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.

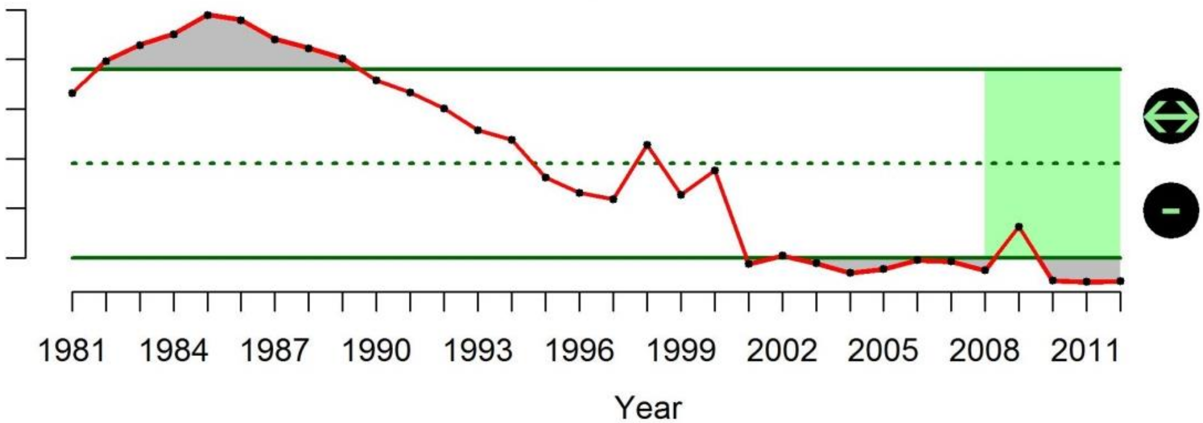

Figure 1.1: Sample figure to demonstrate status trend plots in this document. Dark green horizontal lines show the mean (dashed line) ± 1.0 s.d. (solid lines) of the full time series. The shaded green area represents the last five years of the time series, which are analyzed to produce the symbols to 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.

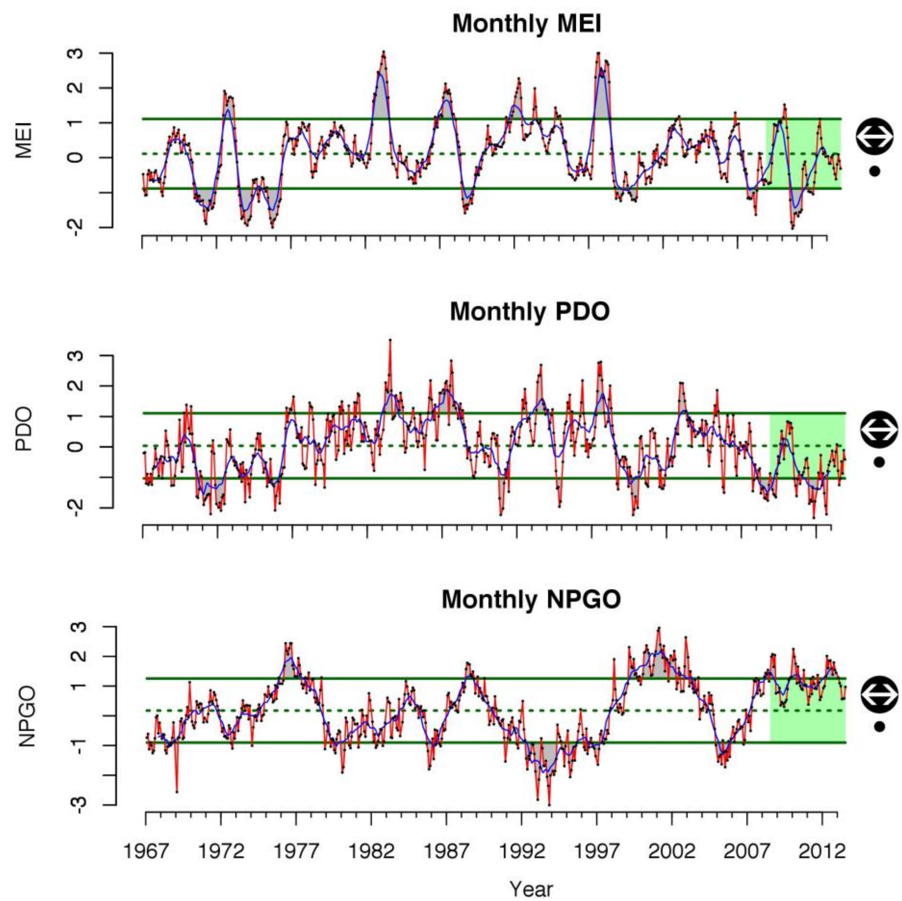

Figure 2.1. Monthly values of basin-scale climate indicators used to assess environmental variability impacts in the California Current ecosystem. The three time series are Multivariate ENSO Index (MEI), Pacific Decadal Oscillation (PDO), and North Pacific Gyre Oscillation (NPGO). Lines, colors and symbols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

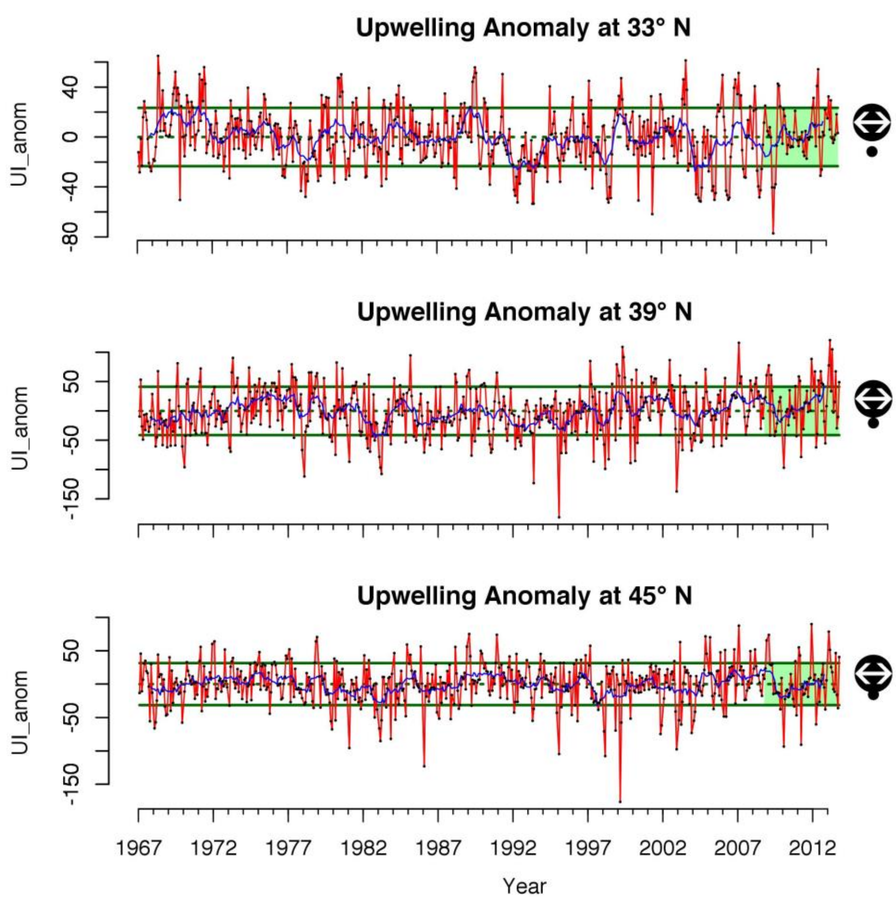

Figure 2.2. Monthly upwelling anomalies ($m^3/s/100$ km) calculated at three locations along the California Current (labeled by latitude North) with seasonal means removed from the Bakun Upwelling Index. Lines, colors and symbols are as in Figure 1.1; the blue line shows the 12-month running avg.

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.

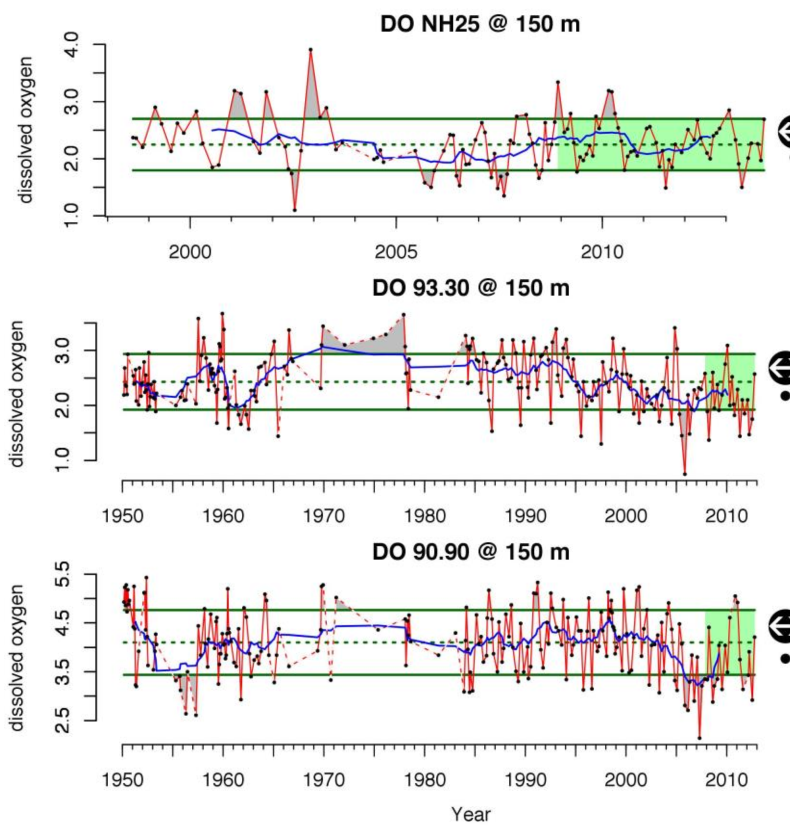

Figure 2.3. Dissolved Oxygen (in ml L^{-1}) in the CCE, 1983-2013. Dissolved oxygen was measured at 150 m depth off of Oregon (Newport Line station NH25) and southern California (CalCOFI stations 93.30 and 90.90). Stations 93.30 and NH25 are located within 50 km from the shore, while station 90.90 is 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.

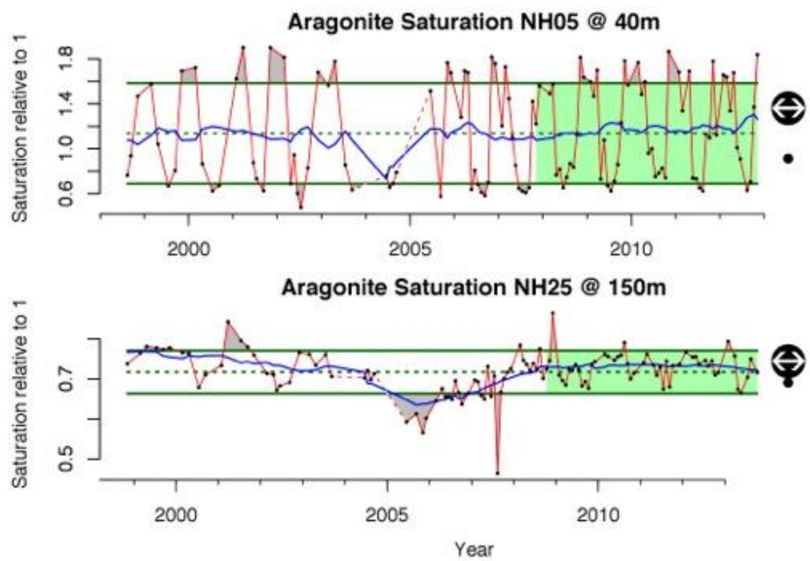

Figure 2.4. Aragonite saturation trends in the northern CCE, 1998-2013 (see text for explanation). Lines, colors and symbols are as in Figure 1.1; the blue line shows the 12-month running average. The time series is similar to the oxygen data shown in Figure 2.2 because aragonite saturation is calculated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

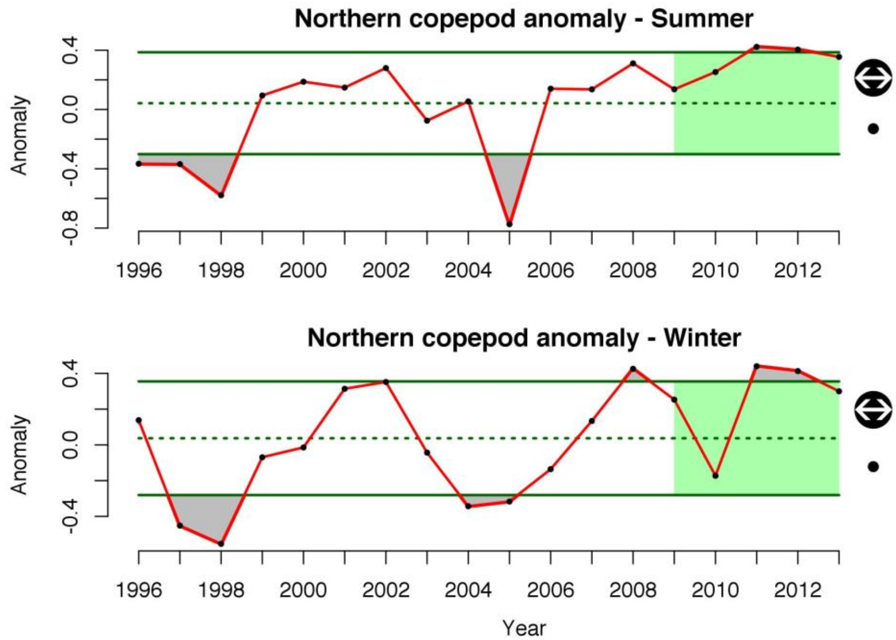

Figure 3.1. Northern copepod biomass anomaly for 1996-2012 in the waters off of Oregon during the winter (Oct-April) and summer (May-Sept). Lines, colors and symbols are as in Figure 1.1. Data courtesy of Bill Peterson.

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.

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

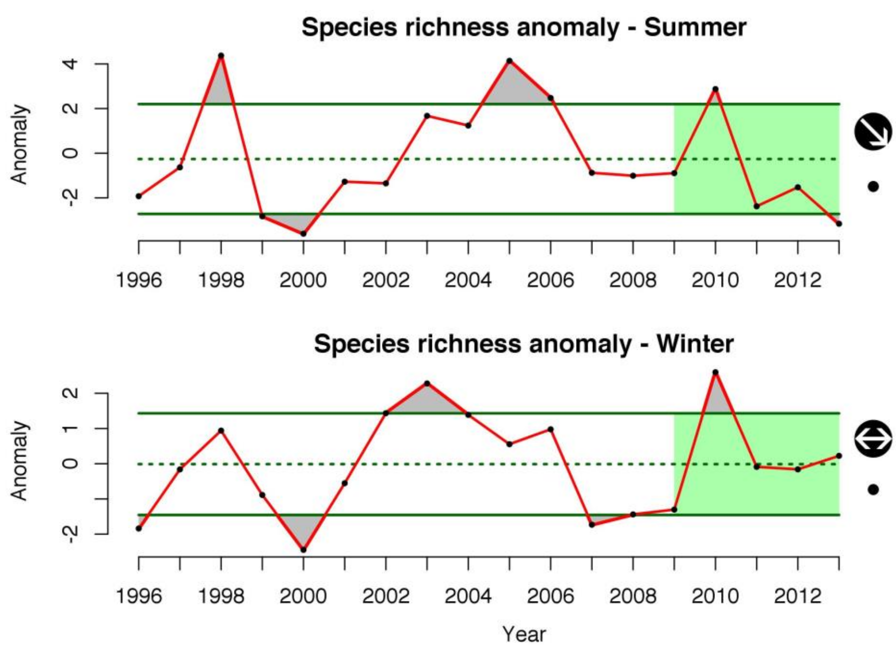

Figure 3.2. Copepod species richness in waters off Oregon from 1997-2012. Lines, colors and symbols are as in Figure 1.1. Data courtesy of Bill Peterson.

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.

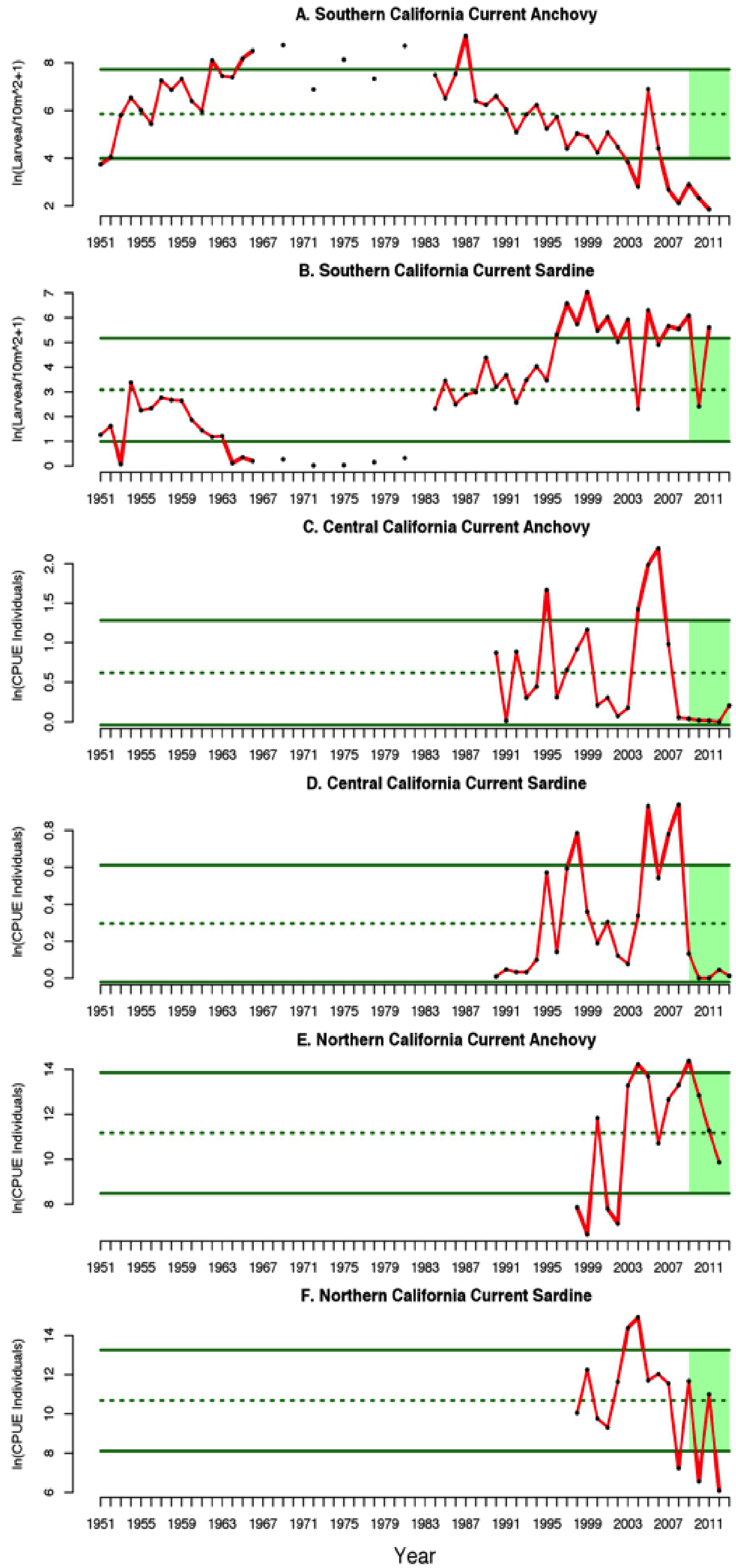

Figure 3.3. Abundance of anchovy and Pacific sardine in surveys. Lines and colors are as in Figure 1.1. Symbols indicating recent trends and means were not used in this figure, due to the life history characteristics of these populations.

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.

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).

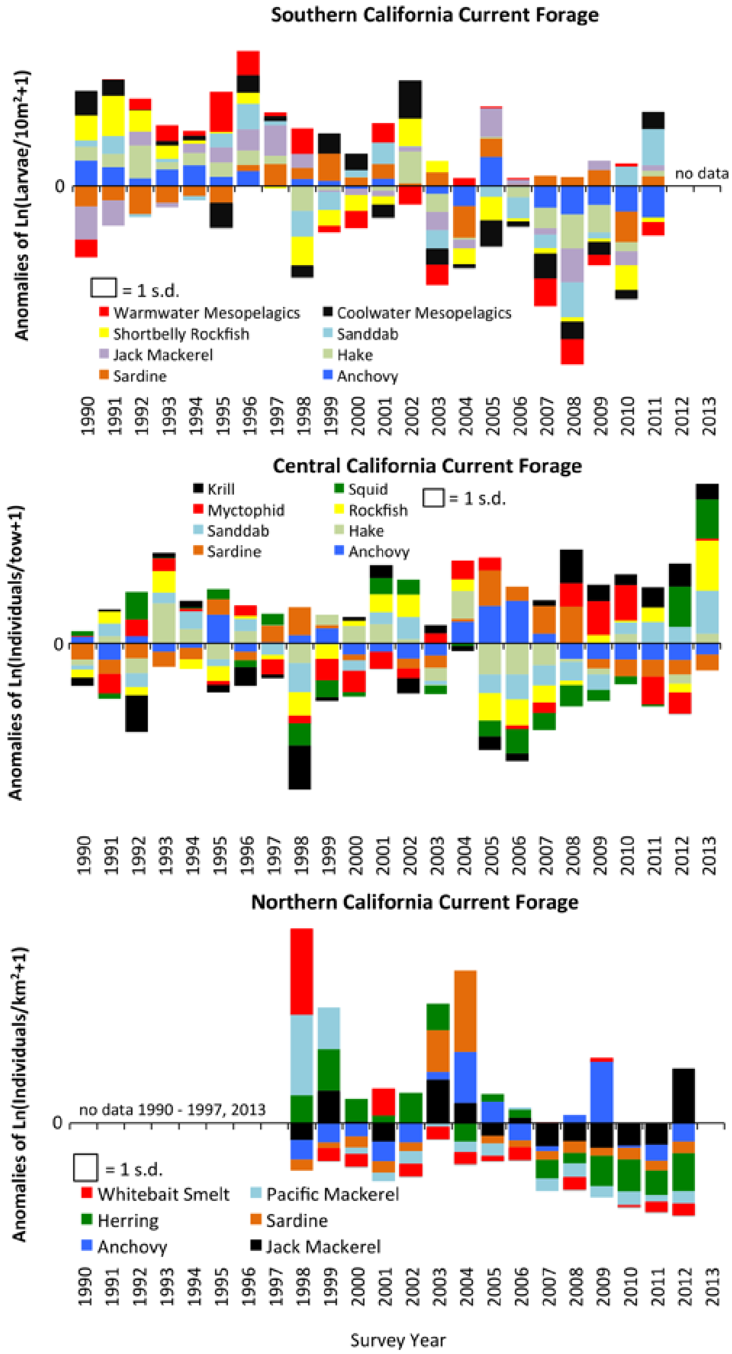

Figure 3.4. Stacked anomalies of the most common species caught in each larval fish survey. Zero reference indicates average; above the line indicates above average for that year. Also shown is a scale for 1 standard deviation (s.d.), indicating the degree to which any given species is above or below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

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.

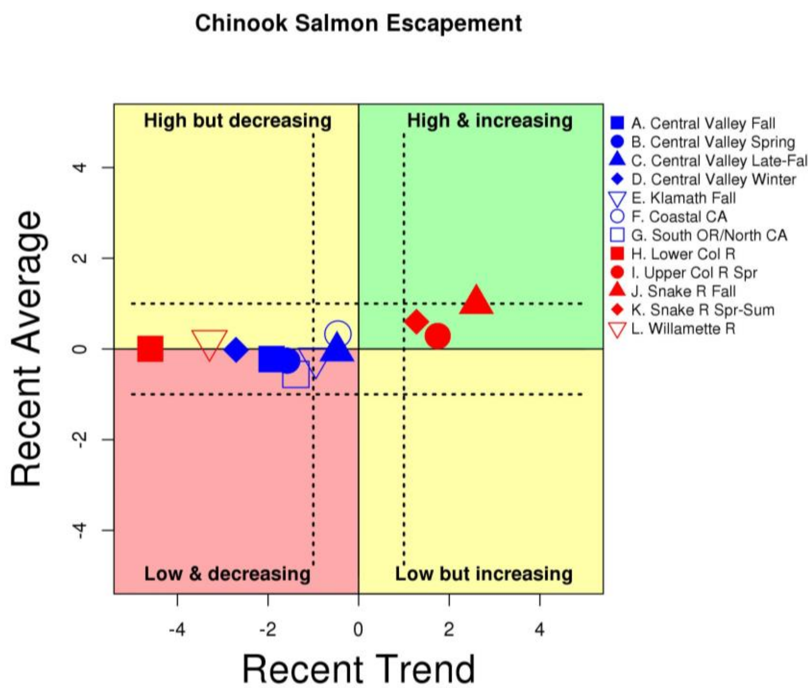

Figure 3.5. West Coast salmon escapement trends.

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 or not 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.

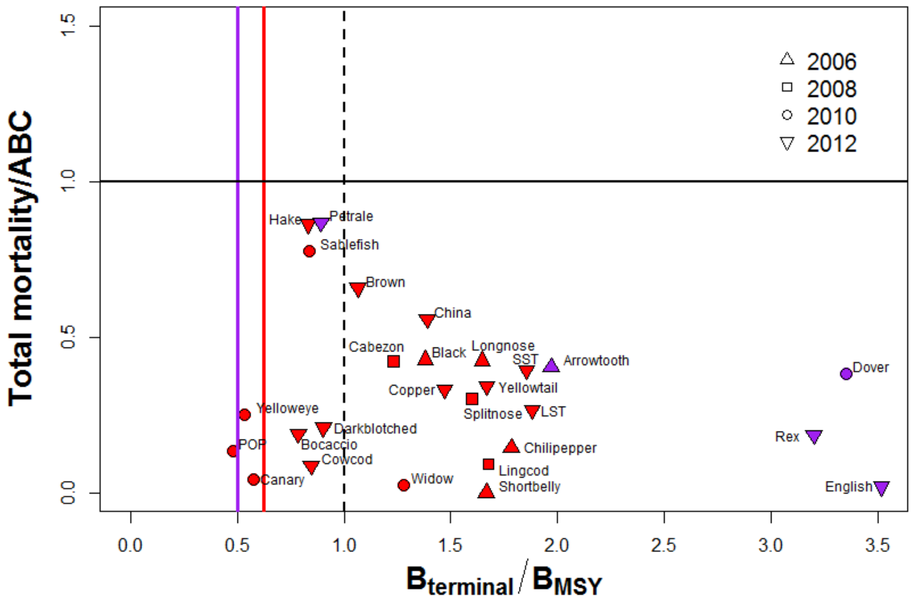

Figure 3.6. Stock status of all California Current groundfish assessed since 2007. The vertical broken line indicates the target biomass reference point. The vertical solid lines indicate the limit reference point showing an overfished status (red for elasmobranchs, rockfishes, and roundfishes; purple 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.

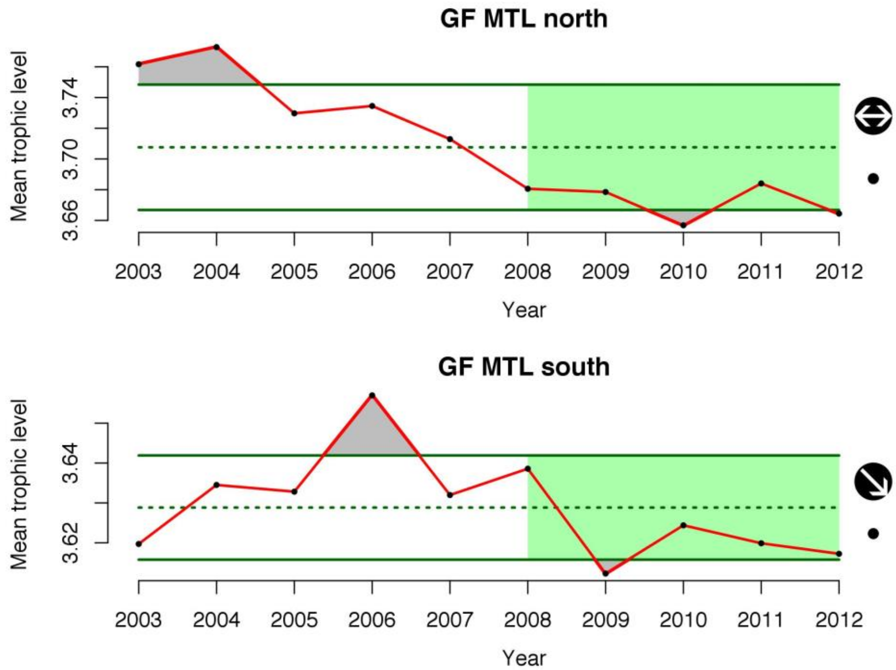

Figure 3.7. Area-weighted mean trophic level (MTL) for West Coast groundfishes north (upper) and south (lower) of Cape Mendocino from 2003 – 2012. Colors, lines and symbols are as in Fig. 1.1. Data are from the West Coast Groundfish Bottom Trawl Survey, courtesy of Beth Horness (Beth.Horness@noaa.gov).

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.

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).

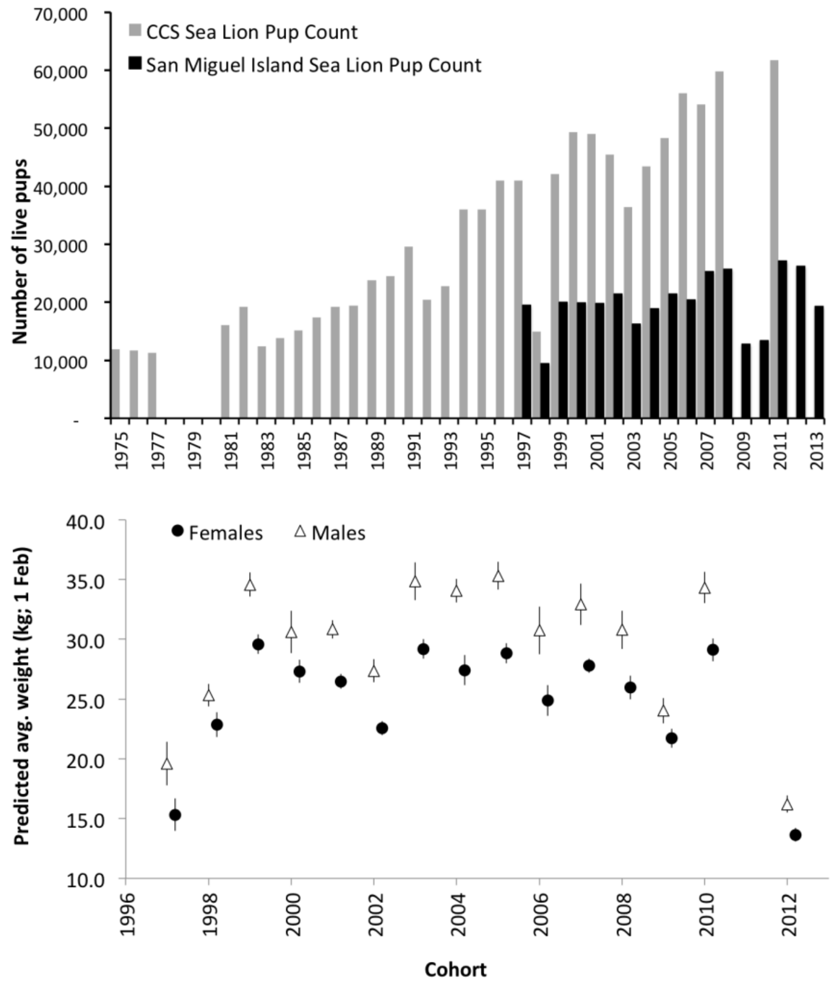

Figure 3.8. Top: California sea lion pup production, 1975 – 2011 across the CCE and at San Miguel Island (1997-2013). Lower: Predicted average daily growth rate of female (circle) and male (triangle) California sea lion pups between 4 and 7 months old at San Miguel Island, California, 1997-2012. Error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

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.

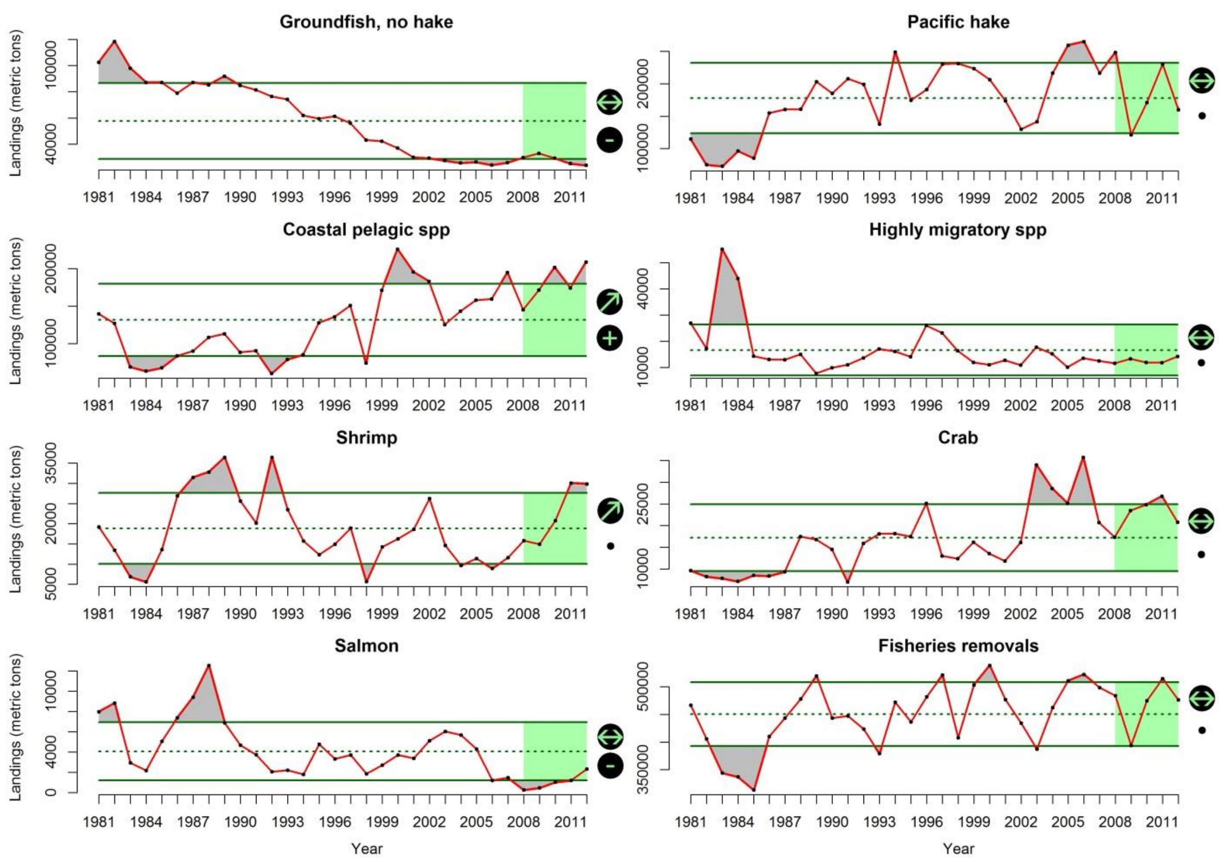

Figure 4.1. Annual landings of seven major West Coast commercial fisheries and total landings from all commercial and recreational fishing. Colors, lines and symbols are as in Fig. 1.1.

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.

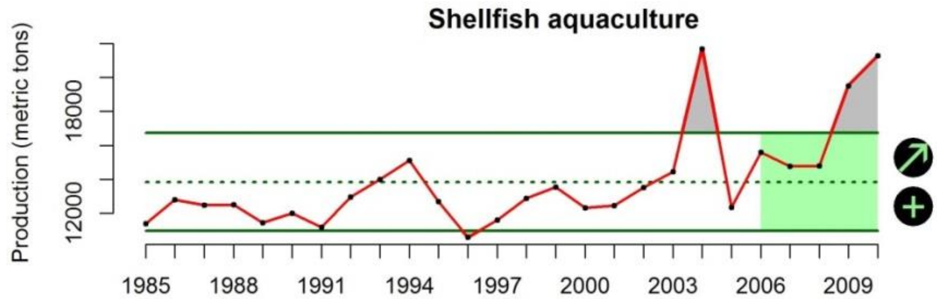

Figure 4.2. U.S. production of shellfish (clams, mussels and oysters) in marine waters of the CCE. Colors, lines and symbols are as in Fig. 1.1.

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).

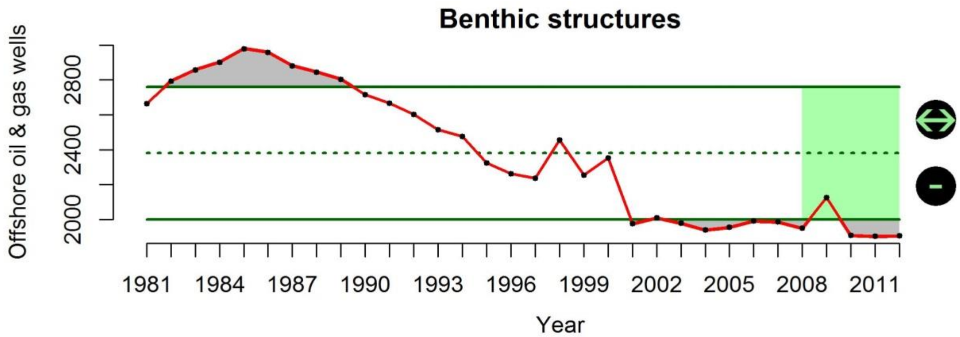

Figure 4.3. The number of offshore oil and gas wells in production or shut-in within the CCE. Colors, lines and symbols are as in Fig. 1.1.

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.

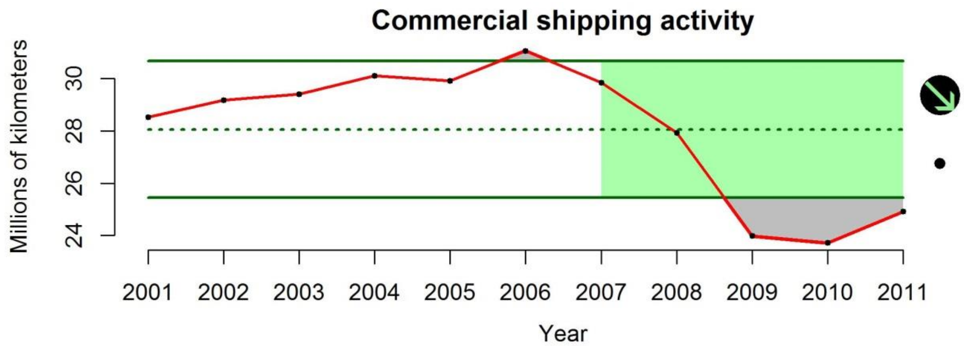

Figure 4.4. Distance transited by commercial shipping vessels along the coast of the CCE. Colors, lines and symbols are as in Fig. 1.1.

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/).

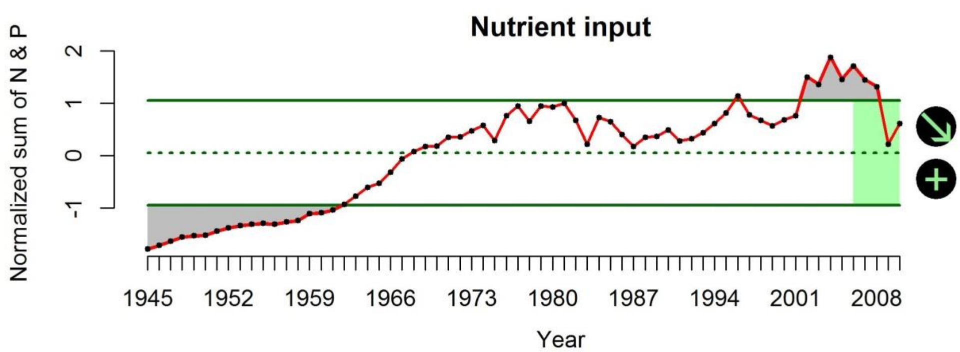

Figure 4.5. Normalized index of the sum of nitrogen and phosphorus applied as fertilizers in WA, OR and CA. Colors, lines and symbols are as in Fig. 1.1.

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.

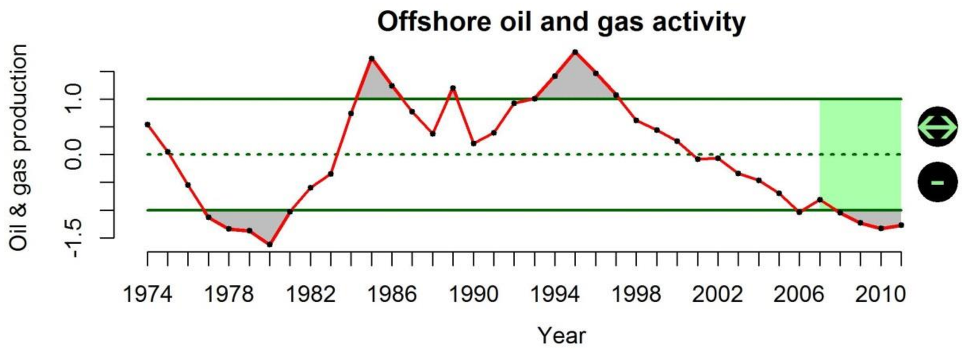

Figure 4.6. Normalized index of the sum of oil and gas production from offshore wells in CA. Colors, lines and symbols are as in Fig. 1.1.

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.

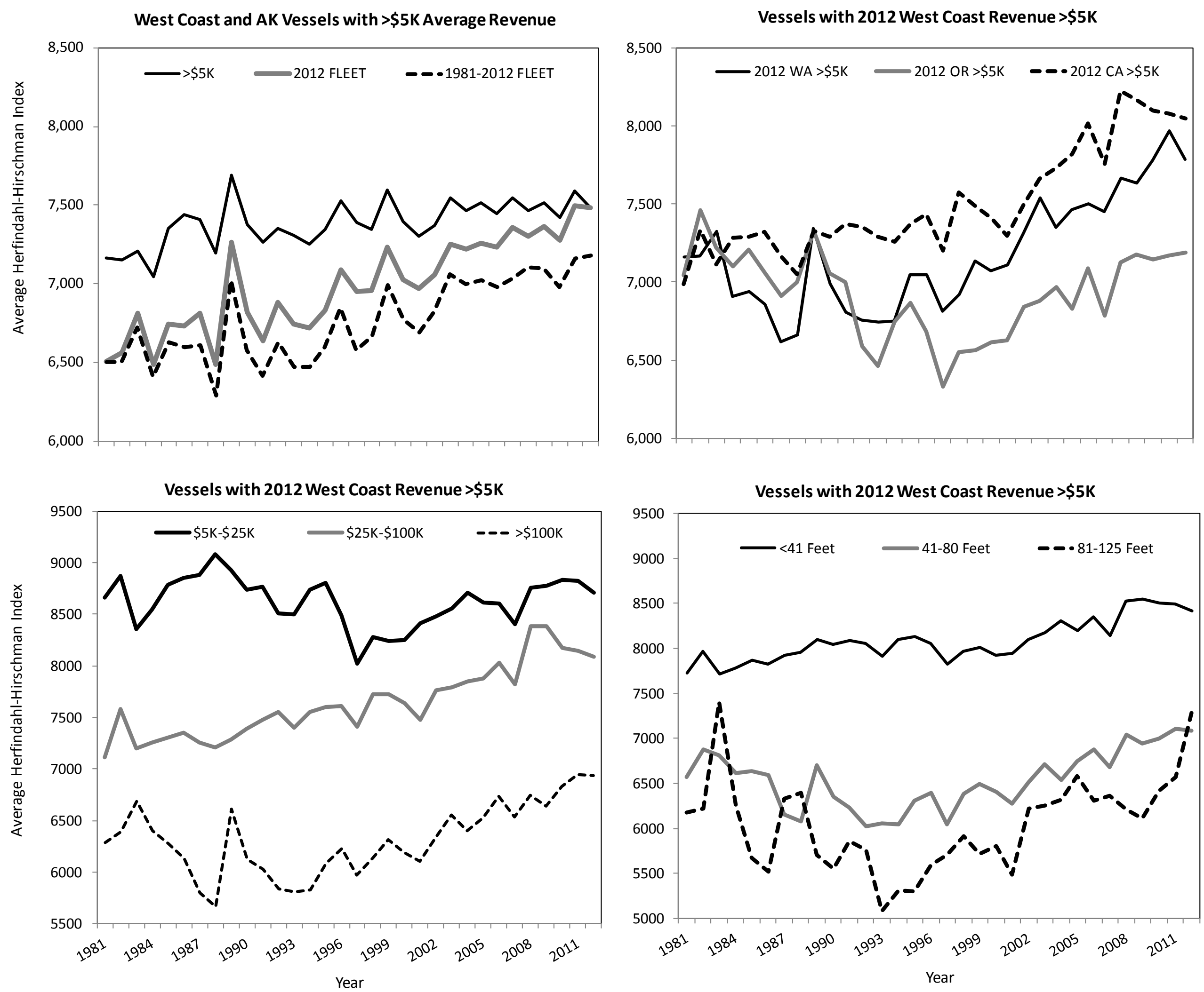

Figure 5.1. Trends in average diversification for US West Coast and Alaskan fishing vessels with over $5K in average revenues (top left) and for vessels in the 2012 West Coast Fleet with over $5K in average revenues, broken out by state (top right), by average gross revenue classes (bottom left) and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

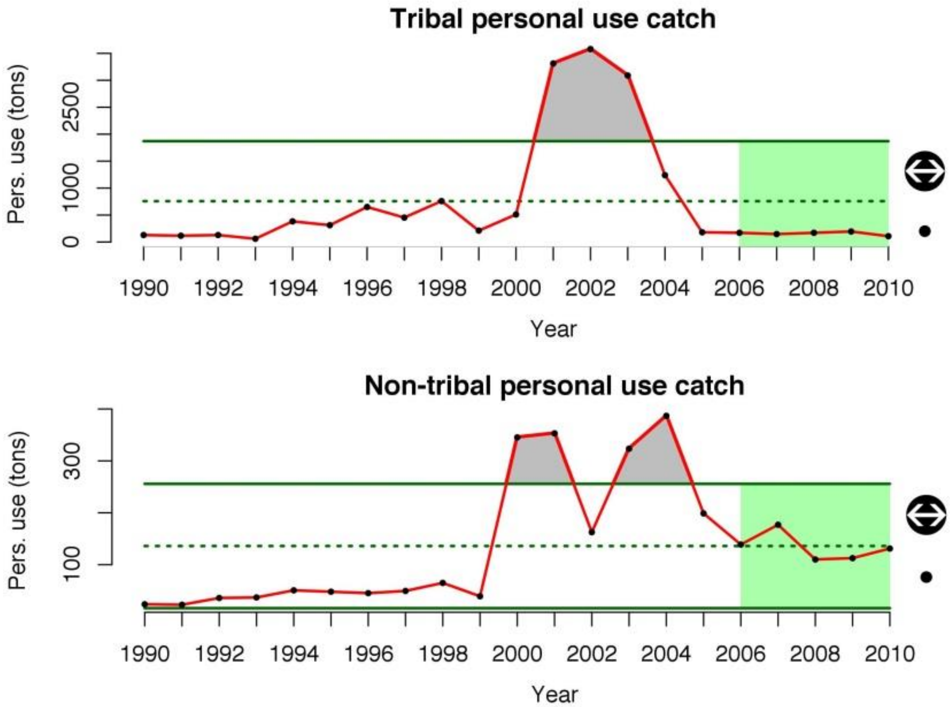

Figure 5.2. Catch retained for personal use from 1990 - 2010 in tons (2000 lbs). Colors, lines and symbols are as in Fig. 1.1. Data source: Pacific Fisheries Information Network (PacFIN), 1990-2010. Data are from landings in 139 of 350 ports in WA and CA; data not collected/reported from OR.

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