INTRODUCTION

Chris J. Harvey[1] and Newell Garfield[2]

[1]Conservation Biology Division, Northwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, 2725 Montlake Blvd E, Seattle, WA 98112, USA

[2]Environmental Research Division, Southwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, 8901 La Jolla Shores Drive, La Jolla, CA 92037, USA

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TABLE OF CONTENTS

PREFACE

In 2010, scientists representing NOAA line offices along the US West Coast initiated the California Current Integrated Ecosystem Assessment (CCIEA), a structured effort to organize and analyze scientific information in the context of ecosystem-based management of the California Current Large Marine Ecosystem (CCLME). The challenging task of assembling and interpreting large volumes of data from a broad range of disciplines, locations and time frames engages over 50 scientists from NOAA's Northwest and Southwest Fisheries Science Centers, other NOAA offices and colleagues from academia and non-governmental entities. The CCIEA team has taken an iterative approach for this work, with this being the third report. The first CCIEA report described the scope and conceptual underpinnings of the CCIEA, and presented preliminary findings on status, risk and management of salmon, groundfish, green sturgeon, and overall ecosystem health as of 2010 (Levin and Schwing 2011). The second "Phase II" report extended previous findings to the year 2012; expanded the range of focal components to include coastal pelagic species, marine mammals, seabirds, and coastal communities; expanded the list of drivers and pressures; and described further risk assessments and potential management strategy alternatives in the CCLME (Levin et al. 2013).

Here, we introduce the "Phase III" report, which describes our understanding of physical, chemical, ecological, and socioeconomic conditions in the California Current through the year 2013. We also formally introduce two major new components into the CCIEA effort: Habitat, the matrix within which ecological interactions occur; and Human Dimensions, the interface between humans and the other components (living and non-living) of the CCLME. We also further advance the effort to make this work truly *integrative* across components, rather than a series of parallel condition reports on co-occurring species and processes; examples of this are perhaps most clearly seen in sections on Salmon, Risk Assessment, and Management Strategy Evaluation.

The Phase III report is presented as a series of time-stamped documents in downloadable formats with accompanying web-based materials available at the CCIEA website (http://www.noaa.gov/iea/regions/california-current-region/). As with prior CCIEA reports, all chapters and appendices in Phase III have been peer-reviewed, and we gratefully thank colleagues who provided their time and expertise in the review process.

WHAT IS AN IEA?

As in previous iterations of the CCIEA (Levin and Schwing 2011, Levin et al. 2013), we follow the NOAA definition of an IEA: a formal synthesis and quantitative analysis of information on relevant natural and socioeconomic factors in relation to specific ecosystem management goals. NOAA defines an ecosystem as a geographically specified system of environments, habitats, processes, and organisms. Importantly, "organisms" explicitly include the humans that live in or near an ecosystem and benefit from its structure and functions, and the "environments" explicitly include social conditions as well as the physical, chemical and biological conditions in which organisms dwell. Ideally, the products of an IEA provide science support for the process of ecosystem-based management (EBM) of resources and resource use.

The general IEA approach has four primary steps: (1) *scoping*, where policymakers, managers, stakeholders and researchers collaborate to identify and articulate management objectives, ecosystem boundaries, key ecosystem attributes and important stressors; (2) *indicator development*, where scientists identify and test indicator variables that are suitable proxies for ecosystem attributes and thus reflect the status of ecosystem conditions relative to management decision rules; (3) *risk analysis*, where indicators are analyzed to determine their exposure and sensitivity to natural and human stressors; and (4) *management strategy evaluation*, where potential management strategies are assessed to determine their effectiveness at meeting management objectives while also identifying potential tradeoffs across different ecosystem components. Most of the work outlined below and detailed elsewhere in the report describes efforts on steps 2-4, which reflects a conscious effort to build up our IEA "science toolkit" in advance of formal scoping; we intend to direct more effort toward scoping in coming years.

EXECUTIVE SUMMARY OF THE 2013 CALIFORNIA CURRENT IEA

OVERALL ASSESSMENT

Recent indicator values leading up to 2013 point to a relatively productive period in the CCLME. Large scale climate and ocean indices all pointed to average or above average conditions for primary production (see Tables 1 and 2 and the end of this chapter). In all regions except southern California (south of 36° N), the Bakun Upwelling Index was the highest on record. Measures of chlorophyll-*a*, determined from satellite imagery, were low in the north and above average in the middle and southern regions. One concern was that strong upwelling might quickly transport primary production offshore, and therefore lower secondary production. This did not appear to happen, as both zooplankton (particularly lipid-rich northern copepods) and coastal pelagic fish populations appeared to be relatively productive and abundant (Tables 2, 5 and 8), except possibly anchovies and sardines.

At higher trophic levels, where longer lifespans and population doubling times lead to temporally lagged responses to changes in production, indicators of population abundance and condition were more mixed. Chinook and coho salmon populations were generally within the bounds of long-term averages, though many populations showed positive or negative short-term trends (Table 6). Groundfish abundance status and trends were generally encouraging, with only a few populations (all rockfish) below the overfished threshold, although the indicators of population structure suggest considerable truncation of age structure among most taxonomic groups (Table 7). The status of birds and mammals is harder to ascertain; although the few species for which we have data appear to have stable or even increasing populations, we lack data or suitable monitoring plans for most species. Of special concern is an unusual mortality event of California sea lion pups that occurred off southern California in 2012-2013.

Total commercial fishery landings increased in recent years, primarily driven by increases in Pacific hake and shrimp, and secondarily by landings of coastal pelagic species and crabs being above the long-term averages (Table 3). However, landings in some commercial fisheries were near historic lows (salmon, groundfish), and the diversity of landings by fishing vessels and ports continued to decrease, which may reflect greater vulnerability to revenue swings. Declines in bottom trawling targeting groundfish may have lessened groundfish mortality and impacts on benthic habitats. Other anthropogenic activities in the CCLME had mixed trends (Table 4); many large-scale human activities were in decline, such as recreational beach use, shipping, and certain forms of pollution; these declines may be related to the recent downturn in US economic conditions and warrant monitoring during economic recovery.

STATUS AND TRENDS OF THE CALIFORNIA CURRENT THROUGH 2013

An IEA goal is to analyze the connectivity between indicators of different environmental drivers and trophic levels to determine how to best represent critical ecosystem status parameters. The ultimate goal is to define the indices which best help describe conditions for any specific ecosystem attribute, e.g., a species, community, habitat, fishery or element of human wellbeing.

The CCIEA has now selected 174 suitable indicators to analyze for conditions and trends. The range is from basic environmental parameters up through top predators and human dimensions. Tables 1 through 8 at the end of this chapter are presented as visual summaries of the indicators, where the arrows indicate the recent trend, the symbols (•,+,-) indicate the index value relative to the long term statistics, and the colors represent our (Harvey and Garfield) qualitative judgment on the trend or status reflecting “good,” “neutral” or “poor” conditions for overall ecosystem processes and functions. Where possible, we break these status and trends indicators out by season or one of three latitudinal ecoregions (Figure 1): the northern California Current region north of Cape Mendocino; the central California Current region between Cape Mendocino and Point Conception; and the southern California Current region, south of Point Conception. There can exist large spatial variation in physical and biological indicators among and within the subregions. Overall, most indicators are within the range of ± 1 standard deviation (s.d.) of the long-term mean, which is taken as within the normal range for the indicator. There are few significant outliers in the last five years, which suggest that conditions were fairly stable. The full temporal variation of each indicator is provided within each relevant chapter of the full Phase III report.

DRIVERS AND PRESSURES

We generally categorize indicators of drivers and pressures in two categories: (1) physical, chemical and climate drivers and pressures, i.e., forcing that is largely driven by natural processes; and (2) anthropogenic drivers and pressures, i.e., forcing that is of human origin. Both types of forces operate across a range of spatial and temporal scales.

PHYSICAL, CHEMICAL AND CLIMATE DRIVERS

The environmental indices at large (Multivariate El Niño Index (MEI), the Northern Oscillation Index (NOI), the North Pacific Gyre Oscillation (NPGO), and the Pacific Decadal Oscillation (PDO)), regional (Eddy Kinetic Energy (EKE)) and local (Upwelling index (UI), Sea Surface Temperature (SST), coastal sea surface height, meridional winds, and pycnocline depth and strength) scales generally remained within the mean range defined by the long term mean ± 1 s.d. (Table 1; see Hazen et al. 2014a). The exception is that the NPGO remained above the mean, which is indicative of stronger gyre circulation that generally favors productivity. Upwelling trends were stable or positive (Tables 1 and 2).

Chemical indices are water column nutrients, represented by nitrate plus nitrite, and dissolved oxygen, which can also serve as a proxy for ocean acidification. Similar to the environmental indicators, both the nutrient and oxygen indices are within the long term mean range with no strong trends (Table 1).

A new index, the Multivariate Ocean Climate Index (MOCI) is introduced in this Phase III report; it is composed of multiple indices and provides a broad perspective on the status of the ecosystem (Hazen et al. 2014a). Similar to the other ecosystem indices, the recent status value is within 1 s.d. of the long-term mean (Table 2).

ANTHROPOGENIC DRIVERS

The 23 anthropogenic drivers and pressures examined show considerable variation among different sectors (Andrews et al. 2014). Among fisheries, landings of demersal groundfish are historically low while those of coastal pelagic species and crabs are higher than average; landings of hake, shrimp, and all fisheries combined are increasing (Table 3). Non-fisheries activities varied widely (Table 4). Some indicators were above average but level (e.g., coastal engineering, power plant activity, sediment retention) while others were below average (offshore oil and gas activity, benthic structures). Many activities had negative trends (e.g., shipping, invasive species, beach use, several forms of pollution), which may be related to weak economic conditions. A few showed positive trends (dredging, shellfish aquaculture), and high or increasing indicators of total fishery landings, aquaculture production and seafood demand warrant continued attention. Anthropogenic activity indicators presently at declining or low levels should also be watched carefully as national and global economic trends change.

HABITAT

A formal selection of indicators of habitat quantity and quality is a new addition to this year's CCIEA. Given the important relationships that habitat types have with all drivers, species, ecological processes and human wellbeing in the CCLME, this is a significant step for the CCIEA. Using the standard CCIEA methods for indicator selection, we identified 33 high priority habitat indicators, relating to the quantity and quality of freshwater, nearshore/estuarine, pelagic, and seafloor habitats, as well as some anthropogenic pressures that are particularly focused on these habitats (Greene et al. 2014). In the coming years, these 33 indicators will be quantified and analyzed for spatial and temporal trends. They will also contribute to synthetic analyses in the IEA framework, such as spatially based risk assessments and management strategy evaluations.

KEY ECOSYSTEM COMPONENTS

ZOOPLANKTON

Zooplankton abundance and composition represent conditions near the base of the food chain, and as such can be used as one of the indicators of ecosystem health. Peterson et al. (2014) have developed a suite of zooplankton indicators based on samples collected monthly along the Newport hydrographic line. Copepod biomass and composition provide an indication of the abundance of the prey resource for higher trophic levels. Copepod composition is further separated into northern and southern copepod assemblages that indicate lipid-richness (northern > southern). All four indices remain within long term ranges and do not show trends during the last five years (Table 2; see also Hazen et al. 2014a).

COASTAL PELAGIC SPECIES

Data describing the abundance of pelagic forage species (e.g., schooling pelagic fishes and squids) are generally obtained from fishery independent surveys, and sampling methods are different in the three regions of the CCLME. Not all of the same species are sampled across regions. In general terms, in the northern and central CCLME the forage community dependent on cool productive conditions became more abundant or remained stable (Table 5; see also Wells et al. 2014a). However, sardine abundance was low throughout much of the CCLME. Anchovy in the fishery-independent sampling off central and southern California remained at a low abundance. In contrast, the biomasses of Pacific mackerel and sardines as derived from formal stock assessments are within ± 1 s.d. of the long-term mean, both slightly above the mean.

SALMON

A general statement on salmon is difficult given the diversity of riverine populations and the timing of the various runs. Here we report on 14 Chinook salmon and 4 coho salmon data-rich populations, separated into Evolutionarily Significant Units (ESUs) based on rivers and reproductive isolation (Wells et al. 2014b). Species abundance is the most common index of condition, although age diversity, percent natural population (versus hatchery) and population growth rate are indices available for some ESUs. Since salmon populations have suffered such historically significant declines, data for determining trends start with 1985; if earlier data were included, many of the current abundance indicators would be well below the long-term means (Wells et al. 2014b).

In general, California Chinook ESUs were within ± 1 s.d. of the 1985 – present data (Table 6). Central Valley winter-run Chinook salmon abundances were quite low. In the Columbia/Snake basin, Chinook salmon stocks were near the mean and showed both increasing and decreasing trends. Coho salmon stocks were also near their long term mean, again showing different trends in abundance among regions.

GROUNDFISH

Of the 90+ shelf and slope groundfish species that are managed in the CCLME, 36 had sufficient data to use as indicators of groundfish community abundance and condition (Cope and Haltuch 2014). A strong majority of these 36 species had stable or increasing population trends and spawning stock biomasses that are above target levels, and all species have fishing mortality rates that are below overfishing limits (Table 7). Biomasses of three rockfish (*Sebastes*) species were below the minimum limit reference point, indicating overfished status; in addition, several species, mostly rockfish, also have experienced long-term truncations in age distribution and declines in proportions of females that are mature (Cope and Haltuch 2014).

SEABIRDS

No status and trend updates for seabirds were conducted for the CCIEA in 2013. The most recent CCIEA review of seabirds, from last year's CCIEA Phase II report (Zamon et al. 2013), examined recent at-sea abundance trends of three indicator species (common murre *Uria aalge*, sooty shearwater *Puffinus griseus*, and Cassin's auklet *Ptychoramphus aleuticus*) in different seasons in the northern and southern regions of the CCLME. These are common birds but are a fraction of the 75+ seabird species present in the region.

Common murre abundance at sea was stable or increasing, sooty shearwater abundance was stable, and Cassin's auklets increased in the north but were stable or decreasing in the south. However, given the small number of indicators, our understanding of seabird status and trends in the CCIEA context is largely inconclusive at this time.

MARINE MAMMALS

No comprehensive marine mammal surveys were conducted in the California Current in 2013, and thus we cannot update the status and trends indicators from past CCIEA reports. The most recent CCIEA review of marine mammal population status, from last year's CCIEA Phase II report (Redfern et al. 2013), noted that coastwide survey frequencies, survey designs, and protracted marine mammal life histories preclude discernment of meaningful short-term trends. Analyses by various investigators suggest several indicator populations are increasing (e.g., humpback whales, fin whales, gray whales, California sea lions), and that apparent decreases in some populations (e.g., blue whales) likely result from distributional shifts, not from changes in abundance. However, an unusual mortality event (UME) among California sea lion pups in 2012-2013 may be evidence of episodic changes in local sea lion feeding conditions (Wells et al. 2013).

INDICATORS OF "ECOLOGICAL INTEGRITY"

CCIEA scientists evaluate many integrative indicators of "ecological integrity," by which we mean the ability of an ecosystem to support and maintain communities that are comparable to those in less-disturbed reference habitats in the same region (Parrish et al. 2003). We are following indicators of two main aspects of ecological integrity: trophic structure and biodiversity.

Indicators of trophic structure reflect average to above-average conditions for consumers in the CCLME through 2013 (Table 8; see also Williams et al. 2014). The biomass anomaly of northern copepods, which are an energy-rich food source for planktivores, was relatively high off Oregon; in contrast, biomasses of gelatinous zooplankton species, which may prey on fish larvae or compete with forage fish for prey, were generally near long-term averages and showed negative trends in some areas and seasons. The proportion of scavengers increased relative to total demersal consumer biomass, largely driven by increased biomass of crabs. Finally, the mean trophic level of groundfishes was relatively low coastwide and even declining south of Cape Mendocino, due to relatively low abundances of two predators, Pacific hake *Merluccius productus* and spiny dogfish *Squalus suckleyi*. Reduced abundances of these predators may further promote good feeding conditions for competitors such as salmon, tunas, and seabirds.

Biodiversity indices (evenness and species richness) for the groups examined were within ±1 s.d. of the long-term mean, although some groups show significant trends in recent years (Table 8). Summer copepod biodiversity had a recent declining trend, consistent with greater amounts of the relatively less-diverse northern copepods that are richer energy sources, suggesting good feeding conditions for higher trophic levels in the pelagic community. Ichthyoplankton biodiversity had a recent increasing trend at a coast-wide scale, but a declining trend in the northern sampling locations, suggesting possible differences in ichthyoplankton ecology in the northern and southern regions of the system. Groundfish diversity has declined recently at the coast-wide scale, driven most strongly by declines south of Cape Mendocino, but evenness of groundfish has increased.

HUMAN DIMENSIONS

Human dimensions include archaeological and historical heritage, contemporary demographic patterns such as population growth and migration, individual and community behaviors, cultural values and trends, social relationships and social movements, political and economic systems, institutions and governance, and perhaps most importantly in this context, the many ways that humans are connected to the environment (Breslow et al. 2014). Because of the significant role that humans play as consumers of ecosystem services and engineers of ecosystem structure, and because of legislative mandates that require consideration of societal impacts of resource management decisions, human dimensions are essential attributes to include in a true ecosystem assessment. The CCIEA has only recently begun identifying and ranking indicators of human wellbeing. Thus we cannot yet comprehensively assess the status and trends of human wellbeing in coastal communities of the CCLME, apart from what might be assumed from the indicators of anthropogenic drivers and pressures alluded to earlier. However, at least one potential indicator within the fisheries sector implies declining wellbeing for some stakeholders: an annual index of diversity of fishery revenue sources is declining across regions, vessel sizes, and vessel income levels (Holland and Kasperski 2014). Lower revenue diversity is consistent with greater variability in annual income, and thus greater financial risk.

ASSESSMENT OF RISK OF KEY ECOSYSTEM COMPONENTS

Modeled response of ten coastal pelagic species to rising sea surface temperature and accompanying variability in chlorophyll-*a* concentrations to represent conditions in 2100 were used to assess risk due to climate change (Samhouri et al. 2014). The results suggest that risk for coastal pelagic species was highest in northern, coastal areas of the California Current and lower in southerly, offshore waters. The sensitivity of individual species to those changes was an order of magnitude greater than the exposure. The findings suggest that higher resolution climate models may be necessary to better resolve the variations.

Cumulative risks of 24 anthropogenic stressors to eight top predators (marine mammals, sea turtles and seabirds) in the U.S. west coast exclusive economic zone (EEZ) were assessed (Hazen et al. 2014b). Cumulative risks were greatest in nearshore areas, particularly within National Marine Sanctuary boundaries (in part because the Sanctuaries correspond with areas frequently used by top predators) and in hotspots near Point Arena and Monterey Bay. Climate change-related stressors posed the greatest risk due to their widespread distribution. The Sanctuary program may provide a basis for increased protection of top predators from human activities.

EVALUATION OF POTENTIAL MANAGEMENT STRATEGIES

Management strategy evaluation efforts in the Phase III CCIEA are focused on narrative scenarios that explore alternative future states of climate change, ocean acidification, and shipping activities (Kaplan et al. 2014). These scenarios, developed through scoping with resource managers, were evaluated through both qualitative and quantitative analyses. The key findings of these management strategy evaluations are summarized below.

Four studies considered the potential impacts of climate change. Two studies focused on how management could mitigate climate impacts on ESA-listed Chinook salmon (*Oncorhynchus tshawytscha*) in the Columbia River system. Crozier and Zabel (2014) found that spring/summer Chinook salmon in the Snake River system face high extinction risk if poor marine conditions (positive signs of the PDO index) increase in frequency; however, that risk can be mitigated almost entirely by actions that increase survival of smolts through dams in the Snake and Columbia rivers. Jorgensen et al. (2014) found that management to improve freshwater survival of pre-smolt juveniles was the best means of mitigating climate effects on Wenatchee River spring Chinook salmon; however, while cumulative management actions could mitigate moderate climate change effects, this population appears vulnerable to severe climate change. A third study, by Ruzicka (2014), examined the effects of interannual variability in a food web model of the northern California Current. Variability was imposed on key pelagic groups that are particularly sensitive to short-term climate variation: phytoplankton, copepods, large jellies, and forage fish. Variability in phytoplankton, due to forcing such as PDO and ENSO dynamics and upwelling, was a dominant structuring force, and strong community responses were also evoked by variability in jellies and forage fish. Interannual variability also affected fisheries: high forage fish years produced higher landings for gears targeting pelagic predators, while high euphausiid years supported greater landings for gears targeting hake and sablefish. These results serve as valuable hypotheses of how local climate conditions, climate variability, and community structure affect different ecosystem properties and fishery production.

The CCLME is potentially vulnerable to the ecological effects of ocean acidification (OA), a lowering of ocean pH and carbonate saturation due to increases in anthropogenic CO_2 (Busch et al. 2014). As part of the CCIEA Phase III report, Hodgson et al. (2014) present a risk analysis for different life history stages of Dungeness crab (*Metacarcinus* [formerly *Cancer*] *magister*) and pink shrimp (*Pandalus jordani*) to the effects of OA. Larval pink shrimp and post-settled megalops of Dungeness crab were the most vulnerable stages based on future spatial projections of OA effects; furthermore, all other life history stages of both species will also be exposed to OA. The effects are predicted to be worse in areas off California than off Washington, implying that fisheries effects will be felt strongest by fleets sailing from California ports.

Management strategy evaluation related to shipping first involved informal discussions with eight experts, who provided insight on expected shipping trends over the next 5-30 years (Kaplan et al. 2014). These discussions led to five potential scenarios that warrant more formal analysis and predictive modeling regarding their effects on California Current resources and human wellbeing. The scenarios were: (1) higher fuel prices, which would sustain reduced ship speeds but would not increase intra-national shipping between US ports; (2) economies of scale, which shift shipping fleets to relatively small numbers of very large ships that concentrate in the largest ports; (3) the widened Panama Canal will shift a large portion of container traffic from the US West Coast to the US East Coast; (4) clean fuel requirements, which will alter shipping routes and reduce ship speeds; and (5) North American energy development increases energy exports from the Pacific Northwest.

A more complete shipping scenario evaluation considers the potential for ship strikes on large whales in the Southern California Bight. Ship traffic in these waters shifted due to recent regulations requiring cleaner burning fuels in coastal waters; the revised routes are closer to military ranges and may also change the risk of ship strikes to several whale species. Redfern (2014) examined ship strike risk in several alternative routes and determined that a new southerly route could lower risk to fin whales (*Balaenoptera physalus*) and humpback whales (*Megaptera novaeangliae*) and also reduce use conflict with other sectors; however, risk to blue whales (*Balaenoptera musculus*) could not be lessened, which is problematic because blue whale mortalities may exceed allowable limits.

NEXT STEPS

This report, along with the initial CCIEA report by Levin and Schwing (2011) and the Phase II report (Levin et al. 2013), have contributed to defining and establishing the basic IEA tool kit of identifying and quantifying good indicators of key ecosystem attributes, developing methods to assess the risk of ecosystem components to natural and anthropogenic stressors, and building quantitative models for evaluating effectiveness and tradeoffs in different management strategies.

Our next effort, the Phase IV report, is targeted for completion in the summer of 2016. Provided that agency resources are suitable for continued CCIEA work, we hope to achieve several major goals in Phase IV, including:

- The first set of indicator time series for habitats;
- An expanded set of time series of human dimensions indicators, including the first set of human wellbeing indicators;
- Greater emphasis on management-relevant, integrated products, including quantitative analysis of relationships between indicators, more risk analyses, and more management strategy evaluations; and
- Products serving broader constituent needs—continuing to expand beyond just fisheries-focused products to serve management needs related to other sectors (e.g., shipping, energy development, etc.), protected resources, and National Marine Sanctuaries within the CCLME.

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FIGURE AND TABLES

For reasons of formatting and readability, Figure 1 and Tables 1-8 are presented on the following pages rather than being embedded within the text of this relatively short chapter.

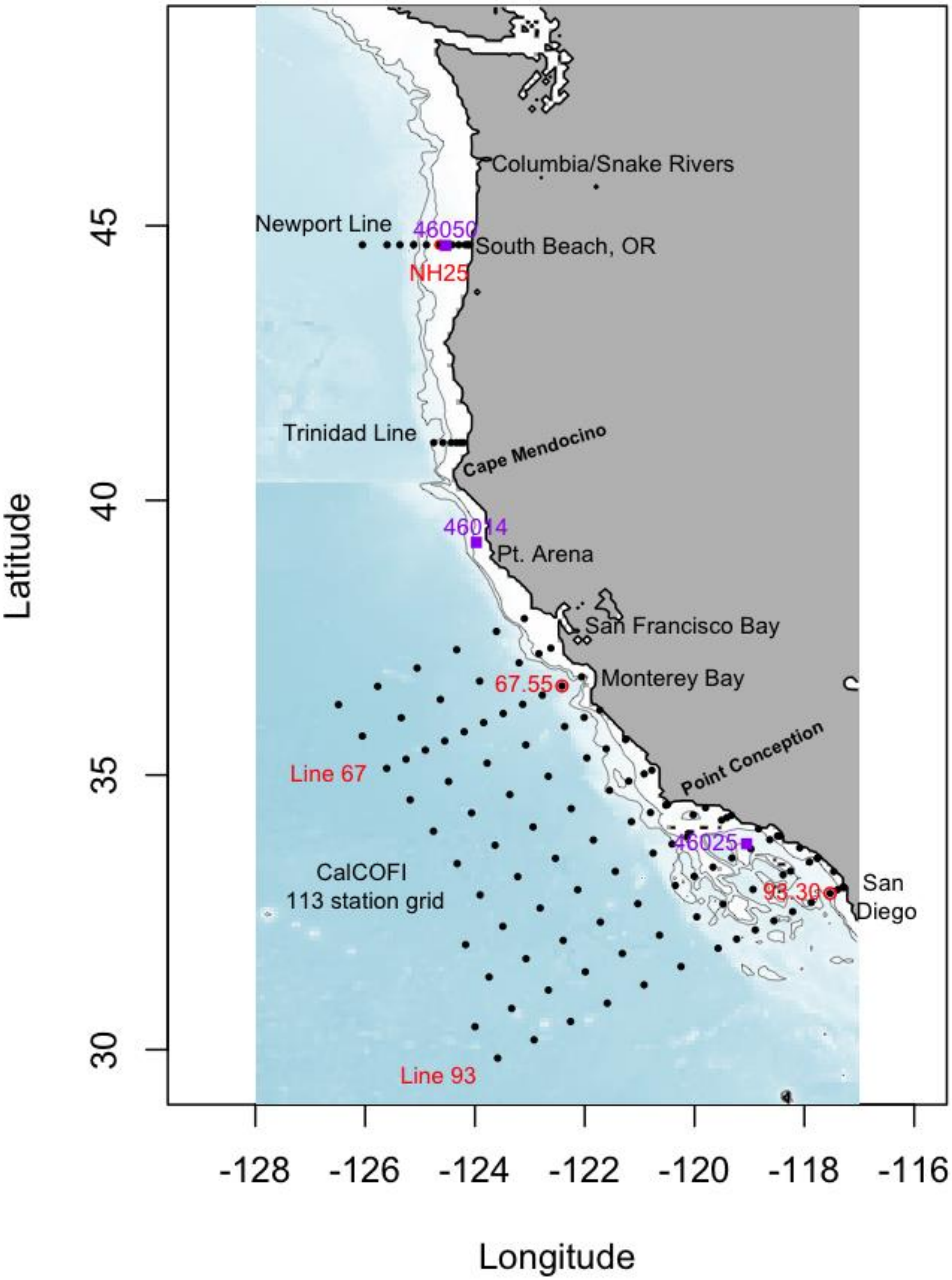


Figure 1. Map of the U.S. waters of the California Current large marine ecosystem (CCLME). Major headlands that demark ecoregional boundaries are labeled (Cape Mendocino, Point Conception), as are the locations of key sampling points that are referred to in Tables 1-8 or elsewhere in the text. Figure credit: Andrew Leising.

Table 1. Trends and status of physical, chemical and climate indicators in the CCLME. Indicators are sorted by season (columns) and location (rows, north to south except basin-scale indicators). Arrows represent the most recent 5-year trend (↗ increasing, ↔ no trend, ↘ decreasing); symbols represent status, i.e., the most recent 5-year mean relative to the long-term mean (– more than 1 s.d. below, ● within ± 1 s.d., + more than 1 s.d. above); colors indicate authors Harvey and Garfield's qualitative appraisal of trend or status as an indicator of overall ecosystem health (green: "good"; blue: "neutral"; red: "poor"; uncolored: inconclusive). Details and figures are in the chapter by Hazen et al. (2014).

		Temporal resolution						
		Monthly		Winter		Summer		Fig. in report
Indicator	Site	Trend	Status	Trend	Status	Trend	Status	
Multivariate El Niño Index	basin-scale	↔	●	↔	●	↔	●	OC27
Northern Oscillation Index	basin-scale	↔	●	↗	●	↔	●	OC8
North Pacific Gyre Oscillation	basin-scale	↔	🟩 +	↔	●	↔	●	OC28
Pacific Decadal Oscillation	basin-scale	↔	●	↔	●	↔	●	OC7
Eddy kenetic energy	45°N	↘	●	↔	●	↘	●	OC15
	39°N	↔	●	↔	●	↔	●	OC16
	33°N	↔	●	↔	●	↔	●	OC17
Upwelling Index	45°N	↔	●	↔	●	🟩 ↗	●	OC18
	39°N	↔	●	🟩 ↗	●	🟩 ↗	●	OC19
	33°N	↔	●	↔	●	🟩 ↗	●	OC20
Sea level height	So. Beach, OR	↔	●	🟩 ↘	●	↔	●	OC1
	San Francisco	↔	●	↔	●	↔	🟥 +	OC2
	San Diego	↔	🟥 +	↔	🟥 +	↔	🟥 +	OC3
Sea surface temperature	NOAA Buoy 46050	↔	●	↔	●	↔	●	OC4
	NOAA Buoy 46014	↔	●	🟩 ↘	●	🟩 ↘	●	OC5
	NOAA Buoy 46025	↔	●	↔	●	🟩 ↘	●	OC6
Meridional winds	NOAA Buoy 46050	↔	●	↔	●	↔	●	OC24
	NOAA Buoy 46014	↔	●	↘	●	↔	●	OC25
	NOAA Buoy 46025	↔	●	↔	●	↗	●	OC26
Pycnocline depth	NH25	↘	●	↔	●	↘	●	OC9
	CalCOFI 67.55	↔	●	↔	●	↘	●	OC10
	CalCOFI 93.30	↔	●	↔	●	↔	●	OC11
Pycnocline strength	NH25	↔	●	↗	●	↘	●	OC12
	CalCOFI 67.55	↔	●	↔	●	↘	●	OC13
	CalCOFI 93.30	↔	●	↔	●	↘	●	OC14
NO_2 + NO_3 @ 150 m	NH25	↔	●	↔	●	↔	●	OC29
	CalCOFI 67.55	↔	●	↗	●	↗	●	OC30
	CalCOFI 93.30	↔	●	↔	●	↗	●	OC31
Dissolved oxygen @ 150 m	NH25	↔	●	↔	●	↔	●	OC35
	CalCOFI 67.55	↔	●	🟥 ↘	●	🟥 ↘	●	OC36
	CalCOFI 93.30	↔	●	↔	●	🟥 ↘	●	OC37

Table 2. Trends and status of additional physical, chemical and climate indicators in the CCLME (these indicators could not be sorted in the same seasonal and spatial manner as indicators in Table 1, and hence are presented separately). Arrows, symbols and colors are as in Table 1. Details and figures are in the chapter by Hazen et al. (2014).

Indicator	Site or season	Trend	Status	Figure in report
Spring transition Julian date	45°N	↗	●	OC21
	39°N	↘	●	OC21
	33°N	n/a		OC21
Length of upwelling season	45°N	↘	●	OC22
	39°N	↗	●	OC22
	33°N	n/a		OC22
Total upwelling magnitude	45°N	↗	●	OC23
	39°N	↗	●	OC23
	33°N	↗	●	OC23
Monthly total copepod biomass	NH Line	↔	●	OC32
Monthly copepod community composition	NH Line	↔	●	OC32
Monthly northern copepod biomass anomaly	NH Line	↔	●	OC33
Monthly southern copepod biomass anomaly	NH Line	↔	●	OC34
Multivariate Ocean Climate Index (MOCI)	Winter	↗	●	OC38
	Spring	↔	●	OC38
	Summer	↘	●	OC38
	Fall	↔	●	OC38

Table 3. Trends and status of indicators of fishery-related anthropogenic activities in the CCLME. Arrows and symbols are as in Table 1. No colors are used to qualitatively appraise these indicators' relationships to overall ecosystem health because such appraisals reflect value judgments that are societal rather than scientific in nature (for example, an increase in fishing could reflect a positive economic effect for a fleet but a negative effect on the population of the targeted fish species). Details and figures are in the chapter by Andrews et al. (2014).

Indicator	Site	Trend	Status	Figure in report
Total annual fisheries landings	Coast-wide	↗	●	AP0
Commercial fisheries				
Groundfish landings (w/o hake)	Coast-wide	↔	–	AP1
Pacific hake landings	Coast-wide	↗	●	AP2
Coastal pelagic species landings	Coast-wide	↔	+	AP3
Highly migratory species landings	Coast-wide	↔	●	AP4
Salmon landings	Coast-wide	↔	●	AP5
Crab landings	Coast-wide	↔	+	AP6
Shrimp landings	Coast-wide	↗	●	AP7
Shellfish landings	Coast-wide	↔	●	AP8
Other species landings	Coast-wide	↔	●	AP9
Total trawl landings	Coast-wide	↗	●	AP11
Shrimp trawl landings	Coast-wide	↗	●	AP12
Hook and line landings	Coast-wide	↔	–	AP13
Net gear landings	Coast-wide	↔	●	AP14
Pot and trap landings	Coast-wide	↔	+	AP15
Troll landings	Coast-wide	↔	●	AP16
Other miscellaneous gear landings	Coast-wide	↔	●	AP17
Total fishing mortality				
Groundfish (w/o hake)	Coast-wide	↘	●	AP19
Pacific hake	Coast-wide	↔	●	AP20
Fishing effects on habitat				
Total distance disturbed	Coast-wide	↘	●	AP22
Disturbance to shelf, hard substrate	Coast-wide	↔	●	AP23
Disturbance to shelf, mixed substrate	Coast-wide	↔	●	AP24
Disturbance to shelf, soft substrate	Coast-wide	↘	●	AP25
Disturbance to upper slope, hard substrate	Coast-wide	↔	●	AP26
Disturbance to upper slope, mixed substrate	Coast-wide	↘	●	AP27
Disturbance to upper slope, soft substrate	Coast-wide	↘	●	AP28
Disturbance to lower slope, hard substrate	Coast-wide	↔	●	AP29
Disturbance to lower slope, soft substrate	Coast-wide	↔	●	AP30

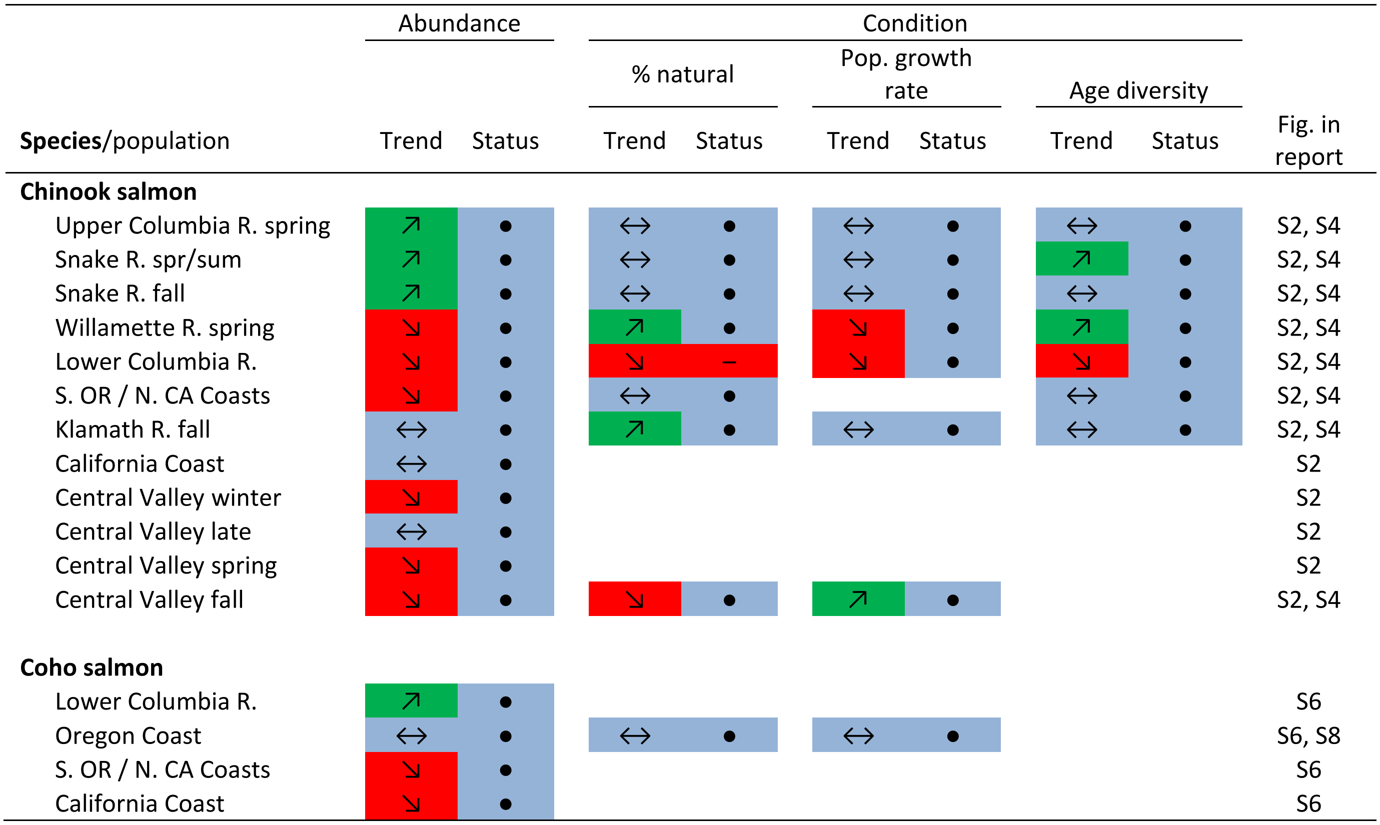
Table 4. Trends and status of indicators of non-fishery related anthropogenic activities in the CCLME. Arrows and symbols are as in Table 1. No colors are used to qualitatively appraise these indicators' relationships to overall ecosystem health because such appraisals reflect value judgments that are societal rather than scientific in nature (for example, an increase in an activity could reflect a positive economic effect for a sector but a negative effect on populations of some marine species). Details and figures are in the chapter by Andrews et al. (2014).

Attribute	Indicator	Site	Trend	Status	Figure in report
Aquaculture	Aquaculture production (finfish)	Coast-wide	↔	+	AP33
	Aquaculture production (shellfish)	United States	↗	+	AP34
Atmospheric pollution	Sulfate deposition	Coast-wide	↘	●	AP35
Benthic structures	# of offshore oil and gas wells	Coast-wide	↔	–	AP36
Coastal engineering	Coastal population	Coast-wide	↔	+	AP37
Commercial shipping	Vol. water disturbed in transit	Coast-wide	↘	●	AP38
Dredging	Vol. dredged sediments	Coast-wide	↗	●	AP39
Freshwater retention	Vol. freshwater stored behind dams	Coast-wide	↔	+	AP40
Inorganic pollution	Toxicity-weighted chemical releases	Coast-wide	↔	●	AP42
Invasive species	Tons of cargo moved through ports	Coast-wide	↘	●	AP43
Light pollution	Average nighttime light	Coast-wide	↔	●	AP45
Marine debris	Predicted debris counts	Northern CC	↗	●	AP46
		Southern CC	↔	●	AP46
Nutrient input	N + P fertilizer applications	Coast-wide	↘	+	AP47
Ocean-based pollution	Vol. water disturbed and cargo moved by shipping activities	Coast-wide	↘	●	AP48
Oil and gas activity	Oil and gas production	California	↔	–	AP49
Organic pollution	Toxicity-weighted pesticide conc.	Coast-wide	↘	●	AP50
Power plants	Vol. saline water withdrawals	Coast-wide	↔	+	AP51
Recreation	Beach attendance	Coast-wide	↘	●	AP52
Seafood demand	Consumption of fisheries products	United States	↔	+	AP53
Sediment retention	Vol. freshwater impoundments	Coast-wide	↔	+	AP54

Table 5. Trends and status of the abundance of pelagic forage in the CCLME, based on data from multiple monitoring programs. Results are sorted into northern, central, and southern regions of the CCLME. Arrows, symbols and colors are as in Table 1. Details and figures are in the chapter by Wells et al. (2014a). Blanks indicate insufficient data.

	Region						
	North		Central		South		
Indicator	Trend	Status	Trend	Status	Trend	Status	Fig. in report
Anchovy	↔	●	↔	●	↔	–	C2, C5, C7
Sardine	↔	●	↔	●	↔	●	C2, C5, C7
Pacific hake			↔	●	↗	–	C2, C5
Pacific sanddab larvae			↗	●	↗	●	C2, C5
Jack mackerel	↘	●			↔	●	C2, C7
Shortbelly rockfish larvae					↔	●	C2
Cool-water larvae					↗	●	C2
Warm-water larvae					↔	●	C2
Rockfish spp. larvae			↗	●			C2, C5, C7
Market squid			↗	●			C5
Krill			↔	●			C5
Pacific herring	↘	●					C7
Whitebait smelt	↗	●					C7

Table 6. Trends and status of the abundance and population condition of salmon in the CCLME. Populations are sorted from north to south. Arrows, symbols and colors are as in Table 1, except salmon status is based on the most recent 10 years of data (rather than 5 years as in Table 1). Condition indicators include the percent of spawners that are of natural origin, the population growth rate, and the diversity of age structure. Details and figures are in the chapter by Wells et al. (2014b). Blanks indicate insufficient data.



	Abundance		Condition						
			% natural		Pop. growth rate		Age diversity		
Species/population	Trend	Status	Trend	Status	Trend	Status	Trend	Status	Fig. in report
Chinook salmon									
Upper Columbia R. spring	↗	●	↔	●	↔	●	↔	●	S2, S4
Snake R. spr/sum	↗	●	↔	●	↔	●	↗	●	S2, S4
Snake R. fall	↗	●	↔	●	↔	●	↔	●	S2, S4
Willamette R. spring	↘	●	↗	●	↘	●	↗	●	S2, S4
Lower Columbia R.	↘	●	↘	–	↘	●	↘	●	S2, S4
S. OR / N. CA Coasts	↘	●	↔	●			↔	●	S2, S4
Klamath R. fall	↔	●	↗	●	↔	●	↔	●	S2, S4
California Coast	↔	●							S2
Central Valley winter	↘	●							S2
Central Valley late	↔	●							S2
Central Valley spring	↘	●							S2
Central Valley fall	↘	●	↘	●	↗	●			S2, S4
Coho salmon									
Lower Columbia R.	↗	●							S6
Oregon Coast	↔	●	↔	●	↔	●			S6, S8
S. OR / N. CA Coasts	↘	●							S6
California Coast	↘	●							S6

Table 7. Trends and status of abundance and population condition of groundfish in the CCLME. Indicators are derived from stock assessments or from trawl surveys conducted by the Northwest Fisheries Science Center (NWFSC). Indicators reflect biomass, the proportion of females that are mature, the cumulative 95% age distribution, and the cumulative 95% length distribution. Arrows, symbols and colors are as in Table 1. Details and figures are in the chapter by Cope and Haltuch (2014).

	Biomass				Population structure				
	Assessment		NWFSC survey		Assessment		NWFSC survey		
Species	Trend	Status	Trend	Status	p(mature)	95% age	p(mature)	95% length	Fig. in report
Elasmobranchs									
Longnose skate	↔	+	↔	●	↔	-	↔	↔	GF3, GF4, GF42, GF43
Spiny dogfish	↔	+			↔	-			GF5, GF44
Spotted ratfish			↔	●			+	↔	GF6, GF45
Flatfishes									
Arrowtooth fl.	+	+	+	●	-	-	-	-	GF7, GF8, GF46, GF47
Dover sole	↔	+			↔	↔			GF12, GF52
English sole	+	+			+	-	-	↔	GF9, GF48, GF49
Flathead sole			↔	●			↔	↔	GF13, GF53
Pacific sanddab			+	●			↔	↔	GF10, GF50
Petrale sole	↔	●			-	-			GF11, GF51
Rex sole	+	+					↔	↔	GF14, GF54
Rockfishes									
Aurora	↔	+			-	↔			GF31
Black	+	+			-	-			GF15
Blackgill	↔	●			-	-			GF32
Bocaccio	+	●			-	-			GF16
Canary	↔	-			-	-			GF17
Chilipepper	↔	+	↔	●	↔	-	-	+	GF18, GF19
Cowcod	↔	-			-	-			GF20
Darkblotched	+	●			-	-			GF21
Greenspotted	+	●			-	-			GF22
Greenstriped	+	+			↔	-			GF23
Pac. ocean perch	↔	-			-	-			GF24
Redstripe			↔	+			-	↔	GF25
Rougheye	+	+			↔	↔			GF33
Sharpchin	+	+							GF26
Shortbelly			↔	●			↔	↔	GF27
Splitnose	+	+			-	-			GF34
Stripetail			↔	●			↔	↔	GF28
Widow	+	+			↔	-			GF29
Yelloweye	↔	-			-	-			GF35
Yellowtail			↔	↔			↔	↔	GF30
Thornyheads									
Longspine	+	+			↔	↔			GF36
Shortspine	-	+			↔	↔			GF37
Roundfishes									
Cabezon	+	+			-	-			GF38
Lingcod	+	+			-	-			GF39
Pacific hake	+	+							GF40
Sablefish	-	●			↔	↔			GF41

Table 8. Trends and status of indicators of ecological integrity in the CCLME, arranged by community, site and/or season. Arrows, symbols and colors are as in Table 1. Details and figures are in the chapter by Williams et al. (2014).

Attribute/indicator	Site	Season	Trend	Status	Fig. in report
Trophic structure, pelagic community					
Northern copepod biomass anomaly	NH line	winter	↔	●	EI5
Northern copepod biomass anomaly	NH line	summer	↔	●	EI6
Aurelia abundance	Central CA	--	↔	●	EI7
Chrysaora abundance	Central CA	--	↔	●	EI7
Chrysaora abundance	OR/WA	June	↘	●	EI8
Chrysaora abundance	OR/WA	Sept	↘	●	EI9
Aequorea abundance	OR/WA	June	↗	●	EI8
Aequorea abundance	OR/WA	Sept	↔	●	EI9
Trophic structure, demersal community					
Groundfish mean trophic level	coast-wide	--	↔	●	EI10
Groundfish mean trophic level	N of Cape Mendocino	--	↔	●	EI11
Groundfish mean trophic level	S of Cape Mendocino	--	↘	●	EI12
Scavenger:total biomass ratio	coast-wide	--	↗	●	EI13
Scavenger:total biomass ratio	N of Cape Mendocino	--	↗	●	EI14
Scavenger:total biomass ratio	S of Cape Mendocino	--	↔	●	EI15
Crab scavengers:total biomass ratio	coast-wide	--	↗	●	EI16
Crab scavengers:total biomass ratio	N of Cape Mendocino	--	↗	●	EI16
Crab scavengers:total biomass ratio	S of Cape Mendocino	--	↔	●	EI16
Finfish scavengers:total biomass ratio	coast-wide	--	↔	●	EI17
Finfish scavengers:total biomass ratio	N of Cape Mendocino	--	↔	●	EI17
Finfish scavengers:total biomass ratio	S of Cape Mendocino	--	↔	●	EI17
Biodiversity, pelagic community					
Copepods, Simpson diversity	NH line	winter	↔	●	EI18
Copepods, Simpson diversity	NH line	summer	↘	●	EI18
Copepods, species richness	NH line	winter	↔	●	EI28
Copepods, species richness	NH line	summer	↘	●	EI29
Ichthyoplankton, Simpson diversity	Southern California	spring	↗	●	EI23
Ichthyoplankton, Simpson diversity	Southern California	summer	↗	●	EI24
Ichthyoplankton, Simpson diversity	Oregon	spring	↘	●	EI25
Ichthyoplankton, Simpson diversity	Oregon	summer	↔	●	EI26
Ichthyoplankton, species number	Southern California	spring	↗	●	EI38
Ichthyoplankton, species number	Southern California	summer	↗	●	EI39
Ichthyoplankton, species number	Oregon	spring	↔	●	EI40
Ichthyoplankton, species number	Oregon	summer	↘	●	EI41
Coastal pelagic fish, Simpson diversity	N of Cape Mendocino	June/Sept	↔	●	EI19
Coastal pelagic fish, species number	N of Cape Mendocino	June/Sept	↘	●	EI27
Biodiversity, demersal community					
Groundfish, Simpson diversity	coast-wide	--	↗	●	EI20
Groundfish, Simpson diversity	N of Cape Mendocino	--	↗	●	EI21
Groundfish, Simpson diversity	S of Cape Mendocino	--	↔	●	EI22
Groundfish, species richness	coast-wide	--	↘	●	EI30
Groundfish, species richness	N of Cape Mendocino	--	↔	●	EI31
Groundfish, species richness	S of Cape Mendocino	--	↘	●	EI32

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Chapter example: Andrews, K.S., G.D. Williams and V.V. Gertseva. 2014. Anthropogenic drivers and pressures. In: Harvey, C.J., N. Garfield, E.L. Hazen and G.D. Williams (eds.). The California Current Integrated Ecosystem Assessment: Phase III Report. Available from http://www.noaa.gov/iea/CCIEA-Report/index.

Appendix example: Holland, D. and S. Kasperski. 2014. Fishery income diversification and risk for fishermen and fishing communities of the US West Coast and Alaska—updated to 2012. Appendix HD-1 to: Breslow, S., and 20 others. Human Dimensions of the CCIEA. In: Harvey, C.J., N. Garfield, E.L. Hazen and G.D. Williams (eds.). The California Current Integrated Ecosystem Assessment: Phase III Report. Available from http://www.noaa.gov/iea/CCIEA-Report/index.