

## **SUPPLEMENTARY MATERIALS TO THE CALIFORNIA CURRENT INTEGRATED ECOSYSTEM ASSESSMENT (CCIEA) CALIFORNIA CURRENT ECOSYSTEM STATUS REPORT, 2019**

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## **Appendix B LIST OF FIGURE AND DATA SOURCES FOR THE MAIN REPORT**

Figure 3.1: Newport Hydrographic (NH) line temperature data from J. Fisher, NMFS/NWFSC, OSU). CalCOFI hydrographic line data from <https://calcofi.org>. CalCOFI data before 2018 are from the bottle data database, while 2018 data are preliminary conductivity, temperature, and depth (CTD) data from the recent CTD database.

Figure 3.1.1: Oceanic Niño Index information and data are from the NOAA Climate Prediction Center ([http://www.cpc.ncep.noaa.gov/products/analysis\\_monitoring/ensostuff/ONI\\_change.shtml](http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ONI_change.shtml)). PDO data are from N. Mantua, NMFS/SWFSC, and are served by the University of Washington Joint Institute for the study of the Atmospheric and Ocean (JISAO; <http://research.jisao.washington.edu/pdo/>). North Pacific Gyre Oscillation data are from E. Di Lorenzo, Georgia Institute of Technology (<http://www.o3d.org/npgo/>).

Figure 3.1.2: Sea surface temperature maps are optimally interpolated remotely-sensed temperatures (Reynolds et al. 2007). The daily optimal interpolated AVHRR SST can be downloaded using ERDDAP (<http://upwell.pfeg.noaa.gov/erddap/griddap/ncdcOisst2Agg.html>).

Figure 3.2.1: Daily 2018 values of BEUTI and CUTI are derived from numerical model outputs described in Jacox et al. (2018); detailed information about these indices can be found at <https://mjacox.com/upwelling-indices/>.

Figure 3.3.1: Newport Hydrographic (NH) line dissolved oxygen data are from J. Fisher, NMFS/NWFSC, OSU. CalCOFI hydrographic line data from <https://calcofi.org>. CalCOFI data before 2018 are from the bottle data database, while 2018 data are preliminary conductivity, temperature, and depth (CTD) data from the recent CTD database.

Figure 3.3.2: Aragonite saturation state data from J. Fisher, NMFS/NWFSC, OSU.

Figure 3.4.1: Data on domoic acid concentrations in razor clams are from A. Coyne (Washington State Department of Health); these data are compiled from tests conducted by a variety of Tribal, State, and County partners on Washington beaches. Sample testing frequency is irregular as it depends on the timing of proposed recreational razor clamming digs by Washington State Department of Fish and Wildlife and prevalence of recent detections.

Figure 3.5.1: Snow-water equivalent data were derived from the California Department of Water Resources snow survey (<http://cdec.water.ca.gov/>) and the Natural Resources Conservation Service's SNOTEL sites in WA, OR, CA and ID (<http://www.wcc.nrcs.usda.gov/snow/>).

Figure 3.5.2: Minimum and maximum streamflow data were provided by the US Geological Survey (<http://waterdata.usgs.gov/nwis/sw>).

Figure 4.1.1: Copepod biomass anomaly data were provided by J. Fisher, NMFS/NWFSC, OSU).

Figure 4.1.2. Krill (*Euphausia pacifica*) data were provided by E. Bjorkstedt, NMFS/SWFSC and Humboldt State University (HSU), and R. Robertson, Cooperative Institute for Marine Ecosystems and Climate (CIMEC) at HSU. Krill were collected at monthly intervals from the Trinidad Head Line (Fig. 2.1b); krill body length (BL) was measured in mm from the back of the eye to base of the telson.

Figure 4.2.1: Pelagic forage data from the Northern CCE were provided by B. Burke, NMFS/NWFSC and C. Morgan, OSU/CIMRS. Data are derived from surface trawls taken during the NWFSC Juvenile Salmon & Ocean Ecosystem Survey (JSOES; <https://www.nwfsc.noaa.gov/research/divisions/fe/estuarine/oeip/kb-juvenile-salmon-sampling.cfm>).

Figure 4.2.2: Pelagic forage data from the Central CCE were provided by J. Field and K. Sakuma, NMFS/SWFSC, from the SWFSC Rockfish Recruitment and Ecosystem Assessment Survey (<https://swfsc.noaa.gov/textblock.aspx?Division=FED&ParentMenuId=54&id=20615>),

Figure 4.2.3: Pelagic forage larvae data from the Southern CCE were provided by A. Thompson, NMFS/SWFSC, and derived from spring CalCOFI surveys (<https://calcofi.org/>).

Figure 4.3.1: Chinook salmon escapement data were derived from the California Department of Fish and Wildlife (<https://www.dfg.ca.gov/fish/Resources/Chinook/CValleyAssessment.asp>), Pacific Fishery Management Council pre-season reports (<https://www.pcouncil.org/salmon/stock-assessment-and-fishery-evaluation-safe-documents/review-of-2017-ocean-salmon-fisheries/>), and the NOAA Northwest Fisheries Science Center's "Salmon Population Summary" database (<https://www.webapps.nwfsc.noaa.gov/sps>), with data provided directly from the Nez Perce Tribe, the Yakama Nation Tribe, and from Streamnet's Coordinated Assessments database ([cax.streamnet.org](http://cax.streamnet.org)), with data provided by the Oregon Department of Fish and Wildlife, Washington Department of Fish and Wildlife, Idaho Department of Fish and Game, Confederated Tribes and Bands of the Colville Reservation, Shoshone-Bannock Tribes, Confederated Tribes of the Umatilla Indian Reservation, and U.S. Fish and Wildlife Service.

Figure 4.3.2: Data for at sea juvenile salmon provided by B. Burke, NMFS/NWFSC, with additional calculations by C. Morgan, OSU/CIMRS. Derived from surface trawls taken during the NWFSC Juvenile Salmon and Ocean Ecosystem Survey (JSOES) cruises.

Figure 4.4.1: Groundfish stock status data provided by J. Cope, NMFS/NWFSC, derived from NOAA Fisheries stock assessments.

Figure 4.5.1: Highly migratory species data provided by B. Muhling, NMFS/SWFSC, and D. Tommasi, NMFS/SWFSC, UCSC. Data are derived from stock assessment reports completed through the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC; [http://isc.fra.go.jp/reports/stock\\_assessments.html](http://isc.fra.go.jp/reports/stock_assessments.html)) or the Inter-American Tropical Tuna Commission (IATTC; <https://www.iattc.org/PublicationsENG.htm>).

Figure 4.6.1: California sea lion data provided by S. Melin, NMFS/AFSC.

Figure 4.6.2: Whale entanglement data provided by D. Lawson, NMFS/WCRO.

Figure 4.7.1: Seabird abundance data from the northern CCE were collected and provided by J. Zamon, NMFS/NWFSC. Seabird abundance data from central CCE (collected on the SWFSC Rockfish Recruitment and Ecosystem Assessment Survey) and southern CCE (collected on the CalCOFI surveys) courtesy of B. Sydeman, Farallon Institute. NCC data are from June surveys, CCC data are from May surveys, and SCC data are from April surveys, as no seabird data were collected during the summer survey.

Figure 5.1.1: Data for commercial landings are from PacFIN (<http://pacfin.psmfc.org>). Data for recreational landings are from RecFIN (<http://www.recfin.org/>).

Figure 5.2.1: Data for total benthic habitat distance disturbed by bottom-contact fishing gears were provided by J. McVeigh, NMFS/NWFSC, West Coast Groundfish Observer Program. Weightings for benthic habitat sensitivity values come from PFMFC's Pacific Coast Groundfish 5-Year Review of Essential Fish Habitat.

Figure 6.1.1: Community social vulnerability index (CSVI) and commercial fishery reliance data provided by K. Norman, NMFS/NWFSC, and A. Varney, PSMFC, with data derived from the US Census Bureau's American Community Survey (ACS; <https://www.census.gov/programs-surveys/acs/>) and PacFIN (<http://pacfin.psmfc.org>), respectively.

Figure 6.1.2: Community social vulnerability index (CSVI) and recreational fishery reliance data provided by K. Norman, NMFS/NWFSC, and A. Varney, PSMFC, with data derived from the US Census Bureau's American Community Survey (ACS; <https://www.census.gov/programs-surveys/acs/>) and from PacFIN (<https://pacfin.psmfc.org>) and RecFIN (<https://www.recfin.org/>), respectively.

Figure 6.2.1: Fishery diversification estimates were provided by D. Holland, NMFS/NWFSC, and S. Kasperski, NMFS/AFSC.

Figure 6.3.1: Estimates of petrale sole and sablefish availability to ports were derived from catch data provided by PacFIN (<http://pacfin.psmfc.org>) and survey data and stock assessment outputs from the NOAA Northwest Fisheries Science Center; analyses provided by R. Selden (Rutgers University), J. Samhoury and N. Tolimieri (NMFS/NWFSC), and J. Thorson (NMFS/AFSC).

Table 4.3.1: Stoplight table of indicators and projected 2019 salmon returns courtesy of B. Burke, NMFS/NWFSC.

## Appendix C CHANGES IN THIS YEAR'S REPORT

Below we summarize changes and improvements in the 2019 Ecosystem Status Report, in response to the requests and suggestions received from the Council and advisory bodies under FEP Initiative 2, "Coordinated Ecosystem Indicator Review" (March 2015, Agenda Item E.2.b). We also note other known data and information gaps that we have filled since last year's report. Finally, we note several instances where elements from past reports were streamlined or cut from this year's report, due to time constraints imposed by the partial federal government shutdown from December 22, 2018-January 25, 2019, during which NOAA line offices were closed.

| Request/Need                                                                                                                                                                                                                                                                                                                                                                                                                 | Response/Location in document                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| The EAS previously noted that they "[a]ppreciated the report's current year information on unusual events like [the Warm] Blob" and also a "presentation slide showing N Pacific SST maps."                                                                                                                                                                                                                                  | In response to this comment and to ongoing concern about marine heatwaves, including in recent media, we added an analysis (reviewed by the SSCES in September 2017) that measures and maps the magnitude, spatial extent and duration of warm SST events in the North Pacific and provides criteria for whether a marine heatwave is occurring. The analysis is depicted in Figure 3.1.3 and in Appendix D.2.                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| The EWG noted that "some effects of upwelling can be positive for some species, while other effects may be negative. [We] suggest more specific information in report on potential effects of upwelling on the biological environment." The SAS and GAS requested similar information on the characteristics of upwelled water in relation to hypoxia, ocean acidification, and other measures of water and habitat quality. | <p>We have improved the upwelling indices to reflect total volume of upwelling (using new metrics that more accurately reflect upwelling magnitude at all latitudes along the west coast, published by Jacox et al. 2018) and that also reflect the amount of nutrients (specifically, nitrate) in the upwelled water. See Fig. 3.2.1. The JSCOPE seasonal forecasts (Section 7) also project hypoxia and ocean acidification on the seafloor off Washington and Oregon; both hypoxia and OA are driven in large part by upwelling. We will continue to build on these improvements.</p> <p>In Appendix E of last year's report, we included a time series of how shallow the OA threshold (aragonite saturation = 1.0) was off of Newport, OR. Due to the partial government shutdown we were unable to update this section of the report.</p> |
| The EWG requested information on "the effects of shifting levels of phytoplankton blooms, domoic acid, and paralytic shellfish poisoning on fisheries"; similarly, the EAS requested "data on chlorophyll concentrations and harmful algal blooms."                                                                                                                                                                          | This year we added time series of the concentrations of domoic acid in razor clams from 6 sites along the central and southern coast of Washington, including some information related to fishery closures (Figure 3.4.1 and Appendix E). We will continue to work with colleagues to identify time series of harmful algal blooms from elsewhere along the coast.                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| The SSC and SSCES requested that we include error bars around point estimates in quad plots to better distinguish significant averages and trends.                                                                                                                                                                                                                                                                           | The models that calculate 95% credible intervals in the quad plots for maximum and minimum stream flows (Figure 3.5.2) have been improved. The models now account for spatial correlations, so that the credible intervals better reflect temporal variability.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |

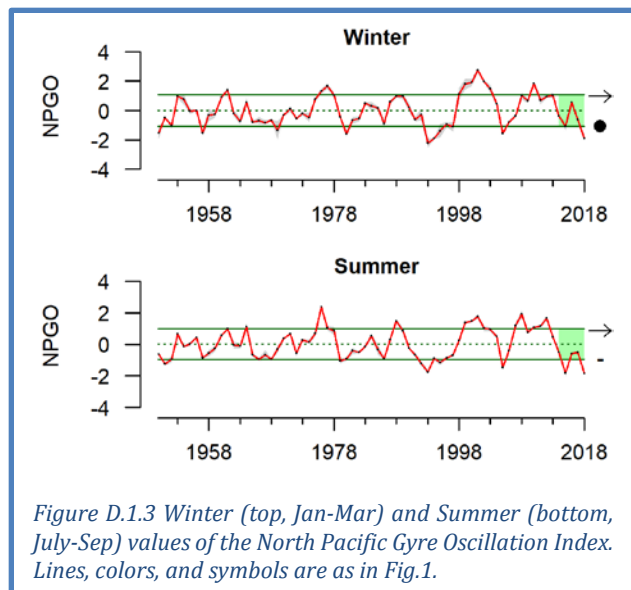
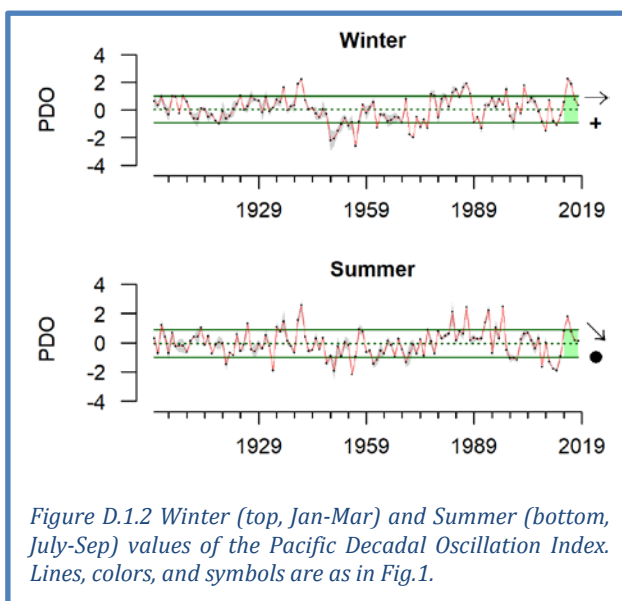
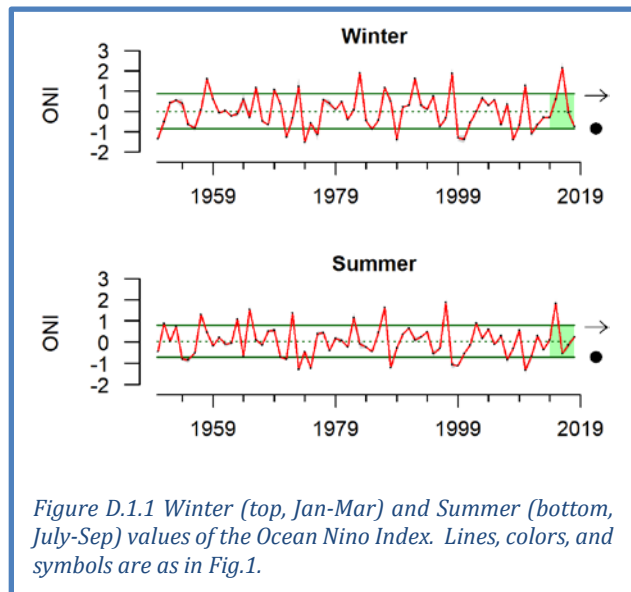
| Request/Need                                                                                                                                                                                                                                                                                                                         | Response/Location in document                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| The GMT stated, “We recommend that IEA scientists focus on improving and/or expanding those indicators that have shown promise in regards to correlations with fisheries productivity.... Copepod data is currently collected only off Newport, but effort could be expanded to other sites along the coast.”                        | This year we have added a new time series of the length of the abundant krill species <i>Euphausia pacifica</i> off of Trinidad Head in northern California (Figure 4.1.2). This indicator reflects the condition of krill, an important prey species for small fishes, at another site along the coast, and thus extends our understanding of lower trophic level productivity. We hope to add copepod data from Trinidad Head in the future.                                                                                   |
| The EWG and other advisory bodies have requested improvements to regional forage time series.                                                                                                                                                                                                                                        | This year we introduce a new statistical approach to analyze forage time series and improve comparability between regions. The analysis, which was reviewed by the SSCES in September 2018, identifies clusters of co-occurring forage species and also identifies years in which the forage composition changed significantly. This allows us to compare the synchrony of changes in forage among regions, and also to determine if forage changes coincide with oceanographic changes. The new analyses appear in Section 4.2. |
| The EWG and other advisory bodies have requested more information on highly migratory species.                                                                                                                                                                                                                                       | Additional information to support interpretation of HMS biomass and recruitment estimates has been added to Appendix I. The information is derived from the most recent HMS stock assessments.                                                                                                                                                                                                                                                                                                                                   |
| Seabird indicators have been limited to abundance estimates and less directly tied to mechanisms, except for reports of mass seabird mortality events                                                                                                                                                                                | In last year’s report, we included information on seabird diets in the Appendix. Due to the partial government shutdown we were unable to update this section of the report, and therefore removed it.                                                                                                                                                                                                                                                                                                                           |
| Updates of non-fishing human activities in the CCE (e.g., aquaculture, shipping, oil and energy activity, nutrient loading)                                                                                                                                                                                                          | Due to the partial government shutdown we were unable to update this section of the report, and thus removed it from this year’s report altogether.                                                                                                                                                                                                                                                                                                                                                                              |
| The EWG asked, “Is there a way to assess longer-term fishing community stability, both in the past (How does distribution of target species catch by port change over time?) and, potentially, in the future (Are there shifts in species distribution in response to climate change and potential effects on coastal communities?). | In Section 6.3, we added a new analysis of shifts in availability of two valuable target stocks (petrale sole and sablefish) to four major ports; availability over time varies as a function of stock abundance and spatial distribution. Methods are described in Appendix O. This analysis can be expanded to additional assessed stocks or ports in the future.                                                                                                                                                              |
| In 2018, the EAS requested that the Human Wellbeing section include indicators of fishery participation and economic status of fishing communities, as relate to National Standard 8 of the Magnuson-Stevens Act                                                                                                                     | Due to the partial government shutdown we were unable to address this request and will attempt to include it in next year’s report.                                                                                                                                                                                                                                                                                                                                                                                              |
| The Habitat Committee “encourages further efforts to define key indicators that can be used for forecasting..” Similarly, the EAS recommends that the report “provide projections of future ecosystem conditions.”                                                                                                                   | In Section 7, we added a section that focuses on forecasts, in particular the J-SCOPE seasonal forecasts of ocean conditions off Washington and Oregon. In addition, we expanded the information on forecasts on salmon returns; text and plots are in Appendix H.3.                                                                                                                                                                                                                                                             |

## Appendix D CLIMATE AND OCEAN INDICATORS

Section 3 of the Main Body describes indicators of basin-scale and region-scale climate and ocean drivers. Here we present additional plots to allow a more complete picture of these indicators.

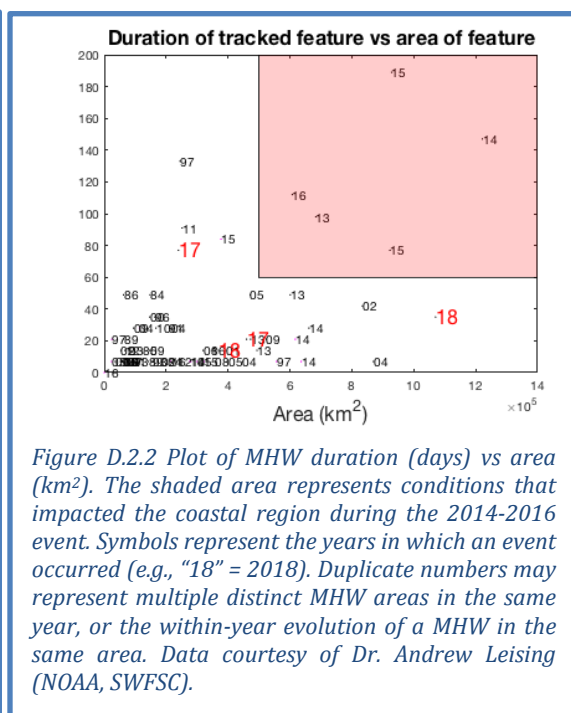
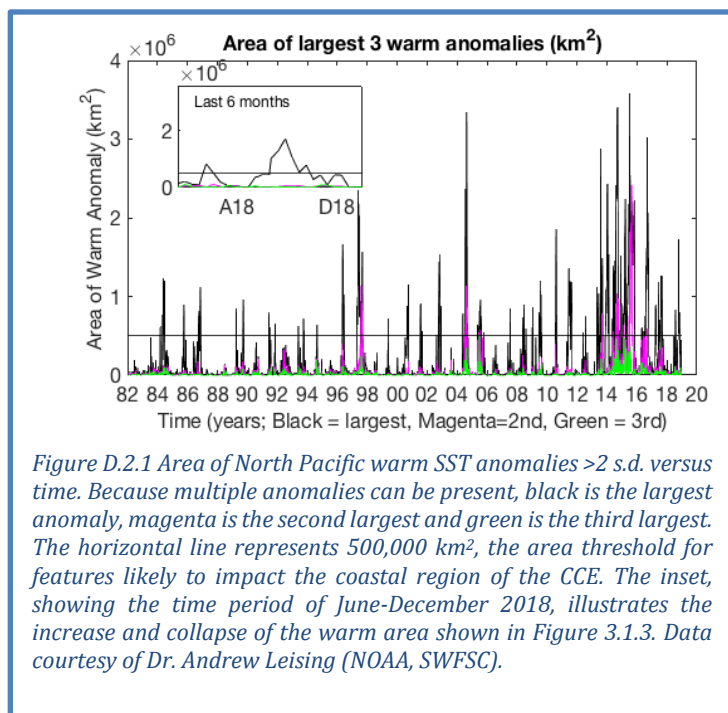
### D.1 BASIN-SCALE CLIMATE/OCEAN INDICATORS AT SEASONAL TIME SCALES

These plots show seasonal averages, short-term trends, and short-term averages of the three basin-scale climate forcing indicators shown in the main report in Figure 3.1.1. Notable outcomes include: winter PDO has been above average over the past 5 years; summer PDO has exhibited a negative trend in the recent 5 years; and summer NPGO has been below average over the past 5 years.



## D.2 ASSESSING THE OCCURRENCE OF MARINE HEATWAVES (MHWs)

Not all warm events in the ocean are marine heatwaves, and not all marine heatwaves in the North Pacific affect the CCE. In the Section 3.1 of the main body of the report, we described a warming event that occurred in the North Pacific in late 2018. Many news media outlets reported that this was a potential return of the “Blob,” the popular name for the marine heatwave (MHW) of 2014-2015 that shifted distributions of marine life, altered food webs, and fueled blooms of toxic algae along the West Coast. In a retrospective analysis of SSTa from 1985-2016, Leising (in prep) concluded that a MHW should be defined as waters where the SSTa is  $>2$  s.d. above 0 for the long-term SSTa time series at a particular location. Furthermore, for a MHW to affect coastal waters of the CCE in a similar way to that of the 2014-2015 event, the anomalous feature should be greater than 500,000 km<sup>2</sup> in area, and last for  $> 60$  days. Although the feature in late 2018 surpassed the area threshold (the horizontal black line in Figure D.2.1), it did not surpass the duration threshold (i.e., it was below the shaded box in Figure D.2.2; see also the December 2018 map panel in Figure 3.1.3). Similarly, one of the warm features observed during 2017 surpassed the duration threshold but did not surpass the area threshold (Figure D.2.2).



### D.3 SEASONAL TRENDS IN DISSOLVED OXYGEN AND OCEAN ACIDIFICATION INDICATORS

The first series of plots in this section shows time series of summer and winter averages for dissolved oxygen (DO) data off Newport, OR (stations NH05 and NH25) and in the Southern California Bight (stations CalCOFI 90.90 and CalCOFI 93.30). The second series shows summer and winter averages of aragonite saturation state (an ocean acidification indicator) off Newport.

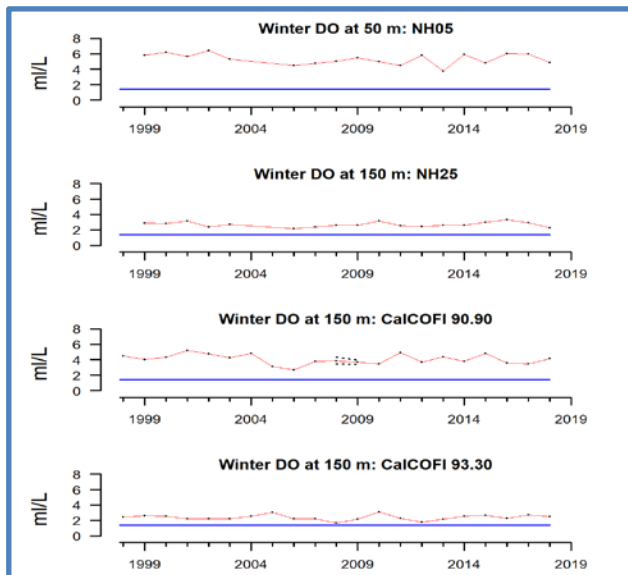


Figure D.3.1 Winter (top, Jan-Mar) dissolved oxygen (DO) at 150 m depth off of Oregon, 1999-2018 and southern California, 1998-2018. Stations NH25 and 93.30 are < 50 km from the shore; station 90.90 is >300 km from shore. Blue line indicates hypoxic threshold of 1.4 ml O<sub>2</sub> per L. Lines, colors, and symbols are as in Fig.1.

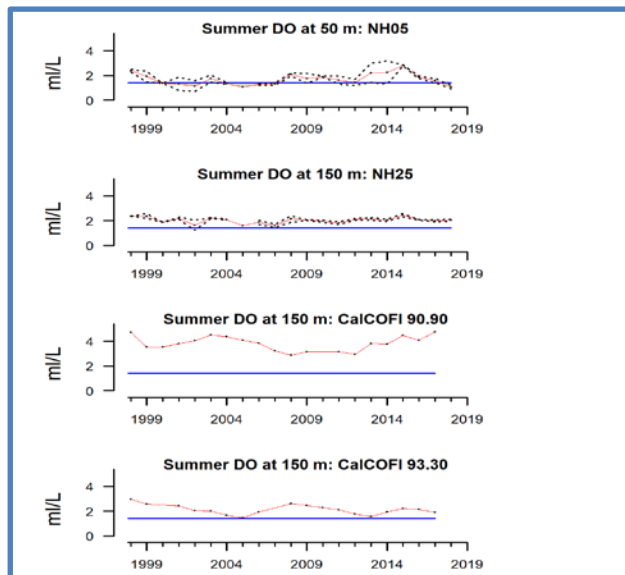


Figure D.3.2 Summer (Jul-Sep) dissolved oxygen (DO) at 50-m and 150 m depth off of Oregon, 1999-2018 and southern California, 1998-2018. Stations NH05, NH25 and 93.30 are < 50 km from the shore; station 90.90 is >300 km from shore. Blue line indicates hypoxic threshold of 1.4 ml O<sub>2</sub> per L. Lines, colors, and symbols are as in Fig.1.

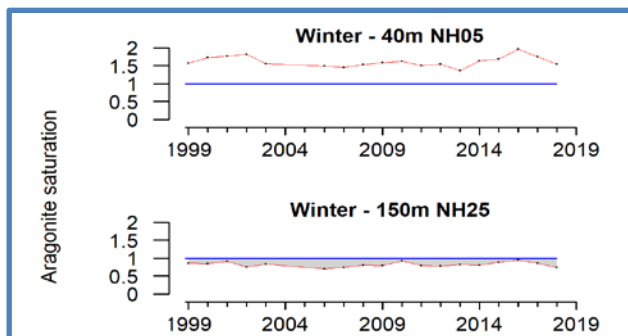


Figure D.3.3 Winter (Jan-Mar) aragonite saturation values at two stations off of Newport, OR, 1999-2018. Blue line indicates saturation state of omega = 1. Dotted lines indicate +/- 1.0 s.e. Lines, colors, and symbols are as in Fig.1.

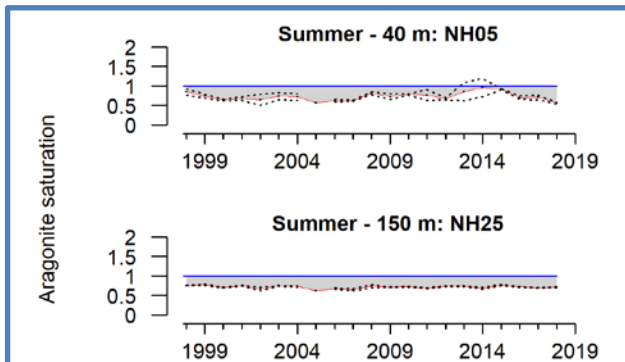
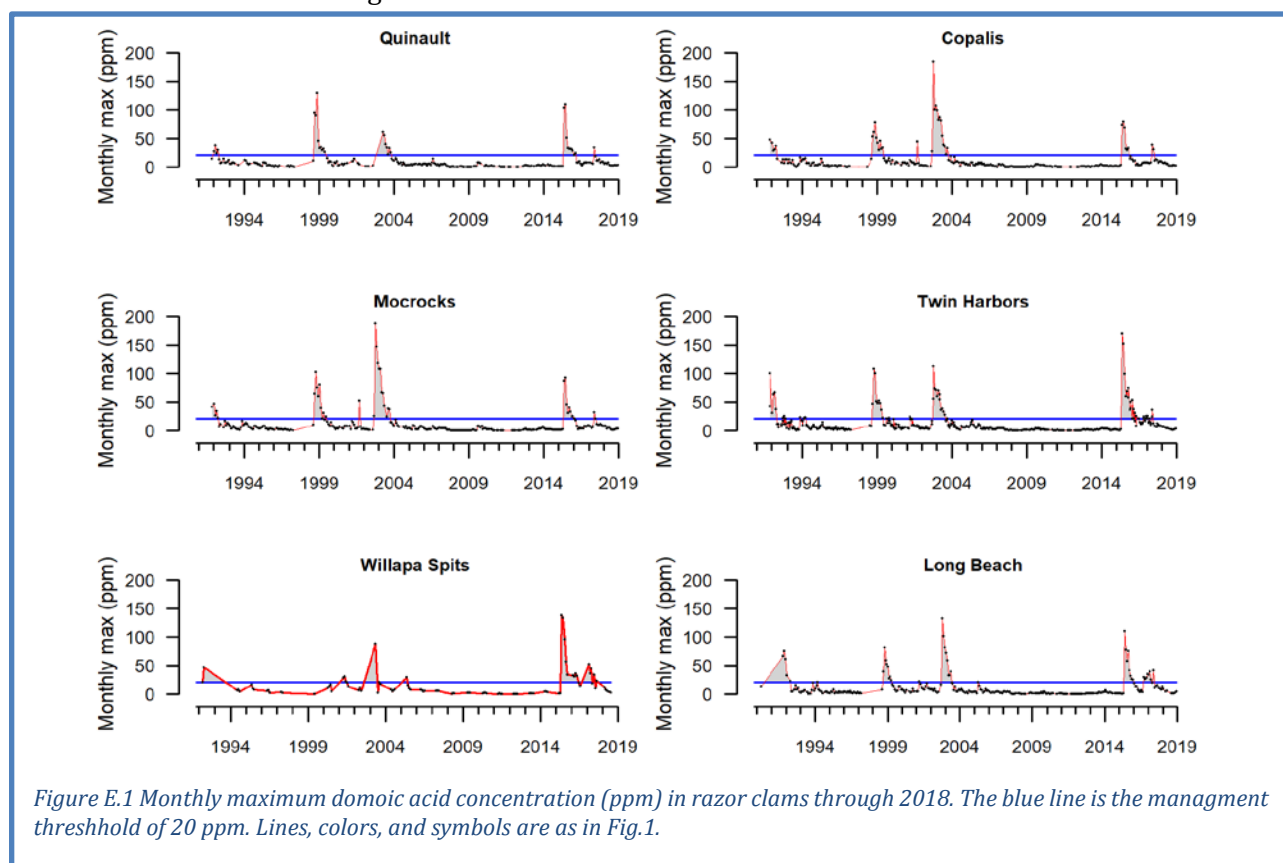


Figure D.3.4 Summer aragonite saturation values at two stations off of Newport, OR, 1998,2018. Blue line indicates saturation state of omega = 1. Dotted lines indicate +/- 1.0 s.e. Lines, colors, and symbols are as in Fig.1.

## Appendix E DOMOIC ACID ON THE WASHINGTON COAST

Domoic acid is a toxin produced by several species of the cosmopolitan diatom genus *Pseudo-nitzschia*. Because domoic acid can cause amnesic shellfish poisoning in humans, shellfish fisheries (including the recreational razor clam and commercial Dungeness crab fisheries) are closed when concentrations exceed regulatory thresholds for human consumption. Razor clams can accumulate and retain domoic acid for up to a year following harmful algal blooms (HABs) of *Pseudo-nitzschia* and they are good indicators of HAB dynamics in the coastal ocean, providing an accurate record the arrival and intensity of HAB events on beaches. Related annual losses to Washington coastal economies have reached \$24.4 million (Dyson and Huppert 2010).

Averaged monthly domoic acid values in razor clams from six sites along the Washington coast from 1991 through 2018 are shown in Figure E.1. The concentrations of domoic acid at the central Washington (Quinault) versus southern Washington (Long Beach) sites can be influenced by the transport of *Pseudo-nitzschia* and domoic acid from different offshore retention sites, including the Juan de Fuca eddy (at the border of US and Canada) and Heceta Bank (off Newport, Oregon) (Trainer et al. 2002; Hickey et al. 2013). The level of toxicity can also be influenced by the directional flow of the Columbia River plume that can help transport *Pseudo-nitzschia* and domoic acid from the south, northward along the Washington coast. The plume can also serve as a protective barrier by preventing offshore toxins from reaching beaches.



Off Washington and Oregon, extremely toxic HABs of *Pseudo-nitzschia* coincide with or closely follow El Niño events or positive PDO regimes and track regional anomalies in southern copepod species (Fisher et al., 2015; McCabe et al. 2016; McKibben et al. 2017). Such events can be seen to have occurred in 1991, 1998, 1999, 2002, 2003, 2015, 2016 and 2017. The 2015 event was the most toxic ever recorded and coincided with the north Pacific marine heatwave.

## Appendix F SNOW-WATER EQUIVALENT, STREAMFLOW, AND STREAM TEMPERATURE

Development of habitat indicators in the CCIEA has focused on freshwater habitats. All habitat indicators are reported based on a hierarchical spatial framework. This spatial framework facilitates comparisons of data at the right spatial scale for particular users, whether this be the entire California Current, ecoregions within these units, or smaller spatial units. The framework we use divides the region encompassed by the California Current ecosystem into ecoregions (Figure 2.1b), and ecoregions into smaller physiographic units. Freshwater ecoregions are based on the biogeographic delineations in Abell et al. (2008; see also [www.feow.org](http://www.feow.org)), who define six ecoregions for watersheds entering the California Current, three of which comprise the two largest watersheds directly entering the California Current (the Columbia and the Sacramento-San Joaquin Rivers). Within ecoregions, we summarized data using evolutionary significant units and 8-field hydrologic unit classifications (HUC-8). Status and trends for all freshwater indicators are estimated using space-time models (Lindgren and Rue 2015), which account for temporal and spatial autocorrelation.

Snow-water equivalent (SWE) is measured using two data sources: a California Department of Water Resources snow survey program (data from the California Data Exchange Center <http://cdec.water.ca.gov/>) and The Natural Resources Conservation Service's SNOTEL sites across Washington, Idaho, Oregon, and California (<http://www.wcc.nrcs.usda.gov/snow/>). Snow data (Figure F.1) are converted into SWEs based on the weight of samples collected at regular intervals using a standardized protocol. Measurements at April 1 are considered the best indicator of maximum extent of SWE; thereafter snow tends to melt rather than accumulate. Data for each freshwater ecoregion are presented in Section 3.5 of the main report.

The outlook for snowpack in 2019 is limited to examination of current SWE, an imperfect correlate of SWE in April due to variable atmospheric temperature and precipitation patterns. SWE as of February 1, 2019 was below the long-term median throughout much of Washington, Oregon and Idaho, but at or slightly above the median in the Sierra Nevadas (Figure F.1).

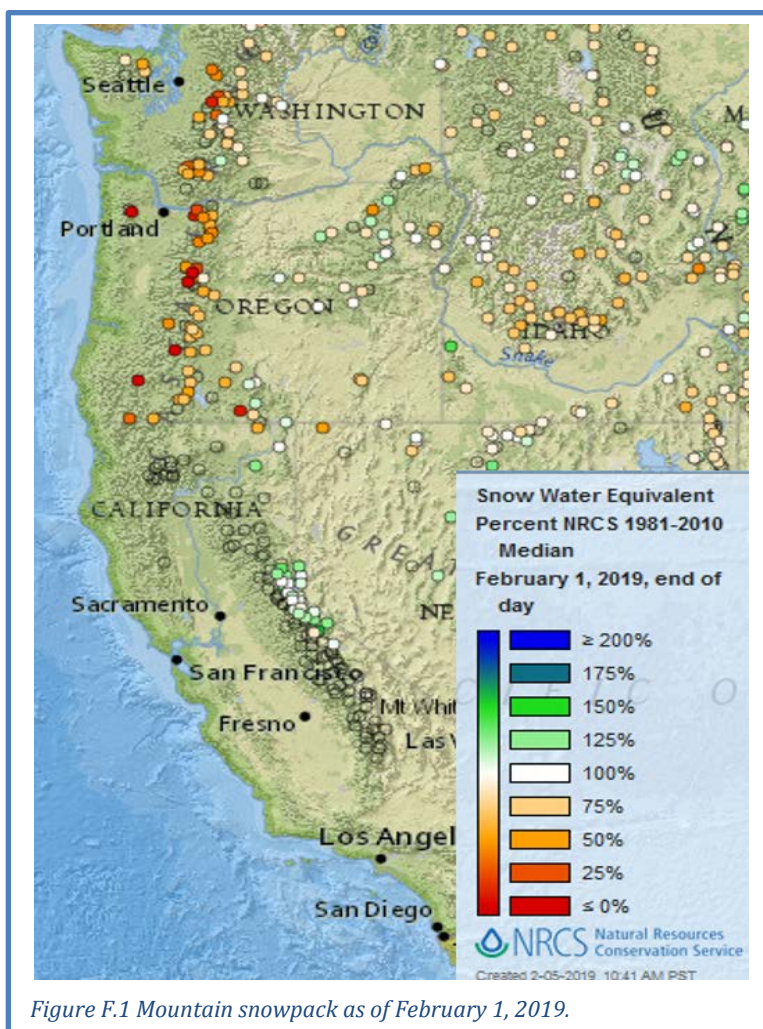
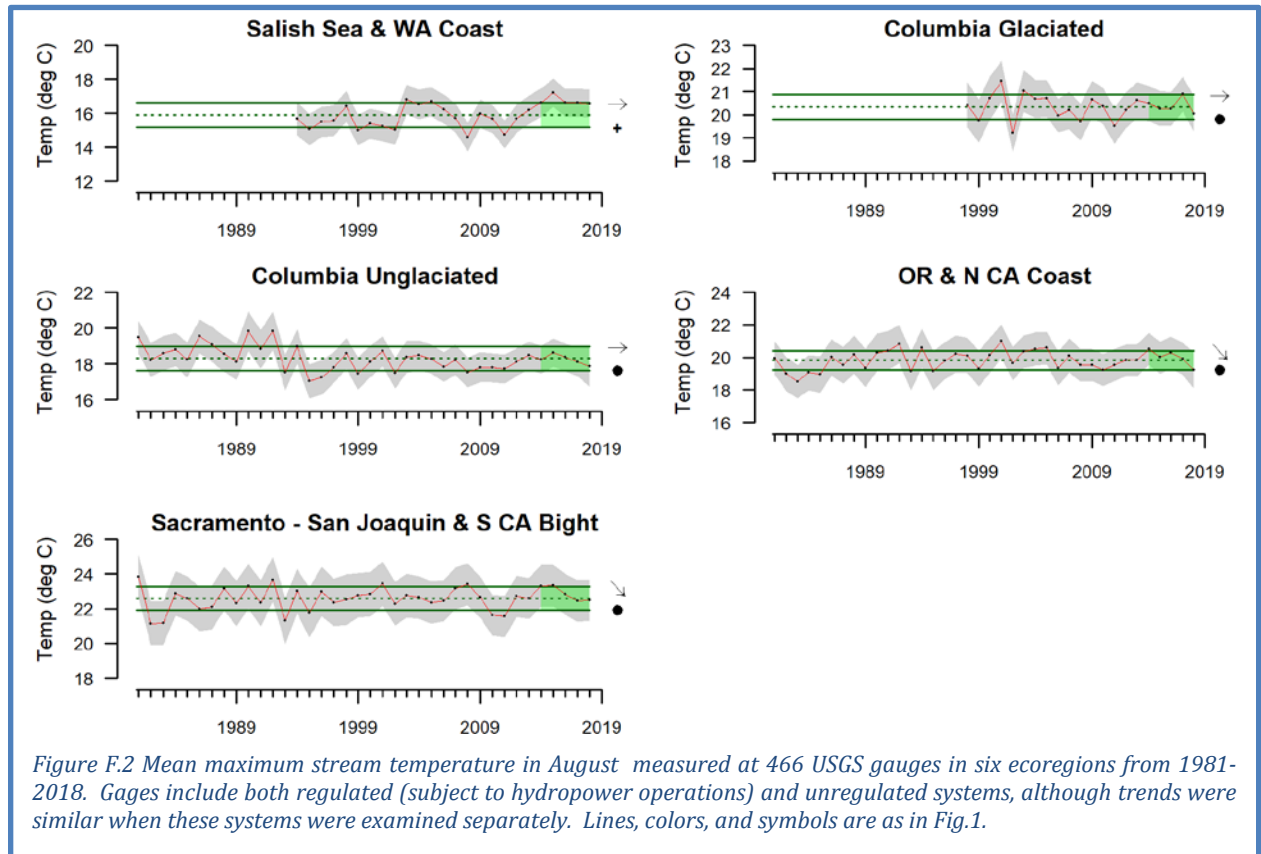


Figure F.1 Mountain snowpack as of February 1, 2019.

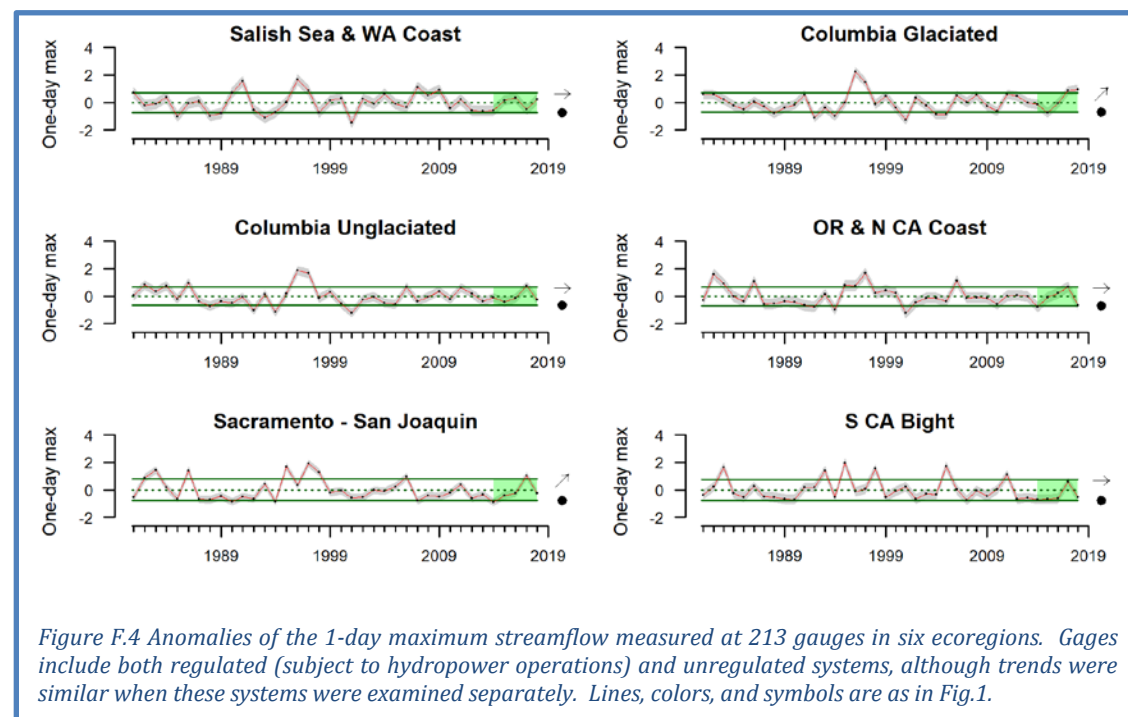
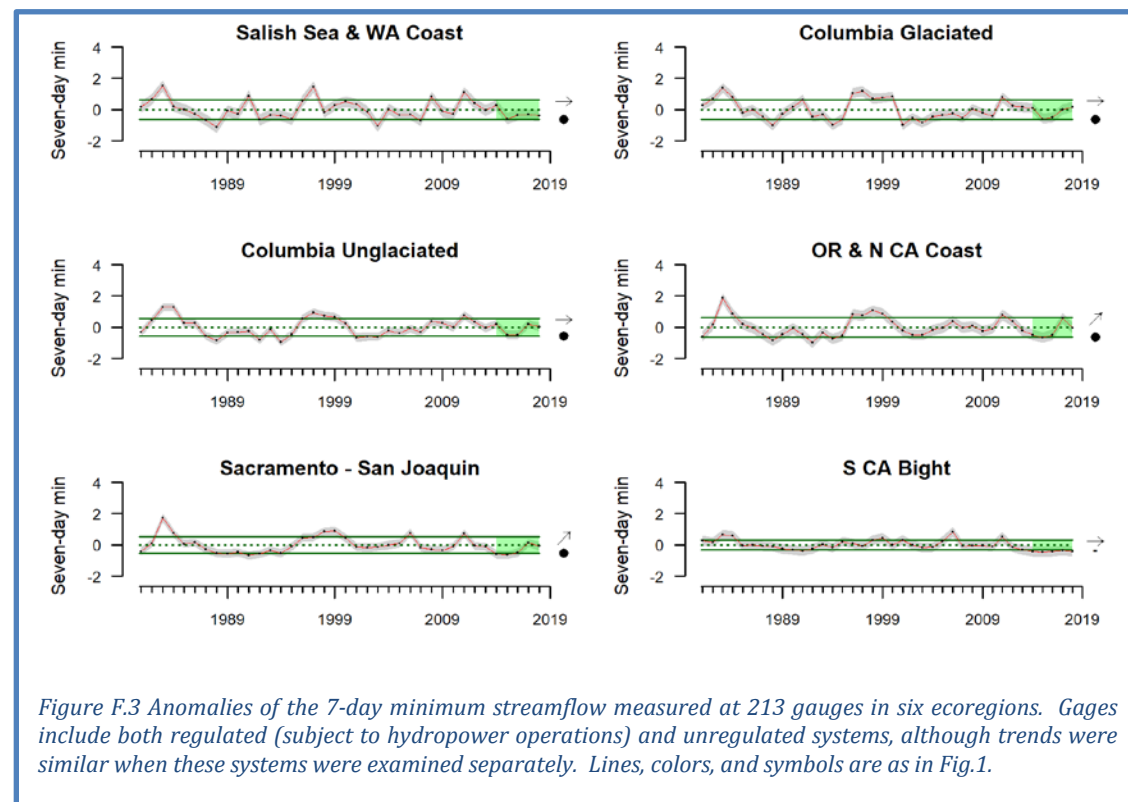
Mean maximum temperatures in August were determined from 446 USGS gages with temperature monitoring capability. While these gages did not necessarily operate simultaneously throughout the period of record, at least two gages provided data each year in all ecoregions. Stream temperature records are limited in California, so two ecoregions were combined. Maximum temperatures continued to exhibit strong ecoregional differences (for example, the Salish Sea / Washington Coast streams were much cooler on average than California streams), but the recent 5 years have been marked by largely average values region-wide. The exception is the Salish Sea and Washington Coast, which has much higher temperatures in the last five years compared to the period of record (Figure F.2). Most ecoregions exhibit long-term increasing trends in maximum temperature going back to the 1980's and 1990's.



Streamflow is measured using active USGS gages (<http://waterdata.usgs.gov/nwis/sw>) with records that meet or exceed 30 years in duration. Average daily values from 213 gages were used to calculate both annual 1-day maximum and 7-day minimum flows. These indicators correspond to flow parameters to which salmon populations are most sensitive. We use standardized anomalies of streamflow time series from individual gages.

Across ecoregions of the California Current, both minimum and maximum streamflow anomalies have exhibited some variability in the most recent five years. Minimum stream flows have exhibited fairly consistent patterns across all ecoregions (Figure F.3, see Figure F.5 for flows by ESU). Most all ecoregions demonstrated a decline in low flows over the last 5-8 years with an uptick in 2017 and average or below-average minimum flows in 2018. Little variation exists for rivers in the Southern California Bight, and their minimum flows have been among the ecoregion's lowest on record for many years. For maximum stream flows (Figure F.4 see Figure F.6 for flows by ESU), most ecoregions except the Salish Sea / Washington Coast and the Columbia Glaciated experienced declines in 2018 relative to 2017. Due to high short-term variability, most ecoregions had no significant trends in the past 5 years; the exception was

the Columbia Glaciated ecoregion, which has seen an increase in maximum flows although its recent 5-year average remains within 1 s.d. of the long-term average.



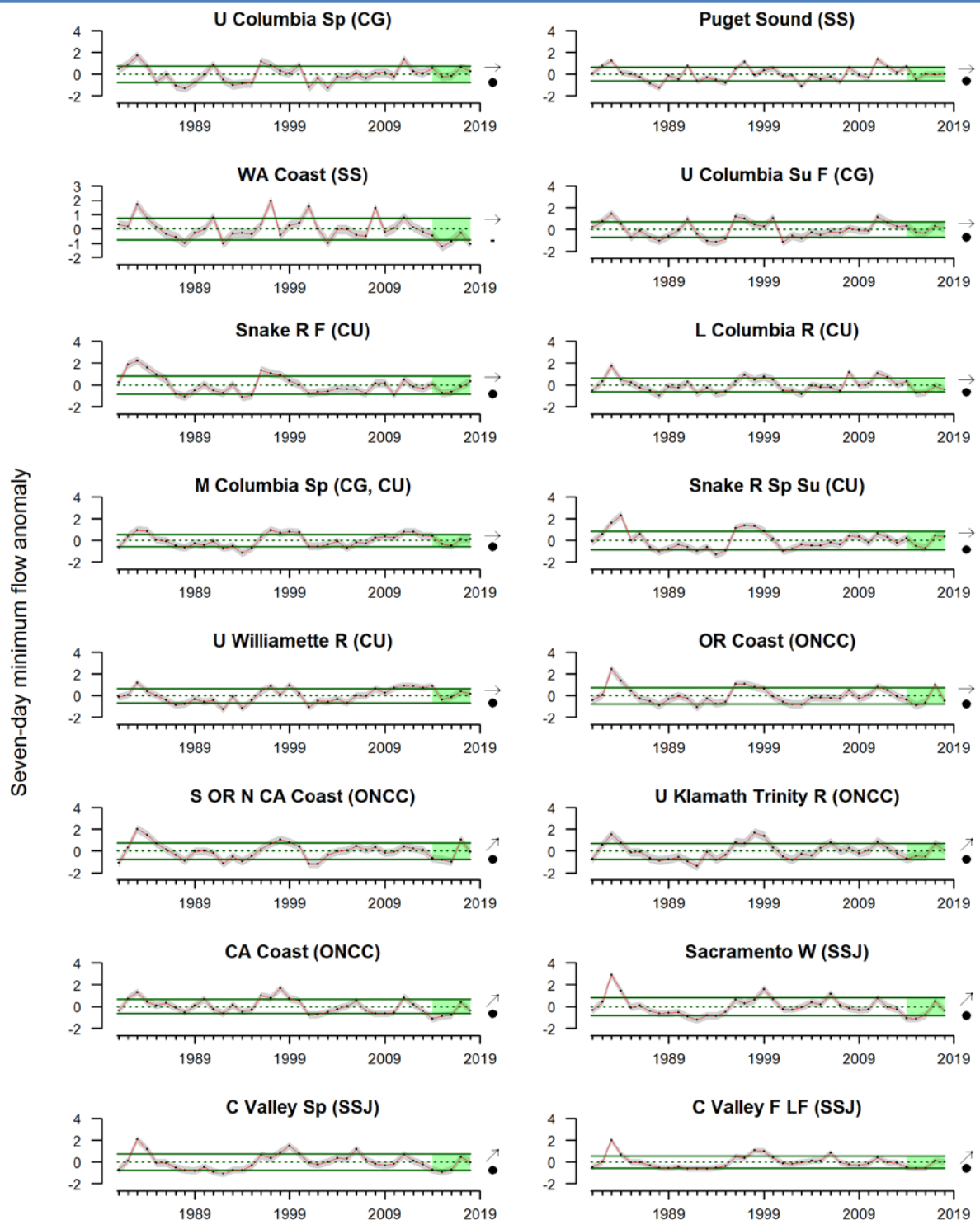


Figure F.5 Anomalies of the 7-day minimum streamflow measured at 213 gauges in 22 Chinook salmon ESUs. Gages include both regulated (subject to hydropower operations) and unregulated systems, although trends were similar when these systems were examined separately. Lines, colors, and symbols are as in Fig.1.

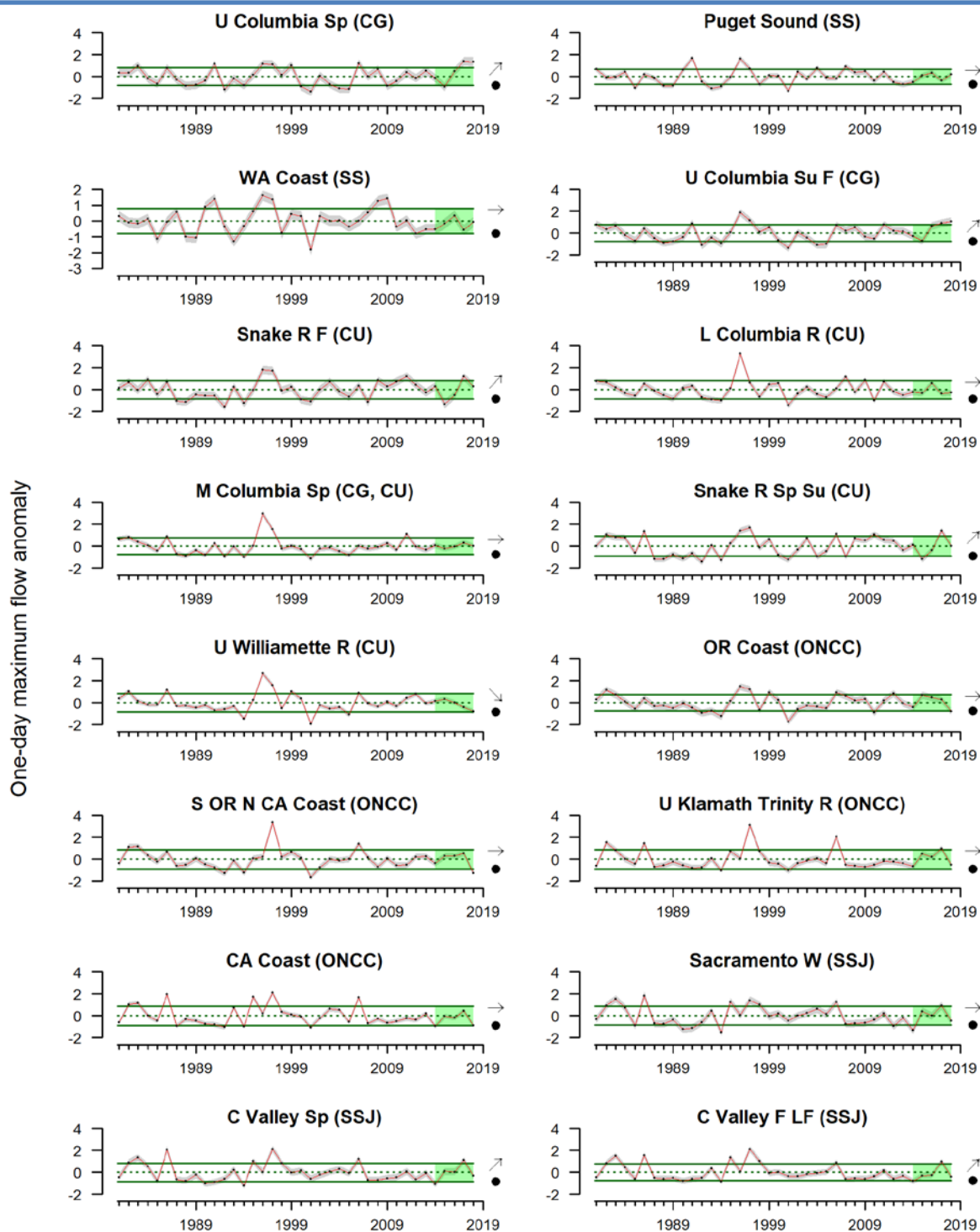


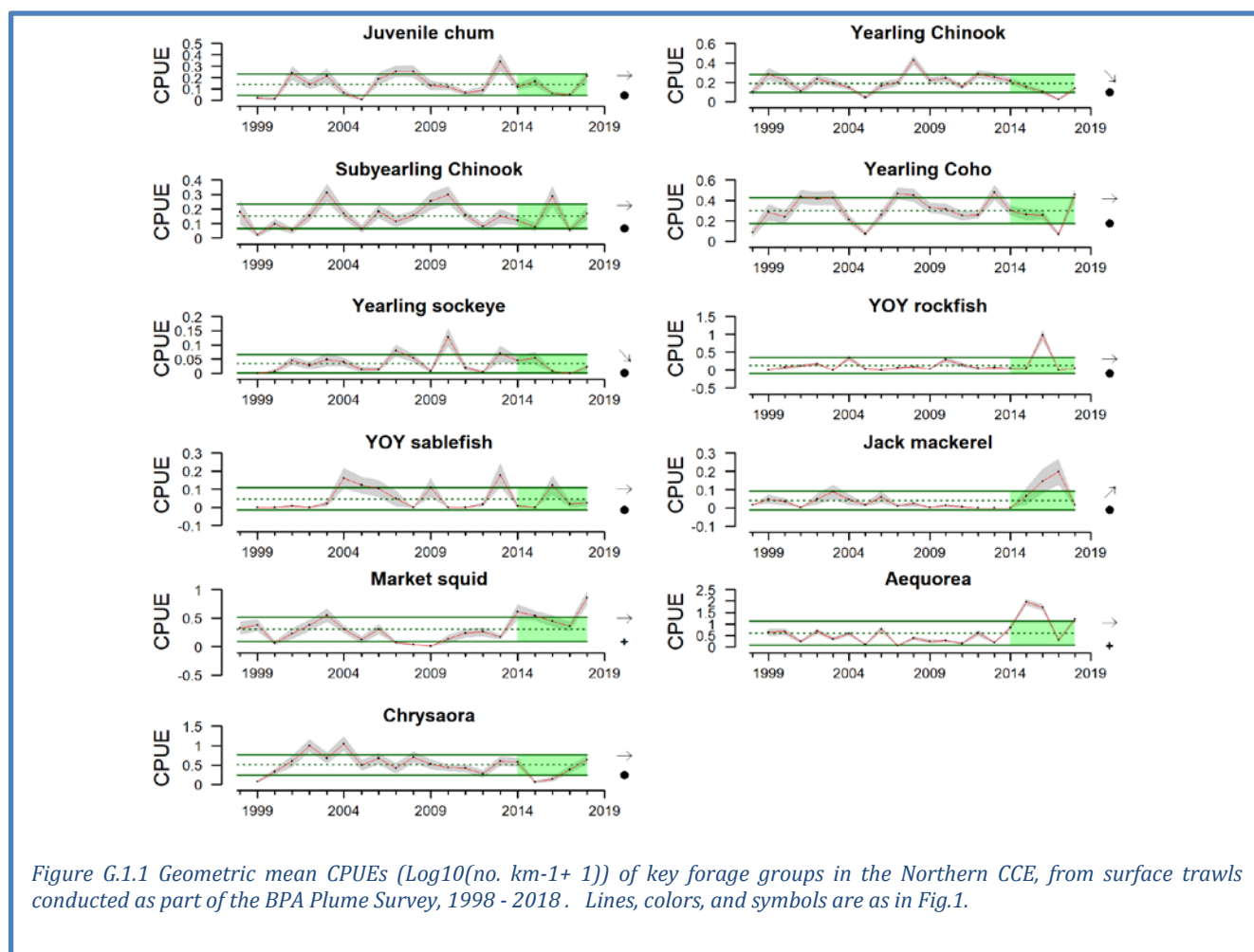
Figure F.6 Anomalies of the 1-day maximum streamflow measured at 213 gauges in 22 Chinook salmon ESUs. Gauges include both regulated (subject to hydropower operations) and unregulated systems, although trends were similar when these systems were examined separately. Lines, colors, and symbols are as in Fig.1.

## Appendix G REGIONAL FORAGE AVAILABILITY

Species-specific trends in forage availability are based on research cruises in the northern, central, and southern portions of the CCE (Figure 2.1). Section 4.2 of the main body of this report describes forage community dynamics using a new cluster analysis method that we implemented this year. There are some differences in which species were used in those analyses and which species appear in this Appendix, plotted in time series. This discrepancy is because we did not have time to fully update this Appendix due to the recent federal government shutdown. There will be better correspondence between the main body and these time series in the future.

### G.1 NORTHERN CALIFORNIA CURRENT FORAGE

The Northern CCE survey (known as the “Juvenile Salmon Ocean Ecology Survey”) occurs in June and targets juvenile salmon in surface waters off Oregon and Washington, but also collects adult and juvenile (age 1+) pelagic forage fishes, market squid, and gelatinous zooplankton (*Aequorea* sp., *Chrysaora* sp.) with regularity. In 2018, catches of juvenile salmon generally increased from lows in previous years, particularly the very poor catches of 2017 (Figure G.1.1). Catches of market squid and jellyfish also increased. Catches of jack mackerel declined after several years of increases.



## G.2 CENTRAL CALIFORNIA CURRENT FORAGE

The Central CCE forage survey (known as the “Juvenile Rockfish Survey”) samples this region using midwater trawls, which not only collect young-of-the-year (YOY) rockfish species, but also a variety of other YOY and adult forage species, market squid, adult krill, and gelatinous zooplankton. Time series presented here are from the “Core Area” of that survey (see Figure 2.1c in the Main Report). In 2018, catches of adult anchovy increased remarkably (Figure G.2.1). and there were also increases in YOY anchovy, YOY sardine and discernible catches of adult sardine for the first time in many years. Other notable results were large catches of krill and market squid, dramatic increases in jellyfish (*Aurelia* sp., *Chrysaora*), and a decline in catches of pyrosomes.

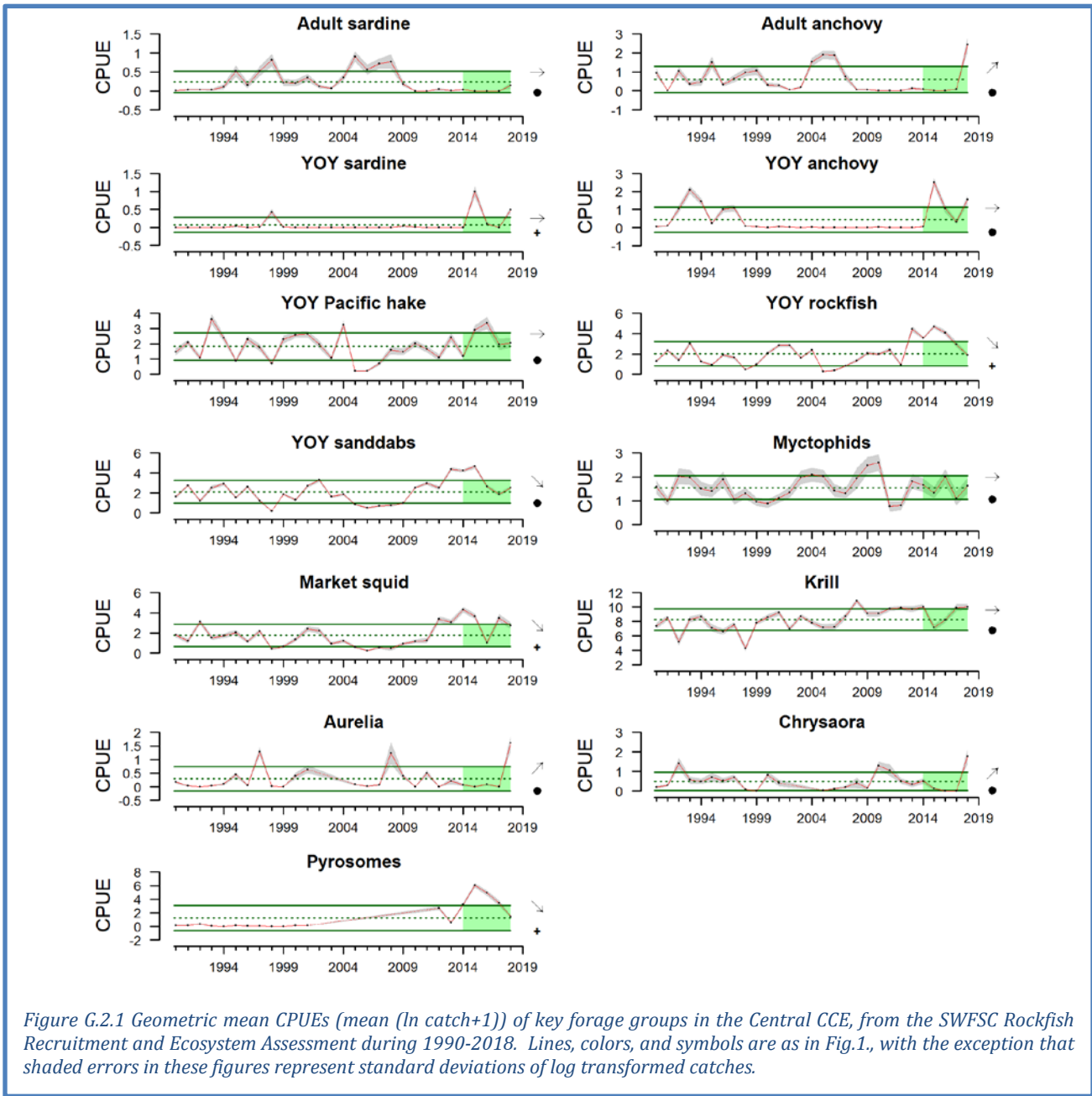
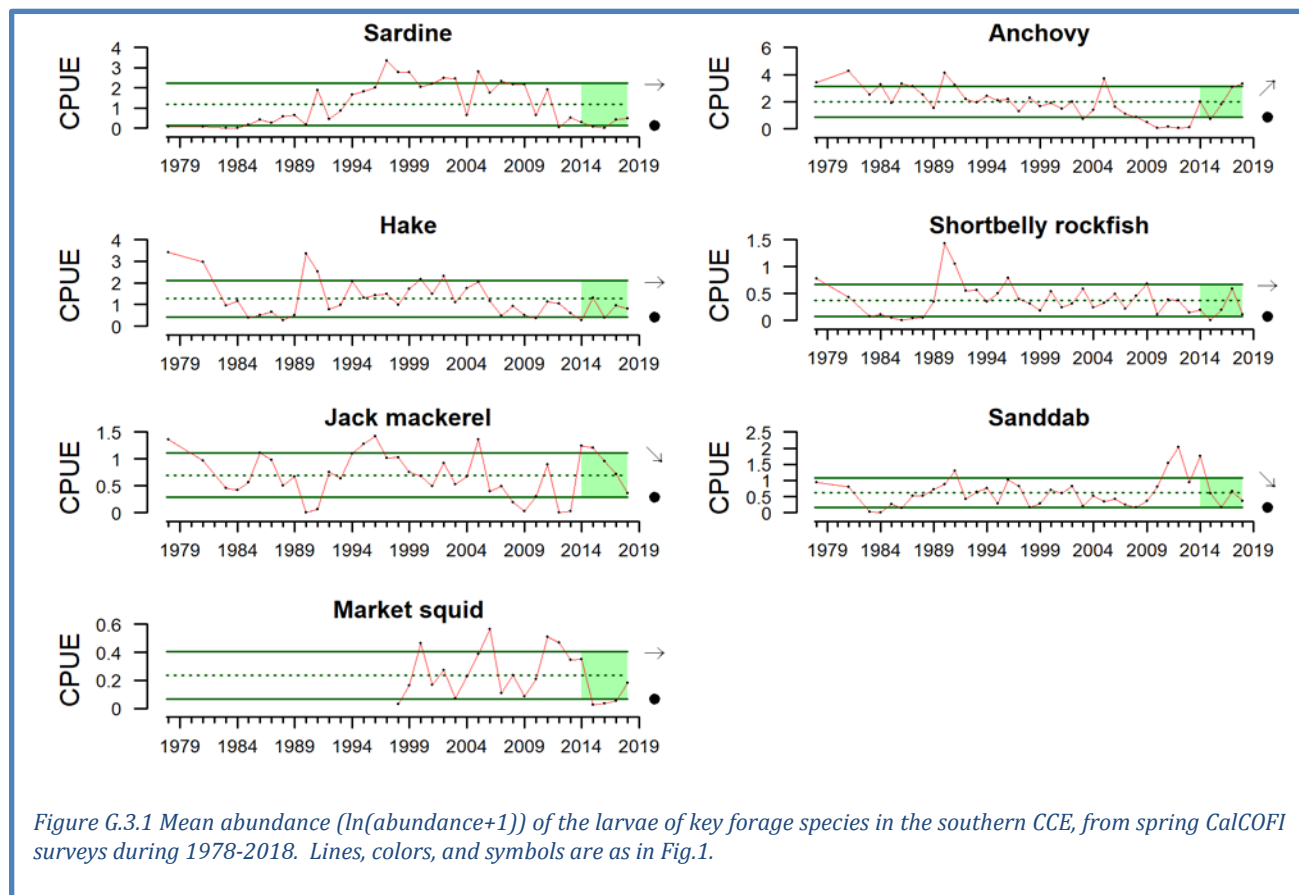


Figure G.2.1 Geometric mean CPUEs (mean (ln catch+1)) of key forage groups in the Central CCE, from the SWFSC Rockfish Recruitment and Ecosystem Assessment during 1990-2018. Lines, colors, and symbols are as in Fig.1., with the exception that shaded errors in these figures represent standard deviations of log transformed catches.

### G.3 SOUTHERN CALIFORNIA CURRENT FORAGE

The abundance indicators for forage in the Southern CCE come from fish and squid larvae collected in the spring across all core stations of the CalCOFI survey using oblique vertical tows of fine mesh Bongo nets to 212 m depth. The survey collects a variety of fish and invertebrate larvae (<5 d old) from several taxonomic and functional groups. Larval data are indicators of the relative regional abundances of adult forage fish, such as sardines and anchovy, and other species, including certain groundfish, market squid, and mesopelagic fishes. Noteworthy observations from 2018 surveys include the ongoing increase in relative abundance of anchovy, and an increase in marketsquid after many years of poor catches (Figure G.3.1). There were also clear declines in larval shortbelly rockfish and jack mackerel.



## Appendix H CHINOOK SALMON ESCAPEMENT INDICATORS

Population-specific status and trends in Chinook salmon escapement are provided in Section 4.3 of the Main Report. Figure 4.3.1 uses a quad plot to summarize recent escapement status and trends relative to full time series. These plots are useful for summarizing large amounts of data, but they may hide informative short-term variability in these dynamic species. The full time series for all populations are therefore presented here. We note again that these are escapement numbers, not run-size estimates, which take many years to develop. Status and trends are estimated for the most recent 10 years of data (unlike 5 years for all other time series in this Report) in order to account for the spatial segregation of successive year classes of salmon.

### H.1 CALIFORNIA CHINOOK SALMON ESCAPEMENTS

The Chinook salmon escapement time series from California include data from as recent as 2017 extending back over 20 years, with records for some populations (Central Valley Late Fall; Southern Oregon/Northern California Coastal; Klamath Fall) stretching back to the 1970s. No population showed near-term trends (Figure H.1.1), but escapement estimates for several populations in 2017 were  $>1$  s.d. below the long-term mean for their respective time series. Many populations have experienced decreasing escapements from 2013-2017 after some increases in the preceding years.

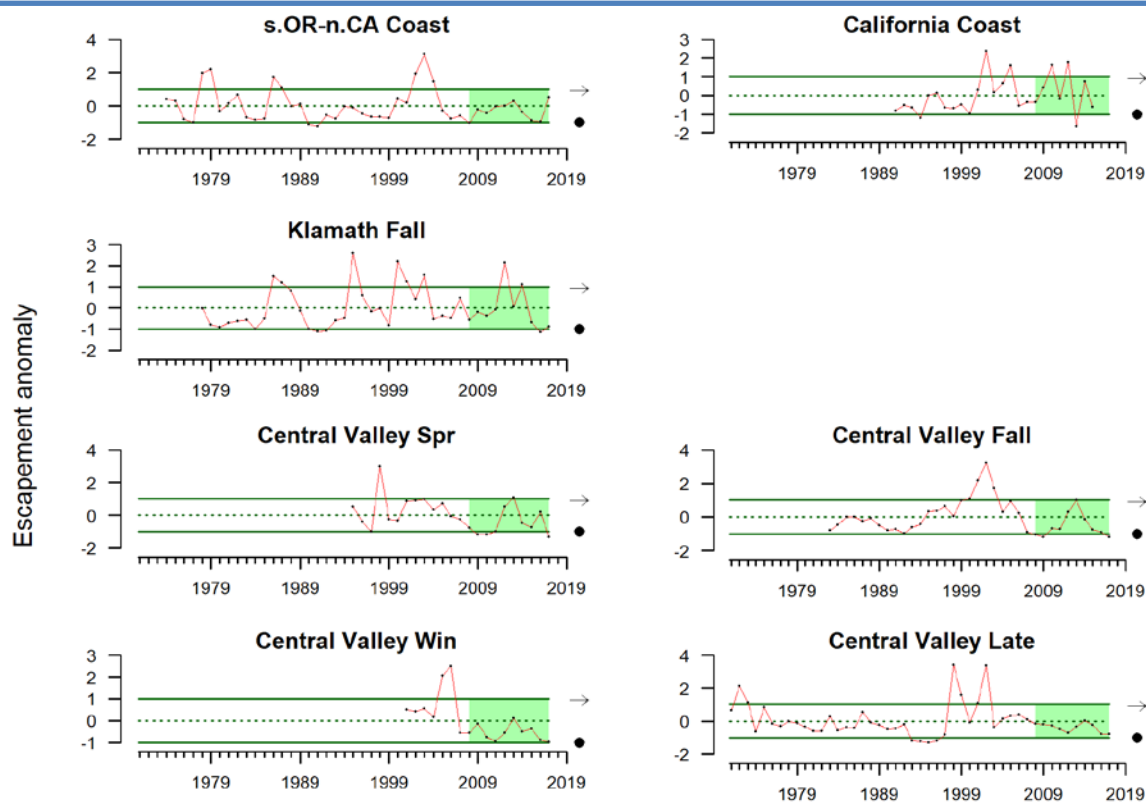
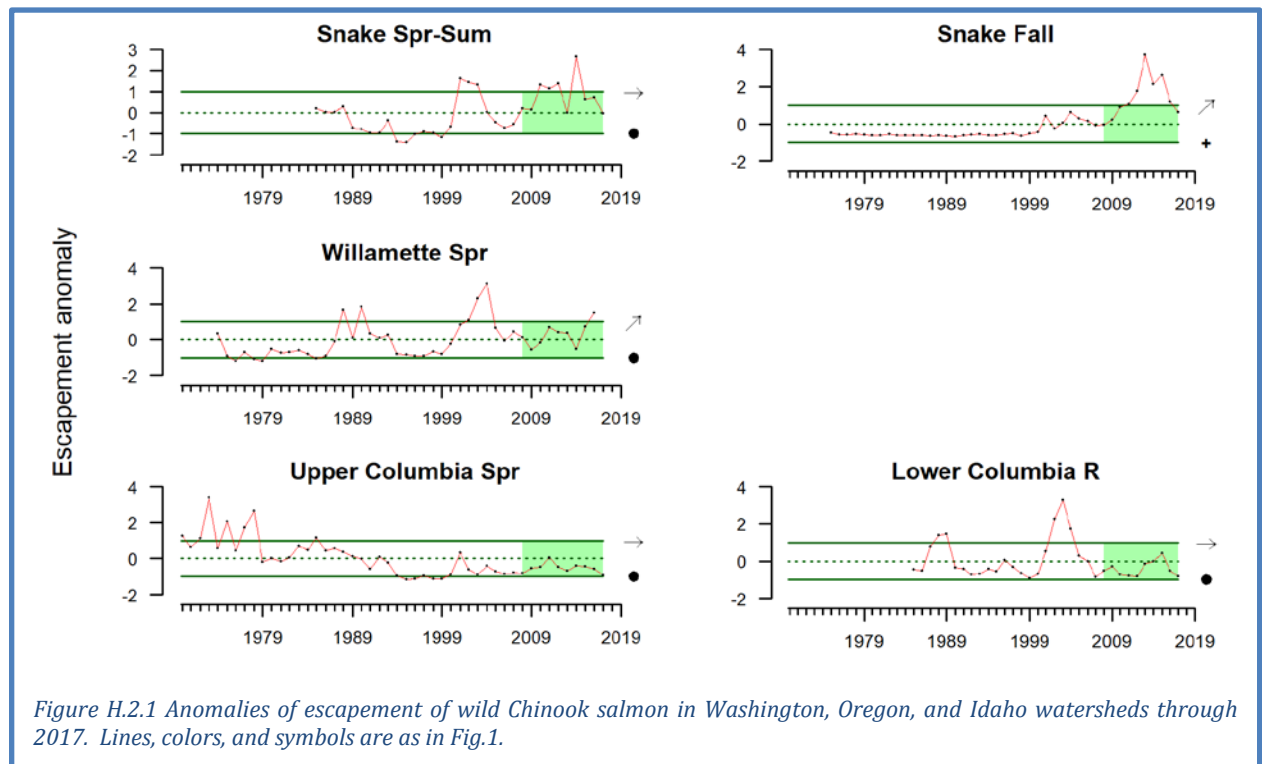


Figure H.1.1 Anomalies of escapement of wild Chinook salmon in California watersheds through 2017. Lines, colors, and symbols are as in Fig.1.

## H.2 WASHINGTON/OREGON/IDAHO CHINOOK SALMON ESCAPEMENTS

The escapement time series used for Chinook salmon populations from Washington, Idaho, and Oregon extend back for up to 40+ years, and the most recent data currently available are through 2017 (Figure H.2.1). Stocks are often co-managed and surveyed by a variety of state and tribal agencies. Snake River Fall Chinook in 2017 were above the long-term mean for the eighth year in a row, and the 10-year average is  $>1$  s.d. greater than the long-term mean. Other populations' recent averages are within 1 s.d. of the long-term mean. The Snake River Fall and Willamette Spring ESUs have shown improving escapement trends in the last ten years.



### H.3 FORECASTS OF 2019 SALMON RETURNS TO THE COLUMBIA AND OREGON PRODUCTION INDEX AREA

The main body of the report features the “stoplight” table (Table 4.3.1) that shows a ranking of indicators of conditions affecting marine growth and survival of Chinook salmon returning to the Columbia Basin, and coho salmon returning to streams in the Oregon Production Index (OPI) area. The stoplight table provides a qualitative perspective on the likely relative run sizes of salmon in the current year, based on indicator measures in the years since returning salmon originally went to sea as smolts. A somewhat more quantitative analysis based on the stoplight table analysis is depicted at the right. Here, annual Chinook salmon counts at Bonneville Dam (Figure H.3.1, top and middle) and OPI coho smolt-to-adult survival (Figure H.3.1, bottom) over the last two decades are plotted against the aggregate mean ranking of indicators in the stoplight table, with 1-year lag for coho and 2-year lag for Chinook. The highest ranking years at the left tend to produce the highest returns and survival. The 2017 stoplight indicators had a relatively low mean rank of 14.5, which would predict relatively low counts of 101,500 Spring and 277,400 Fall Chinook salmon at Bonneville Dam in 2019 (solid arrow, Figure H.3.1, top and middle panels, solid arrows). The 2018 stoplight indicators had a higher mean rank of 11.6, which would predict smolt-to-adult survival of 2.2% for OPI coho in 2019 (Figure H.3.1, bottom, solid arrow). A stoplight indicator ranking of 11.6 in 2018 also corresponds to 2020 Bonneville counts of 127,100 Spring Chinook and 356,800 Fall Chinook (Figure H.3.1, top and middle, dashed arrows). The relationships of past salmon returns to stoplight means explain between 32% (coho) and 55% (Fall Chinook) of variance. This is a fairly simple analysis, however, given that each indicator in the stoplight table is given equal weight.

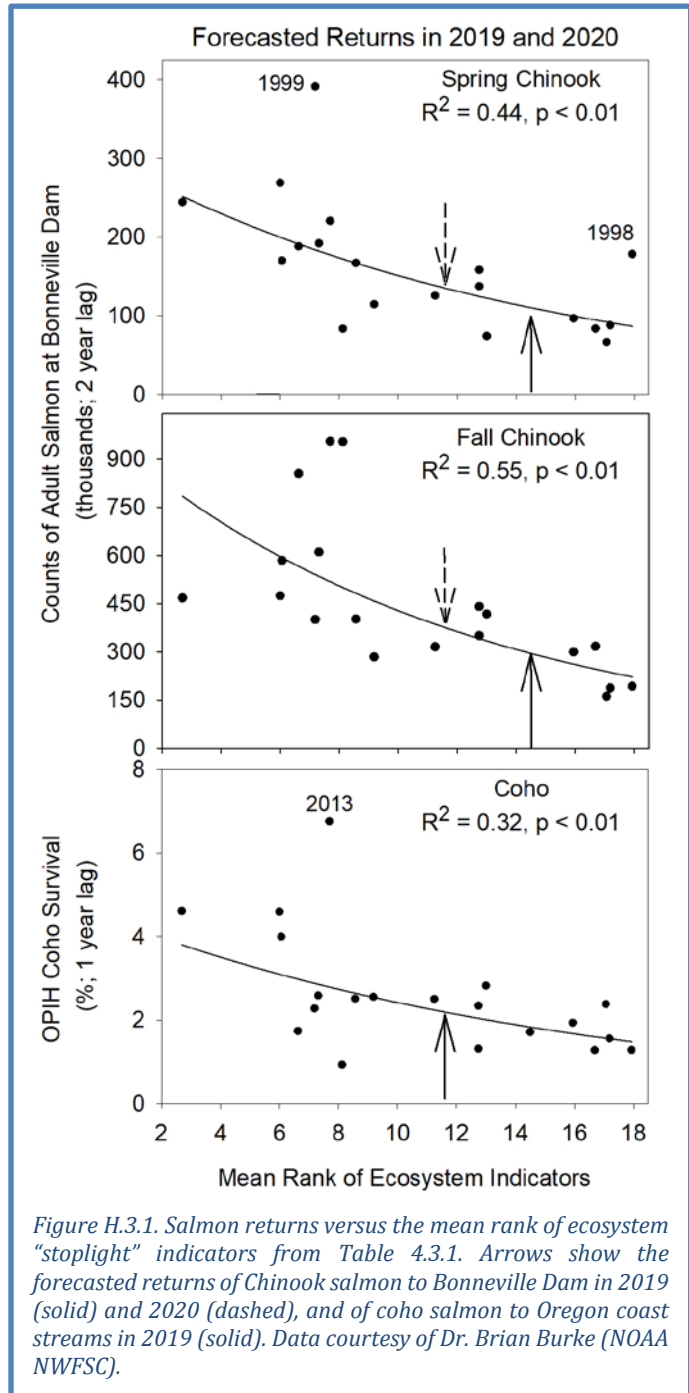


Figure H.3.1. Salmon returns versus the mean rank of ecosystem “stoplight” indicators from Table 4.3.1. Arrows show the forecasted returns of Chinook salmon to Bonneville Dam in 2019 (solid) and 2020 (dashed), and of coho salmon to Oregon coast streams in 2019 (solid). Data courtesy of Dr. Brian Burke (NOAA NWFS).

A more robust quantitative analysis uses an expanded set of ocean indicators plus principal components analysis and dynamic linear modeling to produce salmon forecasts for the same systems. The principal components analysis essentially is used for weighted averaging of the ocean indicators, reducing the total

number of indicators while retaining the bulk of the information from them. The dynamic linear modeling technique relates salmon returns to the principal components of the indicator data, and the approach used here also incorporates dynamic information from sibling regression modeling. The model fits very well to data for Spring Chinook, Fall Chinook and coho salmon at the broad scales of the Columbia River and the OPI area (Figure H.3.2). Forecasts with 95% confidence intervals suggest 2019 Bonneville counts of Spring Chinook salmon that are similar to 2018 (Figure H.3.2, top), and potential increases of Fall Chinook at Bonneville and coho in the OPI area (Figure H.3.2, middle and bottom). Although these analyses represent a general description of ocean conditions, we must acknowledge that the importance of any particular indicator will vary among salmon species/runs. NOAA scientists and partners are working towards stock-specific salmon forecasts by using methods that can optimally weight the indicators for each response variable in which we are interested (Burke et al. 2013).

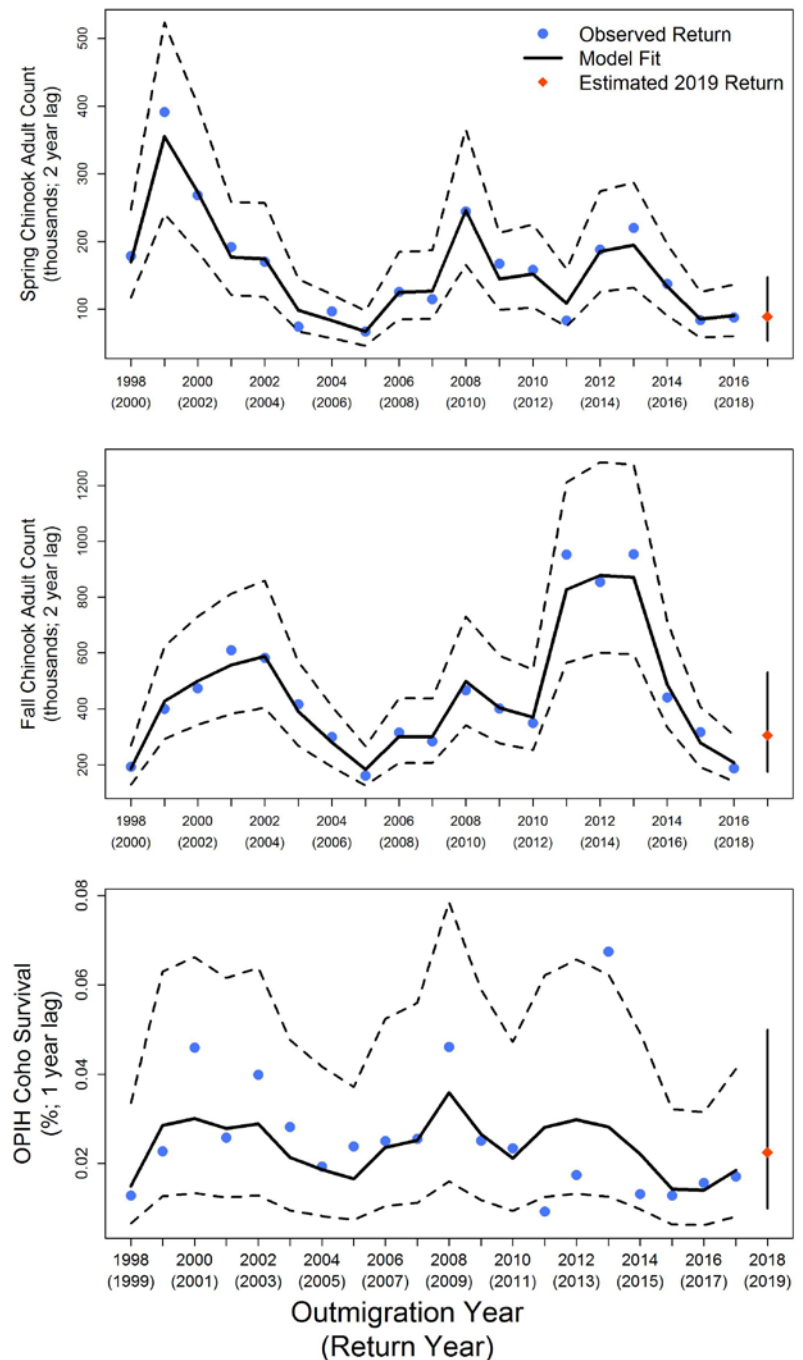
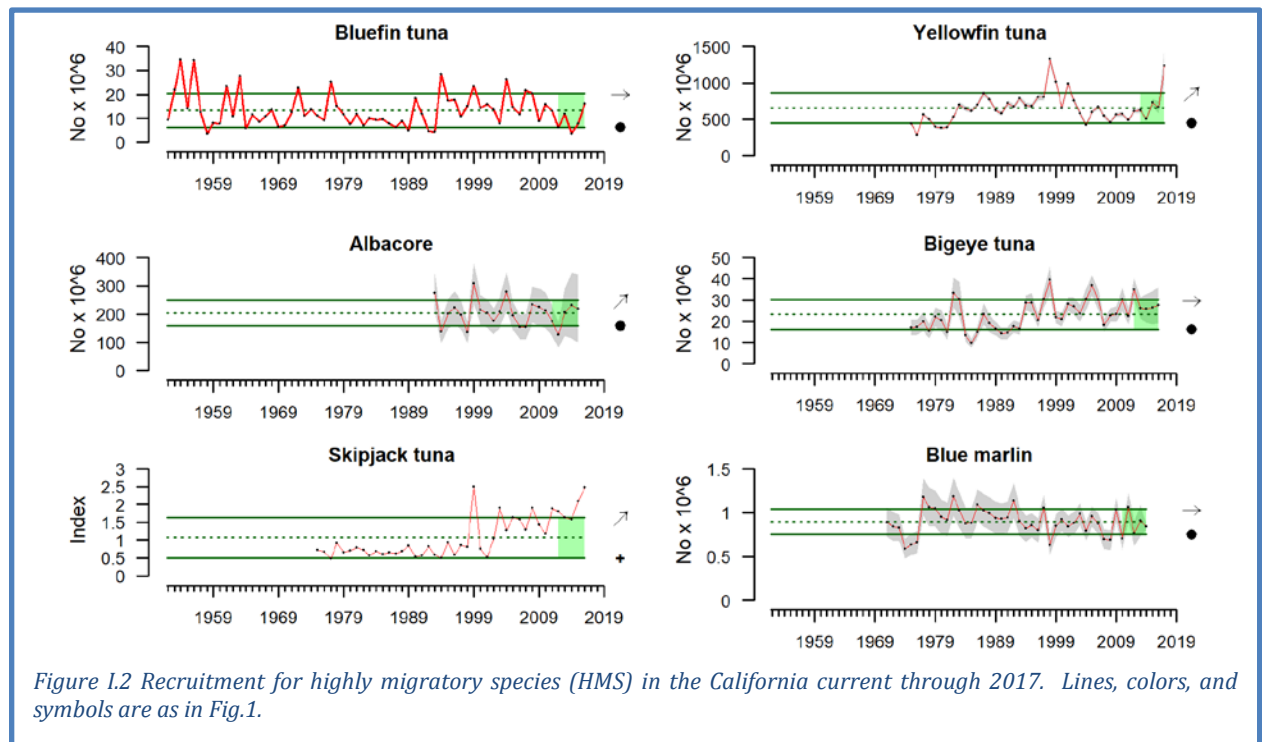
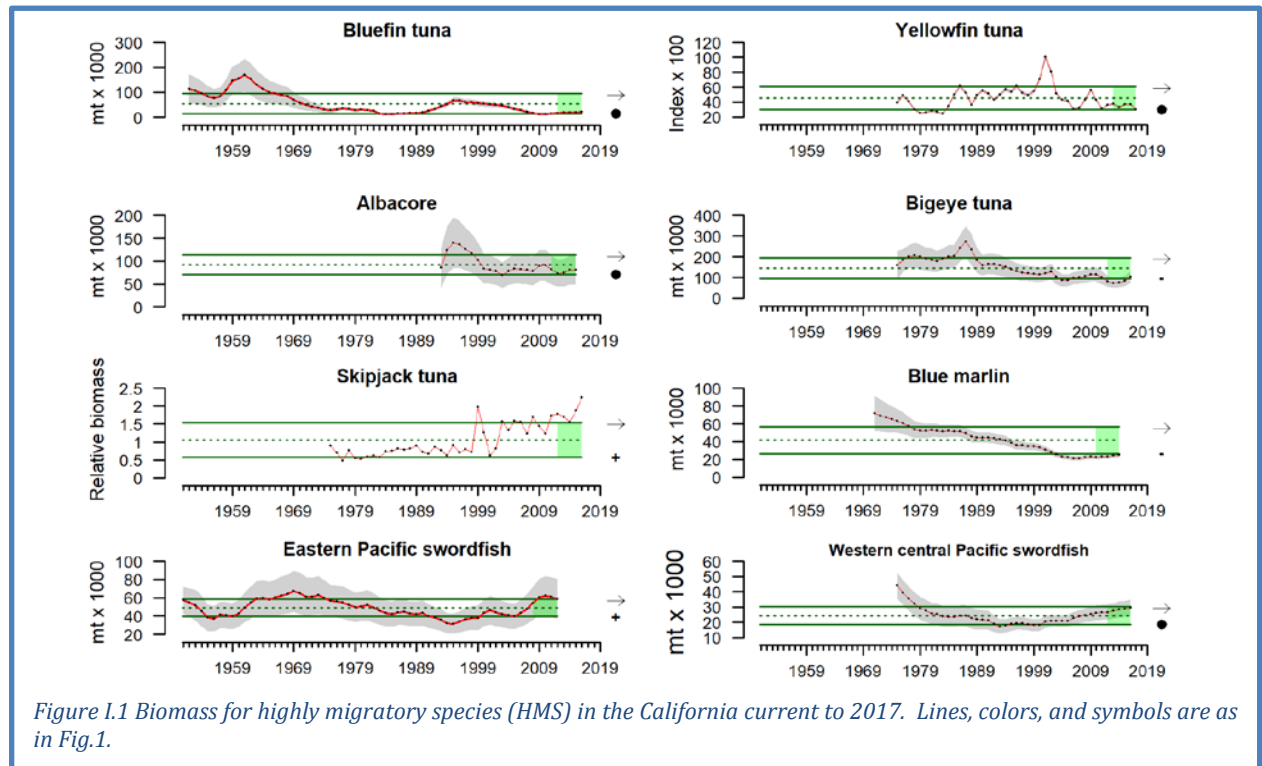


Figure H.3.2. Time series of observed spring Chinook salmon adult counts (top), fall Chinook salmon adult counts (middle), and coho salmon smolt-to-adult survival (bottom) by out-migration year. In each plot, the dark line represents the model fit and lighter lines represent 95% confidence intervals. Forecasts were created from a DLM (Dynamic Linear Models) with log of sibling counts (for the Chinook models only) and first principal component of ocean indicators as predictor variables. Courtesy of Dr. Brian Burke (NOAA, NWFSC).

## Appendix I HIGHLY MIGRATORY SPECIES

Highly migratory species are discussed Section 4 of the main document (Figure 4.5.1). The time series for abundance (Figure I.1) and recruitment (Figure I.2) are plotted here for reference. Additional information on how these estimates were derived is provided below the figures.



## **Pacific bluefin tuna**

*Spawning stock biomass:* This index represents modeled spawning stock biomass from the latest (2018) stock assessment report, completed through the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC). Pacific bluefin are considered to be one stock throughout the Pacific Ocean, and are fished throughout their range by multiple countries and fishing gears. At present, the majority are caught by purse seine gear. Their population dynamics are assessed using a fully integrated age-structured model (Stock Synthesis v3). The 2018 base-case model was constructed with minimal modifications relative the 2016. The full assessment is available from [http://isc.fra.go.jp/reports/stock\\_assessments.html](http://isc.fra.go.jp/reports/stock_assessments.html).

*Recruitment:* Annual recruitment is derived from the stock assessment model, and is primarily indexed by catches from troll fisheries on age-0 juvenile fish near Japan.

*Implications:* Declines in spawning stock biomass appeared to cease in 2010, however the stock remains at near-historic low levels (around 3.3% of unfished biomass). While no reference points have been agreed upon, the stock is likely to be overfished, and overfishing may be occurring. Recent recruitment estimates suggest below-average recruitment from 2010-2015, with some increase in 2016. Although recent recruitment estimates are uncertain, due to being informed only by data from the age-0 troll fishery, this CPUE series has been shown to be a good predictor of recruitment in the past.

## **North Pacific albacore**

*Spawning stock biomass:* This index represents modeled spawning potential biomass from the latest (2017) stock assessment report, completed through the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC). North Pacific albacore are considered to be one stock throughout the North Pacific Ocean, although some studies have suggested that a northern and southern stock may be present within the assessment area. They are fished throughout their range by multiple countries, mostly using surface gear (troll and pole and line), as well as pelagic longlines and other gears. Their population dynamics are assessed using an age-, length- and sex-structured model (Stock Synthesis v3). The full assessment is available from [http://isc.fra.go.jp/reports/stock\\_assessments.html](http://isc.fra.go.jp/reports/stock_assessments.html).

*Recruitment:* Estimates of annual recruitment are derived from the stock assessment model.

*Implications:* Spawning stock biomass has increased slightly in the past few years. The stock is not considered likely to be overfished, and it is not likely that overfishing is currently occurring. Recent recruitment estimates suggest near-average recruitment in the past 5 years, however it should be noted that estimates from terminal model years are highly uncertain.

## **Swordfish**

*Spawning biomass:* This index represents modeled spawning biomass for the western central Pacific swordfish stocks from the latest (2018) stock assessment report, completed through the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC). Swordfish are considered to comprise two stocks in the North Pacific. The western and central Pacific stock is located throughout the entire North Pacific, except for waters off Baja California and Central and South America, which are occupied by the eastern Pacific stock. However, recent electronic tagging of swordfish off the Southern California coast suggests that there may be more mixing of fish between northern and southern regions of the EPO than previously thought. The highest catches of swordfish in the North Pacific are from pelagic longline gears. In 2018, only the western and central North Pacific stock assessment was updated. The assessment is available from [http://isc.fra.go.jp/reports/stock\\_assessments.html](http://isc.fra.go.jp/reports/stock_assessments.html).

*Implications:* Estimates of total stock biomass show a relatively stable population, with a slight decline until the mid-1990s followed by a slight increase since 2000. The base case model indicated that the

WCNPO swordfish stock is not likely overfished and is not likely experiencing overfishing relative to MSY-based or 20% of unfished spawning biomass-based reference points. No long term trend in recruitment is apparent, and recruitment estimates from recent years are around average.

### **Blue marlin**

*Spawning stock biomass:* This index represents modeled spawning stock biomass from the latest (2016) stock assessment report, completed through the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC). Blue marlin are considered to be one stock throughout the Pacific Ocean, and the majority of catch is from pelagic longlines. Their population dynamics are assessed using an age-, length- and sex-structured model (Stock Synthesis v3). The full assessment is available from [http://isc.fra.go.jp/reports/stock\\_assessments.html](http://isc.fra.go.jp/reports/stock_assessments.html).

*Recruitment:* Estimates of annual recruitment are derived from the stock assessment model.

*Implications:* Spawning stock biomass has been largely stable in the past 5 years, at historically low levels (around 21% of unfished biomass). Despite this, the stock is currently considered to be not overfished, and overfishing is not likely to be occurring. However, the stock is near fully exploited. In recent years, recruitment has been variable around historical mean levels, however it should be noted that estimates from terminal model years are highly uncertain.

### **Yellowfin tuna**

*Spawning stock biomass:* This series shows the modeled spawning stock biomass index from the 2018 stock assessment, which was an update of the 2017 assessment. Yellowfin tuna are assessed through the Inter-American Tropical Tuna Commission (IATTC), using Stock Synthesis V3.23b. They are assumed to comprise one stock throughout the Pacific, although tagging data suggest considerable regional fidelity. In the eastern Pacific, they are primarily fished in tropical waters, from Baja California south. Indices were provided by C. Minte-Vera (IATTC).

*Recruitment:* Estimates of recruitment are derived from the assessment model.

*Implications:* Recruitment has been mostly average or below average until 2014. The most recent annual recruitments (2015-2017) were estimated to be at or above average, but these estimates are highly uncertain. The recruitment estimates for 2017 might be upwardly biased, because of a retrospective pattern already noticed in previous assessments. Spawning stock biomass has been near average or below average since 2003, except during 2008-2010. However, this may increase in the next two years, due to the above-average recruitments of 2015 and 2016, which coincided with the 2014-2016 marine heat wave and El Niño event.

The recent fishing mortality is slightly above the MSY level, however the current spawning biomass is estimated to be above that level. The stock assessment report notes that recent biomass of fish aged 3 quarters and older is also higher than that corresponding to the MSY level, because of the large recent recruitments. The catches are predicted to increase in the near future. However, these interpretations are uncertain, and highly sensitive to the assumptions made about the steepness parameter of the stock-recruitment relationship, the average size of the oldest fish, and the assumed levels of natural mortality.

### **Bigeye tuna**

*Spawning stock biomass:* This index shows modeled spawning stock biomass of bigeye tuna from the 2017 stock assessment report, which was completed through the Inter-American Tropical Tuna Commission (IATTC), using Stock Synthesis V3. The assessment assumes that there is one stock of bigeye in the eastern Pacific. However, the assessment report acknowledges that recent tagging research

suggests that bigeye undertake extensive longitudinal movements, which may be at odds with this assumption. Indices were provided by C. Minte-Vera (IATTC).

*Recruitment:* Estimates of recruitment are derived from the assessment model.

*Implications:* The results of the 2018 stock assessment of bigeye tuna in the eastern Pacific Ocean using the same methodology as in previous years revealed several uncertainties which led assessment scientists to question its use as a basis for management advice. The 2018 assessment was therefore not accepted for use in management. Indices from the 2017 assessment are therefore shown here, and will be updated when the uncertainties in the stock assessment have been resolved.

The 2017 biomass indices showed that the stock biomass ratio (compared to estimated unfished biomass) declined to a historically low level of 0.16 in 2013. This may have been partially due to below-average recruitment in 2007 – 2008, coincident with strong La Nina events. Spawning biomass may have increased in recent years, indicated by increases in CPUE of adult fish on pelagic longlines. These trends may be a result of strong recruitment in 2012. The 2017 base-case stock assessment model suggested that the stock was not overfished, or undergoing overfishing, but there is high uncertainty associated with these results. There is some suggestion that recruitment may be higher during El Nino events, thus environmental variability may influence stock productivity in this species.

### **Skipjack tuna**

*Relative biomass:* Skipjack tuna are assumed to comprise one contiguous stock throughout the Pacific ocean. In the eastern Pacific, they are primarily fished in tropical waters, using purse seine gear. Skipjack are difficult to assess with standard stock assessment methods, due to high and variable productivity, and uncertainties in natural mortality and growth. This species is thus assessed using a simple model which generates indicators of biomass, recruitment and exploitation rate, and compares these to historically observed values (Maunder & Deriso 2007). The stock assessment is completed through the Inter-American Tropical Tuna Commission (IATTC). The relative biomass index shown is from the 2017 update assessment, including data up to 2016. Indices were provided by M. Maunder (IATTC).

*Recruitment:* Estimates of recruitment are derived from the assessment model.

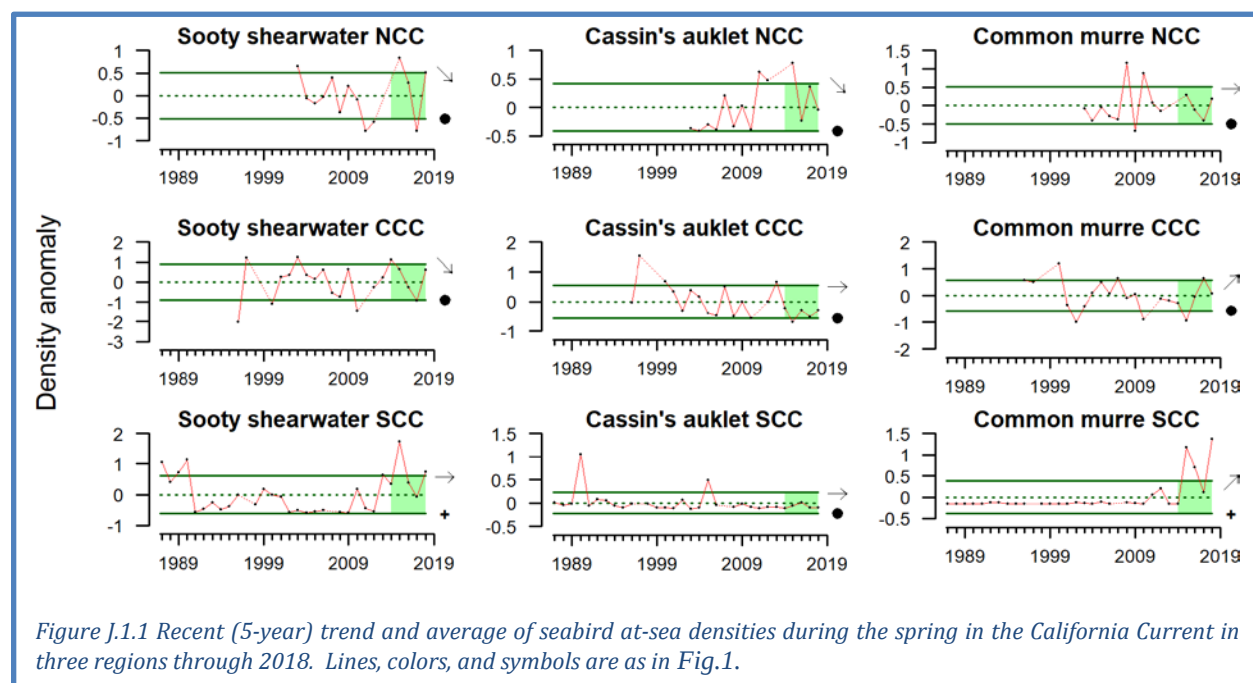
*Implications:* The relative biomass and recruitment indices have been increasing since the mid-2000s, and appear to have been above average in recent years. While no traditional reference points are available for skipjack in the north Pacific, results suggest that the stock is likely not overfished, and overfishing is likely not occurring. The fishery for skipjack tuna in the eastern Pacific is constrained by effort restrictions implemented for the conservation of bigeye tuna. As skipjack tuna are much more productive than bigeye, there was found to be no evidence for concern about the status of the skipjack stock. Biological data suggest that abundance of larval skipjack tends to increase with water temperature, at least up to ~29°C. However, catches of adults by surface gears tend to be reduced during warmer periods (such as El Nino), as fish spend less time near the surface, possibly due to deepening thermoclines. Environmentally variability may therefore influence stock productivity and availability to fisheries.

## Appendix J SEABIRD DENSITY AND MORTALITY

### J.1 SEABIRD AT-SEA DENSITIES

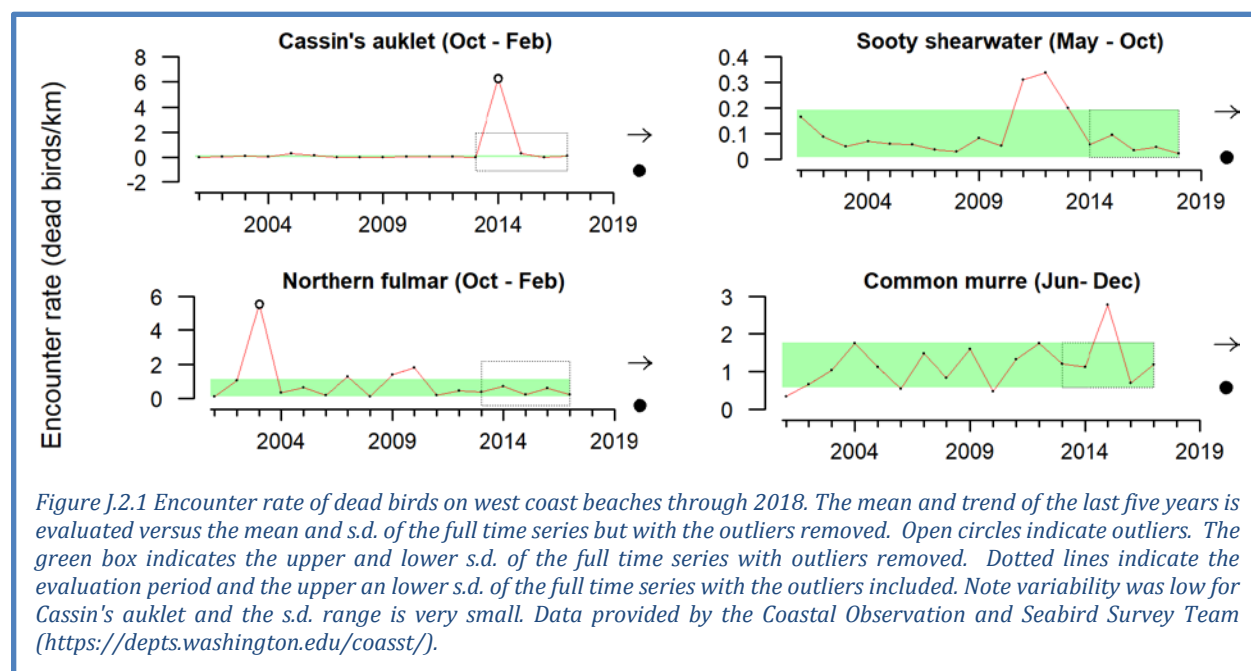
Sooty shearwaters migrate from the southern hemisphere in spring and summer to prey on small fish and squid on the shelf and near the shelf break. Common murres and Cassin's auklets are resident, colony-forming species that feed over the shelf; Cassin's auklets mostly prey on zooplankton, while common murres target small fish and squid.

At-sea densities of these three seabirds in the northern, central and southern CCE (NCC, CCC and SCC respectively) are discussed in the main report. Figure 4.7.1 shows the trends in a quad plot. In Figure J.1.1 we replot the trends in standard time-series figures for more complete reference.



## J.2 SEABIRD MORTALITY

The Coastal Observation and Seabird Survey Team (COASST) documented average to below-average numbers of beached birds for four indicator species in their most recent data (Figure J.2.1). The encounter rate of Cassin's auklet in the fall/winter of 2017–18 remained near baseline levels, where it has been since the large die-off in 2014. The encounter rate of sooty shearwaters in 2018 was low relative to the long-term mean and has had no significant short-term trend since a spike in mortality in 2011–13. The encounter rate of northern fulmars in fall/winter 2017–18 was below the long-term mean, with no significant short-term trend. The encounter rate of common murre in 2018 was unavailable as this report went to press.



## Appendix K STATE-BY-STATE FISHERY LANDINGS AND REVENUES

State-by-state landings and revenues from fisheries are presented here. Data come from the Pacific Fisheries Information Network (PacFIN, <http://pacfin.psmfc.org>) for commercial landings and by the Recreational Fisheries Information Network (RecFIN, <http://www.recfin.org>) for recreational landings. Landings provide the best long-term indicator of fisheries removals. Revenue was calculated based on consumer price indices for 2016.

### K.1 STATE-BY-STATE LANDINGS

Total landings in California decreased to historically low levels in recent years, primarily due to steep decreases in landings of market squid in 2015 and 2016 (Figure K.1.1). Commercial landings of shrimp and salmon also decreased over the last five years, and landings of CPS were consistently below average from 2013-2017. Groundfish, hake, HMS and Other species were relatively unchanged. Crab landings varied around historical averages over the last 5 years. Methods for sampling and calculating total mortality in recreational fisheries changed recently, leading to shorter comparable time series than shown in previous reports. Recreational landings in California (excluding salmon and Pacific halibut) increased from 2008 to 2015, but a 70-80% decrease in yellowfin tuna and yellowtail landings in 2016 brought recreational landings within historical averages over the last 5 years (Figure K.1.1). Recreational salmon landings were relatively unchanged and near the lower bounds of the long-term average.

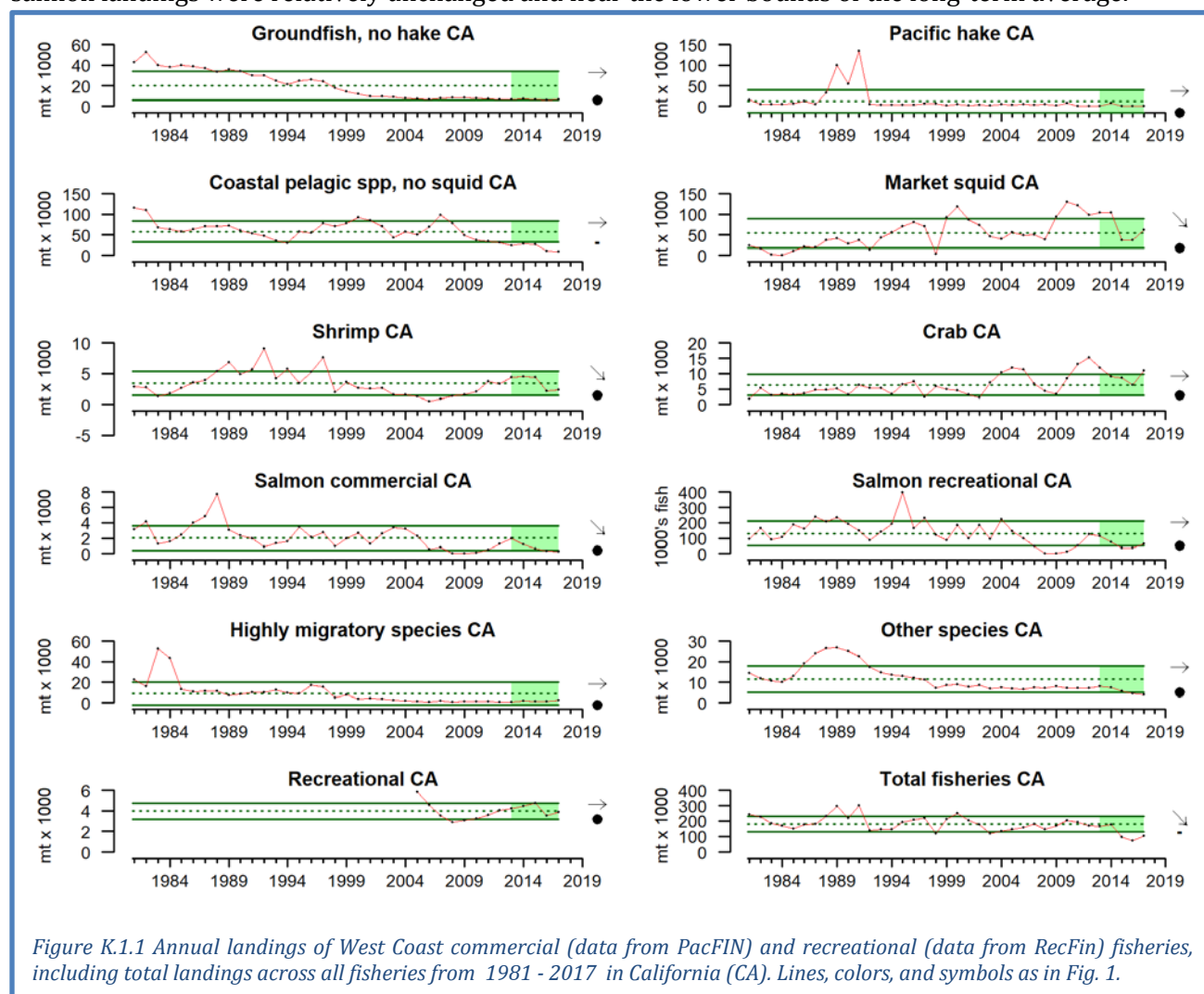
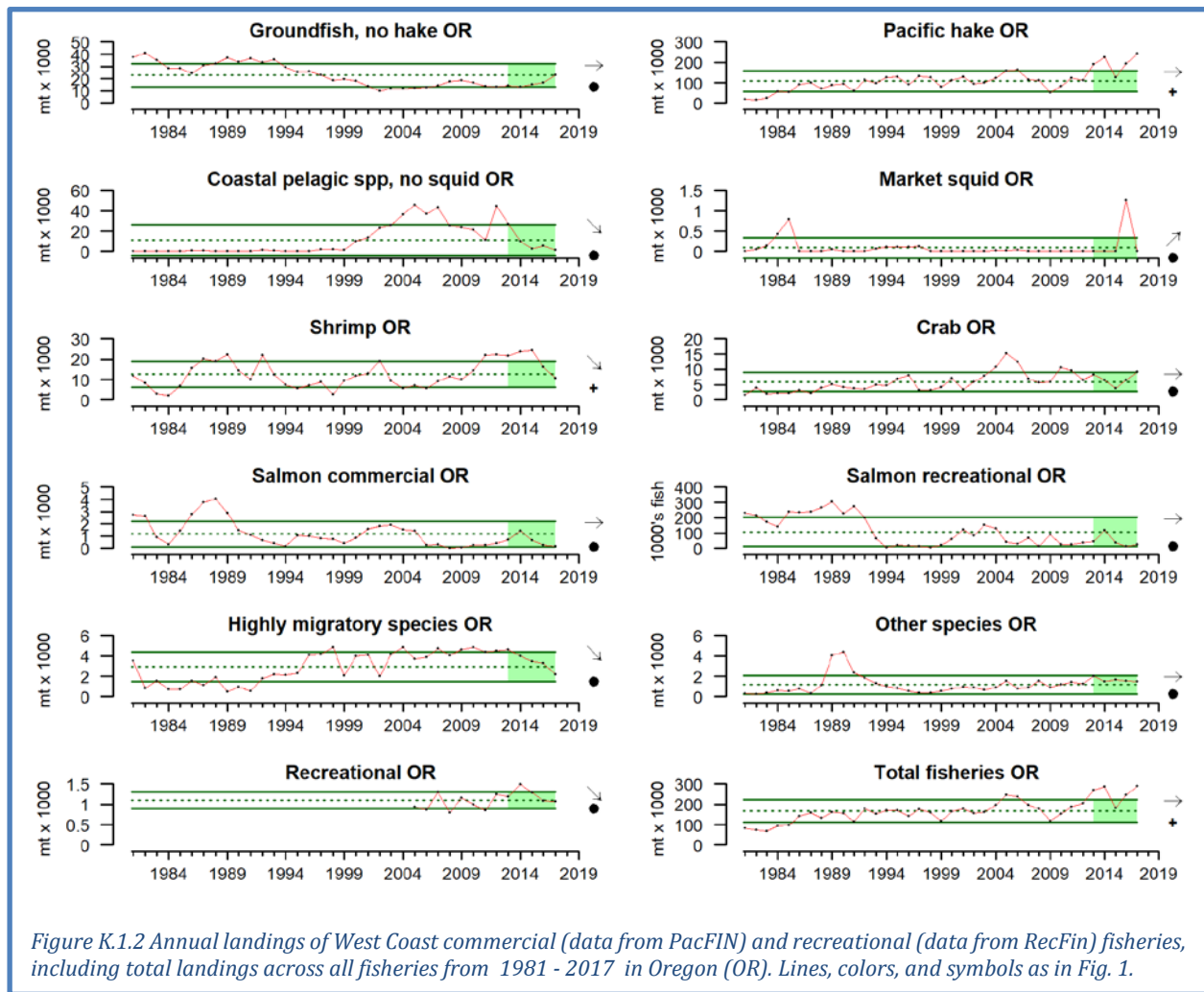


Figure K.1.1 Annual landings of West Coast commercial (data from PacFIN) and recreational (data from RecFin) fisheries, including total landings across all fisheries from 1981 - 2017 in California (CA). Lines, colors, and symbols as in Fig. 1.

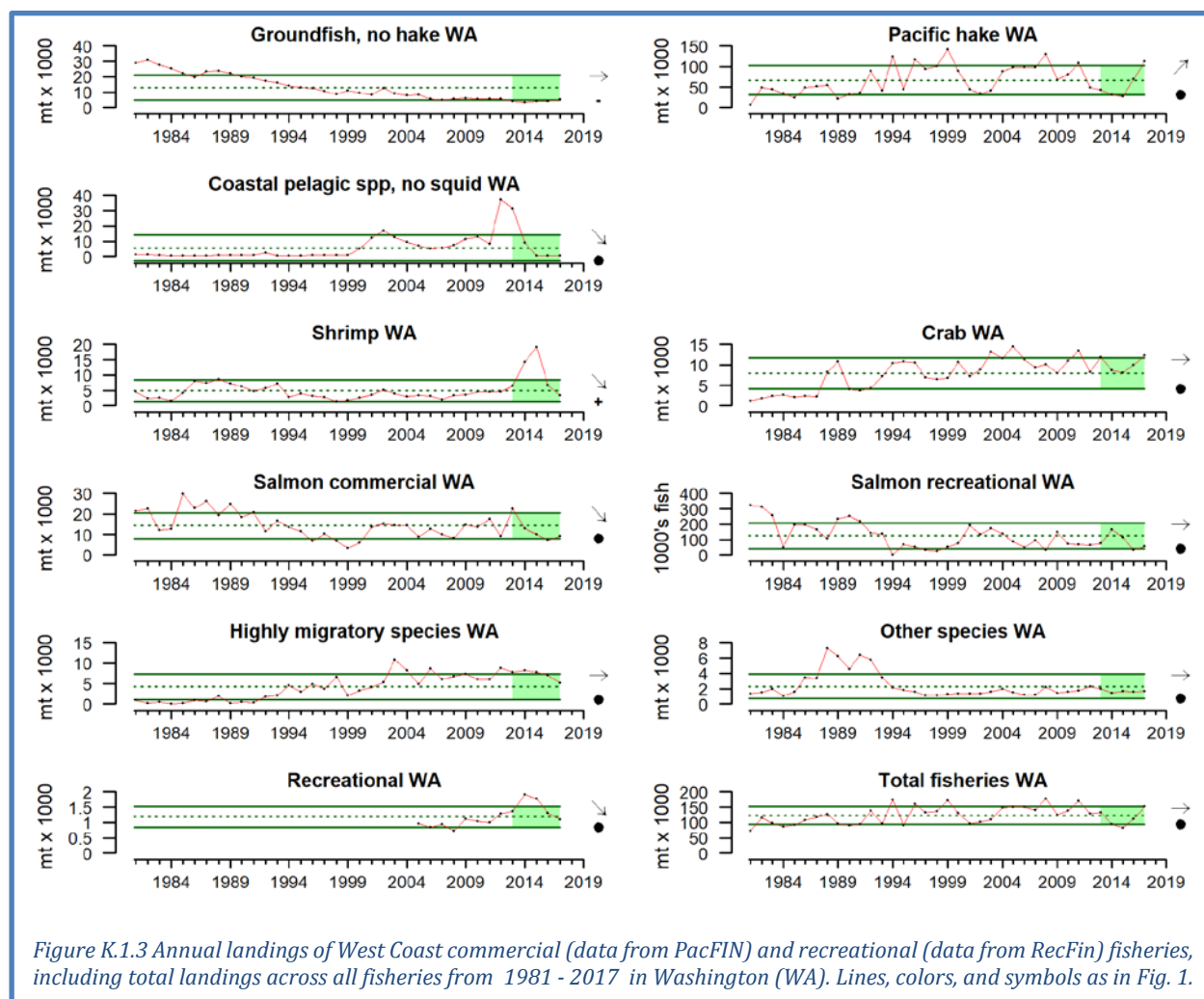
Total fisheries landings in Oregon have varied but were above historical levels from 2013-2017. (Figure K.1.2). These patterns were primarily driven by historically high landings of hake over the last 5 years. Commercial landings of other groundfish, crab, salmon and Other species showed no trends and within historical averages from 2013-2017. CPS (excluding squid), shrimp and HMS landings all decreased over the last 5 years in Oregon, although recent average shrimp landings were still historically high due to high landings from 2013 to 2015. Landings of market squid have been at or near 0 across the time series, but landings over 1200 tons in 2016 caused this indicator to show an increasing recent trend.

Methods for sampling and calculating total mortality in recreational fisheries changed recently, leading to shorter comparable time series than shown in previous reports. Recreational fisheries landings (excluding salmon and Pacific halibut) in Oregon showed a decreasing trend from 2013-2017 relative to the long-term average (Figure K.1.2). Salmon recreational landings showed no recent trends and were within, but near the lower limits of, the historical range over the last 5 years.



Total fisheries landings in Washington were highly variable from 2013-2017, with particularly low landings in 2015 and a large increase in 2017 (Figure K.1.3). These patterns were driven primarily by large increases in hake landings from 2015 to 2017 and large decreases in the landings of CPS (excluding squid), shrimp and commercial salmon over the same period. Landings of groundfish (excluding hake) were consistently below historical averages from 2013-2017, while landings of crab, Other species and HMS showed no current trends and were within 1 s.d. of historical averages over the last 5 years.

Methods for sampling and calculating total mortality in recreational fisheries changed recently, leading to shorter comparable time series than shown in previous reports. Total landings of recreational catch (excluding salmon and halibut) in Washington state decreased, but remained within 1 s.d. of the average from 2013-2017 (Figure K.1.3). Recreational salmon landings showed no trends and were within 1 s.d. of the average over the last 5 years; however, recreational salmon landings have been close to 1 s.d. below average for the past 2 years of available data.



## K.2 COMMERCIAL FISHERY REVENUES

Total revenue across US West Coast commercial fisheries has varied near upper historical averages from 2013–2017 (Figure K.2.1). This pattern was driven primarily by interactions between historically high revenue from Pacific hake, market squid and crab fisheries and historically low and decreasing revenue in the CPS fisheries over the last 5 years. Revenue of groundfish (excluding hake) showed gradual increases that brought the fishery back to within 1 s.d. of the long-term average from 2013–2017. Shrimp fishery revenue varied over the last 5 years, with an average within 1 s.d. of the long-term average and no clear trend. Revenues from commercial salmon, HMS and Other species were relatively unchanged and within 1 s.d. of long-term averages over the last 5 years.

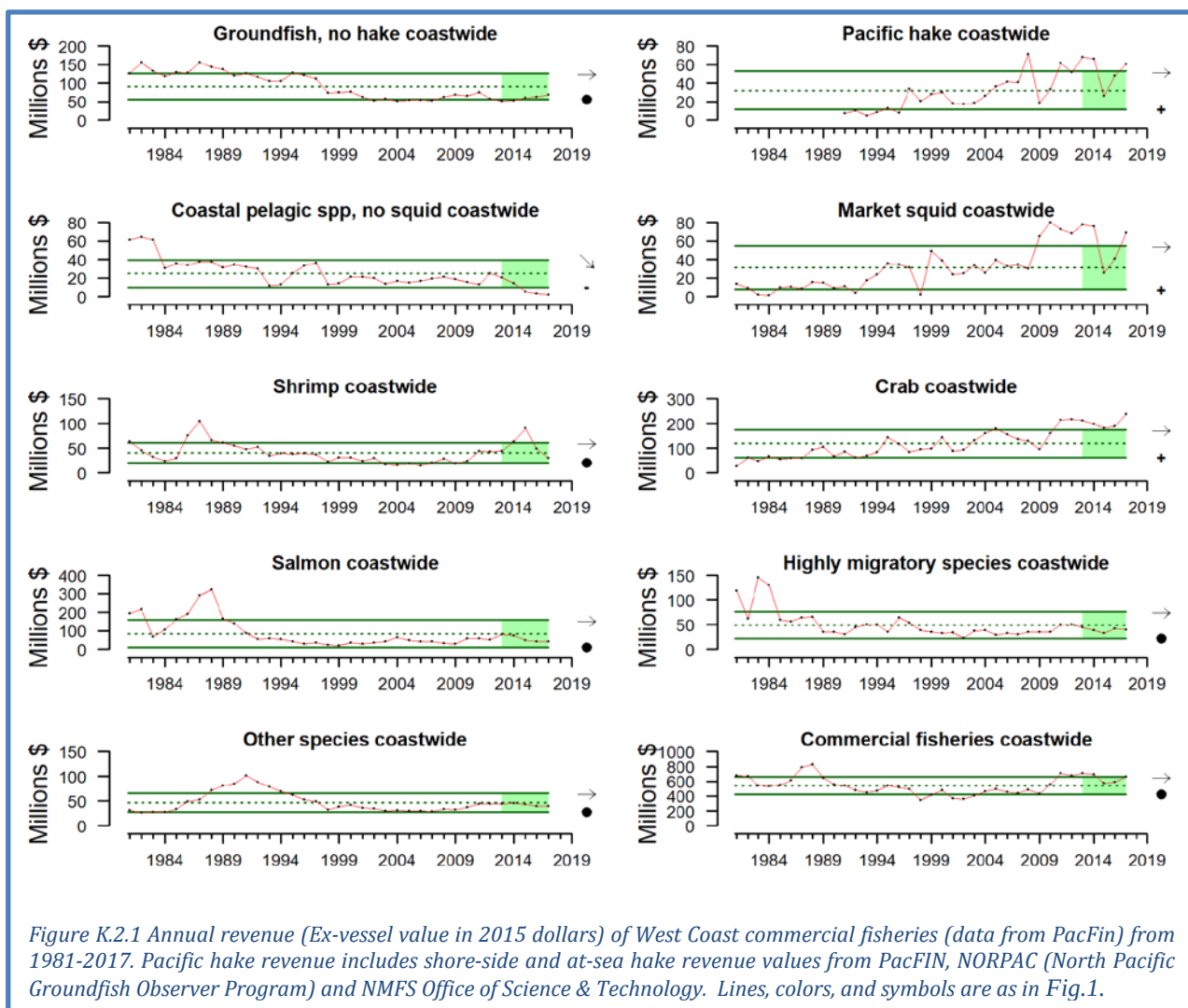
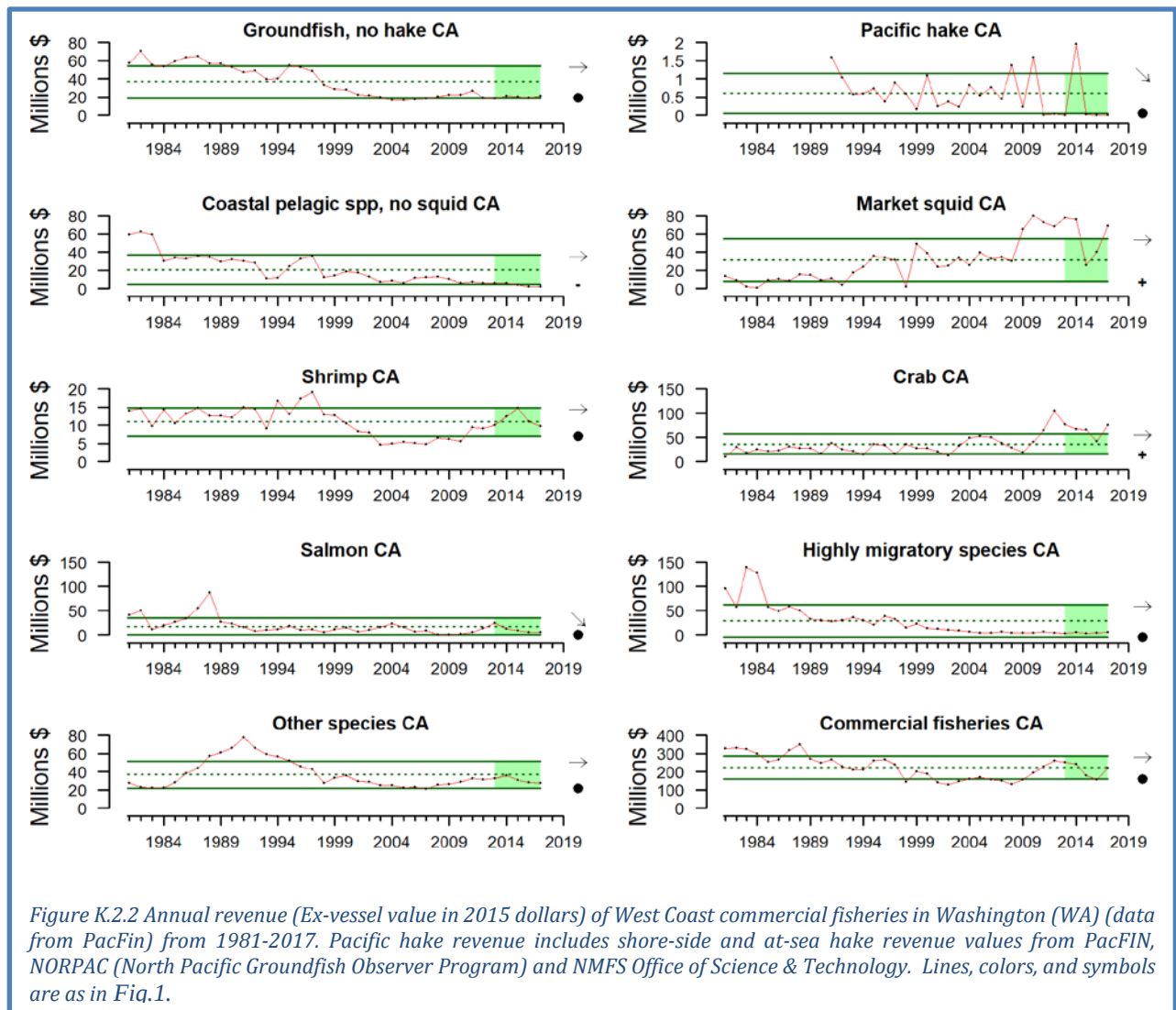
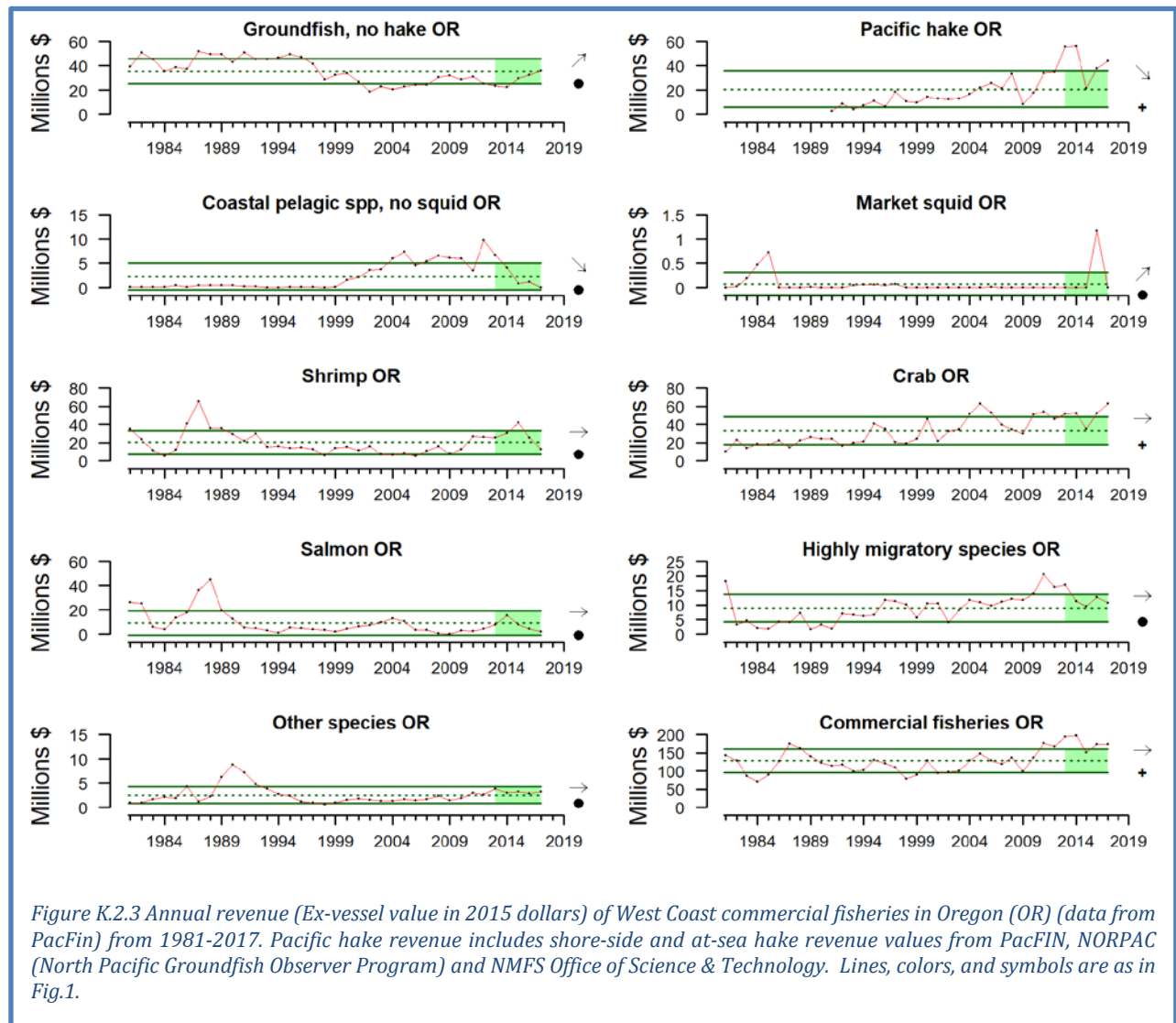


Figure K.2.1 Annual revenue (Ex-vessel value in 2015 dollars) of West Coast commercial fisheries (data from PacFin) from 1981-2017. Pacific hake revenue includes shore-side and at-sea hake revenue values from PacFIN, NORPAC (North Pacific Groundfish Observer Program) and NMFS Office of Science & Technology. Lines, colors, and symbols are as in Fig.1.

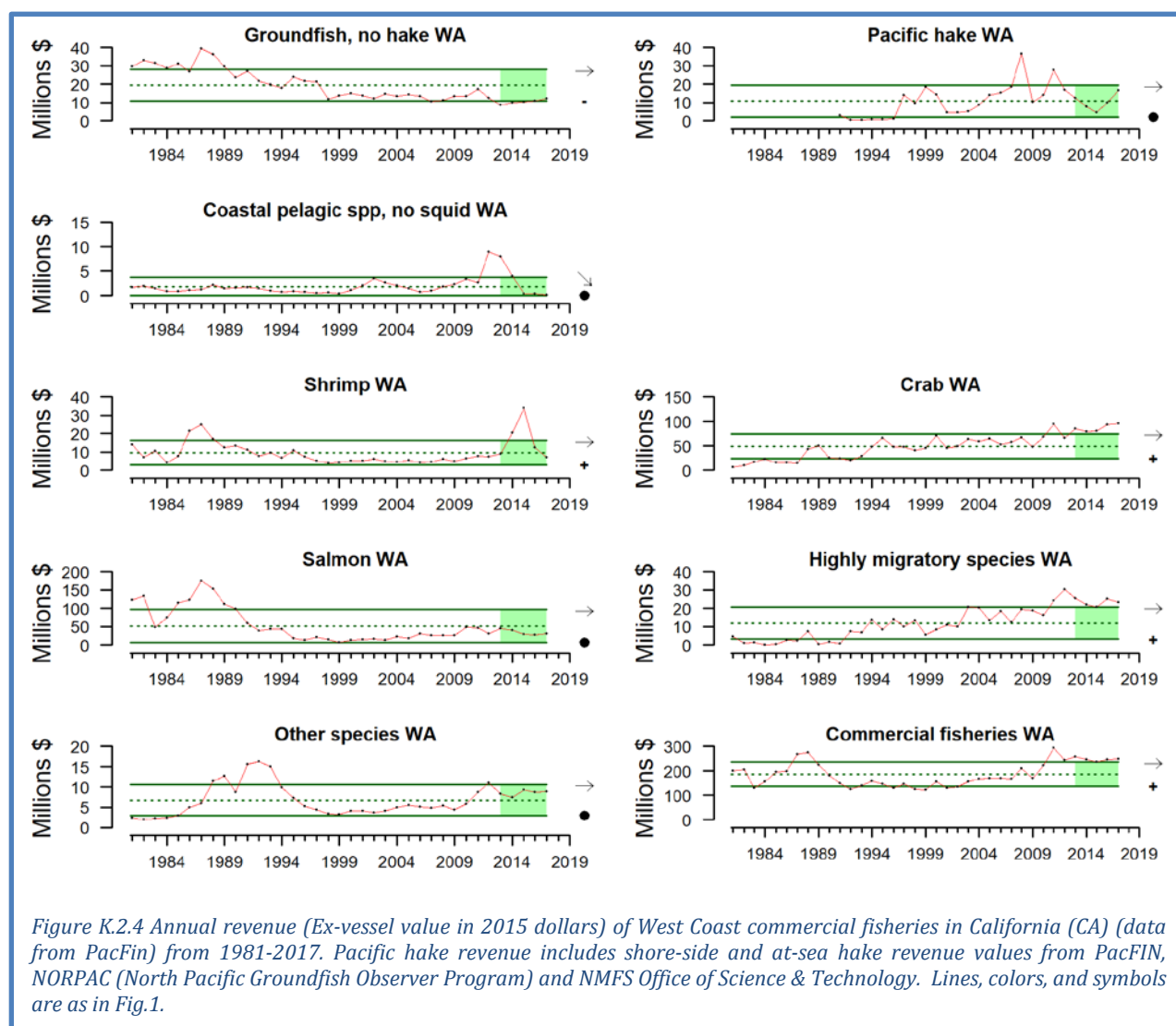
Total revenue across commercial fisheries in California varied from 2013–2017 (Figure K.2.2). This pattern was primarily driven by changes in market squid and crab revenue, which were >1 s.d. above long-term averages but experienced drops and rebounds from 2015 to 2017. Revenue from CPS fisheries were >1 s.d. below historical averages over the last 5 years. There were no fisheries that had increasing trends for revenue over the last 5 years, however revenue from Pacific hake and commercial salmon decreased from 2013-2017. Revenue of groundfish (excluding hake) and HMS remained consistently near historically low levels over the last 5 years, while revenue from shrimp and Other species showed no consistent trends and varied within 1 s.d. of long-term averages over the last 5 years.



Total revenue across commercial fisheries in Oregon was at historically high annual averages from 2013–2017 (Figure K.2.3). This was driven by higher than average revenues for Pacific hake and crab, along with increases in revenue from groundfish fisheries. CPS fishery revenue declined over the last 5 years. Market squid showed an abnormally large and apparently short-lived increase in revenue in 2016 that may be related to the unusual oceanographic conditions of the marine heat wave and major El Niño. With increasing variation in oceanographic conditions, this pattern should be monitored for potential changes in the distribution of market squid revenue among west coast states. All other fisheries showed no trends and were within 1 s.d. of long-term averages in revenue over the last 5 years.



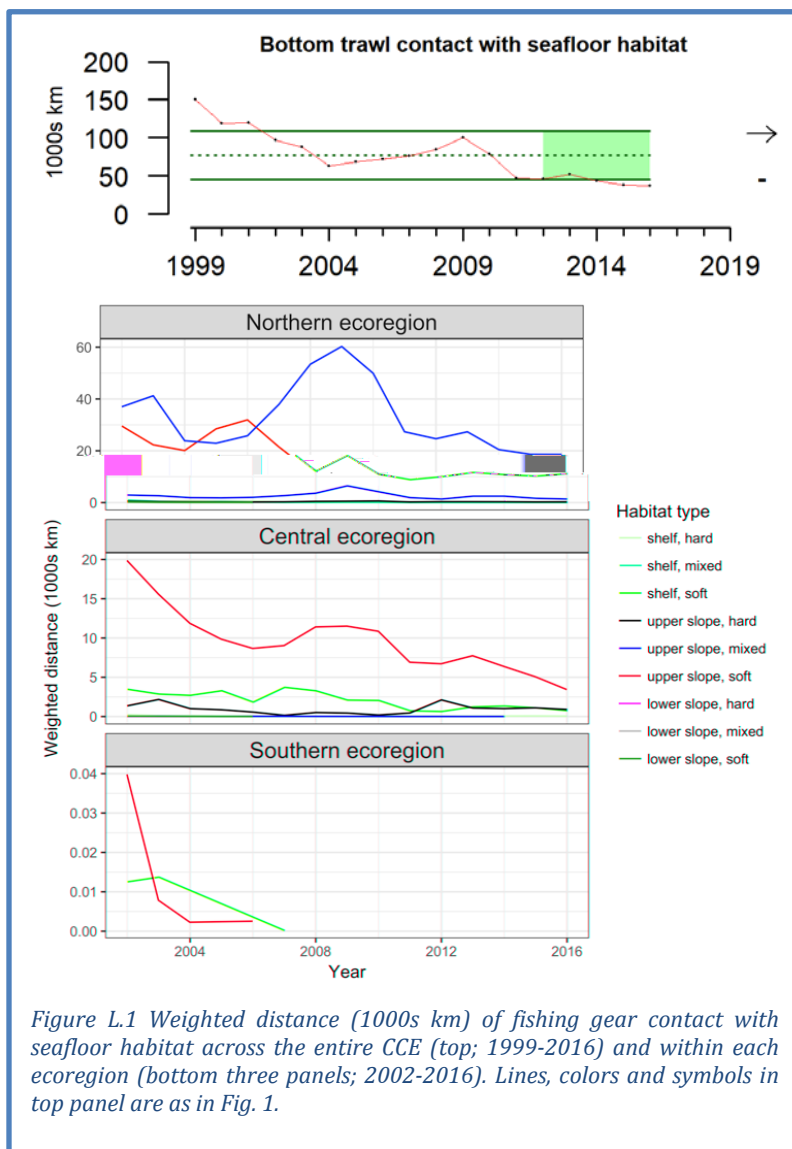
Total revenue across commercial fisheries in Washington remained relatively unchanged and above the long-term average from 2013–2017 (Figure K.2.4). This was a similar pattern to that observed in Oregon over the same time period (Figure K.2.3). This pattern in Washington is primarily driven by the relatively consistent and above-average levels of revenue for crab and HMS and the peak in revenue in the shrimp fisheries observed in 2015. Revenue for CPS fisheries decreased from 2013–2017, while all other fisheries showed no recent trends in revenue. Revenue of groundfish (excluding hake) remained consistently below historic averages from 2013–2017, while revenue from Pacific hake, salmon and Other species showed no significant trends and were within 1 s.d. of long-term averages over the last 5 years.



## Appendix L FISHING GEAR CONTACT WITH SEAFLOOR HABITAT

In Section 5.2 of the report, we presented a spatial representation of the status and trends of gear contact with the seafloor as a function of distances trawled. We used estimates of coastwide distances exposed to bottom trawl fishing gear along the ocean bottom from 1999–2016. We calculated trawling distances based on set and haul-back locations. We weighted distances by fishing habitat according to sensitivity values described in Table A3a.2 of the 2013 Groundfish EFH Synthesis Report to PFMC. Data come from logbooks analyzed by the Northwest Fisheries Science Center’s West Coast Groundfish Observer Program. Here, we present time series of the data at a coastwide scale and broken out by ecoregion (Northern, north of Cape Mendocino; Central, Cape Mendocino to Point Conception; and Southern, south of Point Conception), substrate type (hard, mixed, soft) and depth zone (shelf, upper slope, lower slope).

At the scale of the entire coast, bottom trawl gear contact with seafloor habitat remained consistently at historically low levels from 2012–2016 (Figure L.1, top). During this period, the vast majority of bottom trawl gear contact occurred in soft upper slope and soft shelf habitats (Figure L.1, bottom). The Northern ecoregion also has seen the most bottom trawl fishing gear contact with seafloor habitat with nearly four times the magnitude as observed in the central ecoregion. Very little to no bottom trawling has occurred in the Southern ecoregion within the time series. A shift in trawling effort from shelf to upper slope habitats was observed during the mid-2000’s, which in part corresponded to depth-related spatial closures implemented by the Council. With new regulations beginning, this indicator will be of interest to monitor over the next few years for changes in bottom trawl fishing effort. Reduced bottom trawl gear contact may not coincide with recovery times of habitat depending on how fast recovery happens, which is likely to differ among habitat types (e.g., hard and mixed habitats will take longer to recover than soft habitat).



## Appendix M SOCIAL VULNERABILITY OF FISHING-DEPENDENT COMMUNITIES

In Section 6.1 of the main report, we present information on the Community Social Vulnerability Index (CSVI) as an indicator of social vulnerability in coastal communities that are dependent upon commercial fishing. Fishery *dependence* can be expressed by two terms, or by a composite of both. Those terms are engagement and reliance. *Engagement* refers to the total extent of fishing activity in a community; engagement can be expressed in terms of commercial activity (e.g., landings, revenues, permits, processing, etc.) or recreational activity (e.g., number of boat launches, number of charter boat and fishing guide license holders, number of charter boat trips, number of bait and tackle shops, etc.). *Reliance* is the per capita engagement of a community; thus, in two communities with equal engagement, the community with the smaller population would have a higher reliance on its fisheries activities.

In the main body of the report, Figure 6.1.1 and Figure 6.1.2 plot CSVI in 2016 against commercial and recreational fishing reliance, respectively, for the five most dependent communities in each sector from each of five regions of the CCE. Here, we present similar plots of CSVI relative to commercial and recreational fishing engagement scores. We then compare communities based on their relative commercial:recreational fishing reliance and engagement.

Figure M.1 shows commercial fishing-engaged communities and their corresponding social vulnerability results. Communities above and to the right of the dashed lines are at least 1 s.d. above the coastwide averages of both indices. Of note are communities like Westport, Crescent City, and Port Orford, which have relatively high commercial fishing engagement results and also a high CSVI composite result.

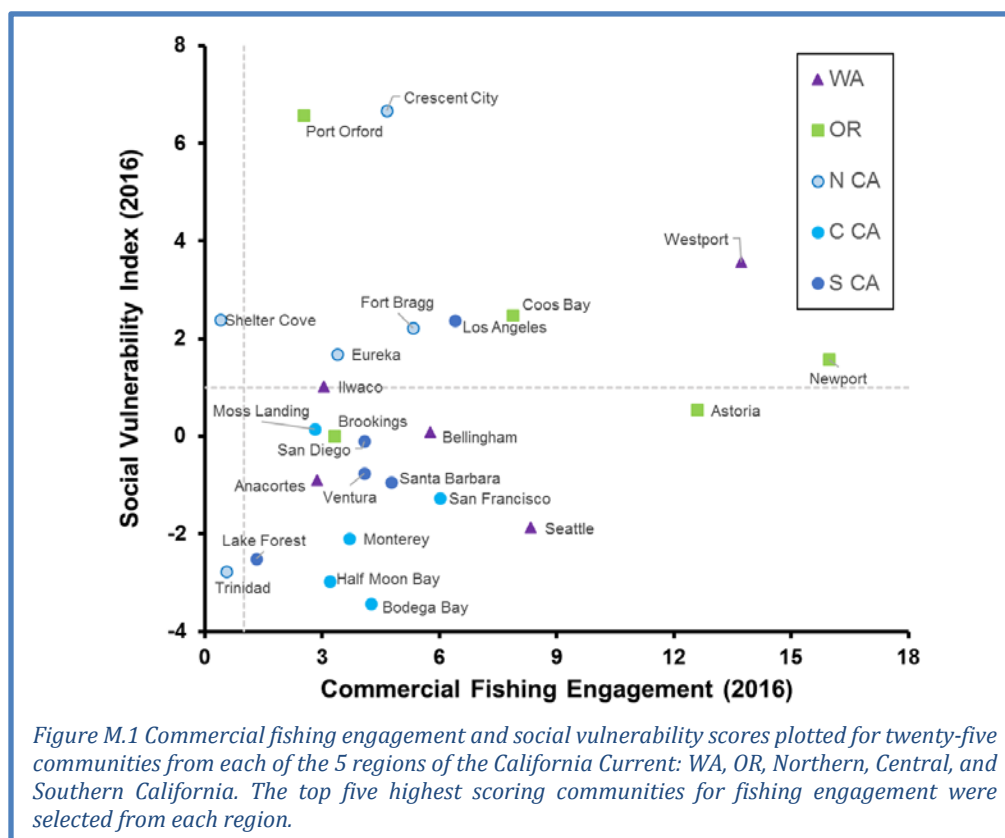
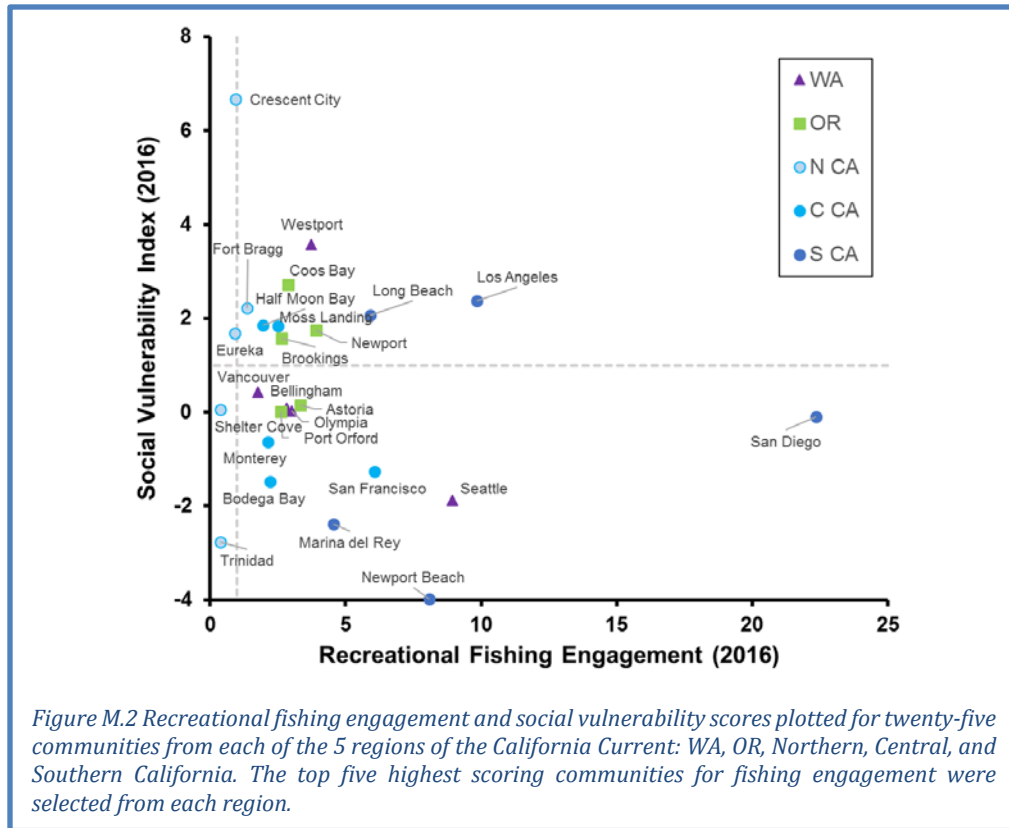


Figure M.2 shows recreational fishing-engaged communities with their corresponding social vulnerability results. Of note are communities like Los Angeles and Westport, which have relatively high recreational fishing reliance results and also high CSVI composite results. In contrast, San Diego has very high recreational fishing engagement, but relatively low social vulnerability. It is also notable that many (but not all) of the communities in Figures M.1 and M.2 are different from those in Figures 6.1.1 and 6.1.2, because these are total community engagement plots, not per capita reliance plots.



Figures Figure M.3 and M.4 are intended to show that some communities are more dependent upon one sector (commercial or recreational) than the other, while also accounting for CSVI. Figure M.3 plots each community's recreational fishing engagement level against its commercial fishing engagement. The size of the plot point for each community is scaled to approximate the level of social vulnerability for each community. All of the communities from Figures 6.1.1., 6.1.2, Figure M.3 and M.4 are included here; it is thus possible for regions to have more than five communities in these plots. San Diego demonstrates a disproportionately high level of engagement in recreational fishing relative to commercial fishing engagement, while Westport, Newport, and Astoria demonstrate a similarly high level of engagement with commercial fishing relative to recreational engagement.

Similarly, Figure M.4 plots each community's results for recreational fishing reliance against each community's results for commercial fishing reliance. Of particular note are the communities of Westport, Winchester Bay and Ilwaco, which exhibit relatively high levels of commercial fishing reliance, recreational fishing reliance and general social vulnerability. Moss Landing and Elkton both present relatively high social vulnerability, and appear as examples of communities that are both outliers in terms of their degrees of reliance on commercial fishing (Moss Landing) and recreational fishing (Elkton).

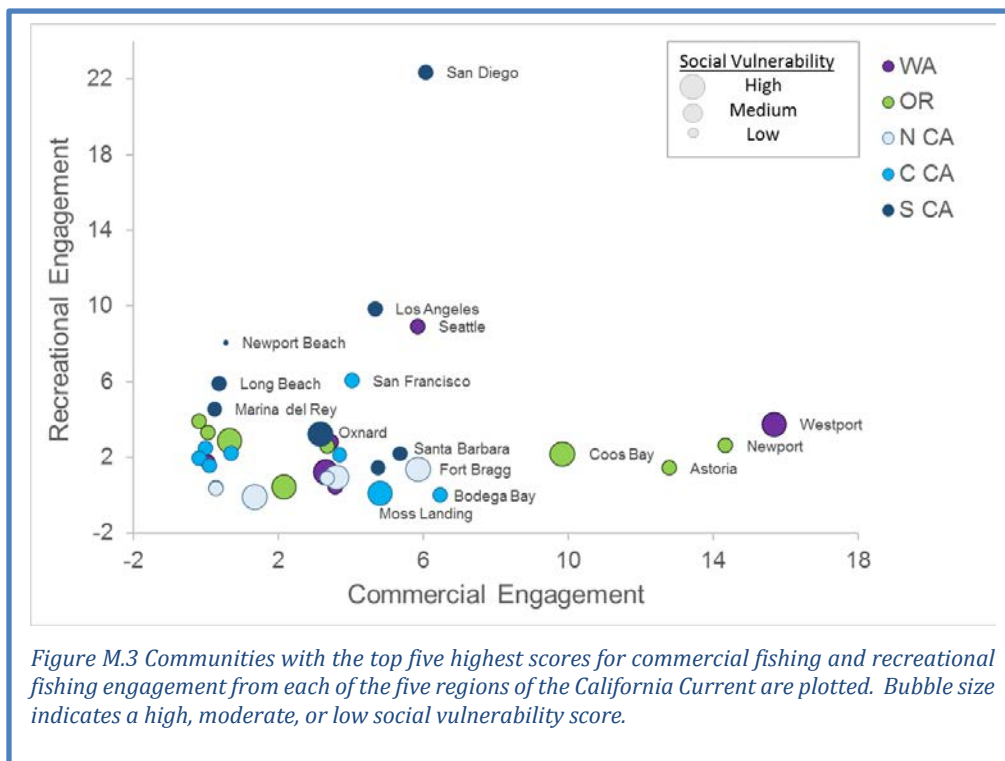


Figure M.3 Communities with the top five highest scores for commercial fishing and recreational fishing engagement from each of the five regions of the California Current are plotted. Bubble size indicates a high, moderate, or low social vulnerability score.

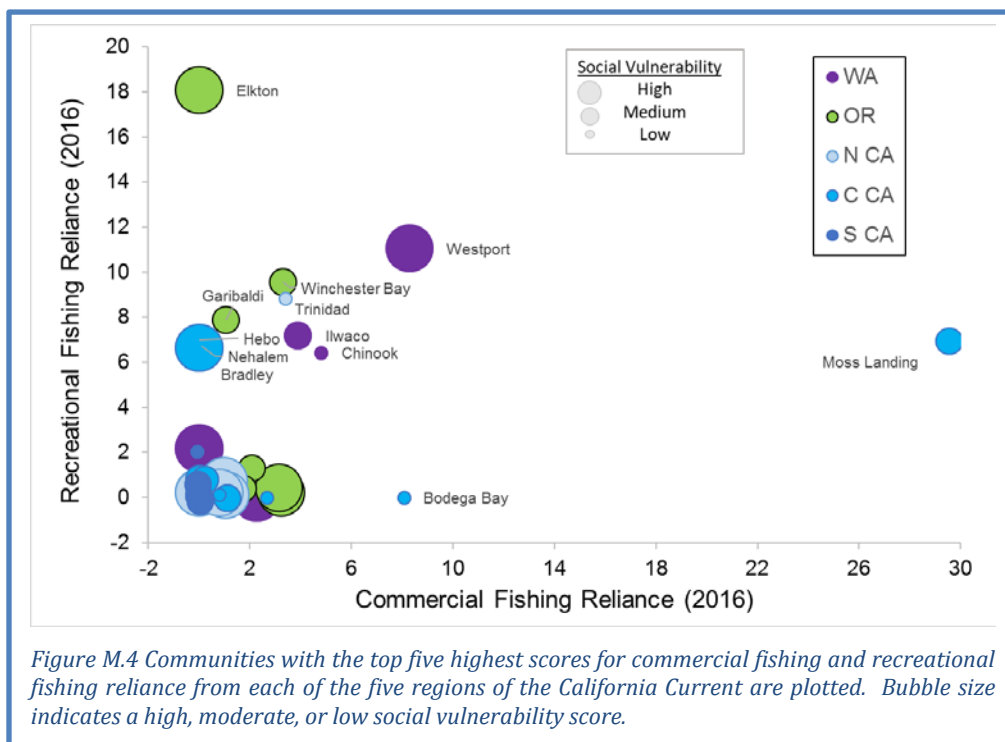


Figure M.4 Communities with the top five highest scores for commercial fishing and recreational fishing reliance from each of the five regions of the California Current are plotted. Bubble size indicates a high, moderate, or low social vulnerability score.

## Appendix N FLEET DIVERSIFICATION INDICATORS FOR MAJOR WEST COAST PORTS

Catches and prices from many fisheries exhibit high inter-annual variability leading to high variability in fishermen's revenue, but variability can be reduced by diversifying fishing activities across multiple fisheries or regions (Kasperski and Holland 2013). We use the effective Shannon index (ESI) to measure fishing vessel diversification. ESI increases as revenues are spread across *more* fisheries, and as revenues are spread more *evenly* across fisheries; ESI = 1 when a vessel's revenues are from a single species group and region; ESI = 2 if revenues are spread evenly across 2 fisheries; and so on. If revenue is not evenly distributed across fisheries, then the ESI value is lower than the number of fisheries a vessel enters.

As is true with individual vessels, the variability of landed value at the port level is reduced with greater diversification of landings. Diversification of fishing revenue has declined over the last several decades for some ports (Figure N.1). Examples include Seattle and most, though not all, of the ports in Southern Oregon and California. However, a few ports have become more diversified, such as Bellingham Bay. Diversification scores are highly variable year-to-year for some ports, particularly those in Southern Oregon and Northern California that depend heavily on the Dungeness crab fishery, which has highly variable landings. Many major ports saw a decrease in diversification between 2016 and 2017, but others saw an increase. No clear recent trends are apparent.

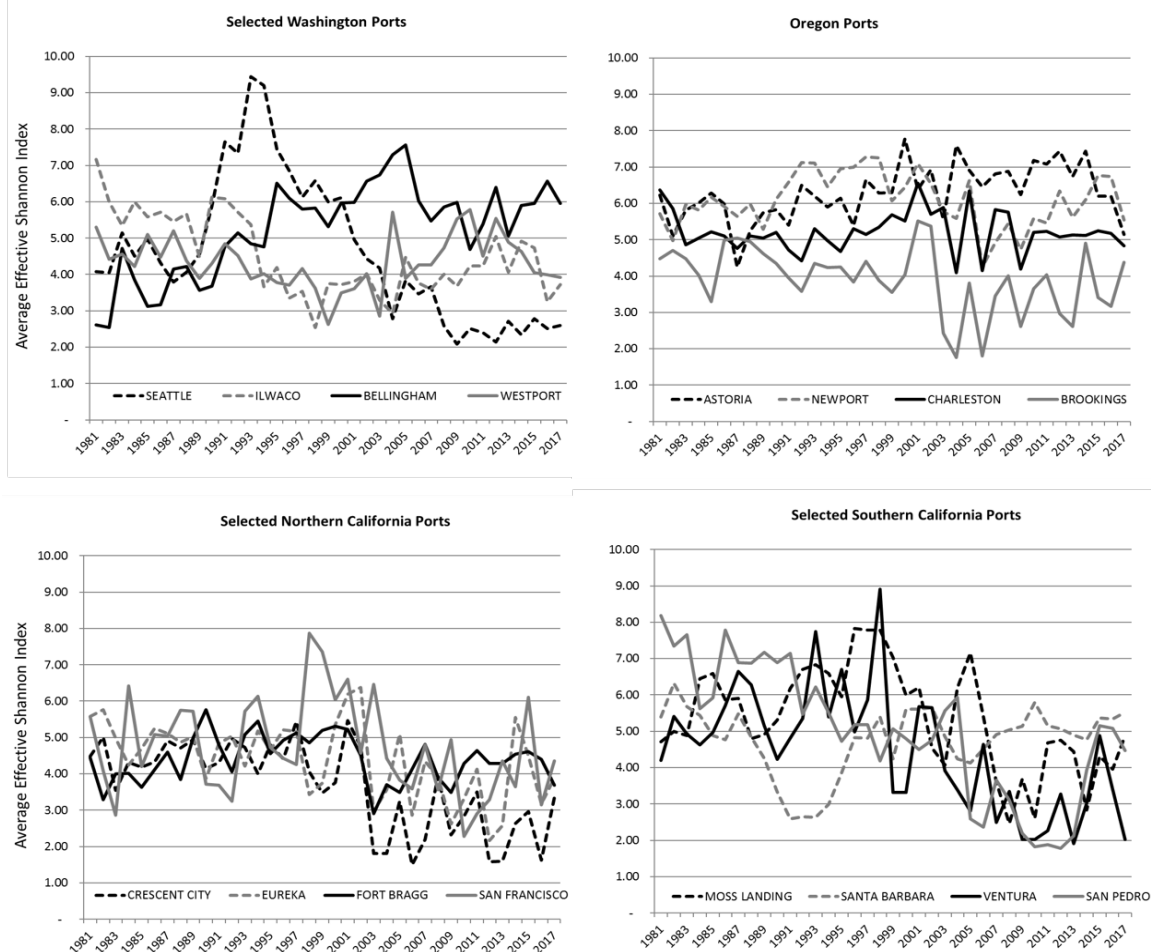


Figure N.1 Trends in diversification in major west coast ports for Washington, Oregon, and California

## Appendix 0 METHODS FOR ESTIMATING GROUNDFISH STOCK AVAILABILITY TO WEST COAST FISHING PORTS

In section 6.3, we introduced an analysis describing shifts in availability of petrale sole and sablefish to the ports of Astoria, Coos Bay, Fort Bragg, and Morro Bay, as a function of changing stock abundance (derived from stock assessments) and spatial distribution (derived from VAST analysis of fishery-independent groundfish survey data).

We estimated stock biomass  $b(s,t)$  for each species at each location within the spatial sampling domain of the NWFSC West Coast Groundfish Bottom Trawl Survey and any year  $t$  from 1977-2017. To do so, we combined two sources of information:

1. Stock assessment estimate of total population biomass  $B(t)$ , developed based on many different data sources. The estimates account for age- and length-based selectivity and catchability within available survey data. By doing so, the assessment also estimates the proportion of total abundance that is not vulnerable to a given survey gear.
2. Spatio-temporal estimates of biomass-density  $d(s,t)$  at each location, where each location is associated with area  $a(s)$  within the sampling domain. These estimates are obtained from available survey data from two different survey sampling designs: the triennial bottom trawl survey (operating 1977-2004) and the annual bottom trawl survey (operating 2003-present). Spatio-temporal analysis (VAST; reviewed by the SSC-ES in September 2018) allows us to estimate the spatial distribution of biomass vulnerable to each sampling gear.

These two data sources predict total biomass (biomass both vulnerable and invulnerable to the trawl survey) at each location using the following equation:

$$b(s,t) = B(t) \frac{a(s)d(s,t)}{\sum_{s=1}^n a(s)d(s,t)}$$

Estimates of biomass density  $d(s,t)$  (in units kg/km<sup>2</sup>) associated with each spatial location  $s$  were multiplied by the area  $a(s)$  associated with each location (km<sup>2</sup>) to generate a location-specific biomass estimate (in units kg). Relative biomass in each location was calculated by dividing the area-level biomass (kg) by the region-wide biomass (kg). Total stock biomass (mt) associated with each location  $b(s,t)$  was computed by multiplying the relative biomass in each location by the total stock-level spawning biomass (mt).

This calculation implicitly assumes that the ratio of vulnerable and invulnerable biomass is constant across space within each year. Future research could develop a spatio-temporal assessment model to estimate spatial variation in catchability, but the current effort is the first to correct estimates of spatial distribution from a spatio-temporal model to account for vulnerability estimates from a stock assessment model (arising from the net effect of catchability and selectivity-at-age estimates).

An index of port-specific stock availability for each species  $A(p,t)$  was created from the log of the average stock biomass (metrics tons) weighted by the inverse distance ( $D$ ) of the location to a port (km):

$$A_{p,t} = \sum_{s=1}^n b(s,t) \frac{1}{D(s,p)}$$

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