012, strong upwelling occurred more widely in the CCS in winter and spring of 2013.

Coastal Sea Surface Temperature

In 2011, the daily December values of SST were below average especially at the northern California and Oregon buoys (fig. S3). This is due to upwelling at the start of December; these winds were especially long in duration for the Oregon buoy, with the event lasting over half of the month. Anomalously cool SST values in December 2011 extended into spring of 2012 as measured by all of the buoys. There was very little temperature variation between winter of 2011/2012 through spring of 2012. Periods of northerly winds occurred in January and February for the northern buoys with these winds switching directions to southerly in March and April. SST increased for the northern two buoys but the southern buoys showed average temperatures. Only one buoy (St. George, CA) had a complete record of winds in the summer (June–August) of 2012, and the winds

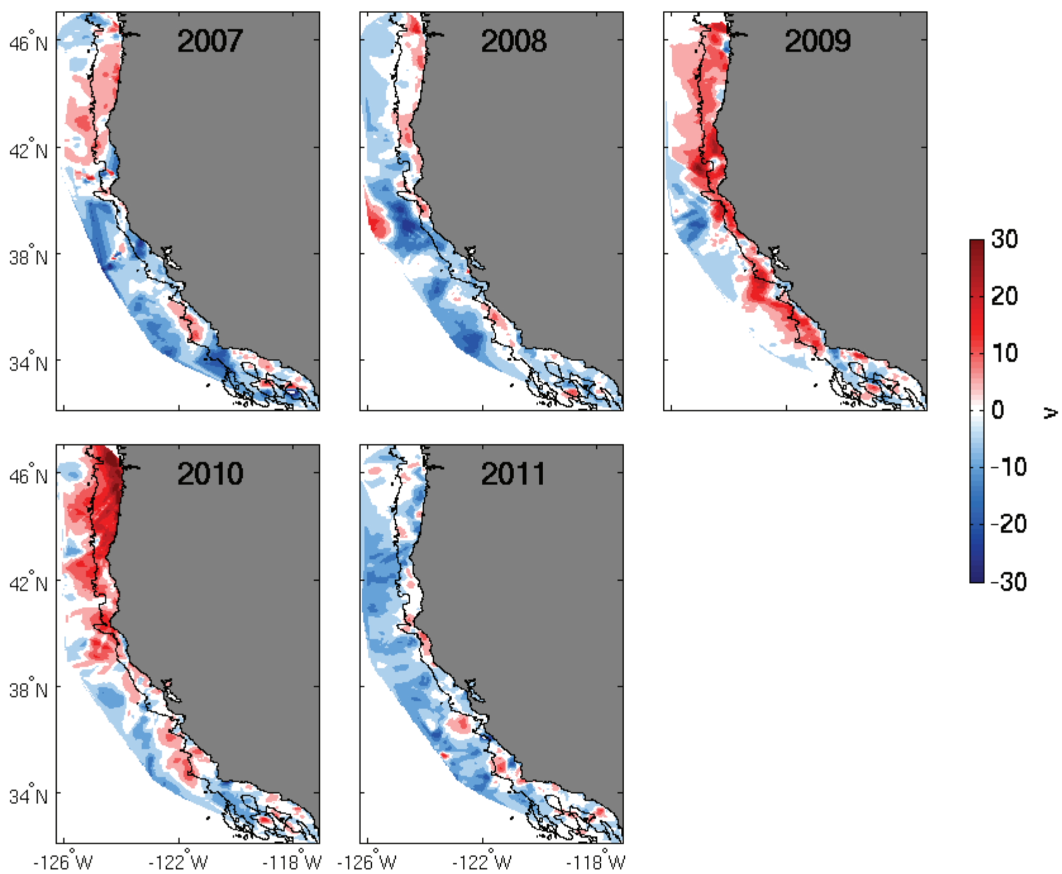


Figure 5. Maps of mean HF radar meridional surface currents observed December 2011 throughout the CCS 2007–11 (December 2012 was not available for this report). Meridional current speed is indicated by color bar (blue shading indicates southward flow) with units of cm/s.

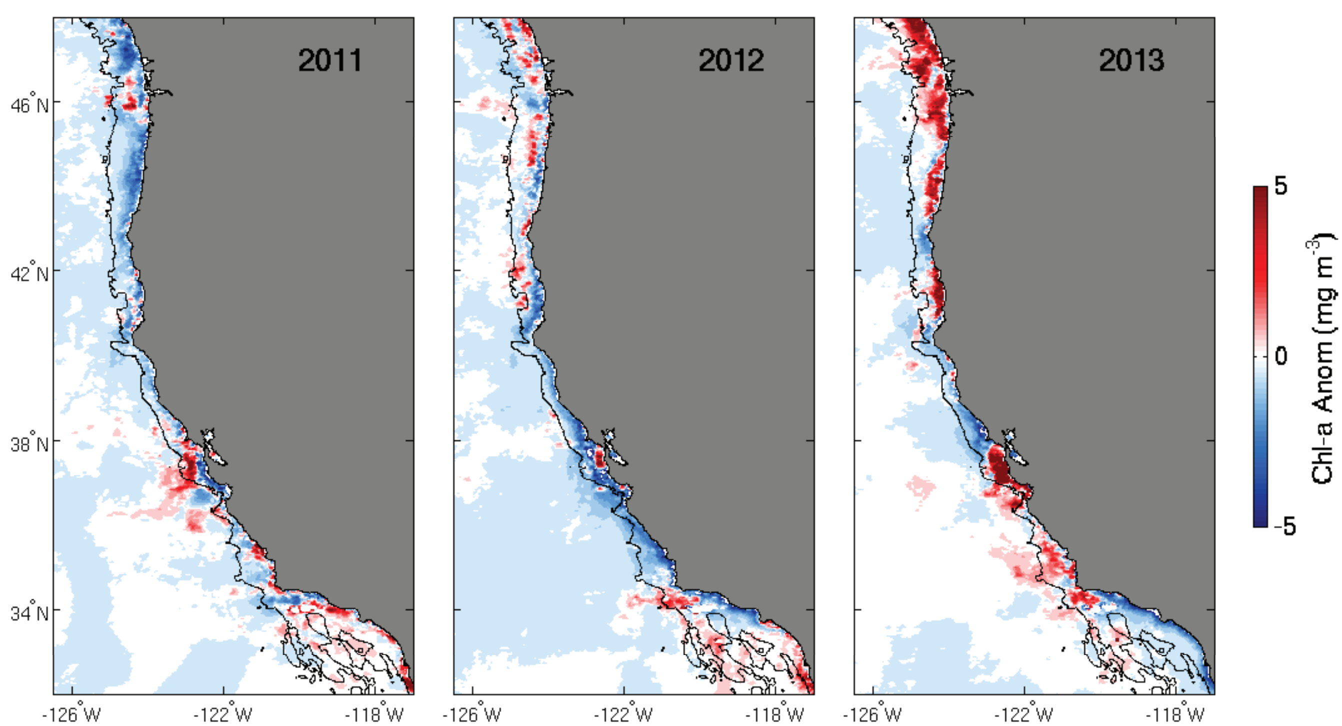


Figure 6. Aqua MODIS satellite measured chlorophyll *a* anomalies for March–May averages. The climatology was based on data for the years 2003–13. The black line is the 1000 m isobath.

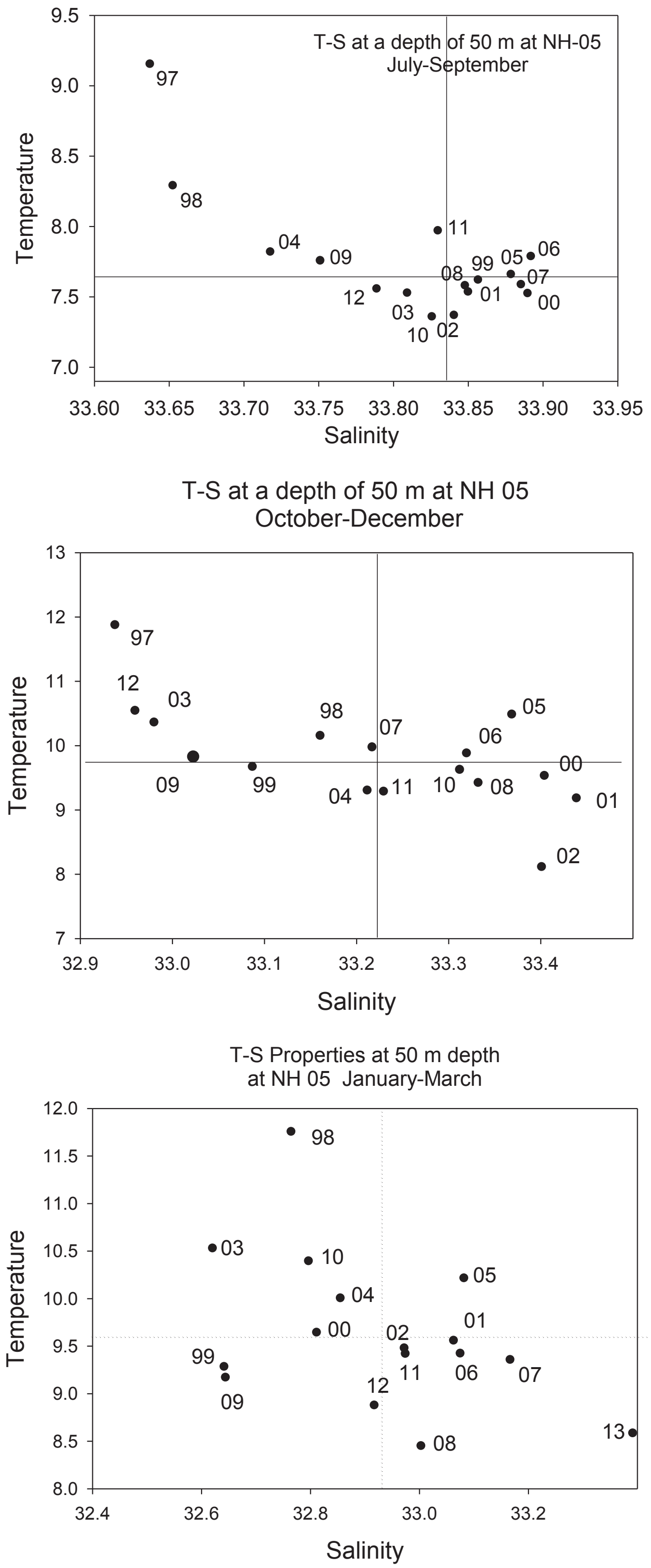


Figure 7. Seasonal mean temperature and salinity at 50 m depth at NH-5 along the Newport Hydrographic Line averaged for summer, fall and winter 2012. Cruises are made biweekly. Numbers adjacent to each data indicate "year."

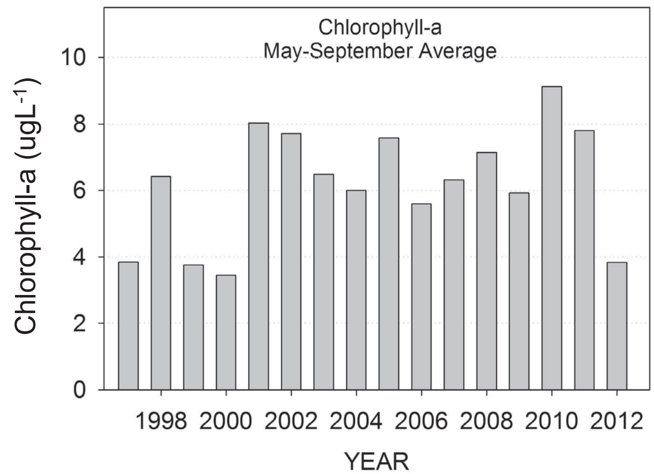


Figure 8. Chlorophyll *a* time series off Newport Oregon at station NH5 showing that chlorophyll *a* averaged over the May–September upwelling season, was unusually low in the year 2012, similar to values not seen since 1999 and 2000.

were predominately downwelling in direction with only a few days of upwelling winds in June. Towards the end of fall (October–November of 2012) above average SSTs occurred for all of the buoys for which we had data. The winds during this time were downwelling-favorable except for a strong upwelling event in the beginning of December. Cool temperatures were evident in early 2013 and persisted until April for all of the buoys. In late April, SSTs dipped due to a strong upwelling event. The winds in January through June of 2013 have mostly been upwelling-favorable except off Oregon where there have been short periods of downwelling.

High Frequency Radar Surface Current Observations

Surface transport was southward in the northern CCS during December 2011, as observed by high frequency (HF) radar (fig. 5) in support of the upwelling (fig. 3) and sea level (fig. 4) data. For the spring of 2012 surface currents observed with HF radar revealed southward currents, developing into marked offshore flow in summer with a general weakening in the fall and a tendency for weak northward flow in winter (see supplement for additional results, fig. S4).

Coast-wide Analysis of Chlorophyll

We used Aqua MODIS satellite measurements to evaluate spring chlorophyll (anomalies; climatology based on 2003–13) in the surface waters of the CCS for 2011–13 (details in supplement). Surface chlorophyll anomalies were generally below average north of San Francisco, CA during the spring of 2011, while the spring values of chlorophyll in 2012 were below average south of Cape Mendocino except for increased production in the Gulf of the Farallones and throughout

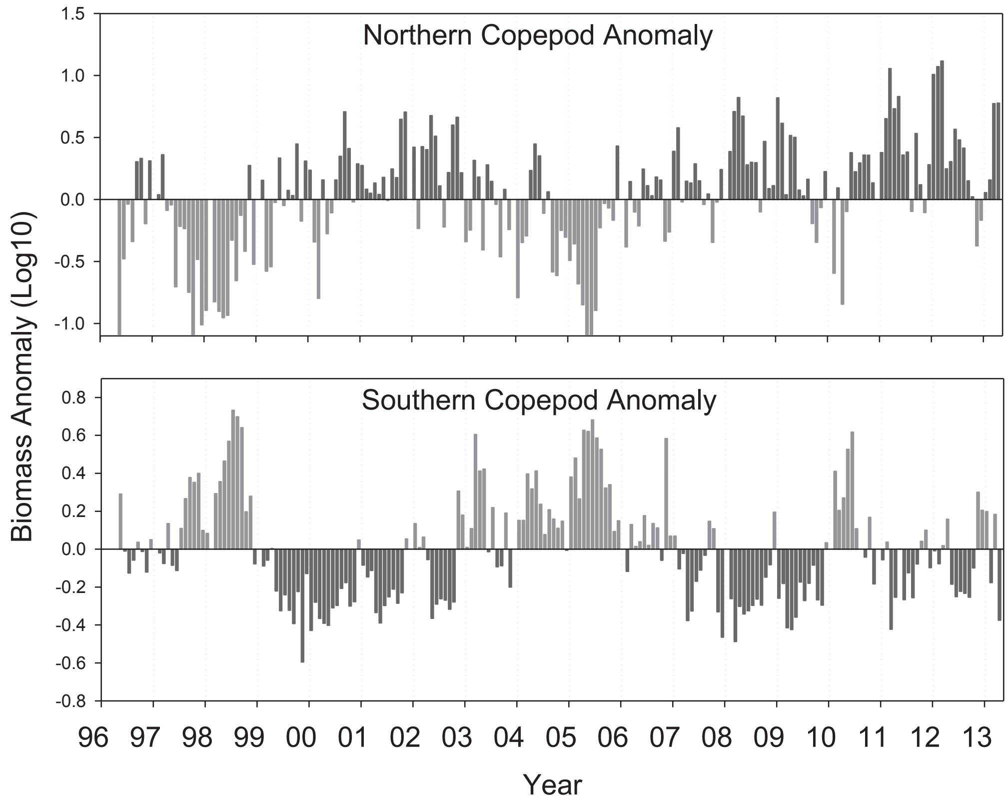


Figure 9. Time series of monthly values of the Northern Copepod Anomaly and Southern Copepod Anomaly. The copepod data are from biweekly sampling at station NH-5 along the Newport Hydrographic Line.

much of the offshore regions south of Point Conception (fig. 6). In spring 2013, chlorophyll was elevated along most of the coast north of Point Conception; south of Point Conception chlorophyll was below average.

REGIONAL SUMMARIES OF HYDROGRAPHIC AND PLANKTONIC DATA

Several ongoing surveys provide year-round hydrographic and planktonic observations across the CCS but vary in terms of spatial extent, temporal resolution survey design, and limitations (fig. 1). In the following section we review recent observations from these surveys from north to south.

Northern California Current: Newport Hydrographic Line

Daily values of SST from the Newport Hydrographic Line showed warm temperature anomalies in June and July 2012, with daily values of temperature anomalies around +3˚C in mid-July. The monthly average anomaly was +1.7˚C for July. SST at hydrographic station NH5 (five miles offshore of Newport) was also above-average over the May–September period with a peak in SST (15.9˚C) observed on 25 June, a value which was the 12th warmest of 450 sampling dates since 1997.

The April–June 2012 data were among the fresher and warmer years; July–September was cool and fresh. By contrast, during the January to March period of 2013, deep water was the most saline of the time series. Concomitant with that, the temperature was also one of the two lowest, 2008 being the lowest (fig. 7). Chlorophyll values at five miles off shore (NH5) averaged over May–September were the lowest they have been since 1999 and 2000 (fig. 8).

Examination of the copepod community can help to determine source waters and provide insights into the productivity of the system (Peterson and Keister 2003). Copepods that arrive from the north are cold-water species that originate from the coastal Gulf of Alaska and include three cold-water species: *Calanus marshallae*, *Pseudocalanus mimus*, and *Acartia longiremis*. Copepods that reside in offshore and southern waters (warm-water species) include *Paracalanus parvus*, *Ctenocalanus vanus*, *Calanus pacificus*, and *Clausocalanus* spp. among others. Copepods are transported to the Oregon coast, either from the north/northwest (northern species) or from the west/south (southern species). The Northern Copepod Index (Peterson and Keister 2003) was positive from autumn 2010 through summer 2012. The January and February 2012 values were the highest ever for the index and occurred after the southern transport anomaly observed in the winter of 2011 (figs. 9 and 4). The

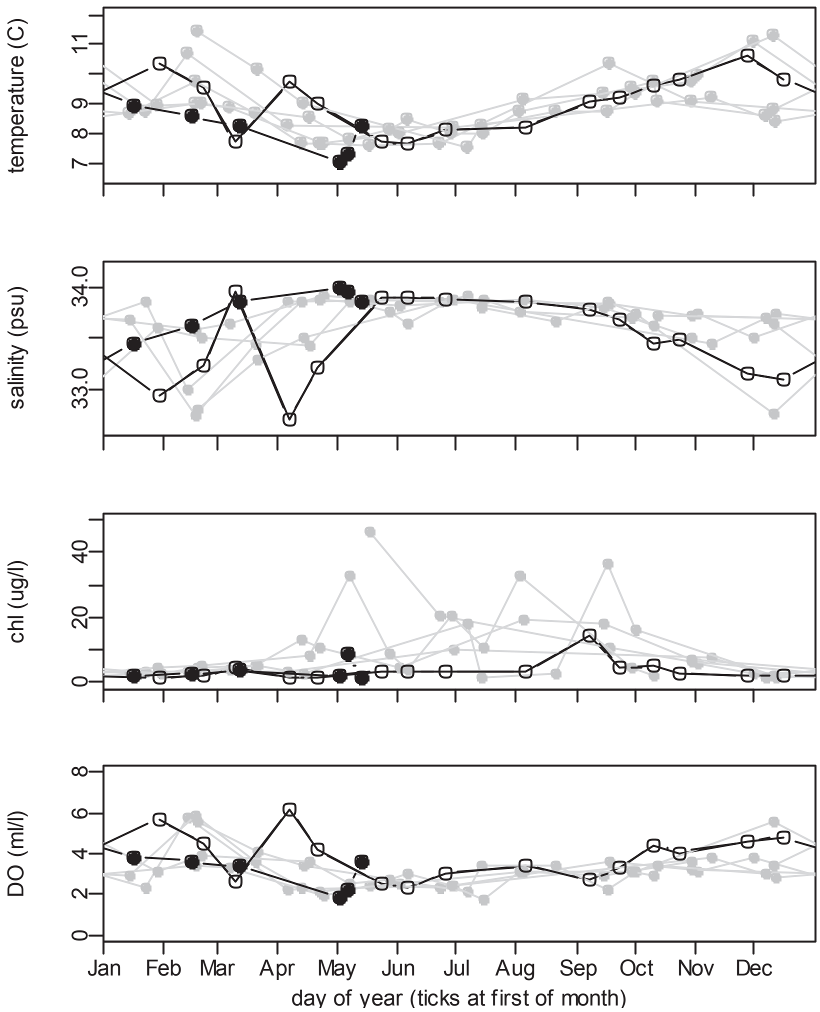


Figure 10. Hydrographic and ecosystem indicators at mid-shelf along the Trinidad Head Line (station TH02, 75 m depth). Panels from top to bottom show near-bottom (60 m) temperature, near-bottom (60 m) salinity, mean chl *a* concentration over the upper 30 meters of the water column, and near-bottom (60 m) dissolved oxygen concentrations. Grey symbols indicate historical observations (2006–11), open circles indicate observations during 2012, and closed symbols indicate observations in 2013.

Southern Copepod Index was predominately negative throughout much of the 2011 to 2013 period (fig. 9).

Northern California Current: Trinidad Head Line

Consistent with the Newport Hydrographic Line, observations along the Trinidad Head Line indicated that coastal waters off northern California were affected by strong downwelling and freshening during a series of storms in spring 2012 (fig. 10). Storm activity continued to affect waters off northern California through the spring and into summer, with northward wind and rain events occurring into July. Chlorophyll concentrations in the upper water column remained very low over the shelf throughout 2012 (figs. 6 and 10), save for a modest bloom that developed in early fall (fig. 10). This trend was apparent along the entire line, out to approximately 50 km offshore. Low chlorophyll concentrations in spring and summer 2012 do not appear to have been a result of low nutrient availability as nutrient concentrations were average.

In contrast to the stormy conditions observed in early 2012, ocean conditions in early 2013 along Trinidad Head Line reflect the effects of a relatively dry winter marked by unusually consistent, extended periods of upwelling favorable winds, and relatively infrequent storms of short duration. Intense upwelling throughout April resulted in the coldest, saltiest water observed on the shelf during the time series; conditions over the shelf remained cold and salty relative to spring 2012 (fig. 10). Since the onset of intense upwelling, average chlorophyll concentrations in the upper water column have remained relatively low (fig. 6).

In 2012 the copepod assemblage over the northern California shelf included relatively few northern neritic species, and high species diversity reflecting the preva-

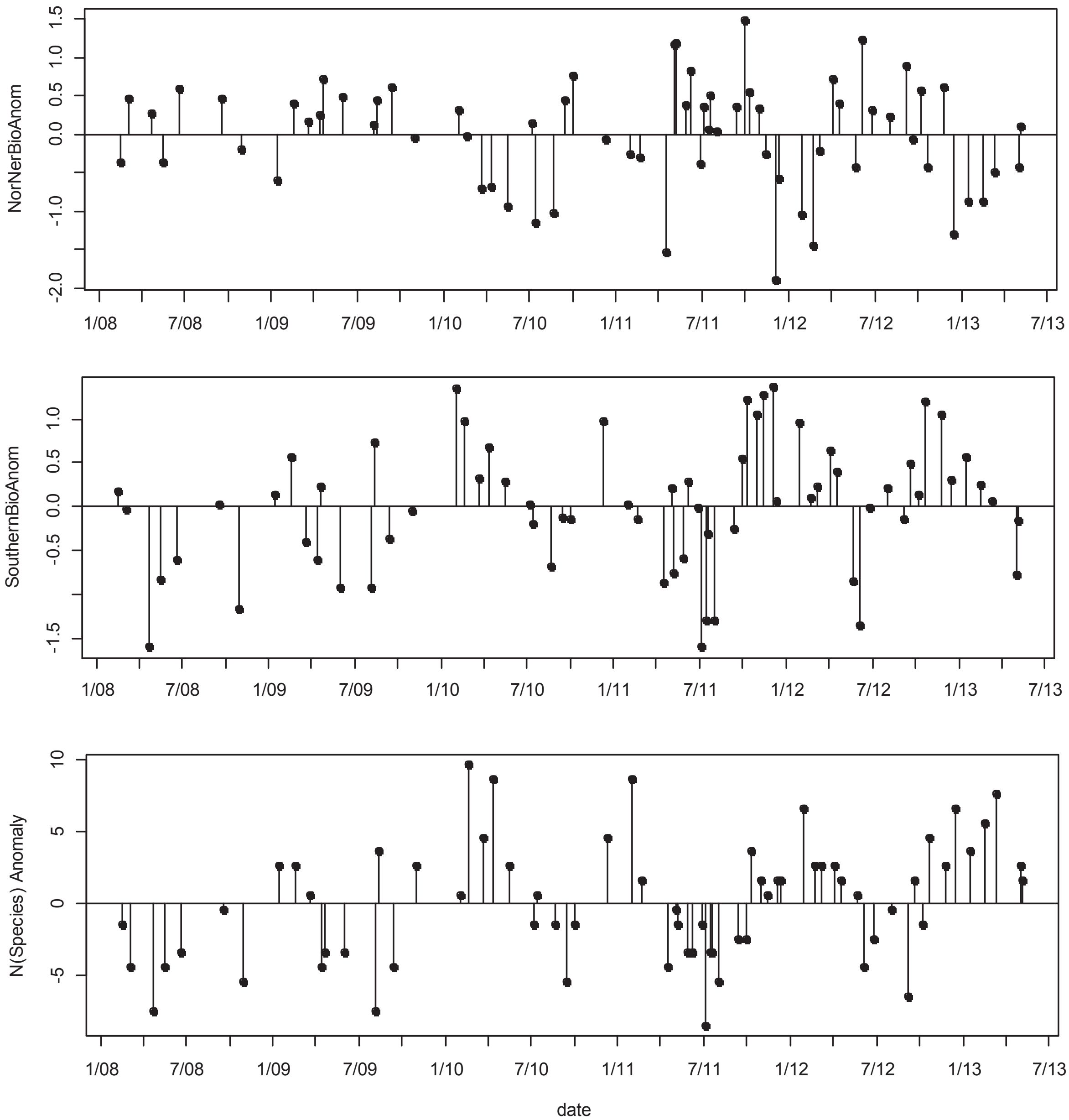


Figure 11. Anomalies (from the 2008–13 mean) in biomass and species richness of the copepod assemblage at mid-shelf on the Trinidad Head Line (station TH02, 75 m depth). Top: Biomass anomaly of dominant northern neritic copepods (dominated by *Pseudocalanus mimus*, *Calanus marshallae*, and *Acartia longiremis*). Middle: Biomass anomaly of southern copepods (neritic and oceanic taxa combined; dominated by *Acartia tonsa*, *Acartia danae*, *Calanus pacificus*, *Ctenocalanus vanus*, *Paracalanus parvus*, *Clausocalanus* spp., and *Calocalanus* spp.). Bottom: species richness anomaly.

lence of "southern" and "offshore" taxa over the shelf (fig. 11). Northern neritic taxa were modestly more abundant in late spring and summer, but southern taxa were displaced from the shelf only for a brief period in summer 2012. Coupled trends in the copepod assemblage (declining biomass of southern and oceanic taxa and increasing biomass of northern neritic species) in early 2013 were consistent with expected effects of physical forcing and patterns observed to the north (Newport Hydrographic Line).

Central California[2]

In January 2012 surface values were colder and saltier due to upwelling winds in late 2011. However, salinity values returned to average by June (fig. 12). Surface temperatures remained lower than average until fall. At 100 m anomalous high salinity and low temperature values persisted from January to May, after which they became average to above average for the remainder of

[2] See supplement for HF radar data and description of surface current patterns in the Central California region.

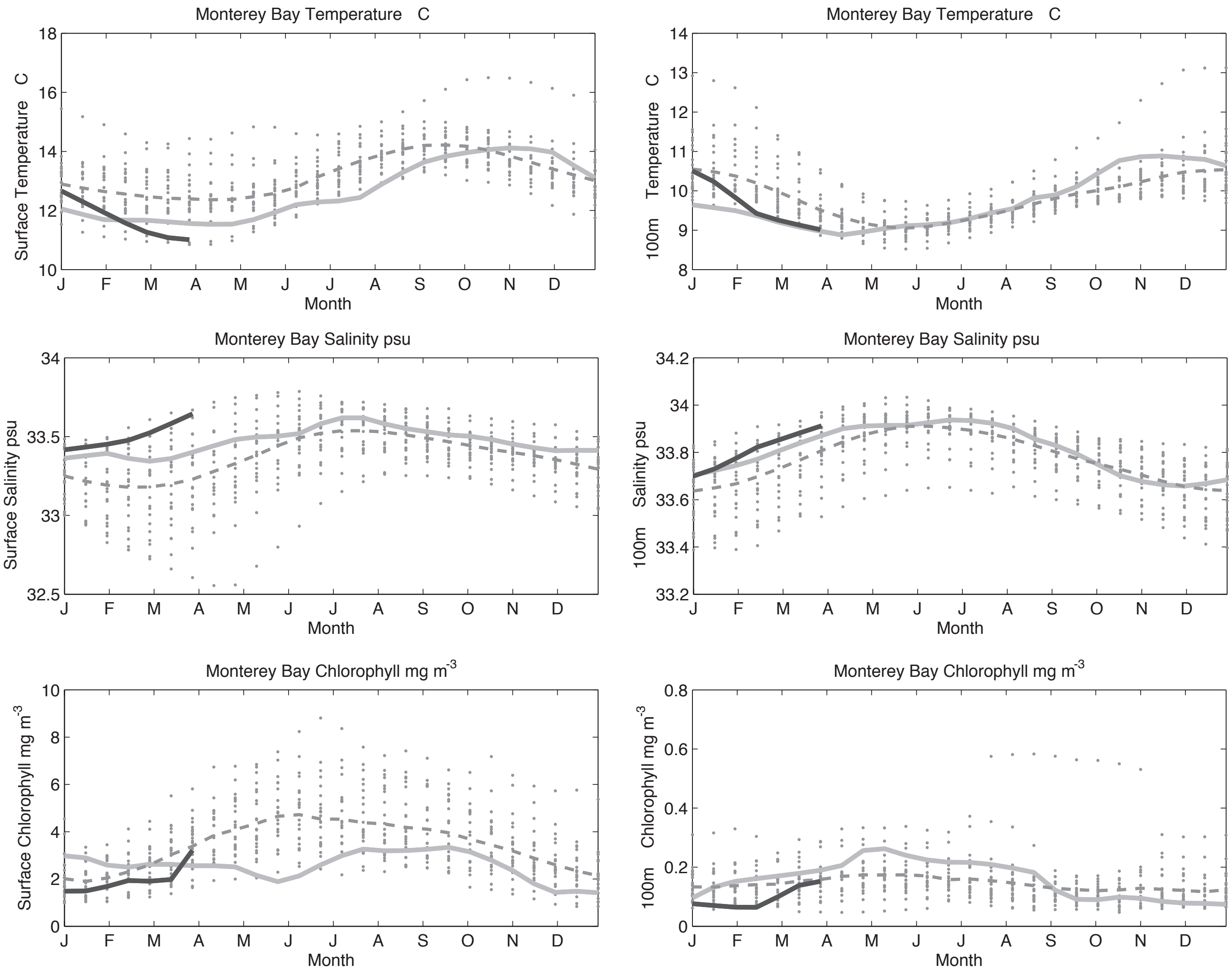


Figure 12. Temperature (top panels), salinity (middle panels) and chlorophyll concentration (bottom panels) at the surface (left hand column) and at 100 m (right hand column) observed at the M1 mooring.

the year. Surface chlorophyll was above average during January–February but was below average in the spring and continued to decrease to the lowest values on record by June (fig. 12). At 100 m chlorophyll was average to above average from January to August.

In early 2013, upwelling was significantly stronger than 2012, with the surface salinity and temperature near their maximum and minimum values respectively by April (fig. 12). Surface chlorophyll values increased from below average values in January to mean values by April. At depth, the relationships were similar to those at the surface (fig. 12).

Southern California

The 2012 mixed-layer temperatures continued to be mostly below long-term averages in southern California (fig. 13), consistent with the trends across much of the northeast Pacific (PDO, fig. 2). Mixed-layer temperatures since the 1998/99 ENSO have been decreasing but not significantly. Mixed-layer salinities have been increasing over the last two years; this increase reflected a similar increase of the NPGO (fig. 2). Areas of the CalCOFI study domain within the California Current and coastal areas affected by it saw the increase in salinity values. The increase in salinity is primarily observed in those areas of the CalCOFI study domain that are affected by the California Current. The salinity signal was not observed in the offshore areas of the CalCOFI domain that represent the edge of the North Pacific Gyre (fig. S6).

Concentrations of nitrate were close to long-term averages, except for above average spring 2013 values (fig. 13). The distinctive increase of nitrate at the σ_t 26.4 kg/m^3 isopycnal from 2009 to 2012 noted in Bjorkstedt et al. 2012 has returned to near-mean values over the last

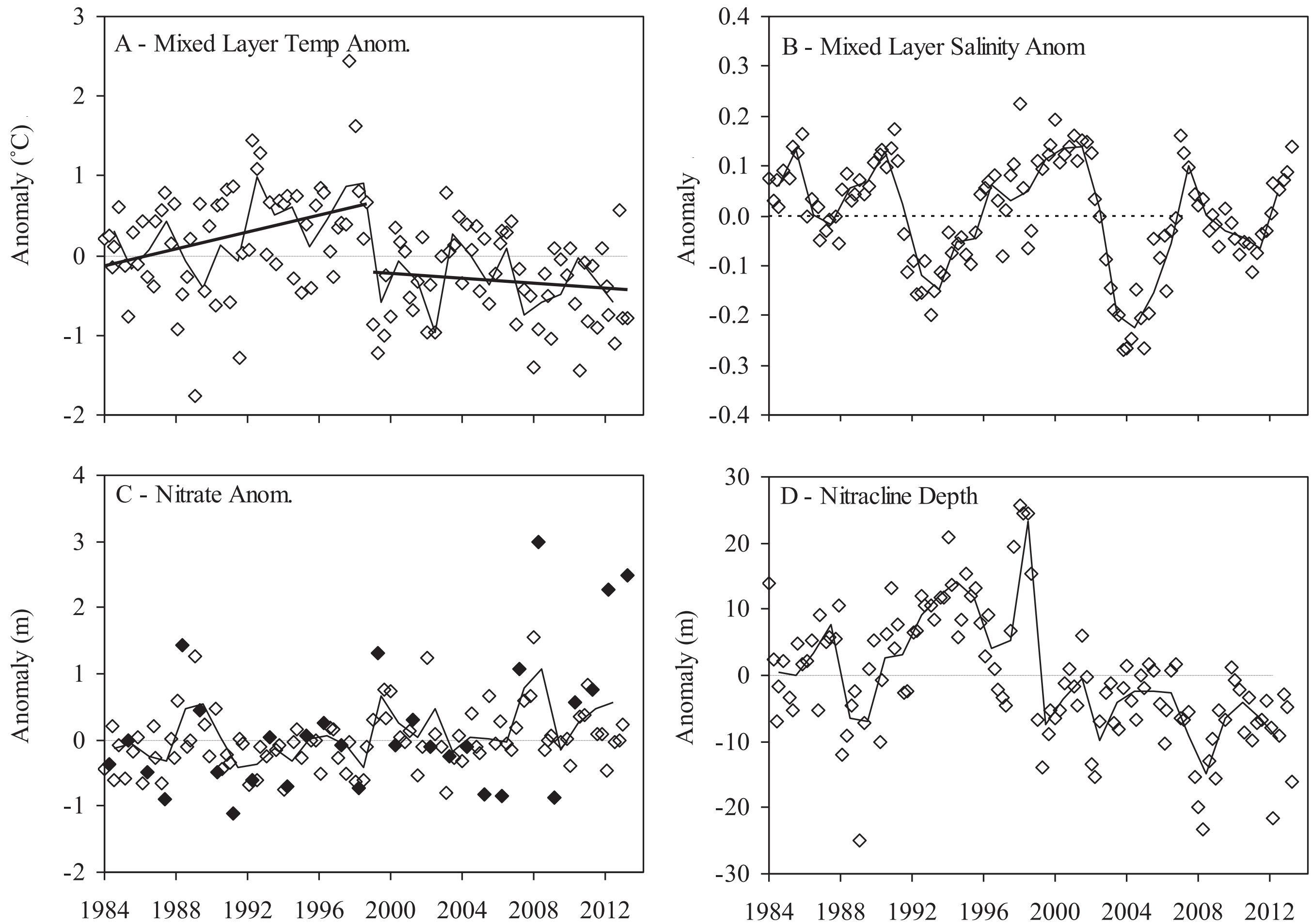


Figure 13. Property anomalies for the mixed layer (ML) of the CalCOFI standard grid: A – ML temperature anomaly, B – ML salinity anomaly, C – ML nitrate concentration anomaly and D – nitracline depth anomalies which are negative when the nitracline is closer than expected to the surface and positive when deeper than long-term averages. Data from individual CalCOFI cruise data are plotted as open diamonds. The thin solid lines represent the annual averages, the dotted lines the climatological mean, which in the case of anomalies is zero and the straight solid lines, when present, long-term linear trends. In panel C, nitrate, solid symbols are spring values.

12 months. Nitrate anomalies at the isopycnal were 1.8 μM during July 2012, the highest value observed over the last 29 years, but dropped to 0.9 μM in the spring of 2013 (data not shown).

In the CalCOFI region (fig. 1) concentrations of chlorophyll were similar to long-term averages (fig. 14) for all four cruises covered by this report. At the edge of the North Pacific Central Gyre, concentrations of chlorophyll were still above long-term averages while the depth of the subsurface chlorophyll maximum dropped from 50 m to 75 m (fig. S7). Similar patterns were observed in the southern California Current region (fig. S7). Concentrations of chlorophyll, however, were at or below long-term averages in the northern California Current region and in the coastal areas (figs. 6 and S7). Values of primary production were below or at long-term averages during the summer and fall of 2012 but substantially above long-term averages during the first half of 2013.

Anomalies of zooplankton displacement volume, a proxy for zooplankton biomass, are only available up to the fall of 2012 (fig. 14, lower panel). Values during 2012 were significantly greater than long-term averages, comparable to values observed during the 1980s and the 1999 La Niña period. These patterns were largely driven by very high abundance of salps and pyrosomes during 2012.

Baja California (Investigaciones Mexicanas de la Corriente de California, IMECOCAL)

Consistent with the observations from 2011–12 (Bjorkstedt et al. 2012), temperatures remained cooler than average in 2012–13. In fact, the three coolest SST values since 1998 occurred in 2011, 2012, and 2013. As well, surface waters continued to be fresher through spring of 2013 but were slightly more saline than that of 2011 (fig. 15). Chlorophyll off Baja California was near average throughout 2011–13, with the exception

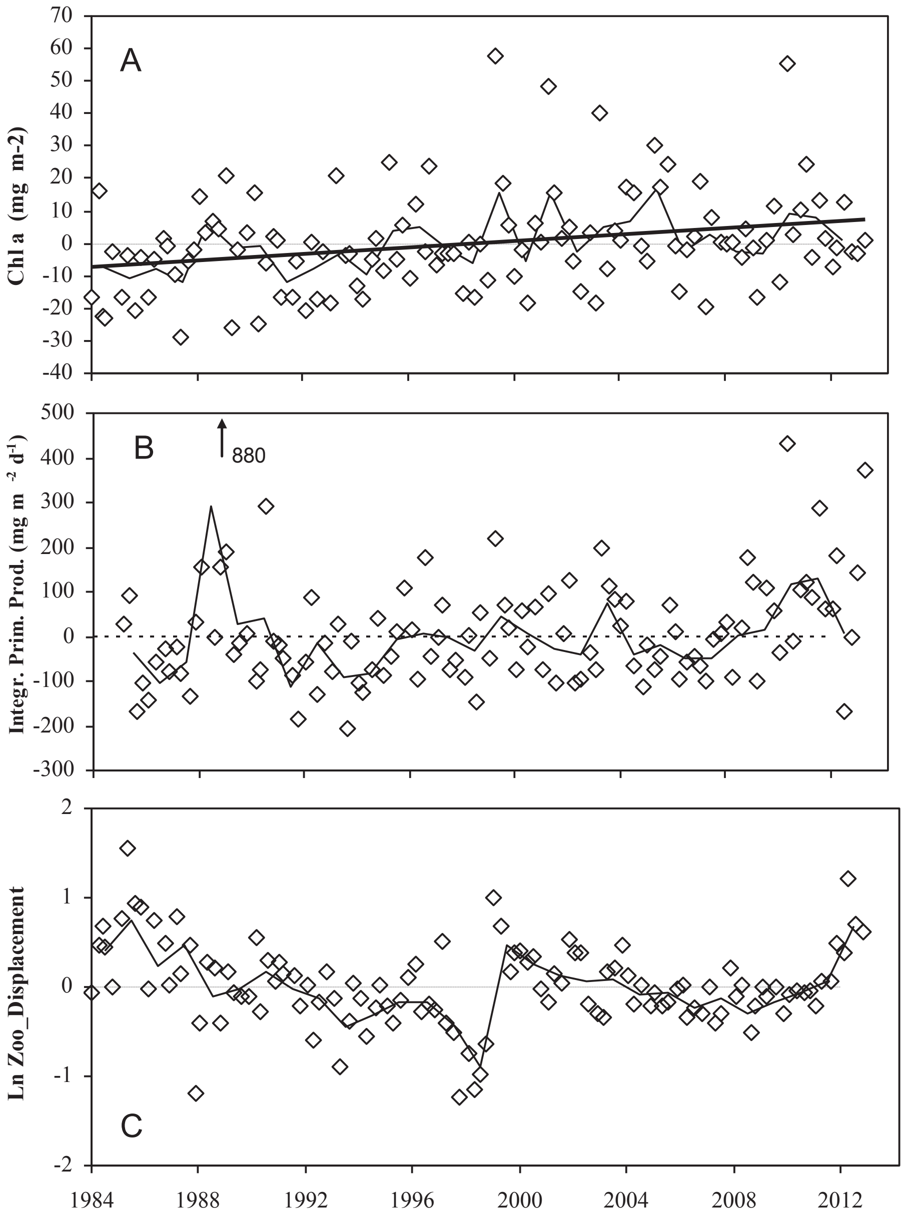


Figure 14. CalCOFI region averages for standing stocks of chlorophyll-*a* (A) and rates of primary production (B) both integrated to the bottom of the euphotic zone and (C) the log of zooplankton displacement volume, all plotted against time.

of a single high and positive anomaly during spring of 2012 (fig. 16).

Zooplankton displacement volume remained high during 2012 through February 2013 continuing an eight-year period of higher than average values (fig. 17). However, euphausiid density was below average between the springs of 2011 and 2012. Copepods have been anomalously abundant since 2010 except for the 2011/2012 winter values.

GELATINOUS ZOOPLANKTON

In this report gelatinous zooplankton are divided into two categories: herbivores and carnivores. Tunicates, the herbivorous filter-feeding forms, include salps, doliolids, pyrosomes, and appendicularians. The carnivorous forms are represented by a variety of taxa, such as jellyfish (e.g., Hydromedusae, Schyphomedusae, siphonophores), pelagic snails (pteropods, heteropods), and arrow worms (chaetognaths).

Northern California

Catches of tunicates in the NWFSC pelagic survey were very low (zero in many cases) from June 2004 until June 2010, after which salp densities spiked over a short period, reaching a maximum of 3400 individuals per 10^6 cubic meters of water sampled by August of

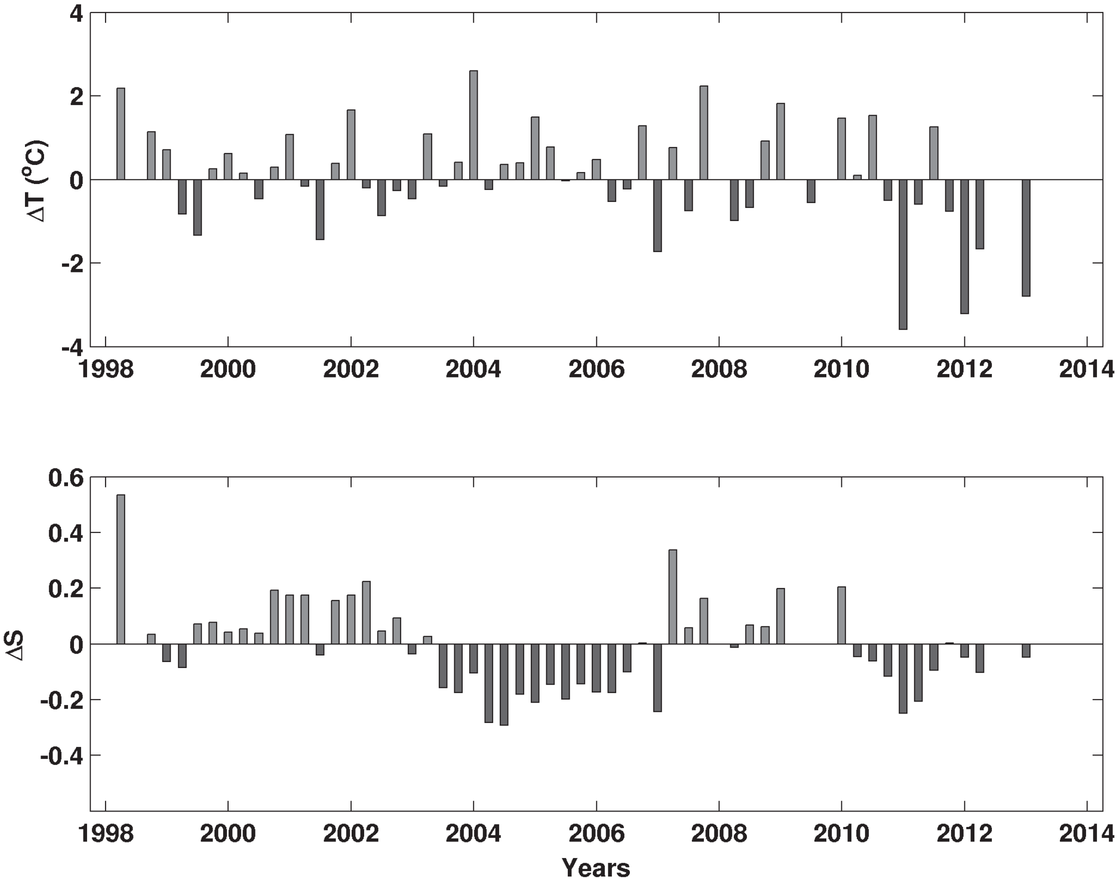


Figure 15. Mixed layer temperature anomaly and mixed layer salinity off Baja California Peninsula (IMECOCAL). Each bar represents each cruise conducted.

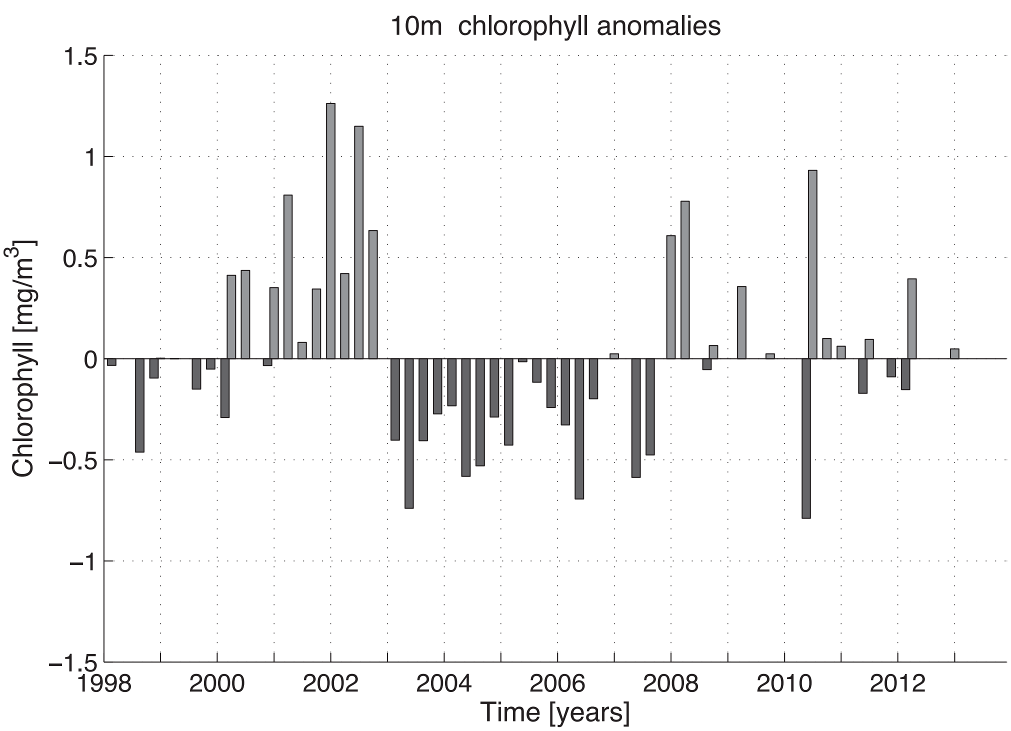
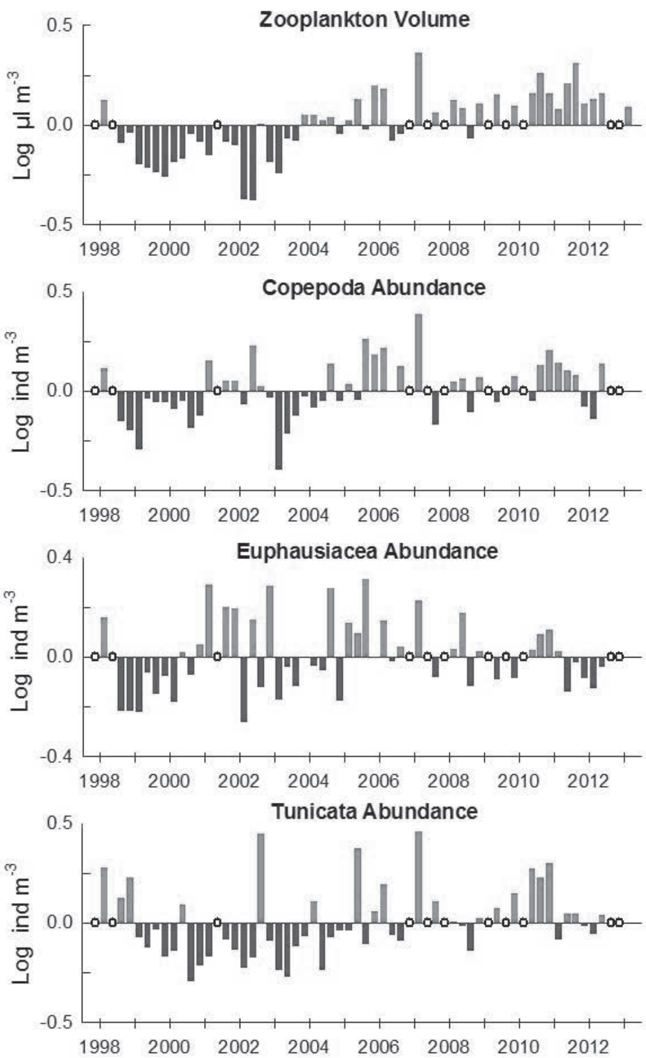


Figure 16. Anomaly time series of 0–100 m integrated chlorophyll *a* off Baja California Peninsula (IMECOCAL). Each bar represents each cruise conducted.



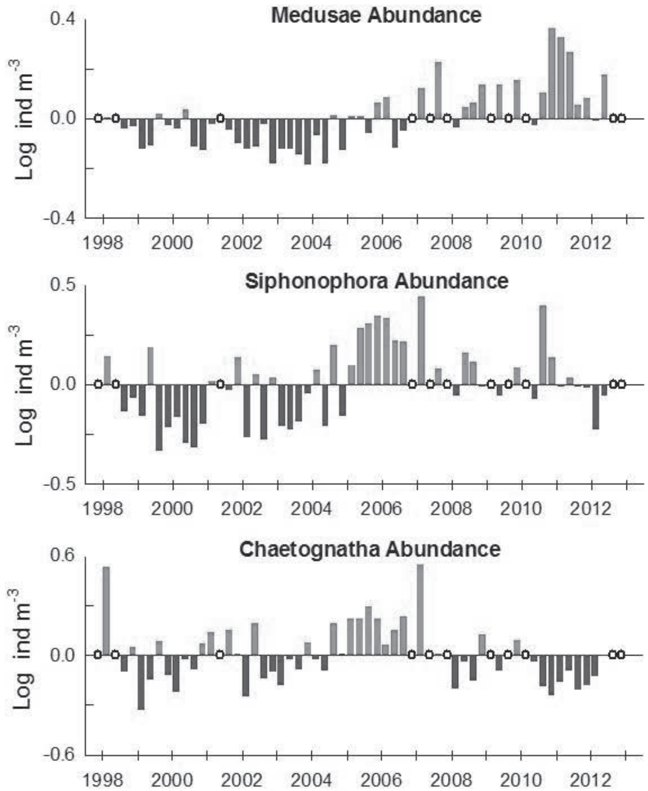


Figure 17. Time series of anomalies of zooplankton volume and group abundances for the Baja California Peninsula (IMECOCAL) region. Each bar represents a single cruise and open circles represent indicate cruises that did not take place or were omitted due to limited sampling.

2010. Densities remained high into early 2011 and then tapered to near normal low catches in 2012 (fig. 18).

Densities of the two dominant larger medusa species in this region, *Chrysaora fuscescens* and *Aequorea* spp., have been monitored as part of a pelagic trawl survey conducted every June and September since 1999 (Suchman et al. 2012)(see supplement for data collection). Catches of both species returned to a more typical level in June 2012, following below-average catches for the last two years (fig. S8). In September 2012, catches of both species were similar to 2011, with densities of *C. fuscescens* being approximately an order of magnitude higher than those of *Aequorea*, similar to that seen earlier by Suchman et al. 2012.

Central California

The major contributors to the herbivorous tunicate catch off Central California were the salps, *Thetys vagina* and *Salpa* spp., as well as pyrosomes, *Pyrosoma* spp. In 2012, the numbers of *S. fusiformis*, other salp species, and pyrosomes in the core region of the SWFSC rockfish recruitment survey (roughly Point Reyes to Point Piños) far exceeded previously recorded values (fig. 19) (Bjorkstedt et al. 2012), although the abundance of *Thetys vagina* remained well within the range of previously observed blooms (fig. 19). The largest salp and pyrosome catches were in the southern region of the expanded coast-wide rockfish recruitment survey (fig. 19). Although there is no baseline data to compare these trawl survey catches, they are consistent with accounts of high salp abundances in this region during 2012 (Bjorkstedt et al. 2012). By spring 2013 salps, pyrosoma, and *Thetys vagina* were near typical values in the core region and reduced in the southern region (fig. 19).

In 2012, within the rockfish recruitment survey's core region, large salp catches mostly occurred at offshore stations, and the magnitude of the catches were substantially larger than the long-term average (fig. 20). Salp

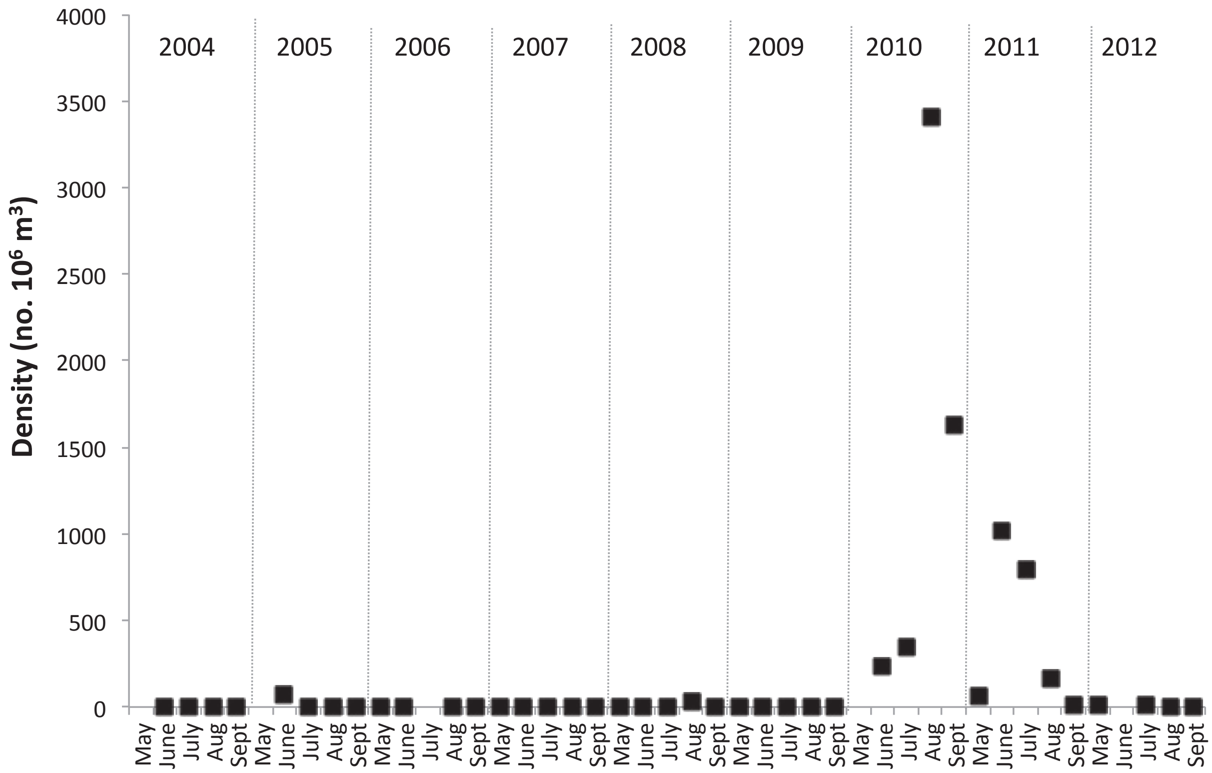


Figure 18. Densities of salps (mostly *Thetys vagina* and *Salpa fusiformis*) observed in the NWFSC pelagic rope trawl surveys off the coast of Oregon and Washington in May–September, from 2004 to 2012.

catches during 2013 have returned to more typical values observed in the survey. The summer salmon survey (fig. 1) that immediately followed the rockfish recruitment survey did not encounter extreme salp concentrations in 2012 and 2013, but this was likely due to the predominantly inshore sampling (data not shown).

The observed abundances of the jellyfish *C. fuscescens* during late spring of 2012 and 2013 were within the range of variability noted since 1990 (fig. 19). As in previous years, the largest catches of *C. fuscescens* occurred within the Gulf of the Farallones while the largest catches of *Aurelia* spp. occurred inside Monterey Bay's upwelling shadow (Graham and Largier 1997).

Southern California

There were large concentrations of gelatinous zooplankton encountered off southern California (predominantly tunicates). A proxy for the abundance of larger, mostly gelatinous, zooplankton is the difference between total zooplankton displacement volume (ZDV) and small fraction ZDV (fig. 21A) leaving the large fraction ZDV (fig. 21B). The latter fraction was substantially increased during 2011 to 2012 compared to the previous decade.

Baja California

At the southern extent of the CCS off Baja, herbivorous tunicates maintained average abundances during the last two years (fig. 17). However high-density patches occurred in discrete locations, such as in Vizcaino Bay. Carnivorous forms were present in similar abundance and composition as the 2011 reported values. Medusae continued to have positive anomalies while chaetognaths maintained negative anomalies. In contrast, the siphonophores shifted from the high positive anomalies in 2010 to a strong negative anomaly in February 2012.

SYNTHESIS OF OBSERVATIONS ON HIGHER TROPHIC LEVELS

Pelagic Fishes off Oregon and Washington

Time series plots of yearly abundance data are presented for each of the five most dominant and consistently collected forage species (jack mackerel, *Trachurus symmetricus*, Pacific sardine, northern anchovy, Pacific herring, *Clupea pallasii*, and whitebait smelt, *Allosmerus elongates*) (fig. 22) measured during the NWFSC-NOAA Bonneville Power Administration (NOAA/BPA) survey surface trawls. The survey also captures Pacific mackerel, *Scomber japonicas*, shown as well. The survey extends from Cape Flattery in northern Washington to Newport in central Oregon from June to September. Although other forage species are caught in these surveys, these five six species represent the bulk of the forage fish catch in surface waters. They include migratory species (Pacific

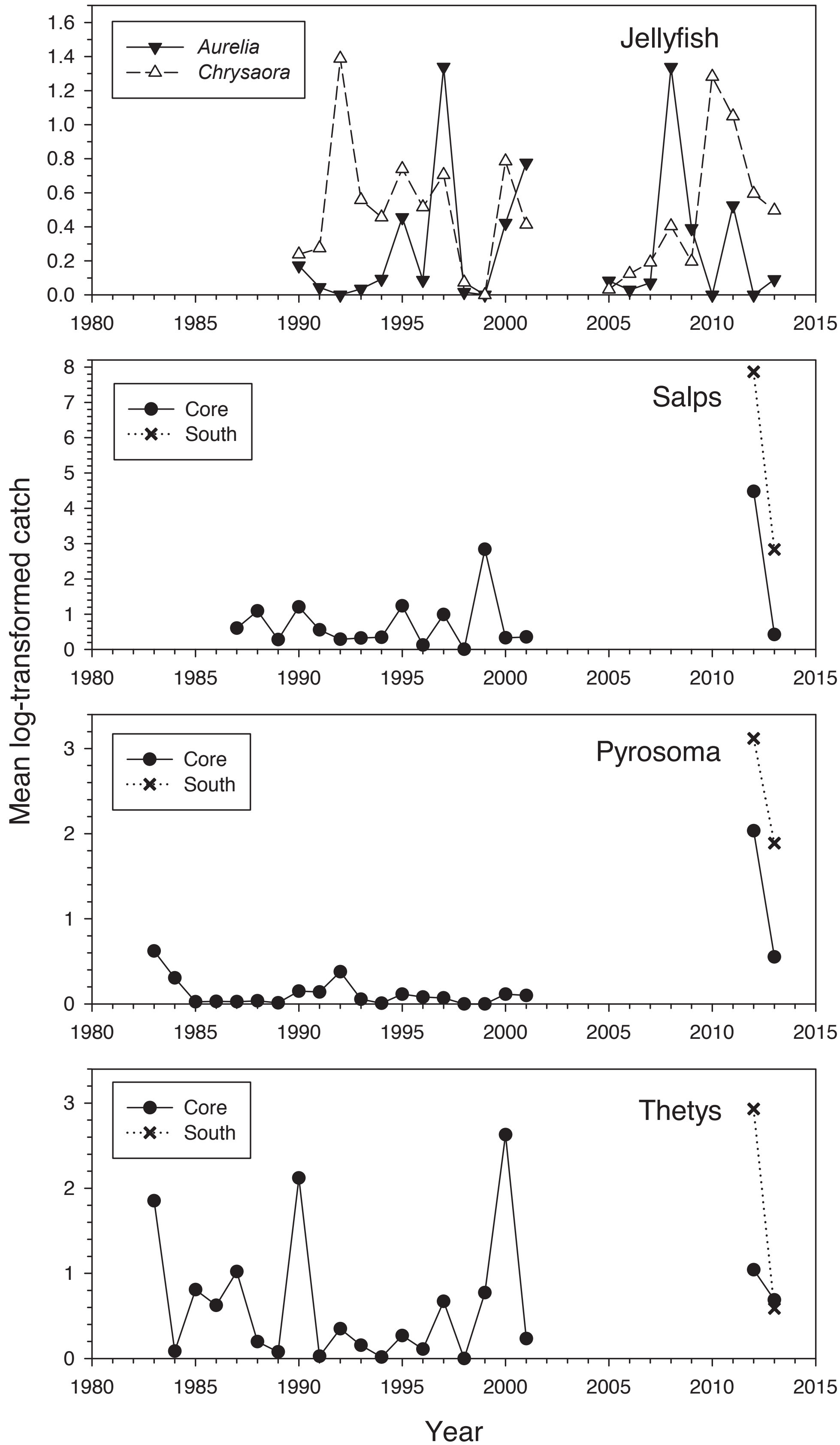


Figure 19. Geometric mean of catches per unit volume of gelatinous zooplankton from the central California rockfish recruitment survey.

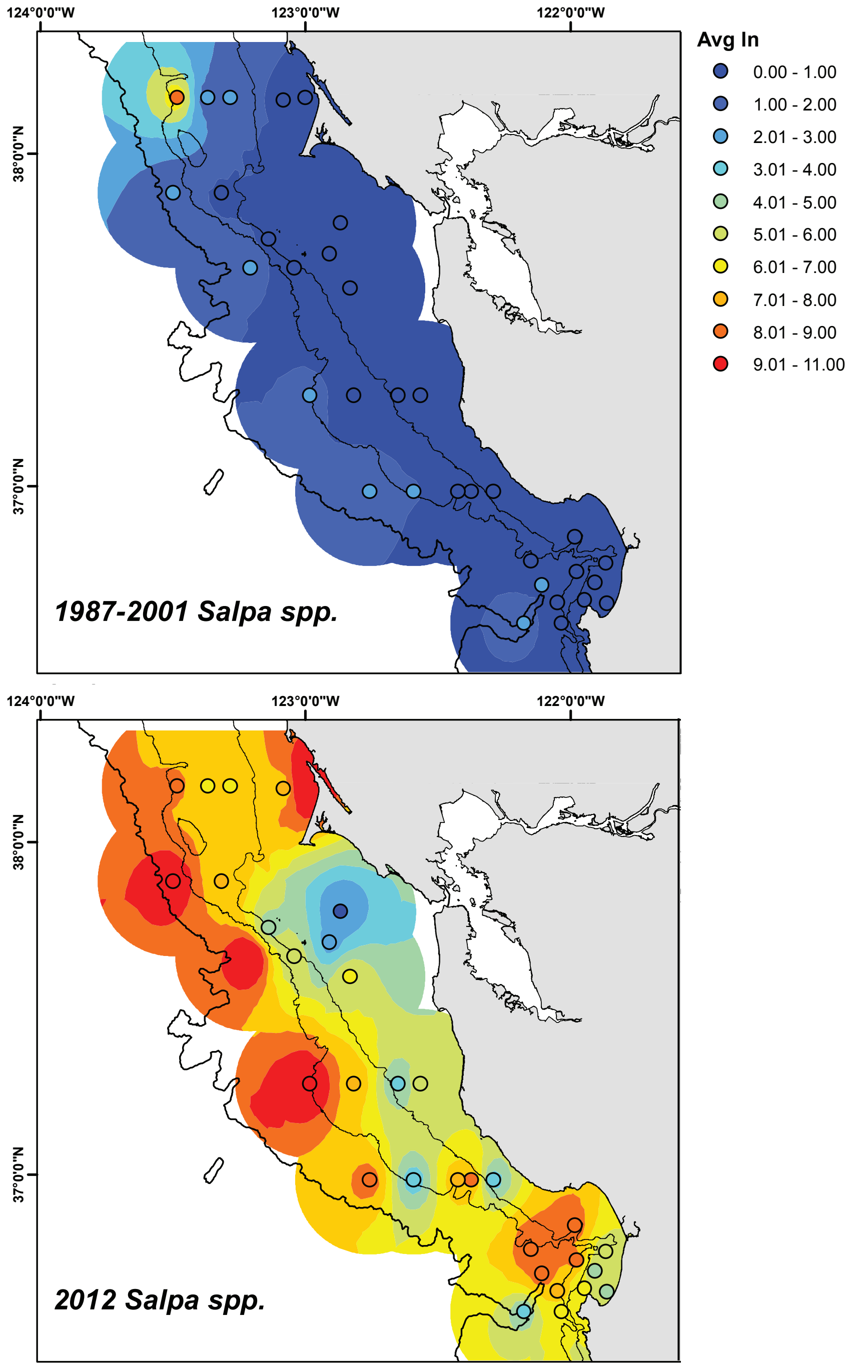


Figure 20. Distribution of the historical geometric mean of catches of salps from central California rockfish recruitment survey, 1987–2011, and those from 2012.

sardines and some northern anchovies) that may spawn off the Pacific Northwest or migrate from California (Emmett et al. 2005; Litz et al. 2008). Jack mackerel serve as a forage fish at younger ages but off Oregon and Washington are too large to be fed upon by most predators such as seabirds or adult rockfishes. Herring and whitebait smelt are likely spawned locally. A number of these species have seasonal trends in abundance (Emmett et al. 2005) so may experience intra-annual variability in abundance that is not captured by sampling two times per year. Ultimately, a number of forage fish are at reduced abundance (fig. 22, survey D, fig. 1). In 2012, Pacific herring, and Pacific sardine were at their lowest observed abundances since the start of the survey in 1998. Northern anchovy abundance was lower than it has been since 2002 (fig. 22).

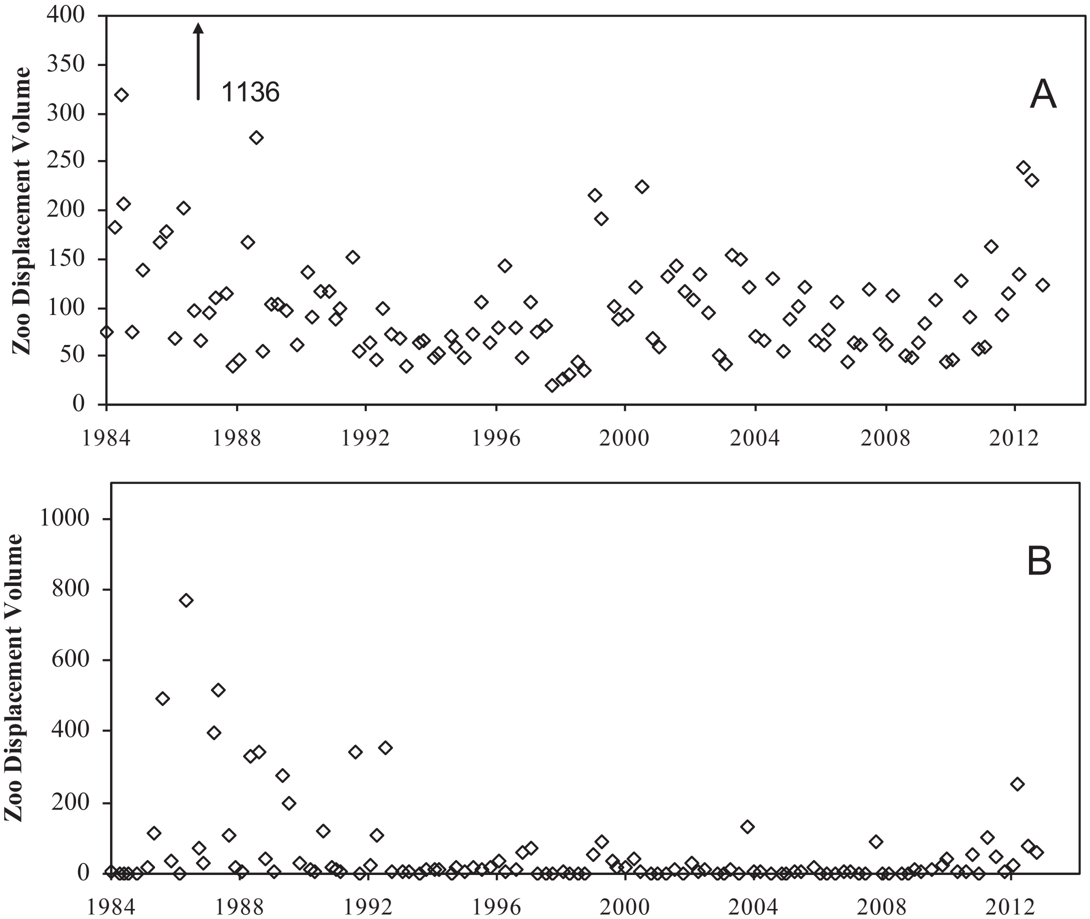


Figure 21. Zooplankton displacement volume (ml per 1000 m² seawater) for the small zooplankton fraction (A) and the large fraction (B). The large fraction consists of all organisms whose individual volume is larger than 5 ml. The small fraction is calculated by difference.

The ichthyoplankton and juvenile fish communities along the Newport Hydrographic Line off the coast of Oregon in May 2012 were similar to the average assemblages found in the same area and month during the previous five years both in terms of mean concentrations and relative concentrations of the dominant taxa (fig. 23). However, larval myctophids were found in the highest concentration in July 2012 of the five-year time series, while larval northern anchovy were found in higher concentrations (>3x) in July 2012 than in the same month in 2007–10. In addition, concentrations of the dominant taxa of juvenile fish were higher in July 2012 than in the same month in the previous five years, largely due to the abnormally high concentration of juvenile rockfish found in July 2012 (>10x that of any other year in 2007–11). No juvenile Pacific hake or northern anchovy were collected from the midwater trawl samples in May or July 2012, although age 1 and adult specimens of both species were found. Similarly, the biomass of ichthyoplankton in 2013 from winter collections along the Newport Hydrographic Line were above average (1998–2013), predicting average-to-good feeding conditions for juvenile salmon during the 2013 out migration (see supplemental results, fig. S9).

In the June NOAA/BPA surveys from 2008 and 2009, catches of juvenile spring-run Chinook salmon were high, with record high catches in 2008. Although catches in June 2011 were poor, catches in June 2012 were high, ranking second among the 15 years of surveys (fig. 24) suggesting excellent nearshore forage. However, catches of coho salmon in September 2012 survey were relatively low (fig. 24).

Pelagic Fishes Off Central California

Trends in both 2012 and 2013 showed higher productivity for the species and assemblages that tend to do better with regionally cool, high southward transport conditions, including juvenile rockfish, market squid, and krill (predominantly *Euphausia pacifica* and *Thysanoessa spinifera*) (fig. 25, see supplement for additional results). In 2012, juvenile rockfish catches were above average, as they have been in most years since 2008, and in 2013 the highest catches of juvenile rockfish in the time series of the survey were recorded, with huge numbers of juvenile

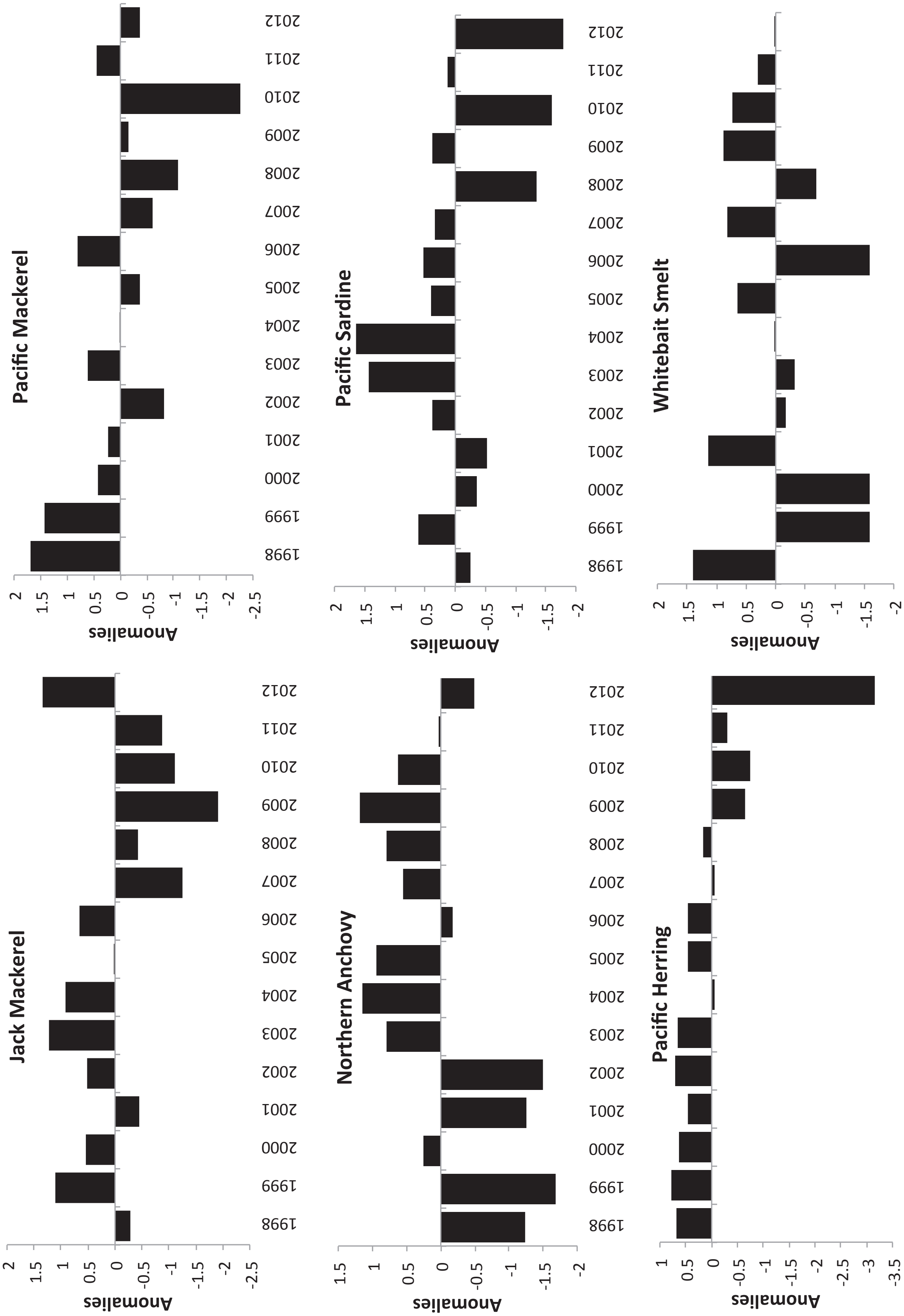


Figure 22. Group anomalies of catches per unit volume for the six most common forage fish collected during the NWFSC pelagic rope trawl survey, 1998–2012.

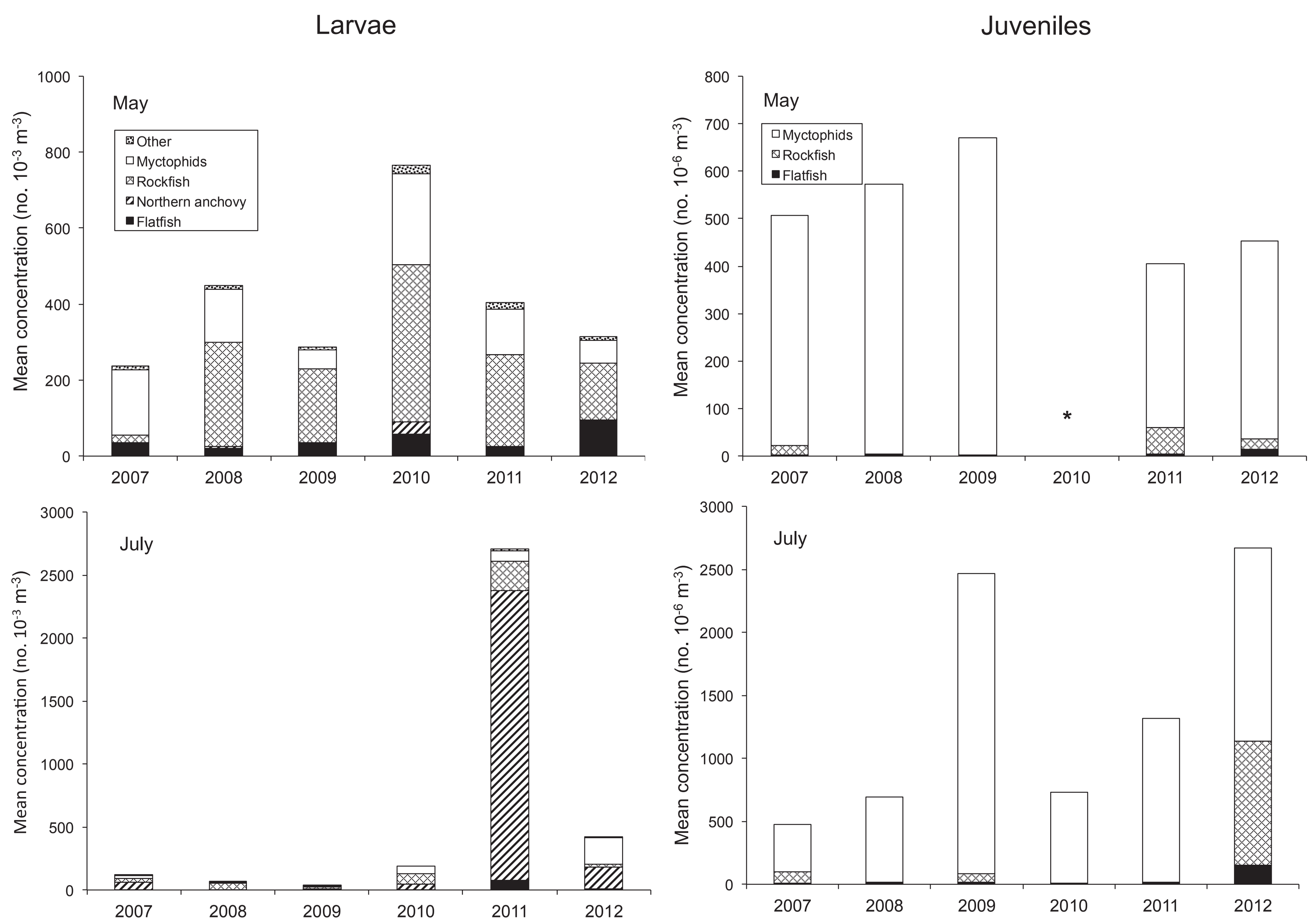


Figure 23. Mean concentrations of the dominant taxa for fish larvae (left) and juveniles (right) collected in May and July in 2007–12 along the Newport Hydrographic (NH) line off the coast of Oregon (44.65°N, 124.41–125.36°W). No midwater trawl samples were collected for juveniles in May 2010.

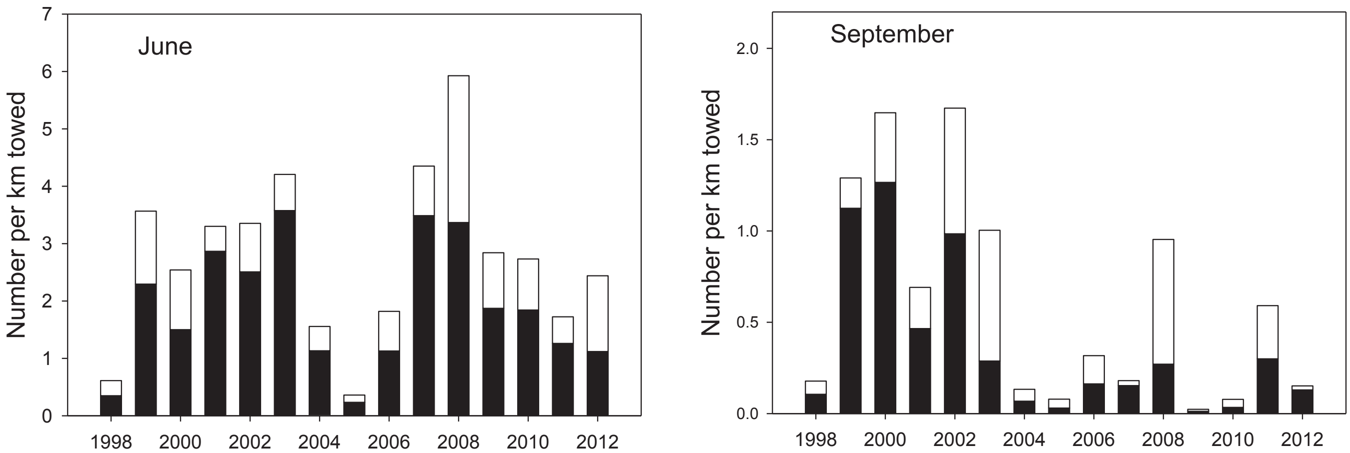


Figure 24. Catches of juvenile coho salmon (black bars) and Chinook salmon (white bars) off the coasts of Washington and Oregon.

rockfish of all species (as well as young-of-year groundfish of other species, such as Pacific hake, flatfishes, and lingcod, *Ophiodon elongates*) encountered throughout both the core and expanded survey areas. Market squid and krill were at very high levels in 2012 and 2013 as well. Although more northern anchovy were encountered in 2013 than in the previous five years, catches of both that species and of Pacific sardine remained well below long-term averages. As with the 2012 results, 2013 continued to indicate a pelagic micronekton community structure dominated by cool-water, high transport, high productivity forage species (juvenile groundfish, krill, and market squid (see Ralston et al. 2013).

Later in the summers of 2010–12 a surface trawl survey was used to characterize juvenile salmon and the micronekton from central California to Newport, Oregon. The summer of 2012 continued a period of extremely low abundance for northern anchovy, Pacific sardine, and Pacific herring. The survey caught no adult northern anchovy in 2011 or 2012 and very few in 2010; no Pacific sardine in 2012 and very few in the two years before that; and very few Pacific herring in all three years, 2010–12. Other important forage fishes such as surf smelt, *Hypomesus pretiosus*, and whitebait smelt were more abundant and were consistently taken in all three years since 2010, but these two osmerid species were primarily encountered in the northern portion of the study area. Market squid was very abundant in all three years and was encountered throughout the study area. Sub-yearling juvenile Chinook salmon (80–250 mm fork length, FL) were less abundant in the catches in 2012 than in the previous two years (fig. 26, see supplement for results concerning additional age classes). Unlike Chinook salmon, the abundance of juvenile coho salmon (100–300 mm FL) was similar in the summer of 2011 and 2012 (fig. 26). Significantly more juvenile coho salmon were caught in either of those two years than in July 2010.

Pelagic Fishes Off Southern California

The spring coastal pelagic species survey showed sardine egg densities were similar in 2012 to those measured in 2011 (methods in supplement, fig. S11). However, densities of sardine eggs and anchovy eggs were lower than those measured in most years since 1997 (fig. 27). Jack mackerel egg densities were similar to those measured during most other years in the time series. In 2013, sardine, anchovy, and jack mackerel egg densities were similar to those measured in the previous two years (fig. 28).

An examination of larval captures from the CalCOFI surveys 1951–2011 demonstrated similar trends (fig. 29). Larval Pacific sardine catches have been relatively stable over recent decades, minus low catches in 2004 and 2010. In general, larval northern anchovy were captured in greater densities than Pacific sardine before the mid-1990s. However, larval northern anchovy catches have declined substantially since the early 1980s (fig. 29). Unfortunately, data on larval catch densities beyond 2011 have not yet been enumerated.

SEABIRDS AND MAMMALS[3]

Breeding Success and Diets of Seabirds at Yaquina Head

Examination of the common murre, *Uria aalge*, diets indicates that smelts were the predominant prey available to the seabirds (fig. S12). When paired with the results from the forage observations in northern CCS, this diet composition was similar to changes in the available proportions in the forage community (fig. 22). The breeding success of common murre remained low relative to 2007–10 (fig. 30, see supplement for data methods). Observations indicate that the reduced

[3]In addition to seabird and sea lion observations, cetacean density and abundance on the southern CalCOFI lines was quantified. Results are shown in the supplement.

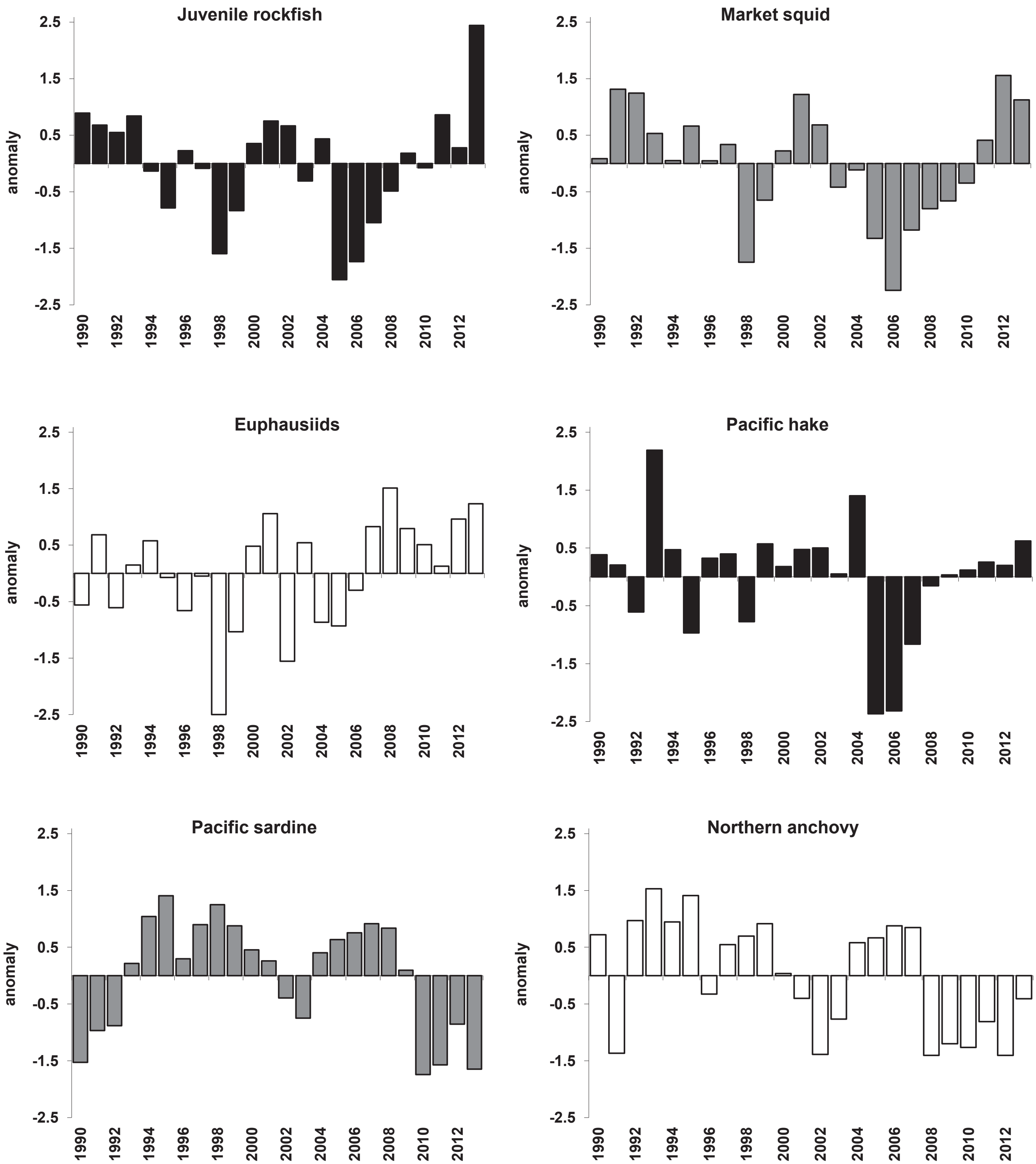


Figure 25. Long-term standardized anomalies of several of the most frequently encountered pelagic forage species from the central California rockfish recruitment survey in the core region (1990–2012).

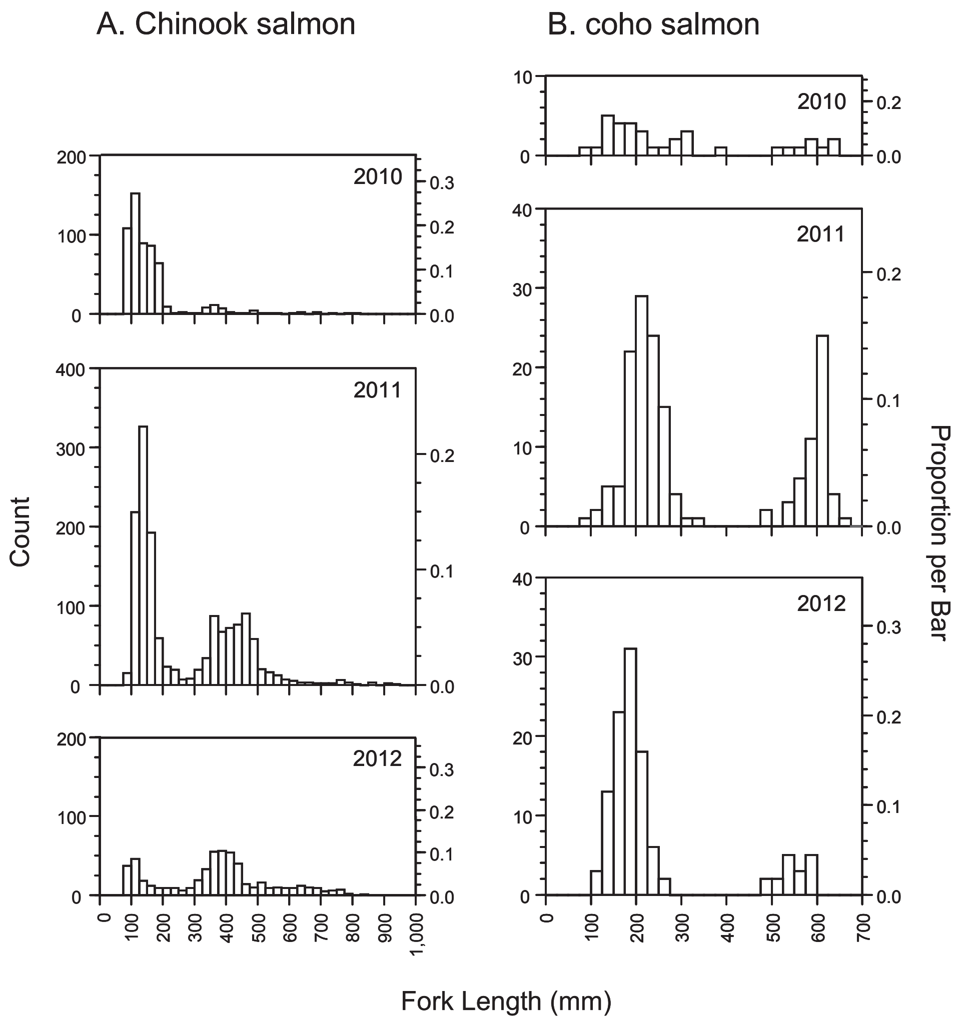


Figure 26. Size frequency distributions of (A) Chinook salmon (*Oncorhynchus tshawytscha*) and (B) coho salmon (*O. kisutch*) captured by rope trawl in the coastal ocean (~1–20 nautical miles offshore) between southern Oregon and central California in June or July of 2010, 2011, and 2012. Counts are total number (not standardized) of fish captured in each year; proportions are fraction of that total count represented by each bar for each year and species. Different scales used for columns A and B.

reproductive success was due to increased predation (e.g., eagles, pelicans, vultures).

Breeding Success of Seabirds at Southeast Farallon Islands

Overall breeding success of seabirds during the 2012 breeding season at Southeast Farallon Island can best be classified as an average year for most species. Cassin's auklets, *Ptychoramphus aleuticus*, which feed primarily on euphausiids, exhibited exceptionally high productivity for the third consecutive year (fig. 31). The average number of chicks fledged per breeding pair was the second highest on record, and reflected both exceptional fledging success and a high rate of successful double brooding. Among the piscivorus seabirds, productivity of common murres was slightly higher than that observed during 2011 while rhinoceros auklets (*Cerorhinca monocerata*) and pigeon guillemots declined to values slightly below the long-term means observed for each species. Pelagic cormorants, *Phalacrocorax pelagicus*, and Brandt's cormorants, *Phalacrocorax penicillatus*, experienced near complete breeding failure in 2012. This is the fifth consecutive year of extremely low reproductive success for Brandt's cormorants but the first breeding failure for the pelagic cormorant since 2005. Productivity of western gulls (*Larus occidentalis*) was slightly higher than during 2011, but continued to be among the poorest years on record, marking the fourth consecutive year of very low reproductive success for this species.

Breeding Success and Diets of Seabirds at Castle Rock

In 2012, the first common murre nest at Castle Rock was initiated on 15 May, between 4 and 32 days later than all other years of study. Although the average nest initiation date could not be determined due to

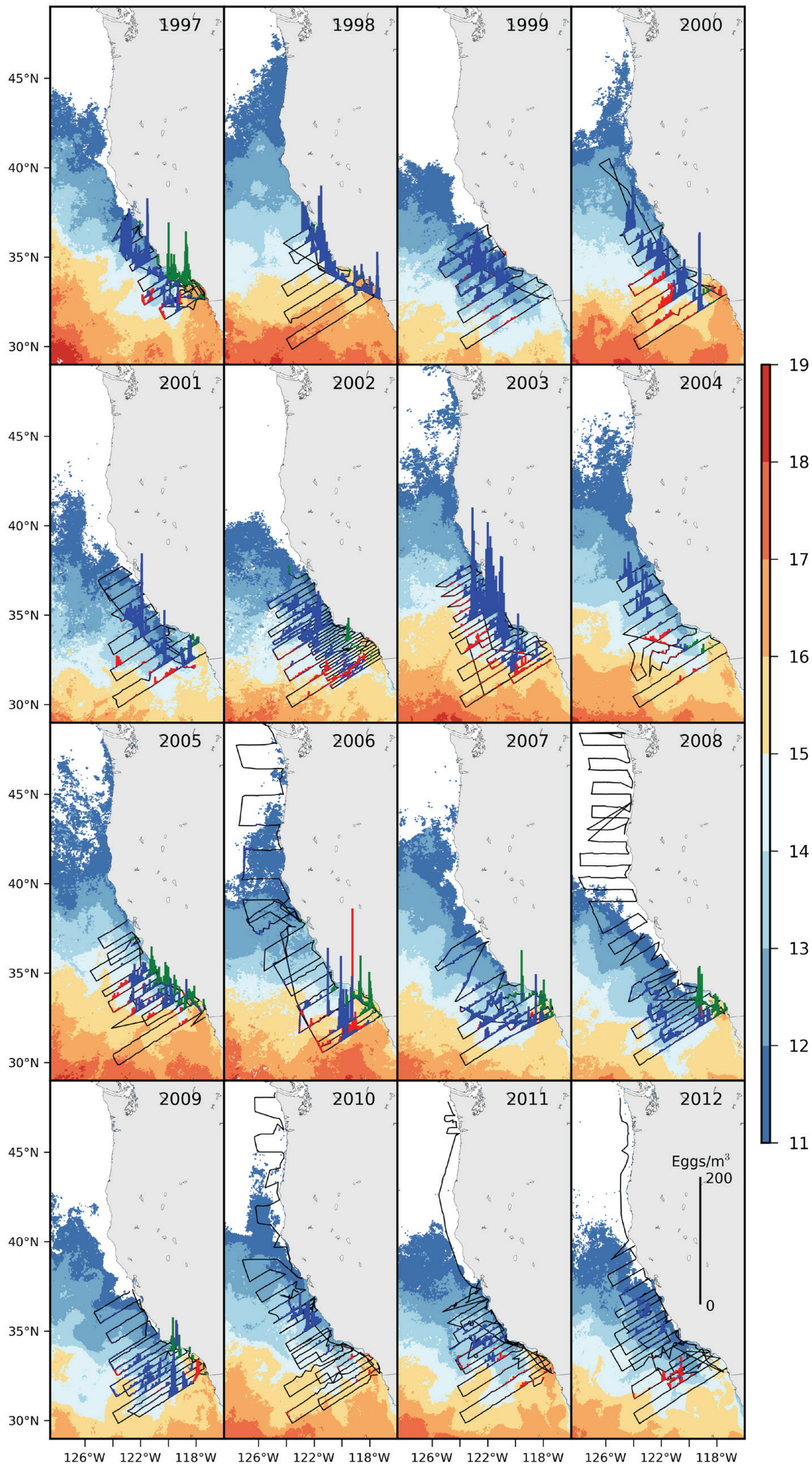


Figure 27. Densities of eggs of Pacific sardine (blue), jack mackerel (red), and northern anchovy (green) collected with the Continuous Underway Fish Egg Sampler (CUFES) along the ship track (black lines) during NOAA spring cruises for 1997 to 2012. The underlying color image shows a monthly composite of satellite AVHRR 1.4 km resolution sea surface temperature (°C) image coincident with the survey period in each year.

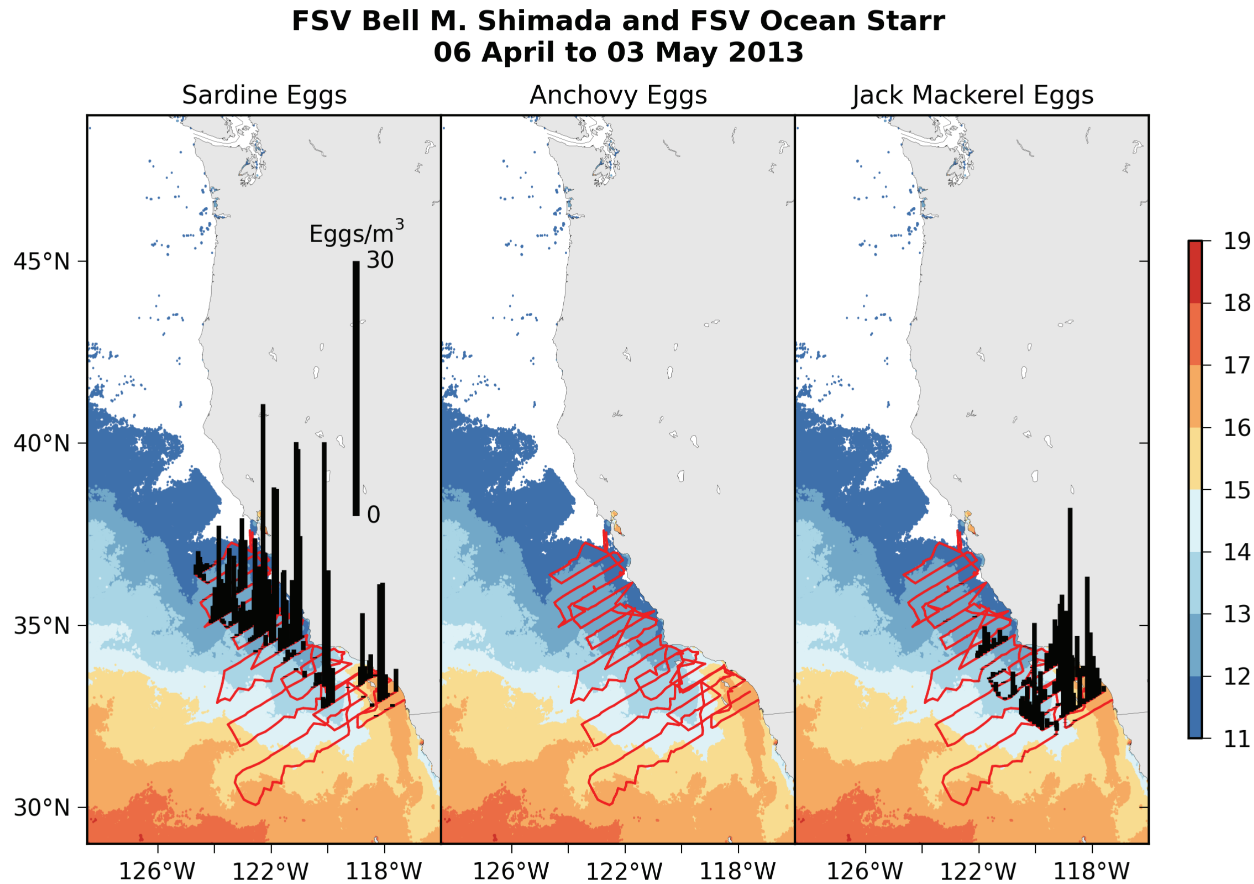


Figure 28. Densities of eggs of Pacific sardine, jack mackerel, and northern anchovy collected with the Continuous Underway Fish Egg Sampler (CUFES) along the ship tracks (red lines) during NOAA coast-wide cruises conducted in spring 2013. The underlying color image shows a monthly composite of satellite AVHRR 1.4 km resolution sea surface temperature (°C) image coincident with the survey period in each year.

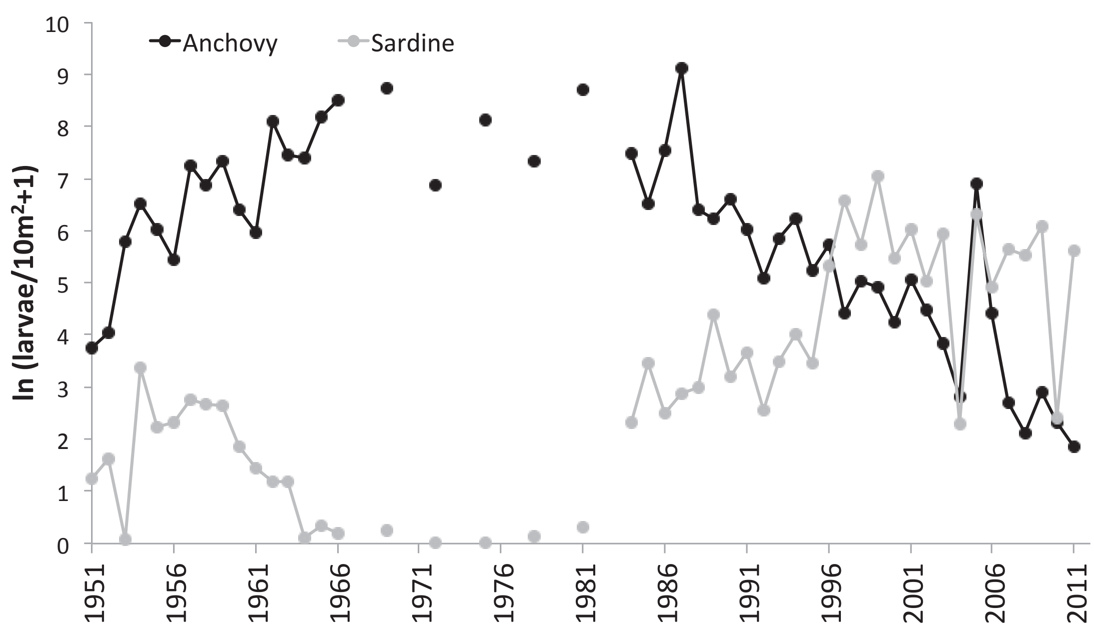


Figure 29. Abundance (ln (number /10 m^2+1)) of northern anchovy and Pacific sardines captured in oblique tows (bongo net) during spring CalCOFI surveys 1951–2011.

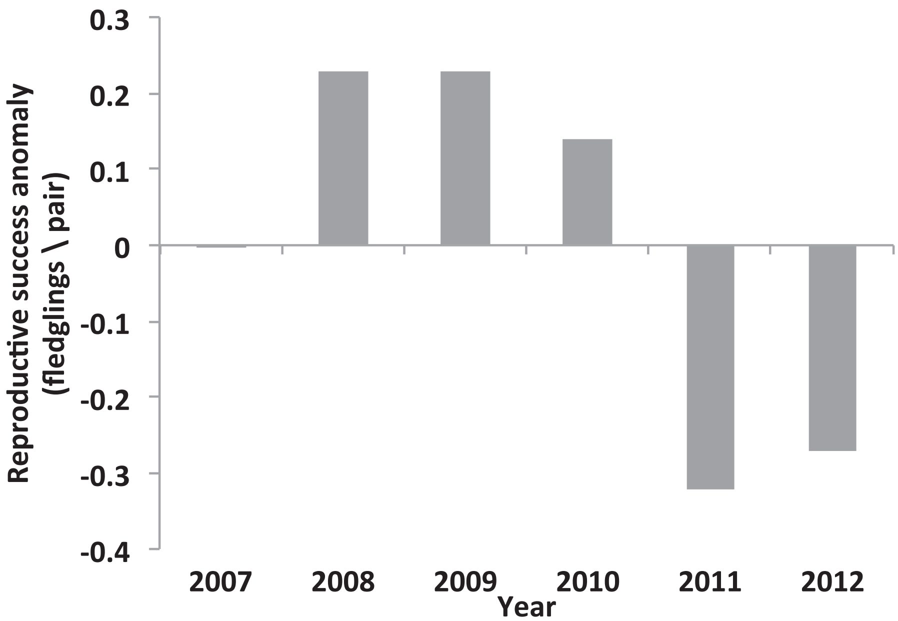


Figure 30. Anomalies of reproductive success (fledglings per breeding pair) of common murre at Yaquina Head.

uncertainties resulting from equipment failure, we concluded that nesting began later than usual in 2012 (see supplement for data collection and additional results, fig. S13).

For Brandt's cormorants, efforts to monitor nest phenology and success began in 2011 and baseline understanding of their reproductive performance is still being developed. Based on nests initiated prior to camera failure in 2012, 71% of first clutches (n = 13) failed during incubation. The failure rate for first clutches was similarly high in 2011, with 68% of first clutches failing during incubation.

At-sea Density of Seabirds off Southern California

Patterns of variability are illustrated in the relative abundance of two species, the sooty shearwater, *Puffinus griseus*, and Cassin's auklet expressed as natural log of density sighted (ln [birds km^{-2} + 1], see supplement for methods). Both species prey upon euphausiid crustaceans, small pelagic fish, and squid. In 2012, there was nothing unusual in the relative abundance of auklets in any season (fig. 32).

In contrast to the resident auklets, shearwaters were most abundant in the study region during the summer (July–August), with lower relative abundance in spring (April–May). During both seasons in 2012, the relative abundance of shearwaters declined (fig. 32). In 2012, numbers were substantially reduced from a recent peak in both spring and summer in 2010. Changes in shearwater abundance may be related to short or long-term changes in food availability. Alternatively, population decreases elsewhere could be affecting our counts; this may be the result of shearwaters declining on some New Zealand islands (Scott et al. 2008).

Productivity and Condition of California Sea Lions at San Miguel Island

California sea lions (*Zalophus californianus*) are permanent residents of the CCS, breeding on the California Channel Islands and feeding throughout the CCS in coastal and offshore habitats. They are also sensitive to changes in the CCS on different temporal and spatial scales and so provide a good indicator species for the status of the CCS at the upper trophic level (Melin et al. 2012). Two indices are particularly sensitive measures of prey availability to California sea lions, pup production, and pup growth through four months of age. Pup production is a result of successful pregnancies and is an indicator of prey availability and nutritional status of adult females from October to the following June. Pup growth from birth to four months of age is an index of the transfer of energy from the mother to the pup through lactation between June and October, which is related to prey availability to adult females during that time and to survival of pups after weaning. The average number of live pups counted at San Miguel Island in July 2012 was 24,993 (fig. 33). The high live pup count in 2012 suggests that pregnant females experienced good foraging conditions from October 2011 to July 2012.

However, the pup growth index for California sea lions at San Miguel Island indicated that dependent pups were in poor condition by the time they reached four months of age. In October 2012, the average predicted

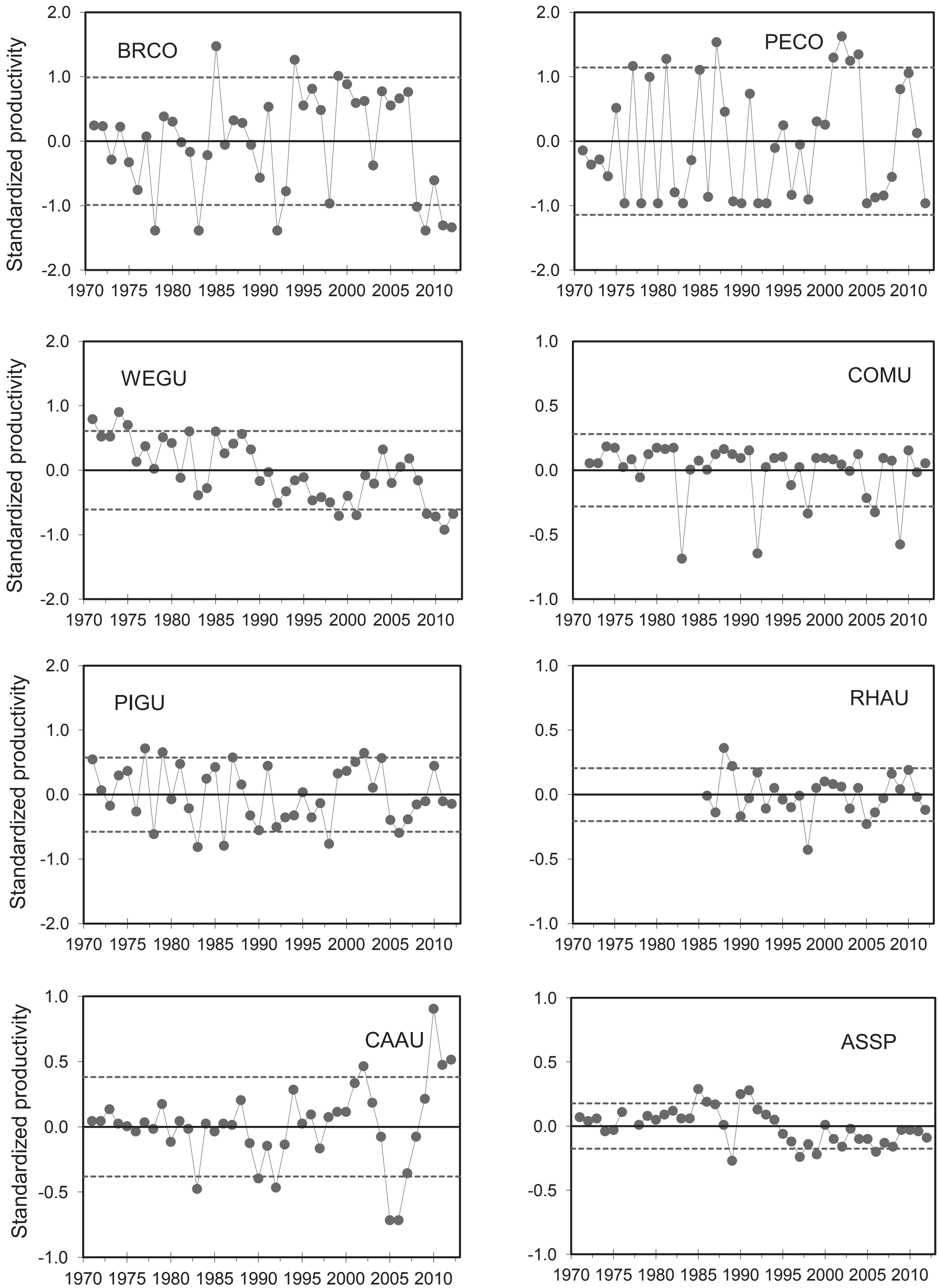


Figure 31. Standardized productivity anomalies (annual production–long term mean) for 8 species of seabirds on Southeast Farallon Island, 1971–2012. The dashed lines represent the 80% confidence interval for the long-term mean. Abbreviations are used fro Brandt's cormorant (BRCO), pelagic cormorant (PECO), western gull (WEGU), common murre (COMU), pigeon guillemot (PIGU), rhinoceros auklet (RHAU), Cassin's auklet (CAAU), and storm petrel (ASSP).

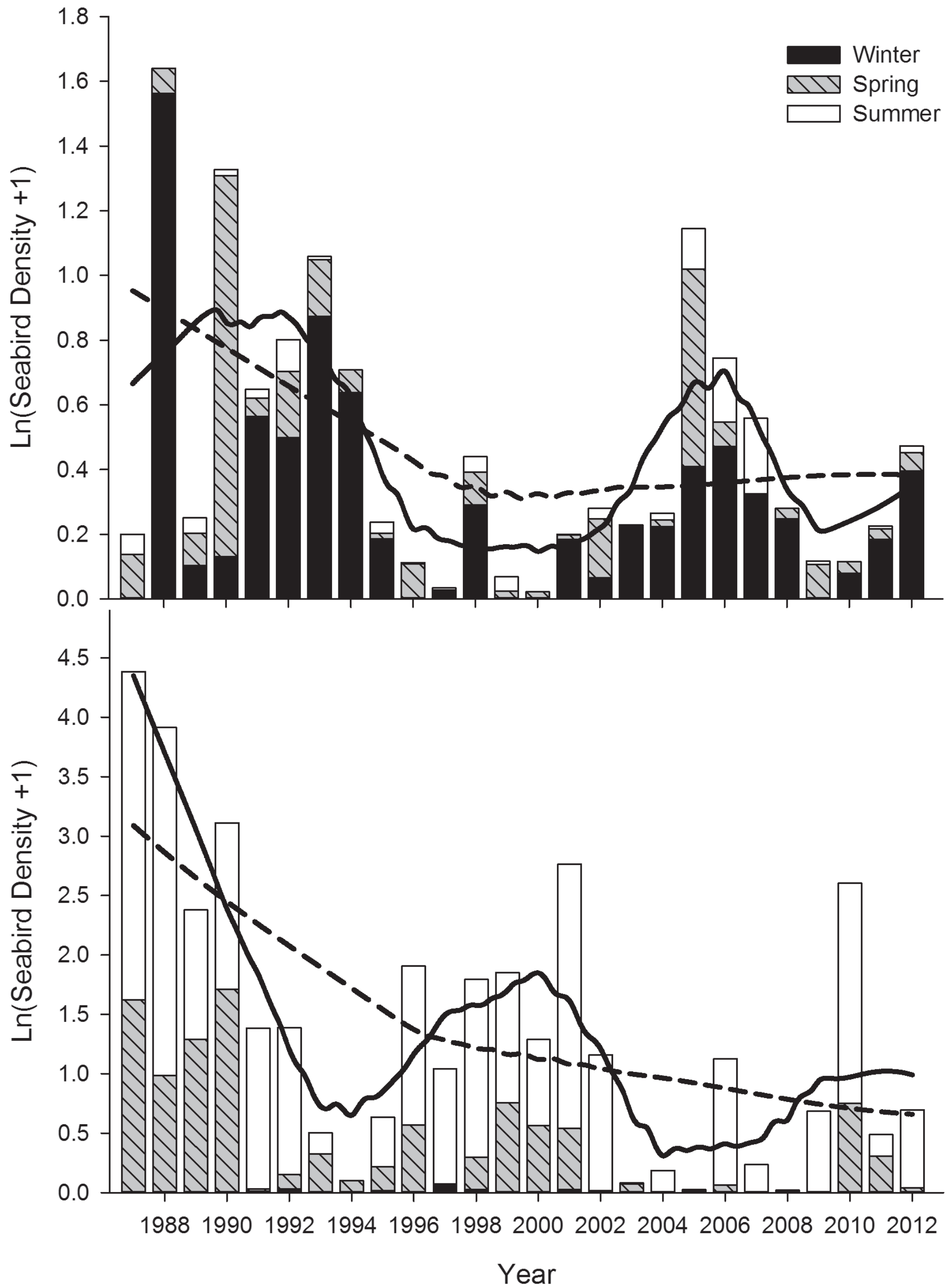


Figure 32. Changes in resident Cassin's auklet (upper panel) and migratory Sooty Shearwater (lower panel) relative abundance (natural log of birds km^{-2}) on 90 CalCOFI/CCE-LTER surveys, May 1987–July 2012. Stacked bars denote seasonal density estimates, with 2 Locally Weighted Regression (LOWESS) smoothing lines on summed annual estimates shown to illustrate short-term (bandwidth = 0.3, solid) and long-term (bandwidth = 0.8, dashed) variability.

weights of four-month-old female (13.0 kg, SE = 0.14) and male (14.5 kg, SE = 0.20) pups were significantly lower compared to the long-term mean for female and male pups (females, mean = 17.4 kg, SE = 0.35; males, mean = 20.2 kg, SE = 0.43) (fig. 34). Average October weights of California sea lion pups have been declining since 2008 but the mean weights for the 2012 cohort were significantly lower than the previous four years. By February 2013, at 7 months of age, pups remained significantly underweight (females, mean = 13.6 kg, SE = 0.55; males, mean = 16.2 kg, SE = 0.69) (fig. 34); an estimated 12 kg and 14.4 kg below the long-term average for females and males, respectively. A longitudinal analysis of pup daily growth rates of branded pups between four and seven months of age showed significantly lower daily growth rates compared to other years for female and male pups (fig. 34). In both October and February, the mean weights for the 2012 cohort were similar to

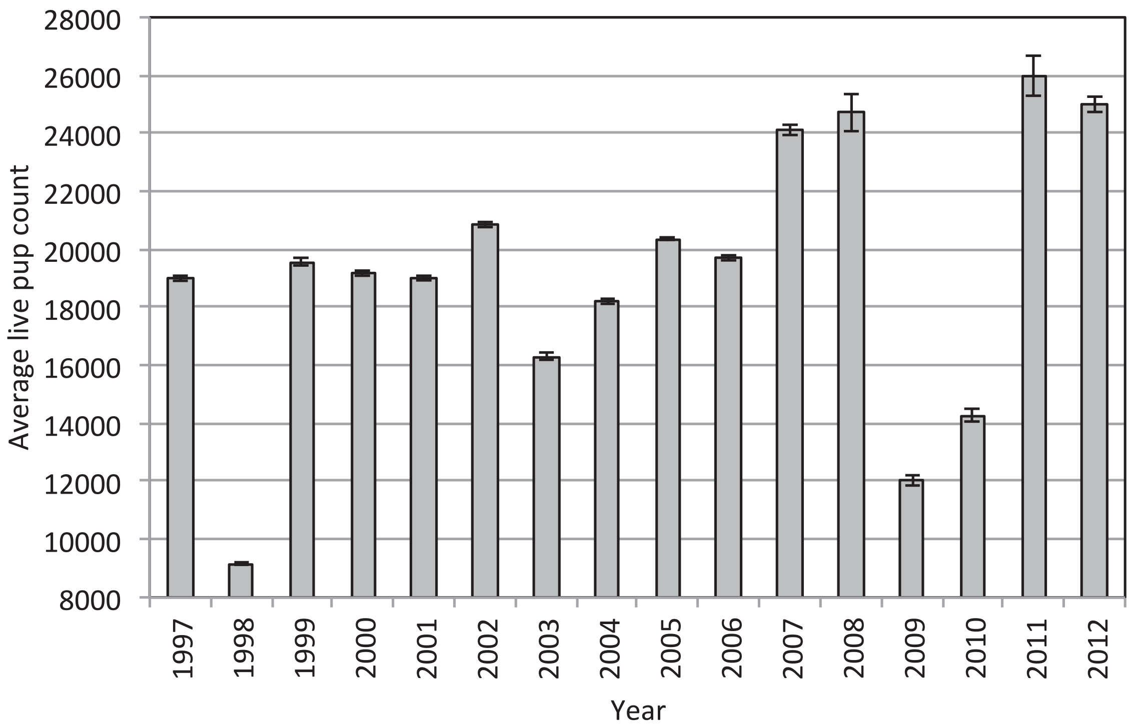


Figure 33. The average number of live California sea lion pups counted at San Miguel Island, California, 1997–2012 in late July when surviving pups were about 6 weeks old. Error bars are ±1 standard deviation.

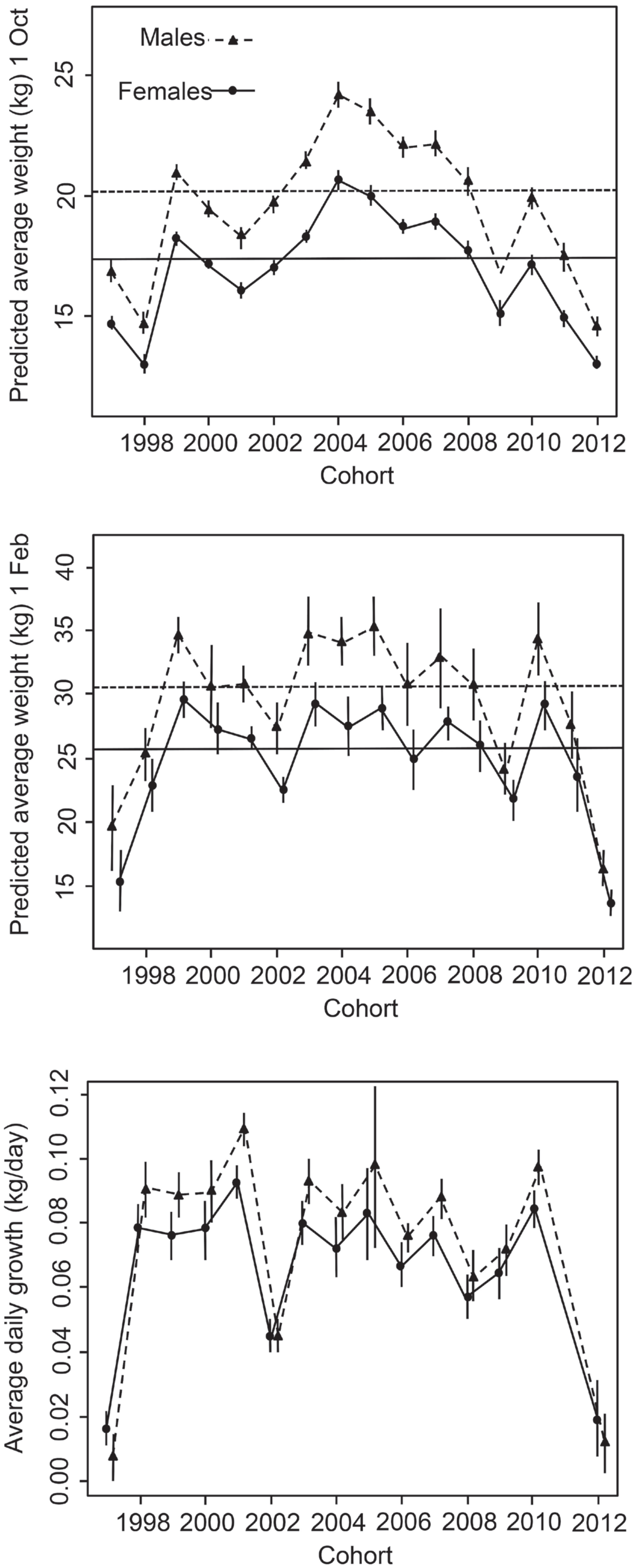
the 1997 cohort, as were the daily growth rates between October and February. The 1997 cohort was impacted by a strong El Niño event that prevailed in the California Current between May 1997 and May 1998. The oceanographic conditions associated with the El Niño resulted in poor foraging conditions by reducing prey availability for lactating California sea lion females and consequently, their dependent pups were in poor condition (Melin et al. 2012; Melin et al. 2010).

In addition to poor condition of pups on the rookery at San Miguel Island, high numbers of emaciated pups began stranding on southern California beaches in January 2013, indicating that pups were weaning up to three months earlier than normal. High levels of strandings continued into April with three times the normal level of strandings during the four-month period (http://www.nmfs.noaa.gov/pr/health/mmume/californiasealions2013.htm). Although early weaning of pups and emaciated pups at the rookeries could be due to high mortality of adult females, there was no increase in strandings of lactating females during this period and emaciated pups were observed suckling robust females, suggesting that the cause for the poor condition of the pups was not related to mortality of their mothers. In response to the poor condition of pups at the rookeries and the high level of strandings, the National Marine Fisheries Service declared an Unusual Mortality Event of California sea lion pups on March 25, 2013. Two lines of investigation were initiated to explain the Unusual Mortality Event, one focusing on disease in pups or their mothers and the other on a shortage of food available to lactating females (see supplement for comment).

DISCUSSION

In 2012 the basin-scale indices and conditions from regional surveys indicate that oceanographic characteristics of the CCS were similar to recent cool years. The PDO signaled a continued pattern of cool SST and the NPGO was consistent with strong southward transport (fig. 2). The MEI demonstrated a short-lived switch to positive values in the summer of 2012, but was not sufficiently strong to elicit a response in CCS SST. During winter of 2011/2012, upwelling in the northern CCS was substantial, especially north of 39˚N (fig. 3). However, in the north, upwelling winds weakened in midwinter and remained weak until resuming to near-average values in May. In the south, upwelling remained strong. Regional hydrographic studies also demonstrated that conditions were not too dissimilar from conditions observed since 2007 for SST or salinity (figs. 7, 10, 12, 13, and 15).

Winter of 2011/2012 presented an uncharacteristic upwelling period and strong southward transport leading into 2012. Between 36˚N and 45˚N, the winds in December 2011 were unusual because the expected downwelling-producing winds were replaced by mod-



erate upwelling-producing winds, while north of 45˚N downwelling winds weakened (fig. 3). The upwelling and weakened downwelling winds resulted in coastal sea levels that suggested transport was more southward than had been observed in the past 45 Decembers (fig. 4). This southward transport was corroborated by HF radar showing anomalous equatorward surface velocities north of Cape Blanco in December 2011 (fig. 5). Consistent with increased southward transport, the northern copepod index calculated for the Newport Hydrographic Line had the largest ever values of northern copepod species during winter 2011/2012 (fig. 9). Interestingly, there was not a similar increase in northern copepods at Trinidad Head, however, an examination of HF radar (fig. 5) suggests that the surface source waters at Trinidad Head during winter 2011 may have been derived from immediately south of Cape Mendocino.

We acknowledge there are limitations and differences between survey designs represented here, but from our available observations, a CCS-wide pattern emerged with reduction of two primary forage fishes, namely northern anchovy and Pacific sardine (as well as Pacific herring where sampled in central and northern California). The abundances of these species along the CCS were near record minima in surveys. In the CalCOFI survey region, egg densities for both northern anchovy and Pacific sardine were low indicating a possible reduction in the spawning stock and/or the spawning stock resided outside the study region (figs. 27 and 28). Similarly, these fishes were caught in reduced numbers in central and northern California (figs. 22 and 25).

Lower observed abundance in northern anchovy in 2012 may have been an extension of a declining trend. Catches of larval anchovy in the southern California waters have declined over the last three decades with the lowest densities recorded in the recent five years ending in 2011 (fig. 29). This pattern indicates either a reduction in spawning stock biomass, early survival, or increased advection from the region (Bakun and Parrish 1982). What made 2012 particularly intriguing relative to forage, was not only that northern anchovy abundance was reduced across the CCS but that Pacific sardine and Pacific herring were at low abundances as well. That 2012 saw a reduction in the clupeiform forage community along the coast suggests that common factors could

Figure 34. Top panel: Predicted average weights of 4 month old female (circle) and male (triangle) California sea lion pups at San Miguel Island, California, 1997–2012 and long-term average between 1975 and 2012 for females (solid line) and males (dashed line). Error bars are ±1 standard error. Middle panel: Predicted average weights of 7 month old female (circle) and male (triangle) California sea lion pups at San Miguel Island, California, 1997–2012 and long-term average between 1975 and 2012 for females (solid line) and males (dashed line). Error bars are ±1 standard error. Bottom panel: Predicted average daily growth rate of female (circle) and male (triangle) California sea lion pups between 4 and 7 months old at San Miguel Island, California, 1997–2012. Error bars are ±1 standard error.

have led to or exacerbated the reduction in all species, although the data here may be limited for addressing the specific causes.

Strong, early onset of upwelling in the southern CCS region in 2012 had the potential to have distributed forage fishes farther offshore and make them less accessible to the surveys and, possibly, predators (Bakun and Parrish 1982). In fact, at 33˚N the cumulative upwelling during the beginning of 2012 was greater than most values on record (fig. S2). However the winds in this southern region relaxed to near climatological means by early spring 2012 (fig. 3). By the time of the 2012 survey, Pacific sardine eggs were distributed in an area narrower than that of 2011, concentrated primarily between CalCOFI line 60–76.7 and reduced numbers were observed between CalCOFI line 85–90 (fig. 27) (Lo et al. 2013). This distribution suggests that fish spawned nearshore, or those offshore did not spawn, or the relaxation of upwelling moved eggs inshore, or something else affected pelagic egg production that is yet to be fully quantified. By contrast, in the north, to where northern anchovy and Pacific sardine migrate, the upwelling winds were more modest and there was not anomalously high offshore advection, therefore, advection would not likely be a primary cause for the reduction in their abundance in those regions (fig. 3). Coming into 2013, a winter and spring of exceptional winds coast-wide, Pacific sardines, northern anchovy, and jack mackerel egg densities in southern California were similar to the previous two years (fig. 28). However, young-of-the-year northern anchovies had increased to near average abundance in the more northern surveys.

Those fishes whose abundance is reliant more on local (typically onshelf) conditions of production (Emmett et al. 2006; Santora et al. 2012) also displayed a CCS-wide signal; in all regions they exhibited improved production/abundance in 2012. For instance, in central California, a micronekton assemblage of rockfish, market squid, euphuasiids (fig. 25), lingcod (not shown), flatfishes (not shown), and octopi (not shown) continued a recent trend of improved production, consistent with increased local upwelling and productive shelf conditions. Similarly, whitebait smelt abundance (Emmett et al. 2006) was at average levels in the north in contrast to the low abundances of northern anchovy and clupeids. It followed that smelt, which sustained an average abundance (fig. 22), comprised a greater proportion of the diets for seabirds located at Yaquina Head than other prey (fig. S12).

The reductions of Pacific sardine and northern anchovy and the improved production of the forage reliant on shelf productivity may point to variability in the quality of the shelf and off-shelf habitats. Namely, over much of the range of northern anchovy, the fish feed, and may even spawn, at and beyond the shelf break (Kramer and Ahlstrom 1968; Smith 1972). In part, the northern anchovy may be held offshore by advection (Bakun and Parrish 1982). This is clear in the central California region where, even during the cool, productive conditions that benefit northern anchovy production (Lindegren et al. 2013), the northern anchovy are not abundant in the survey region (fig. 1). It is only when upwelling subsides, or during relatively unproductive years associated with reduced winds, that northern anchovy become increasingly available to the trawls and the inshore environment. Pacific sardine, as well, reside more offshore at or beyond the shelf break (Kramer 1970). By contrast, the fishes reliant on productive, cool waters inshore have had improved production recently. These fishes, such as rockfish, market squid, lingcod, and others, reside largely in the productive cool nearshore waters during upwelling periods.

While unsubstantiated in the CCS, there is a potential that dense salp concentrations in central and southern California (but not so far south as Baja California) during 2012 could have exacerbated the recent patterns in the forage community (Lavaniegos and Ohman 2003; Loeb et al. 1997). Specifically, research should be considered to examine the negative impacts of massive blooms on feeding rates, growth, reproduction, and survival of fishes in the CCS. The impacts of herbivorous, filter-feeding salps on primary production and food web dynamics can be striking (Alldredge and Madin 1982; Andersen 1998; Madin et al. 2006). These animals are characterized by fast growth rates, short generation times, relatively large body sizes, and very high filtering rates. Their life histories allow them to exist with minimal reproduction during periods of low food supply but also permit rapid, exponential population increases to take immediate advantage of elevated food concentrations. These characteristics underlie episodic population explosions during which time salps can quickly and efficiently remove particulates from large volumes of seawater thereby negatively impacting other herbivores (Alldredge and Madin 1982; Andersen 1998; Madin et al. 2006).

High concentrations of salps occurred in the northern CCS in 2010 and 2011 (fig. 18) and subsequently were anomalously abundant off central and southern California in 2012 (fig. 19), suggesting a spatial-temporal delay in their distribution from north to south. This delay may be due to the advection of seed stocks into, and explosive population growth within, waters offering appropriate conditions. In southern California, there was an increase in the volume of larger zooplankton (mostly salps and pyrosomes) early in 2012 that was about twice as large as values observed in 2011 and larger than any value seen in 20 years (fig. 21). In fact, local abundances were so great that by April 2012 the salps interfered with the coolant system of the Diablo Canyon power plant in south-central California, leading to a shutdown (http://articles.latimes.com/2012/apr/26/local/la-me-0426-jellyfish-nukes-20120426).

Anomalously strong southward transport from northern CCS during December 2011 (figs. 3, 4, and 5) potentially advected abundant seed populations of salps and pyrosomes produced in northern CCS waters during 2010 and 2011, into central and southern California waters as has been demonstrated by Roesler and Chelton 1987. The upwelling event of December 2011 following a downwelling period suggests that any seed populations of salps could have been nearshore when the winds switched, making them particularly vulnerable to southward transport. Once further south, they encountered appropriate primary productivity levels promoting further population increases followed by a reduction in the phytoplankton biomass in the region due to grazing pressure. The regional studies in central and northern California, as well as the remote sensing of the CCS, demonstrated just such a pattern (figs. 6, 10, and 12). In spring of 2011 chlorophyll values in the northern CCS were, indeed, anomalously low but were greater in 2012 (fig. 6). In contrast, central and southern California chlorophyll values were average to above average in spring 2011 but for the most part anomalously low in 2012. The exception in 2012 was a positive anomaly offshore south of Point Conception, near central gyre waters (fig. 6).

Where observed off central California, salps were predominantly at offshore stations (fig. 20; note the log scale). The central California salmon survey, occurring just a month later than the rockfish survey, did not encounter anything so pronounced due to its predominantly inshore stations (fig. 20). Closer inspection of chlorophyll distribution patterns in the spring (fig. 6) suggests higher than typical primary production on the shelf in the Gulf of the Farallones region vitally important to production off central California. By contrast, just south of the Gulf of the Farallones over the Monterey Canyon region, where salps were very abundant (fig. 20), surface chlorophyll values were the lowest on record by June (fig. 12). Off southern California the onshore presence of dense salp aggregations, such as those that shut down the Diablo Canyon nuclear power plant, could have had an impact on coastal ecosystems.

The population dynamics and foraging ecology of seabirds are closely related to ocean conditions and forage abundance, distribution, and composition within the California Current (Ainley and Hyrenbach 2010; Ainley et al. 1995; Santora et al. 2011; Veit et al. 1996). In 2012, seabirds on Southeast Farallon Island had generally average production (few species indicators fell outside of 1 s.d.). However, Cassin's auklet and Brandt's cormorant were notable in the degree to which they had good and poor reproductive success, respectively. These differences may relate to changes in the forage community. Cassin's auklet, who rely on more onshelf (nearer to nesting sites) prey such as *T. spinifera* (Sydeman et al. 2001; Sydeman et al. 1997), had exceptional reproductive success (fig. 31); consider as well the reproductive failures of 2005 and 2006 were associated with reduced prey availability on the shelf. In 2012, Cassin's auklet in southern California also did not demonstrate substantial changes to their foraging behavior that would be indicative of a drastic reduction or redistribution in their forage (fig. 32). Brandt's cormorant rely, in part, on northern anchovy in the neritic environment (Sydeman et al. 1997) and, therefore, reduced availability in northern anchovy inshore is a likely cause of their poor reproductive success.

In the northern CCS at Yaquina Head, common murre did experience reduced fledgling success in contrast to that at Southeast Farallon Island, but this reduction was likely the result of predators at the colony (e.g., brown pelicans, *Pelecanus occidentalis*, and bald eagles, *Haliaeetus leucocephalus*) (fig. 30). The top-down impacts of seabird predators may be related to bottom-up processes affecting prey availability (Hipfner et al. 2012). For example, in 2012 brown pelicans caused dramatic common murre chick mortality at Yaquina Head, more than any previous year recorded. Pelicans were observed grabbing common murre chicks on the colony and consuming some directly, but shaking others until the chicks regurgitated fish, then the pelicans consumed the regurgitated fish. Northern anchovy and Pacific sardine are dominant prey items for pelicans and, with their regional abundance greatly reduced in 2012, the pelicans may have been desperate for alternative prey (Horton and Suryan 2012).

Consistent with a coast-wide change in the forage community was the poor condition and mortality event of California sea lion pups from San Miguel Island. It is suspected that this event was brought on by the inability of mothers to provide sufficient nourishment to their dependent pups through lactation (fig. 34). The population response was very similar to that observed during strong El Niño events when the availability of sea lion prey is diminished in the CCS, and the unusual mortality event in 2012 may be related to the reduced availability of forage fish during 2012. The unusual mortality event is currently under investigation and both forage community dynamics and disease are being considered (see supplement).

Interestingly, the estimated abundances of another predator, juvenile Chinook salmon, in California did not show a pattern of abundance easily attributable to the observed changes in the forage community, as did seabirds and sea lions. This was surprising, as it would be expected that juvenile Chinook salmon, reliant on forage on the shelf (Daly et al. 2009; Wells et al. 2012), would have been universally successful in 2012. Rather, catches of juvenile Chinook salmon in California were observed at lower abundance than the previous two years of the survey. However, what was a reduction in observed abundance of salmon in the California in 2012 may not have been great if a longer time series (more than the current 2010–13) had been available for comparison with the 2012 survey. Consistent with the possibility that 2012 was not as poor a year for California Chinook salmon as the three-year survey may suggest, juvenile Chinook salmon were abundant in the northern CCS during June off Washington and Oregon.

With 2013 came an exceptionally strong winter and spring upwelling period (fig. 3) that acted predictably on the regional hydrography; salinities were greater and surface temperatures lower (figs. 7, 10, and 12). Biological data, for the most part, has yet to be processed, therefore, the biological signal will be discussed in greater detail in the next year's report. However, the May–June juvenile rockfish survey did report record numbers of young-of-the-year pelagic rockfish, and high abundances of many other micronekton forage species as well (other juvenile groundfish, krill, and market squid). While beyond the defined time period of this report, it is also worth noting that by the end of summer and early fall, upwelling relaxed dramatically and, with the associated reduction in advection, anchovy abundance was observed to be very high nearshore in central California leading to impressive feeding aggregations of marine mammals and seabirds (see http://www.santacruzsentinel.com/santacruz/ci_24091445/whale-time-anchovies-bring-record-numbers-humpbacks).

The coming year will offer an opportunity to evaluate the coast-wide effects of strong winds early in the year on the system. Specifically, following on the findings of previous work (e.g., Bakun and Parrish 1982; Cury and Roy 1989; Mackenzie and Leggett 1991; Piatt and Springer 2003) we may observe changes indicative of poor production for a number of the indicators we examine in this report. Namely, increased diffusion of nutrients and phytoplankton away form the coast (i.e., reduced coastal front development due to turbulence) may be noted, forage composition and distribution may be altered, and there may be reductions in seabird production brought on by changes in the seascape. However, 1999 also represented a strong upwelling year and, from that, rockfish, salmon, and seabirds, as well as other taxa, were very productive along much of the CCS. Obviously these species did not experience the hypothesized negative effects of too much upwelling.

ACKNOWLEDGEMENTS

We thank three anonymous reviewers for their comments that improved this manuscript and provided guidance for continued development of reports in the series. Financial and collaborative support comes from diverse agenecies and government entities including NOAA's California Current Integrated Ecosystem Assessment (CCIEA), Integrate Ocean Observing Systems (IOOS), National Marine Fisheries Service (NMFS) and its Stock Assessment Improvement Pan (SAIP) and Fisheries and the Environment programs (FATE), Mexico's Consejo Nacional de Ciencia y Tecnología (CONA-CyT), the U.S. National Science Foundation (NSF), Bonneville Power Administration (BPA), United States Fish and Wildlife Service (USFWS), Navy's Living Marine Resources Program and university partners through the Coastal Observing Research and Development Center, California's Ocean Protection Council, and Redwood National and State Parks. The David and Lucile Packard Foundation supported central California morring observations. The Baker Trust, the Marisla Foundation, the Campini Foundation, the Kimball Foundation, and the Mead Foundation supported seabird work on the Southeast Farallon Island. HF radar data are available thanks to the initial investment of the State of California in establishing the array in California and to the National Science Foundation for establishing elements of the array in Oregon and California; NOAA-IOOS and participating universities (listed at http://cordc.ucsd.edu/projects/mapping/) have provided ongoing operating funds and support. We also thank the captains and crew of the vessels that supported this work, including R/V *Coral Sea*, R/V *Francisco de Ulloa*, *Elahka*, FS/V *Ocean Starr*, R/V *New Horizon*, FS/V *Bell M. Shimada*, F/V *Frosti*, F/V *Miss Sue*, F/V *Piky*, R/V *Elahka*, and F/V *Excalibur*. We also sincerely thank the many dedicated individuals who have participated in, advised, collaborated in, or otherwise contributed to the collection, management, and analysis of these data both in recent years and in the past.

LITERATURE CITED

Ainley, D. G. and K. D. Hyrenbach. 2010. Top-down and bottom-up factors affecting seabird population trends in the California current system (1985–2006). Progress in Oceanography 84:242–254.

Ainley, D. G., W. J. Sydeman, and J. Norton. 1995. Upper Trophic Level Predators Indicate Interannual Negative and Positive Anomalies in the California Current Food-Web. Marine Ecology Progress Series 118:69–79.

Alldredge, A. L. and L. P. Madin. 1982. Pelagic Tunicates—Unique Herbivores in the Marine Plankton. Bioscience 32:655–663.

Andersen, V. 1998. Salp and pyrosomid blooms and their importance in biogeochemical cycles. In *The Biology of Pelagic Tunicates*, Q. Bone, ed. Oxford:Oxford University Press, pp. 125–137.

Bakun, A. and R. H. Parrish. 1982. Turbulence, transport, and pelagic fish in the California and Peru Current systems. California Cooperative Oceanic Fisheries Investigations Report 23:99–112.

Bjorkstedt, E., R. Goericke, S. McClatchie, E. Weber, W. Watson, N. Lo, B. Peterson, B. Emmett, R. Brodeur, J. Peterson, M. Litz, J. Gomez-

Valdez, G. Gaxiola-Castro, B. Lavaniegos, F. Chavez, C. A. Collins, J. Field, K. Sakuma, P. Warzybok, R. Bradley, J. Jahncke, S. Bograd, F. Schwing, G. S. Campbell, J. Hildebrand, W. Sydeman, S. Thompson, J. Largier, C. Halle, S.Y. Kim, and J. Abell. 2012. State of the California Current 2010–2011: Regional Variable Responses to a Strong (But Fleeting?) La Niña. California Cooperative Oceanic Fisheries Investigations Report 52:36–68.

Bograd, S. J., I. Schroeder, N. Sarkar, X. M. Qiu, W. J. Sydeman, and F. B. Schwing. 2009. Phenology of coastal upwelling in the California Current. Geophysical Research Letters 36:doi 10.1029/2008gl035933.

Cury, P. and C. Roy. 1989. Optimal Environmental Window and Pelagic Fish Recruitment Success in Upwelling Areas. Canadian Journal of Fisheries and Aquatic Sciences 46:670–680.

Cury, P. M., I. L. Boyd, S. Bonhommeau, T. Anker-Nilssen, R. J. M. Crawford, R. W. Furness, J. A. Mills, E. J. Murphy, H. Osterblom, M. Paleczny, J. F. Piatt, J. P. Roux, L. Shannon, and W. J. Sydeman. 2011. Global Seabird Response to Forage Fish Depletion—One-Third for the Birds. Science 334:1703–1706.

Daly, E. A., R. D. Brodeur, and L. A. Weitkamp. 2009. Ontogenetic Shifts in Diets of Juvenile and Subadult Coho and Chinook Salmon in Coastal Marine Waters: Important for Marine Survival? Transactions of the American Fisheries Society 138:1420–1438.

Di Lorenzo, E., N. Schneider, K. M. Cobb, P. J. S. Franks, K. Chhak, A. J. Miller, J. C. McWilliams, S. J. Bograd, H. Arango, E. Curchitser, T. M. Powell, and P. Riviere. 2008. North Pacific Gyre Oscillation links ocean climate and ecosystem change. Geophysical Research Letters 35:doi 10.1029/2007gl032838.

Emmett, R. L., R. D. Brodeur, T. W. Miller, S. S. Pool, G. K. Krutzikowsky, P. J. Bentley, and J. McCrae. 2005. Pacific sardine (*Sardinops sagax*) abundance, distribution, and ecological relationships in the Pacific Northwest. California Cooperative Oceanic Fisheries Investigations Reports 46:122–143.

Emmett, R. L., G. K. Krutzikowsky, and P. Bentley. 2006. Abundance and distribution of pelagic piscivorous fishes in the Columbia River plume during spring/early summer 1998–2003: Relationship to oceanographic conditions, forage fishes, and juvenile salmonids. Progress in Oceanography 68:1–26.

Graham, W. W. and J. L. Largier. 1997. Upwelling shadows as nearshore retention sites: the example of northern Monterey Bay. Continental Shelf Research 17:509–532.

Hipfner, J. M., L. K. Blight, R. W. Lowe, S. I. Wilhelm, G. J. Robertson, R. T. Barrett, T. Anker-Nilssen, and T. P. Good. 2012. Unintended consequences: how the recovery of sea eagle *Haliaeetus* spp. populations in the northern hemisphere is affecting seabirds. Marine Ornithology 40:39–52.

Horton, C. A. and R. M. Suryan. 2012. Brown Pelicans: A new disturbance source to breeding Common Murres in Oregon? Oregon Birds 38:84–88.

Kramer, D. 1970. Distributional atlas of fish larvae in the California Current region: Pacfiic sardine, *Sardinops caerulea* (Girard), 1951–66. California Cooperative Oceanic Fisheries Investigations Atlas No. 12.

Kramer, D. and E. H. Ahlstrom. 1968. Distributional atlas of fish larvae in the California Current region: northern anchovy, *Engraulis mordax* (Girard), 1951–65. California Cooperative Oceanic Fisheries Investigations Atlas No. 9.

Lavaniegos, B. E. and M. D. Ohman. 2003. Long-term changes in pelagic tunicates of the California Current. Deep-Sea Research Part Ii—Topical Studies in Oceanography 50:2473–2498.

Lindegren, M., D. M. Checkley, T. Rouyer, A. D. MacCall, and N. C. Stenseth. 2013. Climate, fishing, and fluctuations of sardine and anchovy in the California Current. Proceedings of the National Academy of Sciences doi: 10.1073/pnas.1305733110.

Litz, M. N. C., S. S. Heppell, R. L. Emmett, and R. D. Brodeur. 2008. Ecology and Distribution of the Northern Subpopulation of Northern Anchovy (*Engraulis Mordax*) Off the US West Coast. California Cooperative Oceanic Fisheries Investigations Reports 49:167–182.

Lo, N. C. H., B. J. Macewicz, and D. Griffith. 2013. Spawning biomass of Pacific sardine (*Sardinops sagax*) off California in 2012. Nat. Oceanic Atmos. Admin., U. S. Dep. Commer., Tech. Memo. NOAA-TM-NMFS-SWF-SC-505. 45 pp.

Loeb, V., V. Siegel, O. HolmHansen, R. Hewitt, W. Fraser, W. Trivelpiece, and S. Trivelpiece. 1997. Effects of sea-ice extent and krill or salp dominance on the Antarctic food web. Nature 387:897–900.

Mackenzie, B. R. and W. C. Leggett. 1991. Quantifying the Contribution of Small-Scale Turbulence to the Encounter Rates between Larval Fish and Their Zooplankton Prey—Effects of Wind and Tide. Marine Ecology Progress Series 73:149–160.

Madin, L. P., P. Kremer, P. H. Wiebe, J. E. Purcell, E. H. Horgan, and D. A. Nemazie. 2006. Periodic swarms of the salp Salpa aspera in the Slope Water off the NE United States: Biovolume, vertical migration, grazing, and vertical flux. Deep-Sea Research Part I—Oceanographic Research Papers 53:804–819.

Mantua, N. J. and S. R. Hare. 2002. The Pacific decadal oscillation. Journal of Oceanography 58:35–44.

Melin, S. R., A. J. Orr, J. D. Harris, J. L. Laake, and R. L. DeLong. 2012. California Sea Lions: An Indicator for Integrated Ecosystem Assessment of the California Current System. California Cooperative Oceanic Fisheries Investigations Reports 53:140–152.

Melin, S. R., A. J. Orr, J. D. Harris, J. L. Laake, R. L. Delong, F. M. D. Gulland, and S. Stoudt. 2010. Unprecedented Mortality of California Sea Lion Pups Associated with Anomalous Oceanographic Conditions Along the Central California Coast in 2009. California Cooperative Oceanic Fisheries Investigations Reports 51:182–194.

Peterson, W. T. and J. E. Keister. 2003. Interannual variability in copepod community composition at a coastal station in the northern California Current: a multivariate approach. Deep-Sea Research Part I I—Topical Studies in Oceanography 50:2499–2517.

Piatt, J. F. and A. M. Springer. 2003. Advection, pelagic food webs and the biogeography of seabirds in Beringia. Marine Ornithology 31:141–154.

Pikitch, E., P. D. Boersma, I. L. Boyd, D. O. Conover, P. Cury, T. Essington, S. S. Heppell, E. D. Houde, M. Mangel, D. Pauly, É. Plagányi, K. Sainsbury, and R. S. Steneck. 2012. Little Fish, Big Impact: Managing a Crucial Link in Ocean Food Webs. Lenfest Ocean Program, Washington, DC. 108 pp.

Ralston, S., K. M. Sakuma, and J. C. Field. 2013. Interannual variation in pelagic juvenile rockfish (*Sebastes* spp.) abundance—going with the flow. Fisheries Oceanography 22:288–308.

Roesler, C. S. and D. B. Chelton. 1987. Zooplankton variability in the California Current, 1951–82. California Cooperative Oceanic Fisheries Investigations Report 28:59–96.

Santora, J. A., J. C. Field, I. D. Schroeder, K. M. Sakuma, B. K. Wells, and W. J. Sydeman. 2012. Spatial ecology of krill, micronekton and top predators in the central California Current: Implications for defining ecologically important areas. Progress in Oceanography 106:154–174.

Santora, J. A., W. J. Sydeman, I. D. Schroeder, B. K. Wells, and J. C. Field. 2011. Mesoscale structure and oceanographic determinants of krill hotspots in the California Current: Implications for trophic transfer and conservation. Progress in Oceanography 91:397–409.

Scott, D., P. Scofield, C. Hunter, and D. Fletcher. 2008. Decline of Sooty Shearwaters, Puffinus griseus, on The Snares, New Zealand. Papers and Proceedings of the Royal Society of Tasmania 142:185–196.

Smith, P. E. 1972. The increase in spawning biomass of northern anchovy, *Engraulis mordax*. Fishery Bulletin 70:849–874.

Suchman, C. L., R. D. Brodeur, E. A. Daly, and R. L. Emmett. 2012. Large medusae in surface waters of the Northern California Current: variability in relation to environmental conditions. Hydrobiologia 690:113–125.

Sydeman, W. J., M. M. Hester, J. A. Thayer, F. Gress, P. Martin, and J. Buffa. 2001. Climate change, reproductive performance and diet composition of marine birds in the southern California Current system, 1969–97. Progress in Oceanography 49:309–329.

Sydeman, W. J., K. A. Hobson, P. Pyle, and E. B. McLaren. 1997. Trophic relationships among seabirds in central California: Combined stable isotope and conventional dietary approach. Condor 99:327–336.

Veit, R. R., P. Pyle, and J. A. McGowan. 1996. Ocean warming and long-term change in pelagic bird abundance within the California current system. Marine Ecology Progress Series 139:11–18.

Wells, B. K., J. A. Santora, J. C. Field, R. B. MacFarlane, B. B. Marinovic, and W. J. Sydeman. 2012. Quantifying the dynamics of Chinook salmon (*Oncorhynchus tshawytscha*) relative to prey availability in the central California coastal region. *Marine Ecology Progress Series*. 457:125–137

Wolter, K. and M. S. Timlin. 1998. Measuring the strength of ENSO events—how does 1997/98 rank? Weather 53:315–324.

2014 STATE OF THE CALIFORNIA CURRENT REPORT

CALIFORNIA CURRENT INTEGRATED ECOSYSTEM ASSESSMENT

SECTION 3 – FOCAL COMPONENTS OF ECOLOGICAL INTEGRITY

3.1 & 3.2 Northern Copepod Biomass Anomaly and Copepod species richness off Washington and Oregon

Please see the following:

Peterson, W. T., J. E. Keister. 2003. Interannual variability in copepod community composition at a coastal station in the northern California Current: a multivariate approach. Deep Sea Research Part II: Topical Studies in Oceanography, 50:2499-2517.

http://www.sciencedirect.com/science/article/pii/S0967064503001309

Peterson, W. T. 2009. Copepod species richness as an indicator of long–term changes in the coastal ecosystem of the northern California Current. California Cooperative Oceanic Fisheries Investigations (CalCOFI) Report 50:73-81.

http://calcofi.org/publications/calcofireports/v50/73-81_Peterson.pdf

3.3 Coastal Pelagic Species: Anchovy, Sardine, and Forage Diversity

Among other locations, much of the information below is expanded upon in Wells et al. (2013). The three regional surveys use different gear types (bongo nets for larvae, and two different trawls). The catchability of the gear is different in these surveys, and time series in this report should not be considered directly comparable.

Southern California

The California Cooperative Oceanic Fisheries Investigations (CalCOFI) provides the longest and most complete estimates of larval abundance of over 400 combined fish and cephalopod species (Table C1). Here we utilized CalCOFI ichthyoplankton data from 1951 to 2011 collected by oblique vertical plankton tows as described by Kramer et al (1972) and Smith and Richardson (1977) (see review of gear changes in McClatchie 2013). All data are from the core CalCOFI sampling area (lines 76.7-93.3, stations 28.0 – 120.0; Figure C1) for years when the core area was sampled during each quarter of the year. Mean larval abundances (larvae/10 m^2) were estimated for each 3.3-line by 10-station cell in the core area for each quarter, and then cells were summed over the year. Means across the entire time series were then calculated using the delta-lognormal distribution. This procedure standardized the data given unequal sampling effort during some cruises, many zero catches, and seasonal but variable patterns of spawning for the fishes analyzed.

The table below defines those fishes classified as cool- and warm-water mesopelagics.

Genus species	Common name	Subcategory
Bathylagus pacificus	slender blacksmelt	cool-water
Bathylagus wesethi	snubnose blacksmelt	warm-water
Ceratoscopelus townsend	fangtooth lanternfish	warm-water
Diogenichthys atlanticus	longfin lanternfish	warm-water
Diogenichthys laternatus	diogenes laternfish	warm-water
Leuroglossus stilbius	California smoothtongue	cool-water
Lipolagus ochotensis	eared blacksmelt	cool-water
Protomyctophum crockeri	California flashlightfish	cool-water
Stenobrachius leucopsarus	northern lampfish	cool-water
Symbolophorus californiensis	bigfin laternfish	warm-water
Tarletonbeania crenularis	blue laternfish	cool-water
Triphoturus mexicanus	Mexican lampfish	warm-water
Vinciguerria spp.	Lightfishes	warm-water

Central California

Observations reported here are based on midwater trawl surveys (modified Cobb) that target young-of-the-year (YOY) rockfish and other groundfish, but that also samples small (1–20 cm) pelagic and mesopelagic fishes and invertebrates. The survey is conducted in May and June of each year, when YOY groundfish are still in their pelagic stage, and the core area of the survey is conducted off central California (a region running from just south of Monterey Bay to just north of Point Reyes, CA, and from near the coast to about 60 km offshore) since 1983 (see Sakuma et al. 2006 for methods and details on spatial extent of survey). Since the early 2000s this and comparable sampling programs have expanded in range to survey the entire coast in most years, in order to develop coastwide indices of abundance for use in groundfish stock assessments, as those time series are of shorter duration they were not included here.

However, preliminary analysis of rockfish catches from a broader spatial scale demonstrate some coastwide coherence in catch rates, albeit with strong regional differences in some years (Ralston and Stewart 2013). Certain taxa were not consistently enumerated prior to 1990 (e.g., krill and market squid). Data for the 2013 survey presented here are preliminary, and data collected since 2009 do not account for potential vessel-related differences in catchability. Ongoing analyses indicate that transport in the California Current is a primary forcing factor for changes in the abundance of the taxa collected in this survey (Ralston et al. 2013, Ralston et al. in review).

Northern California

Pelagic nekton catch data were collected by the NWFSC-NOAA Bonneville Power Administration survey surface trawls (Nordic 264) on standard transects and stations between Tatoosh Island, WA, and Cape Perpetua, OR, in June and September from 1998 to 2011. All tows were made during the day at predetermined locations along transects extending off the coast to the shelf break (Brodeur et al. 2005). Numbers of individuals were recorded for each species caught in each haul and were standardized by the horizontal distance sampled by the towed net as CPUE (no. $km^{2\ -1}$ towed). Yearly abundance data were obtained by summing the standardized count data of each species captured during June for each year

Time series plots of standardized yearly abundance data are presented for each of the five most dominant and consistently collected forage species measured (jack mackerel, *Trachurus symmetricus*, Pacific sardine, Northern anchovy, Pacific herring, *Clupea pallasii*, and whitebait smelt, *Allosmerus elongatus*). Although other forage species are caught in these surveys, these five species represent the bulk of the forage fish catch in surface waters during the day. They include migratory species (sardines and some anchovies) that may spawn off the Pacific Northwest or migrate from California (Emmett et al. 2005, Litz et al. 2008). Jack mackerel can be a forage fish at younger ages but off Oregon and Washington are too large to be fed upon by a number of predators such as seabirds or adult rockfishes. They spawn off southern California and arrive during summer to feed off Oregon and Washington. Herring and whitebait smelt are likely spawned locally. A number of these species may have seasonal trends in abundance (Emmett et al. 2005) so may have different trends than taken twice a year but over a broader geographical area. Because the data are log-normally distributed they were log-transformed for this analysis.

Brodeur, R.D., J.P. Fisher, C.A. Morgan, R.L. Emmett, and E. Casillas. 2005. Species composition and community structure of pelagic nekton off Oregon and Washington under variable oceanographic conditions. *Mar. Ecol. Prog. Ser.* 298:41-57.

Emmett, R. L., R. D. Brodeur, T. W. Miller, S. S. Pool, G. K. Krutzikowsky, P. J. Bentley, and J. McCrae. 2005. Pacific sardines (*Sardinops sagax*) abundance, distribution, and ecological relationships in the Pacific Northwest. CalCOFI Report **49**:167-182

Kramer, D., M. Kalin, E. Stevens, J. Thrailkill, and J. Zweifel. 1972. Collecting and processing data on fish eggs and larvae in the California Current region. NOAA Technical Report NMFS CIRC-370.

Litz, M. C., R. L. Emmett, S. S. Heppell, and R. D. Brodeur. 2008. Ecology and distribution of the northern subpopulation of northern anchovy (*Engraulis mordax*) off the U. S. West Coast. CalCOFI Report **49**:167-182.

McClatchie, S.. Regional fisheries oceanography of the California Current system and the CalCOFI program. Springer Berlin. 235pp. ISBN 978-94-007-7222-9, 2013.

Ralston, S., K.M. Sakuma and J.C. Field. 2013. Interannualvariation in pelagic juvenile rockfish abundance– going with the flow. Fisheries Oceanography 22: 288–308.

Ralston, S., and I. Stewart. 2013. Anomalous distributions of pelagic juvenile rockfish on the U.S. West Coast in 2005 and 2006.California Cooperative Oceanic and Fisheries Investigations Reports 54.

Ralston, S., J.C. Field and K.M. Sakuma. In review. Longterm variation in a central California forage assemblage. Journal of Marine Systems.

Sakuma, K. M., S. Ralston, and V.G. Wespestad. 2006. Interannual and spatial variation in the distribution of young-of-the-year rockfish (Sebastes spp.): expanding and coordinating a survey sampling frame. California Cooperative Oceanic Fisheries Investigations Reports 47:127-139.

Smith, P. and S. Richardson. 1977. Standard techniques for pelagic fish egg and larva surveys. FAO Fisheries Technical Paper 175, Food and Agriculture Organization of the United Nations.

Wells, B.K. and 47 authors. 2013. State of the California Current 2012-2013: No such thing as an ‘average’ year. California Cooperative Oceanic Fisheries Investigations Reports. 54:37-71.

3.4 Salmon: Chinook Salmon Abundance

Table S3.1. California ESUs/Stocks and Data available for Abundance Estimates in Figure 3.4.

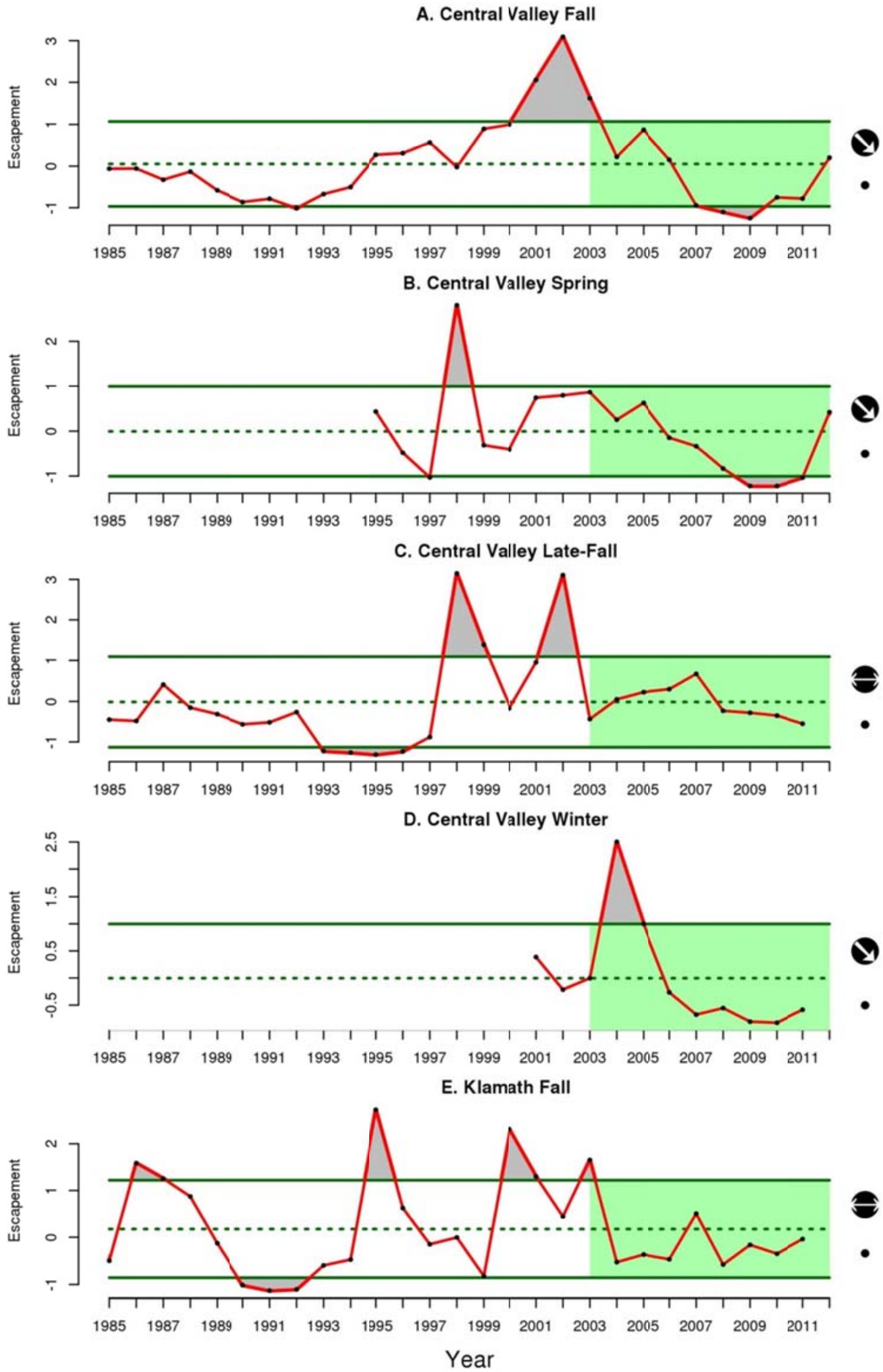
Population	***Data Available: Escapement***	***Period***
Central Valley Fall Run	Escapement to system	1983-2012
Central Valley Late Fall Run	Escapement to system	1971-2011
Central Valley Winter Run	Escapement to system, carcass survey	2001-2011
Central Valley Spring Run	Escapement to Sacramento R.	1970-2008
Klamath R. Fall Run	Escapement to system (Klamath+Trinity)	1978-2012
SONCC Chinook Fall	Umpqua Escapement (Rogue River will be used in later analyses but was unavailable for this report)	1946-2011
Cal Coastal Chinook	Tomki Cr. (Live/Dead Counts)	1979-2011
	Cannon Cr. (live/Dead Counts)	1981-2011
	Sprowl Cr. (Live/Dead Counts)	1974-2011

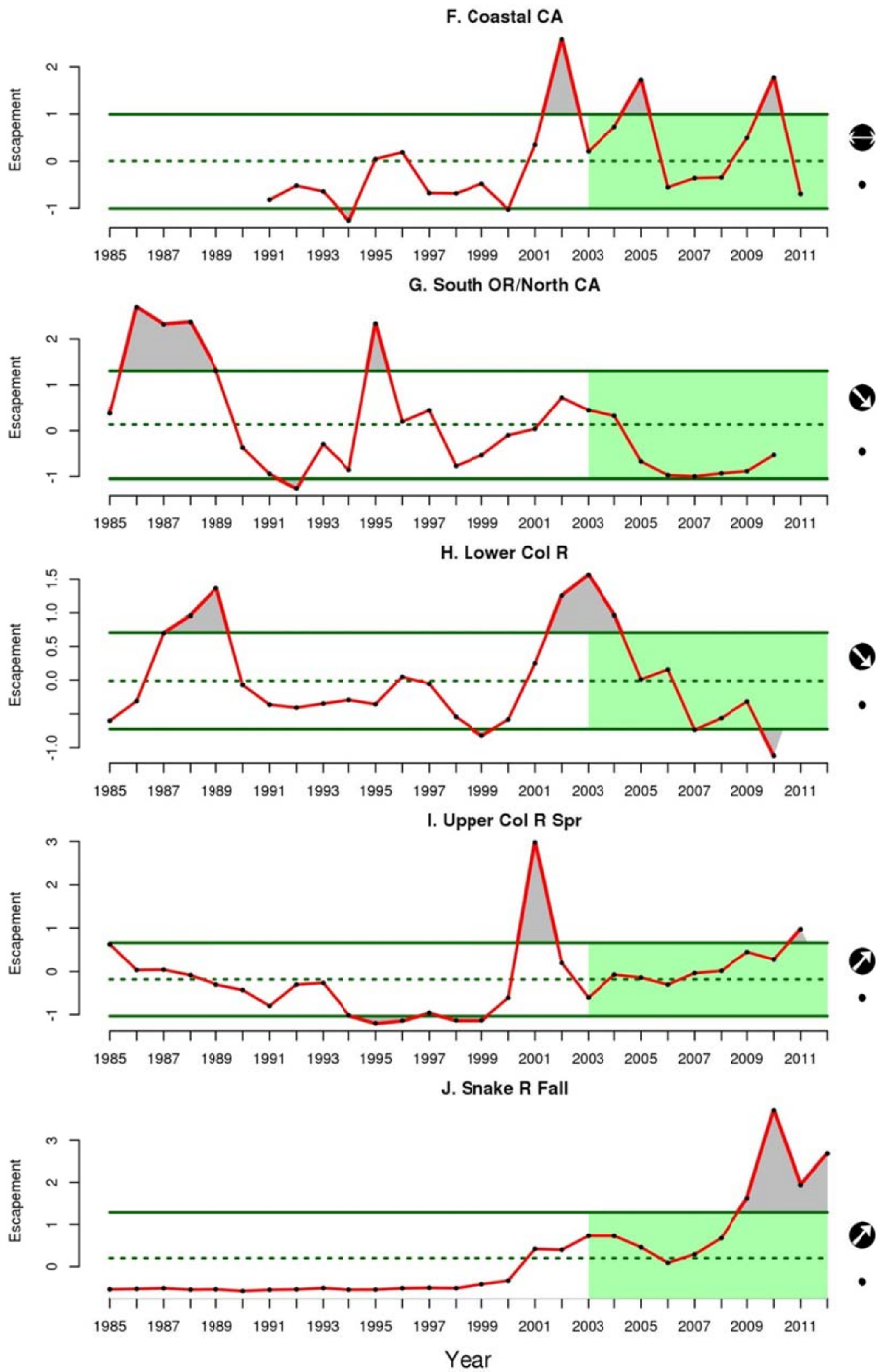
Table S3.2. Oregon-Washington ESUs/stocks and data available for abundance estimates. Each of these series met the criteria for inclusion in the analyses and was used.

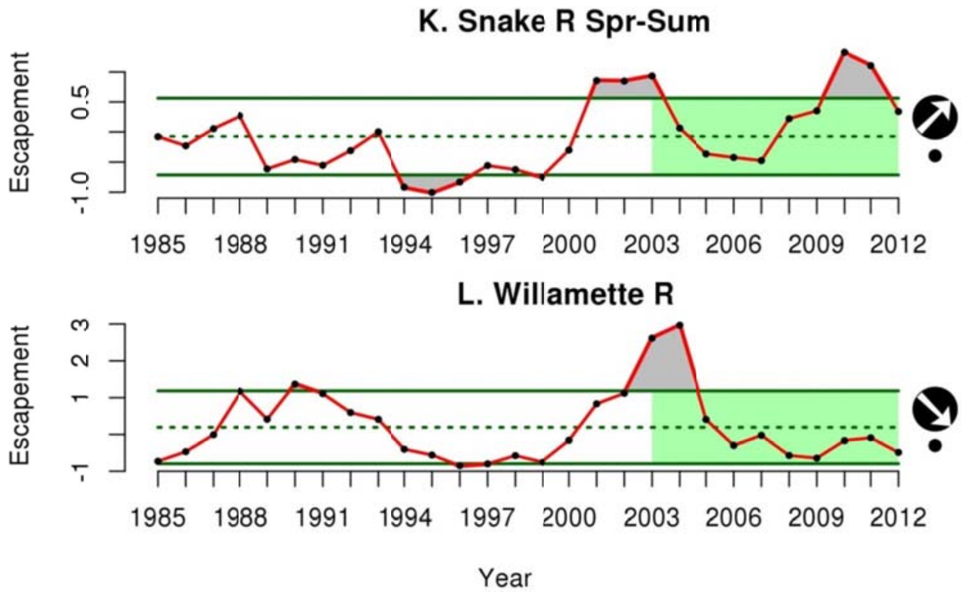
Stock/ESU	**Data Available: Escapement**	**Period**
Lower Columbia R. ESU	Clatskanie R. Fall	1974-2006
	Coweeman R. Fall	1977-2010
	Elochoman R. Fall	1975-2010
	Grays R. Fall	1964-2010
	Kalama R. Fall	1964-2010
	Kalama R. Spring	1980-2009
	Lewis R.	1964-2009
	Lewis R. Fall	1977-2010
	Lower Cowlitz R. Fall	1977-2010
	Mill Cr. Fall	1980-2010
	North Fork Lewis R. Spring	1980-2008
	Sandy R. Fall (Bright)	1981-2007
	Sandy R. Spring	1981-2009

	Toutle R. Fall	1964-2009
	Upper Cowlitz R. Spring	1980-2009
	Upper Gorge Tributaries Fall	1964-2008
	Washougal R. Fall	1977-2010
	White Salmon R. Fall	1976-2009
Snake R. Fall-run ESU	Snake R. Lower Mainstem Fall	1975-2012
Snake R. Spring/Summer-run ESU	Bear Valley Cr.	1960-2012
	Big Cr.	1957-2012
	Camas Cr.	1963-2012
	Catherine Cr. Spring	1955-2011
	Chamberlain Cr.	1985-2012
	East Fork Salmon R.	1960-2012
	East Fork South Fork Salmon R.	1958-2012
	Grande Ronde R. Upper Mainstem	1955-2011
	Imnaha R. Mainstem	1949-2011
	Lemhi R.	1957-2012
	Loon Cr.	1957-2012
	Lostine R. Spring	1959-2011
	Marsh Cr.	1957-2012
	Minam R.	1954-2012
	Pahsimeroi R.	1986-2012
	Salmon R. Lower Mainstem	1957-2012
	Salmon R. Upper Mainstem	1962-2012
	Secesh R.	1957-2011
	South Fork Salmon R. Mainstem	1958-2012
	Sulphur Cr.	1957-2012
	Tucannon R.	1979-2011
	Valley Cr.	1957-2012
	Wenaha R.	1964-2012
	Yankee Fork	1961-2011
Upper Columbia R. Spring-run ESU	Entiat R.	1960-2011
	Methow R.	1960-2011
	Wenatchee R.	1960-2011
Upper Willamette R. ESU	Clackamas R. Spring	1974-2011
	McKenzie R. Spring	1970-2012

Shown below are the time series plots for each population shown in Figure 3.4




F. Coastal CA
G. South OR/North CA
H. Lower Col R
I. Upper Col R Spr
J. Snake R Fall
Escapement
Year
1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011


K. Snake R Spr-Sum
Escapement
0.5
-1.0
1985 1988 1991 1994 1997 2000 2003 2006 2009 2012
L. Willamette R
Escapement
3 2 1 -1
1985 1988 1991 1994 1997 2000 2003 2006 2009 2012
Year

3.6 Mean Trophic Level of West Coast Groundfish

Please see the following:

Tolimieri, N., J. F. Samhouri, V. Simon, B. E. Feist, P. S. Levin. 2013. Linking the trophic fingerprint of groundfishes to ecosystem structure and function in the California Current. Ecosystems 16:1216-1229

http://link.springer.com/article/10.1007/s10021-013-9680-1

3.7 Mammals: California Sea Lion pup production - Supplement

U.S. Stock: Language for U.S. stock estimations is from stock status report (http://www.nmfs.noaa.gov/pr/pdfs/sars/po2011slca.pdf).

There are no international agreements between the U.S., Mexico, and Canada for joint management of California sea lions, and the number of sea lions at the Coronado Islands is not regularly monitored. Consequently, the stock assessment report, http://www.nmfs.noaa.gov/pr/pdfs/sars/po2011slca.pdf, considers only the U.S. Stock, i.e., sea lions at rookeries within the U.S. pup production at the Coronado Islands is minimal (between 12 and 82 pups annually) and does not represent a significant contribution to the overall size of the Pacific Temperate population.

Abundance estimates were determined from four rookeries in southern California and for haulouts in central and northern California. The mean was used when more than one count was available for a given rookery. A regression of the natural logarithm of the pup counts against year indicates that the counts of pups increased at an annual rate of 5.4% between 1975 and 2008, when pup counts for El Niño years (1983, 1984, 1992, 1993, 1998, and 2003) were removed from the 1975-2005 time series. Using 1975-2008 non-El Niño year data, the coefficient of variation for this average annual growth rate (CV=0.04) was computed via bootstrap sampling of the count data.

San Miguel Island: Language provided by S. Melin and available in Wells et al (2013**).**

San Miguel Island, California (34.03° N, 120.4° W) is one of the largest colonies of California sea lions, representing about 45% of the U. S. breeding population. As such, it is a useful colony to measure trends and population responses to changes in the marine environment.

We used the number of pups alive at the time of the live pup census conducted in late July and the average weights of pups at 4 months and 7 months of age between 1997 and 2012 as indices of the population response to annual conditions in the CCS.

The number of live pups in late July represents the number of pups that survived from birth to about 6 weeks of age. Live pups were counted after all pups were born (between 20-30 July) each year. A mean of the number of live pups was calculated from the total number of live pups counted by each observer.

Each year, between 300 and 500 pups were weighed when about 4 months old. Pups were sexed, weighed, tagged, branded, and released. Up to 60 pups were captured in February and weighed and measured at 7 months of age. Of the 60 pups captured in February, up to 30 pups were branded and provided a longitudinal dataset for estimating a daily growth rate between 4 months and 7 months old.

We used a linear mixed-effects model fit by REML in R to predict average weights on 1 October and 1 February in each year because the weighing dates were not the same among years. The model contained random effects with a sex and days interaction (days = the number of days between weighing and 1 October or 1 February) that allowed the growth rate to vary by sex and year, and a full interaction fixed effects of sex and days. The average weights between 1997 and 2012 were compared to the long-term average for the average pup weights between 1975 and 2012. More details can be found in Wells et al. (2013).

Wells, B.K. and 47 authors. 2013. State of the California Current 2012-2013: No such thing as an 'average' year. California Cooperative Oceanic Fisheries Investigations Reports. 54:37-71.

2014 STATE OF THE CALIFORNIA CURRENT REPORT

CALIFORNIA CURRENT INTEGRATED ECOSYSTEM ASSESSMENT

SECTION 4 – HUMAN ACTIVITIES

4.1 Total Landings by Major Fisheries

Commercial landings by state

Figures S4.1-S4.7 show the time-series of commercial landings for different species groups in the CCLME by West Coast state (California, Oregon and Washington), with graphic indicators of two relative statistics on the right hand side. The arrow at the top right indicates whether the trend of the last five-years is positive (arrow up), negative (arrow down) or unchanged (arrow sideways). The sign at the bottom right shows whether the mean of the last five years is greater than (a plus sign), less than (a negative sign) or within one standard deviation of the mean (a large dot) of the entire time series.

These are landings from shoreside commercial fisheries. It also includes tribal removals and catches from exempted fishing permit studies. Commercial landings represent the bulk of fishery removals for those species with high retention rates, which are often highly priced, but not for bycatch species that are often discarded when caught. These landings, therefore, may not thoroughly represent changes in fishery removals, and will also reflect changes in markets or/and management measures employed by the Pacific Fishery Management Council and NMFS to prevent overfishing. Landings of Pacific hake are reported separately from other groundfish species, since the Pacific hake fishery is the largest (by weight) on the U.S. West Coast, and, when combined with other species, hake landings even in the shoreside fishery alone dominate the landings for the entire group, and conceal changes in catch of other groundfish species.

Since 1981, landings of groundfish (without Pacific hake) followed the similar trends in all three states. They decreased in all three states, in part due to management measures, and stayed relatively stable during the most recent years (Fig. S4.1). Landings of highly migratory species and shrimp also most recently had similar dynamics in all three states, even though in the long term landings in different states had different trends (Figs. S4.4, S4.7). Landings of Pacific hake from the shoreside sector, on the contrary, exhibited different dynamics in all three states in the last five years; they decreased in California, increased in Oregon and did not significantly change in Washington (Fig. S4.2). Landings of coastal pelagic species were stable in California and Oregon, but most recently were increasing in Washington (Fig. S4.3). Crab and salmon landings in the last five years were stable in Oregon and Washington, and increasing in California (Figs. S4.5-S4.6).

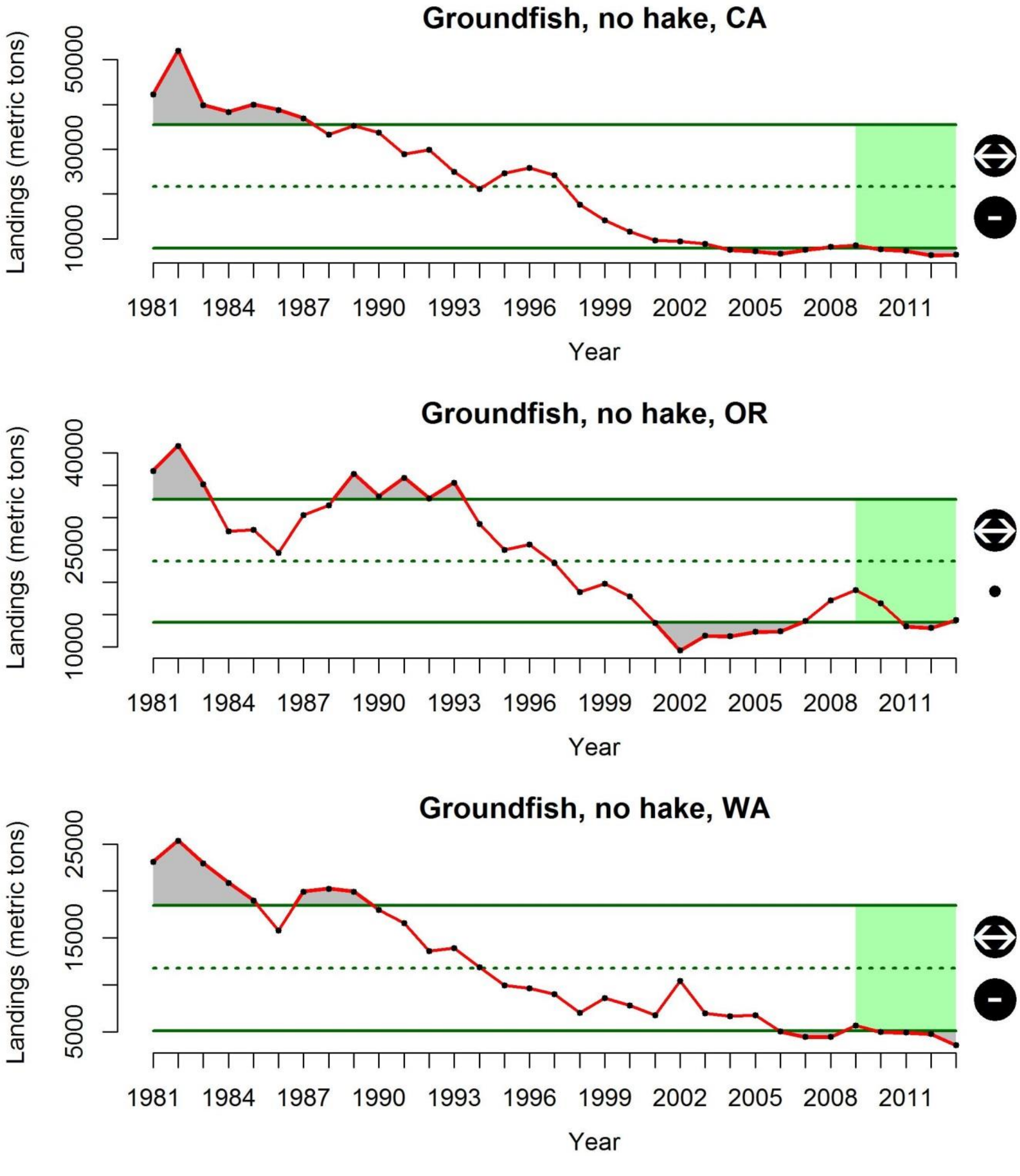


Figure S4.1. The time-series of groundfish landings (Pacific hake excluded) for West Coast states, with two relative statistics on the right hand side: the arrow in top right indicates whether the trend of the last five-years is positive (arrow up), negative (arrow down) or unchanged (arrow sideways); the sign at the bottom right shows whether the mean of the last five years is greater than (a plus sign), less than (a negative sign) or within 1SD of the mean (a large dot) of the entire time series.

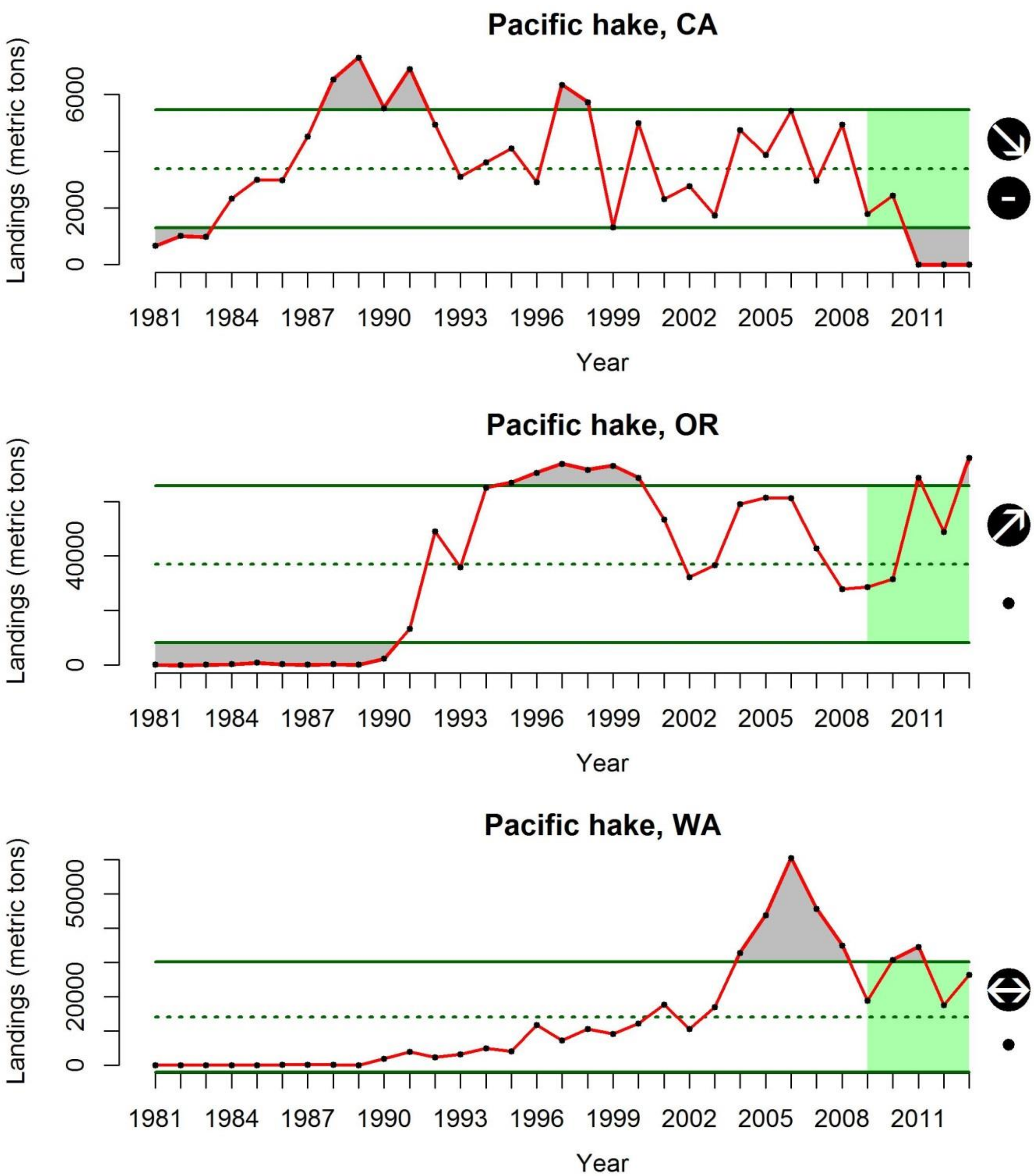


Figure S4.2. The time-series of shoreside Pacific hake landings for West Coast states, with two relative statistics on the right hand side: the arrow in top right indicates whether the trend of the last five-years is positive (arrow up), negative (arrow down) or unchanged (arrow sideways); the sign at the bottom right shows whether the mean of the last five years is greater than (a plus sign), less than (a negative sign) or within 1SD of the mean (a large dot) of the entire time series.

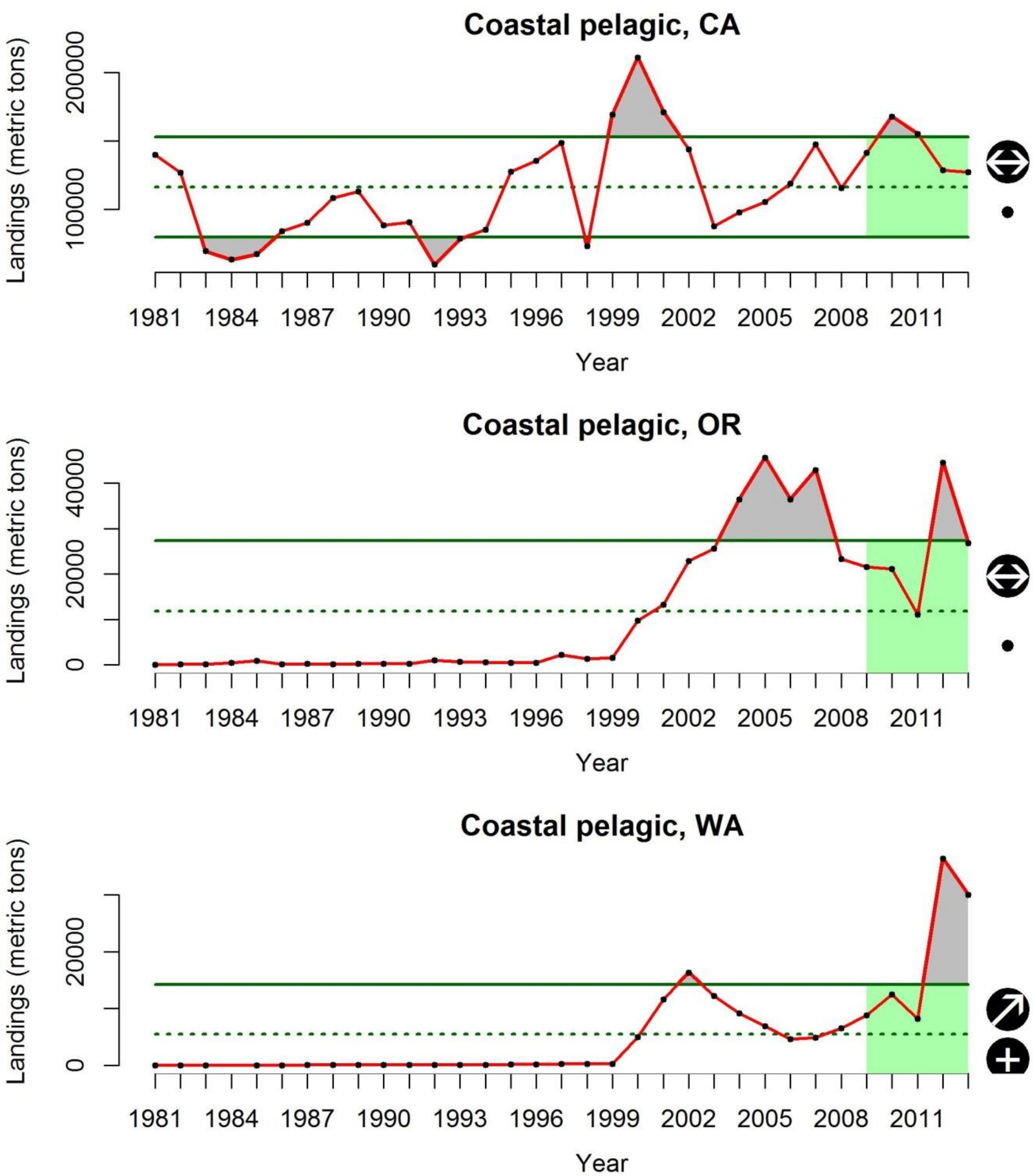


Figure S4.3. The time-series of coastal pelagic species landings for West Coast states, with two relative statistics on the right hand side: the arrow in top right indicates whether the trend of the last five-years is positive (arrow up), negative (arrow down) or unchanged (arrow sideways); the sign at the bottom right shows whether the mean of the last five years is greater than (a plus sign), less than (a negative sign) or within 1SD of the mean (a large dot) of the entire time series.

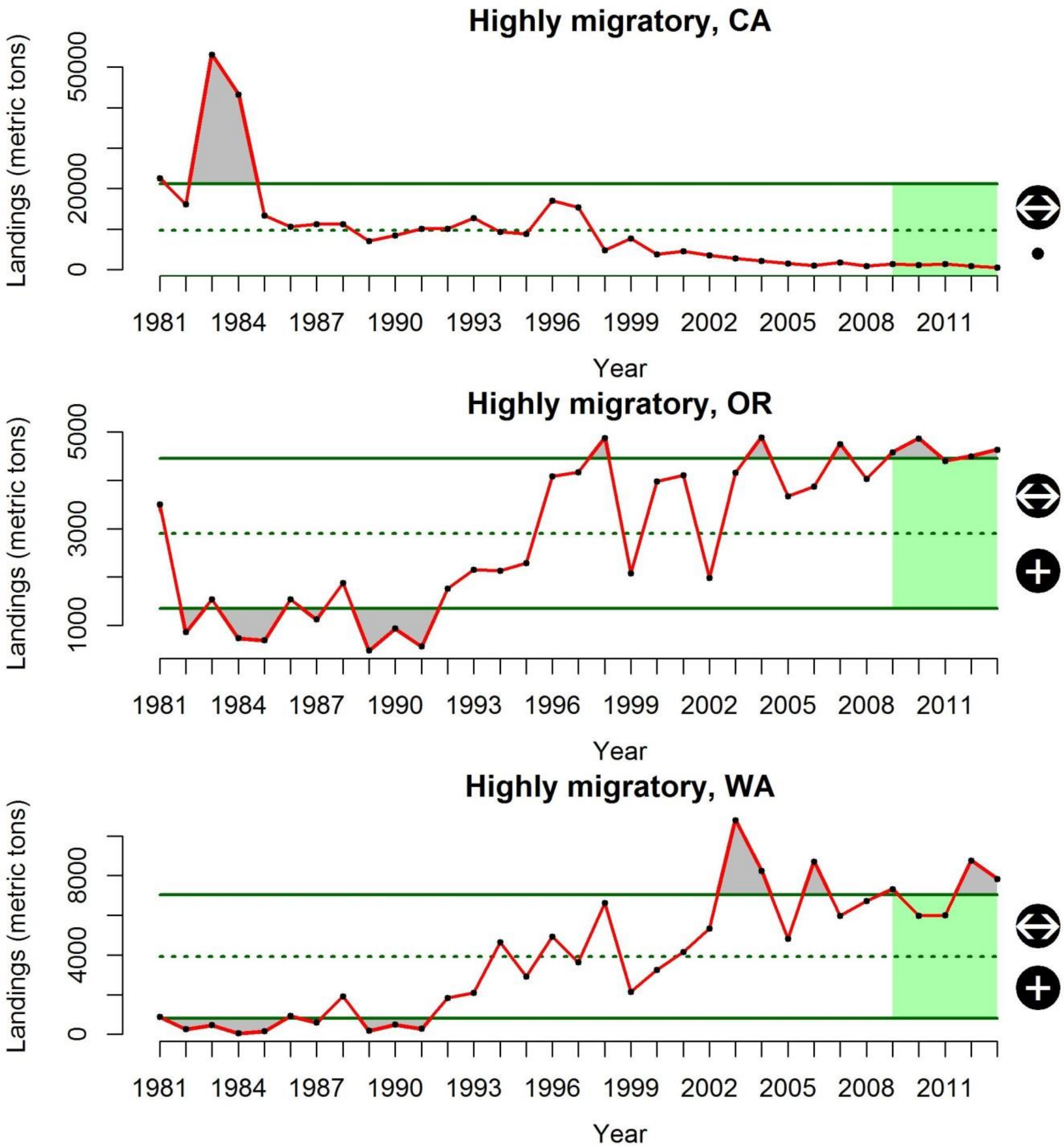


Figure S4.4. The time-series of highly migratory species landings for West Coast states, with two relative statistics on the right hand side: the arrow in top right indicates whether the trend of the last five-years is positive (arrow up), negative (arrow down) or unchanged (arrow sideways); the sign at the bottom right shows whether the mean of the last five years is greater than (a plus sign), less than (a negative sign) or within 1SD of the mean (a large dot) of the entire time series.

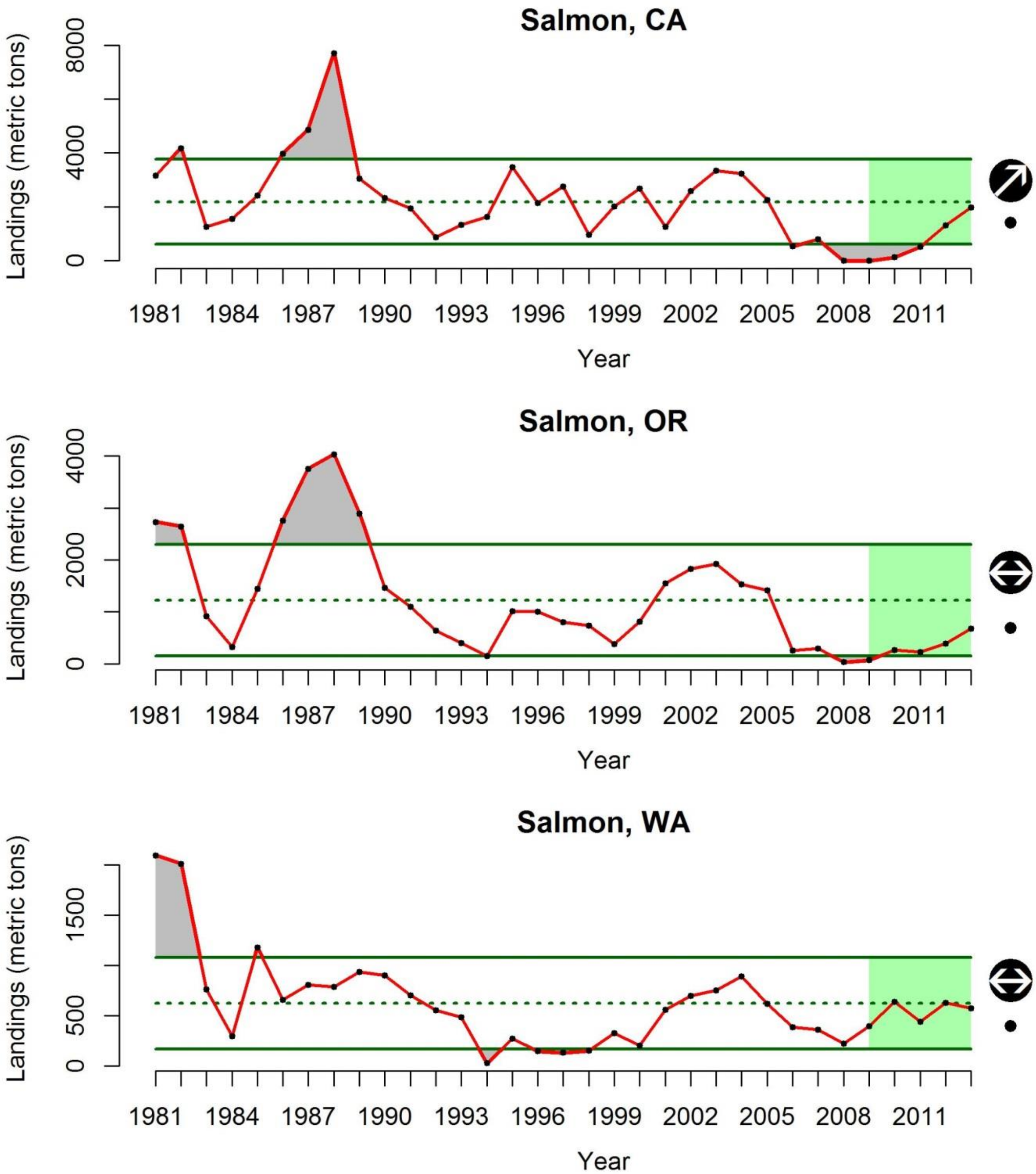


Figure S4.5. The time-series of salmon landings for West Coast states, with two relative statistics on the right hand side: the arrow in top right indicates whether the trend of the last five-years is positive (arrow up), negative (arrow down) or unchanged (arrow sideways); the sign at the bottom right shows whether the mean of the last five years is greater than (a plus sign), less than (a negative sign) or within 1SD of the mean (a large dot) of the entire time series.

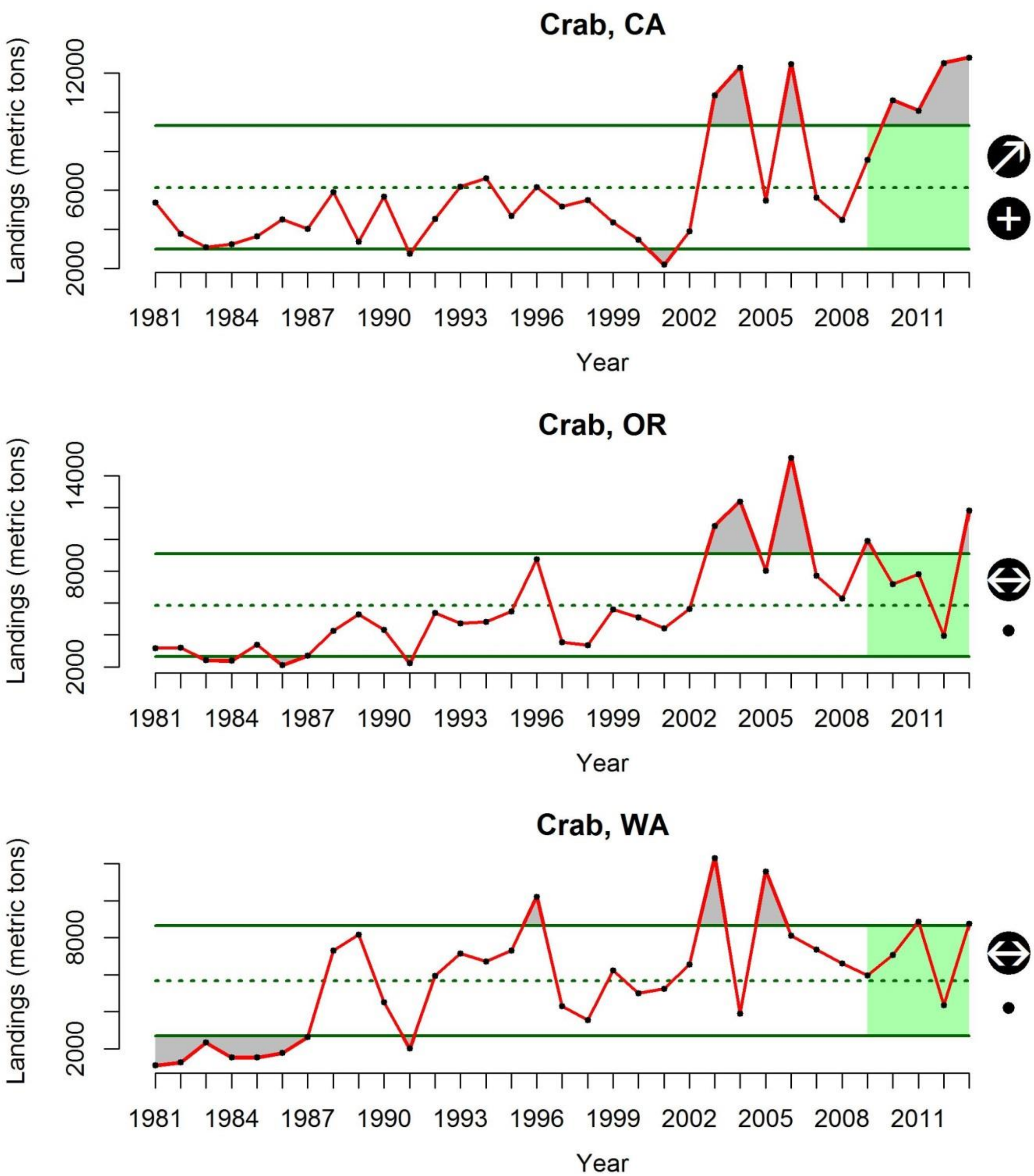


Figure S4.6. The time-series of crab landings for West Coast states, with two relative statistics on the right hand side: the arrow in top right indicates whether the trend of the last five-years is positive (arrow up), negative (arrow down) or unchanged (arrow sideways); the sign at the bottom right shows whether the mean of the last five years is greater than (a plus sign), less than (a negative sign) or within 1SD of the mean (a large dot) of the entire time series.

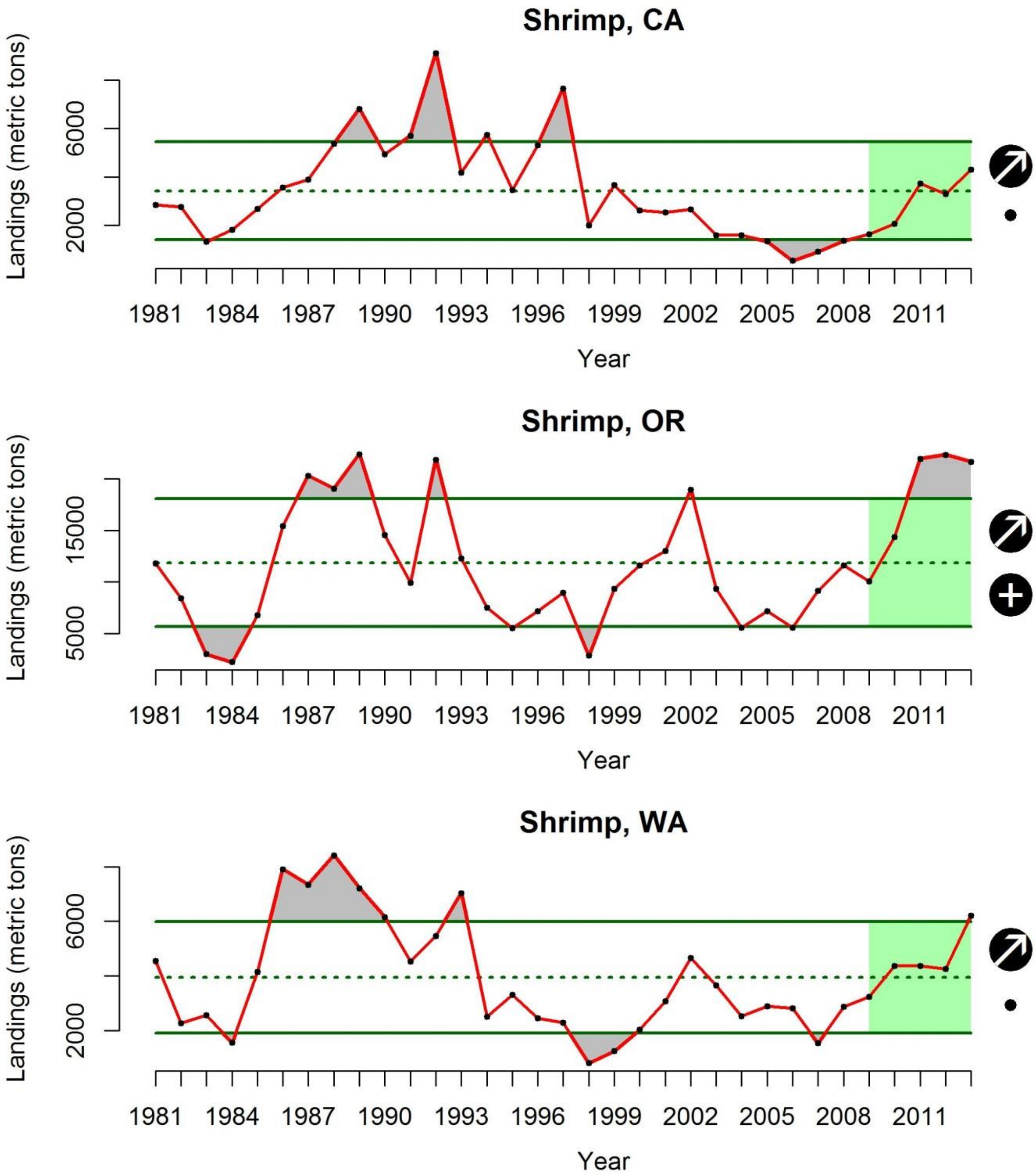


Figure S4.7. The time-series of shrimp landings for West Coast states, with two relative statistics on the right hand side: the arrow in top right indicates whether the trend of the last five-years is positive (arrow up), negative (arrow down) or unchanged (arrow sideways); the sign at the bottom right shows whether the mean of the last five years is greater than (a plus sign), less than (a negative sign) or within 1SD of the mean (a large dot) of the entire time series.

Price per pound by state

Figures S4.8-S4.14 show time-series of average price per pound for different species groups in the CCLME by West Coast state (California, Oregon and Washington), with graphic indicators of two relative statistics on the right hand side. The arrow at the top right indicates whether the trend of the last five-years is positive (arrow up), negative (arrow down) or unchanged (arrow sideways). The sign at the bottom right shows whether the mean of the last five years is greater than (a plus sign), less than (a negative sign) or within one standard deviation of the mean (a large dot) of the entire time series.

Price per pound of groundfish (without Pacific hake), highly migratory species, salmon and crab exhibit similar long term and short term trends in all three states (Figs. S4.8, 11,12,13).Groundfish prices increased on the long term, but stayed relatively stable during the last five years, while prices of highly migratory species, samon and crab had positive long and short term dynamics. For Pacific hake, price per pound has been increasing in the all three states in the long term, but the mean of the last five years was greater than one standard deviation of the mean of the entire time series in both California and Oregon, and stayed within one standard deviation of the mean in Washington (Fig. S4.9). Price per pound of coastal pelagic species over the last five years followed a positive trend in California, but was relatively stable in Oregon and Washington (Fig. S4.10). There has been substantial variation in the price of shrimp since 1981, but in the last five years it has been increasing in Oregon, and stayed relatively stable in California and Washington (Fig. S4.14).

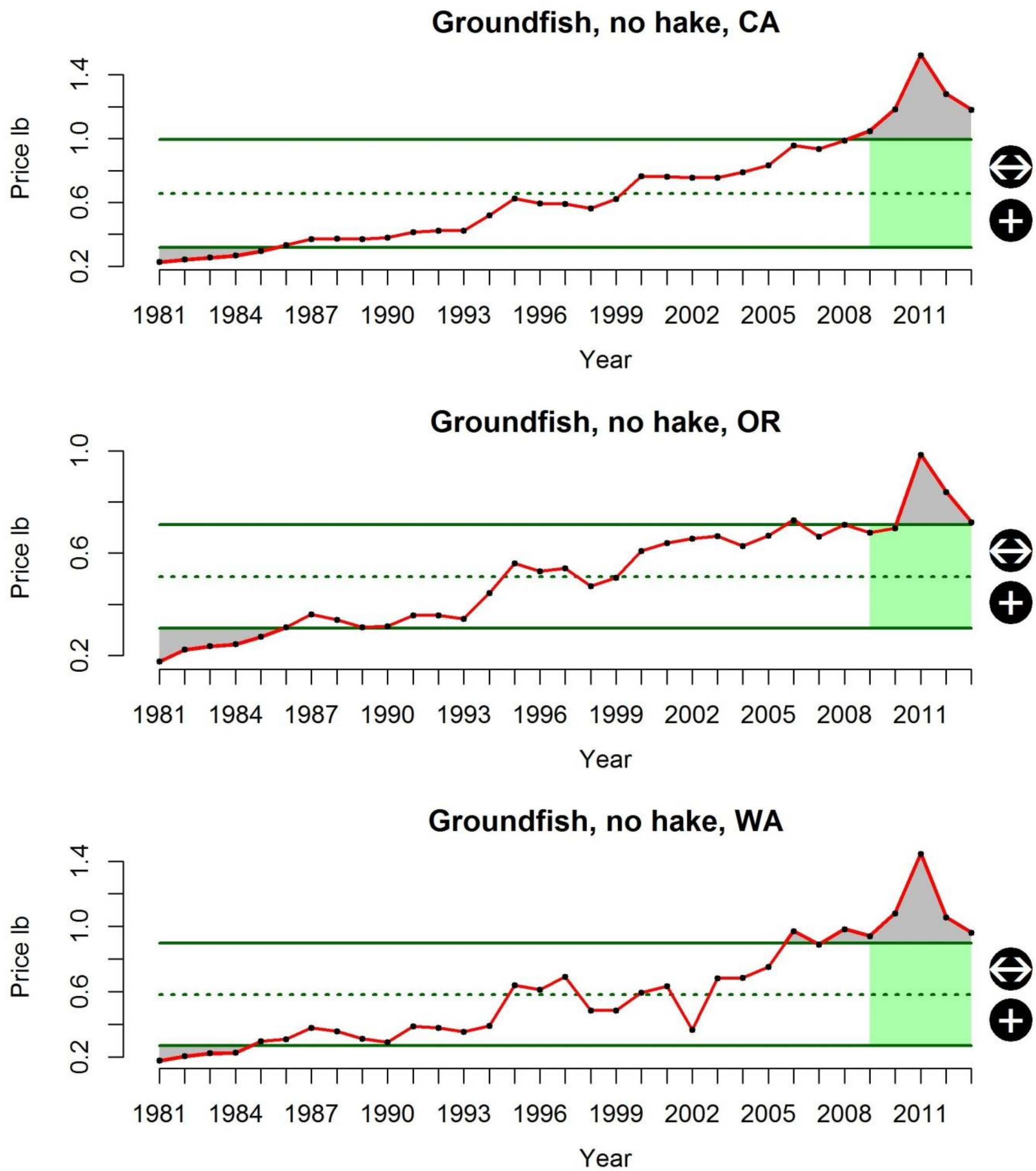


Figure S4.8. The time-series of groundfish average price per pound (Pacific hake excluded) for West Coast states, with two relative statistics on the right hand side: the arrow in top right indicates whether the trend of the last five-years is positive (arrow up), negative (arrow down) or unchanged (arrow sideways); the sign at the bottom right shows whether the mean of the last five years is greater than (a plus sign), less than (a negative sign) or within 1SD of the mean (a large dot) of the entire time series.

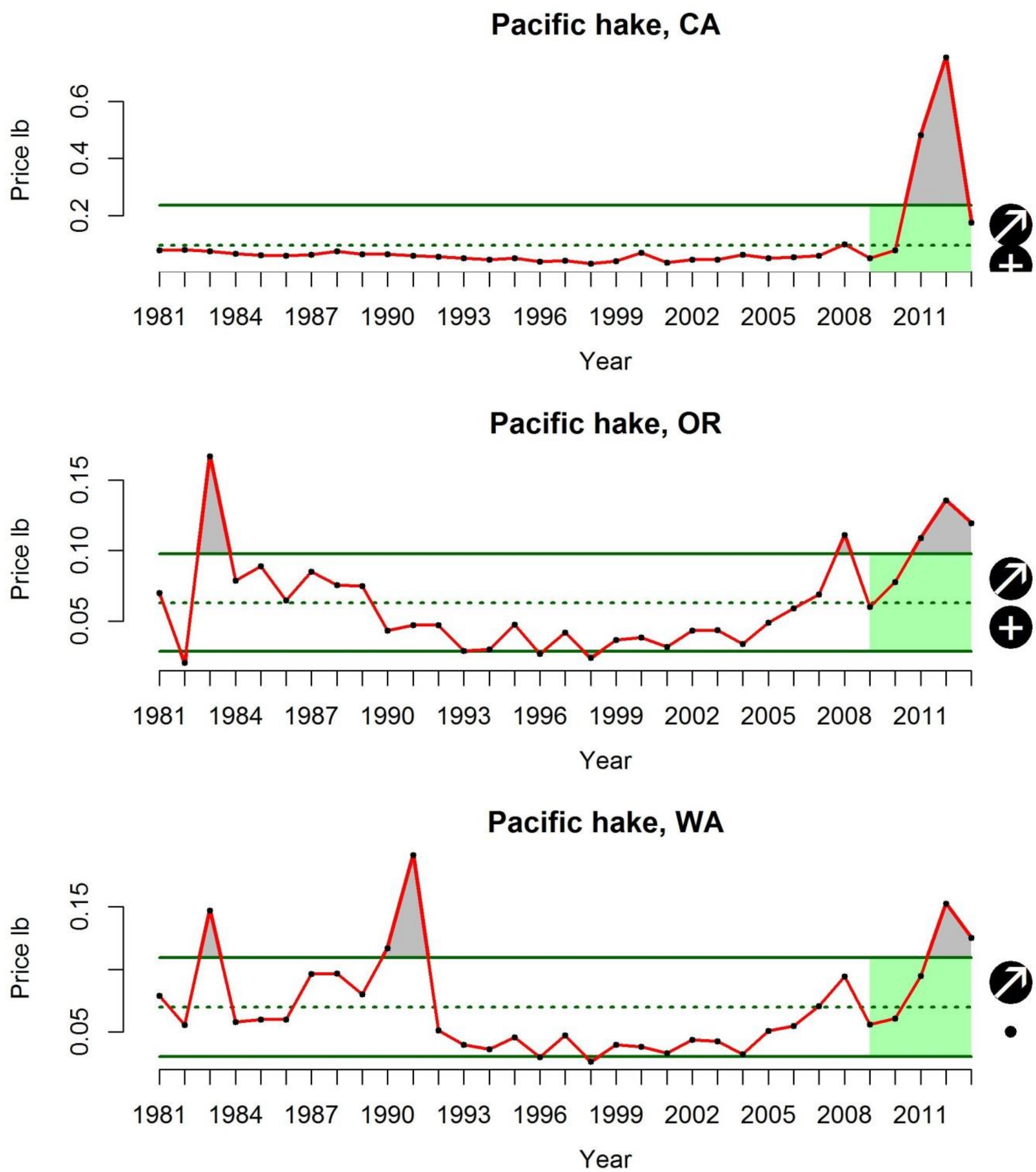
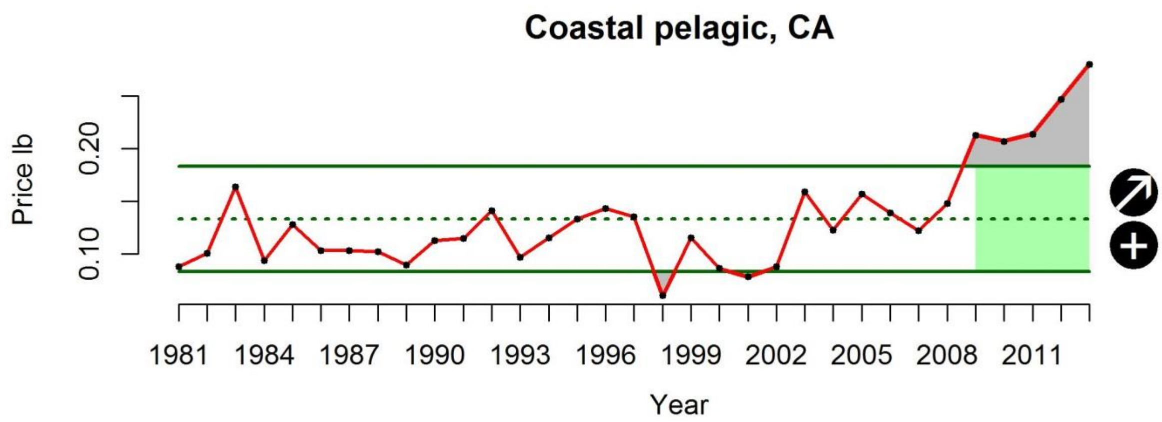
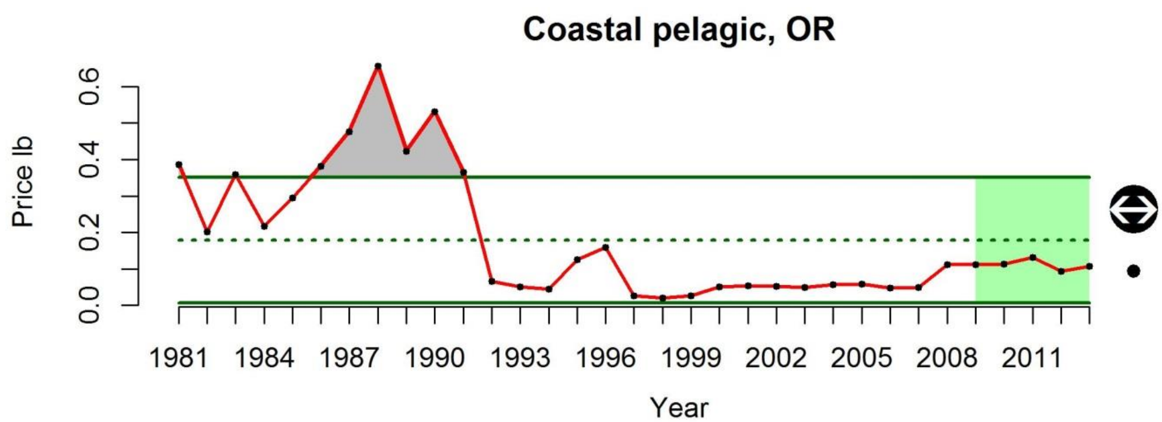


Figure S4.9. The time-series of shoreside Pacific hake average price per pound for West Coast states, with two relative statistics on the right hand side: the arrow in top right indicates whether the trend of the last five-years is positive (arrow up), negative (arrow down) or unchanged (arrow sideways); the sign at the bottom right shows whether the mean of the last five years is greater than (a plus sign), less than (a negative sign) or within 1SD of the mean (a large dot) of the entire time series.





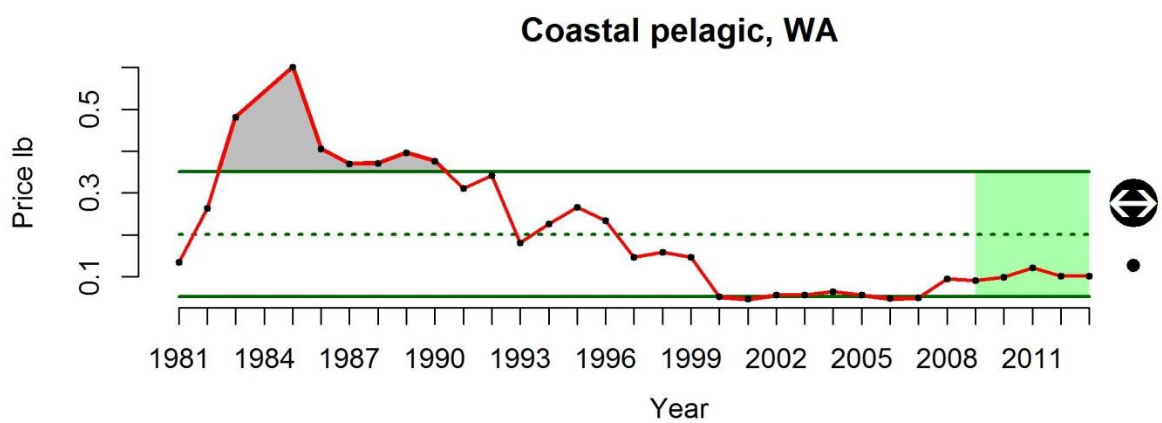


Figure S4.10. The time-series of coastal pelagic species average price per pound for West Coast states, with two relative statistics on the right hand side: the arrow in top right indicates whether the trend of the last five-years is positive (arrow up), negative (arrow down) or unchanged (arrow sideways); the sign at the bottom right shows whether the mean of the last five years is greater than (a plus sign), less than (a negative sign) or within 1SD of the mean (a large dot) of the entire time series.

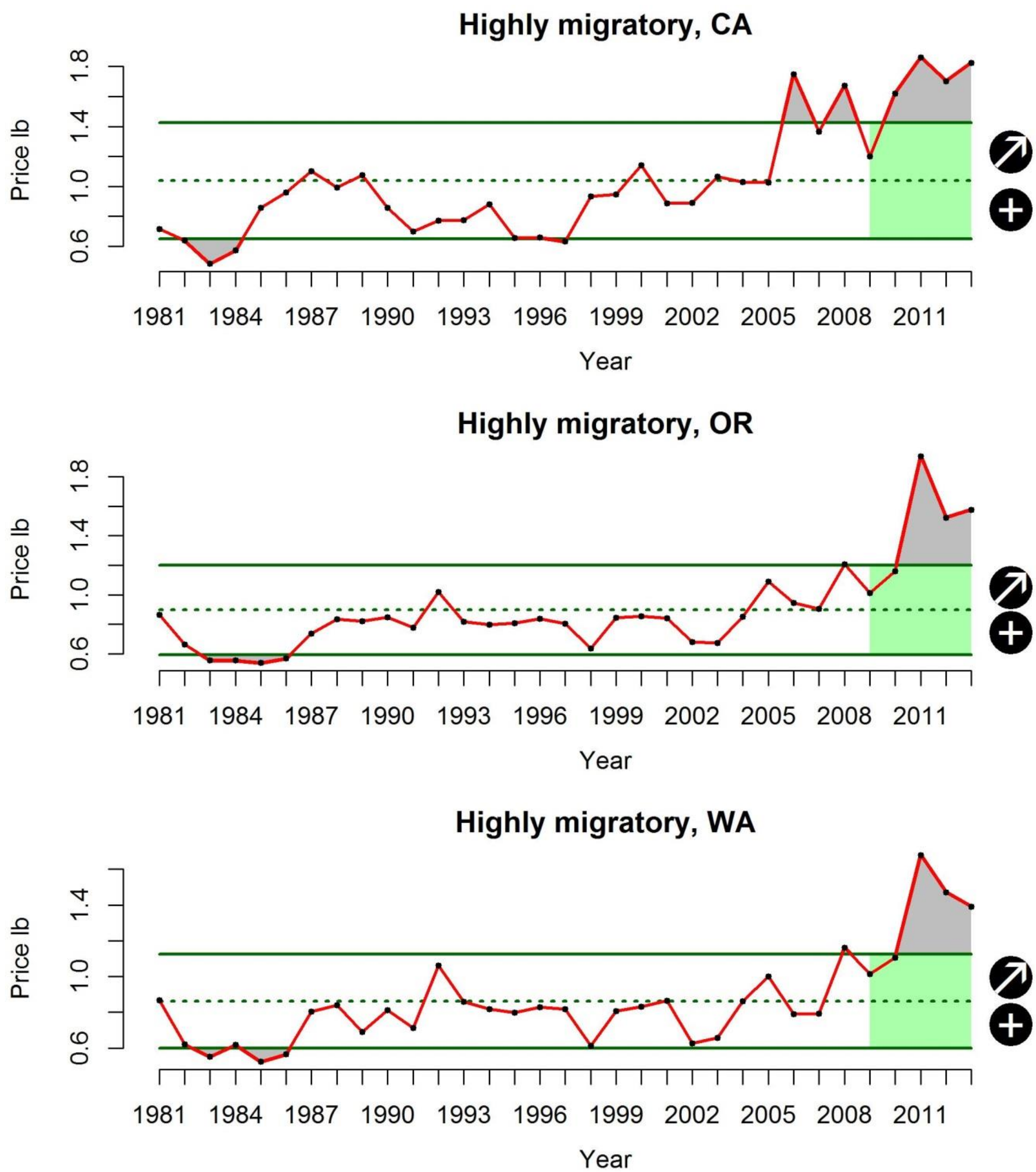


Figure S4.11. The time-series of highly migratory species average price per pound for West Coast states, with two relative statistics on the right hand side: the arrow in top right indicates whether the trend of the last five-years is positive (arrow up), negative (arrow down) or unchanged (arrow sideways); the sign at the bottom right shows whether the mean of the last five years is greater than (a plus sign), less than (a negative sign) or within 1SD of the mean (a large dot) of the entire time series.

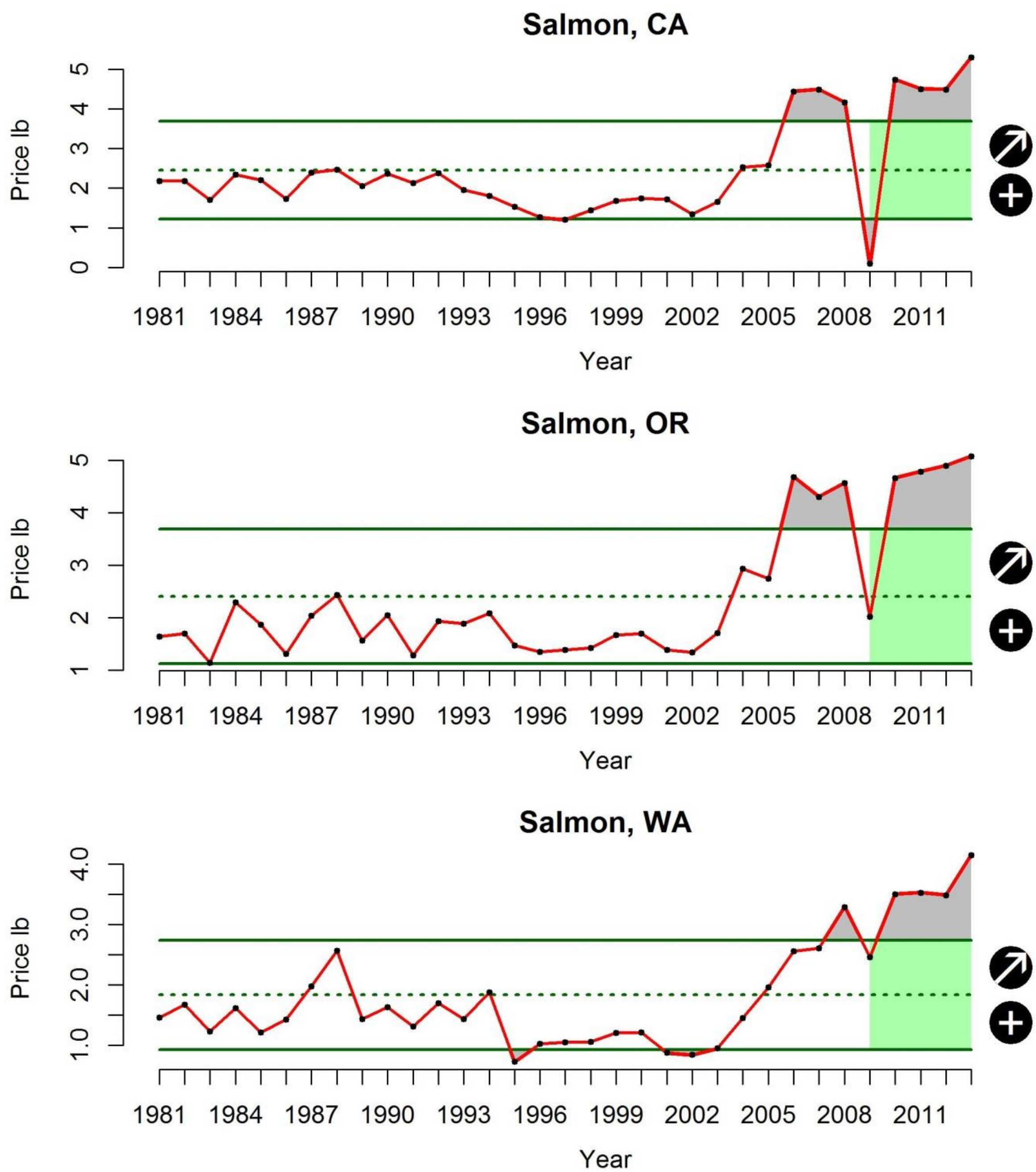


Figure S4.12. The time-series of salmon average price per pound for West Coast states, with two relative statistics on the right hand side: the arrow in top right indicates whether the trend of the last five-years is positive (arrow up), negative (arrow down) or unchanged (arrow sideways); the sign at the bottom right shows whether the mean of the last five years is greater than (a plus sign), less than (a negative sign) or within 1SD of the mean (a large dot) of the entire time series.

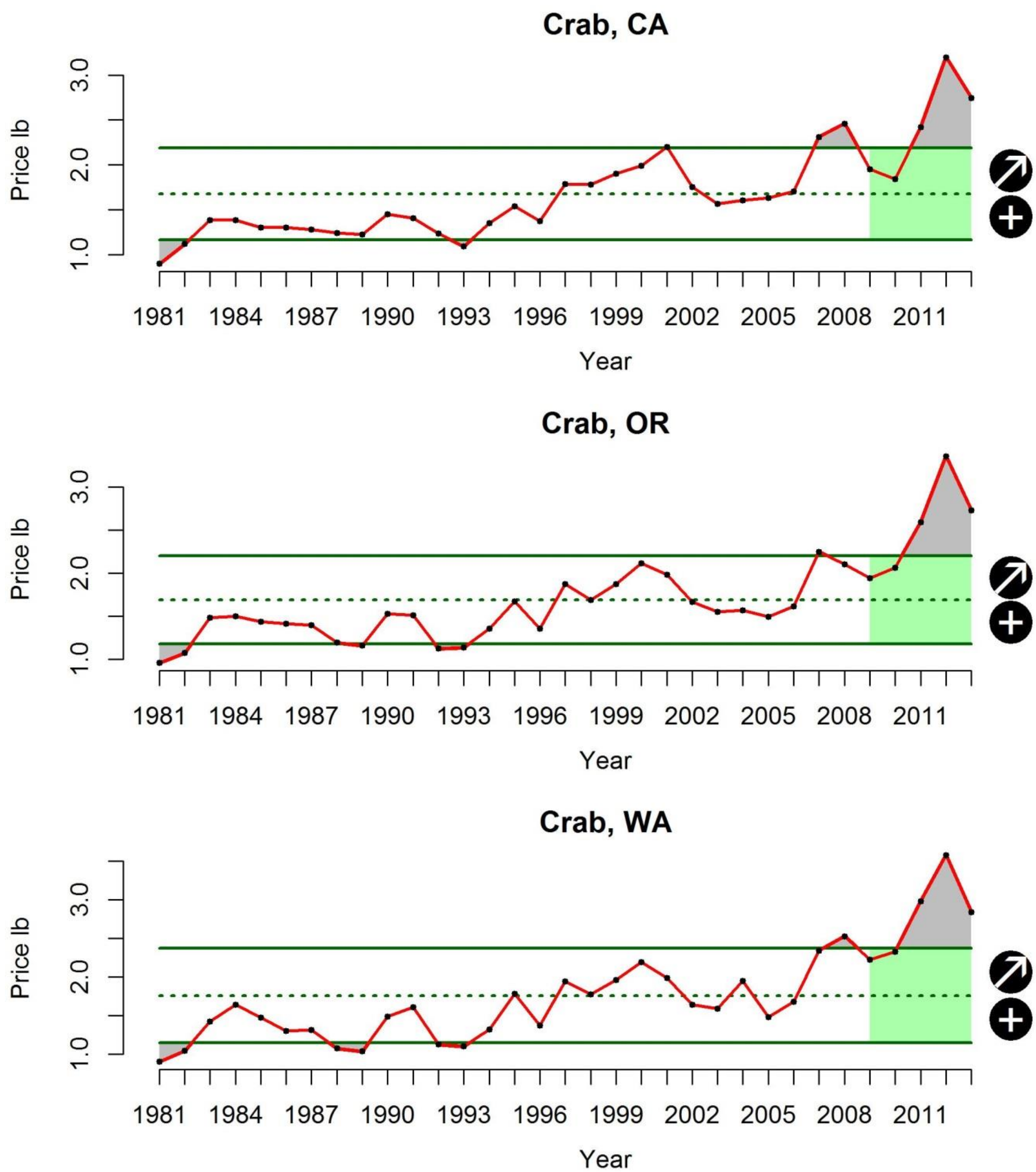


Figure S4.13. The time-series of crab average price per pound for West Coast states, with two relative statistics on the right hand side: the arrow in top right indicates whether the trend of the last five-years is positive (arrow up), negative (arrow down) or unchanged (arrow sideways); the sign at the bottom right shows whether the mean of the last five years is greater than (a plus sign), less than (a negative sign) or within 1SD of the mean (a large dot) of the entire time series.

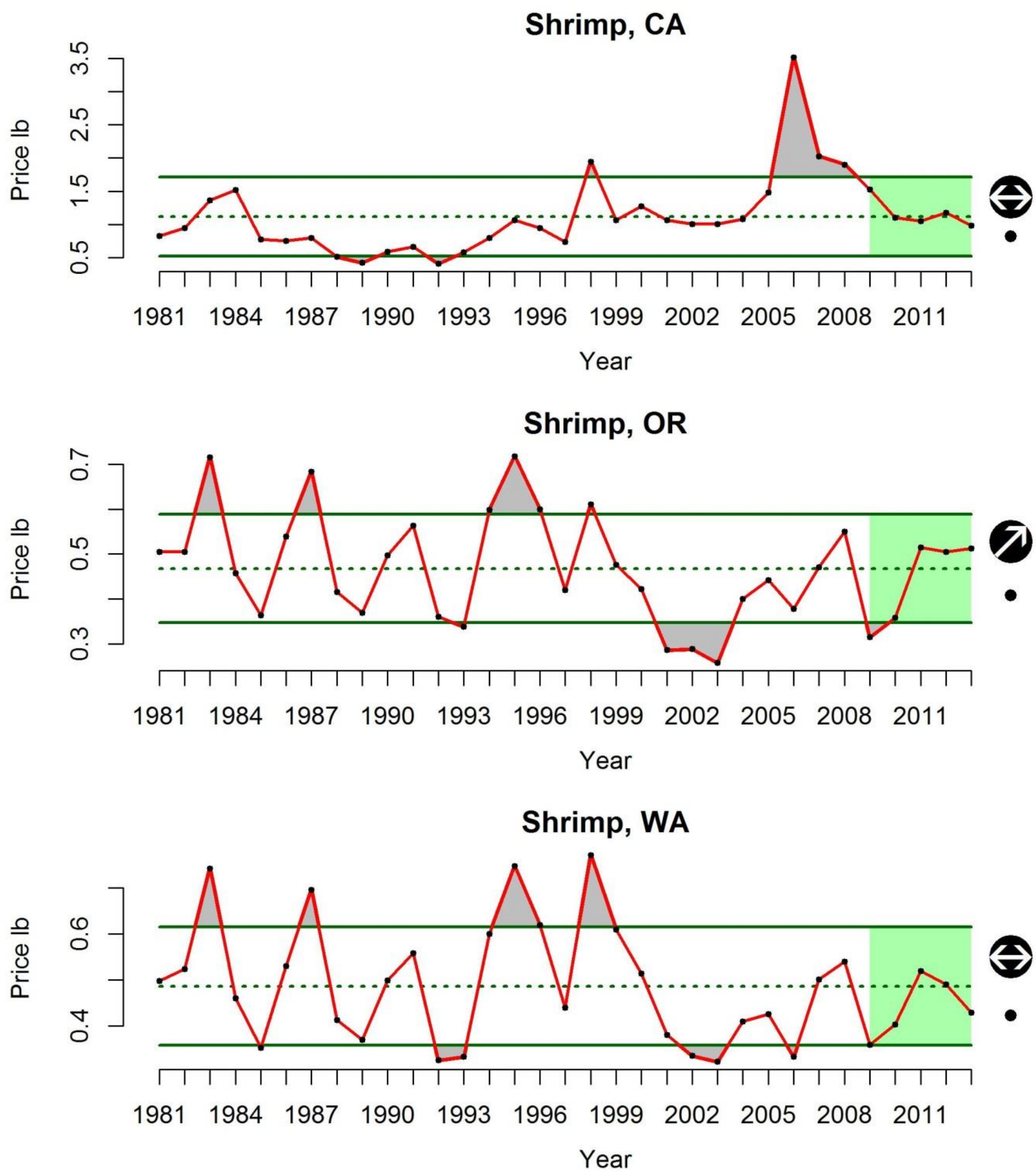


Figure S4.14. The time-series of shrimp average price per pound for West Coast states, with two relative statistics on the right hand side: the arrow in top right indicates whether the trend of the last five-years is positive (arrow up), negative (arrow down) or unchanged (arrow sideways); the sign at the bottom right shows whether the mean of the last five years is greater than (a plus sign), less than (a negative sign) or within 1SD of the mean (a large dot) of the entire time series.

2014 STATE OF THE CALIFORNIA CURRENT REPORT

CALIFORNIA CURRENT INTEGRATED ECOSYSTEM ASSESSMENT

SECTION 5 – HUMAN WELLBEING

5.1 Fleet Diversity Indices

Please see Kasperski and Holland (2013):

Income diversification and risk for fisherman

Kasperski, S. and D.S. Holland. 2013. Income Diversification and Risk for Fishermen. Proc. Nat. Acad. Sci. 100(6):2076-2081. doi: 10.1073/pnas.1212278110

Writeup for IEA Phase III (2014) report:

FISHERY INCOME DIVERSIFICATION AND RISK FOR FISHERMEN AND FISHING COMMUNITIES OF THE US WEST COAST AND ALASKA – UPDATED TO 2012

Daniel Holland, Northwest Fisheries Science Center, dan.holland@noaa.gov
Stephen Kasperski, Alaska Fisheries Science Center, stephen.kasperski@noaa.gov

Introduction and Methodology

Catches and prices from many fisheries exhibit high inter-annual variability leading to variability in the income derived by fishery participants. The economic risk posed by this variability might be mitigated in some cases if individuals participate in several different fisheries; particularly if revenues from those fisheries are uncorrelated or vary asynchronously. High annual variation in income is a common problem among natural resource dependent individuals and communities, and there has been extensive study of risk-coping mechanisms for farmers (Alderman and Paxson, 1992; Paxson, 1992; Townsend, 1994). Crop diversification is a common means of reducing risk in agriculture taking advantage of asynchronous variation in yields response and prices to minimize idiosyncratic risk (Heady, 1952; Johnson, 1967). Another common strategy in agriculture, particularly in semiarid regions with high fine scale variation in rainfall, is to farm a number of geographically separated plots to ensure some will be in areas with sufficient rainfall (Rosenzweig and Binswanger, 1993). A number of authors have argued that common property provides an important means risk reduction that may be undermined by privatization (Bromley and Chavas, 1989; Nugent and Sanchez, 1998; Thompson and Wilson, 1994). This literature relates primarily to grazing lands held in common to protect against the potential spatial for variation in rainfall that would impact small private holdings but smooth risk for herders utilizing a much larger area held in common, but similar strategies apply to fishermen. While formal insurance programs do not exist, fishermen's fishing strategies provide a means to reduce risk, in particular by diversifying their fishing activity across a variety of fisheries or areas (Minnegal and Dwyer 2008; van Oostenbrugge et al. 2002). There is also a growing literature suggests that fishermen should adopt portfolio approaches to their species composition to achieve the lowest variance in income for any level of expected return (Baldursson and Magnusson, 1997, Hilborn et al. 2001, Kasperski and Holland 2013, Perusso et al. 2005, Sethi 2010, Sethi et al. 2012, Smith and McKelvey 1986).

Following Kasperski and Holland (2013), we measure diversification of West Coast and Alaskan entity's gross revenues across species groups and regions each year. We consider two types of entities for this analysis, individual fishing vessels and individual fishing ports. For both types of entity, we utilize the Herfindahl-Hirschman Index (HHI) defined as:

$$H = \sum_{i=1}^{S_j} \sum_{j=1}^{4} p_{ij}^2, \qquad (1)$$

where p_{ij} represents percent (ranging from 0 to 100) of an entity's total gross revenues derived from species group i in region *j*. We define p_{ij} to be the percent of an entity's total annual gross revenue from one of 40 different species groupings in one of four regions – the Bering Sea/Aleutian Islands, Gulf of Alaska, Alaskan in-state waters, and the WC (Table S5.1). Not every species group is caught in each region, so there are a total of 84 total region-specific species groupings. HHI theoretically ranges from zero when revenues are spread amongst an infinite number of fisheries to 10,000 for an entity that derives all revenue for a single fishery. Thus, the less diversified an entity's revenue sources are, the higher the HHI. We evaluate how diversification has changed over time for various fleet groups and ports. To explore how diversification of fishery income affects year-to-year variation and thus financial risk, we estimate the statistical relationship between HHI and the coefficient of variation (CV) of gross revenues for each entity across years.

Results

We work with a large data set that includes annual landings and revenues between 1981 and 2012 by species, port and vessel from all commercial fisheries in the US EEZ off the West Coast and Alaska. We present analysis based on 28,151 vessels with average fishing revenues over $5000 (adjusted to 2005 values) and at least two years of documented landings. The port level analysis includes 166 ports with average fishing revenues over $100,000 (adjusted to 2005 values) and includes 79 ports along the West Coast and 87 ports in Alaska. The large data set enables us to identify trends in diversification and relationships between diversification and variation in revenues despite the relationship being very noisy. We also consider a number of subsets of the larger fleet categorized by average revenues, length and whether they had landings in West Coast states (i.e., excluding vessels with revenue only from Alaska).

Average fishery revenue diversification of West Coast and Alaskan fishing vessels is variable but shows distinct trends over time (Figure S5.1). The HHI for most vessel groups, though erratic, has generally been increasing over time meaning that diversification of fishery income has been declining. The current fleet of vessels on the US West Coast and in Alaska (those that fished in 2012) is less diverse than at any point in the past 30 years, except that they are slightly more diverse than they were in 2011. For smaller vessels diversification has generally been declining (HHI increasing) since 1981. For larger vessels, diversification increased through the early 1990s but has mostly declined since. The causes of the decline in diversification are not completely clear and probably vary by fleet sector. One likely factor that correlates with the observed trend is the successive implementation and tightening of limited access programs and later individual quota programs. By the mid-1990s, entry into new fisheries was no longer possible for most vessels since nearly all fisheries had moratoriums on entry, and many were beginning to reduce fleets through attrition, vessel buybacks or catch share programs. These programs limit fishermen's ability to move into new fisheries and often push out less active participants from a fishery. This is often necessary to limit catch and improve economic viability of the remaining participants, but it can also result in decreased diversification. Vessels that were in the fishery since 1981 have maintained a higher level of diversification than the overall fleet while vessels that entered later tend to be less diversified, possibly due to limited access programs in many fisheries. We also look specifically at diversification trends for vessels with at least $5000 in revenues from landings in WA, OR or CA in 2012. Overall, trends for vessels fishing the West Coast are similar to those for the larger fleet of vessels fishing the West Coast and/or Alaska.

While we can see some clear trends in diversification for various classes of vessels over time, there is wide variation in the degree of diversification across vessels within each class (Figure S5.2). Higher earning and large vessels tend to be more diversified on average than smaller vessels and those with lower earnings. The current 2012 West Coast fleet appears to be slightly less diversified on average than the larger fleet which includes all vessels from the West Coast and Alaska, and both current and former participants.

If vessels are able to diversify into multiple fisheries whose revenues vary independently or asynchronously, they should experience a reduction in volatility of revenues and thus financial risk. This is confirmed for all of our fleet groupings by estimating quadratic regressions of the CV of gross fishery revenue as a function of HHI and HHI squared. Our analysis indicates a dome shaped relationship between variability of individuals' income and income diversification which implies that a small amount of diversification actually increases risk for some fleet categories, but moderate amounts of diversification can substantially reduce the variability of income that individuals receive from fishing. The decrease in CV with increased diversification varies substantial across vessel categories (Figure S5.3 and Table S5.2), but for nearly all vessel categories there is a substantial decrease in CV when moving from a low level of diversification (e.g. a 90-10 split in revenues between two fisheries) to a high level of diversification (e.g., a 50-25-25 split). Annual revenues for fishing vessels in our sample have an average coefficient of variations of 0.78. To illustrate how the decrease in CV associated with diversification affects the range of annual income a vessel might expect, we calculate the 50th percentile range of gross revenues for four hypothetical diversification schemes based on the functional relationship between HHI and CV for all vessels with mean annual revenues greater than $5,000. The 50th percentile range of expected revenues contracts from a range of $72,000 to $239,000 with when all revenue comes from one fishery to a range of $105,000 to $206,000 with a 50-25-25 split of revenues across three fisheries.

Individual fishing ports experience a high degree of variation in diversification as well as landed revenue (Figures S5.4 and S5.5). Diversification of landed revenue for some ports has clearly decreased as evidenced by an increasing HHI. Examples include Seattle and most, though not all, of the ports in Southern Oregon and California. A few ports have become more diversified including Bellingham Bay in Washington and Westport, Washington which became less diversified through the mid 1990s but has since reversed that trend. Diversification scores at the port level are generally much lower than for individuals since they reflect landings of many different fishermen who individually may be less diversified but in aggregate land a variety of species. Diversification scores are highly variable for some ports, particularly those in Southern Oregon and Northern California that depend heavily on the Dungeness crab fishery. Crab revenue, and consequently overall landed value, in those ports over the last decade has varied dramatically year to year which in turn drives variability in diversification (Figure

S5.5). When crab revenues are very high they dominate landed value for the port and drive up the HHI (i.e. lower diversification). HHI for Southern California ports has increased substantially in recent years as landed value from these ports has become increasingly dominated by squid.

As is true with individual vessels, the variability of landed value at the port level is correlated with HHI. The fitted relationship between the CV of annual landed value and HHI is domed shape as it is for individual vessels, thus the predicted CV declines at an increasing rate as the diversification of the port increases (HHI declines) (Figure S5.6). However, relative to the to the fitted relationship for vessels, the relationship between CV of annual landed revenues and HHI for ports has substantially more curvature and requires a much higher level of diversification to begin experiencing a decline in the CV of annual landed revenues (HHI of 3,750, such as a 50-25-25 split).

Discussion

Diversification across multiple fisheries can reduce variation and the associated financial risk. It can also increase the minimum annual revenue relative to average revenue, which should reduce the risk of a business failure (Kasperski and Holland, 2013). The ability of fishermen to diversify may be limited (or facilitated) by management approaches and regulatory actions. This should be a consideration when evaluating management actions, though in some cases management actions that reduce diversification are needed to remove excess capacity and promote efficiency.

There are a number of factors that may limit the feasibility or desirability of greater diversification. In many cases different fisheries require different gear that must be purchased and there are often costs of acquiring licenses and, increasingly, quota. It may also be the case that a vessel that can participate in several fisheries may be less efficient than more specialized vessels creating a trade-off between risk reduction through diversification and fishing efficiency. Exploration of this potential tradeoff would be an important extension of our research. Owners of multiple vessels can diversify by having individual vessels to specialize in different fisheries. Some fishermen may diversify their income with non-fishing sources. This seems particularly likely for vessels with low levels of revenue. We were unable to explore the degree or effects of this type of diversification due to a lack of data on non-fishing income. We hope to collect data on non-fishery income in future to explore this issue.

It is not clear that ports could or should increase diversification to reduce variation in landed value, but it does appear that high levels of diversification can reduce variation in landed value. High variation in overall landed value for several ports is associated with dependence on fisheries that have high variation in revenues. This variation could be socially disruptive, but this may be somewhat unavoidable if those ports want to continue to attract the landings from valuable fisheries like crab that have highly volatile annual landings. It should also be noted that the variation in landed value at ports is not necessarily closely correlated with variation in fishing income of fishermen living in those communities since those fishermen may be landing catch in other ports. The link between diversification of individual fishermen and ports and socio-economic wellbeing of communities is one that deserves further research.

References

Alderman H & Paxson CH (1992) *Do the poor insure?: a synthesis of the literature on risk and consumption in developing countries* (World Bank Publications).

Baldursson, F.M., Magnusson, G. (1997). Portfolio fishing. Scand. J. Econ. 99 (3), 389–403.

Bromley, D.W., and J-P. Chavas (1989). On Risk,Transactions, and Economic Development in the Semiarid Tropics. Econ. Develop. And Cultur. Change 37:719-36

Heady E.O (1952) Diversification in resource allocation and minimization of income variability. J. Farm Econ. 34(4):482-496.

Hilborn, R., J.-J. Maguire, A. M. Parma, and A. A. Rosenberg (2001). The Precautionary Approach and risk management: can they increase the probability of successes in fishery management? Can. J. Fish. Aquat. Sci. 58:99-107.

Johnson, S. (1967) A re-examination of the farm diversification problem. J. Farm Econ. 49(3):610-621.

Kasperski, S. and D.S. Holland (2013). Income Diversification and Risk for Fishermen. Proc. Nat. Acad. Sci. 100(6):2076-2081. doi: 10.1073/pnas.1212278110

Minnegal M & Dwyer PD (2008) Managing risk, resisting management: Stability and diversity in a southern Australian fishing fleet. Human Org. 67(1):97-108.

Nugent J.B. and N. Sanchez. (1998). Common Property Rights as an Endogenous Response to Risk. Amer. J. of Agric. Econ., Vol. 80, No. 3 (Aug., 1998), pp. 651-657

Paxson CH (1992) Using weather variability to estimate the response of savings to transitory income in Thailand. *Am. Econ. Rev.*:15-33.

Perusso, L., Weldon, R.N., Larkin, S.L. (2005). Predicting optimal targeting strategies in multispecies fisheries: a portfolio approach. Mar. Resour. Econ. 20 (1), 25–45.

Rosenzweig, M., Binswanger (1993): Wealth, weather risk and the composition and profitability of agricultural investments. Econ. J. 103:56-78.

Sethi, S.A. Risk Management for Fisheries. (2010). Fish and Fish. 11:341-365.

Sethi SA, Dalton M, Hilborn R, & Rochet MJ (2012) Quantitative risk measures applied to Alaskan commercial fisheries. Can. J. Fish. Aquat. Sci. 69(3):487-498.

Smith, C. L. and R. McKelvey (1986). Specialist and generalist roles for coping with variability. N. Amer. J. Fish. Manag. 6:88-99.

Thompson, G., and RN. Wilson (1994). "Common Property as an Institutional Response to Environmental Variability." Contemp. Econ. Policy 12:10-21.

Townsend RM (1994) Risk and insurance in village India. *Econometrica* 62(3):539-591.

van Oostenbrugge J, Bakker E, Van Densen W, Machiels M, & Van Zwieten P (2002) Characterizing catch variability in a multispecies fishery: implications for fishery management. Can. J. Fish. Aquat. Sci. 59(6):1032-1043.

Table S5.1: Species groups used for diversification indices.

West Coast	Alaska
Pacific Whiting	Pacific Cod
Dover Sole, Thornyheads, Sablefish	Flatfish
Rockfish and Flatfish	Rockfish
Skate, Dogfish, Sharks	Atka Mackerel
Pacific Halibut	Pollock
California Halibut, Croaker	Other Groundfish
Pink Shrimp	Sablefish
Other Prawns and Shrimp	Pacific Halibut
Crab	Herring
Salmon	Chinook Salmon
Tuna	Sockeye Salmon
Herring	Coho Salmon
Coastal Pelagics	Pink Salmon
Echinoderms	Chum Salmon
Other Shellfish	Other Salmon
Squid	Red King Crab
Other Species	Other King Crab
	Opilio Crab
	Other Snow Crab (Bairdi)
	Other Crab
	Scallops
	Other Shellfish
	Other Species

Table S5.2: Predicted coefficient of variation (CV) of gross fishery revenue for Herfindahl-Hirschman index scores associated with alternative diversification schemes for groupings of WC and AK fishing vessels

	Predicted CV Herfindahl Index						
Vessel Category	Single Fishery	90-10 Split	50-50 Split	50-25-25 Split	%Drop Single Fishery to 50-25-25	Sample Size	Mean Revenue ($1000)
All >$5K Rev	0.80	0.85	0.66	0.48	23%	28,151	$ 155
2012 Fleet >$5K	0.68	0.75	0.60	0.45	33%	8,522	$ 272
1981-2012 Fleet >$5K	0.67	0.72	0.60	0.49	27%	2,577	$ 224
$5K-$25K Rev	0.86	0.94	0.75	0.55	36%	12,431	$ 12
$25K-$100K Rev	0.69	0.81	0.64	0.44	37%	10,329	$ 56
>$100K Rev	0.59	0.68	0.60	0.49	17%	5,391	$ 534
<40Feet	0.80	0.87	0.68	0.49	38%	21,848	$ 49
40-80 Feet	0.78	0.78	0.61	0.48	38%	5,269	$ 201
80-125 Feet	0.79	0.77	0.48	0.44	45%	612	$ 993
2012 WA >$5K	0.68	0.72	0.58	0.44	35%	917	$ 280
2012 OR >$5K	0.72	0.76	0.52	0.31	57%	808	$ 194
2012 CA >$5K	0.74	0.76	0.53	0.34	54%	1,359	$ 201
2012 WC $5-25K	0.79	0.90	0.50	0.14	82%	798	$ 16
2012 WC $25-100K	0.63	0.77	0.51	0.23	63%	1,048	$ 59
2012 WC >$100K	0.55	0.61	0.53	0.44	19%	898	$ 380
2012 WC <40 Feet	0.69	0.80	0.49	0.19	72%	1,618	$ 90
2012 WC 41-80 Feet	0.77	0.72	0.54	0.43	44%	1,065	$ 283
2012 WC 81 -125 Feet	0.64	0.66	0.52	0.39	38%	58	$ 1,177

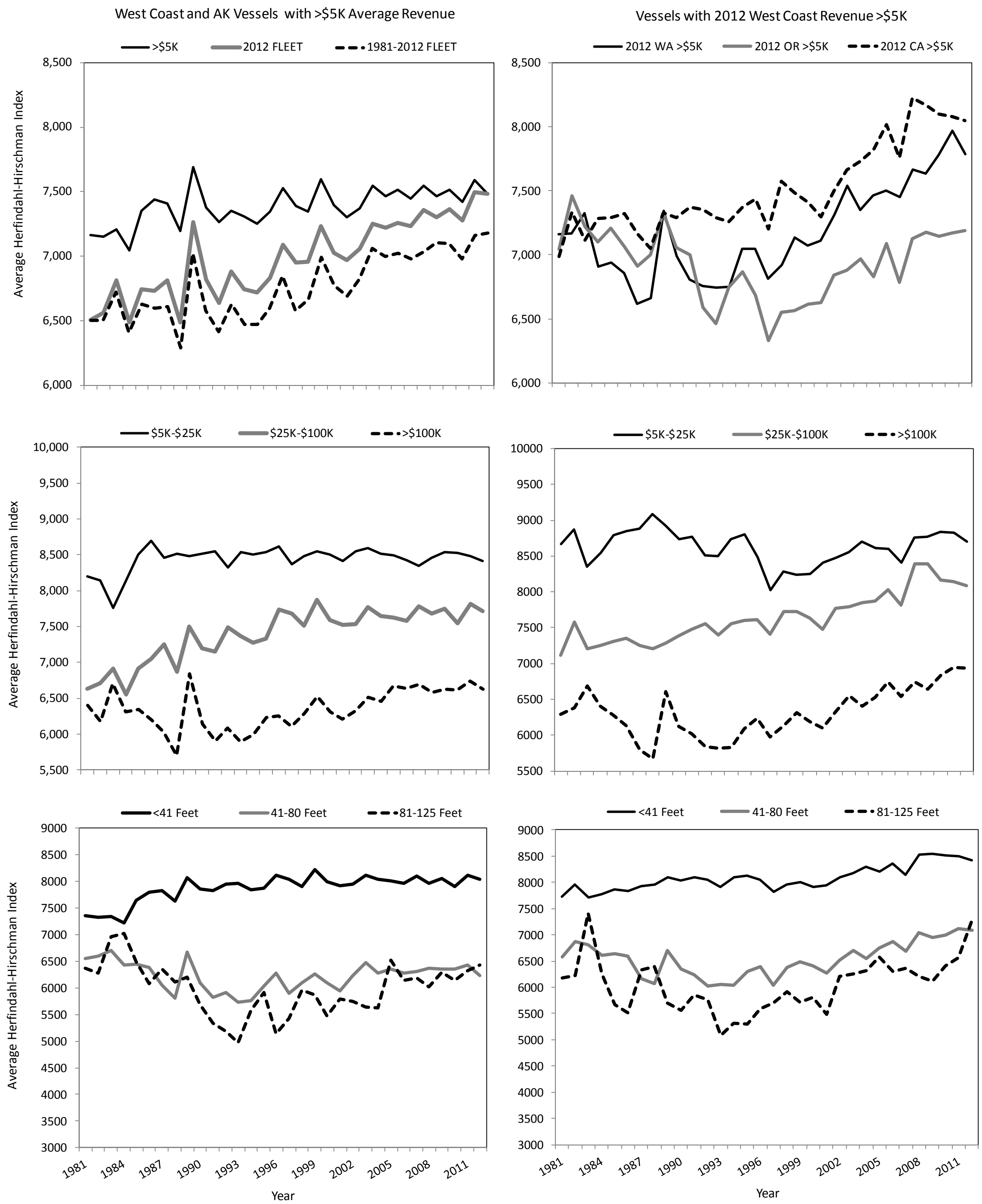


Figure S5.1: Trends in average diversification for US West Coast and Alaskan fishing vessels (left panels) and the 2012 West Coast Fleet (right panel) filtered by all vessels with over $5,000 in average revenues (top panel), by average gross revenues classes (middle panel) and by vessel length classes (bottom panel).

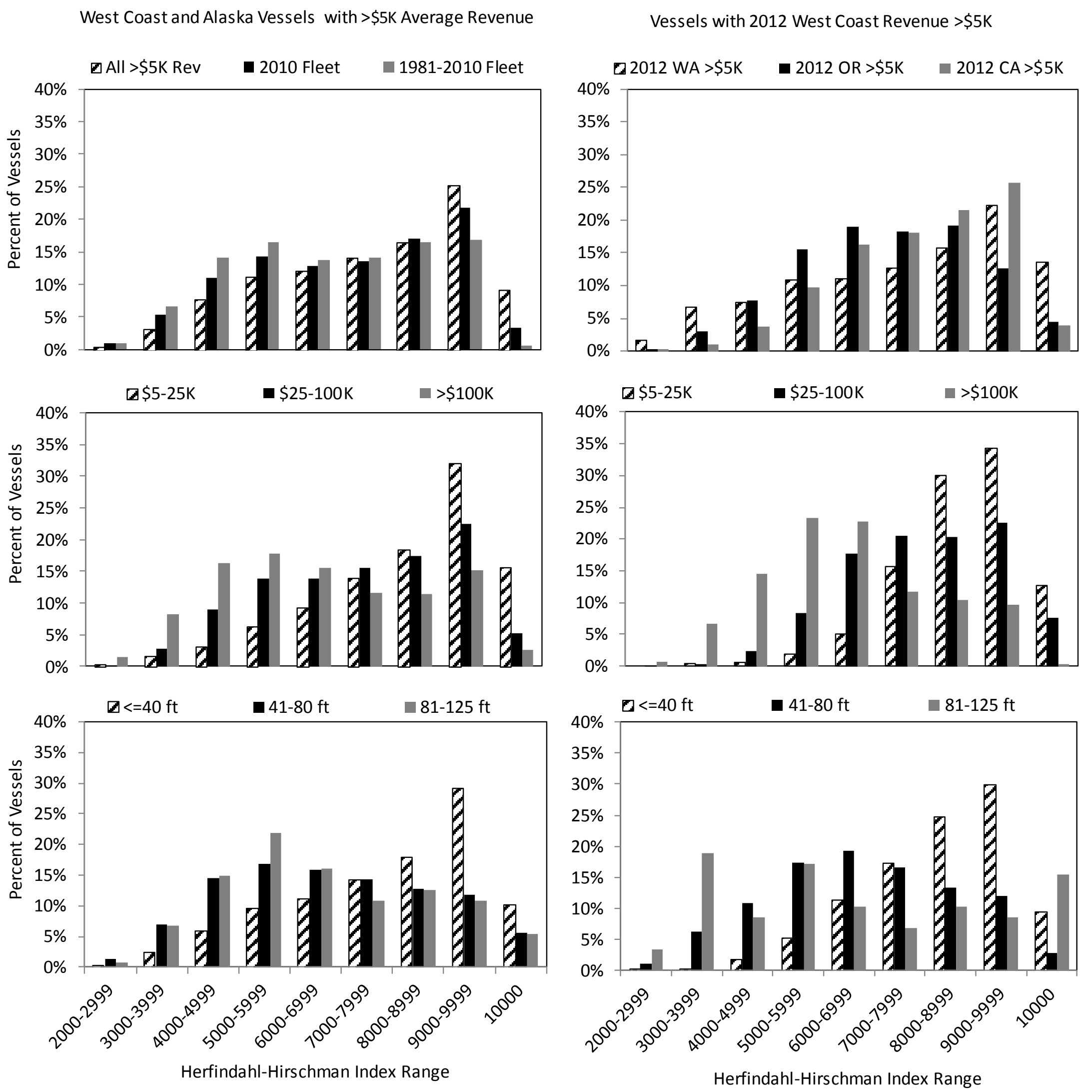


Figure S5.2: Histograms showing percentage of vessels by ranges of Herfindahl-Hirschman index scores for US West Coast and Alaskan fishing vessels (left panels) and the 2012 West Coast Fleet (right panel) filtered by all vessels with over $5,000 in average revenues (top panel), by average gross revenues classes (middle panel) and by vessel length classes (bottom panel).

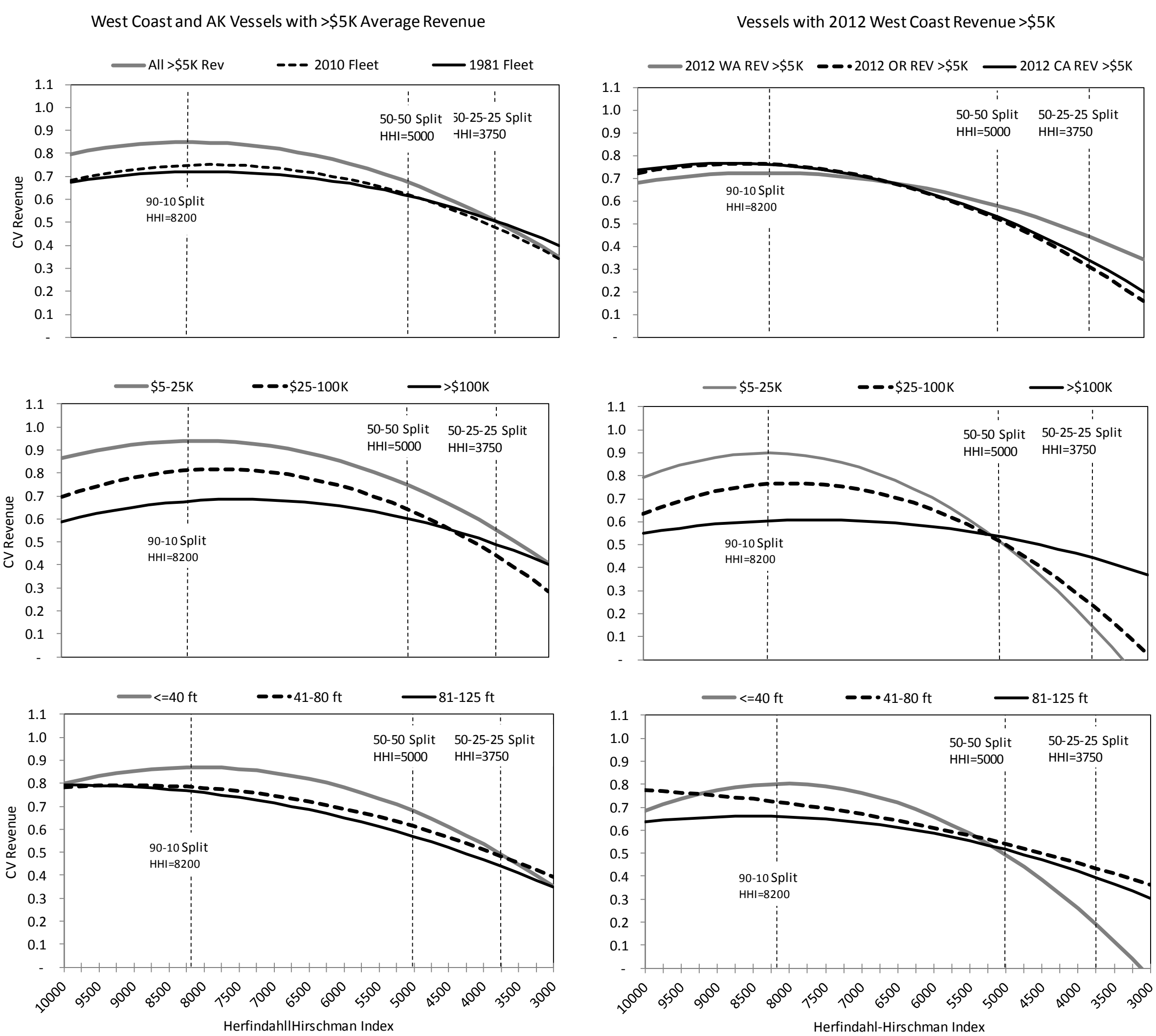


Figure S5.3: Fitted relationships between the coefficient of variation (CV) of gross revenues for US West Coast and Alaskan fishing vessels (left panels) and the 2012 West Coast Fleet (right panel) filtered by all vessels with over $5,000 in average revenues (top panel), by average gross revenues classes (middle panel) and by vessel length classes (bottom panel).

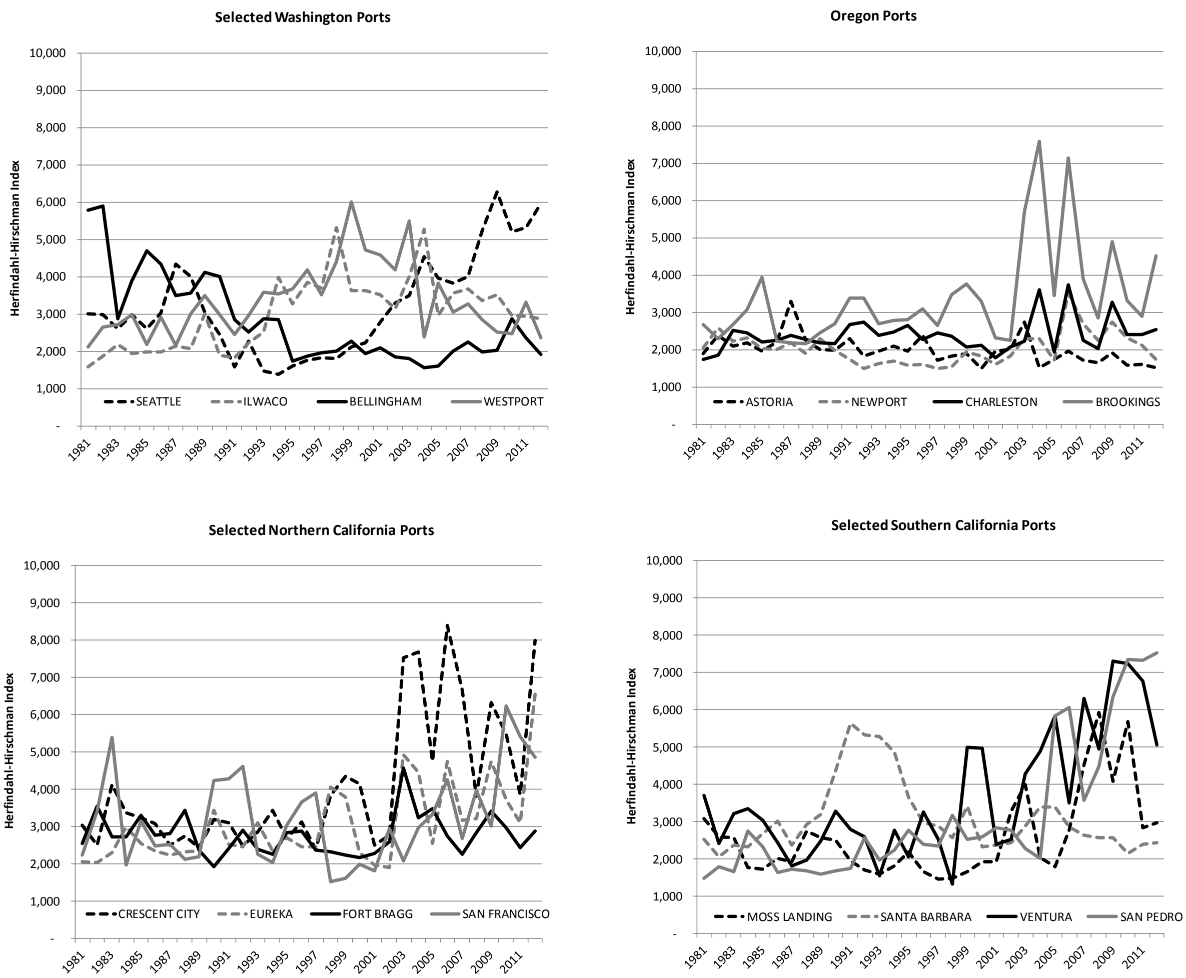


Figure S5.4: Trends in diversification for selected primary West Coast ports in Washington, Oregon, and California.

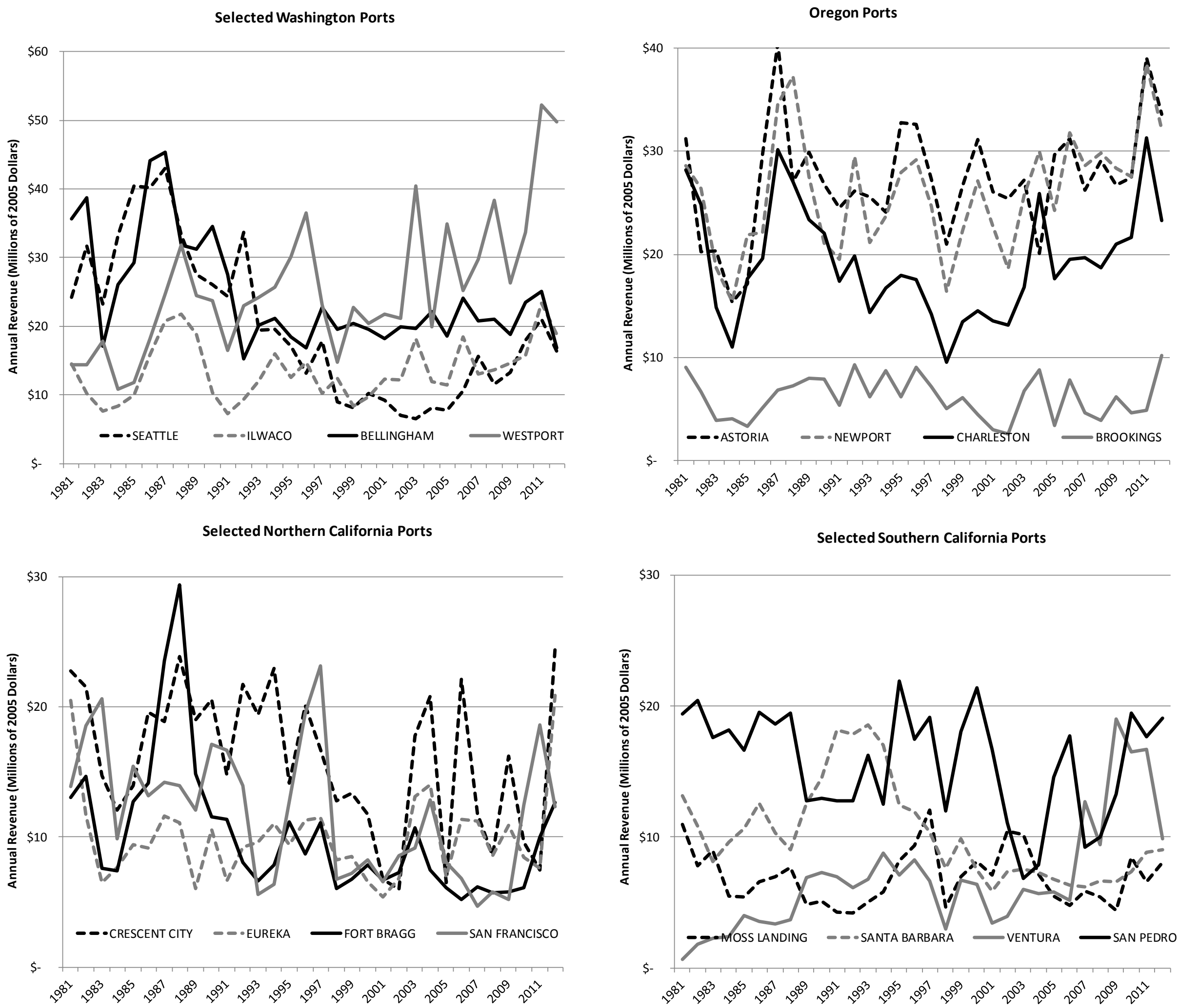


Figure S5.5: Total landed value in 2005 dollars for selected primary West Coast ports in Washington, Oregon, and California.

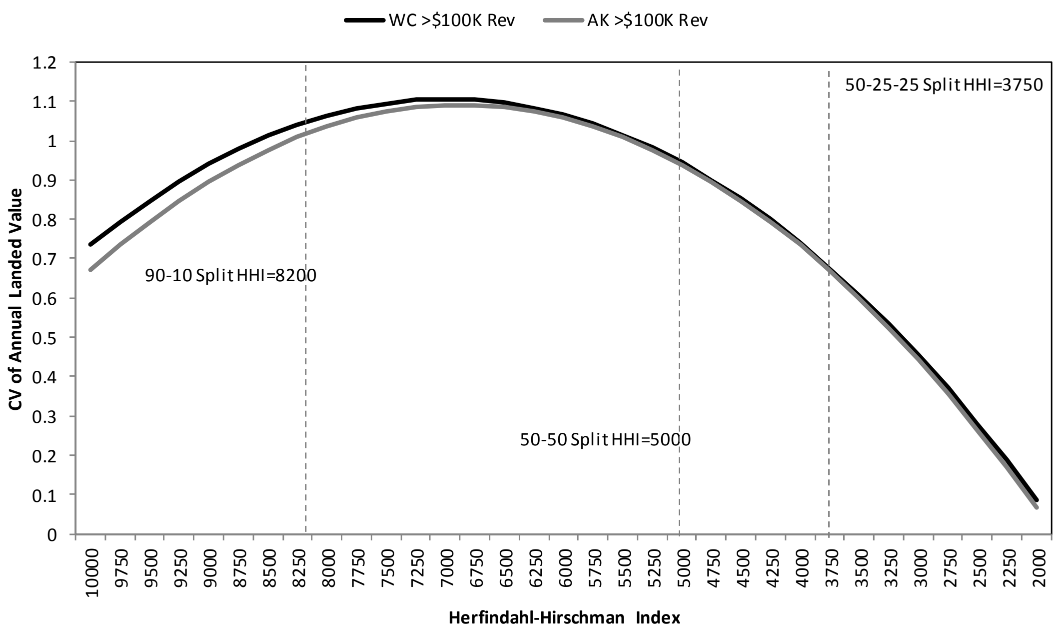


Figure S5.6: Fitted relationships between the coefficient of variation (CV) of gross revenues for US West Coast and Alaskan fishing ports.

5.2. Personal Use: Subsistence and Informal Economic Practices Among Commercial Fisheries in Washington and California

This report documents the volume of fish and shellfish kept for personal use from commercial vessels in Washington and California.[1] Between 1990 to 2010, over 37.5 million pounds of seafood were kept for "personal use", a category used as a proxy for subsistence and informal economic share systems. These 37.5 million pounds of personal use constitute a fraction (.2%) of the total catch (16.3 billion pounds) landed during that same period. Nearly 85% (31.8 million pounds) of the personal use removals is from tribal participants. Slightly more than 15% of the personal use removals is from nontribal participants. Ninety-six percent of the retained catch of tribal participants is comprised of Salmonids. Nontribal participants retain a wider diversity (breadth) of species than their Tribal counterparts. California ports record less personal use overall than Washington ports, but the species breadth in CA is greater (e.g. in CA, 229 species were kept for personal use and in WA, 93 species were kept). The majority of personal use, (over 30.4 million pounds or 81.3%) was landed in Puget Sound.

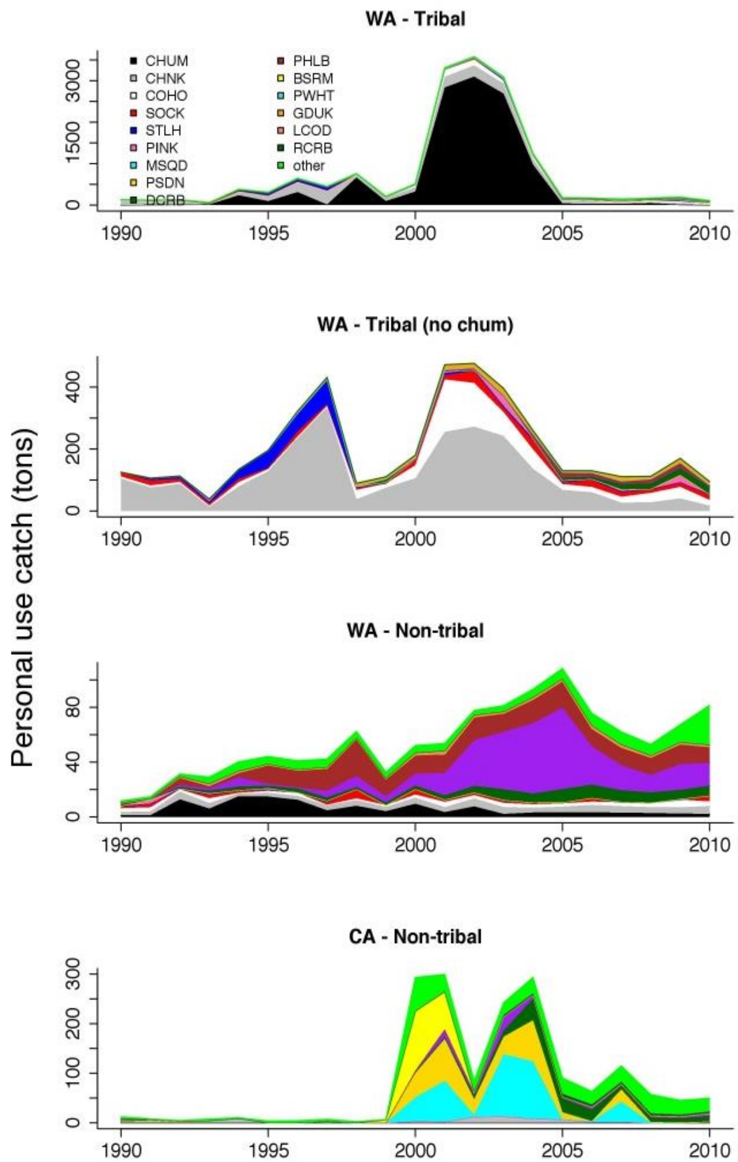


Figure S5.7. Annual personal catch in tons (2000 lbs) for WA tribal fishers, WA non-tribal fishers and CA non-tribal fishers from 1990-2010. CHUM = chum salmon, CHNK = Chinook salmon, COHO = coho salmon, SOCK = sockeye salmon, STLH = steelhead, PINK = pink salmon, MSQD = market squid, PSDN = pacific sardine, DCRB = Dungeness crab, ALBC = albacore, PHLB = Pacific halibut, BSRM = unidentified bait shrimp, PWHT = Pacific whiting (hake), GDUK = geoduck, LCOD = lingcod, RCRB = rock crab.

[1] Data Source: Pacific Fisheries Information Network (PacFIN), 1990-2010; Data from landings in 139 of 350 ports in WA and CA, data not collected/reported from OR.

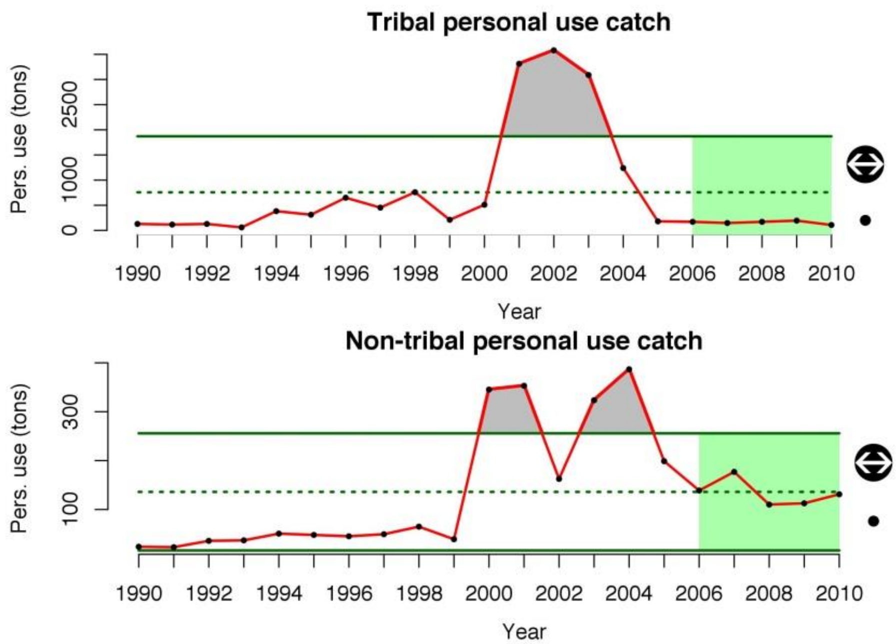


Figure S5.8. Catch retained for personal use from 1990 - 2010 in tons (2000 lbs). Dark green horizontal lines show the mean (dotted) and ± 1.0 s.d. (solid line) of the full time series. The shaded green area is the last five years of the time series, which is analyzed to produce the symbols to the right of the plot. The upper symbol indicates whether the modeled trend over the last 5-years increased (↗), or decreased (↘) by more than 1.0 s.d., or was within one 1.0 s.d. (↔) of the long-term trend. The lower symbol indicates whether the mean of the last five years was greater than (+), less than (-), or within (·) one s.d. of the long-term mean.

I. STATE OF THE CALIFORNIA CURRENT ANNUAL REPORT

NOAA's Integrated Ecosystem Assessment team has produced a second State of the California Current Ecosystem report, following past Council guidance on indicators and report content. The purpose of this report is to bring ecosystem information for the California Current Large Marine Ecosystem (CCLME) into the Council process in a succinct, straightforward format to (help) the council consider ecosystem variability in decision-making. This report includes a synthesis of 22 key environmental, biological and socio-economic indicators in the California Current Large Marine Ecosystem.

Many of the indicators that measure environmental variability (e.g., Pacific Decadal Oscillation, upwelling anomaly, dissolved oxygen) and ecological integrity (e.g., copepod species richness, salmon abundance, groundfish stock status) may be found in other reports or online; the goal of this report is to present trends in physical and biological components of the ecosystem - alongside fisheries, ecosystem impacts from other human activities, and socioeconomic factors of the California Current large marine ecosystem.

Some of the indicators in this report with differing trends between 2012 and 2013 conditions:

- Strong cumulative upwelling occurred during 2012 for southern and central California and during 2013 for the whole coast, indicating higher productivity.
- Survey catches indicate that Northern anchovy abundance is reduced along much of the coast recently; however, a number of other forage fishes have responded positively to productive conditions.
- In response to the poor condition of sea lion pups at rookeries and a high level of strandings, NMFS declared an Unusual Mortality Event (UME) of California sea lion pups in March 2013

We modified the 2014 report in response to Council comments and requests. This includes adding new indicators for ocean acidification (aragonite saturation), forage fish (fish community structure), and socioeconomic conditions (subsistence practices among commercial fisheries) and modifying fisheries' landings (summarized by region and price) to better (elucidate) shifts among West coast fisheries. We also provide supplementary background materials, by section, for most of the indicators.

II. IEA PHASE II REPORT 2013

The California Current Integrated Ecosystem Assessment Phase II Report is a web-based, interactive report that synthesizes status, trends, and risks facing the U.S. West Coast marine ecosystem. This is a peer-reviewed report of 2011-2012 research based on contributions of the California Current Integrated Ecosystem Assessment Team authors and affiliates - 57 authors and 15 affiliations. This interactive report is an evolving product – it will be updated annually and builds on previous technical background (Levin et al 2009, Levin and Schwing (eds.) 2011), and is completed as part of NOAA's National IEA program. In addition to the report and related publications, we also produced an IEA video in 2013, which includes members of the IEA team and the Pacific Fishery Management Council – go here to view video.

The IEA is organized around three questions:

- What is the status and trends of key indicators of ecosystem health in the U.S. West Coast marine ecosystem?
- What is the status and trends of drivers and pressures affecting the health of the U.S. West Coast marine ecosystem?
- How might potential future management options influence the health of the U.S. West Coast marine ecosystem?

  - Link to latest California Current IEA Report
  - NOAA's National IEA California Current Home page
  - IEA Overview Video

III. IEA CURRENT WORK – 2013-2014

Conceptual models

We are in the process of developing graphical conceptual models to directly identify the linkages between bio-physical (e.g., upwelling, chlorophyl, copepods, salmon) and societal (e.g., cultural, economic) components across the ecosystem. These models act as a framework for quantifying the links between system components as well as communicating linkages to managers.

Social Science

One of our focus areas in 2013 and 2014 on the California Current IEA is human dimensions, specifically to identify measures that reflect vulnerability of fishing communities and measures of human wellbeing

- *Subsistence and Informal Economic Practices among Commercial Fisheries:* We summarized the volume of fish and shellfish kept for personal use from commercial vessels, by both tribal and non-tribal participants in Washington and California between 1990 and 2010. This work is described in the 2014 State of the California Current report.
- *Community vulnerability:* We analyzed demographic, geographic, quality of life and fisheries-specific data for 2,529 coastal communities across the West coast, and are deriving indicators of community vulnerability (e.g., coastal poverty). Such indicators of wellbeing, paired with fishing metrics can illuminate connections to the marine environment, and may provide a way to integrate the socioeconomic dimension into research and management approaches.

Habitat

Habitat was added to the CCIEA in 2013 and we have completed the initial phase of work necessary to understand habitat health in the context of the CCLME. We have defined key California Current LME habitats (freshwater, estuary/nearshore, pelagic and seafloor), developed a working list of potential indicators for habitat quantity, quality and relate pressures, and have designed an overarching spatial habitat framework for the West coast.

Management Scenarios

We continue to test the implications of management decisions under alternate future conditions in the California Current. In IEA 3, we have added additional analyses for scenarios related to climate change and shipping, in addition to fishing. Models developed in 2013 (IEA 3) include:

- Climate change effects on salmon in fresh and salt water, groundfish, and pelagic species.
- Management scenario testing to identify robust, multi-sector management approaches under climate change
- Predictions of ocean acidification risk for calcifiers (shelled) species and corals
- Shipping and ship strikes of marine mammals

We received a request from the SSC to review *Atlantis* in June of 2014, so we are preparing for that. Next year, we will include scenarios in which we tackle a single question with multiple models, to increase our ability to quantitatively estimate uncertainties, and to distill results into more concise summaries (based on reviewer feedback).

Agenda Item C.1.b
Supplemental CCIEAT PowerPoint
March 2014

STATE OF THE CALIFORNIA CURRENT ECOSYSTEM IN 2013

California Current Integrated Ecosystem Assessment Team

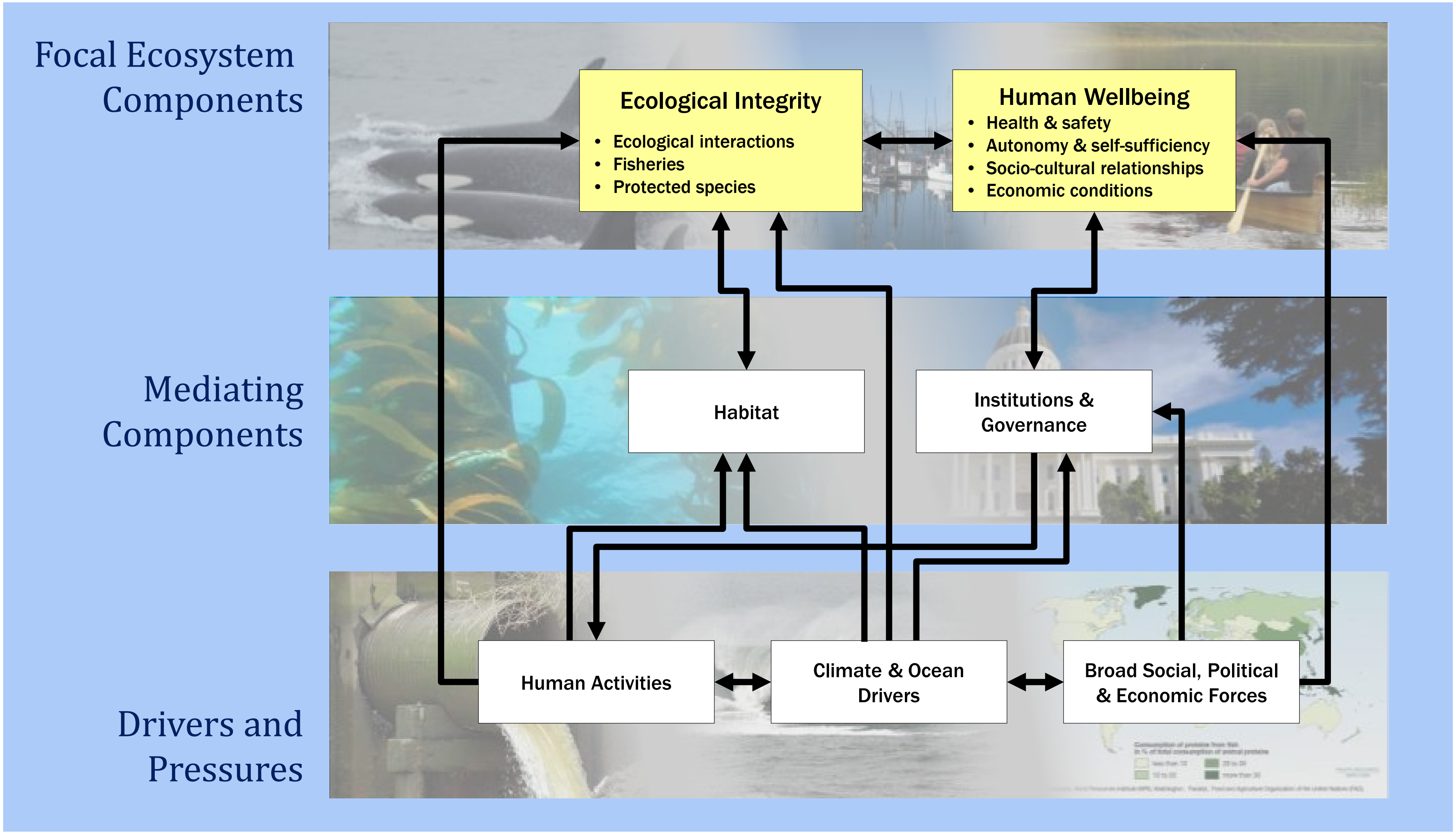
SOCIO-ECOLOGICAL SYSTEM OF THE CALIFORNIA CURRENT

Focal Ecosystem Components

Mediating Components

Drivers and Pressures

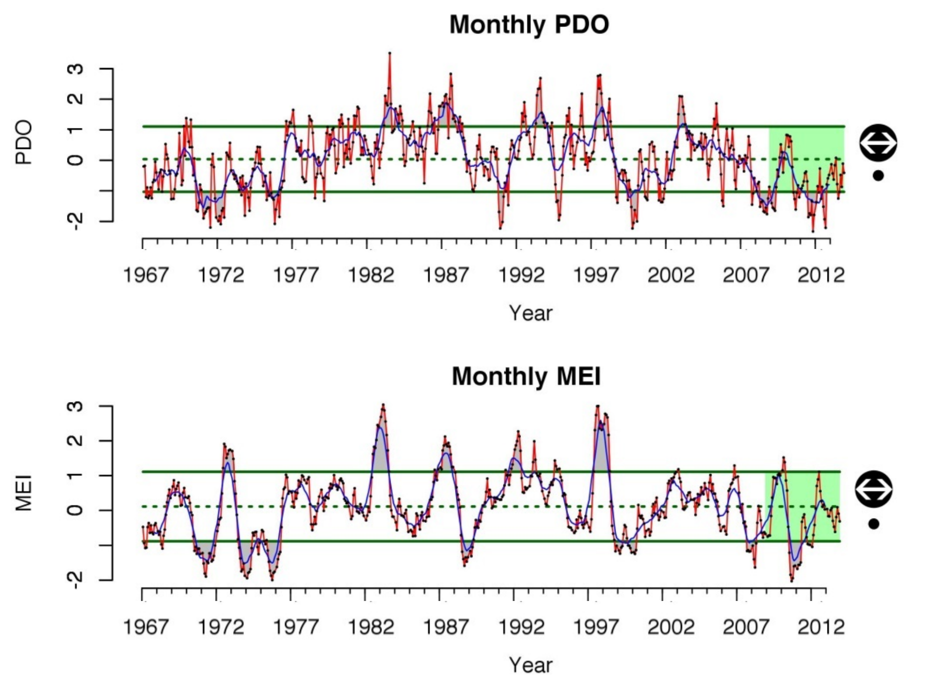
SOCIO-ECOLOGICAL SYSTEM OF THE CALIFORNIA CURRENT



CLIMATE AND OCEAN DRIVERS

The coast of Santa Rosa Island (NOAA Photo Library)

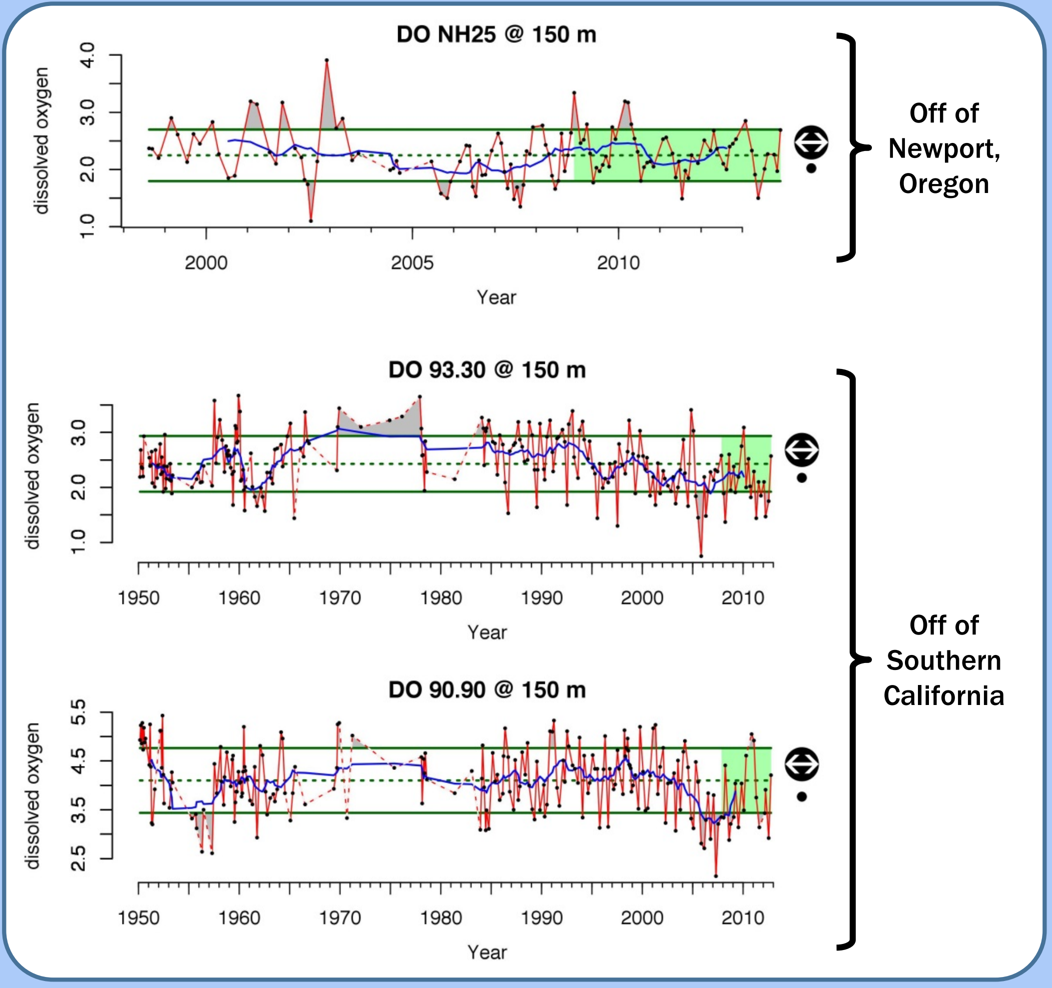
CLIMATE AND OCEAN DRIVERS



BASIN SCALE DRIVERS

- Temperature and upwelling indicators generally **stable** and close to long-term average
- Pointing toward **cooler, more productive system**

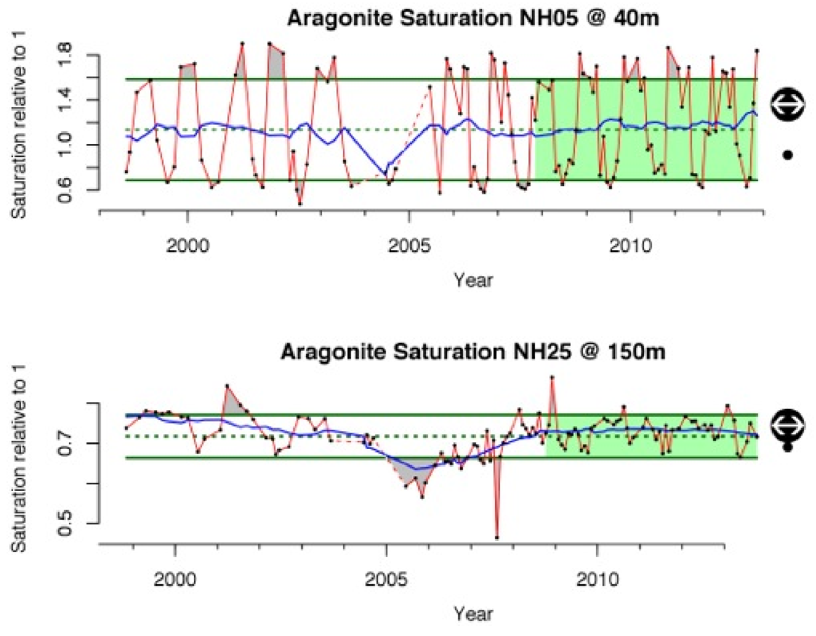
CLIMATE AND OCEAN DRIVERS



DISSOLVED OXYGEN (DO)

- Generally **stable** and mostly **above "hypoxia" threshold** (1.4 ml L^{-1})
- A localized process; these sites may not capture nearshore hypoxic events

CLIMATE AND OCEAN DRIVERS



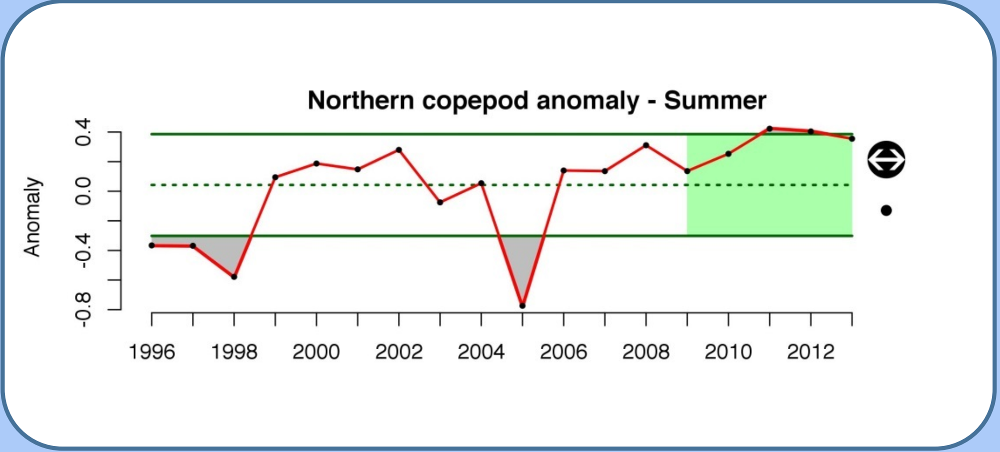
OCEAN ACIDIFICATION

- Aragonite saturation off Newport is **stable**
- But, water is **corrosive** (saturation state < 1) during upwelling season in shallow water
- Nearly always corrosive in deep water

COMPONENTS OF ECOLOGICAL INTEGRITY

Cowcod rockfish, Sebastes levis, *over rocky substrate and crinoids (NOAA Photo Library)*

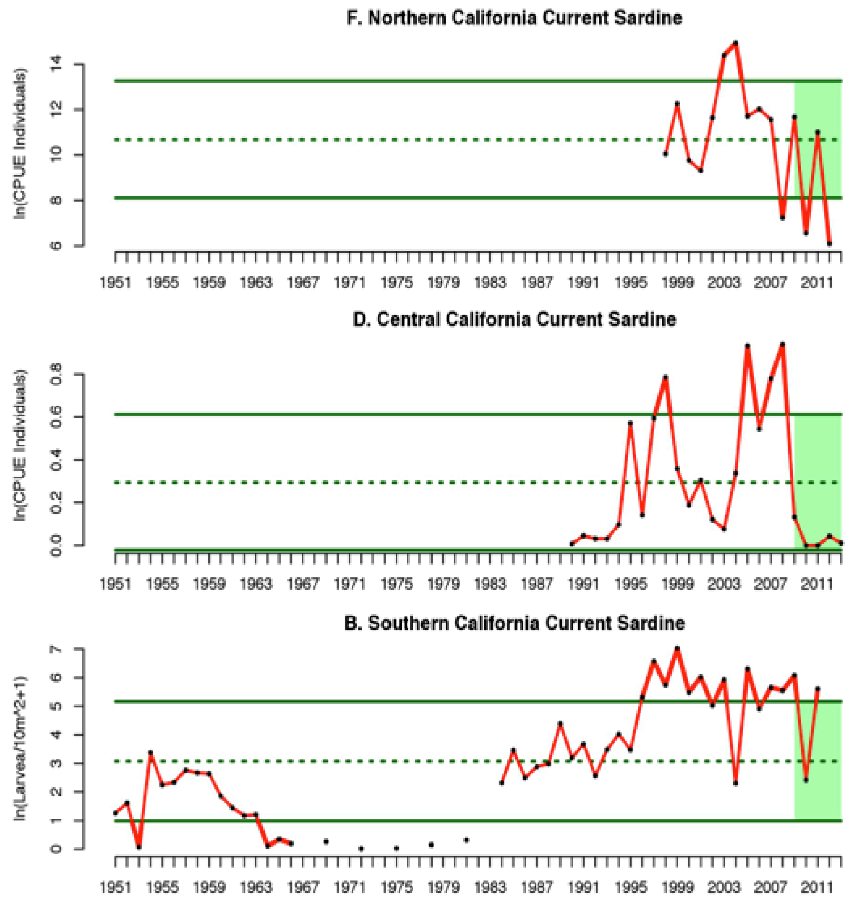
COMPONENTS OF ECOLOGICAL INTEGRITY



NORTHERN COPEPODS

- Biomass anomaly is stable; **relatively high values** in most recent years suggest generally productive state
- High in fatty acids, valuable **forage for salmon** and other fishes

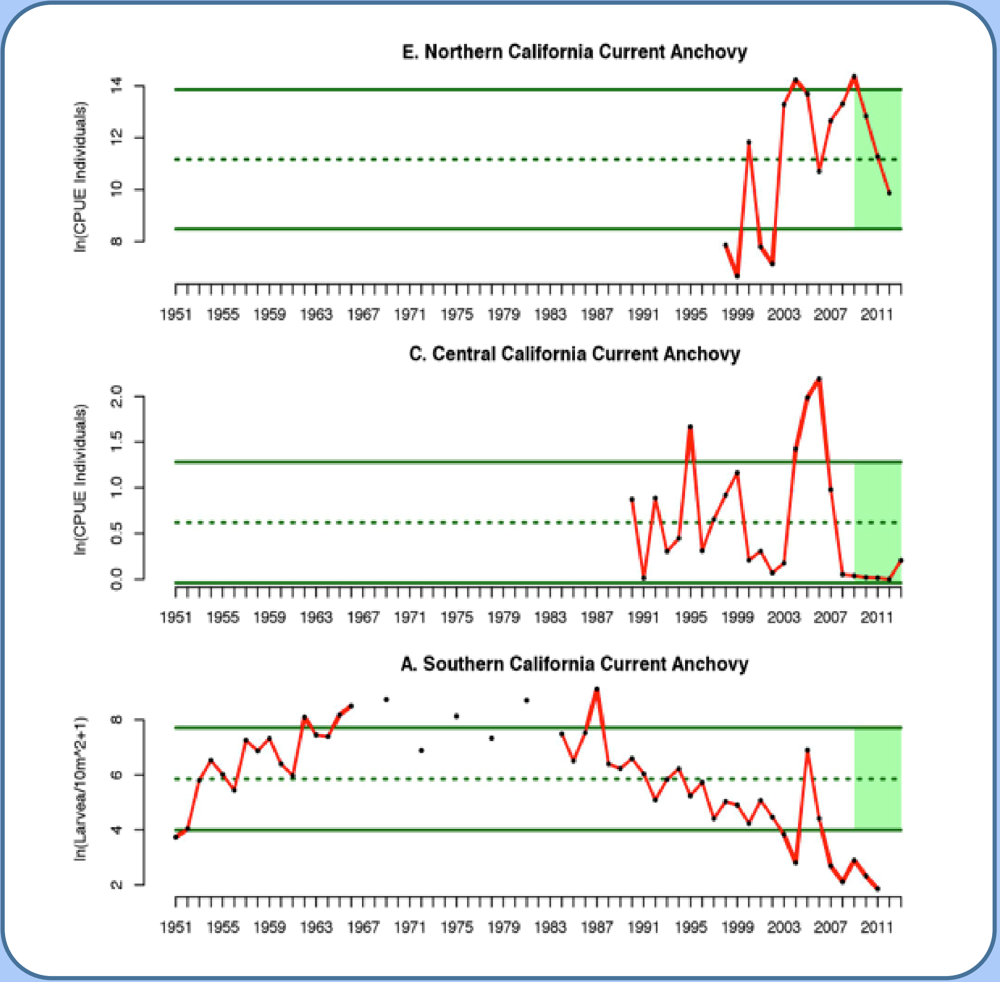
COMPONENTS OF ECOLOGICAL INTEGRITY



SARDINE

- Sardine abundance is reduced in central and northern cruises

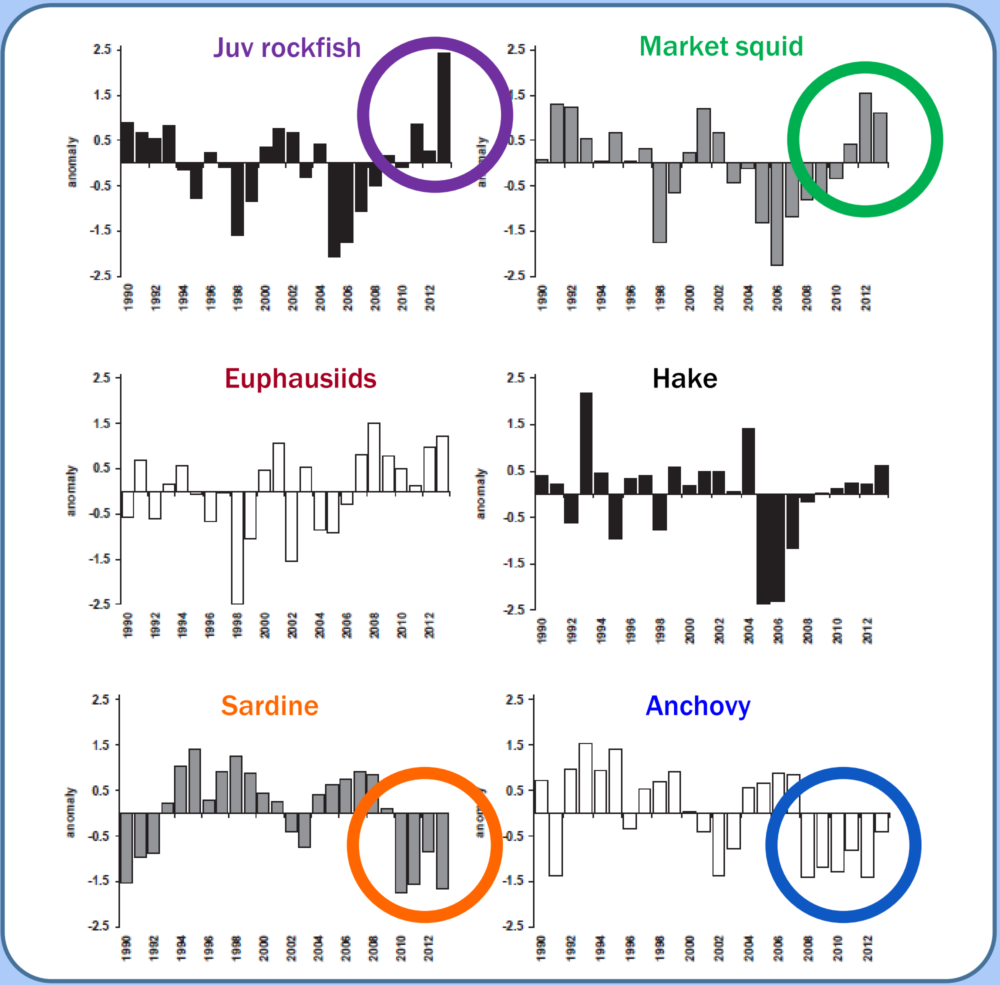
COMPONENTS OF ECOLOGICAL INTEGRITY



ANCHOVY

- Anchovy abundance is reduced in southern and central cruises

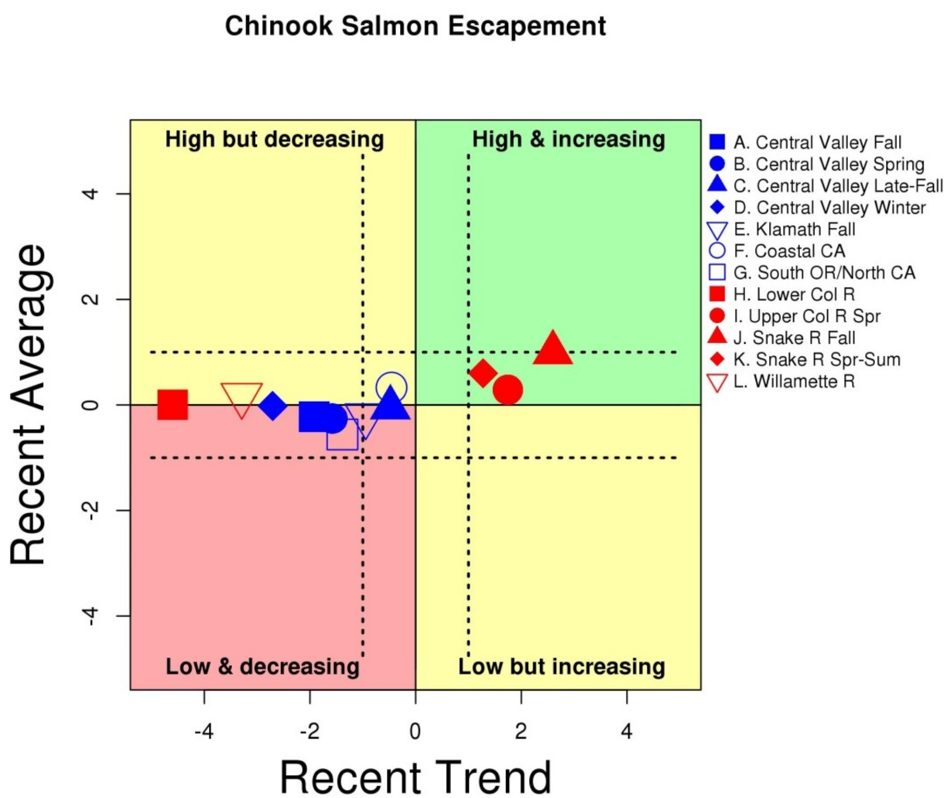
COMPONENTS OF ECOLOGICAL INTEGRITY



FORAGE SPECIES

- Anchovy and sardine appear reduced
- But, other forage species such as juvenile rockfishes and squid are above average in a number of cruises along the CCE.

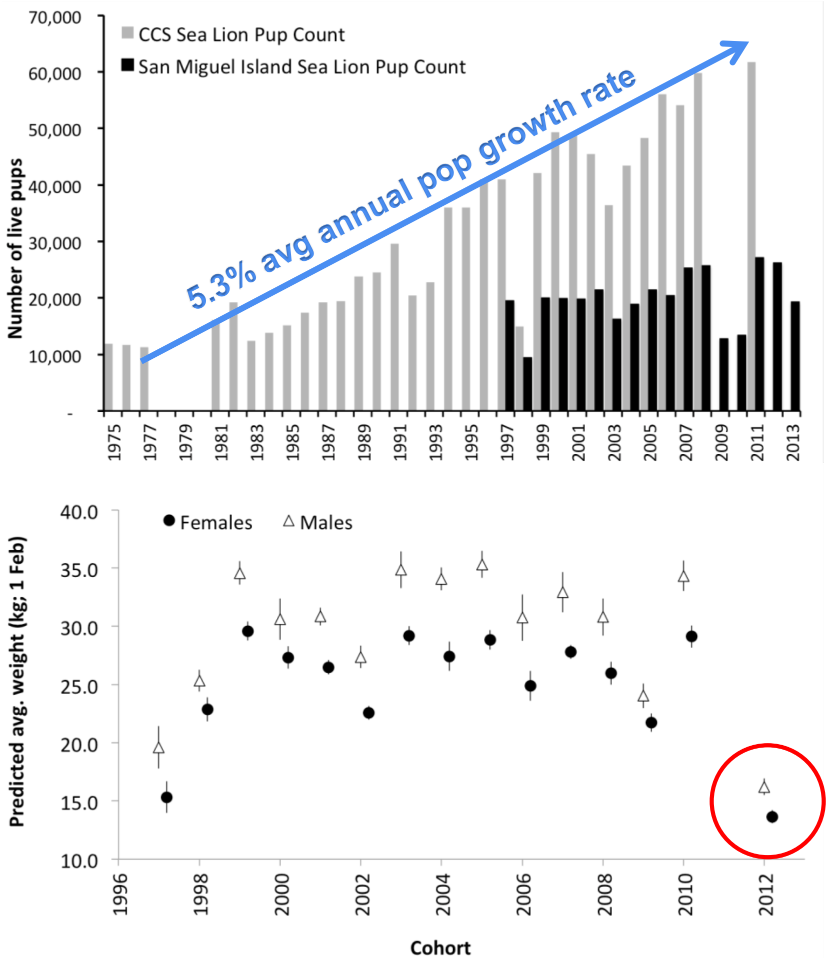
COMPONENTS OF ECOLOGICAL INTEGRITY



CHINOOK SALMON

- Recent escapements have been **average**
- But, some increasing trends, several decreasing trends
- **ENSO events** have potential to negatively affect many of these stocks

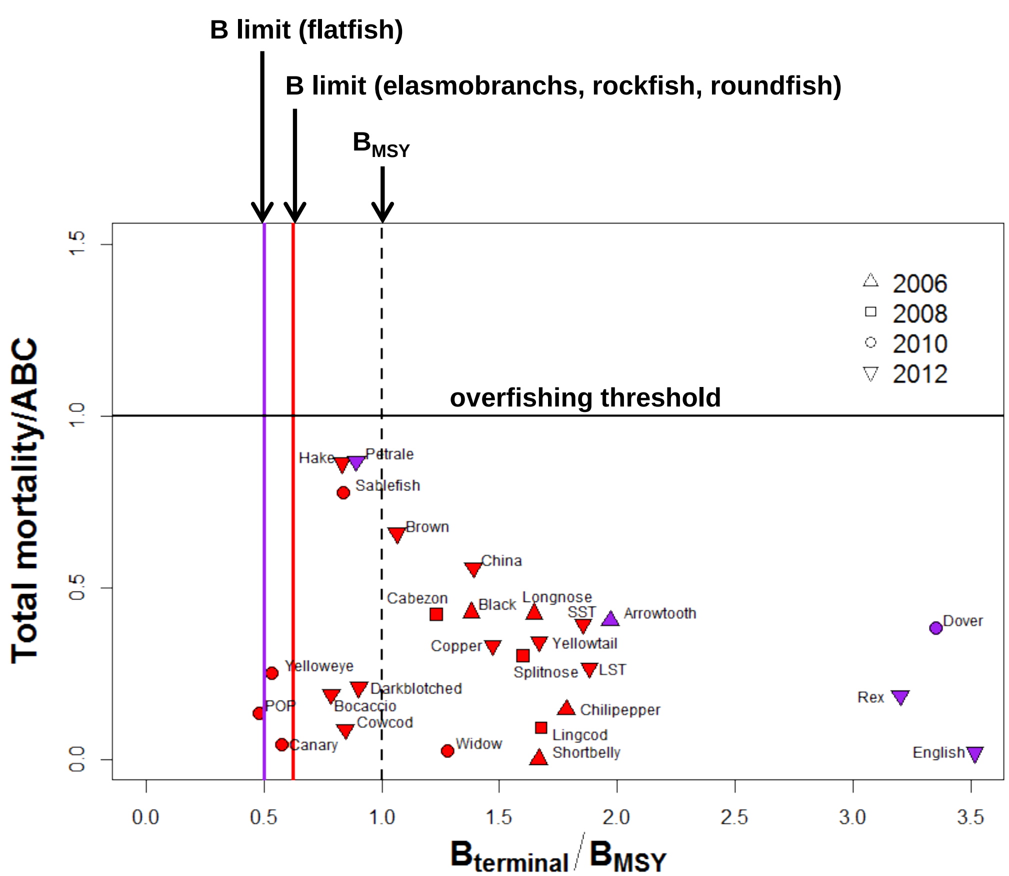
COMPONENTS OF ECOLOGICAL INTEGRITY



CA SEA LION PUPS

- Long-term increase
- Pup weight dropped 40 to 45% in 2012
- Unusual Mortality Event, January-April 2013

COMPONENTS OF ECOLOGICAL INTEGRITY



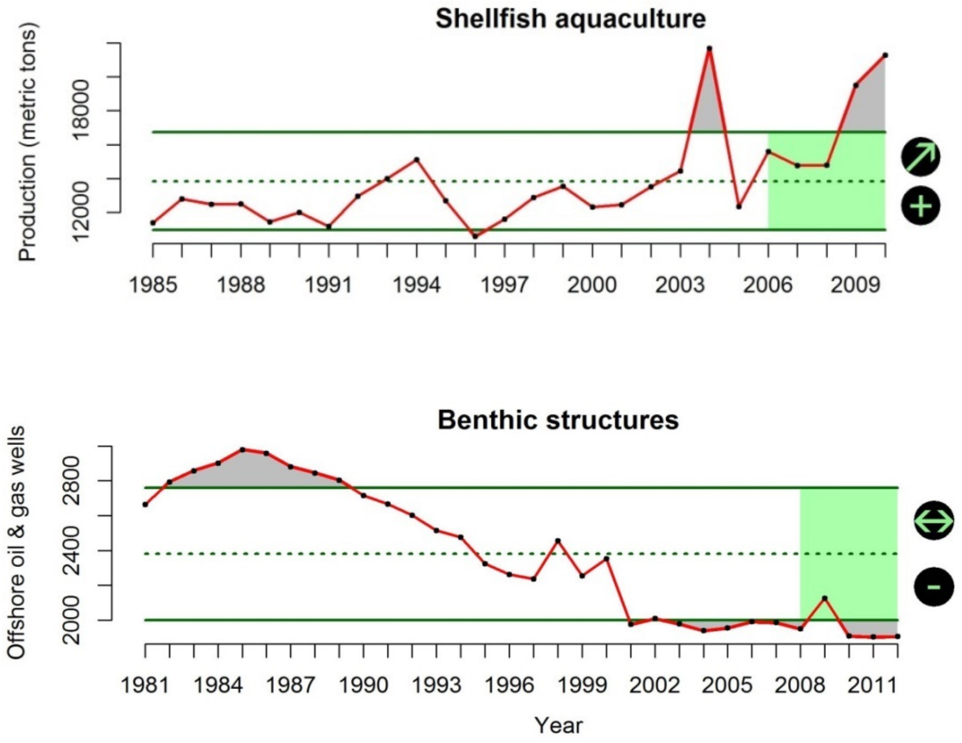
GROUNDFISH

- Most stocks assessed since 2006 are **above B_{MSY} and increasing**
- All **below** overfishing threshold
- 3 overfished stocks: yelloweye, canary, POP

HUMAN ACTIVITIES

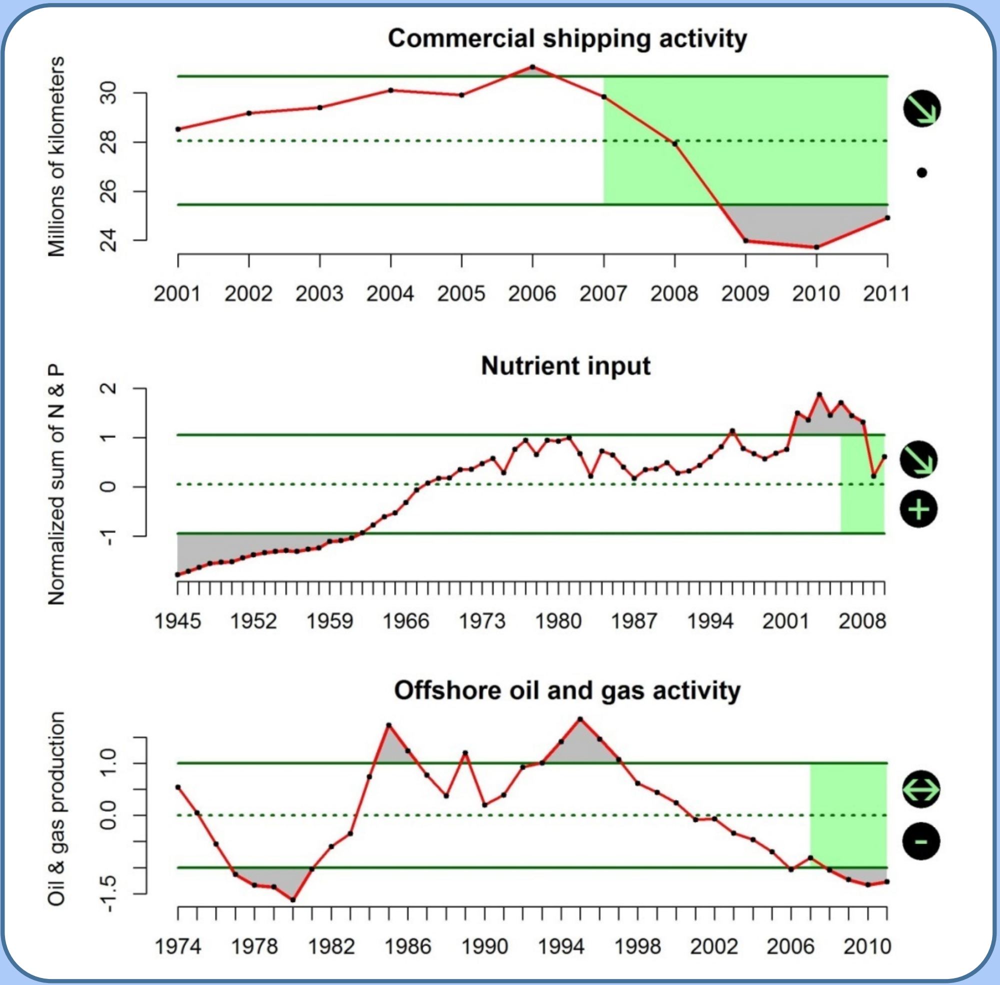
Container ship and tug in Alameda Harbor (NOAA)

HUMAN ACTIVITIES



- Shellfish aquaculture has increased and is above long-term average
- Benthic structures stable over previous 5 years, and below long-term average

HUMAN ACTIVITIES

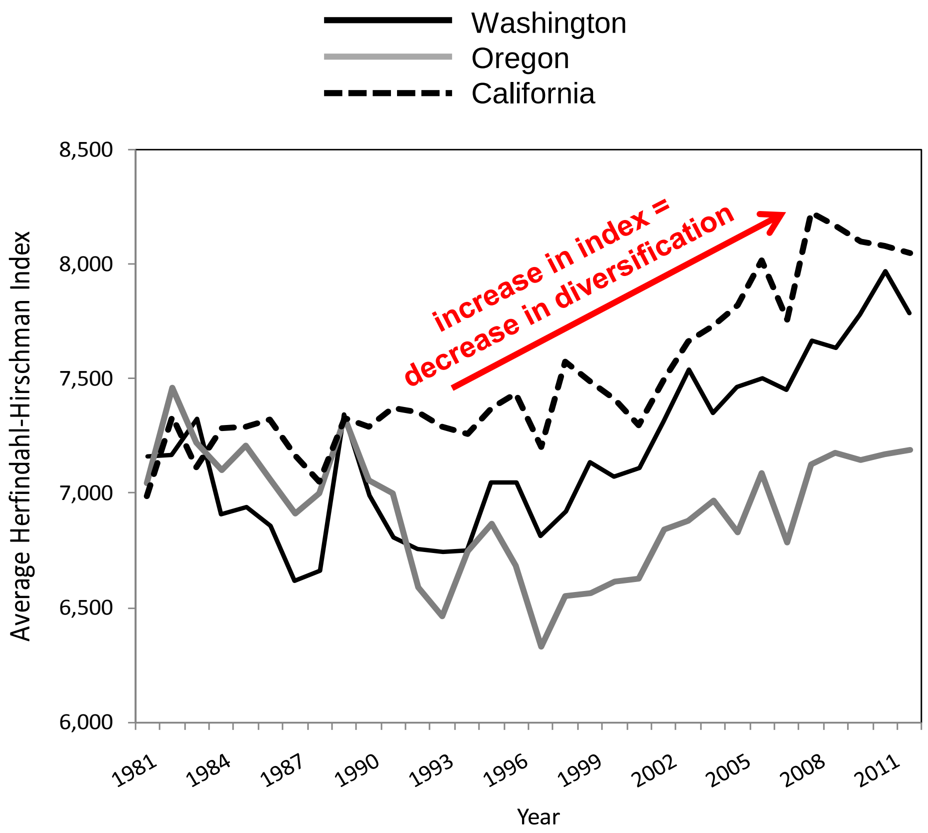


- Commercial shipping has declined
- Nutrient inputs (N & P fertilizers) elevated but declining recently
- Offshore oil and gas activity has leveled off following decline

HUMAN WELLBEING

Anglers near Gig Harbor, WA
(Carol Baldwin, NOAA Photo Library)

HUMAN WELLBEING



FLEET DIVERSIFICATION

- **Revenue stability** increases when fishing activity is diversified
- Diversification of West Coast Fleet is generally **declining** (HHI index ↑)
- Diversification and regulation **interact**

SUMMARY

Seastacks along the Oregon coast (Michael Theberge, NOAA Photo Library)

SUMMARY

- Recent oceanographic patterns stable, supportive of higher primary productivity
- Northern copepod biomass indicates average to favorable conditions for secondary production
- Forage and salmon exhibiting mixed trends
- Groundfish stocks trending higher
- Unusual Mortality Event (UME) of CA sea lion pups in 2013
- Non-fisheries human activities are generally low with stable or declining trends (exceptions: shellfish aquaculture, nutrient input)
- West Coast fleet diversification is declining

GROUNDFISH ADVISORY SUBPANEL REPORT ON CALIFORNIA CURRENT ECOSYSTEM REPORT INCLUDING INTEGRATED ECOSYSTEM ASSESSMENT

Dr. Chris Harvey, Dr. Phil Levin, and Dr. Brian Wells briefed the Groundfish Advisory Subpanel (GAP) on the California Current Ecosystem Report and Integrated Ecosystem Assessment (IEA). Dr. Harvey summarized the state of information, and the GAP was pleased to see that most indicators pointed to generally positive ocean conditions. In some categories, the GAP had questions about information that seemed dated or where conditions had recently changed. The GAP understands that the IEA seeks to use the most current information available but in some cases that information may be several years old.

Dr. Levin's presentation highlighted the importance of considering the human dimension as part of the ecosystem assessment. The GAP endorses that approach and welcomes the opportunity to provide information to Dr. Levin and the IEA to assist with making that portion of the assessment more comprehensive and meaningful.

The GAP appreciates receiving periodic reports about development of the IEA and the opportunity to provide input in the IEA development process.

PFMC
03/08/14

GROUNDFISH MANAGEMENT TEAM REPORT ON CALIFORNIA CURRENT ECOSYSTEM REPORT INCLUDING INTEGRATED ECOSYSTEM ASSESSMENT

The Groundfish Management Team (GMT) attended a joint presentation with the Scientific and Statistical Committee (SSC) by the Integrated Ecosystem Assessment (IEA) Team on the materials presented under this agenda item. The GMT appreciated the presentation and report as a means of introducing broader ecosystem factors and longer-term trends into the discussion. Our impression is that there is interest on both sides for more engagement with the IEA Team and the Council advisory bodies; however, once a year engagement may not be enough. More frequent opportunity to exchange ideas would benefit progress toward using ecosystem information to aid fisheries management discussions. As we have said in the past, we continue to see benefits to integrating the efforts of the IEA Team in National Environmental Policy Act analyses conducted under the Groundfish Fisheries Management Plan.

PFMC
03/08/14

HABITAT COMMITTEE REPORT ON CALIFORNIA CURRENT ECOSYSTEM REPORT INCLUDING INTEGRATED ECOSYSTEM ASSESSMENT

The Habitat Committee (HC) received a briefing from Phil Levin and Correigh Greene (National Marine Fisheries Service) on the Annual State of the California Current Ecosystem (CCE) Report, Integrated Ecosystem Assessment (IEA) Phase II Report and current IEA work.

The HC appreciates the extensive effort required to compile and synthesize ecosystem information in these reports for use by the Council, and believes the two reports are valuable assets that the Council can use as it continues to make progress towards integrating ecosystem information into its management decision-making framework. The following points highlighted in the Annual State of the CCE Report were of particular interest to the HC:

1. From late 2010 to 2012, the trophic Pacific transitioned from weak La Niña to El Niño Southern Oscillation-neutral conditions.
2. Strong upwelling occurred in 2012 for southern and central California and in 2013 for the whole coast, indicating higher primary productivity.
3. Copepod biomass and diversity indicate generally average to favorable conditions for secondary production in the CCE.
4. Survey catches indicate that Northern anchovy abundance is reduced along much of the coast recently; however, a number of other forage fish populations have responded positively to productive conditions.
5. Most salmon populations examined are near their average escapement, but trends are mixed: three populations show increasing trends, six show downward trends, and three show no trends.
6. The mean trophic level of groundfish exhibited a declining trend south of Cape Mendocino, but has been largely stable since 2009 throughout the CCE.
7. In response to the poor condition of sea lion pups at rookeries and a high level of strandings, National Marine Fisheries Service declared an “unusual mortality event” of California sea lion pups in March 2013.
8. Non-fisheries human activities in the CCE that may negatively impact the ecosystem are generally low with stable or declining trends. Nutrient input is an exception: it is elevated, although it shows a declining trend at the coast-wide scale.

With the goal of keeping the Annual State of the CCE Report to a succinct and manageable level, the HC finds the topic descriptions and display of data to be in a useful, easily interpreted, and easily understandable format that clarifies current status and trends compared to long-term trends.

Looking toward the future, it would be beneficial for the IEA Team to engage directly with Council advisory bodies to plan ecosystem scenarios that are useful for Council management. This would enhance future planning of IEA Team activities. The HC looks forward to continued integration of ecosystem-based information into the Council process and hopes to work closely with the IEA Team to enhance this process. Further, the HC strongly supports continued annual reports on the State of the CCE to help inform specific management decisions.

PFMC
03/08/14

Agenda Item C.1.b
Supplemental SAS Report
March 2014

SALMON ADVISORY SUBPANEL REPORT ON THE CALIFORNIA CURRENT ECOSYSTEM REPORT INCLUDING INTEGRATED ECOSYSTEM ASSESSMENT

The Salmon Advisory Subpanel (SAS) reviewed the State of the California Current Ecosystem Report (CCER) (Agenda Item C.1.a, Attachment 1). The SAS found this report to be very informative in broadening our understanding of "ocean conditions". The SAS feels the CCER has immense value for helping the Pacific Fishery Management Council and other fishery managers more accurately predict survival and recruitment of salmon. The prediction of salmon stock abundance levels is essential to the development of prudent and appropriate management and harvest strategies. The SAS views this report to be an important tool in that effort and is supportive of the continued funding of ecosystem research and reporting.

In addition, while much is known about inland salmon habitats, those marine habitats important to salmon during most of their life cycle have not been a focus for agencies, fishermen or the public. The CCER consolidates ocean habitat research and applicable data into a single source document. The SAS views that as a significant step in focusing attention and discussion on measurable environmental parameters as opposed to a vague reference to "ocean conditions".

The SAS recommends continued funding of this effort

PFMC
03/08/14

THE CALIFORNIA CURRENT INTEGRATED ECOSYSTEM ASSESSMENT (CCIEA)

John Stein
Northwest Fisheries
Science Center

Cisco Werner
Southwest Fisheries
Science Center

8 March 2014

California Current Integrated Ecosystem Assessment Team

WHAT IS AN IEA?

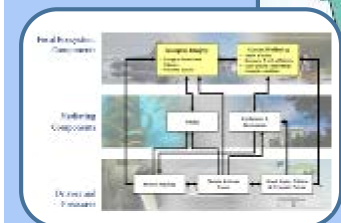
IEAs provide '*a **synthesis and integration of information** on relevant physical, chemical, ecological, and human processes in relation to specified management objectives*'

IEAs draw on **both the natural and human-dimension sciences**

IEAs determine the status of **coupled Social-Ecological Systems** and to evaluate management options

IEAs are both a process and products

THE CCIEA IN ACTION



CONCEPTUAL MODELS
and SCOPING EFFORTS
help frame the issues

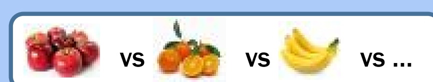
Fi...
data provide
STATUS AND TRENDS

Is the ecosystem “healthy”?

How vulnerable is the ecosystem to human uses and natural perturbations?

RISK

Exposure



Now what do we do?

0 5 10 15 20 25 30

Year

IEA PRODUCTS

HOW THE CCIEA SUPPORTS PFMC ACTIVITIES

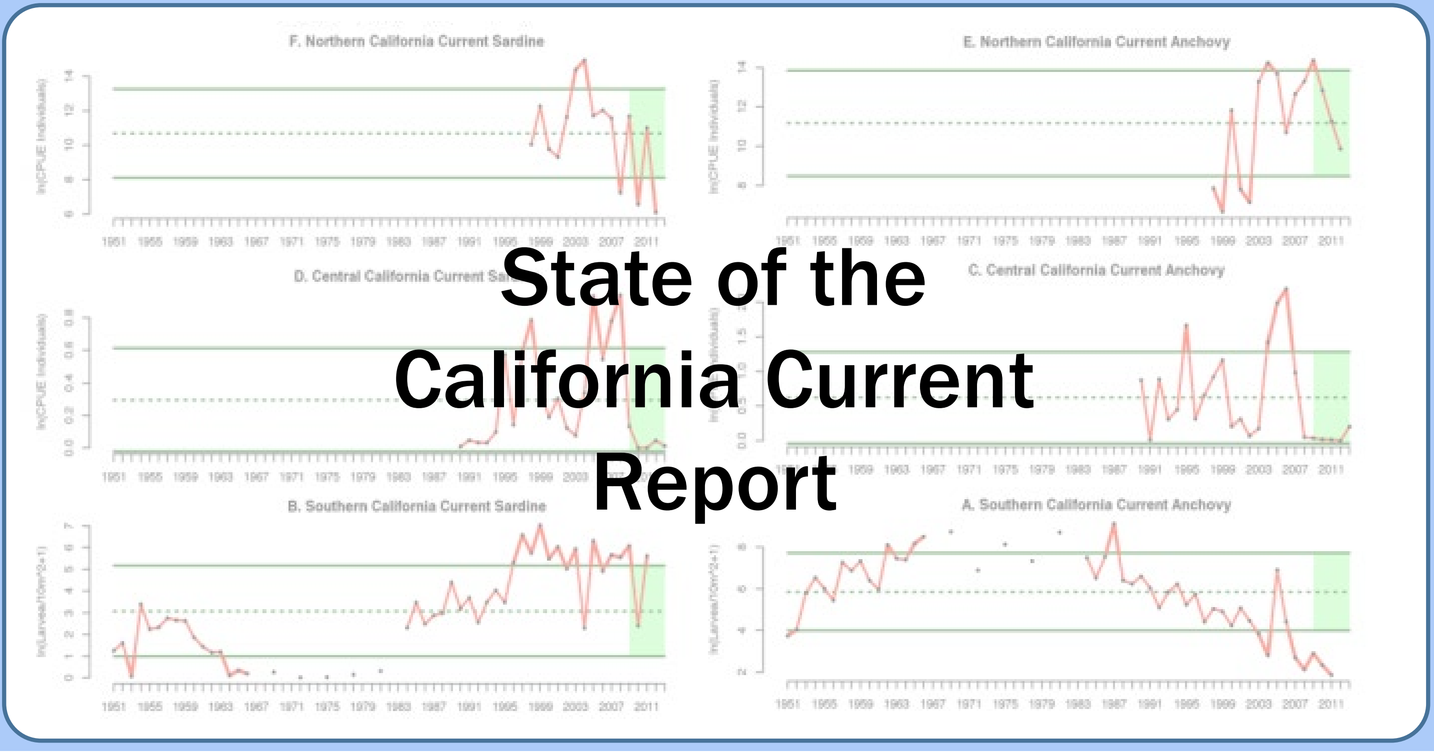
CCIEA products are relevant to and/or provide support for:

- ✓ Annual "State of the California Current" report
- Fishery Ecosystem Planning (ex: forage fish)
- Essential Fish Habitat designations (ex: groundfish)
- Salmon Management
- Environmental Impact Statements

THE CCIEA IN ACTION

<u>Example: forage fish and climate change</u>

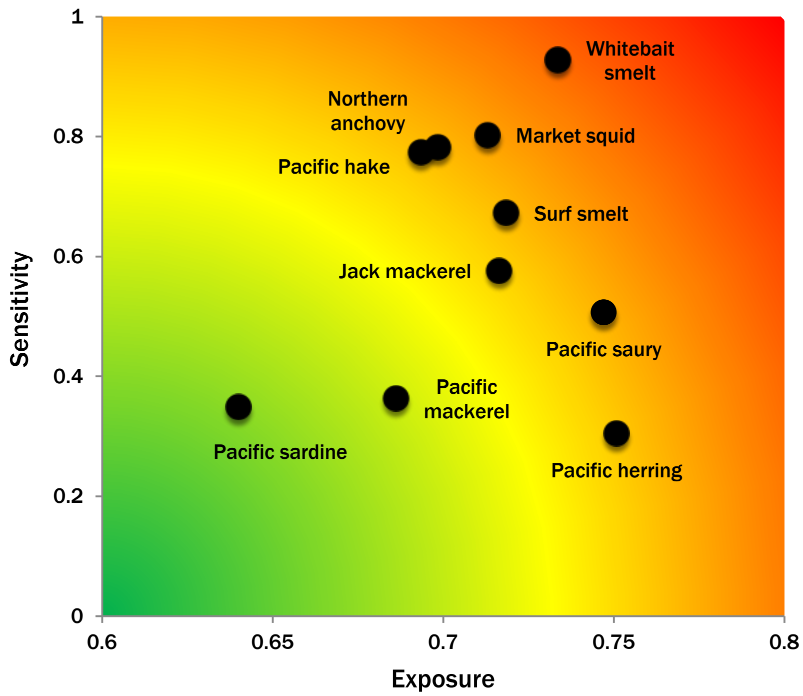
- Status and trends
- Risk analysis
- Scenario evaluation



THE CCIEA IN ACTION

Example: forage fish and climate change

- Status and trends
- Risk analysis
- Scenario evaluation

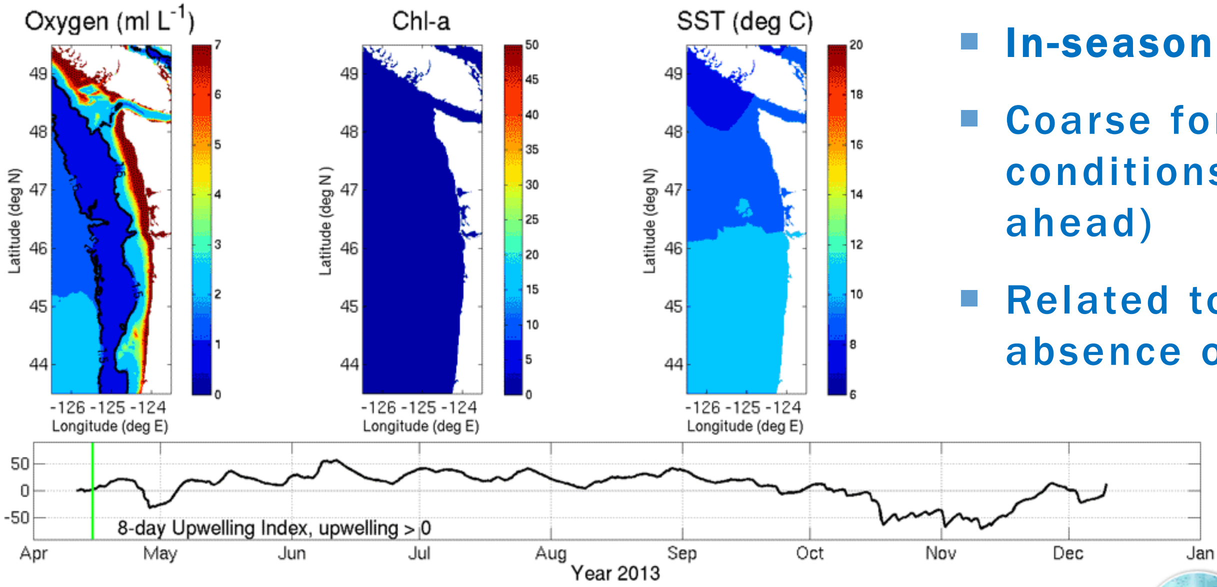


- Risk assessment of forage fish in the California Current to climate change in the coming century
  - SST (average, variability)
  - Chl-*a* (average, variability)

THE CCIEA IN ACTION

Example: forage fish and climate change

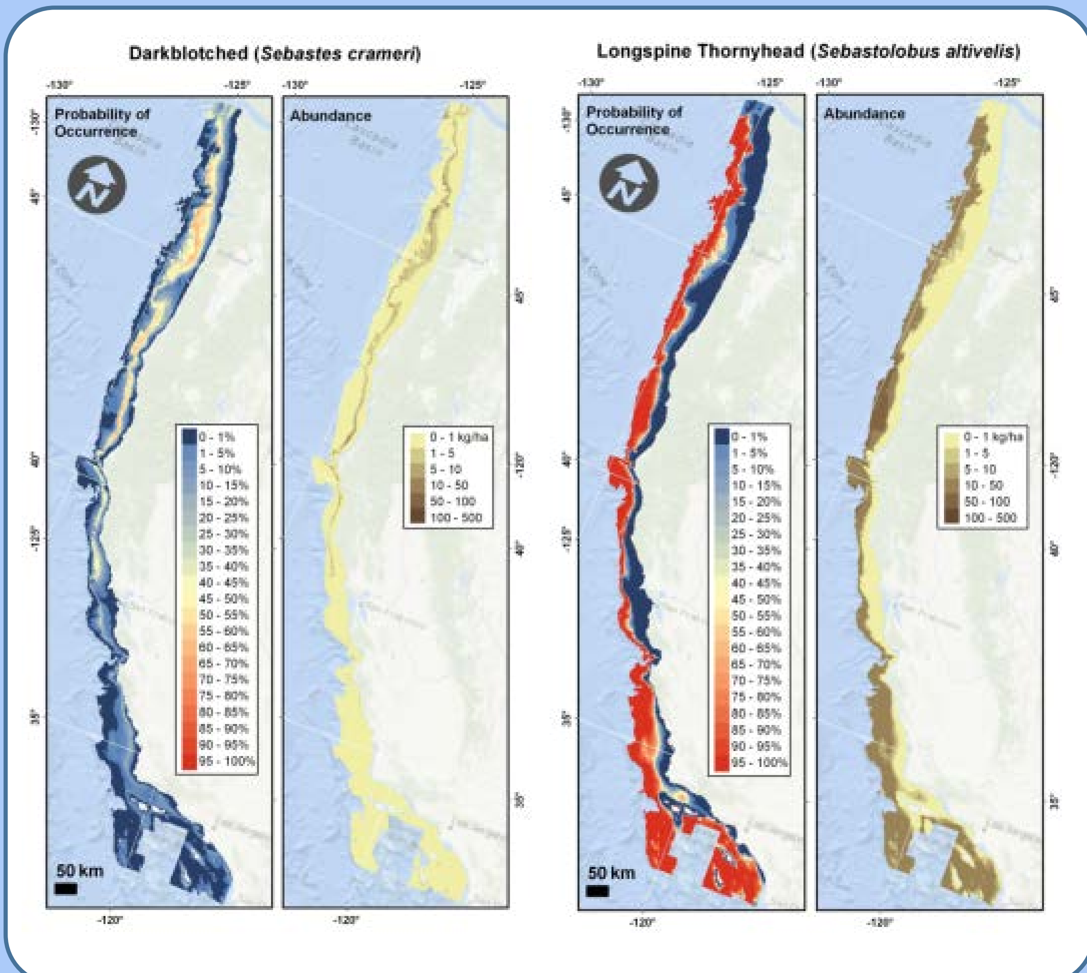
- Status and trends
- Risk analysis
- Scenario evaluation



- In-season climate scenarios
- Coarse forecasts of ocean conditions (6-9 months ahead)
- Related to presence/ absence of sardines

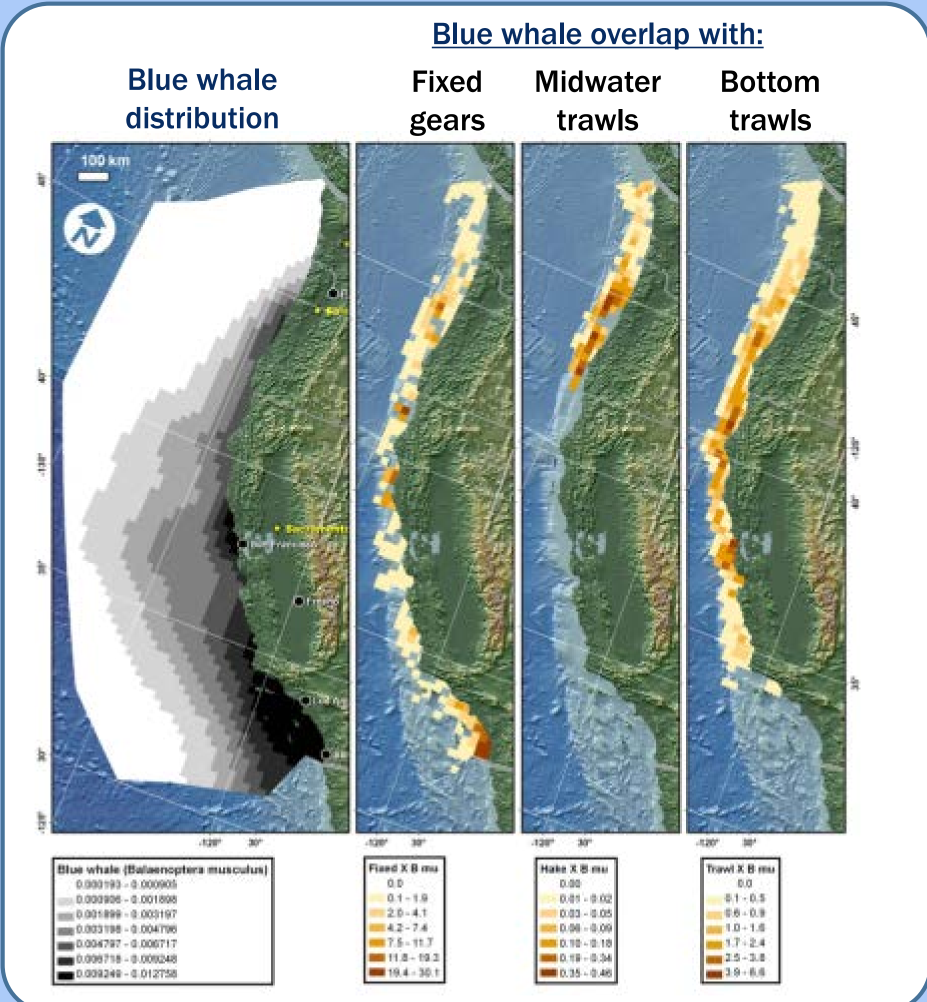
http://www.nanoos.org/products/j-scope/forecasts.php

HOW THE CCIEA SUPPORTS PFMC ACTIVITIES



- <u>Groundfish EFH</u>
- Habitat-based predictions of distribution and abundance
- Predictive models for:
  - Darkblotched rockfish
  - Yelloweye rockfish
  - Greenstriped rockfish
  - Petrale sole
  - Sablefish
  - Longspine thornyhead

THE CCIEA IN ACTION

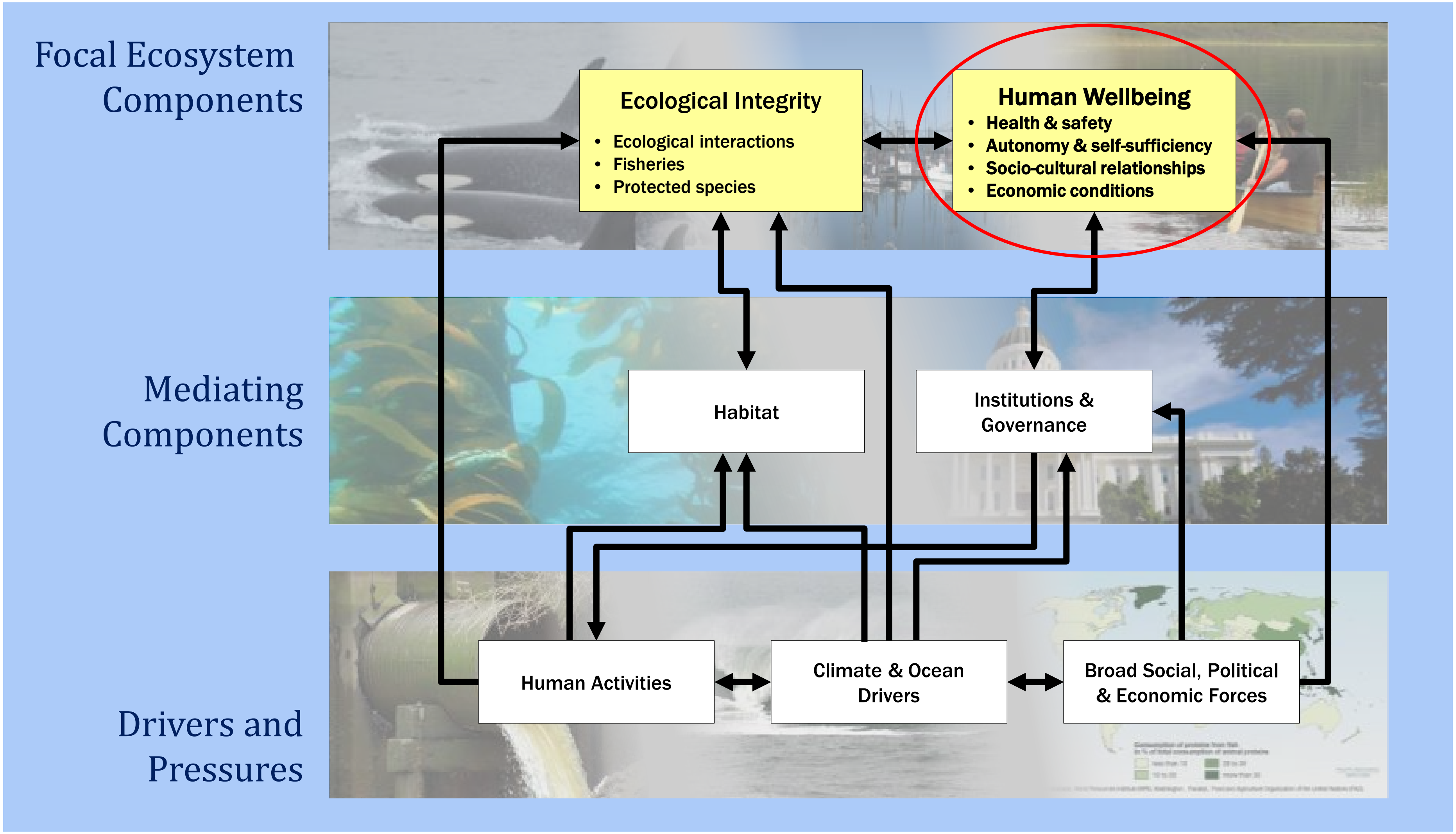


Increased Understanding

As an example:

- Potential interactions between groundfish gears and distributions of protected species

SOCIO-ECOLOGICAL SYSTEM OF THE CALIFORNIA CURRENT

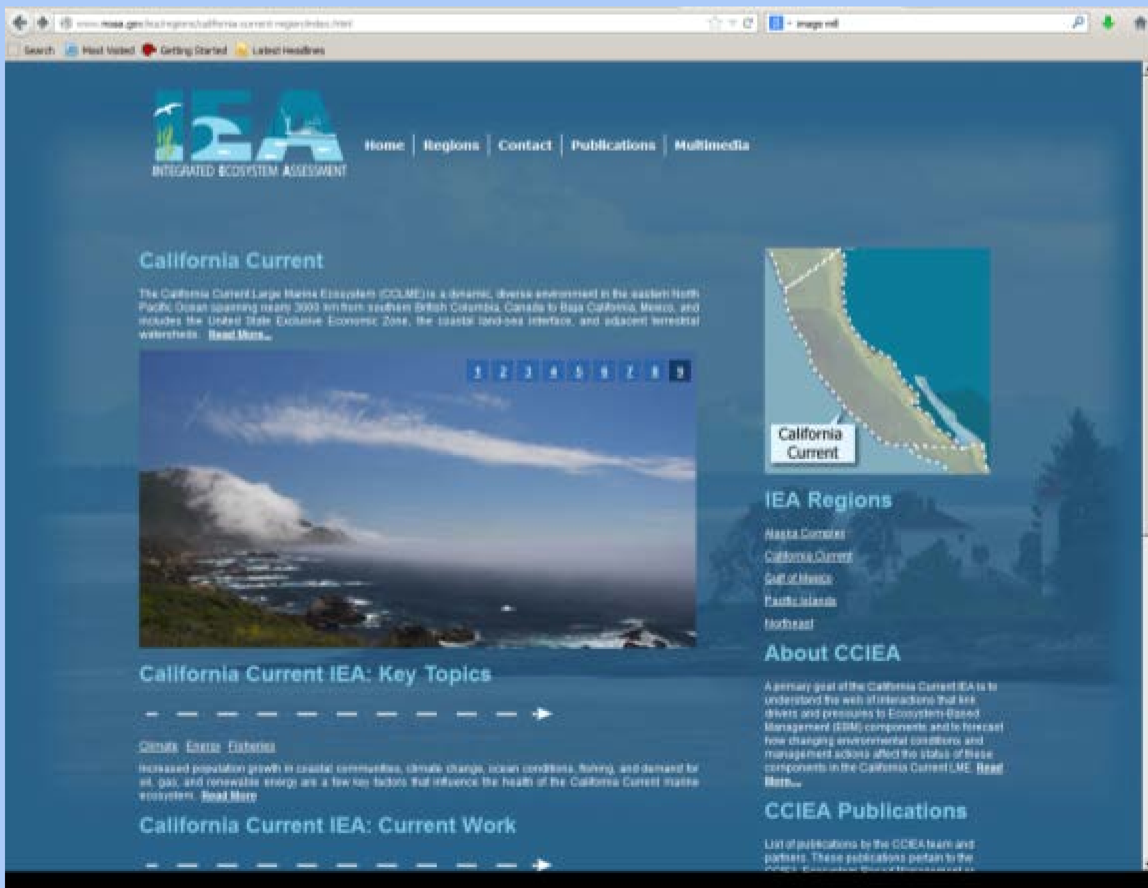


HUMAN WELLBEING

Culture
Community
Continuity
Cash
(eConomy)

CCIEA WEBSITE

www.noaa.gov/iea/regions/california-current-region/



- Up-to-date research priorities and highlights
- Products
  - Findings
  - Reports formatted for easy web-based viewing
  - Peer reviewed
- Coming soon: web-based data portal and visualization tools

PARTIAL LIST OF CCIEA PRODUCTS

- <u>Synthesis products</u>
  - Annual reports on status and trends of major components of ecosystem
  - Indicators and conceptual models for marine spatial planning on Washington Coast
- <u>Fisheries management</u>
  - Evaluation of impacts of fishing on forage fish
  - Evaluation of impacts of new fisheries
  - Evaluation of cumulative impacts of fisheries on ecosystem
  - Evaluation of effects of gear switching and spatial closures
  - Evaluation of potential conflicts between wave energy development and fisheries
  - Evaluation of effects of catch shares on ecosystem, landings, revenues
- <u>Risk assessments</u>
  - Risk assessment to fisheries and habitat from human activities
  - Risk assessment of groundfish fisheries to marine mammals
  - Risk assessment for Monterey Bay National Marine Sanctuary
- <u>Protected resources</u>
  - Salmon return forecast model
  - Evaluation of effects of dam removal on salmon
  - Assessment of drivers leading to sea lion UME
  - Coast-wide marine sturgeon habitat models
- <u>Climate effects</u>
  - Effects of climate change on pelagic system
  - Evaluation of effects of temperature and flow on salmon habitat and survival
  - Summary of salmon and climate change modeling
- <u>Non-fisheries activities</u>
  - Expert-based narrative forecast of shipping trends

NEXT STEPS

- Expansion and completion of:
  - Habitat component
  - Human dimensions
  - HMS
- SSC review of Atlantis ecosystem model (June 2014)
- Developing tactical EBFM tools
- Seeking Council and community input
  - Developing social indicators
  - Developing specific, PFMC-relevant scenarios

REFLECTIONS

- The engagement we desired occurred
- We received critical comments about the science
- What we heard from the SSC, GAP, Habitat Comm, and GMT:
  - Estimates of probability--accuracy and uncertainty; perhaps something that should be elevated to a national level IEA discussion
  - What can we predict/project based on diagnostics, models; what happens as a result of events (ENSOs)
  - We need better ways to visually present/communicate findings

CONFIDENCE AND LIKELIHOOD SCALES

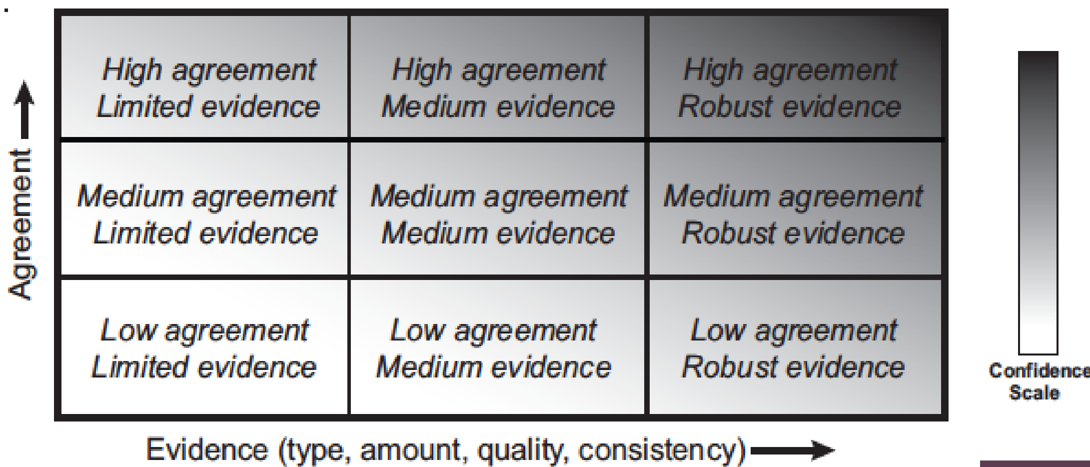


Table 1. Likelihood Scale

Term*	**Likelihood of the Outcome**
Virtually certain	99-100% probability
Very likely	90-100% probability
Likely	66-100% probability
About as likely as not	33 to 66% probability
Unlikely	0-33% probability
Very unlikely	0-10% probability
Exceptionally unlikely	0-1% probability

http://www.ipcc.ch/pdf/supporting-material/uncertainty-guidance-note.pdf

REFLECTIONS

- What we heard from the SSC, GAP, Habitat Comm, and GMT:
  - Strategic and tactical "How do we use this work for assessments?"
  - The speed at which some our products are being developed is behind the general knowledge of the system.
  - The fishermen know the system, thus provide good reviews and direction.
  - Quote from GAP: "We're being regulated out of business"
  - We need to continue and improve engagement to all committees.

SCIENTIFIC AND STATISTICAL COMMITTEE REPORT ON
THE CALIFORNIA CURRENT ECOSYSTEM REPORT INCLUDING INTEGRATED
ECOSYSTEM ASSESSMENT

The Scientific and Statistical Committee (SSC) reviewed the Annual State of the California Current Ecosystem Report and Supplement (Agenda Item C.1.a, Attachments 1 and 2) and the California Current Integrated Ecosystem Assessment (IEA) Phase II Report (Agenda Item C.1.a, Attachments 3 and 4). Dr. Chris Harvey from the Northwest Fisheries Science Center (NWFSC) and Dr. Brian Wells from the Southwest Fisheries Science Center (SWFSC) presented on the State of the California Current report. Dr. Phil Levin (NWFSC) presented on the Phase II report.

The Annual State of the California Current Ecosystem Report is a succinct source of information on trends in climate indicators, fish abundance, sea lion abundance and condition, non-fishing human activities, and major fisheries. The report is an important first step in providing the Council family with an ecosystem perspective on West Coast fish stocks, fisheries, and coastal communities. The SSC appreciates the authors' responsiveness to suggestions offered by the Council and SSC on the previous year's report. Useful background information and additional details are provided in the supplemental attachment 2 and journal articles linked therein.

The SSC recommends incorporating information on measurement/sampling uncertainty for indices whenever they are available.

The SSC also notes that that some ecosystem attributes are so intrinsically variable that short-term trends are unlikely to be statistically distinguishable even if present. The SSC also recommends attempting to identify threshold values of indicators, with these proposed thresholds subsequently reviewed by the SSC.

The SSC is concerned that the data presented on coastal pelagic species (CPS) and forage species abundance (Figures 3.3 and 3.4) are drawn from surveys that used different gear, were limited in spatial extent, and were not designed to sample forage fish, and may therefore be misleading.

The SSC suggests that Chapter 4 (human activities) and 5 (human wellbeing) be reorganized to characterize all of the mentioned activities as sources of wellbeing, with the level of each activity suggestive of both the extent of wellbeing and adverse effects on the ecosystem. Activity levels should in turn be distinguished from indicators that are more directly relevant to ecosystem effects (e.g., nutrient input, ship strikes).

The State of the California Current Ecosystem Report is currently limited to 20 pages at the Council's request, which necessarily limits what can be included. The SSC recommends inclusion of information on additional upper trophic level predators (e.g., sea birds and marine mammals other than sea lions) and abundance estimates for CPS derived from stock assessments when available. IEA team members expressed interest in presenting habitat information as well as more economic analyses. To make room for this information, forage fish abundance, information on vessels fishing in Alaska, and human well-being data from Puget Sound could be dropped.

One hour of Committee time is not sufficient to provide a meaningful review of all aspects of the Annual State of the California Current Ecosystem Report. The SSC recommends a meeting of the Ecosystem Based Management Subcommittee of the SSC toward the end of the year to conduct a more thorough review of the Annual State of the California Current Ecosystem Report and some elements of the IEA, in addition to the planned review of Atlantis. The SSC recommends establishing a routine process for feedback between the IEA team and the Council.

PFMC
03/08/14