CCIEA PHASE III REPORT 2013: ECOSYSTEM COMPONENTS, FISHERIES – COASTAL PELAGICS AND FORAGE

COASTAL PELAGIC AND FORAGE FISHES

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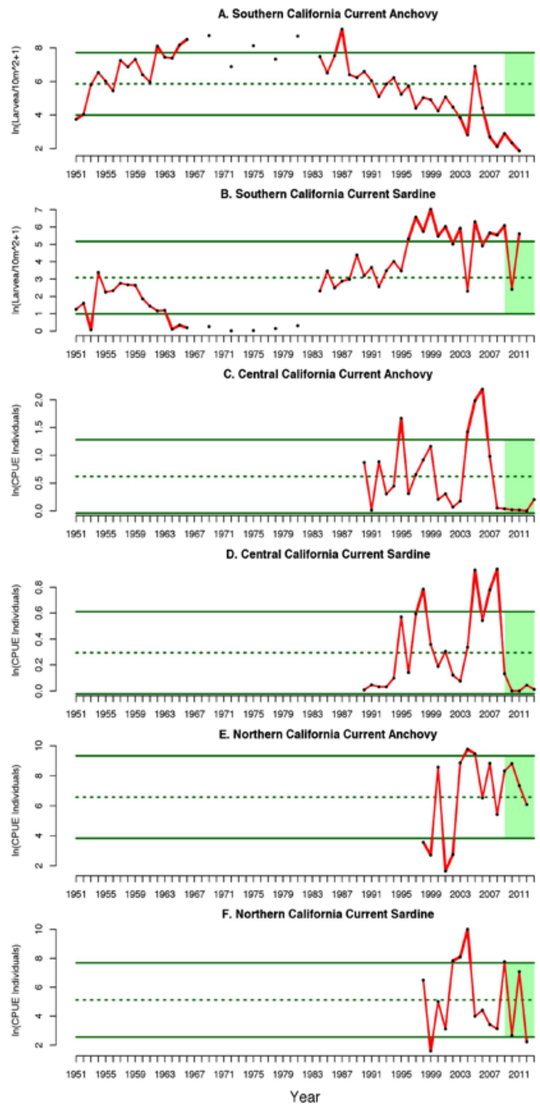
OVERVIEW

In the central and northern California Current regions, the forage community dependent on cool productive conditions became more abundant or remained stable. However, sardine abundance was low along much of the CCLME, but in the context of the longer time frame, abundance of sardines is about average. Anchovy in southern and central California remained at a low abundance. In southern California the low abundances observed follow a 30-year decline in abundance.



Abundance time series for anchovy and sardine from three regions of the California Current system. Absence of red line indicates years of no survey results , green area indicates the last five years of the data series, dashed green line indicates mean and solid green lines indicate +/- 1 s.d.

EXECUTIVE SUMMARY

Here, we examine trends in abundance and condition of coastal pelagic species and additional forage species collected from cruises along the California Current Large Marine Ecosystem (CCLME). Primarily we rely on the data collected from fishery independent surveys in southern California (1951-2011), central California (1990-2013), and Washington and Oregon (1998-2012). Given the differences in methods, catchability, and timing, these surveys are not directly comparable and for that reason are presented in separate figures. As well, it is important to recognize that these trends are not necessarily representative of abundance of the complete forage community. However, the trends are representative of the communities residing in the cruise areas during the timing of the cruises and a wealth of research has made the connections between the forage community dynamics in these regions and predator responses (e.g., Emmett et al. 2005, Daly et al. 2009, Phillips et al. 2009, Santora et al. 2011, Santora et al. 2012, Thompson et al. 2012b, Wells et al. 2012, Koslow et al. 2013, Wells et al. 2013). We also use assessment reports of the Pacific Fisheries Management Council (1929-2013; Crone et al. 2011, Hill et al. 2013) to estimate trends in biomass and age structure of assessed coastal pelagic species.

There is substantial regional variability in the forage base dynamics in the California Current system. Generally, in the central and northern California Current regions, the forage community dependent on cool productive conditions became more abundant or remained stable. However, sardine abundance was low along much of the CCLME, but in the context of the longer time frame (multiple decades), abundance of sardines is about average. Anchovy in southern and central California remained at a low abundance. In southern California the low abundances observed follow a 30 decline in abundance (data currently available to 2011). The accompanying figure can be used to demonstrate these points.

DETAILED REPORT

The purpose of this chapter of the CCIEA is to examine trends in available indicators relevant to coastal pelagic species and additional forage fishes along the California Current and to qualitatively evaluate variability in the forage community relative to pressure. It is important to recognize that we refer to "status" here quite differently than the Pacific Fisheries Management Council (PFMC), and any difference between our status statements and those should not be considered a conflict. We are not using similar models nor benchmarks as those traditionally used. Our purpose is to set the framework for evaluating the forage community from an ecosystem perspective. This approach starts with a simple selection of indicators and evaluation of the trends. As well, we use these biological indicators in combination with indicators of environmental and anthropogenic pressures to evaluate potential risk to the forage community. Indicators for various pressures can be found in other chapters of the full CCIEA (e.g., Anthropogenic Drivers and Pressures, Oceanographic and Climatic Drivers and Pressures).

Coastal pelagic species (CPS) and forage species support important commercial fisheries as well as a number of higher trophic level species including those that are commercially exploited (e.g., rockfish, salmon) and/or legally protected (e.g., salmon, marine mammals, seabirds). In the context of this report, we consider species to be forage if they are often present in high abundance, feed on plankton for a portion of their life cycle and form dense schools or aggregations (e.g., anchovy, sardine, herring, mackerel, as well as invertebrate species such as squid and krill). Such species are often the principal means of transferring production from primary and secondary tropic levels (typically phytoplankton and zooplankton) to larger predatory fish, marine mammals and seabirds. Although the potential dynamics between the forage base and ecosystem integrity is not the primary aim of this section, we note that recent work Smith et al. (2011) and Kaplan et al. (2013) demonstrates the likely negative effects on the ecosystem caused by reductions in abundance of lower trophic level species.

Here, we define coastal pelagic species as recognized by the PFMC: northern anchovy, Pacific sardine, jack mackerel, Pacific mackerel, market squid, and krill. However, when data are available, we also include trends in other fishes that make up the forage complex including juvenile groundfish, herring, whitebait smelt, sanddabs, and selected mesopelagic assemblages. It is important to also recognize that these indices represent the temporal-spatial restrictions of the cruises. Therefore, we refrain from extending our cruise indicators to the full population dynamics, as they may not be well represented. However, there is a wealth of research connecting the data series we use here to the environmental drivers that determine the variability in the time series and resultant variability in upper predators reliant on the forage communities (e.g., Emmett et al. 2005, Daly et al. 2009, Phillips et al. 2009, Santora et al. 2011, Santora et al. 2012, Thompson et al. 2012b, Wells et al. 2012, Koslow et al. 2013, Wells et al. 2013).

INDICATOR SELECTION: SOUTHERN CALIFORNIA CURRENT, CALCOFI

INDICATOR EVALUATION: SOUTHERN CALIFORNIA CURRENT, CALCOFI

We considered a number of indicators to represent the coastal pelagic larval and forage assemblage in southern California. Our choice of indicators of trend was based on relative abundances, time series length and availability. As well, the literature indicates that unexploited oceanic assemblages are more sensitive to climatic effects than coastal and/ or exploited species (Hsieh and Ohman 2006). Data sources potentially included: 1. estimates of small pelagic fish biomass from acoustics (MacLennan and Simmonds 1992, Demer and Zwolinski 2012, Zwolinski et al. 2012), and 3. Daily Egg Production Method (DEPM) surveys for sardine (Lasker 1985, Lo et al. 1996). Although these series are valuable and both the acoustic surveys and the DEPM surveys produce biomass or spawning biomass estimates, results from these surveys are integrated in the sardine stock assessment (Crone et al 2011, Hill et al. 2011) , and we therefore do not use them individually in this report.

An additional data source, the California Cooperative Oceanic Fisheries Investigations (CalCOFI) provides the longest and most complete estimates of abundance of over 400 combined fish and cephalopod species (Table C1). Here we use CalCOFI ichthyoplankton data from 1951 to 2011 collected through oblique vertical plankton tows as described by Kramer et al (1972) and Smith and Richardson (1977).

Table C1: List of mesopelagic and coastal pelagic species from CalCOFI surveys used in this report. Subcategory lists mesopelagic species associated with warm or cool water conditions in the Southern California Bight. As well, "Trend" and "PCA" indicate species used in those analysis, respectively. All species were captured as larvae and enumerated in units of mean larvae/10m^2 captured in the CalCOFI core area within three month periods (i.e., quarters) and summed over all four quarters for a year.

Genus species	Common name	Subcategory	Trend	PCA
Bathylagus pacificus	slender blacksmelt	cool-water	X	
Bathylagus wesethi	snubnose blacksmelt	warm-water	X	X
Ceratoscopelus townsend	fangtooth lanternfish	warm-water	X	X
Citharichthys sordidus	Pacific sanddab		X	X
Citharichthys stigmaeus	speckled sanddab			X
Cyclothone signata	showy bristlemouth			X
Diaphus theta	California headlight fish			X
Diogenichthys atlanticus	longfin lanternfish	warm-water	X	X
Diogenichthys laternatus	diogenes laternfish	warm-water	X	
Engraulis mordax	northern anchovy		X	X
Idiacanthus antrostomus	Pacific black dragon			X
Leuroglossus stilbius	California	cool-	X	X

	smoothtongue	water		
Lipolagus ochotensis	eared blacksmelt	cool-water	X	X
Merluccius productus	hake		X	X
Nannobrachium ritteri	broadfin lampfish			X
Protomyctophum crockeri	California flashlightfish	cool-water	X	X
Sardinops sagax	Pacific sardine		X	X
Sebastes jordani	shortbelly rockfish		X	X
Stenobrachius leucopsarus	northern lampfish	cool-water	X	X
Symbolophorus californiensis	bigfin laternfish	warm-water	X	X
Tarletonbeania crenularis	blue laternfish	cool-water	X	X
Trachurus symmetricus	Pacific jack mackerel			X
Triphoturus mexicanus	Mexican lampfish	warm-water	X	X
Vinciguerria spp.	lightfishes	warm-water	X	X

We have restricted our analysis to the most abundant and potentially influential CPS and forage species for which we have data. To provide an integrated measure of large-scale responses to environmental variability, we aggregated the mesopelagic fishes into cool- and warm-water groups following Hsieh et al. (2005). These groups are likely to reflect general trends in the ecosystem better than time series for individual species, some of which are relatively data poor. The species and groups analyzed were Pacific sardine, northern anchovy, hake, jack mackerel, Pacific sanddab, shortbelly rockfish, cool-water mesopelagics, and warm-water mesopelagics.

To evaluate community variability we performed principal component analysis of the Hellinger-transformed ichthyoplankton assemblage (#indiv/10 m^2) collected from core

CalCOFI stations during spring and summer cruises (Thompson et al. 2012a). This analysis included all the species in Table C1. Such an indicator allows fo the interpretation of similarity and dissimilarity between years over which the survey occurred. Principle component analysis was performed using the years 1993-2011. During this time a greater number of species was enumerated. Those that significantly contribute to the PCA were included in an examination of community variability.

Summary of indicators: Southern California Current, CalCOFI

1. 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 (Pennington 1983). 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.
2. Trends of individual species analyzed were Pacific sardine, northern anchovy, Pacific hake, jack mackerel, Pacific sand dab, and shortbelly rockfish.
3. The cold- and warm-water associated mesopelagic species were summed for each net tow and then analyzed as groups following the same method described above for individual species.
4. Principal component analysis of the Hellinger-transformed ichthyoplankton assemblage (#indiv/10 m^2) collected from core CalCOFI stations during spring and summer cruises.

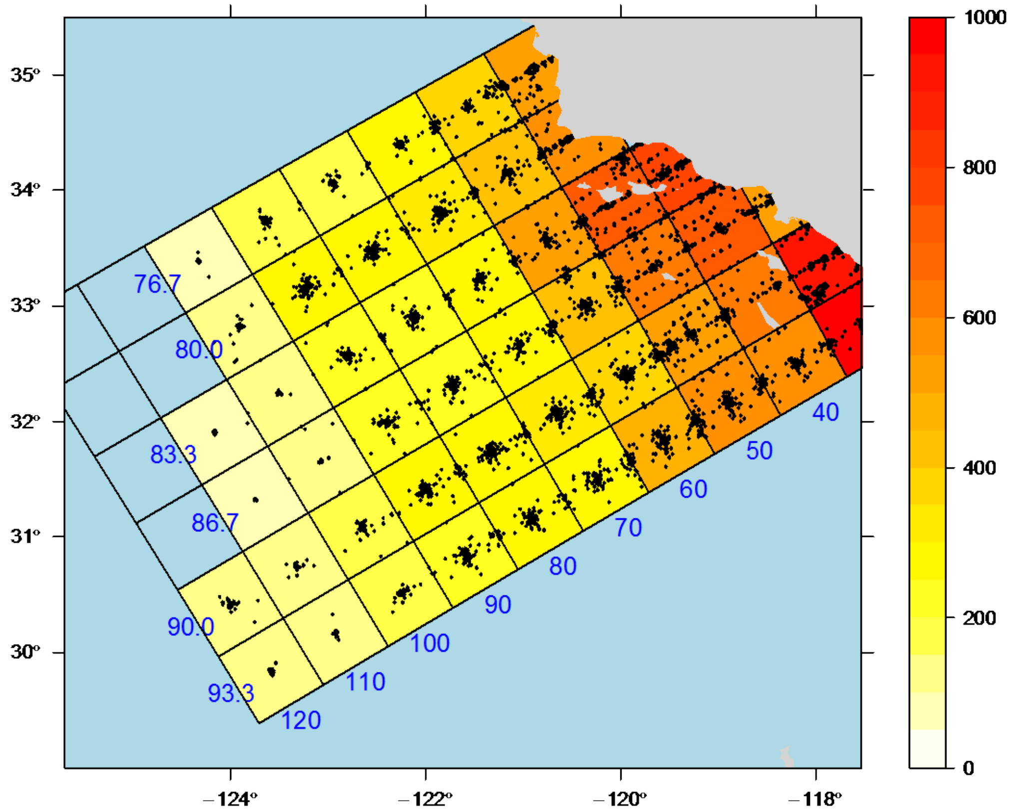
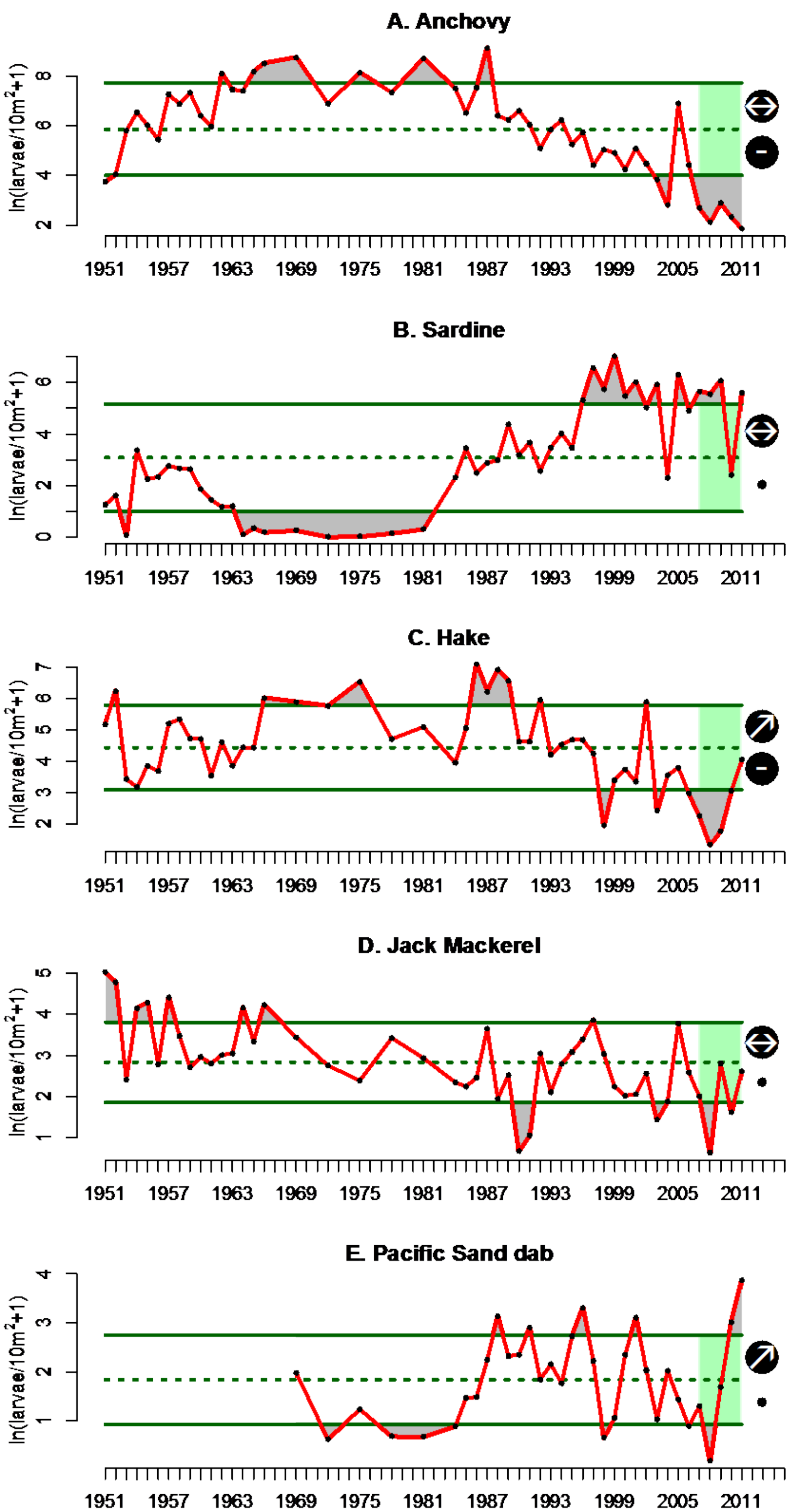


Figure C1. *CalCOFI Sampling Pattern for Oblique Net Tows*. Grid pattern of 3.3-line by 10-station cells in the core CalCOFI sampling area (lines 76.7-93.3) used for analysis of Southern California forage. Color key indicates actual number of samples collected within each cell for the period 1951-2011. Black dots indicate actual sample locations.


A. Anchovy
B. Sardine
C. Hake
D. Jack Mackerel
E. Pacific Sand dab
ln(larvae/10m2+1)
1951
1957
1963
1969
1975
1981
1987
1993
1999
2005
2011

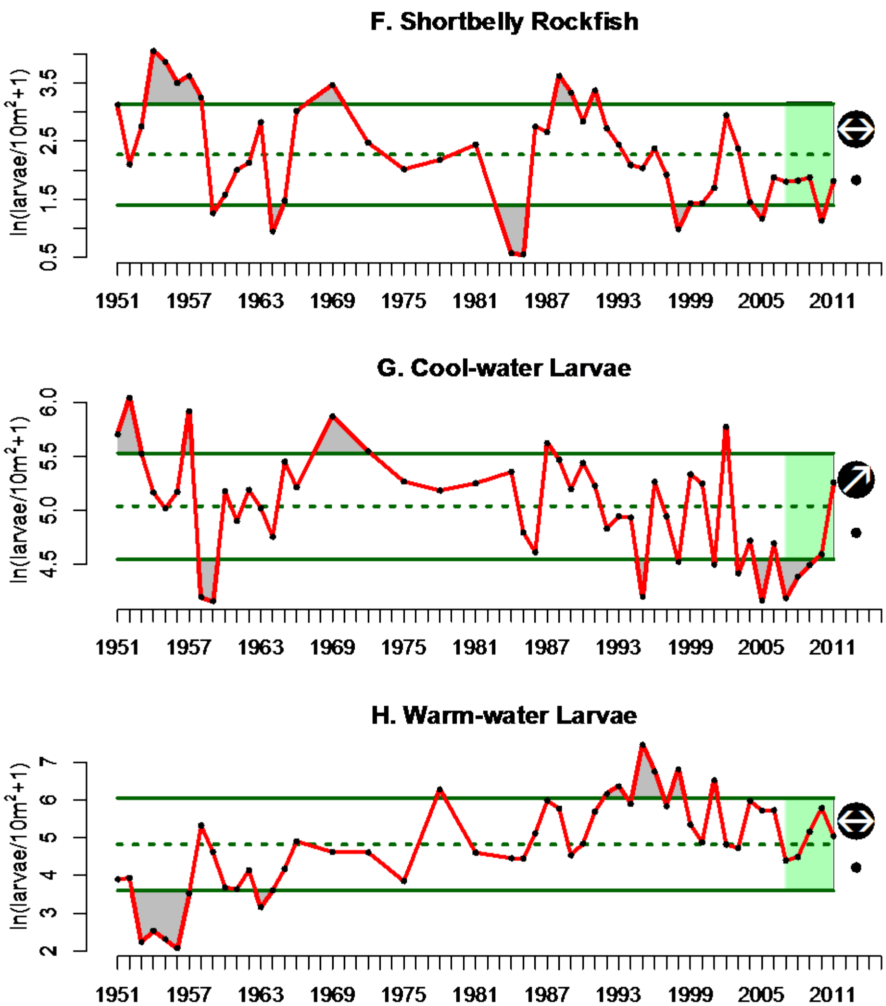


Figure C2. *Southern California Forage, CalCOFI.* Most time series are plotted in a standard format. Dark green horizontal lines show the mean (dotted) and ± 1.0 s.d. (solid line) of the full time series. The shaded green area is the last 5-years of the time series, which is analyzed to produce the symbols to the right of the plot. The upper symbol indicates whether the 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 low symbol indicates whether the mean of the last 5 years was greater than (+), less than (-)or within (·) one s.d. of the long-term mean.

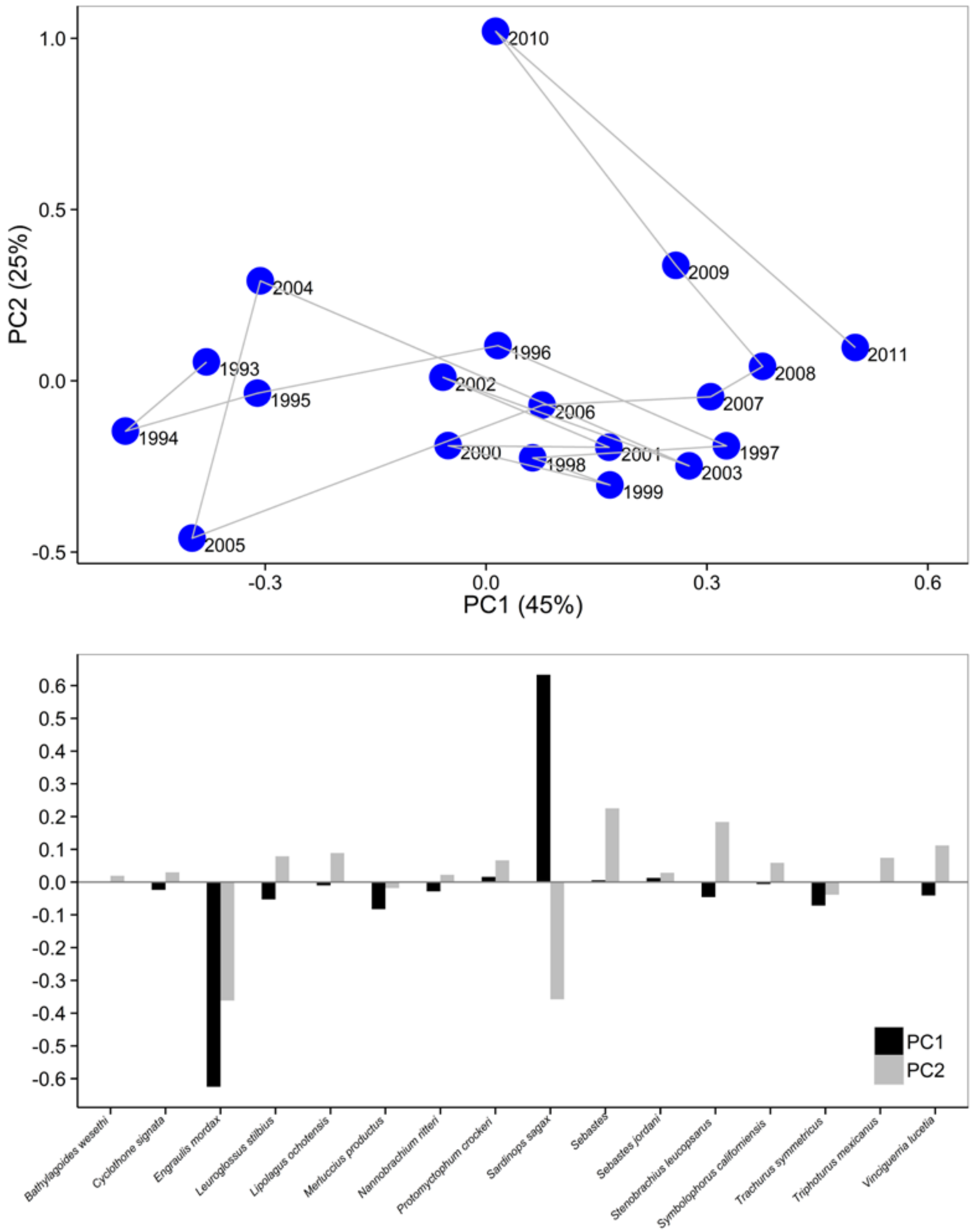


Figure C3. *Spring southern California Ichthyoplankton from oblique bongo net tows.* The top plot illustrates the loadings of years on principle components (PC) 1 and 2. The bottom plot shows the most abundant species loaded onto components 1 and 2.

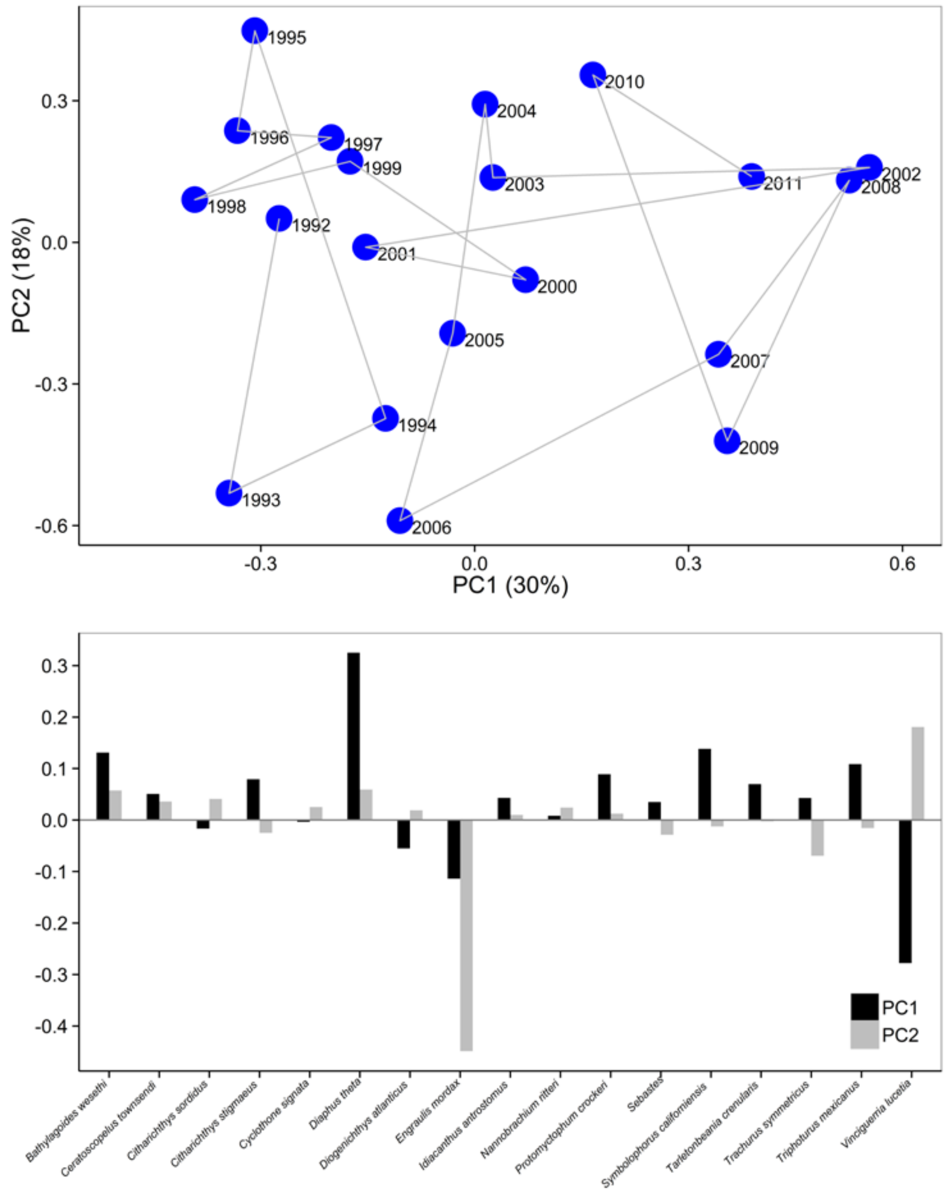


Figure C4. *Summer southern California ichthyoplankton from oblique bongo net tows.* The top plot illustrates the loadings of years on principle components (PC) 1 and 2. The bottom plot shows the most abundant species loaded onto components 1 and 2.

MAJOR FINDINGS: SOUTHERN CALIFORNIA CURRENT, CALCOFI

Since 1951 the 6 species indicators and 2 species group indicators have shown high variability and limited covariation (Figure C2). Larval anchovy abundance continued a declining trend over the last thirty years to the lowest abundance since 1951 (last data available is 2011). Sardine has been above the long-term average since 1996, minus 2004 and 2010 during which the abundance was average. Fish larvae dependent on cool productive conditions demonstrated average to above average abundance (e.g., hake, sanddabs, rockfish, and the consolidate cool-water species group).

SUMMARY AND STATUS OF TRENDS: SOUTHERN CALIFORNIA CURRENT, CALCOFI

We report both long-term means and recent trends in this status review. Under the current framework, an indicator is considered to have changed in the short-term if there are significant increasing or decreasing trends over the last five years. An indicator is considered to be above or below long-term norms if the mean of the last five years of the time series differs from the mean of the full time series by more than 1.0 standard deviation.

Anchovy, hake, and cool-water mesopelagics have generally decreased over the last 30 years (Figure C2). Anchovy abundance ending in 2011 was the lowest abundance recorded. Sardine abundance was above its long-term average. Sardine larvae show a different trend to anchovy, and it has been postulated (Chavez et al. 2003) that abundance peaks of these species alternate at decadal time scales (although the CalCOFI time series is too short to evaluate this hypothesis (McClatchie 2012). Sardine larvae in the 1980s and 90s have increased from the collapse of the stock in the 1950s. Although there has been a minor decline in sardine larval abundance since 2000, sardine larval abundance has remained above the mean of the last 60 years (Fig. C2).

Hake and cool-water mesopelagic larvae have increased substantially in the last five years and are near their long-term average values (Fig. C2). In addition to hake and cool-water mesopelagics, sanddab larvae are also increasing in the last five years. The remaining species examined (jack mackerel, rockfish, and warm-water mesopelagics) remained stable near average values (Fig. C2).

Principal component analysis of the Hellinger-transformed ichthyoplankton assemblage (#indiv/10 m^2) collected from core CalCOFI stations during spring cruises demonstrated PC1 and PC2 capture approximately 70% of the total variance (Figure C3).

PC1 mainly characterizes a gradient between assemblages dominated by anchovy (negative loadings) and sardine (positive loading). Years with high loadings on PC2 are characterized by greater influence of rockfish and northern lampfish relative to other taxa. Anchovy had the greatest influence in the years 1993-1995 and 2004-2005 while sardines were the main taxa in 1997, 2003, 2007-2009, and 2011. In 2010 both anchovy and sardine larvae were scarce and the most important taxa were rockfish and northern lampfish.

Principal component analysis of the summer CalCOFI ichthyoplankton assemblage indicated PC1 and PC2 explain approximately 48% of the total variance (Figure C4). PC1 mainly characterizes a gradient between assemblages dominated by Panama lightfish (negative loadings) and California headlightfish (positive loading). Both of these utlize mesopelagic habitats but Panama lightfish have a more southern biogeographic range than California headlight fish. Years with low loadings on PC2 are characterized by greater influence of anchovy. California headlight fish tended to be most important in the recent years of 2002, 2007,2008, 2010 and 2011 while Panama lightfish were most influential in the previous decade (1992-1999). Anchovy exhibited greater influence in the summers of 1993 and1994 as well as 2006, 2007, and 2009.

INDICATOR SELECTION: CENTRAL CALIFORNIA CURRENT, MIDWATER TRAWL SURVEY

INDICATOR EVALUATION: CENTRAL CALIFORNIA CURRENT, MIDWATER TRAWL SURVEY

General description: Central California, midwater trawl survey

We evaluated a number of indicators to represent the abundance of young-of-the-year (YOY) groundfish, coastal pelagic species and other micronekton in the coastal and offshore waters of central California. Data are based on mid-water trawl collections, as described in Ralston et al. (2013b). Available data for coastal pelagic forage species include krill (Euphausiids*)*, market squid, anchovy, and sardine. In addition, numerous other members of the forage community are available including pelagic young-of-the-year (YOY) rockfish, pelagic YOY sanddabs, YOY hake, octopus, seregestid shrimp and numerous mesopelagic species (Santora et al. 2012). Although the time series of the YOY groundfish extends back to 1983 (Ralston et al. 2013b), many of the other micronekton species have only been reliably quantified since 1990. For analysis of trends we focus here on the most abundant, continuously present, and available species: anchovy, sardine, market squid, krill, YOY rockfishes, YOY sand dabs, and YOY hake (Table C2). Four of these, anchovy, sardine, market squid and krill represent the CPS. Importantly, the abundance of anchovy and sardine from this survey in central California is not likely to correlate to overall population strengths as much as it represents variability in the distribution throughout the CCE latitudinally and longitudinally (Bjorkstedt et al. 2012, Song et al. 2012). As a consequence, unlike the overall trend in CCE, anchovy and sardine are positively correlated for the majority of the time series. We did not include juvenile salmon because the net is inefficient at collecting salmon.

For our multivariate analysis we use a broader suite of fishes including those more rarely captured but necessary for a evaluation of the community variability. The multivariate approach allows for a comparison of community structure variability and an evaluation of the similarity between like years.

Samples were collected during the May-June period, the peak of the abundance of pelagic YOY rockfish that are the focus of the survey, and are limited spatially to the region between southern Monterey Bay (approximately 36 N) and just north of Point Reyes, CA (~ 38 N). Since the early 2000s both this and a comparable survey have operated from the U.S./Mexico border to Cape Flattery, WA (see Ralston and Stewart 2013), however only rockfish data from the expanded range have been rigorously analyzed and other forage species from the broader range will be discussed in future reports. Samples are collected using a modified Cobb midwater trawl, with a head rope depth of 30 m (the average depth of the thermocline in the region) at a speed of ~2 knots for 15 minutes at depth, with the exception of stations that were too shallow (< ~60m) such as those in the Gulf of the Farallones for which the headrope depth was 10 m (Sakuma et al. 2006). In all cases, samples represent catch per standard 15 minute trawl (CPUE). The data was log-transformed data because it was log-normally distributed.

Table C2. Species collected and enumerated (geometric mean of catch per unit effort) in the mid-water trawl survey along Central California.

Genus species	Common name	Stage	Trend	PCA
Bathylagus pacificus	blacksmelt	juvenile		X
Citharichthys sordidus	Pacific sanddab	juvenile	X	X
Citharichthys stigmaeus	speckled sanddab	juvenile		X
Engraulis mordax	northern anchovy	adult	X	X
Euphausiids	krill	adult	X	X
Glyptocephalus zachirus	rex sole	juvenile		X
Leuroglossus stilbius	smoothtongue	juvenile		X
Loligo opalescens	market squid	juvenile, adult	X	X
Merluccius productus	Pacific hake	juvenile	X	X
Myctophum punctatum	blue lantern fish	juvenile		X
Octopus spp.	octopus	juvenile		X
Sardinops sagax	Pacific sardine	adult	X	X
Sebastes spp.	rockfishes	juvenile	X	X
Sergestidae	sergestids	juvenile	X	X
Stenobrachius leucopsarus	northern lampfish	juvenile		X

Appropriate indicators: Central California Current, midwater trawl survey

We examined trends in anchovy and Pacific sardine. Along the CCE northern anchovy abundance variability tends to be positively related to warmer, less productive conditions. In central California, temporal dynamics of northern anchovy abundance likely reflect a change in the distribution relative to CCE as a whole (for the May-June period in which the survey is conducted) rather than overall changes in the stock. However, while the anchovy abundance variability is poorly correlated to ocean temperatures in central California, during times of low productivity across the CCE northern anchovy make up a greater proportion of the diets of seabirds locally and, therefore, their relative abundance in the forage community can indicate overall productivity conditions. In central California, the relative abundance of Pacific sardine in late spring likely represents a change in the average distribution that relates to ocean conditions.

As well, we examined trends in a number of additional fishes that during a period of their life cycle are important contributors to the forage community, including: juvenile Pacific hake, juvenile rockfish, and juvenile Pacific sanddabs. Currently the factors that drive variability in Pacific hake abundance in this survey are not entirely clear, as hake typically spawn in southern California and northern Mexico waters, high numbers may represent a strong year class or a shift in the distribution of young-of-the-year. Juvenile and sub-adult hake are an important prey for many other higher trophic level predators. Juvenile rockfish captured in this data series represent juveniles spawned in the current winter (e.g., young-of-the-year individuals). While pelagic, they represent a critical prey resource for predators such as Common murre, rhinoceros auklets and Chinook salmon, and there is a significant relationship between juvenile rockfish abundance and breeding success of many central California seabirds (Wells et al. 2008a, Field et al. 2010). Pacific sanddabs, when juveniles, are pelagic and represent a moderately important prey resource for many seabirds and other predators in the region.

Krill is a reasonable indicator of local environmental quality. Krill abundance is known to increase during productive conditions with optimal winds (Cury and Roy 1989). Central California represents a region with several well known krill hot spots (Santora et al. 2011) where seabirds, mammals, salmon (adult and juveniles), rockfishes and a number of other species feed on krill. Wells et al. (2008b) and Wells et al (2012) demonstrate the critical role of krill on seabirds, rockfish and salmon. Here, we do not separate the two dominant species of krill in central California (*Euphausia pacifica* and *Thysanoessa spinifera*) because they were not identified to the species level until 2002. However, the two species generally occupy different habitats (inner-shelf vs outer-shelf, (Santora et al. 2012))and have different life-histories.

Monterey Bay is a spawning ground for market squid, and this species forms one of the largest and most lucrative California fisheries (although the greatest landings are typically in southern California). Both juvenile and adult squid make up a significant proportion of the diets of many predators. High market squid abundance is generally positively associated with cool, productive conditions. Data series are log-normally distributed so in these analyses we log-transformed the data.

A multivariate indicator can be used to indicate the overall forage assemblage characteristics and similarity to previous years. Beyond the seven species examined specifically, we included a suite of species commonly collected including rockfish, speckled sanddab, Pacific sanddab, market squid, Pacific hake, octopus, krill, rex sole, Seregestids, smooth tongue, blacksmelt, blue lantern, anchovy, and sardine. These species were included in a principle component analysis and the results demonstrate patterns in forage complex over the years.

STATUS AND TRENDS: CENTRAL CALIFORNIA CURRENT, MIDWATER TRAWL SURVEY

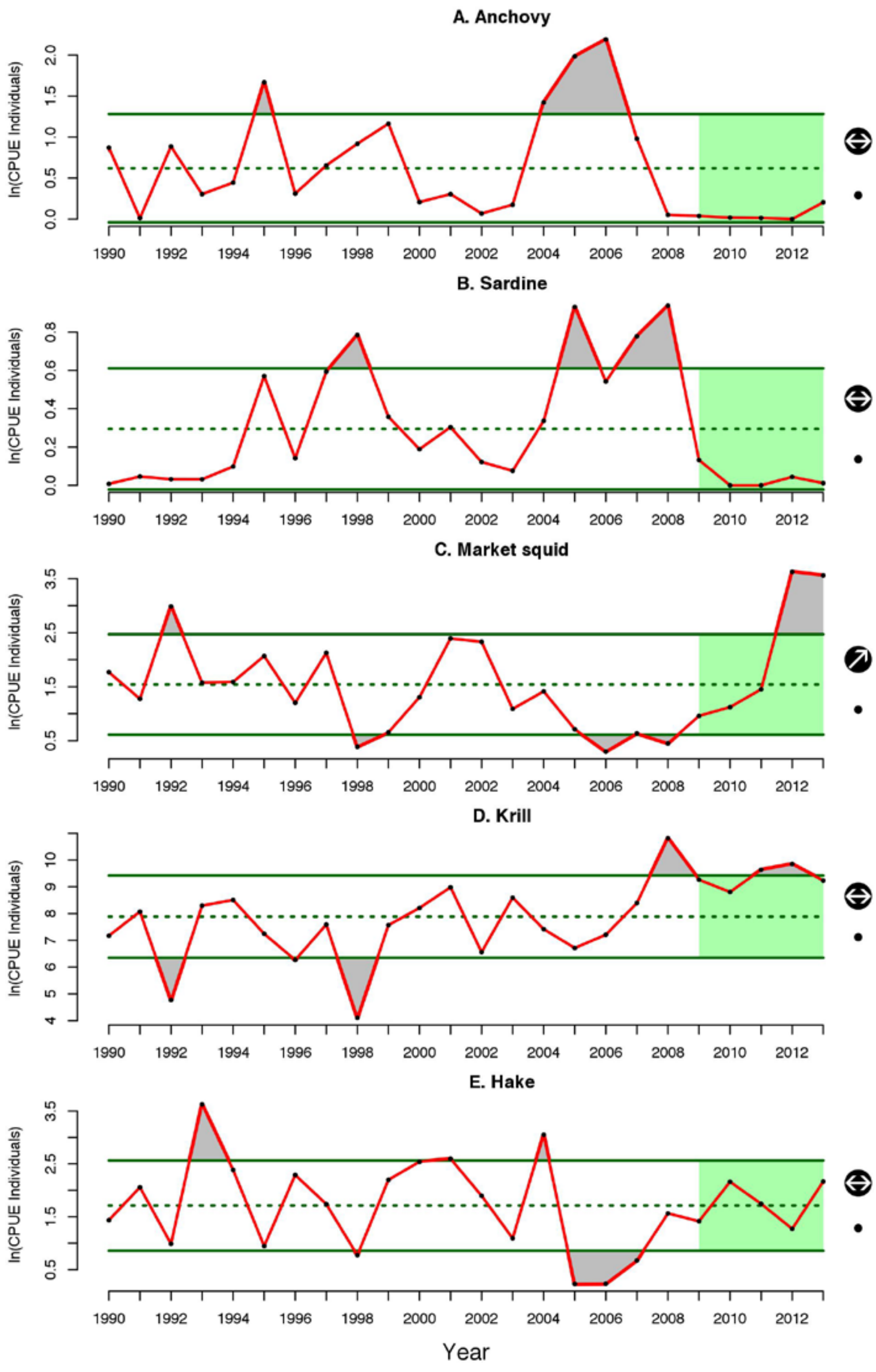
MAJOR FINDINGS: CENTRAL CALIFORNIA CURRENT, MIDWATER TRAWL SURVEY

Overall, these data series suggest that recent years have been conducive to more production and improved forage abundance for onshelf species, in agreement with Bjorkstedt et al. (2012). However, while fish reliant on productive onshelf conditions experienced increased production, those further offshore were at record low values (Wells et al. 2013).

SUMMARY AND STATUS OF TRENDS: CENTRAL CALIFORNIA CURRENT, MID-WATER TRAWL SURVEY

Anchovy and sardine continued a period of low abundance with no indication of a declining nor increasing trend over the last 5 years (Figure C5). However, rockfish, sanddabs, and market squid have recovered from record low levels observed in 2005 and 2006, and were all at record high levels leading to a positive trend in the last five years. These 3 groups are favored under high transport (advection) conditions that are associated with cool and productive conditions on the shelf (Wells et al. 2013). Likewise, krill and hake abundances have trended upward since 2005. In fact, krill achieved record levels in 2008 and has maintained relatively high abundance since (Figure C5). Finally, market squid is presently experiencing the greatest of the three boom periods of the last 20 years leading to a significantly positive five-year tend (Figure C5). This trend is consistent with consistently high landings of market squid throughout California waters in recent years.

The trends observed in the 7 indicators shown in Figure C3 are consistent with trends across a broader suite of taxa within this region, with the first and second components (of a principle components analysis of 15 of the dominant taxon) explaining approximately 36% and 16% of the variance in the data respectively. Loadings of these groups indicate strong covariance among young-of-the-year groundfish (rockfish, sanddabs and Pacific hake), cephalopods and euphausiids, which in turn tend to be negatively correlated over time with coastal pelagic and mesopelagic species. Specifically, in the central California region, those species loading positive high on the first component represent productive onshelf conditions. Principle component 2 is less obvious in its interpretation. 2012 and 2013 continued to indicate a pelagic micronekton community structure conditions similar to those seen in the early 1990s and early 2000s (Figure C6).


A. Anchovy
B. Sardine
C. Market squid
D. Krill
E. Hake
ln(CPUE Individuals)
Year
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012

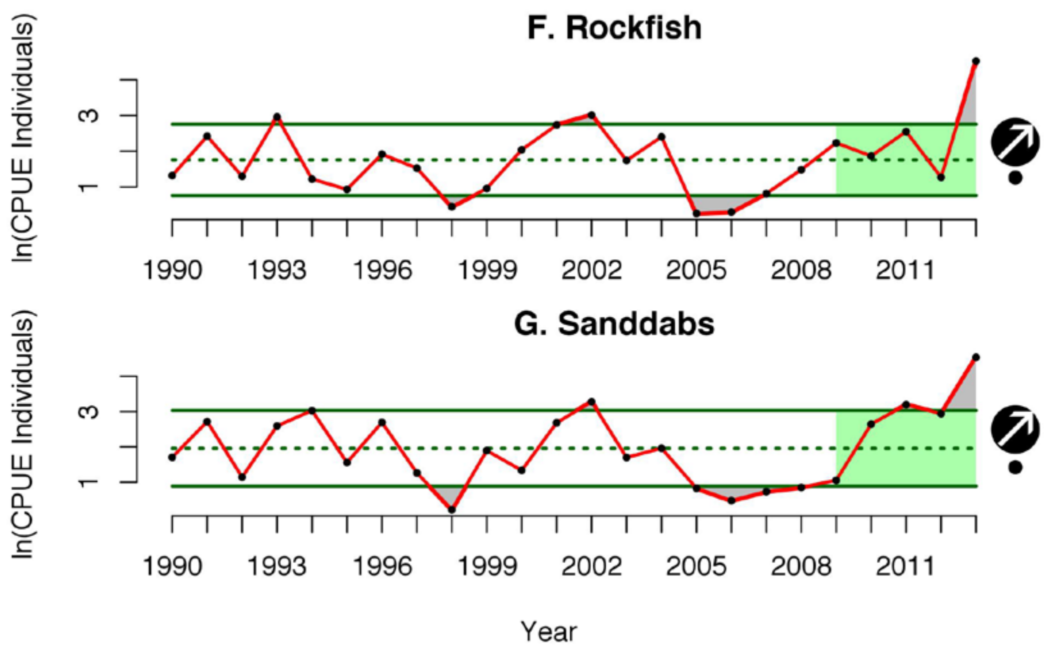


Figure C5. *Central California Forage, mid-water trawl.* Most time series are plotted in a standard format. Dark green horizontal lines show the mean (dotted) and ± 1.0 s.d. (solid line) of the full time series. The shaded green area is the last 5-years of the time series, which is analyzed to produce the symbols to the right of the plot. The upper symbol indicates whether the 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 low symbol indicates whether the mean of the last 5 years was greater than (+), less than (-)or within (·) one s.d. of the long-term mean.

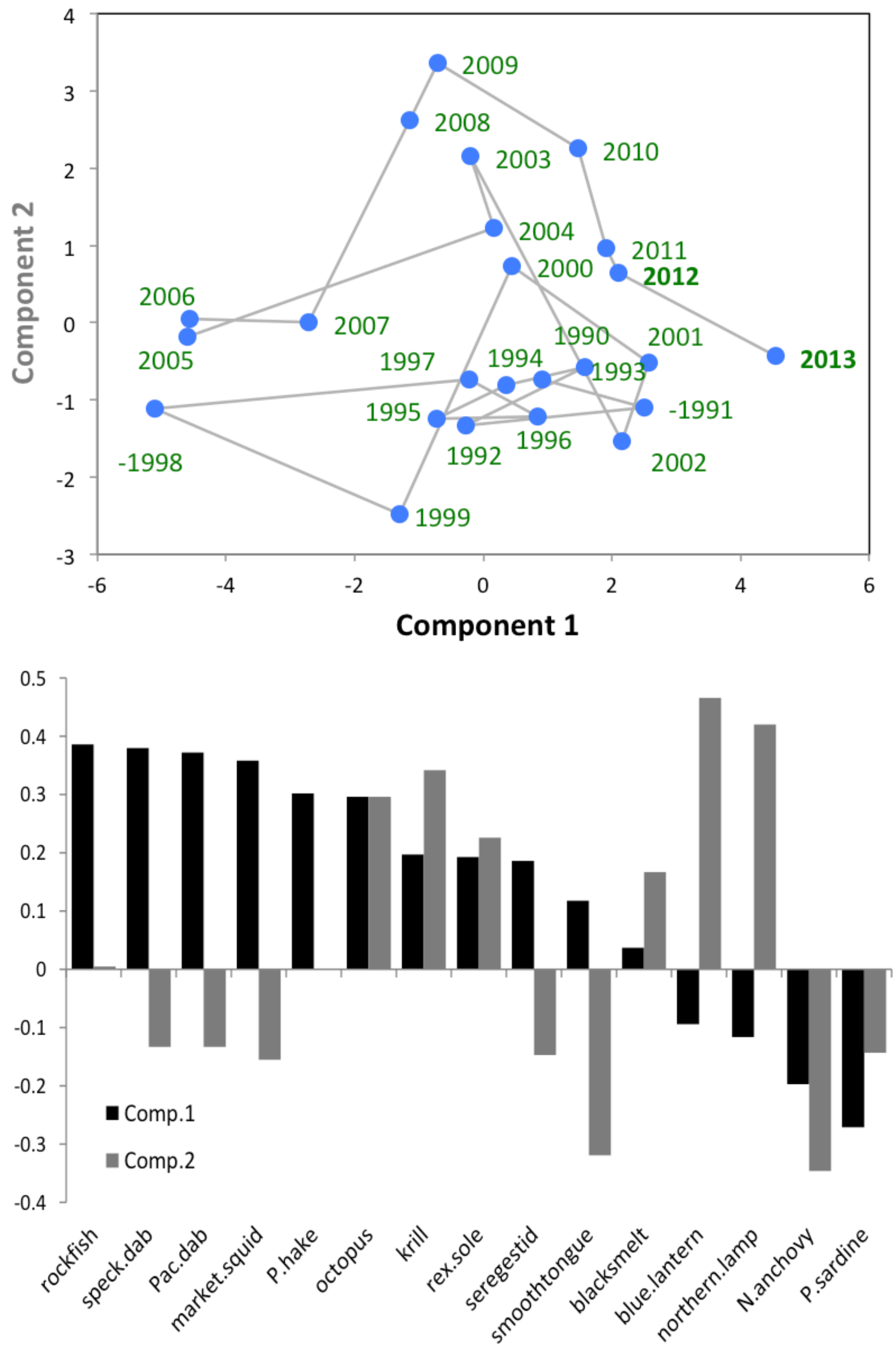


Figure C6. *Central California Forage, mid-water trawl.* The top plot demonstrates the similarity between forage communities between years. The bottom plot shows how the individual species loaded onto these components. Note, 2013 is characterized by very good production of onshelf forage fishes (as indicated by positive loadings on component 1).

INDICATOR EVALUATION: NORTHERN CALIFORNIA CURRENT

General description: Northern California Current

Pelagic nekton catch data were collected by the NWFSC-NOAA Bonneville Power Administration survey surface trawls on standard transects and stations between Tatoosh Island, WA and Cape Perpetua, OR in June from 1998 to 2012. 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 (#/km^2 towed). Yearly abundance data were obtained by combining (summing) the standardized count data of each species captured during June for each year.

Table C3. Species collected in the surface trawl of the Northern California Current survey (#indiv/km2) (using a $\log_{10}(x+1)$ transformation).

Genus species	Common name	Stage	Trend	PCA
Allosmerus elongatus	whitebait smelt	juvenile, adult	X	X
Anarrhichthys ocellatus	wolf eel			X
Anoplopoma fimbria	sablefish	juvenile		X
Clupea pallasii	Pacific herring	juvenile, adult	X	X
Cololabis saira	Pacific saury	juvenile, adult		X
Engraulis mordax	northern anchovy	juvenile, adult	X	X
Galeorhinus galeus	soupfin shark			X
Oncorhyncus keta	chum salmon	juvenile		X
Oncorhyncus kisutch	coho salmon	juvenile		X
Oncorhynchus nerka	sockeye salmon	juvenile		X

Oncorhyncus tshawytscha	Chinook salmon	juvenile		X
Osmeridae	smelts	juvenile, adult		X
Sardinops sagax	Pacific sardine	juvenile, adult	X	X
Scomber japonicus	Pacific mackerel	juvenile, adult		X
Trachurus symmetricus	Jack mackerel	juvenile, adult	X	X

Appropriate indicators: Northern California Current

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, Pacific sardine, northern anchovy, Pacific herring and whitebait smelt; Table C4). Although other forage species are caught in these surveys (see multivariate analysis of community), 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.

We also characterized the variability in the community makeup. A PCA allows for a comparison between years. We examined the 15 most dominant taxa sampled in the plume survey (log10(x+1) transformation).

MAJOR FINDINGS: NORTHERN CALIFORNIA CURRENT

The environment has fluctuated during the period since 1998 between relatively cool years (2008, 2011, 2012) to warm years (2010) (Bjorkstedt et al. 2012), likely leading to great variability in jack mackerel, Pacific herring, and sardine. Notably herring and jack mackerel catch per unit effort in June were exceptionally low in 2012.

SUMMARY AND STATUS OF TRENDS: NORTHERN CALIFORNIA CURRENT

Jack mackerel has generally decreased over the last 5 years and is currently at its record low CPUE (Figure C7). Herring shows a declining trend over the last six years and experienced a decline to low abundance in 2012 (Figure C7). The whitebait smelt population appears to be generally stable through time with an increase in recent years following some years (1999, 2000, 2002, 2006, 2008) of below average values (Figure C7). Anchovy has been relatively stable since its highest abundance in 2004, and recent values remain greater than the low values demonstrated in the late 1990s and early 2000's (Figure C7). Sardine have had fluctuating abundances in recent years after the high abundances observed in 2003 and 2004. In the last 5 years sardine abundance has been highly variable with two of the three lowest years in the full series occurring in 2010, and 2012, only slightly higher than the lowest level in 1999.

Principal component analysis of 15 of the dominant taxa abundances (#indiv/km2) (using a $\log_{10}(x+1)$ transformation) quantitatively sampled in the BPA plume survey between 1998 and 2012 explained a total of 44.8% of the variability (PC 1 and 2 explained 28% and 16.8%, respectively, Figure C8). Years with similar community structures include 2001, 2011, and 2012, whereas years 1998, 2005 and 2008 have very distinct communities from other years. Salmonid species show strong loadings on PC 1 and 2 and smelts (Osmeridae spp., and whitebait smelt) are negatively loaded onto PC 1. Forage species (sardine, anchovy, saury and sablefish) are positively loaded onto PC1 and 2. In general, smelts are negatively correlated with pelagic forage species over time on both components.

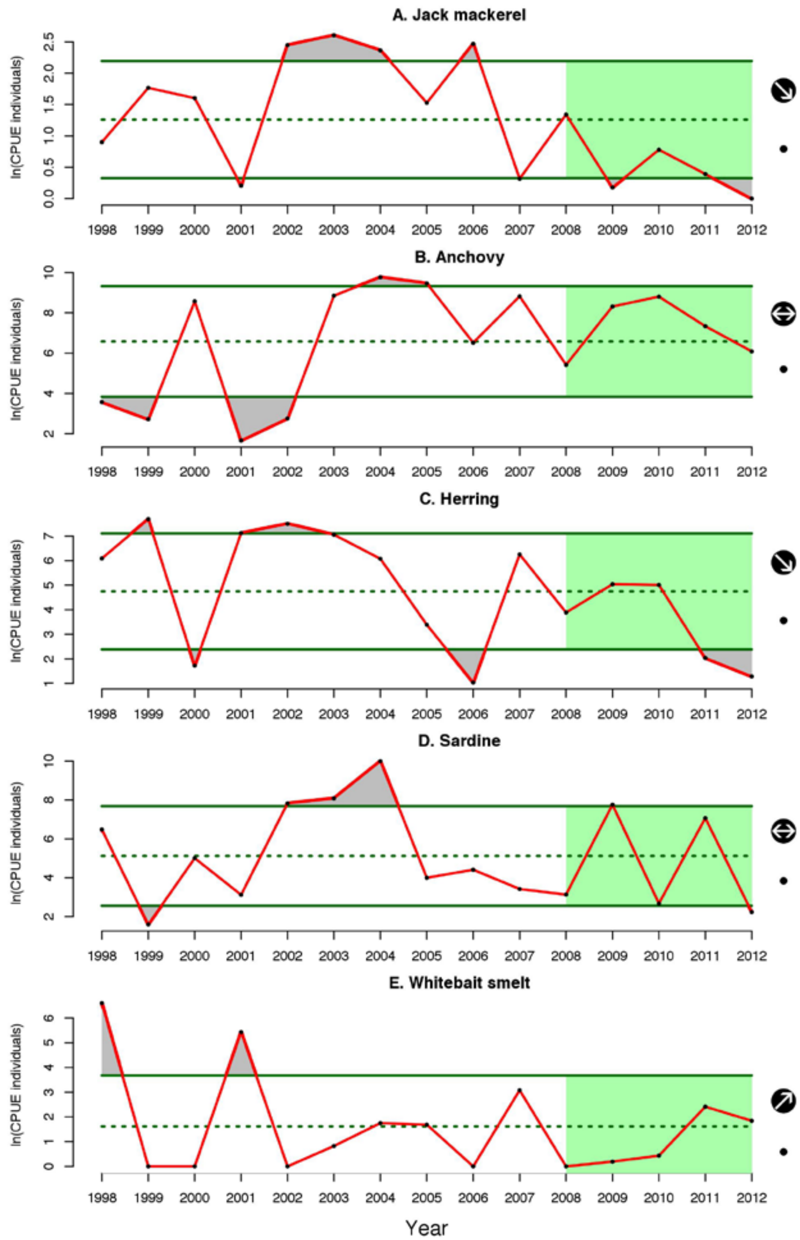


Figure C7. *Northern California Forage (NWFSC/BPA)*. Most time series are plotted in a standard format. Dark green horizontal lines show the mean (dotted) and ± 1.0 s.d. (solid line) of the full time series. The shaded green area is the last 5-years of the time series, which is analyzed to produce the symbols to the right of the plot. The upper symbol indicates whether the 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 low symbol indicates whether the mean of the last 5 years was greater than (+), less than (-) or within (.) one s.d. of the long-term mean

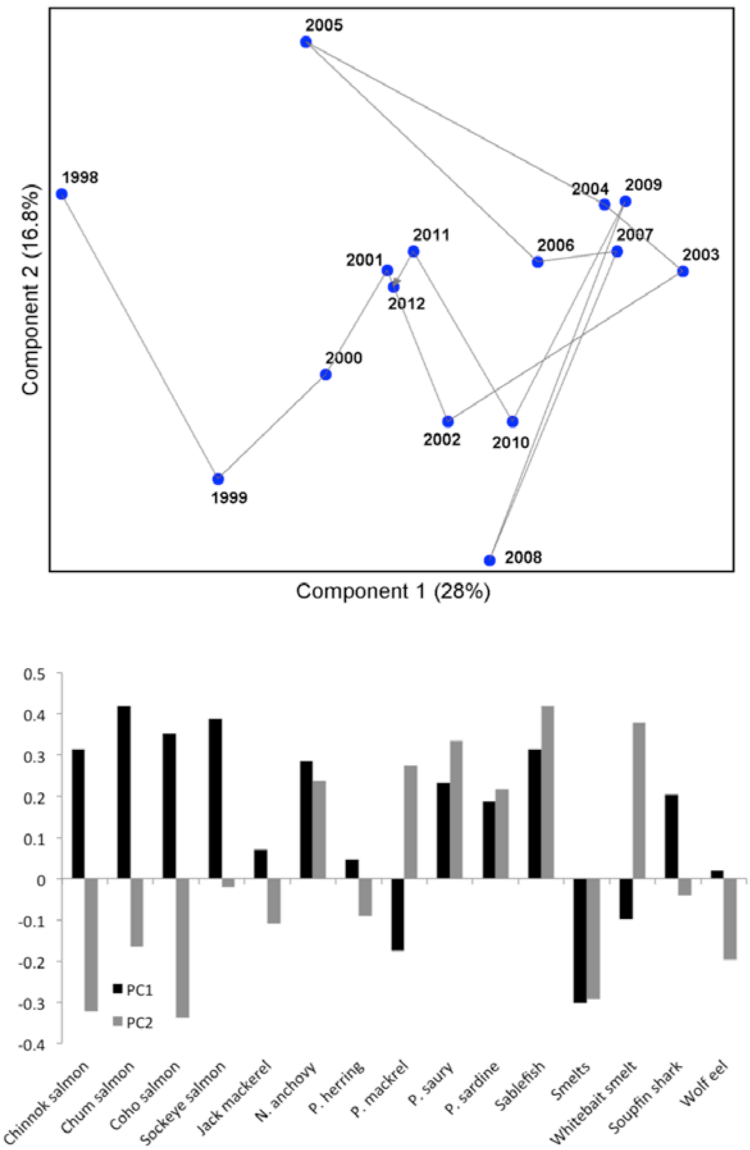


Figure C8. *Northern California Pelagic Community, surface trawl.* The top plot illustrates the similarity between years in terms of their pelagic communities. The bottom plot shows the most abundant species in June loaded onto components 1 and 2. Notably, 2001, 2011 and 2012 have very similar communities, and years 1998, 2005 and 2008 are distinct in their community composition from other years of the survey

INDICATOR SELECTION: ASSESSMENTS

INDICATOR EVALUATION: ASSESSMENTS

General description: Assessments

Pacific mackerel and sardine assessments are prepared for the PFMC to be used for developing harvest specifications. The assessments incorporate data from a number of sources and determine the biomass and age distribution of the populations along the coast. They represent the most complete analysis of recent abundance trends across the CCE. Therefore, we use recent assessments (Crone 2013, Hill et al. 2014), along with previously reviewed assessments (Murphy 1966, MacCall 1979, Dorval et al. 2008, Crone et al. 2009, Hill et al. 2010, Crone et al. 2011), to guide our estimation of long-term population trends of abundance and current stock status for these two species.

The Pacific mackerel assessment is an age-structured model incorporating information on catch, length and age distributions, and recreational fishery surveys (Crone et al. 2011). Full model details, problems and uncertainties are disclosed at http://www.pcouncil.org/coastal-pelagic-species/stock-assessment-and-fishery-evaluation-safe-documents/ and in Crone et al. (2011).

The sardine assessment includes fishery and survey data (egg production, and acoustic estimates of biomass). Full model details, problems, uncertainties are disclosed at http://www.pcouncil.org/coastal-pelagic-species/stock-assessment-and-fishery-evaluation-safe-documents/ and in Hill et al. (2014).

Appropriate indicators: Assessments

We focus on three indicators representing abundance and condition of Pacific mackerel and sardine. To estimate abundance trends we evaluate the biomasses of the two species.

1. The biomass time series for Pacific sardine is compiled from the most recent stock assessment (Hill et al. 2014) appended with previous assessments covering earlier periods of time (Murphy 1966, MacCall 1979, Hill et al. 2010). Biomass units are for sardine ages 2 and older, log-transformed metric tons.

2. Biomass time series for Pacific mackerel is the most recent stock assessment (Crone 2013), appended with previously reviewed assessments covering the historic period (Dorval et al. 2008, Crone et al. 2009). Biomass units are for mackerel ages 1 and older, log-transformed metric tons.

MAJOR FINDINGS BASED ON INDICATORS

In recent years the biomasses of Pacific mackerel and sardine have been average relative to the long-term mean yet, for sardine, the recent values are greater than the period following the population crash between 1950 and the early 1990s.

SUMMARY AND STATUS OF TRENDS BASED ON INDICATORS

In the first half of the 20th century both Pacific mackerel and sardine were relatively abundant. In the late 1970s and 1980s Pacific mackerel demonstrated above average production but production has declined in the past two decades. In the last five years population estimates of biomass are within 1 s.d. of the long-term mean and there is no apparent trend (Figure C9). Similarly, sardine experienced near-above average production in the past 10-20 years yet the estimates of biomass are with 1 s.d. of the long-term mean suggesting that, while the abundance in greater in recent years, it is still only a portion of that observed in the earlier part of the 20th century (Figure C9).

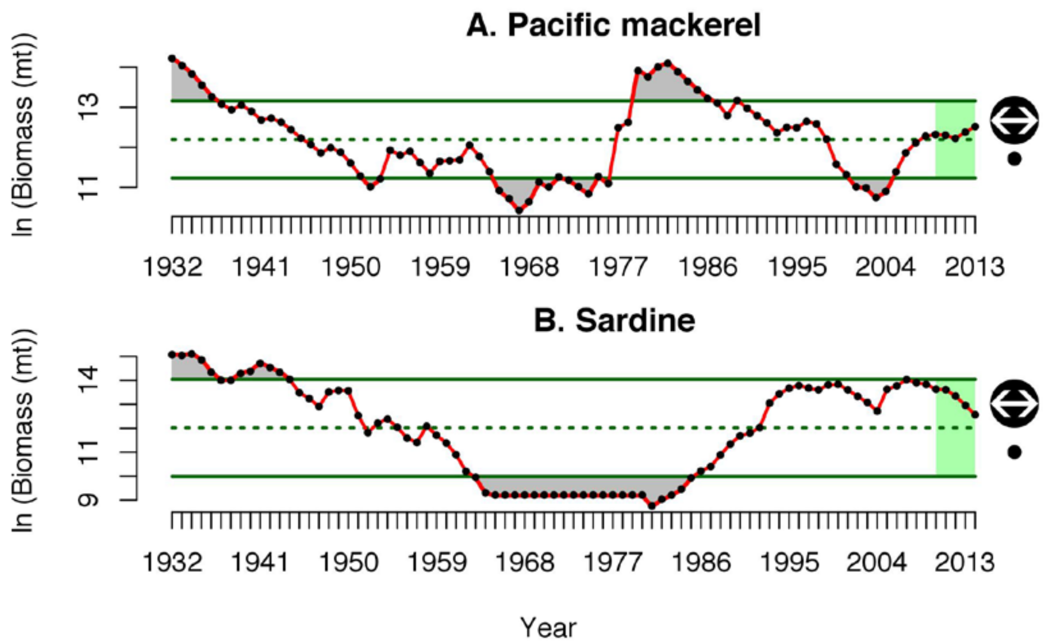


Figure C9*. Assessment biomass.* Most time series are plotted in a standard format. Dark green horizontal lines show the mean (dotted) and ± 1.0 s.d. (solid line) of the full time series. The shaded green area is the last 5-years of the time series, which is analyzed to produce the symbols to the right of the plot. The upper symbol indicates whether the 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 low symbol indicates whether the mean of the last 5 years was greater than (+), less than (-)or within (·) one s.d. of the long-term mean.

POSSIBLE FORAGE AND PREDATOR RESPONSES TO RECENT OCEAN CONDITIONS

Comparison of the abundances of various species across the three parts of the CCE indicates that their dynamics are not necessarily in sync across regions. Similarly, a recent analysis of ichthyoplankton assemblage structure between 2004 and 2011 in the northern and southern CCE showed that fish larvae respond to environmental variation very differently in California and Oregon, and that there was no correlation in the abundance of species found in both areas (e.g., northern anchovy) through time (Thompson et al. 2014) This emphasizes the need to sample widely throughout the system to understand how forage species in the broad ecosystem respond to environmental variability induced by El Niños.

In 2012 and 2013 the basin-scale indices and conditions from regional surveys indicated that oceanographic characteristics of the CCE were similar to recent cool years., Hereafter, we reference figures from the 'Oceanographic and Climatic Drivers and Pressures' (Hazen et al. 2014) chapter of this web report , indicated by the prefix 'OC'. The Pacific Decadal Oscillation (PDO) and Northern Oscillation Index (NOI) signaled a continued pattern of increased production and cool ocean waters and the NPGO was consistent with strong southward transport (see Figures OC7, OC8, and OC28 in Hazen et al. 2014, Ocean and Climate Drivers section of this report). Consistent with these large-scale signals, the CCE was cooler than typical 2009-2013, but an increasing trend is noted for the summer period (Fig.s OC39, OC40) (Hazen et al. 2014).

The timing of the spring transition is important to the development of forage community; early stronger winds are typically associated with improved production of the coastal forage community. At 45°N the spring transition occurred later 2008-2012 but was average in 2013 (Fig. OC21) (Hazen et al. 2014). By contrast, at 39°N the spring transition has been trending toward occurring earlier (Fig. OC21) (Hazen et al. 2014). Upwelling in the northern CCE was substantial, especially north of 39°N and the trend has been positive over the last five years (Fig.s OC18, OC19) South of 39°N upwelling winds have been at or slightly below typical (Fig. OC20) (Hazen et al. 2014). These regional and basin-scale conditions are conducive to an increased and more diverse coastal forage community (Brodeur and Pearcy 1992, Wells et al. 2008a, Santora et al. 2009, Sydeman et al. 2009, Santora et al. 2011, Santora et al. 2012, Thompson et al. 2012b, Schroeder et al. 2013, Wells et al. 2013).

There are limitations and differences between data series represented here, but in 2012 from our available observations, a CCE-wide pattern emerged with reduction of northern anchovy larvae (Figures C2, C5, and C7) and, to some degree, Pacific sardine larvae (Figures C5, C7, and C9). Catches of larval anchovy in the southern CCE waters have declined over the last three decades with the lowest densities recorded in the recent five years ending in 2011 (the last year of available data). The three possible causes of these trends are a reduction in spawning stock biomass, early survival, or increased advection from the region (Bakun and Parrish 1982).

Generally, in central and northern CCE those fishes whose abundance is reliant more on local (typically onshelf) conditions of production (Emmett et al. 2006, Santora et al. 2012) exhibited improved production/abundance in 2012 (Figures C6 and C8). For instance, in central CCE, a micronekton assemblage of rockfish, market squid, euphausiids, and flatfishes had improved production since 2005, 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 declining abundances of northern anchovy and clupeids.

The reductions of Pacific sardine and northern anchovy larvae and the improved production of the forage reliant on shelf productivity may point to variability in the quality of the shelf and offshelf 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), however the scale of upwelling is only of the order 50 km. This is clear in the central CCE region where, even during the cool, productive conditions that benefit northern anchovy production (Lindegren et al. 2013), the northern anchovy are not overwhelmingly abundant in the survey region. It is only when upwelling subsides, or during relatively unproductive years associated with reduced winds (e.g., 2005 and 2006, Figure C5) (Peterson et al. 2006, Schwing et al. 2006) 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, flatfishes and others, reside largely in the productive cool nearshore waters during upwelling periods (Figure C5).

With 2013 came an exceptionally strong winter and spring upwelling period that acted predictably on the regional hydrography; salinities were greater and surface temperatures lower (Wells et al. 2013). Biological data, for the most part, has yet to be processed, therefore, the biological signal will be discussed in greater detail in the next 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).

EL NIÑO

The Climate Prediction Center (CPC) of the National Weather Service is forecasting a reasonable likelihood of an El Niño event in the near future. The CPC posted on the El Niño /Southern Oscillation (ENSO) Diagnostics Discussion board (http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso_advisory/ensodisc.html) 10 April 2014 "While ENSO-neutral is favored for Northern Hemisphere spring, the chances of El Niño increase during the remainder of the year, exceeding 50% by summer." Importantly, El Niño periods have the potential to affect the forage community along the CCE and the predators that rely on them.

In southern CCE, El Niño events (e.g., 1983, 1992, 1998, and 2004) can potentially lead to variability in the productivity and distribution of the forage community. Sardine spawning habitat is expected to increase (Song et al. 2012). During the 1998 El Niño event, an increase in sardine catches was, indeed, noted (Figure C2). As well, there were decreases in fishes associated with cooler, typically more coastal waters such as hake, sanddab, rockfishes, and cool-water mesopelagics (Figure C2). In general, however, across the CalCOFI sampling region, variability in forage assemblages due to typical El Niño events may be modest but with an observed increase in oceanic contributors as warmer, offshore oceanic waters encompass a larger portion of the sampling area (Thompson et al. 2012a). An examination of Figures C3 and C4 demonstrate that there has not been a dramatic signal in larval fish assemblage structure representing El Niño years; although summer of 1998 had the lowest PC1 score of the years examined (largely reflecting extremely high abundances of Panama lightfish) it is not greatly unlike other more average years nor similar to 2003 and 2004 El Niño years. Further, spring of 1998 did not stand out from the other years. At a smaller scale, however, variations in assemblage makeup and distribution can be dramatic. Specifically, along more inshore regions of southern CCE, coastally-dependent fishes (e.g., northern anchovy, smoothtongue, and hake) can experience reduced production while oceanic-dependent fishes (e.g., broadfin lampfish, California flashlightfish, and bigfin laternfish, and longfin laternfish) increase in relative abundance as they become impinged closer to the coast (Thompson et al. 2012a). Such variability can impact foragers and lead to dependence on inferior prey. For instance, California sea lions, while dependent on sardine, also rely on coastal forage such as squid which is drastically reduced in the diets during El Niño events (Lowry and Carretta 1999). As demonstrated by the 1998 El Niño event, if prey availability is reduced to lactating females, their dependent pups may be in poor condition (Melin et al. 2010, Melin et al. 2012)

In central California, during strong El Niño events there have been reduced catches of pelagic juvenile rockfish and other juvenile groundfishes (Figure C5)(Ralston et al. 2013a, Ralston and Stewart 2013). However, in explaining the common trend in juvenile rockfish abundance there has been stronger correlation with relative sea level (as an indicator of transport, Fig. OC1) (Hazen et al. 2014) rather than either the MEI or other El Niño indices (Ralston et al. 2013a). This is largely due to the relatively poor correlation to years of high abundance, although some of the years of the highest abundance (e.g., 1999, Figure C5) follow strong El Niño events (and/or anomalously high northward transport in winter).

During El Niño events there has been a reduction in other coastally-dependent forage species (e.g., krill, particularly *Thysaonessa spinifera,* sanddabs, and market squid, Figure C5) and an associated increased abundance of sardine and mesopelagic fishes in the core survey area. Variability of sardine and mesopelagic fish abundances largely reflects changes in distribution and timing of movement patterns (so relates to local availability rather than coast-wide abundance). Such variability in forage dynamics can translate into availability of forage for predators such as seabirds and salmon, that subsequently rely on a different suite of prey species during El Niño years, with resultant real impacts to their productivity (Ainley et al. 1995, Sydeman et al. 1997, Sydeman et al. 2001, Sydeman et al. 2006, Wells et al. 2008a, Sydeman and Bograd 2009, Sydeman et al. 2009, Cury et al. 2011, Thompson et al. 2012b, Wells et al. 2012, Wells et al. 2013, Thayer et al. 2014). The multivariate methodology shown in Figure C6 demonstrates the dichotomy between the coastally-dependent forge species (e.g., rockfish) and those originating from more oceanic waters (e.g., sardines). It is clear from this analysis that the 1998 El Niño resulted in a dramatically different forage community from the average years. It was similar to only two other years (2005 and 2006) that, while not El Niño years, did demonstrate a similar ecosystem condition (Peterson et al. 2006, Schwing et al. 2006).

Along the northern CCE, during low upwelling, like 2005 and typical of El Niño years (Peterson et al. 2006, Schwing et al. 2006), there has been relatively low nutrients on the shelf leading to a dinoflagellate dominated phytoplankton community rather than a diatom phytoplankton community. This is likely to lead to longer food webs (more intermediate trophic levels) resulting in a less productive system (Brodeur and Pearcy 1992). As well, a relatively large euphausiid, *Thysaonessa spinifera,* is replaced by the southern smaller *Nyctiphanes simplex* and the large northern copepods are replaced with small southern ones. The impact of these changes is realized in the lipid and fatty acid composition of forage fish (Litz et al. 2010) that makes them less desirable as prey for higher trophic levels. The forage species' growth is also reduced leading to smaller size at age (Takahashi et al. 2012). These overall forage conditions lead to poor recruitment and condition of top predators such as salmon (Peterson and Keister 2003).

Consider, however, in the northern CCE, spawning of species like anchovy may actually be earlier and over a broader area in the warm El Niño years, leading to a potential good year class if conditions improve by late summer (Takahashi et al. 2012). In general, total larvae are more abundant during El Niño and/or low upwelling years and more larval and juvenile rockfish are found over the shelf rather than offshore (Auth 2008, 2011, Thompson et al. 2014) likely as a result of onshore impingement and increased ocean temperatures, which may expand spawning habitat and lead to better survival of those the impinged fishes. For the species we examined here, anchovy abundance was relatively low but sardine and whitebait smelt abundances increased during the 1998 El Niño (Figure C7). This was a particularly dramatic El Niño and, as indicated by multivariate analysis, 1998 was significantly separated from the other years on record as a result, in part, by a reduction in salmon and increase in the availability of more offshore-dependent species (e.g., sardine) (Figure C8).

CLIMATE CHANGE

Climate change has the potential to impact the forage community in a variety of ways. Some examples of these impacts are explored within the Management Strategy Evaluation (MSE) chapters of this report (e.g., Ruzicka 2014).

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