CCIEA ESR Technical Documentation

California Current Integrated Ecosystem Assessment

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Preface

This document is our initial attempt at consolidating in one place the detailed methods used to collect and analyze the indicator data presented in the California Current Ecosystem Status Report (ESR). This online technical documentation archive is designed to serve as a repository for the methods used to access, collect, process, and analyze the indicators presented in the report, while also reducing the length of the ESR and the redundancy among the annual reports.

This repository will be provided both as an online website https://cciea-esr.github.io/ESR-Technical-Documentation-FY2025/ and a time-stamped Appendix (Appendix V) to the 2024-25 report, until it is reviewed by the SSC and Council. Thereafter, however, we intend for it to exist solely as an evolving online repository that documents changes to the indicator portfolio, the source data, and the methods used to derive them.

Chapters of this document are organized similarly to the structure of the ESR (i.e. one "chapter" of the technical documentation per section of the ESR). In some cases, we also may also include detailed methods for indicators that no longer are published in the most current version of the ESR document.

We thank the scientists at the Northeast Fisheries Science Center (DePiper et al. 2017) who provided the inspiration and initial template for some of this work https://noaa-edab.github.io/tech-doc/index.html.

Introduction

The purpose of this document is to collate the methods used to access, collect, process, and analyze derived data ("indicators") used to describe the status and trend of social, economic, ecological, and biological conditions in the California Current Large Marine Ecosystem (see Fig. 1, below). These indicators are further synthesized in Ecosystem Status Reports produced annually by the Northwest and Southwest Fisheries Science Centers for the Pacific Fisheries Management Council. The metadata for each indicator (in accordance with the Public Access to Research Results (PARR) directive) and the methods used to construct each indicator are described in the subsequent chapters, with each chapter title corresponding to an indicator or analysis present in Ecoystem Status Reports. The most recent and usable html version of this document can be found at https://cciea-esr.github.io/ESR-Technical-Documentation-FY2025/. The PDF version of this and future versions document will be archived in NOAA's Institutional Repository.

Indicators included in this document were selected to clearly align with management objectives, which is required for integrated ecosystem assessment (Levin et al. 2009), and has been advised many times in the literature (Degnbol and Jarre 2004; Jennings 2005; Rice and Rochet 2005; Link 2005). A difficulty with practical implementation of this in ecosystem reporting can be the lack of clearly specified ecosystem-level management objectives (although some have been suggested (Murawski 2000)). In our case, considerable effort had already been applied to derive both general goals and operational objectives from both US legislation such as the Magnuson-Stevens Fisheries Conservation and Management Act (MSA) and regional sources (Harvey et al. 2021).

SAMPLING LOCATIONS

We generally refer to areas north of Cape Mendocino as the "Northern CCE," Cape Mendocino to Point Conception as the "Central CCE", and south of Point Conception as the "Southern CCE." Figure 1 shows sampling areas for most regional oceanographic data. Key oceanographic transects are the Newport Line off Oregon, the Trinidad Head Line off northern California, and CalCOFI lines further south, while shaded marine regions indicate sampling areas for most biological surveys. This sampling is complemented by basin-scale oceanographic observations and by outputs from various models. Figure 1 also shows sampling areas for most biological indicators. The shaded terrestrial areas in Figure 1 represent freshwater ecoregions in the

CCE, and are the basis by which we summarize indicators for snowpack, flows, and stream temperatures.

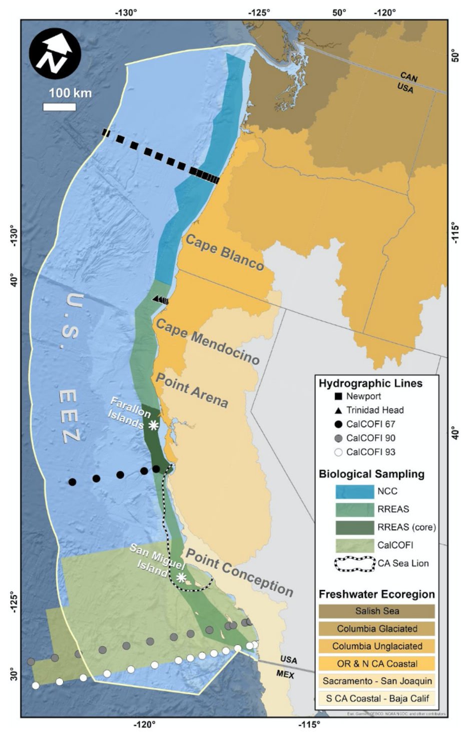

Figure 1: Map of most sampling efforts in the California Current Ecosystem (CCE) and U.S. west coast Exclusive Economic Zone (EEZ). Symbols indicate hydrographic line sampling stations for oceanographic data. Shaded ocean regions represent biological sampling areas for the Northern California Current (NCC), which includes the Juvenile Salmon and Ocean Ecology Survey (JSOES); the Rockfish Recruitment and Ecosystem Assessment Survey (RREAS), including its Core Area; and the CalCOFI sampling region. The NCC and RREAS shaded areas, combined, also approximate the survey footprints for NOAA's coastwide CPS acoustic/trawl and groundfish bottom trawl surveys. Dashed line approximates foraging area for adult female California sea lions from the San Miguel colony. Shaded terrestrial areas represent the six freshwater ecoregions in the CCE.

Part I

General Methods

1 Data and Code Access

About the CCIEA Ecosystem Status Report (ESR) The annual CCIEA Ecosystem Status Report (ESR) is a Quarto document; hosted on the NOAA Northwest Fisheries Science Center (NWFSC) Github page, and developed in R.

Indicator data Derived data sets make up the majority of the indicators presented in the CCIEA ESR. In this technical documentation, we list the derived indicators, their source, and where possible, the computations used to produce them from the raw data. This metadata is also publicly available for download. The derived indicator data can be downloaded using links in the sections of this document unless there are privacy concerns involved. In that case, it may be possible to access source data by reaching out to the Data Steward associated with that data set.

Data flow Indicator data is submitted by data providers in a standard format consisting of "long" csv files with standardized column headers and consistent file names. These requirement allow all indicators to be handled with the same R plotting code and enable automation of the data upload process.

After uploading, standardized data and metadata is organized on a private Google Drive by ESR year, and served publicly via ERDDAP™ (Simons and John 2022)

References

2 Time Series and Quadplots

Methods The California Current Ecosystem Status Report uses a standard time-series and quadplot format for many data streams (Fig. 2.1).

The standard time-series plot (a) shows indicator data relative to the mean and ±1.0 standard deviation of the long-term statistical evaluation period–set to a "climatology" period of 1991-2020 for all time series to match climate and oceanographic approaches. Black points (when included) indicate data, whereas dotted black lines are used to indicate missing data. The arrow at the right indicates if the trend over the evaluation period (shaded blue) is positive ( ), negative ( ), or neutral ( ). The symbol at the lower right indicates if the recent mean was greater than (+), less than (-), or within 1.0 SD of the long-term mean. When possible, times series indicate observation error (gray envelope), defined for each plot (e.g., SD, standard error, or 95% confidence intervals).

In some cases where the indicator has defined threshold values (e.g., hypoxia or domoic acid toxicity levels), the time-series plot (b) shows the indicator data relative to these threshold value, indicated with a blue line. In this case, dashed lines indicate upper and lower observation error, and the dotted black lines indicate missing data.

Sample quad plots (c) are also used in some other cases (e.g., streamflow), where each point represents one normalized time series. The position of a point indicates if the recent trend (x-axis) was increasing or decreasing over the evaluation period and whether the recent mean (y-axis) was above or below the evaluation period mean. Symbols fall therefore fall into quadrants based on recent average (high or low) and recent trend (increasing or decreasing) relative to a defined, long-term evaluation period.

Data Source(s) NA

Data Extraction NA

Data Analysis NA

References

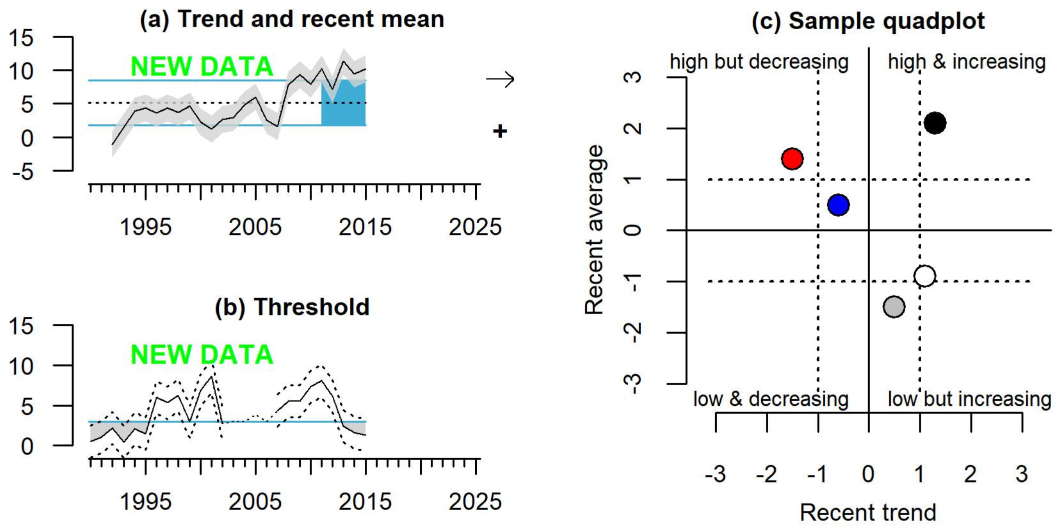

Figure 2.1: a) Sample time-series plot, with indicator data relative to the mean (black dashed horizontal line) and ±1.0 standard deviation (SD; solid blue lines) of the long-term statistical evaluation period (1991-2020). Dotted black line indicates missing data, and points (when included) indicate data. Arrow at the right indicates if the trend over the evaluation period (shaded blue) is positive ( ), negative ( ), or neutral ( ). Symbol at the lower right indicates if the recent mean was greater than (+), less than (-), or within 1.0 SD of the long-term mean. When possible, times series indicate observation error (gray envelope), defined for each plot (e.g., SD, standard error, or 95% confidence intervals). b) Sample time-series plot with the indicator plotted relative to a threshold value (blue line). Dashed lines indicate upper and lower observation error, again defined for each plot. Dotted black line indicates missing data. c) Sample quad plot where each point represents one normalized time series. The position of a point indicates if the recent trend was increasing or decreasing over the evaluation period and the position of the recent average relative to the evaluation period.

Part II

Climate and Oceans

3 ONI (Oceanic Niño Index)

Description The CCLME is driven by atmosphere–ocean energy exchange that occurs on many temporal and spatial scales. El Niño–Southern Oscillation (ENSO) events impact the CCLME by modifying the jet stream and storm tracks, changing the nearshore thermocline, and influencing coastal currents that affect poleward transport and distribution of equatorial and subequatorial waters (and species). the status of the equatorial ENSO is described by the Oceanic Niño Index. An ONI above 0.5°C indicates El Niño conditions, which often lead to lower primary production, weaker upwelling, poleward transport of equatorial waters and species, and more southerly storm tracks in the CCE. An ONI below -0.5°C means La Niña conditions, which create atmospheric pressure conditions that lead to upwelling-favorable winds that drive productivity in the CCE.

Oceanic Nino Index

- Component Category: Climate and Ocean Drivers
- Data Steward: isaac.schroeder@noaa.gov
- Institution: NOAA, Climate Prediction Center (CPC)
- Source Data: NOAA/CPC (http://origin.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ON The ONI is the 3 month running mean of sea surface temperature anomalies in the Nino 3.4 region

Data extraction

ERDDAP™ link: https://oceanview.pfeg.noaa.gov/erddap/tabledap/cciea_OC_ONI.html

Data analysis

4 PDO (Pacific Decadal Oscillation)

Description The CCLME is driven by atmosphere–ocean energy exchange that occurs on many temporal and spatial scales. The Pacific Decadal Oscillation (PDO) describes North Pacific sea surface temperature (SST) anomalies that may persist for many years. Positive PDOs are associated with warmer SST and lower productivity in the CCE, while negative PDOs indicate cooler SST and are associated with higher productivity.

Pacific Decadal Oscillation Index

- Component Category: Climate and Ocean Drivers
- Data Steward: isaac.schroeder@noaa.gov
- Institution: NOAA SWFSC/FED
- Source Data: **Note: 2023-03-10 UW-JISAO PDO is not longer being updated. This PDO is now ERSST V5** PDO index is defined as the projections of the ERSST V5 monthly SSTA onto the 1st EOF pattern of North Pacific 20N-60N. 1900-1993 DATA from ERSST V3b is used to derived the climatology and the 1st EOF pattern.Reference: Wen, C., A. Kumar, and Y. Xue, 2014: Factors contributing to uncertainty in Pacific decadal oscillation index. Geophys. Res. Lett., 41, 7980-7986, doi:https://doi.org/10.1002/2014GL061992 ERSST.V5 : Huang, B., Peter W. Thorne, et. al, 2017: Extended Reconstructed Sea Surface Temperature version 5 (ERSSTv5), Upgrades, validations, and intercomparisons. J. Climate Smith, T. M., Reynolds, R. W., Peterson, T. C., and Lawrimore, J. (2008), Improvements to NOAA's historical merged land-ocean surface temperature analysis (1880-2006), J. Clim., 21(10), 2283-2296.

Data extraction

ERDDAP™ link: https://oceanview.pfeg.noaa.gov/erddap/tabledap/cciea_OC_PDO.html

5 NPGO (North Pacific Gyre Oscillation)

Description The CCLME is driven by atmosphere–ocean energy exchange that occurs on many temporal and spatial scales. The North Pacific Gyre Oscillation (NPGO) is a low-frequency variation of sea surface height, indicating variations in the circulation of the North Pacific Subtropical Gyre and the Alaskan Gyre, which in turn relate to the source waters for the CCLME. Positive NPGO values are associated with increased equatorward flow, along with increased surface salinities, nutrients, and chlorophyll-a. Negative NPGO values are associated with decreases in such values, implying less subarctic source water and generally lower productivity.

North Pacific Gyre Oscillation Index

- Component Category: Climate and Ocean Drivers
- Data Steward: isaac.schroeder@noaa.gov
- Institution: Georgia Institute of Technology (GT)
- Source Data: http://www.o3d.org/npgo/npgo.php The NPGO is calculated from an Empirical Orthogonal Function analysis of sea-surface height in the Northeast Pacific. The NPGO is the second dominant mode.

Data extraction

ERDDAP™ link: https://oceanview.pfeg.noaa.gov/erddap/tabledap/cciea_OC_NPGO.html

6 North Pacific High Indicators

Description Variations in the areal extent of the North Pacific High (NPH) during the winter is predictive of winter upwelling. The January and February average of the NPH area can be used as a "preconditioning" index for ecosystem responses in the spring.

- Indicators:
  - North Pacific High Area
  - North Pacific High Area, January - February Mean
- Component Category: Climate and Ocean Drivers
- Data Steward: isaac.schroeder@noaa.gov
- Institution: NOAA SWFSC/ERD
- Source Data: Variations in large-scale atmospheric forcing influence upwelling dynamics and ecosystem productivity in the California Current System.The area of the North Pacific High (NPH) is characterized by areal extent of the 1020 Pa isobar. Winter values (January - February mean) of the NPH area can be used as an ecosystem pre-conditioning index (Schroeder et al., doi:10.1002/grl.50100).The area of the NPH are calculated from monthly mean sea level pressure (SLP) fields created by the U.S. Navy Fleet Numerical Meterology and Oceanography Center (FNMOC). Monthly SLP data available at https://upwell.pfeg.noaa.gov/erddap/index.html , search for Dataset ID: erdlasFnWPr. The area is the areal extent of the 1020 hPa contour for a given month. The January - February mean is the average of the January and February areas for a given year.
- Additional Calculations: The NRT ROMS temperature data downloaded from the UCSC website (http://oceanmodeling.pmc.ucsc.edu:8080/thredds) has grid points with 2 m temperature data reported as Not-A-Number, these values are 2 m temperatu. Tdata at these grid points are obtained by extrapolating the data to 2 m depth using the interp1d routine from the Python library scipy.interpolate sub-package.

Data sources The U.S. Navy Fleet Numerical Meteorology and Oceanography Center (FNMOC) to take advantage of the Navy's global oceanographic and meteorological databases. FNMOC produces operational forecasts of the state of the atmosphere and the ocean several times daily and maintains archives of several important parameters, such as sea level pressure and temperature. The NPH area is derived from FNMOC Sea Level Pressure (SLP) monthly means. The SLP data are available at https://upwell.pfeg.noaa.gov/erddap/griddap/erdlasFnWPr.html.

Additional Information During the winter, periods of upwelling or, farther north, reduced downwelling can limit stratification and facilitate introduction of nutrients to the surface, acting to precondition the ecosystem for increased production in the spring (Isaac D. Schroeder et al. 2009; Black et al. 2010). The area of sea level pressure associated with the North Pacific High (NPH) can be used as an index of this winter preconditioning (Isaac D. Schroeder et al. 2013).

Data extraction

ERDDAP™ links:

https://oceanview.pfeg.noaa.gov/erddap/tabledap/cciea_OC_NPH.html https://oceanview.pfeg.noaa.gov/erddap/tabledap/cciea_OC_NPH_JF.html

References

7 SST (Sea Surface Temperature)

Buoy Data

Indicators

- Latitudes:
  - 33.7 N
  - 39.2 N
  - 44.6 N
- Component Category: Climate and Ocean Drivers
- Data Steward: isaac.schroeder@noaa.gov
- Institution: NOAA NDBC, NOAA
- Source Data: NOAA/ERD (https://coastwatch.pfeg.noaa.gov/erddap/tabledap/cwwcNDBCMet.html) NOAA NDBC (https://www.ndbc.noaa.gov/)
- Additional Calculations: The National Data Buoy Center (NDBC) distributes meteorological data from moored buoys maintained by NDBC and others. This dataset is a standardized, reformatted, and lightly edited version of that source data, created by NOAA NMFS SWFSC ERD and then monthly averaged. See the summary global attribute at https://coastwatch.pfeg.noaa.gov/erddap/info/cwwcNDBCMet/index.html

Data extraction

ERDDAP™ link: https://oceanview.pfeg.noaa.gov/erddap/tabledap/cciea_OC_SST.html

Satellite data

Satellite data which has been collected in a similar fashion since 1982, allows for a basin-scale view of sea surface temperature (SST) at up to daily and sub-degree (spatial) resolution.

Glider data

Glider data has also become an increasingly useful tool for analyzing trends in subsurface water temperatures over time. Subsurface gliders, which generally sample in onshore-offshore transects on a weekly to monthly basis, have been in service long enough for the development of climatologies, which are then used to compute temperature anomalies.

References

8 SST anoms, 5-year means and trends

```
cciea_yr <- 2024
```

Description Seasonal SST summary maps are derived from the three statistics shown in the IEA type time series (current value, mean and trend over the last 5 years). The current value is shown as an anomaly and the 5-year mean and trend are

Indicator Category Climate and Ocean Drivers

Data Steward Schroeder

Additional Information The seasonal averages are: winter (Jan-Mar), spring (Apr-Jun), summer (Jul-Sep), and summer (Oct-Nov). Daily SST maps are optimally interpolated, remotely sensed temperatures (Huang et al. 2021). The daily optimal interpolated AVHRR SST can be downloaded from ERDDAP, https://coastwatch.pfeg.noaa.gov/erddap/index.html, dataset ID: ncdcOisst21Agg.

References

9 Marine Heatwaves

Description Marine heatwaves (MHW) occur when ocean temperatures are much warmer than usual for an extended period of time; they are specifically defined by the difference between the current temperature and the expected temperature for a specific location and time of year [1]. MHWs are a growing field of study worldwide because of their effects on ecosystem structure, biodiversity, and regional economies.

Indicators

- Marine Heat Wave Heatwave Cover
  - *Component Category:* Climate and Ocean Drivers
  - *Data Steward:* andrew.leising@noaa.gov
  - *Institution:* NOAA/SWFSC/ERD
  - *Source Data:* Marine heatwaves, or MHWs, occur when ocean temperatures are much warmer than usual for an extended period of time; they are specifically defined by differences in expected temperatures for the location and time of year. MHWs are a growing field of study worldwide because of their effects on ecosystem structure, biodiversity, and regional economies. Developed by oceanographers from NOAA Fisheries' Southwest Fisheries Science Center as an experimental tool for natural resource managers, the California Current MHW Tracker is a program designed to understand, describe, and provide a historical context for the 2014-16 blob. It also produces a range of indices that could help forecast or predict future MHWs expected to impact our coast.
- Marine Heat Wave Maximum Area
  - *Component Category:* Climate and Ocean Drivers
  - *Data Steward:* andrew.leising@noaa.gov
  - *Institution:* NOAA/SWFSC/ERD
  - *Source Data:* Marine heatwaves, or MHWs, occur when ocean temperatures are much warmer than usual for an extended period of time; they are specifically defined by differences in expected temperatures for the location and time of year. MHWs are a growing field of study worldwide because of their effects on ecosystem structure, biodiversity, and regional economies. Developed by oceanographers from NOAA Fisheries' Southwest Fisheries Science Center as an experimental tool for natural resource managers, the California Current MHW Tracker is a program designed to understand, describe, and provide a historical context for the 2014-16 blob. It

also produces a range of indices that could help forecast or predict future MHWs expected to impact our coast.

- Marine Heat Wave Maximum Intensity
  - *Component Category:* Climate and Ocean Drivers
  - *Data Steward:* andrew.leising@noaa.gov
  - *Institution:* NOAA/SWFSC/ERD
  - *Source Data:* Marine heatwaves, or MHWs, occur when ocean temperatures are much warmer than usual for an extended period of time; they are specifically defined by differences in expected temperatures for the location and time of year. MHWs are a growing field of study worldwide because of their effects on ecosystem structure, biodiversity, and regional economies. Developed by oceanographers from NOAA Fisheries' Southwest Fisheries Science Center as an experimental tool for natural resource managers, the California Current MHW Tracker is a program designed to understand, describe, and provide a historical context for the 2014-16 blob. It also produces a range of indices that could help forecast or predict future MHWs expected to impact our coast.

Additional Information

There is growing recognition that marine heatwaves can have strongly disruptive impacts on the CCE (Morgan et al. 2019). Based on an analysis of sea surface temperature anomalies (SSTa) obtained from satellite measurements (OISST); we define marine heatwaves as 1.0 times when normalized SSTa >1.29 s.d. (90th percentile) of the long-term SSTa time series at a location, and 2. lasts for >5 days; which are analogous to the thresholds suggested in Hobday et al. (2016). Here, we further report on statistics concerning large heatwaves (LHW) which were tracked through space and time, with LHW defined as those heatwaves with an area > 400,000 km2 (these denote the top 20% of all heatwaves by area as measured since 1982 when satellite data became available for tracking.

The underlying climatology used for SST anomaly analysis has changed from 1982-2010, to now encompass 1982-2020; hence small changes in the retrospective analysis of tracked heatwaves reported more recently as compared to previous reports.

Data extraction

ERDDAP™ link: https://oceanview.pfeg.noaa.gov/erddap/tabledap/cciea_OC_MHW.html

References

10 Habitat Compression Index

Description The Habitat Compression Index (HCI) is the area of cool habitat along the coast, which is suitable for a diverse and productive portion of the CCE food web. HCI is estimated in four biogeographic provinces along the shelf within the CCE. See (Santora et al. 2020; Isaac D. Schroeder et al. 2022) for more information.

Indicators

- Latitude bands:
  - 30 - 35.5 N
  - 35.5 - 40 N
  - 40 - 43.5 N
  - 43.5 - 48 N
- Component Category: Climate and Ocean Drivers
- Data Steward: isaac.schroeder@noaa.gov
- Institution: NOAA SWFSC/FED
- Source Data: The habitat compression index uses 2 m temperature from the historic and NRT data assimilative ROMS physical model of the California Current system (http//:oceanmodeling.ucsc.edu/index.html). Grid points between 30-48 degrees N and from the shore out to 150 km offshore are used in the analysis.
- Additional Calculations: In eastern boundary upwelling ecosystems the spatial footprint of cool upwelled water is regularly demarcated by the differential boundary of warmer oceanic water offshore from cooler coastal water, with upwelling conditions varying with latitude. Therefore, the goal of the habitat compression index (HCI) is to track the area of cool surface waters as an index of potential 'upwelling habitat' for assessing the spatio-temporal aspects of upwelling. Upwelling patterns of cold nutrient-rich water are clearly assessed by models and satellite observations and classified spatially by monitoring SST values less than and equal to a monthly resolved temperature threshold. The HCI tracks the amount of area, determined by the number of grid cells in the model with 2 m surface temperature values less than the monthly temperature threshold, therefore the time series reflects the area of cool water adjacent to the coastline and provides a measure for how compressed cool surface temperatures may be in a particular month. In this study (Schroeder et al. 2022; https://www.sciencedirect.com/science/article/pii/S1470160X22009931), we extracted modeled 2 m temperature fields over the domain of 35.5-40 degree N for each month and

tracked the amount of area with temperature values less than and equal to a monthly temperature threshold, resulting in monthly time series starting January 1980. Monthly temperature thresholds for a given month is the spatial average of 2 m temperature grid cells between 35.5-40N from shore out to 75 km for the time period 1980-2010. Cool expansion periods (low compression) are defined as months with HCI values exceeding + 1 standard deviation (SD) of the full time series, limited cool habitat (high compression) where area of cool water is less than the mean (MN) of the full time series, and periods of medium compression when the area of cool water falls between the +1 SD and the MN.

Public availability statement Source data are publicly available.

Data sources Surface temperature data are the 2 m temperature levels of the University of California Santa Cruz 31-year historical reanalysis (https://oceanmodeling.ucsc.edu/reanalccs31/) and near-real-time (NRT; https://oceanmodeling.ucsc.edu/ccsnrt/) data-assimilative models.

Data extraction

ERDDAP™ link: https://oceanview.pfeg.noaa.gov/erddap/tabledap/cciea_OC_HCI.html

References

11 CUGN glider time-depth

Description Time versus depth profiles of water temperatures off of Monterey (66), Pt Conception (80), and north of San Diego (90) demonstrate the extent of recent warm and cool anomalies into the water column, as well as spatial and temporal dynamics of these anomalies.

Metafile name Not in CCIEA Metadatabase

Indicator Category Climate and Ocean Drivers

Data Steward Schroeder

Erddap Dataset ID NA

CCIEA timeseries ID NA

Region Lines 66, 80, 90

Public availability statement Source data are publicly available.

Data sources Netcdf files of the three lines can be downloaded from https://spraydata.ucsd.edu/projects/CUGN/. The data downloaded are temperature anomalies created by CUGN.

Additional Information The temperature anomaly data provided in the netcdf file has data across the line at 5 m intervals over 0-500 m and distances at 5 km from the coat out to the end of the line (66=400 km, 80=365 km, 90=530 km). Distance can be averaged using Python xarray to select specific distance ranges and then averaging over the distances. The time interval of the netcdf file is 10 days.

12 Upwelling

Description

The CCE is an upwelling dominated system, with the interaction between upwelling, stratification, and source water properties controlling much of coastal temperatures, nutrient input, and overall productivity.

The Coastal Upwelling Transport Index (CUTI, pronounced "cutie") and the Biologically Effective Upwelling Transport Index (BEUTI; pronounced "beauty") leverage state-of-the-art ocean models as well as satellite and in situ data to improve upon historically available upwelling indices for the U.S. west coast (Jacox et al. 2018). CUTI provides estimates of vertical transport near the coast (i.e., upwelling/downwelling). It was developed as a more accurate alternative to the previously available 'Bakun Index'. BEUTI provides estimates of vertical nitrate flux near the coast (i.e., the amount of nitrate upwelled/downwelled), which may be more relevant than upwelling strength when considering some biological responses.

The historical Bakun (Bakun (1973); Bakun (1975)) upwelling indices provide long time series of upwelling, and are based on estimates of offshore Ekman transport driven by geostrophic wind stress. Geostrophic winds are derived from mean surface atmospheric pressure fields provided by the U.S. Navy Fleet Numerical Meteorological and Oceanographic Center (FNMOC), Monterey, CA.

Time series of the upwelling indices provide information on upwelling strength at sub-seasonal frequency and upwelling phenology, and allow interannual comparisons of seasonal upwelling timing and frequency. Additionally, the calculation of cumulative upwelling allows for a comparison of the total amount of upwelling a region receives during the entire course of the year. Cumulative upwelling is calculated as the daily summation of upwelling values (additive for positive upwelling, and subtractive for negative upwelling - aka downwelling) starting on Jan 1 and ending on Dec 31st.

Coastal Upwelling Transport Index (CUTI)

- Latitudes:
  - 33 N
  - 39 N
  - 45 N
- Component Category: Climate and Ocean Drivers

- Data Steward: isaac.schroeder@noaa.gov
- Institution: NOAA/SWFSC/ERD
- Source Data: CUTI is a new upwelling index that leverages state-of-the-art ocean models as well as satellite and in situ data to improve upon historically available upwelling indices for the U.S. west coast. CUTI provides estimates of vertical transport near the coast (i.e., upwelling/downwelling). It was developed as a more accurate alternative to the previously available Bakun Index. See Jacox, M. G., C. A. Edwards, E. L. Hazen, and S. J. Bograd (2018) Coastal upwelling revisited: Ekman, Bakun, and improved upwelling indices for the U.S. west coast. Journal of Geophysical Research, doi:10.1029/2018JC014187.

Biologically Effective Upwelling Transport Index (BEUTI)

- Latitudes:
  - 33 N
  - 39 N
  - 45 N
- Component Category: Climate and Ocean Drivers
- Data Steward: isaac.schroeder@noaa.gov
- Institution: NOAA/SWFSC/ERD
- Source Data: BEUTI is a new upwelling index that leverages state-of-the-art ocean models as well as satellite and in situ data to improve upon historically available upwelling indices for the U.S. west coast. BEUTI provides estimates of vertical nitrate flux near the coast (i.e., the amount of nitrate upwelled/downwelled), which may be more relevant than upwelling strength when considering some biological responses. See Jacox, M. G., C. A. Edwards, E. L. Hazen, and S. J. Bograd (2018) Coastal upwelling revisited: Ekman, Bakun, and improved upwelling indices for the U.S. west coast. Journal of Geophysical Research, doi:10.1029/2018JC014187.

Bakun Upwelling Index

- Latitudes:
  - 33 N
  - 39 N
  - 45 N
- Component Category: Climate and Ocean Drivers
- Data Steward: isaac.schroeder@noaa.gov
- Institution: NOAA/SWFSC/ERD
- Source Data: Upwelling index computed from 1-degree 6-hourly FNMOC sea level pressure 33 degrees of latitude. The coastal Upwelling Index is an index of the strength of the

wind forcing on the ocean which has been used in many studies of the effects of ocean variability on the reproductive and recruitment success of many fish and invertebrate species. NOAA/ERD (https://oceanview.pfeg.noaa.gov/erddap/tabledap/erdUI336hr.html)

Data extraction

ERDDAP™ links:

https://oceanview.pfeg.noaa.gov/erddap/tabledap/cciea_OC_CUTI.html https://oceanview.pfeg.noaa.gov/erddap/tabledap/cciea_OC_BEUTI.html https://oceanview.pfeg.noaa.gov/erddap/tabledap/cciea_OC_UI.html

References

13 Dissolved Oxygen

Description Nearshore dissolved oxygen (DO) depends on many processes, including currents, upwelling, air–sea exchange, and community-level production and respiration in the water column and benthos. DO is required for organismal respiration; low DO can compress habitat and cause stress or die-offs for sensitive species. Waters with DO levels <1.4 mL/L (~ 2 mg/L, note unit change) are considered to be hypoxic; such conditions may occur on the shelf following the onset of spring upwelling, and continue into the summer and early fall months until the fall transition vertically mixes shelf waters. Upwelling-driven hypoxia occurs because upwelled water from deeper ocean sources tends to be low in DO, and microbial decomposition of organic matter in the summer and fall increases overall system respiration and oxygen consumption, particularly closer to the seafloor [(]Chan et al. (2008)].

CalCOFI Indicators

- Locations:
  - 150 m: 800_800
  - 150 m: 900_900
  - 150 m: 933_300
- Component Category: Climate and Ocean Drivers
- Data Steward: isaac.schroeder@noaa.gov
- Institution: NOAA SWFSC
- Source Data: Isaac Schroeder (isaac.schroeder@noaa.gov) Dissolved oxygen is measured by an automated oxygen titrator mounted to the CTD rosette and oxygen data is sampled at depths consistent with those of temperature and salinity. Additional information can be found at http://www.calcofi.org/new.data/index.php/reporteddata/hydrographic-data/introductions.
- Additional Calculations: Each unique depth profile of dissolved oxygen (DO) was linearly interpolated on 1 m intervals, without any extrapolation for intervals above/below sampled depths. Outliers a profile might contain were removed by applying a Hample filter. The filter had a window size of 5 m above and below an observation, and considers the observation an outlier if a sample differs from the median by more than four standard deviations (see https://www.mathworks.com/help/signal/ref/hampel.html). Outliers are filled by linear interpolation of the points above and below. Then the DO at 150 m (DO@150) was extracted from the linearly interpolated profile. A time series of DO@150 was created using each unique profile of DO data available. A monthly mean time series

was calculated from this time series. A standard deviation value was calculated if more than one profile was made during a given month, otherwise the standard deviation value was NaN (not a number).

Newport Line Indicators

- Locations:
  - 150 m: NH25
  - 50 m: NH05
- Component Category: Climate and Ocean Drivers
- Data Steward: isaac.schroeder@noaa.gov
- Institution: NOAA SWFSC
- Source Data: Dr. Jennifer Fisher (jennifer.fisher@noaa.gov) Dissolved oxygen is measured by an automated oxygen titrator mounted to the CTD rosette and oxygen data is sampled at depths conin Peterson, J.O, Morgan, C. A., Peterson, W.T., Di Lorenzo, E. 2013) Seasonal and interannual variation in the extent of hypoxia in the northern California Current from 1998-2012, Limnology and Oceanography, 58(6):2279-2292, DOI:10.4319/lo.2013.58.6.2279.
- Additional Calculations: Each unique depth profile of dissolved oxygen (DO) was linearly interpolated on 1 m intervals, without any extrapolation for intervals above/below sampled depths. Outliers a profile might contain were removed by applying a Hample filter. The filter had a window size of 5 m above and below an observation, and considers the observation an outlier if a sample differs from the median by more than four standard deviations (see https://www.mathworks.com/help/signal/ref/hampel.html). Outliers are filled by linear interpolation of the points above and below. Then the DO at 40 m (DO@40) was extracted from the linearly interpolated profile. A time series of DO@40 was created using each unique profile of DO data available. A monthly mean time series was calculated from this time series. A standard deviation value was calculated if more than one profile was made during a given month, otherwise the standard deviation value was NaN (not a number).

Data extraction

ERDDAP™ link: https://oceanview.pfeg.noaa.gov/erddap/tabledap/cciea_OC_DO.html

References

14 Ocean Acidification

Description Ocean acidification (OA) occurs when atmospheric CO2 dissolves into seawater, reduces seawater pH and carbonate ion levels. Upwelling transports low oxygen, acidified waters from deeper offshore onto the continental shelf, where increased community-level metabolic activity can further exacerbate OA (Feely et al. 2008). A key measure of OA is aragonite saturation state, which is related to availability of aragonite (a form of the mineral calcium carbonate) to form or dissolve. Aragonite saturation <1.0 indicates relatively acidified, corrosive conditions that are stressful for many CCE species, particularly shell-forming invertebrates. OA impacts on these species can propagate through marine food webs and potentially affect fisheries (Marshall et al. 2017). Aragonite saturation states tend to be lowest during spring and summer upwelling, and highest in winter.

Newport Line Aragonite Saturation

- Locations:
  - 150 m: NH25
  - 40 m: NH05
- Component Category: Climate and Ocean Drivers
- Data Steward: isaac.schroeder@noaa.gov
- Institution: NOAA NWFSC
- Source Data: Data are derived from methods in Juranek et al. 2009: Juranek, L.W., Feely, R.A., Peterson, W.T., Alin, S.R., Hales, B., Lee, K., Sabine, C.L. and Peterson, J., 2009. A novel method for determination of aragonite saturation state on the continental shelf of central Oregon using multi-parameter relationships with hydrographic data. Geophysical Research Letters, 36(24).
- Additional Calculations: Data are derived from methods in Juranek et al. 2009: Juranek, L.W., Feely, R.A., Peterson, W.T., Alin, S.R., Hales, B., Lee, K., Sabine, C.L. and Peterson, J., 2009. A novel method for determination of aragonite saturation state on the continental shelf of central Oregon using multi-parameter relationships with hydrographic data. Geophysical Research Letters, 36(24).

Data extraction

ERDDAP™ link: https://oceanview.pfeg.noaa.gov/erddap/tabledap/cciea_OC_ARG.html

References

15 Snow-water equivalent

Description Snow-water equivalent (SWE) is measured using data from the California Department of Water Resources snow survey program (California Data Exchange Center, cdec.water.ca.gov) and The Natural Resources Conservation Service's SNOTEL sites across Washington, Oregon, California and Idaho. Snow data are converted into SWEs based on the weight of samples collected at regular intervals using a standardized protocol. Measurements on April 1 are considered the best indicator of maximum extent of SWE; thereafter snow tends to melt rather than accumulate.

Freshwater habitat indicators are reported based on a hierarchical spatial framework. The framework facilitates comparisons of data at the right spatial scale for particular users, whether this be the entire California Current, ecoregions within the CCE, or smaller spatial units. The framework we use divides the region encompassed by the CCE into ecoregions (Fig. 1.1), and ecoregions into smaller physiographic units. Freshwater ecoregions are based on the biogeographic delineations in (Abell et al. 2008), see also 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 at scales of evolutionary significant units (ESUs) and 8-field hydrologic unit classifications (HUC-8). Status and trends for all freshwater indicators are estimated using space-time models that account for spatial and temporal autocorrelation (Lindgren and Rue 2015).

Streamflow Snow water equivalent Ecoregion indicators:

- Ecoregions:
  - Salish Sea & WA coast
  - Columbia Glaciated
  - Columbia Unglaciated
  - Oregon and Northern California Coastal
  - Sacramento - San Joaquin
- Component Category: Habitat
- Data Steward: correigh.greene@noaa.gov
- Institution: NOAA NWFSC
- Source Data: 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 from sites with records that meet or exceed 30 years in duration (http://www.wcc.nrcs.usda.gov/snow/).

- Additional Calculations: Anomalies of April 1 snow-water equivalents (SWE) for the CCE, calculated as an area-weighted average of data from the Sacramento-San Joaquin ecoregion. SWE is a measure of the total water available in snowpack. Measurements on April 1st are considered the best indicator of maximum extent of snowpack.

Data extraction

ERDDAP™ link: https://oceanview.pfeg.noaa.gov/erddap/tabledap/cciea_HB_FLOW.html

References

16 Maximum Stream Temperatures

Description Mean maximum stream temperatures in August were determined from 446 USGS gauges with temperature monitoring capability. While these gauges did not necessarily operate simultaneously throughout the period of record, at least two gauges provided data each year in all ecoregions. Stream temperature records are limited in California, so two ecoregions (Sacramento/San Joaquin and Southern California Bight-Baja) were combined. Maximum temperatures exhibit strong ecoregional differences in absolute temperature (for example, Salish Sea and Washington Coast streams are much cooler on average than California streams).

Freshwater habitat indicators are reported based on a hierarchical spatial framework. The framework facilitates comparisons of data at the right spatial scale for particular users, whether this be the entire California Current, ecoregions within the CCE, or smaller spatial units. The framework we use divides the region encompassed by the CCE into ecoregions (Fig. 1.1), and ecoregions into smaller physiographic units. Freshwater ecoregions are based on the biogeographic delineations in (Abell et al. 2008), see also 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 at scales of evolutionary significant units (ESUs) and 8-field hydrologic unit classifications (HUC-8). Status and trends for all freshwater indicators are estimated using space-time models that account for spatial and temporal autocorrelation (Lindgren and Rue 2015).

Streamflow August Mean Max stream temperature Ecoregion indicators:

- Ecoregions:
  - Salish Sea & WA coast
  - Columbia Glaciated
  - Columbia Unglaciated
  - Oregon and Northern California Coastal
  - Sacramento - San Joaquin & southern California Bight
- Component Category: Habitat
- Data Steward: correigh.greene@noaa.gov
- Institution: NOAA NWFSC
- Source Data: August mean maxium temperature is measured using active USGS gages (http://waterdata.usgs.gov/nwis/sw)

- Additional Calculations: Average daily values from 446 gages were used to calculate annual mean maximum Aug temp

Data extraction

ERDDAP™ link: https://oceanview.pfeg.noaa.gov/erddap/tabledap/cciea_HB_FLOW.html

Data analysis

References

17 Streamflow

Flow is derived from active USGS gauges with records that are of at least 30 years' duration (waterdata.usgs.gov/nwis/sw). Daily means from 213 gauges were used to calculate annual 1-day maximum and 7-day minimum flows for ecoregion and Chinook salmon ESU boundaries. These indicators correspond to flow parameters to which salmon populations are most sensitive. We use standardized anomalies of streamflow time series from individual gauges.

Freshwater habitat indicators are reported based on a hierarchical spatial framework. The framework facilitates comparisons of data at the right spatial scale for particular users, whether this be the entire California Current, ecoregions within the CCE, or smaller spatial units. The framework we use divides the region encompassed by the CCE into ecoregions (Fig. 1.1), and ecoregions into smaller physiographic units. Freshwater ecoregions are based on the biogeographic delineations in (Abell et al. 2008), see also 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 at scales of evolutionary significant units (ESUs) and 8-field hydrologic unit classifications (HUC-8). Status and trends for all freshwater indicators are estimated using space-time models that account for spatial and temporal autocorrelation (Lindgren and Rue 2015).

Streamflow 1 day max Ecoregion indicators:

- Ecoregions:
  - Salish Sea & WA coast
  - Columbia Glaciated
  - Columbia Unglaciated
  - Oregon and Northern California Coastal
  - Sacramento - San Joaquin
  - Southern CA bight
- Component Category: Habitat
- Data Steward: correigh.greene@noaa.gov
- Institution: NOAA NWFSC
- Source Data: Streamflow is measured using active USGS gages (http://waterdata.usgs.gov/nwis/sw) with records that meet or exceed 30 years in duration.

- Additional Calculations: Average daily values from 213 gages were used to calculate annual 1-day maximum flows. These indicators correspond to flow parameters to which salmon populations are most sensitive. Standardized anomalies of time series from individual gages were then averaged to obtain weighted averages for ecoregions (for which HUC-8 area served as a weighting factor) and for the entire California current (weighted by ecoregion area).

Streamflow 7 day min Ecoregion indicators:

- Ecoregions:
  - Salish Sea & WA coast
  - Columbia Glaciated
  - Columbia Unglaciated
  - Oregon and Northern California Coastal
  - Sacramento - San Joaquin
  - Southern CA bight
- Component Category: Habitat
- Data Steward: correigh.greene@noaa.gov
- Institution: NOAA NWFSC
- Source Data: Streamflow is measured using active USGS gages (http://waterdata.usgs.gov/nwis/sw) with records that meet or exceed 30 years in duration.
- Additional Calculations: Average daily values from 213 gages were used to calculate annual 7-day minimum flows. These indicators correspond to flow parameters to which salmon populations are most sensitive. Standardized anomalies of time series from individual gages were then averaged to obtain weighted averages for ecoregions (for which HUC-8 area served as a weighting factor) and for the entire California current (weighted by ecoregion area).

Streamflow 1 day max ESU indicators:

- ESUs:
  - Upper Columbia Spring
  - Oregon Coast
  - S. Oregon N. California coast
  - Upper Klamath Trinity River
  - California Coast
  - Sacramento Winter
  - Central Valley Spring
  - Central Valley Fall late Fall
  - Puget Sound
  - Washington coast
  - Upper Columbia Summer Fall

    - Snake River Fall
    - Lower Columbia River
    - Mid-Columbia Spring
    - Snake River Spring Summer
    - Upper Willamette River

- Component Category: Habitat
- Data Steward: correigh.greene@noaa.gov
- Institution: NOAA NWFSC
- Source Data: Streamflow is measured using active USGS gages (http://waterdata.usgs.gov/nwis/sw) with records that meet or exceed 30 years in duration.
- Additional Calculations: Average daily values from 213 gages were used to calculate annual 1-day maximum flows. These indicators correspond to flow parameters to which salmon populations are most sensitive. Standardized anomalies of time series from individual gages were then averaged to obtain weighted averages for each of 17 Chinook salmon ESU boundaries (for which HUC-8 area served as a weighting factor).

Streamflow 7 day min ESU indicators:

- ESUs:
    - Upper Columbia Spring
    - Oregon Coast
    - S. Oregon N. California coast
    - Upper Klamath Trinity River
    - California Coast
    - Sacramento Winter
    - Central Valley Spring
    - Central Valley Fall late Fall
    - Puget Sound
    - Washington coast
    - Upper Columbia Summer Fall
    - Snake River Fall
    - Lower Columbia River
    - Mid-Columbia Spring
    - Snake River Spring Summer
    - Upper Willamette River
- Component Category: Habitat
- Data Steward: correigh.greene@noaa.gov
- Institution: NOAA NWFSC
- Source Data: Streamflow is measured using active USGS gages (http://waterdata.usgs.gov/nwis/sw) with records that meet or exceed 30 years in duration.
- Additional Calculations: Average daily values from 213 gages were used to calculate annual 7-day minimum flows. These indicators correspond to flow parameters to which

salmon populations are most sensitive. Standardized anomalies of time series from individual gages were then averaged to obtain weighted averages for each of 17 Chinook salmon ESU boundaries (for which HUC-8 area served as a weighting factor).

Data extraction

ERDDAP™ link: https://oceanview.pfeg.noaa.gov/erddap/tabledap/cciea_HB_FLOW.html

References

Part III

Focal Components of Ecological Integrity

18 Copepods

Description Copepod biomass anomalies represent variation in northern copepods (cold-water crustacean zooplankton species rich in wax esters and fatty acids) and southern copepods (smaller species with lower fat content and nutritional quality). Northern copepods usually dominate the summer zooplankton community along the Newport Line, while southern species dominate winter. Positive northern copepod anomalies generally correlate with stronger returns of Chinook salmon to Bonneville Dam and coho salmon to coastal Oregon (Peterson et al. (2014)). Historically, northern copepods typically have been favored by La Niña and negative PDO conditions (Keister et al. (2011); Jennifer L. Fisher, Peterson, and Rykaczewski (2015)).

Indicators

- Northern copepod biomass anomaly 44.6N
  - *Component Category:* Ecological Integrity
  - *Data Steward:* jennifer.fisher@noaa.gov
  - *Institution:* NOAA NWFSC
  - *Additional Calculations:* Monthly anomalies of the northern copepod biomass from 1996-present in waters off Newport, OR. See Fisher et al. 2015 for methods.
  - *Source Data:* Jennifer Fisher, NOAA (jennifer.fisher@noaa.gov); http://www.nwfsc.noaa.gov/researc
- Southern copepod biomass anomaly 44.6N
  - *Component Category:* Ecological Integrity
  - *Data Steward:* jennifer.fisher@noaa.gov
  - *Institution:* NOAA NWFSC
  - *Additional Calculations:* Monthly anomalies of the southern copepod biomass from 1996-present in waters off Newport, OR. See Fisher et al. 2015 for methods.
  - *Source Data:* Jennifer Fisher, NOAA (jennifer.fisher@noaa.gov); http://www.nwfsc.noaa.gov/researc
- Copepod species richness anomaly
  - *Component Category:* Ecological Integrity
  - *Data Steward:* jennifer.fisher@noaa.gov
  - *Institution:* NOAA NWFSC
  - *Additional Calculations:* Monthly anomaly of copepod species richness in the Northern California Current off Newport, Oregon, 1996-present.
  - *Source Data:* Jennifer Fisher, NOAA (jennifer.fisher@noaa.gov); http://www.nwfsc.noaa.gov/researc

Data extraction

ERDDAP™ link: https://oceanview.pfeg.noaa.gov/erddap/tabledap/cciea_EI_COP.html

Data analysis

References

19 Krill

Description Krill are among the most important prey in the CCE. The krill Euphausia pacifica is sampled year-round along the Trinidad Head Line off northern California (Fig. 1.1). Mean adult length and total biomass of E. pacifica sampled off the Trinidad Head Line indicate productivity at the base of the food web, krill condition, and energy content for predators (Robertson and Bjorkstedt 2020; Jennifer L. Fisher et al. 2020).

Trinidad Head krill data are provided by E. Bjorkstedt, NMFS/SWFSC SWFSC, Cal Poly, Humboldt and R. Robertson, Cooperative Institute for Marine Ecosystems and Climate (CIMEC) at Cal Poly, Humboldt.

Krill are also detected acoustically during the Joint U.S.-Canada Pacific Hake Ecosystem and Acoustic Trawl (PHEAT) Survey, conducted between June-September from Point Conception, California to Dixon Entrance, British Columbia. The coastwide nautical-area-backscattering coefficient (NASC) represents relative krill abundance observed between 50-300 m water depth (Phillips et al. 2022).

Krill biomass estimates derived from the Joint U.S.-Canada Pacific Hake Ecosystem and Acoustic Trawl (PHEAT) survey hydroacoustic data are provided by E. Phillips, NMFS/NWFSC.

Indicators

- Euphausia pacifica (krill) adult mean biomass
  - *Additional Calculations:* Carbon biomass of krill is calculated from body length measurements following length to weight conversions in Fisher et al., 2020.
- Euphausia pacifica (krill) length anomaly
  - *Additional Calculations:* Carbon biomass of krill is calculated from body length measurements following length to weight conversions in Fisher et al., 2020.
- Euphausia pacifica (krill) mean length
  - *Additional Calculations:* Krill body length was measured from the back of the eye to the base of the telson.
- Euphausia pacifica (krill) total biomass anomaly
  - *Additional Calculations:* Carbon biomass of krill is calculated from body length measurements following length to weight conversions in Fisher et al., 2020.

- Euphausia pacifica (krill) total mean biomass
  - *Additional Calculations:* Krill body length was measured from the back of the eye to the base of the telson.
- Component Category: Ecological Integrity
- Data Steward: eric.bjorkstedt@noaa.gov
- Institution: NOAA SWFSC; Cal Poly Humboldt
- Source Data: Krill (Euphausia pacifica) data were provided by Dr. Eric Bjorkstedt (eric.bjorkstedt@noaa.gov), NMFS/SWFSC and Cal Poly Humboldt, and R. Robertson (roxanne.robertson@noaa.gov), Cooperative Institute for Marine, Earth, and Atmospheric Systems (CIMEAS) at Cal Poly Humboldt.

Data extraction

ERDDAP™ link: https://oceanview.pfeg.noaa.gov/erddap/tabledap/cciea_EI_KRILLEN.html

References

20 Northern California Current Forage

Description The Northern CCE survey (known as the Juvenile Salmon Ocean Ecology Survey, JSOES) occurs in June and targets juvenile salmon in surface waters off Oregon and Washington. It also collects adult and juvenile (age 1+) pelagic forage fishes, market squid, and gelatinous zooplankton with regularity. A Nordic 264 rope trawl is towed for 15-30 min at approximately 6.5 km/hr. The gear is fished during daylight hours in near-surface (upper 20 m) waters, which is appropriate for targeting juvenile salmon.

Several other taxa collected by the June JSOES surface trawl are noted in terms of their relative prevalence (proportion of stations where they were caught), but are not considered to be sampled quantitatively due to their behavior and mesh size of sampling gear.

Pelagic forage data from the Northern CCE are 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.fisheries.noaa.gov/west-coast/science-data/ocean-ecosystem-indicators-pacific-salmon-marine-survival-northern). Similarity analysis and cluster plot by A. Thompson, NMFS/SWFSC.

Indicators

- Species:
  - Market squid
  - Juvenile chum
  - Pompano
  - Subyearling Chinook
  - Yearling Chinook
  - Yearling Coho
  - Juvenile sockeye
  - Adult Anchovy
  - Adult Sardine
  - Total Krill
  - Market Squid
  - Total Myctophids
  - Octopus
  - Pyrosomes
  - Salps
  - Thetys

- YOY Anchovy
  - YOY Pacific Hake
  - YOY Rockfish
  - YOY Sanddabs
  - YOY Sardine
  - YOY sablefish
  - Aequorea Water Jelly
  - Moon jelly
  - Chrysaora Sea Nettle
  - Egg yolk jelly

- Component Category: Ecological Integrity
- Data Steward: brian.burke@noaa.gov
- Institution: NOAA NWFSC
- Source Data: Dr. Brian Burke (NOAA; brian.burke@noaa.gov); derived from surface trawls taken during NOAA Northwest Fisheries Science Center Juvenile Salmon & Ocean Ecosystem Survey (JSOES). Additional calculations by Cheryl Morgan (OSU - CIMERS; cheryl.morgan@oregonstate.edu). Partial funding is from the Bonneville Power Administration (1998-014-00).
- Additional Calculations: To be included in this analysis, stations must have been 1) sampled during the day time, 2) on the continental shelf (greater than 200 m water depth), and 3) sampled during at least half of the years of the JSOES effort. Sampling occurs from the northern tip of Washington (48N 13.7') down to Newport, Oregon (44N 40.0') in late June. A Nordic 264 rope trawl (Nor'Eastern Trawl Systems, Bainbridge Island, WA) is towed at the surface (upper 20 m) for 15 - 30 min at approximately 6.5 km/hr. The total abundance for each nekton species caught in each haul was either determined directly or estimated from the total weight of the species in a catch and the weight and number of individuals in a subsample of that catch. Trawl catches were standardized to linear density by dividing catch of each species at a station by the distance between the start- and endpoints of the tow as determined by a global positioning system receiver and log10 transformed (Log10(no. km-1+ 1)).

Data extraction

ERDDAP™ link: https://oceanview.pfeg.noaa.gov/erddap/tabledap/cciea_EI_FBN.html

Data analysis

References

21 Central California Current Forage

Description The Central CCE forage survey (known as the Rockfish Recruitment and Ecosystem Assessment Survey, RREAS) samples much of the West Coast each May to mid-June, using midwater trawls sampling between 30 and 45 m depths during nighttime hours. The survey targets young-of-the-year (YOY) rockfish species and a variety of other YOY and adult forage species, market squid, adult krill, and gelatinous zooplankton. Juvenile rockfish, anchovy, krill, and market squid are among the most important prey for CCE predators (Szoboszlai et al. 2015). Time series presented here are from the "Core Area" of that survey, centered off Monterey Bay. Catch data were standardized by using a delta-GLM to estimate year effects while accounting for spatial and temporal covariates to yield relative abundance indices, shown with their approximate 95% confidence limits (Santora et al. 2021). The 2023 survey effort in the "Core Area" was comparable to previous years, apart from 2020.

Pelagic forage data from the Central CCE were provided by J. Field, T. Rogers, K. Sakuma, and J. Santora, NMFS/SWFSC, from the SWFSC Rockfish Recruitment and Ecosystem Assessment Survey (https://go.usa.gov/xGMfR). Similarity analysis and cluster plot by A. Thompson, NMFS/SWFSC.

Indicators

- Species:
  - Aurelia
  - Chrysaora
  - Adult Anchovy
  - Adult Sardine
  - Total Krill
  - Market Squid
  - Total Myctophids
  - Octopus
  - Pyrosomes
  - Salps
  - Thetys
  - YOY Anchovy
  - YOY Pacific Hake
  - YOY Rockfish
  - YOY Sanddabs
  - YOY Sardine

- Component Category: Ecological Integrity
- Data Steward: john.field@noaa.gov
- Institution: NOAA SWFSC
- Source Data: Dr. John Field (NOAA; john.field@noaa.gov) and Tanya Rogers (NOAA; tanya.rogers@noaa.gov) from the SWFSC Rockfish Recruitment and Ecosystem Assessment Survey (RREAS; https://storymaps.arcgis.com/collections/af0fa37db2bf4f1cadb024ec0ffbdfb5).
- Additional Calculations: Samples represent catch (individuals) per standard 15 minute trawl (CPUE) from the historical core area (36.5-38.2N) of the RREAS during late spring (May to mid-June). Data are log(CPUE+1) transformed, with geometric means calculated on non-zero data. Note: Sampling effort was greatly reduced in time and space during 2020 due to COVID restrictions, and associated data reflected substantial bias for many taxa. Catches were standardized by using a Bayesian delta-GLM to estimate year effects while accounting for spatial and temporal covariates, and to estimate approximate 95% confidence limits; see Santora et al. 2021 (https://doi.org/10.1038/s41467-021-26484-5) for model approaches used to develop alternative indices in 2020.

Data extraction

ERDDAP™ link: https://oceanview.pfeg.noaa.gov/erddap/tabledap/cciea_EI_FBC.html

References

22 Southern California Current Forage

Description Abundance indicators for forage in the Southern CCE come from fish and squid larvae collected in the spring (May-June) across all core stations of the CalCOFI survey. 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. The survey samples a variety of fish and invertebrate larvae (<5 d old) from several taxonomic and functional groups, collected via oblique vertical tows of fine mesh Bongo nets to 212 m depth. In 2020, the spring larval survey was canceled due to COVID-19, and thus no data are available for that year, but survey operations resumed in 2021.

Pelagic forage larvae data from the Southern CCE were provided by A. Thompson, NMFS/SWFSC, from spring CalCOFI surveys (https://calcofi.org/); data were not collected in 2020 due to survey cancellations associated with the COVID pandemic. Similarity analysis and cluster plot by A. Thompson, NMFS/SWFSC.

Indicators

- Species:
  - anchovy
  - CA smoothtongue
  - croakers
  - eared blacksmelt
  - English sole
  - Jack mackerel
  - market squid
  - northern lampfish
  - hake
  - Pacific mackerel
  - rockfishes
  - sanddabs
  - sardine
  - slender sole
  - southern mesopelagics
- Component Category: Ecological Integrity
- Data Steward: andrew.thompson@noaa.gov
- Institution: NOAA SWFSC

- Source Data: Dr. Andrew Thompson (NOAA; andrew.thompson@noaa.gov); derived from spring CalCOFI surveys (http://calcofi.org/)
- Additional Calculations: Larval fish data summed across all stations of the CalCOFI survey in spring (units are in number under 10 sq. m of surface area; ln(abundance+1)). Note: The spring CalCOFI cruise was not conducted in 2020 due to COVID restrictions, and winter surveys were used to develop alternative indices of larval abundance; see Appendix G.3 in Harvey et al 2021 (https://www.pcouncil.org/documents/2021/02/i-1-a-iea-team-report-2.pdf/) for methods used to develop alternative indices in 2020.

Data extraction

ERDDAP™ link: https://oceanview.pfeg.noaa.gov/erddap/tabledap/cciea_EI_FBS.html

Data analysis

References

23 CPS Survey

Description Acoustic-trawl method (ATM) surveys have been used by the NOAA Southwest Fisheries Science Center in most years since 2006 to map the distributions and estimate the abundances of coastal pelagic fish species (CPS) in the coastal region from Vancouver Island, Canada, to San Diego, California (Zwolinski et al. 2014). In 2021 and 2022, the surveys were expanded to include portions of Baja California, Mexico (**zwolinski2023distribution?**; **stierhoff2023distribution?**). The surveys cover waters to at least the 1,000-fathom (1829-m) isobath, or 65 km from shore. The five most abundant CPS in this domain are Northern Anchovy, Pacific Herring, Pacific Sardine, Jack Mackerel, and Pacific Mackerel. The biomass of Pacific Sardine is calculated separately for the northern and southern stocks based on oceanographic habitat, spatial separation, and demographic structure (Zwolinski and Demer 2024). The ATM combines data from echosounders, which record CPS echoes, and trawls, which produce information about the composition, sizes, and ages of the fishes. This survey also samples the densities of CPS eggs at 3-m depth using a continuous underway fish egg sampler (CUFES) mounted on the ship's hull.

CPS surveys typically span the area between Cape Flattery and San Diego, but in some years also include Vancouver Island, Canada (2015-2019) and portions of Baja CA (2021-2022). Data and figure provided by K. Stierhoff, NMFS/SWFSC and J. Zwolinski, UCSC and NMFS/SWFSC.

Indicator Category Ecological Integrity

Data Steward Stierhoff; kevin.stierhoff@noaa.gov

Additional Information

Data sources

Data extraction

Data analysis

References

24 Juvenile Salmon

Description The Northern CCE survey (known as the Juvenile Salmon Ocean Ecology Survey, JSOES) occurs in June and targets juvenile salmon in surface waters off Oregon and Washington. A Nordic 264 rope trawl is towed for 15-30 min at approximately 6.5 km/hr. The gear is fished during daylight hours in near-surface (upper 20 m) waters, which is appropriate for targeting juvenile salmon.

Juvenile salmon data from the Northern CCE are 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.fisheries.noaa.gov/west-coast/science-data/ocean-ecosystem-indicators-pacific-salmon-marine-survival-northern). Similarity analysis and cluster plot by A. Thompson, NMFS/SWFSC.

Indicators

- Species:
  - Subyearling Chinook
  - Yearling Chinook
  - Yearling Coho
- Component Category: Salmon
- Data Steward: brian.burke@noaa.gov
- Institution: NOAA NWFSC
- Source Data: Dr. Brian Burke (NOAA; brian.burke@noaa.gov); derived from surface trawls taken during NOAA Northwest Fisheries Science Center Juvenile Salmon & Ocean Ecosystem Survey (JSOES). Additional calculations by Cheryl Morgan (OSU - CIMERS; cheryl.morgan@oregonstate.edu). Partial funding is from the Bonneville Power Administration (1998-014-00).
- Additional Calculations: To be included in this analysis, stations must have been 1) sampled during the day time, 2) on the continental shelf (greater than 200 m water depth), and 3) sampled during at least half of the years of the JSOES effort. Sampling occurs from the northern tip of Washington (48N 13.7') down to Newport, Oregon (44N 40.0') in late June. A Nordic 264 rope trawl (Nor'Eastern Trawl Systems, Bainbridge Island, WA) is towed at the surface (upper 20 m) for 15 - 30 min at approximately 6.5 km/hr. The total abundance for each nekton species caught in each haul was either determined directly or estimated from the total weight of the species in a catch and the weight and number of individuals in a subsample of that catch. Trawl catches

were standardized to linear density by dividing catch of each species at a station by the distance between the start- and endpoints of the tow as determined by a global positioning system receiver and log10 transformed (Log10(no. km-1+ 1)).

Data extraction

ERDDAP™ link: https://oceanview.pfeg.noaa.gov/erddap/tabledap/cciea_EI_FBN.html

Data analysis

References

25 Salmon Stoplight Tables

Description Northern California Current; Columbia Basin stocks: We use color to represent anomalous years for the stoplight tables presented in the salmon section of the report. As described in Harvey et al. (2023), we have addressed past feedback from the SSC and others by developing a more statistically based stoplight table format, which produces five bins that are determined relative to a fixed baseline reference period. In this new format, we assumed a normal distribution for each of the indicators and estimated a mean and standard deviation for the base period. For each cell within a given indicator, we determined how many standard deviations the values were from their respective base period mean and used a five-color set to indicate whether a value was >2 s.d. below the mean, 1 to 2 s.d. below the mean, within 1 s.d. of the mean in either direction, 1 to 2 s.d. above the mean, or >2 s.d. above the mean. This approach overcomes many of the issues that had been previously identified (e.g., better highlighting values that represent truly exceptional years; past values are now static and do not suddenly change colors; etc.).

Central California Current; Klamath / Sacramento / Central Valley stocks: The process of identifying key indicators for salmon habitat stoplight tables is ongoing (Munsch et al. in prep). To summarize our approach and findings to date, we used linear models to relate recruitment of SRFC, CVSC, and KRFC to salmon habitat indicators. In light of the potential for recruitment-indicator relationships to change over time, we selected indicators based on model performance metrics that suggested that the indicators were persistently or recently important to recruitment. Through preliminary analyses, we selected twelve key indicators, two of which are shared among the California Central Valley stocks (SRFC and CVSC) for a total of ten unique indicators. We note that we only found strong evidence for a linear relationship between natural spawners and future recruitment for SRFC (and thus use this indicator for forecasts below), but report natural spawner counts for other stocks for context. Our ongoing analyses will examine for evidence of a Ricker stock-recruitment relationship, which is not included here.

We also report new efforts to examine thiamine deficiency in hatchery eggs across the Central Valley in California. Some of the indicators we selected, particularly those relevant to SRFC, have been identified as important by previous research efforts (Friedman et al. 2019; Munsch, Greene, et al. 2020; Munsch et al. 2022). Indicators were indexed according to brood year or outmigration year and then adjusted to return or fishing year via the assumptions that juveniles migrated the calendar year after their brood year and that most adults were harvested or returned as spawners three years after their brood year.

[this section will require a bit more writing to incorporate evolving approaches and methods]

Data sources

Data extraction

Data analysis

References

26 Chinook Salmon Escapement - Columbia River

Description In this analysis, models are fit to past smolt-to-adult return (SAR) data, and use the most recent ecosystem indicator data to predict what smolt-to-adult survival will be for cohorts that have gone to sea but not yet returned. Separate models have been developed for spring and fall Chinook salmon and steelhead from the Snake River basins and spring Chinook salmon from the Upper Columbia basin. The specific approach uses a Dynamic Linear Model, founded on linear regressions of single ecosystem indicators vs. survival rates of PIT-tagged fish that left Bonneville Dam as smolts and returned as adults. The model labeled "Stoplight PC1" uses the first principal component (PC1) from a Principal Component Analysis of the stoplight chart as a covariate. The second model, labeled "CMISST" uses a Covariance Map Index of Sea Surface Temperature (B. Burke, unpublished), which is a metric derived by calculating the similarity of sea surface temperature (SST) spatial patterns in the North Pacific Ocean to a stock-specific optimal pattern. The CMISST metric is still in development, but analyzes to date indicate that the CMISST model has better prediction skill for spring Chinook salmon and steelhead SAR, while the PC1 model has better prediction skill for fall Chinook salmon SAR.

Indicator Category Ecological Integrity

Data Steward Burke; brian.burke@noaa.gov

Data sources

Data extraction

Data analysis

References

27 Chinook Salmon Ecosystem Conditions - California

Description. Central Valley Fall Chinook salmon stoplight table: In the 2019-2020 ecosystem status report (REFERENCE), we introduced a relatively simple "stoplight" table of ecosystem indicators that were shown by Friedman et al. (2019) to be correlated with returns of naturally produced Central Valley Fall Chinook salmon. In an updated stoplight chart for adult Fall Chinook salmon returning to the Central Valley in 2024, the focal ecosystem indicators are: spawning escapement of parent generations; egg incubation temperature between October and December at Red Bluff Diversion Dam (Sacramento River); egg thiamine concentrations based on averages of samples collected from Central Valley fall run hatchery programs; median flow in the Sacramento River in the February after fry emergence; and a marine predation index based on the abundance of common murres at Southeast Farallon Island and the proportion of juvenile salmon in their diets. Reflecting discussions with the SSC-ES in September 2020, we emphasize that this stoplight chart is strictly qualitative and contextual decision-support information. Qualitative descriptors (color-coded terms like "very poor") are based on recent time series and on expert opinion of how a given indicator relates to quantitative analysis of the relationship between the indicator and life-stage specific survival (see Figure 5 in Friedman et al. 2019). For example, in the stoplight Table flows rated "very low" (<7,000 cfs) are consistent with <25% rearing/outmigration survival rates, while the flows rated "low" (7,000 to 20,000 cfs) were consistent with 25-50% outmigrant survival (see Fig. 5 in, Friedman et al. 2019). Egg incubation temperatures in the Table were consistent with egg-to-fry survival ranging from ~50% (which we rated as "suboptimal") to 0% at > 13 C ("very poor/cohort failure"). We continue to refine these qualitative categories for future reports so that their basis is more explicit.

The escapement descriptor is a qualitative evaluation of how natural-area escapement of a parent generation relates to the natural area + hatchery escapement goal of 122,000– 180,000 fish, with 122,000 spawners as the SMSY target (PFMC 2022d). Natural area escapement is relevant to the stoplight table as an indicator of total natural area egg production (Munsch, Andrews, et al. 2020). However, the qualification of this indicator requires future research. Obviously, using a natural+hatchery target as the qualifier for natural-only escapement is problematic. Perhaps more importantly, the SSC and STT have both recommended research and reconsideration of the Sacramento River fall Chinook SMSY objective (PFMC 2022e,f), and (**satterthwaite202approach?**) has concluded that an escapement of 122,000 adults is insufficient to maximize natural production. We have not been able to fully address the SSC and SST comments yet.

The qualitative nature of this stoplight table is in part due to the fact that some of the parameters used by Friedman et al. (2019) were estimated using information from both natural-origin and hatchery-origin fish, and while it is reasonable to assume that true parameter values would be similar, given correlations between natural and hatchery escapements, additional data specific to natural-origin fish are likely necessary in order to improve model fits, evaluate other potential covariates, and support adequate testing of model predictive skill.

[include here Table J.1 which documents the habitat indicators, definitions, and key references]

Indicator Category Ecological Integrity

Data Steward Greene and Munsch; correigh.greene@noaa.gov, stuart.munsch@noaa.gov

Additional Information Methods. The indicators in Table J.1 have been shown in previous studies or were proposed in rebuilding plans to be strongly related with life-stage specific Chinook salmon productivity, and these studies helped determine expected directionality of indicators with stock productivity (see below and Harvey et al. 2020 for additional justification). Four of the five broad categories of indicators in the stoplight charts align with the simpler stoplight chart for Central Valley fall Chinook salmon presented in the main body of this report (Table 3.2): Adult Spawners, Incubation conditions, Freshwater / Estuarine Residence conditions, and Marine Residence conditions (for the first year of marine residence). The fifth category of indicators, Hatchery Releases, expands the scope of these tables relative Table 3.2, which focuses only on natural-area fish. The habitat indicator charts also share qualities with the stoplight chart developed for Columbia Basin Chinook salmon and Oregon coast coho salmon (Table 3.1) by including regional and basin-scale oceanographic indicators as part of early marine residence conditions. Data on krill off northern California are also presented within the table for KRFC.

The indicators in Table J.1 and in the stoplight tables above have undergone several important adjustments from previous reports:

Updates to SRFC and KRFC include changes in some indicators to ensure more reliable and timely data capture. However, updates of many indicators in 2023 remain challenging due to delays in posting of online datasets, resulting in several indicators that could not be updated for this year's report and preliminary estimates for several others. These challenges underscore the importance of including multiple indicators, highlight the potential fragility of these annual summaries, and point to the importance of many individuals for maintaining the databases required for summarizing habitat indicators.

Recent analysis of krill off northern California have revealed that krill length is a much better indicator than krill biomass for predicting productivity of Klamath Fall run, so we have substituted length for this indicator.

CVSC differs from SRFC not only in migration timing but also in their behavior and spatial distribution. Habitat indicators reflect these differences, by characterizing early upstream migration starting in February, holding in pools through the summer, and spawning in a small number of creeks in the late summer and fall. Adult numbers focused on spawner counts in Butte, Mill, and Deer Creeks. Butte Creek spawners migrate from the Sacramento River through Sutter Bypass to Butte Creek, and outmigrants may rear within Sutter Bypass during outmigration. Hence, flow and temperature metrics relied on gages from these systems in addition to the Sacramento mainstem, and Sutter Bypass inundation instead of Yolo Bypass. Finally, the sole hatchery for CVSC is from Feather River, so releases and timing metrics focused on data from just this hatchery.

The stoplight tables are categorized from favorable to poor conditions using the same approach as described for the Northern California Current salmon indicator stoplight table. Specifically, after indicator datasets were collected, all indicators were "directionalized" to account for their expected relationships with stock productivity (based on the "Effect" column in (Table J.1) and converted into standardized values. These values are reported in the stoplight tables above, with colors delineating statistically meaningful departures (>2 s.d.) toward poorer (warm shades) or more productive (cool shades) conditions compared to near-average years (within ±1 s.d., yellow). The main difference for the tables shown here relative to Columbia River salmon stoplight tables is that we have not yet determined a fixed historic reference period for the SRFC, KRFC and CVSC tables, due in part to missing data from one or more indicators in large portions of the time series.

Habitat Indicator Descriptions. Adults returning and migrating to spawning grounds: Spawning adults set the cohort size (Friedman et al. 2019) and potential for density-dependent habitat limitations at future life stages (Munsch, Andrews, et al. 2020), so we incorporated estimated escapements from PFMC preseason forecasts. Adults must navigate multiple potential barriers to reach spawning grounds, including low river flows and high temperatures at the end of summer. We used flow and temperature measurements from the lower portions of the Sacramento and Klamath Rivers in September and October. In the Sacramento River, adults must also navigate the channel network of the delta, and the rebuilding plan proposed examining potential effects of the Delta Cross Channel as a migration barrier. We used the proportion of time the Cross Channel was closed in September and October as the indicator.

Indicators for adult migrations differ for CVSC due to their early migration timing (February to May), spring-summer holding in pools, and spawning in a small number of Sacramento tributaries. We restricted the enumerated spawner abundance to Deer, Mill, and Butte Creeks, for which records were consistently maintained throughout the 1983-present period of record. To fill in data gaps of spawner counts for Butte Creek (the largest spawning population) to complete the retrospective time series to the 1983 brood year, we used predictions from regressions of Butte Creek spawner counts and snorkel surveys. Flows and temperatures during holding were restricted to the river with the greatest spawner abundance (Butte Creek). In addition, CDFW conducts estimates of pre-spawn mortality which we added as an indicator due to CVSC's exposure to warm in-river conditions.

Incubation to emergence: After spawning, incubating eggs may be subject to dewatering in the river (Jager et al. 1997) and are sensitive to high temperatures (Friedman et al. 2019). For SRFC, the river flow indicator was derived from the seven-day 10th percentile of flow for the Sacramento River from October to December at Bend Bridge near Red Bluff. For CVSC, we used similar flow conditions for Butte Creek. For KRFC, dewatering previously was observed in various tributaries of the Klamath. Hence, minimum flows from four gages (Klamath at Iron Gate, Scott River, Shasta River, and Trinity River at Lewiston Dam) were used, and the index was calculated from the average of standardized flow values. Incubation temperature records were obtained for all three river systems, albeit for a much shorter time series in the Klamath. SRFC incubation temperature estimates are from Red Bluff Diversion Dam (data in Friedman et al. 2019), CVSC records are from Butte Creek, and Klamath records are from Seiad Valley. Egg-fry productivity as measured by migrants per spawner were initiated in the early 2000s for all stocks.

Freshwater and estuary residence: During migration to the ocean, fall Chinook salmon stocks take advantage of temporary residence in riverine and estuary habitats before transitioning to marine environments. We used a variety of indicators of habitat conditions during this stage. Freshwater conditions are set by precipitation and spring air temperatures, both of which influence snowpack salmon runs and river flow (Munsch et al. 2019) in both tributaries (important for CVSC in particular) and mainstem. In turn, flows from December to May (and their temporal variation) set conditions for rearing in river and estuary systems as fish move downstream, and have been linked to freshwater (Munsch et al. 2019) and life-cycle productivity (Michel 2019, Friedman et al. 2019). Higher flows also determine access to floodplain rearing in reaches such as the Yolo Bypass for SRFC (Limm and Marchetti 2009) and Sutter Bypass for CVSC, as well as the potential to flush polychaete hosts of the parasite Ceratomyxa shasta that infects juvenile salmon during outmigration (Jordan 2012). Flows also determine the outflow through the Sacramento delta (Reis et al. 2019), which can influence estuarine rearing opportunities (Munsch, Andrews, et al. 2020). To shift freshwater flows to pumping facilities, the Bureau of Reclamation opens the Delta Cross Channel, and this pathway can entrain salmon in pumps or otherwise expose them to higher mortality (Perry et al. 2013).

Magnitude and timing of hatchery releases: While much of the habitat indicators focus on natural-area fish, hatchery releases make up a significant contribution of each run and may also contribute to density dependence. We therefore included the annual total of hatchery releases, using data from up to four SRFC hatcheries on the Sacramento (San Joaquin hatcheries were not included), the Feather River hatchery for CVSC, and Trinity and Iron Gate hatcheries in the Klamath. While hatchery-origin juveniles are also sensitive to the conditions natural-origin juveniles face, they are generally raised until they are primed for rapid migration. Following concepts of match-mismatch theory (Cushing 1990), we compared release date with the date of peak spring flow in freshwater and the spring transition in the ocean, as Satterthwaite et al. (2014) showed that both timing of release relative to the spring transition and overall later release timing were positively correlated with survival rates. Fates of hatchery fish may be a consequence of release location (Sturrock et al. 2019), including locations external to the

Sacramento River system, so we also included the proportion of releases that were seaward of Sherman Island in the lower delta.

Marine residence: Marine residence of 1 to 5 years completes the life cycle for fall run Chinook salmon populations. While a broad number of marine habitat indicators have been examined (Wells et al. 2008), we focused on a limited subset of possible indicators representing initial set-up of ocean entry conditions (March-May), including sea surface temperature, the North Pacific Index, and North Pacific Gyre Oscillation. We also included an index of predation by common murres nesting at Southeast Farallon Island, which was a strong predictor in Friedman et al. (2019). Unfortunately, this indicator currently cannot be updated quantitatively. On the positive side, we have updated the krill prey indicator for Klamath River fall Chinook salmon from biomass to average length to better reflect stronger correlations with recruits per spawner. Where indicators were averaged to obtain a marine habitat conditions score, hatchery release timing relative to the spring transition was also included as a marine habitat condition.

Data sources

Data extraction

Data analysis

References

28 Groundfish Stock Abundance

Description We present relative Stock Status of groundfish in the CCE as the ratio of the current year spawning biomass (in mt) or output (typically in billions of eggs) to unfished relative to the target reference point (as a percentage of unfished biomass; 0.4 for scorpaenids and other fishes; 0.25 for flatfishes). Fishing Intensity uses the fishing rate to achieve a specific spawner potential ratio (SPR), defined as F/FSPR, where SPR is the maximum sustainable yield (MSY) proxy.

"Overfishing" occurs when catches exceed overfishing limits (OFLs), but not all stocks are managed by OFLs. For summary purposes, our best alternative is to compare fishing rates to proxy rates that are based on a stock's spawner potential ratio (SPR). Our relative stock status plots present a horizontal line as the fishing intensity rate reference; above the line is above the reference level and indicates overfishing. The vertical lines in the plot represent the biomass target reference points (TRP=1; dashed line) and limit reference points (LRPs; red lines); left of the LRP indicates an overfished status. Symbols indicate taxonomic groups. All points in the plot represent values from the most recent PFMC-adopted full stock assessments. Groundfish stock status data provided by J. Cope, NMFS/NWFSC, derived from NOAA Fisheries stock assessments.

- Species:
  - Arrowtooth flounder
  - English sole
  - Flathead sole
  - Longnose skate
  - Pacific sanddab
  - Shortbelly rockfish
  - Spotted ratfish
  - Stripetail rockfish
- Component Category: Groundfish
- Data Steward: jason.cope@noaa.gov
- Institution: NOAA NWFSC
- Source Data: Groundfish data are from the NMFS U.S. West Coast Groundfish Bottom Trawl Survey (http://www.nwfsc.noaa.gov/research/divisions/fram/groundfish/bottom_trawl.cfm) and were provided by Dr. Todd Hay and Ms. Beth Horness (NOAA).

- Additional Calculations: Reference Cope and Haltuch (2014) CCIEA PHASE III REPORT 2013: ECOSYSTEM COMPONENTS - GROUNDFISH report for full explanation of what sources of information were used for each species.

Data extraction

ERDDAP™ link: https://oceanview.pfeg.noaa.gov/erddap/tabledap/cciea_GF_ABND.html

Data analysis

29 Juvenile Groundfish Abundance

Description Yearly indices of the abundances of juvenile sablefish, Dover sole, shortspine thornyhead, and longspine thornyhead along the West Coast were calculated using species distribution models. Strong year classes can determine age structure and set stock size for marine fishes, and may also indicate favorable environmental conditions, increased future catches, and impending potential bycatch issues. Here, we provide estimates of juvenile abundance for 13 species of West Coast groundfishes, including four from DTS assemblage (Dover sole, thornyheads, and sablefish) as a potential leading indicator of incoming strong year classes. The DTS assemblage is a valuable fishery, and bycatch of some species, like small sablefish, can impact other fisheries such as the at-sea hake fishery.

Data sources Data for indicators come from the West Coast Groundfish Bottom Trawl Survey (WCGBTS) (Keller et al. 2017) for 2003-2021. There were no data for 2020 because the WCGBTS was canceled due to the COVID-19 pandemic. The survey data includes estimates of age, length, and biomass for subsamples of each haul, and occasionally for the entire haul when catch is low.

Data extraction Data were downloaded from the Fishery Resource Analysis and Monitoring data Warehouse (https://www.webapps.nwfsc.noaa.gov/data/map)

Data analysis We used species distribution models to calculate indices of abundance for juvenile groundfish. The approach follows the general approach of Tolimieri, Wallace, and Haltuch (2020) but uses the 'sdmTMB' package (Anderson et al. 2022) for R instead of the 'VAST' package (Thorson 2019). VAST was was reviewed by the SSC-ES in September 2021. The sdmTMB approach is used by many West Coast groundfish stock assessment biologists to assimilate survey data and was reviewed favorably by the SSC-Groundfish Subcommittee in summer of 2022 (PFMC 2022c).

The analyses estimate the biomass for each species by using length-age and length-weight relationships to expand the trawl data. Length is measured (cm total length) for all individuals in the subsample, but many individual fishes lack weight or age data due to time constraints in the field and ageing lab. To expand the subsample,

1. Missing weights for individuals in the subsample were obtained by first estimating the length-weight relationship from existing data and using this relationship to estimate the missing weights from known lengths. For Dover sole, sablefish and longspine thornyhead, male and female length-weight relationships were estimated separately and the average

of these relationships used to determine weights for individuals where sex was not known. For shortspine thornyhead, we used a single length-weight relationship.

2. Individual fish were then allocated to age classes following Tolimieri, Wallace, and Haltuch (2020) by using length-age relationships from the WCGBTS data to determine age-class maximum lengths. See Tolimieri, Wallace, and Haltuch (2020) for more detail. The maximum lengths used here (Table 29.1) were taken from Tolimieri, Wallace, and Haltuch (2020) (Table 29.1).
3. The proportional biomass of juveniles in each subsample was calculated and used to estimate the total biomass of juvenile fishes in the full trawl.
4. Trawl biomass was then used in the following sdmTMB species distribution models.

Table 29.1: Length, age, and depth range information.

Common name	Species	Max length (cm)	Age class	Dept
Arrowtooth flounder	Atheresthes stomias	22	1	
Darkblotched rockfish	Sebastes crameri	15	0-1	
Dover sole	Microstomus pacificus	17	1-2	
English solea	Parophrys vetulus	16	1	
Lingcod	Ophiodon elongatus	25	0	
Longspine thornyhead	Sebastolobus altivelis	7	<5	3
Pacific grenadier	Coryphaenoides acrolepis	3	~1	4
Pacific hake	Merluccius productus	15	0-1	
Pacific sanddab	Citharichthys sordidus	13	0-1	
Petrale sole	Eopsetta jordani	21	1-2	
Sablefish	Anoplopoma fimbria	29	0	
Shortspine thornyhead	Sebastolobus alascanus	8	<5	1
Splitnose rockfish	Sebastes diploproa	10	0-1	

Coastwide juvenile groundfish abundances were estimated using a spatially explicit, species distribution model evaluated with the sdmTMB package in R. The response variable was CPUE quantified as kg of juveniles per km^2. The models included one common intercept across years, and spatial and spatiotemporal random fields, with anisotropy to account for different rates of autocorrelation with latitude versus longitude (~ depth). The common intercept prevents the model from forcing biomass to increase or decrease coastwide in a given year (thereby potentially overestimating recruitment in some areas) as would be the case for yearly intercept. Normalized depth was included to account for differences in density across depths.

To avoid projecting to areas with zero biomass, the depth range of the data used for each species in the analysis was restricted based on the distribution of positive biomass observations (Table K.1). Again, the values used here follow Tolimieri et al. (2020) with the exception that the lower depth limit for sablefish was set to 250 m, which encompasses more than 99% of their observed juvenile biomass. Pass was included as a fixed factor (as a proxy for time of year; the WCGBTS conducts two coastwide passes each year, in May-July and August-October). Models were fit with a delta-gamma distribution to account for the prevalence of zeros in the data, and the mesh was set to 10 km, resulting in 650-800 knots depending upon species. Model fits were then extrapolated to a 2x2 km grid of the West Coast to estimate total abundance in kg for juveniles in a given year. For some species, it was necessary to combine age or size classes to obtain enough data for models to converge. The resulting biomass estimate was converted to an index scaled between 0-1 by dividing all values by the maximum upper 95% confidence limit in the time series.

To address previous suggestions by the SSC-ES, we also evaluated models with year included as a fixed factor or allowed year to have a random intercept. When included as a fixed factor, models failed to converge likely due to identifiability problems due to also including the spatiotemporal random field. For sablefish and Dover sole, inclusion of year with a random intercept also created fit problems leading to very large standard errors for some estimated parameters. Therefore, we excluded the term from the final models.

2025-01 Update

Previously models for all species included a delta-poisson-link-gamma model/error structure and normalized depth as a linear variable. In 2025 models were updated to tailor model structure and the form of depth (linear, quadratic, smoothed) to individuals species. We fit models with Tweedie, delta-lognormal, delta-poisson-link-gamma, and delta-gamma model/errors. Depth was normalized and included as a linear variabe, as a quadratic, smoothed (GAM), or not included. The best model was chosen for each species based on a comparison of AIC values, QQ residual plots, and sanity (model fit) output (Table 29.2). This approach produced better residuals and tended to dampen some of the higher biomass estimates (see sablefish in the main report).

Table 29.2: Model informaiton for juvenile abundance models used in the FY2025 report.

Species	Distribution	Depth
Arrowtooth flounder	Tweedie	GAM smooth
Darkblotch rockfish	Tweedie	GAM smooth

Species	Distribution	Depth
Dover sole	delta-gamma-poisson-link	quadratic
English sole	delta-gamma	quadratic
Lingcod	Tweedie	quadratic
Longspine thornyhead	delta-lognormal	GAM smooth
Pacific grenadier	delta-gamma	GAM smooth
Pacific hake	Tweedie	GAM smooth
Pacific sandlance	Tweedie	quadratic
Petrale sole	delta-lognormal	quadratic
Sablefish	delta-lognormal	quadratic
Shortspine thornyhead	Tweedie	quadratic
Splitnose rockfish	Tweedie	GAM smooth

References

30 Groundfish Port Availability

Description We estimated the relative availability of groundfish biomass to individual ports following the methods described in Selden et al. (2020), with some exceptions. In brief, we used data from the Northwest Fisheries Science Center's West Coast Groundfish Bottom Trawl Survey (Keller et al. 2017) to estimate spatial distribution of species-specific biomass (Location Biomass), and the Center of Gravity (CoG) of the Location Biomass. We then calculate the Availability Index for each port by summing the Location Biomass within a radius from that port based on the 75th quantile of the distance traveled from port to harvest of species of interest, weighted by catch, as measured from trawl logbooks. We analyzed 12 species that make up a large component of landings for vessels using bottom trawl gear along the West Coast, or that have broader management interest (e.g., shortbelly rockfish).

The present analysis differs from Selden et al. (2020) in three ways:

1- We estimated the spatial distribution of species using the R package sdmTMB (Anderson et al. 2022; R Core Team 2023) instead of VAST (Thorson 2019). The sdmTMB models included Pass and normalized depth as fixed parameters. Year was a time variable and models included both spatial and spatiotemporal (iid) autocorrelation, and a delta-poisson-link-gamma error distribution (Thorson 2018) error distribution.

2- We used the Location Biomass directly instead of scaling it by spawning stock biomass from the assessment. Thus, the Availability Index is a relative biomass index and not actual available biomass. Biomass was then scaled to 0-1 for presentation by dividing by the highest value in any year.

3- We used only the WCGBTS, and did not combine the Triennial survey (1980-2004) with the WCGBTS. This approach shortens the analysis period but allows us to expand the depth range to 55-1250 m.

2025-01 Update Previous sdmTMB models used a delta-poisson-link-gamma model structure/distribution and included depth a linear factor. In 2025 (for the CY2025 ESR), models were updated to use a delta-lognormal model structure, and normalized depth was included as a smoothed variable (with three knots). The delta-lognormal models produced better residuals (as evaluate with QQ-plots) than the delta-poisson-link-gamma models. The smoothed depth term allowed non-linear relationships with depth, such as higher mid-depth abundance versus shallow and deeper zones.

Data sources Data for indicators come from the West Coast Groundfish Bottom Trawl Survey (WCGBTS) (Keller et al. 2017) for 2003-2021. There were no data for 2020 because the

WCGBTS was canceled due to the COVID-19 pandemic. The survey data includes estimates of age, length, and biomass for subsamples of each haul, and occasionally for the entire haul when catch is low.

Data extraction

Data analysis

References

31 HMS Spawning Stock Biomass and Recruitment

Description Biomass and recruitment estimates for many HMS stocks that occupy the California Current are available from stock assessments conducted by collaborators under the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC) or the Inter-American Tropical Tuna Commission (IATTC). The only assessment updates since the 2023-24 ecosystem status report are for Pacific bluefin tuna, skipjack tuna, and bigeye tuna.

The 2024 bigeye tuna assessment underwent several changes since the last benchmark assessment (Xu et al. 2024) The assessment uses a risk analysis approach, encompassing three levels of hypotheses structured hierarchically to address the main uncertainties in the assessment. The time-series shown here are multi-model estimates. The 2024 skipjack tuna assessment is a significant improvement over the 2022 interim assessment (Bi et al. 2024). It reflects major advancements in the assessment methodologies and incorporates new data sets, including tagging data. The Pacific bluefin tuna assessment also included some improvements to the model used in the last (2022) benchmark assessment (ISC 2024). One of the major changes made was to shorten the assessment time period to start in 1983 instead of 1952. This adjustment was implemented because more reliable data were available after 1983. For all species, we emphasize that the status and trends symbols shown in our status and trend figures reflect short-term patterns relative to time series averages (with a period of reference of 1991-2020), and do not necessarily reflect reference points based on, e.g., unfished stock biomass.

[this section will require a bit more writing to incorporate evolving approaches and methods]

Indicators

- Species:
  - Albacore:Recruits (x1000)
  - Bigeye tuna:Recuitment
  - Blue marlin:Recruits (x1000)
  - Bluefin tuna:Recruitment
  - North Pacific swordfish:Recruits (x1000)
  - Skipjack tuna:Recruitment
  - Yellowfin tuna:Recruitment
- Component Category: Highly Migratory Species

- Data Steward: barbara.muhling@noaa.gov
- Institution: NOAA SWFSC/FRD
- Source Data: Estimates of annual recruitment are derived from the stock assessment model. The latest (2023) stock assessment report was 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. 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 assessment model used was similar to that in the 2017 benchmark assessment, with four important changes: 1) adjusting coefficients of variation for the abundance index in 2020-21 to better reflect uncertainty surrounding disruptions from the COVID-19 pandemic, 2) adjustments to Japan longline fleet structure, 3) adjustments to adult abundance indices, and 4) adjustments to age selectivity. The full assessment is available from http://isc.fra.go.jp/reports/stock_assessments.html. The next benchmark assessment is expected in 2026.
- Additional Calculations:

Data extraction

ERDDAP™ link: https://oceanview.pfeg.noaa.gov/erddap/tabledap/cciea_HMS_recruit.html

Data analysis

References

32 HMS Diets

Description Quantifying the diets of highly migratory fishes in the CCE can complement existing trawl-based assessments of the available forage, provide insight into how forage varies over time and space, as well as provide a direct metric of forage utilization. Albacore Tuna, Bluefin Tuna, and Broadbill Swordfish are opportunistic predators that consume a wide variety of prey taxa across a range of depths and habitats. Albacore, Bluefin, and Swordfish stomachs were provided by commercial and recreational fishers, and prey were identified from whole or hard part remains and are reported as a mean percent abundance. A subset of prey species are presented here focusing on prey that are either themselves under a management plan, or considered ecosystem component species, to highlight their links to highly migratory species. Juvenile Albacore Tuna were collected off Northern California, Oregon, and Washington during the summer and fall fishing season. Bluefin Tuna were collected by recreational fishers in the Southern California Bight from spring until early fall. Swordfish were collected off Southern and Central California during the commercial drift gillnet season (August 15th through January 31st). Swordfish stomachs are classified by the year the fishing season began (stomachs from January are assigned to the previous year's fishing season).

[need for descriptive text for figures?]

Albacore tuna diet

- Species:
  - anchovy
  - Euphausiidae
  - hake
  - jack mackerel
  - market squid
  - other
  - Pacific mackerel
  - Pacific saury
  - rockfishes
  - sardine
- Component Category: Highly Migratory Species
- Data Steward: heidi.dewar@noaa.gov
- Institution: NOAA SWFSC/FRD

- Source Data: Diets of albacore tuna provided by C. Nickels, and A. Preti (NMFS/SWFSC). Antonella.Preti@noaa.gov Data are proportional contributions of key prey classes.
- Additional Calculations: Albacore stomachs were provided by commercial and recreational fishers, and prey were identified from whole or hard part remains and are reported as a mean percent abundance. Juvenile Albacore Tuna were collected off Northern California, Oregon, and Washington during the summer and fall fishing season.

Bluefin diet

- Species:
  - anchovy
  - Euphausiidae
  - hake
  - jack mackerel
  - market squid
  - other
  - Pacific mackerel
  - Pacific saury
  - rockfishes
  - sardine
- Component Category: Highly Migratory Species
- Data Steward: heidi.dewar@noaa.gov
- Institution: NOAA SWFSC/FRD
- Source Data: Diets of bluefin tuna provided by T. Richards, and A. Preti (NMFS/SWFSC). Antonella.Preti@noaa.gov Data are proportional contributions of key prey classes.
- Additional Calculations: Bluefin stomachs were provided by commercial gillnet fishery, and prey were identified from whole or hard part remains and are reported as a mean percent abundance.

Swordfish diet

- Species:
  - anchovy
  - Euphausiidae
  - hake
  - jack mackerel
  - market squid
  - other
  - Pacific mackerel
  - Pacific saury

- rockfishes
- sardine

- Component Category: Highly Migratory Species
- Data Steward: heidi.dewar@noaa.gov
- Institution: NOAA SWFSC/FRD
- Source Data: Diets of swordfish provided by A. Preti (NMFS/SWFSC). Antonella.Preti@noaa.gov Data are proportional contributions of key prey classes.
- Additional Calculations: Swordfish stomachs were provided by commercial gillnet fishery, and prey were identified from whole or hard part remains and are reported as a mean percent abundance. Swordfish were collected off Southern and Central California during the commercial drift gillnet season (August 15th through January 31st).

Data extraction

ERDDAP™ links:

https://oceanview.pfeg.noaa.gov/erddap/tabledap/cciea_HMS_ALB_DIET.html https://oceanview.pfeg.noaa.gov/erddap/tabledap/cciea_HMS_BLF_DIET.html https://oceanview.pfeg.noaa.gov/erddap/tabledap/cciea_HMS_SWD_DIET.html

Data analysis

33 Seabird Productivity

Description Seabird population productivity, measured through indicators of reproductive success, tracks marine environmental conditions and often reflects forage production near breeding colonies. We report on standardized anomalies of fledgling production per pair of breeding adults for the Northern CCE (one species at Destruction Island, Washington and three species at Yaquina Head, Oregon) and the Central CCE (five species on Southeast Farallon Island and two species on Año Nuevo Island). These focal species span a range of feeding habits and ways of provisioning their chicks, and thus provide a broad picture of the status of foraging conditions.

[add Table N.1]

Indicator Regions

CeCC; Ano Nuevo, CA

- Species:
  - Brandt's cormorant
  - Rhinoceros auklet
- Component Category: Seabirds
- Data Steward: tom.good@noaa.gov
- Institution: Oikonos/Point Blue Conservation Science
- Source Data: Data from Oikonos Ecosystem Knowledge Ano Nuevo Seabird Conservation and Restoration Project; contact Ryan Carle (ryan@oikonos.org) before citing or distributing these data.
- Additional Calculations: Productivity anomaly is the annual mean number of chicks fledged per breeding pair minus the long term mean.

NoCC; Yaquina Head, OR

- Species:
  - Brandts cormorant
  - Common murre
  - Pelagic cormorant
- Component Category: Seabirds
- Data Steward: tom.good@noaa.gov

- Institution: OSU Seabird Oceanography Lab
- Source Data: Data from Hatfield Marine Science Center Seabird Oceanography Lab Yaquina Head Seabird Studies; contact Rachael Orben (Rachael.Orben@oregonstate.edu) before citing or distributing these data.
- Additional Calculations: Productivity anomaly is the annual mean number of chicks fledged per breeding pair minus the long term mean, which is calculated by averaging all of the annual means prior to the most recent year (for data from 2007 to 2020, the long term mean is calculated including data from 2007-2019).

CeCC; Farallon Islands, CA

- Species:
  - Brandts cormorant
  - Cassins auklet
  - Common murre
  - Pigeon guillemot
  - Rhinoceros auklet
- Component Category: Seabirds
- Data Steward: tom.good@noaa.gov
- Institution: Point Blue Conservation Science
- Source Data: Data from Point Blue Conservation Science collected on Southeast Farallon Island in collaboration with the Farallon Islands National Wildlife Refuge (USFWS); contact Dr. Jaime Jahncke (jjahncke@pointblue.org) before citing or distributing these data.
- Additional Calculations: Productivity anomaly is the annual mean number of chicks fledged per breeding pair per species minus the long term mean, which is calculated by averaging all of the annual means prior to the most recent year (for data from 1986 to 2018, the long term mean is calculated including data from 1986-2017.

Data extraction

ERDDAP™ links:

https://oceanview.pfeg.noaa.gov/erddap/tabledap/cciea_B_PR_ANOM.html https://oceanview.pfeg.noaa.gov/erddap/tabledap/cciea_B_PR_ANOM_ND.html

34 Seabird At-Sea Density

Description Seabird densities on the water during the breeding season can track marine environmental conditions and may reflect regional production and availability of forage. Data from this indicator type can establish habitat use and may be used to detect and track seabird population movements or increases/declines as they relate to ecosystem change. We monitor and report on at-sea densities of three focal seabird species in the Northern, Central, and Southern CCE.

Sooty shearwaters migrate to the CCE from the Southern Hemisphere in spring and summer to forage on the shelf and near the shelf break on small fish, including northern anchovy, as well as squid and zooplankton. Common murres and Cassin's auklets are resident species in the CCE that feed primarily over the shelf. Common murres target a variety of pelagic fish, while Cassin's auklets prey mainly on zooplankton and small fish.

Indicator Regions

Cape Flattery, WA to Newport, OR

- Species:
  - Cassins auklet, Summer
  - Common murre, Summer
  - Sooty shearwater, Summer
- Component Category: Seabirds
- Data Steward: tom.good@noaa.gov
- Institution: NOAA NWFSC
- Source Data: Data from Jen Zamon (jen.zamon@noaa.gov). Data are shipboard counts conducted during the NOAA Northwest Fisheries Science Center's Juvenile Salmon & Ocean Ecosystem Survey (JSOES).
- Additional Calculations: Data are shipboard counts, transformed as ln(bird density/km-2 +1) and expressed as an anomaly of log density relative to the long-term mean.

N of Bodega Bay, CA to south of Monterey Bay, CA

- Species:
  - Cassins auklet, Summer
  - Common murre, Summer

  - Sooty shearwater, Summer

- Component Category: Seabirds
- Data Steward: tom.good@noaa.gov
- Institution: Farallon Institute
- Source Data: Data are from the SWFSC Rockfish Recruitment and Ecosystem Assessment Survey (https://swfsc.noaa.gov/textblock.aspx?Division=FED&ParentMenuId=54&id=20615), courtesy of Dr. Bill Sydeman of the Farallon Institute (wsydeman@faralloninstitute.org)..
- Additional Calculations: Data are shipboard counts, transformed as ln(bird density/km-2 +1) and expressed as an anomaly of log density relative to the long-term mean.

CalCOFI lines 76 to 93

- Species:
  - Cassins auklet, Spring
  - Common murre, Spring
  - Sooty shearwater, Spring
  - Cassins auklet, Spring
  - Common murre, Spring
  - Sooty shearwater, Spring
- Component Category: Seabirds
- Data Steward: tom.good@noaa.gov
- Institution: Farallon Institute
- Source Data: Data are from CalCOFI surveys (http://calcofi.org/field-work/underway-observations/380-bird-observations.html), courtesy of Dr. Bill Sydeman of the Farallon Institute (wsydeman@faralloninstitute.org).
- Additional Calculations: Data are shipboard counts, transformed as ln(bird density/km2 +1) and expressed as an anomaly of log density relative to the long-term mean.

Data extraction

ERDDAP™ link: https://oceanview.pfeg.noaa.gov/erddap/tabledap/cciea_B_AS_DENS.html

Data analysis

35 Seabird Mortality

Description Monitoring of dead beached birds provides information on the health of seabird populations, ecosystem health, and unusual mortality events, and previous ESRs from the anomalously warm and unproductive years of 2014–2016 noted major seabird mortality events in each year.

In the Northern CCE, the Coastal Observation and Seabird Survey Team (COASST) at the University of Washington monitors beaches in Washington, Oregon, and northern California. In the Central CCE, the Beach Watch program monitors beaches from Point Arena to Point Año Nuevo, California.

Indicator Regions

Ce/So CC

- Species:
  - Brandts cormorant encounter rate (Ce CC)
  - Cassins auklet encounter rate (Ce CC)
  - Common murre encounter rate(Ce CC)
  - Northern fulmar encounter rate (Ce CC)
  - Sooty shearwater encounter rate (Ce CC)
  - Brandts cormorant encounter rate (Ce/So CC) Central
  - Cassins auklet encounter rate (Ce/So CC) Central
  - Common murre encounter rate(Ce/So CC) Central
  - Northern fulmar encounter rate (Ce/So CC) Central
  - Sooty shearwater encounter rate (Ce/So CC) Central
  - Brandts cormorant encounter rate (Ce/So CC) North
  - Cassins auklet encounter rate (Ce/So CC) North
  - Common murre encounter rate(Ce/So CC) North
  - Northern fulmar encounter rate (Ce/So CC) North
  - Sooty shearwater encounter rate (Ce/So CC) North
  - Brandts cormorant encounter rate (Ce/So CC) South
  - Cassins auklet encounter rate (Ce/So CC) South
  - Common murre encounter rate(Ce/So CC) South
  - Northern fulmar encounter rate (Ce/So CC) South
  - Sooty shearwater encounter rate (Ce/So CC) South
- Component Category: Seabirds

- Data Steward: tom.good@noaa.gov
- Institution: BeachCOMBERS
- Source Data: Data from BeachCombers, who coordinate a team of trained volunteers that collect effort-controlled survey data on an approximately monthly basis, recording beached bird numbers and identity from survey locations in Central/Southern California. Contact BeachCombers (https://www.mlml.calstate.edu/beachcombers/) for details on calculations before citing or distributing these data.
- Additional Calculations: Annual mean encounter rates (bird carcasses/km surveyed) aggregated from May to October (inclusive) for each surveyed beach location, and then averaged across all beaches surveyed in that year.

Cape Blanco, OR to Cape Flattery, WA

- Species:
  - Northern fulmar (No CC Oct - Feb)
- Component Category: Seabirds
- Data Steward: tom.good@noaa.gov
- Institution: COASST
- Source Data: Data from the Coastal Observation and Seabird Survey Team (COASST), who coordinate a team of trained volunteers that collect effort-controlled survey data on an approximately monthly basis, recording beached bird numbers and identity from survey locations in Northern California through to Northern Washington and into Alaska and the Bering Sea. Contact COASST (https://depts.washington.edu/coasst/) for details on calculations before citing or distributing these data.
- Additional Calculations: Annual mean encounter rates (bird carcasses/km surveyed) aggregated from October to April (inclusive, with years labelled according to the convention that Oct 2014 to Apr 2015 are labelled as 2014) for each surveyed beach location, and then averaged across all beaches surveyed in that year.

CA-OR border to Cape Flattery, WA

- Species:
  - Cassins auklet (No CC Oct - Feb)
- Component Category: Seabirds
- Data Steward: tom.good@noaa.gov
- Institution: COASST
- Source Data: Data from the Coastal Observation and Seabird Survey Team (COASST), who coordinate a team of trained volunteers that collect effort-controlled survey data on an approximately monthly basis, recording beached bird numbers and identity from survey locations in Northern California through to Northern Washington and into Alaska and the Bering Sea. Contact COASST (https://depts.washington.edu/coasst/) for details on calculations before citing or distributing these data.

- Additional Calculations: Annual mean encounter rates (bird carcasses/km surveyed) aggregated from October to February (inclusive, with years labelled according to the convention that Oct 2014 to Feb 2015 are labelled as 2014) for each surveyed beach location, and then averaged across all beaches surveyed in that year.

Eureka, CA to Cape Flattery, WA

- Species:
  - Common murre (No CC Jun - Dec)
  - Sooty shearwater (No CC May - Oct)
- Component Category: Seabirds
- Data Steward: tom.good@noaa.gov
- Institution: COASST
- Source Data: Data from the Coastal Observation and Seabird Survey Team (COASST), who coordinate a team of trained volunteers that collect effort-controlled survey data on an approximately monthly basis, recording beached bird numbers and identity from survey locations in Northern California through to Northern Washington and into Alaska and the Bering Sea. Contact COASST (https://depts.washington.edu/coasst/) for details on calculations before citing or distributing these data.
- Additional Calculations: Annual mean encounter rates (bird carcasses/km surveyed) aggregated from May to October (inclusive) for each surveyed beach location, and then averaged across all beaches surveyed in that year.

Data extraction

ERDDAP™ link: https://oceanview.pfeg.noaa.gov/erddap/tabledap/cciea_B_B_MORT.html

Data analysis

36 Seabird Diet

Description Seabird diet .....

Indicator Regions

NoCC; Destruction Island, WA

- Species:
  - Rhinoceros auklet diet - Anchovy
  - Rhinoceros auklet diet - Herring
  - Rhinoceros auklet diet - Rockfish
  - Rhinoceros auklet diet - Sandlance
  - Rhinoceros auklet diet - Smelt
- Component Category: Seabirds
- Data Steward: tom.good@noaa.gov
- Institution: NOAA NWFSC
- Source Data: Data from Washington Rhinoceros Auklet Ecology Project; contact tom.good@noaa.gov before citing or distributing these data
- Additional Calculations: Diets of rhinoceros auklet chicks (% occurrence) calculated from bill loads of returning adults to the colony at Destruction Island, WA.

NoCC; Yaquina Head, OR

- Species:
  - Common murre diet - Flatfish
  - Common murre diet - Herring/Sardines
  - Common murre diet - Rockfish
  - Common murre diet - Sandlance
  - Common murre diet - Smelt
- Component Category: Seabirds
- Data Steward: tom.good@noaa.gov
- Institution: OSU Seabird Oceanography Lab
- Source Data: Data from Hatfield Marine Science Center Seabird Oceanography Lab Yaquina Head Seabird Studies; contact Rachael Orben (Rachael.Orben@oregonstate.edu) before citing or distributing these data.

- Additional Calculations: Diets of common murre chicks (% occurrence) observed as bill loads of returning adults to colonies at Yaquina Head, OR.

CeCC; Ano Nuevo, CA

- Species:
  - Rhinoceros auklet diet - Anchovy
  - Rhinoceros auklet diet - Rockfish
  - Rhinoceros auklet diet - Squid
  - Rhinoceros auklet diet - Salmon
- Component Category: Seabirds
- Data Steward: tom.good@noaa.gov
- Institution: Oikonos/Point Blue Conservation Science
- Source Data: Data from Oikonos Ecosystem Knowledge Ano Nuevo Seabird Conservation and Restoration Project; contact Ryan Carle (ryan@oikonos.org) before citing or distributing these data.
- Additional Calculations: Diets of rhinoceros auklet chicks (% occurrence) calculated from bill loads of returning adults to the colony at Ano Nuevo Island, CA.

CeCC; Farallon Islands, CA

- Species:
  - Brandt's cormorant diet - Anchovy
  - Brandt's cormorant diet - Rockfish
  - Cassin's auklet diet - Euphausia
  - Cassin's auklet diet - Mysids
  - Common murre diet - Anchovy/sardine
  - Common murre diet - Rockfish
  - Common murre diet - Salmon
  - Pigeon guillemot diet - Rockfish
  - Rhinoceros auklet diet - Anchovy
  - Rhinoceros auklet diet - Rockfish
- Component Category: Seabirds
- Data Steward: tom.good@noaa.gov
- Institution: Point Blue Conservation Science
- Source Data: Data from Point Blue Conservation Science collected on Southeast Farallon Island in collaboration with the Farallon Islands National Wildlife Refuge (USFWS); contact Dr. Jaime Jahncke (jjahncke@pointblue.org) before citing or distributing these data.
- Additional Calculations: Diet is percent occurrence of fish species in the diets of adult birds that are provisioning chicks calculated from bill loads of adults returning to the colony at Southeast Farallon Island, CA.

Data extraction

ERDDAP™ links:

https://oceanview.pfeg.noaa.gov/erddap/tabledap/cciea_B_AS_DIET.html https://oceanview.pfeg.noaa.gov/erddap/tabledap/cciea_B_AS_DIET_ND.html

Data analysis

37 Sea Lion Productivity

Description California sea lion pup count and condition are robust indicators of prey quality and abundance even when the sea lion population is at or near carrying capacity (see Appendix L in Harvey et al. 2022). Pup count relates to prey availability and nutritional status for gestating females from October to June. Pup growth from birth to age 7 months is related to prey availability to lactating females from June to February. Data on the overwinter growth rate of sea lion pups were not available at the time of submission of this document. Nursing female diet information was also not available in time for this report but the lower number of births and moderate condition of pups for the 2023 cohort indicates that foraging conditions may have declined for nursing females in the past year.

To reduce disturbance to California sea lions and to improve the accuracy of our pup counts, we transitioned to using small drones (Aerial Imagery Systems' APH-28 and the Parrot Anafi) for our pup census in 2023. A pilot study in 2017 and 2018 that paired drone surveys and ground counts for the same areas showed no significant differences in counts determined from drones or ground counts. The drone surveys were flown at an altitude of 46 m over small or narrow sections of coastline or in transects over large areas. The images were stitched together using DigiKam software and pups were counted using DotDotGoose software that automatically entered the counts into a data file for analysis. In 2023, weather conditions precluded using the drones for the entire count so we conducted ground counts for about 20% of the colony and used drones for 80%.

Female sea lion pup growth rate

- Component Category: Marine Mammals
- Data Steward: sharon.melin@noaa.gov
- Institution: NOAA AFSC/MML
- Source Data: AFSC/NMML (http://www.afsc.noaa.gov/nmml/species/species_cal.php)
- Additional Calculations: Predicted average (+/-1 s.e.) daily growth rate of female California sea lion pups at San Miguel Island between 4-7 months of age for cohorts from 1997-present. (Note: In 2020, data was not collected due to COVID-19 restrictions to field operations.)

Female sea lion pup weight index

- Component Category: Marine Mammals
- Data Steward: sharon.melin@noaa.gov
- Institution: NOAA AFSC/MML

- Source Data: AFSC/NMML (http://www.afsc.noaa.gov/nmml/species/species_cal.php)
- Additional Calculations: Predicted average pup weights for female California sea lion pups born at San Miguel Island, California. Pups are weighed in September or October each year and weights are adjusted using a mixed effects model to a 1 October weighing date. (Note: In 2020, data was not collected due to COVID-19 restrictions to field operations.)

Sea lion pup count, San Miguel Isl.

- Component Category: Marine Mammals
- Data Steward: sharon.melin@noaa.gov
- Institution: NOAA AFSC/MML
- Source Data: AFSC/NMML (http://www.afsc.noaa.gov/nmml/species/species_cal.php)
- Additional Calculations: Average number of California sea lion pups at San Miguel Island for cohorts from 1997-present. (Note: In 2020, data collection was limited to estimates from aerial surveys due to COVID-19 restrictions to field operations. M. Ball [Wildlands Conservation Science] conducted the aerial surveys and E. Jaime [AFSC] interpreted images to derive counts.)

Data extraction

ERDDAP™ link: https://oceanview.pfeg.noaa.gov/erddap/tabledap/cciea_MM_pup_count.html

Data analysis

38 Whale Entanglement

Description The dynamics of entanglement risk and reporting are complex, and are affected by shifts in ocean conditions and prey fields, changes in whale populations, changes in distribution and timing of fishing effort, and increased public awareness.

Indicators

- Species:
  - Blue Whale
  - Fin Whale
  - Gray Whale
  - Humpback Whale
  - Killer Whale
  - Minke Whale
  - Sperm Whale
  - Grand Total
  - Unidentified Other
  - Unidentified Whale
- Component Category: Ecological Integrity
- Data Steward: dan.lawson@noaa.gov
- Institution: NOAA SWFSC
- Source Data: Whale entanglement data provided by D. Lawson and L. Saez, NMFS/WCR. For more information, consult: https://www.fisheries.noaa.gov/west-coast/marine-mammal-protection/west-coast-large-whale-entanglement-response-program#reportsy
- Additional Calculations: NOAA Fisheries collects, verifies, documents, and responds to reports of large whale entanglements that originate from a variety of sources including boaters, fishermen, law enforcement, marine resource agencies, and the public. NOAA Fisheries confirmed the reports based upon the documents submitted, follow-up sightings, and entanglement response information provided to us from our West Coast Region Marine Mammal Stranding Network partners.

Data extraction

ERDDAP™ link: https://oceanview.pfeg.noaa.gov/erddap/tabledap/cciea_EI_WH_ENT.html

Data analysis

References

39 Harmful Algal Blooms

Description Harmful algal blooms (HABs) of diatoms in the genus Pseudo-nitzschia have been a recurring concern along the West Coast. Certain species of Pseudo-nitzschia produce the toxin domoic acid, which can accumulate in filter feeders and extend through food webs to cause harmful or lethal effects on people, marine mammals, and seabirds (Lefebvre et al. 2002; McCabe et al. 2016). Because domoic acid can cause amnesic shellfish poisoning in humans, fisheries that target shellfish (including razor clam, Dungeness crab, rock crab, and spiny lobster) are delayed, closed, or operate under special orders or health advisories when domoic acid concentrations exceed regulatory thresholds for human consumption. Fishery closures can cost tens of millions of dollars in lost revenue, and cause a range of sociocultural impacts in fishing communities (Dyson and Huppert 2010; Ritzman et al. 2018; Holland and Leonard 2020; Moore et al. 2020), including a "spillover" of fishing effort into other fisheries.

Ocean conditions associated with marine heatwaves, El Niño events, or positive PDO regimes may further exacerbate domoic acid toxicity and fishery impacts, and domoic acid toxicity tracks anomalies of southern copepod biomass (Fig. 3.1) (McCabe et al. 2016; McKibben et al. 2017). The largest and most toxic HAB of Pseudo-nitzschia on the West Coast occurred in 2015, coincident with the 2013-2016 marine heatwave, and caused the longest-lasting and most widespread HAB-related fisheries closures on record (McCabe et al. 2016; Moore et al. 2019; Trainer et al. 2020). Closures and delays in the opening of West Coast crab fisheries resulted in the appropriation of >$25M in federal disaster relief funds (McCabe et al. 2016).

According to thresholds set by the U.S. Food and Drug Administration, domoic acid levels 20 parts per million (ppm) trigger actions for all seafood and tissues except Dungeness crab viscera, for which the level is >30 ppm (California applies this to rock crab viscera as well) (FDA 2011). Under evisceration orders, Dungeness crab can be landed when the viscera exceeds the threshold but the meat does not, provided that crab are eviscerated by a licensed processor. Oregon was the first West Coast state to pass legislation allowing evisceration, in November 2017, followed by California in October 2021. Washington adopted an emergency evisceration rule in February 2021, and is considering legislation to grant long-term authority for issuing evisceration orders.

[add more from past ESRs]

Data sources

Data extraction

Data analysis

Part IV

Fishing and Non-Fishing Human Activities

40 Fishery Landings

Description Fishery landings are indicators of ecosystem services provided and also reflect removals from the CCE. Commercial landings data are best summarized by the Pacific Fisheries Information Network (PacFIN; pacfin.psmfc.org), and recreational landings are best summarized by the Recreational Fisheries Information Network (RecFIN; www.recfin.org). Landings provide the best long-term indicator of fisheries removals. Status and trends are estimated relative to a frame of reference of 1991-2020. In most cases, landings data for the most recent reporting years are only complete through the latter months (e.g., October-December); these data are updated in the next annual cycle.

Commercial landings data are reported coastwide and by state (CA, OR, WA) by fishery species category; in the case of recreational landings, however, we use the same geographic reporting distinctions but differentiate only between salmon recreational and total recreational landings.

Indicators

- **Coastal pelagic spp, no squid CA**
  - *Source Data:* Pacific Fisheries Information Network (PacFIN; http://pacfin.psmfc.org/)
- **Coastal pelagic spp, no squid coastwide**
  - *About this indicator:* Coastal pelagic species (without market squid (Loligo opalescens)) landings (1000's of metric tons) on the U.S. West Coast. Coastal pelagic species include Pacific herring (Clupea harengus pallasii), round herring (Etrumeus teres), chub mackerel (Scomber japonicus), jack mackerel (Trachurus symmetricus), northern anchovy (Engraulis mordax), Pacific bonito (Sarda chiliensis), Pacific sardine (Sardinops sagax), and unspecified mackerel.
  - *Source Data:* Pacific Fisheries Information Network (PacFIN; http://pacfin.psmfc.org/)
- **Coastal pelagic spp, no squid OR**
  - *About this indicator:* Coastal pelagic species (without market squid (Loligo opalescens)) landings (1000's of metric tons) in Oregon. Coastal pelagic species include Pacific herring (Clupea harengus pallasii), round herring (Etrumeus teres), chub mackerel (Scomber japonicus), jack mackerel (Trachurus symmetricus), northern anchovy (Engraulis mordax), Pacific bonito (Sarda chiliensis), Pacific sardine (Sardinops sagax), and unspecified mackerel.

- *Source Data:* Pacific Fisheries Information Network (PacFIN; http://pacfin.psmfc.org/)

- **Coastal pelagic spp, no squid WA**
  - *Source Data:* Pacific Fisheries Information Network (PacFIN; http://pacfin.psmfc.org/)

- **Crab CA**
  - *About this indicator:* Crab landings (1000's of metric tons) in California. Crab species include Dungeness (Metacarcinus magister), tanner (Chionoecetes spp.), rock (Cancer spp.) and unspecified crabs.
  - *Source Data:* Pacific Fisheries Information Network (PacFIN; http://pacfin.psmfc.org/)

- **Crab coastwide**
  - *About this indicator:* Crab landings (1000's of metric tons) on the U.S. West Coast. Crab species include Dungeness (Metacarcinus magister), tanner (Chionoecetes spp.), rock (Cancer spp.) and unspecified crabs.
  - *Source Data:* Pacific Fisheries Information Network (PacFIN; http://pacfin.psmfc.org/)

- **Crab OR**
  - *About this indicator:* Crab landings (1000's of metric tons) in Oregon. Crab species include Dungeness (Metacarcinus magister), tanner (Chionoecetes spp.), rock (Cancer spp.) and unspecified crabs.
  - *Source Data:* Pacific Fisheries Information Network (PacFIN; http://pacfin.psmfc.org/)

- **Crab WA**
  - *About this indicator:* Crab landings (1000's of metric tons) in Washington. Crab species include Dungeness (Metacarcinus magister), tanner (Chionoecetes spp.), rock (Cancer spp.) and unspecified crabs.
  - *Source Data:* Pacific Fisheries Information Network (PacFIN; http://pacfin.psmfc.org/)

- **Highly migratory species CA**
  - *About this indicator:* Highly migratory species landings (1000's of metric tons) in California. Highly migratory species primarily consist of tunas (Thunnus spp), swordfish (Xiphias gladius) and pelagic sharks (e.g., blue (Prionace glauca), thresher (Alopias spp), and shortfin mako (Isurus oxyrinchus).
  - *Source Data:* Pacific Fisheries Information Network (PacFIN; http://pacfin.psmfc.org/)

- **Highly migratory species coastwide**
  - *About this indicator:* Highly migratory species landings (1000's of metric tons) on the U.S. West Coast. Highly migratory species primarily consist of tunas (Thunnus spp), swordfish (Xiphias gladius) and pelagic sharks (e.g., blue (Prionace glauca), thresher (Alopias spp), and shortfin mako (Isurus oxyrinchus).
  - *Source Data:* Pacific Fisheries Information Network (PacFIN; http://pacfin.psmfc.org/)

- **Highly migratory species OR**
  - *About this indicator:* Highly migratory species landings (1000's of metric tons) in Oregon. Highly migratory species primarily consist of tunas (Thunnus spp), swordfish (Xiphias gladius) and pelagic sharks (e.g., blue (Prionace glauca), thresher (Alopias spp), and shortfin mako (Isurus oxyrinchus).
  - *Source Data:* Pacific Fisheries Information Network (PacFIN; http://pacfin.psmfc.org/)
- **Highly migratory species WA**
  - *About this indicator:* Highly migratory species landings (1000's of metric tons) in Washington. Highly migratory species primarily consist of tunas (Thunnus spp), swordfish (Xiphias gladius) and pelagic sharks (e.g., blue (Prionace glauca), thresher (Alopias spp), and shortfin mako (Isurus oxyrinchus).
  - *Source Data:* Pacific Fisheries Information Network (PacFIN; http://pacfin.psmfc.org/)
- **Market squid CA**
  - *About this indicator:* Market squid (Loligo opalescens) landings (1000's of metric tons) in California.
  - *Source Data:* Pacific Fisheries Information Network (PacFIN; http://pacfin.psmfc.org/)
- **Market squid coastwide**
  - *Source Data:* Pacific Fisheries Information Network (PacFIN; http://pacfin.psmfc.org/)
- **Market squid OR**
  - *Source Data:* Pacific Fisheries Information Network (PacFIN; http://pacfin.psmfc.org/)
- **Non-whiting groundfish CA**
  - *About this indicator:* Non-whiting groundfish (Merluccius productus) landings (1000's of metric tons) in California. Groundfish taxa include flatfishes, rockfishes and abundant demersal roundfishes.
  - *Source Data:* Pacific Fisheries Information Network (PacFIN; http://pacfin.psmfc.org/)
- **Non-whiting groundfish coastwide**
  - *About this indicator:* Non-whiting groundfish (Merluccius productus) landings (1000's of metric tons) on the U.S. West Coast. Groundfish taxa include flatfishes, rockfishes and abundant demersal roundfishes.
  - *Source Data:* Pacific Fisheries Information Network (PacFIN; http://pacfin.psmfc.org/)
- **Non-whiting groundfish OR**
  - *About this indicator:* Non-whiting groundfish (Merluccius productus) landings (1000's of metric tons) in Oregon. Groundfish taxa include flatfishes, rockfishes and abundant demersal roundfishes.
  - *Source Data:* Pacific Fisheries Information Network (PacFIN; http://pacfin.psmfc.org/)

- **Non-whiting groundfish WA**
  - *About this indicator:* Non-whiting groundfish (Merluccius productus) landings (1000's of metric tons) in Washington. Groundfish taxa include flatfishes, rockfishes and abundant demersal roundfishes.
  - *Source Data:* Pacific Fisheries Information Network (PacFIN; http://pacfin.psmfc.org/)
- **Other species CA**
  - *About this indicator:* Other species landings (1000's of metric tons) in California. Other species include several taxa, but consists primarily of red sea urchin (Stronglyocentrotus franciscanus) and hagfish (Eptatretus spp.).
  - *Source Data:* Pacific Fisheries Information Network (PacFIN; http://pacfin.psmfc.org/)
- **Other species coastwide**
  - *About this indicator:* Other species landings (1000's of metric tons) on the U.S. West Coast. Other species include several taxa, but consists primarily of red sea urchin (Stronglyocentrotus franciscanus) and hagfish (Eptatretus spp.).
  - *Source Data:* Pacific Fisheries Information Network (PacFIN; http://pacfin.psmfc.org/)
- **Other species OR**
  - *About this indicator:* Other species landings (1000's of metric tons) in Oregon. Other species include several taxa, but consists primarily of red sea urchin (Stronglyocentrotus franciscanus) and hagfish (Eptatretus spp.).
  - *Source Data:* Pacific Fisheries Information Network (PacFIN; http://pacfin.psmfc.org/)
- **Other species WA**
  - *About this indicator:* Other species landings (1000's of metric tons) in Washington. Other species include several taxa, but consists primarily of red sea urchin (Stronglyocentrotus franciscanus) and hagfish (Eptatretus spp.).
  - *Source Data:* Pacific Fisheries Information Network (PacFIN; http://pacfin.psmfc.org/)
- **Pacific whiting CA**
  - *About this indicator:* Pacific whiting (Merluccius productus) landings (1000's of metric tons) in California. Pacific whiting landings include data from shoreside and at-sea processors.
  - *Source Data:* Pacific Fisheries Information Network (PacFIN; http://pacfin.psmfc.org/)
- **Pacific whiting coastwide**
  - *About this indicator:* Pacific whiting (Merluccius productus) landings (1000's of metric tons) on the U.S. West Coast. Pacific whiting landings include data from shoreside and at-sea processors.
  - *Source Data:* Pacific Fisheries Information Network (PacFIN; http://pacfin.psmfc.org/)

- **Pacific whiting OR**
  - *About this indicator:* Pacific whiting (Merluccius productus) landings (1000's of metric tons) in Oregon. Pacific whiting landings include data from shoreside and at-sea processors.
  - *Source Data:* Pacific Fisheries Information Network (PacFIN; http://pacfin.psmfc.org/)
- **Pacific whiting WA**
  - *About this indicator:* Pacific whiting (Merluccius productus) landings (1000's of metric tons) in Washington. Pacific whiting landings include data from shoreside and at-sea processors.
  - *Source Data:* Pacific Fisheries Information Network (PacFIN; http://pacfin.psmfc.org/)
- **Recreational CA**
  - *About this indicator:* Total landings of all species from recreational fisheries in California from www.recfin.org using weight of catch type "A + B1" metric tons.
  - *Source Data:* Recreational Fisheries Information Network (RecFIN; http://www.recfin.org/)
- **Recreational coastwide**
  - *About this indicator:* Total landings of all species from recreational fisheries from www.recfin.org using weight of catch type "A + B1" metric tons.
  - *Source Data:* Recreational Fisheries Information Network (RecFIN; http://www.recfin.org/)
- **Recreational OR**
  - *About this indicator:* Total landings of all species from recreational fisheries in Oregon from www.recfin.org using weight of catch type "A + B1" metric tons.
  - *Source Data:* Recreational Fisheries Information Network (RecFIN; http://www.recfin.org/)
- **Recreational WA**
  - *About this indicator:* Total landings of all species from recreational fisheries in Washington from www.recfin.org using weight of catch type "A + B1" metric tons.
  - *Source Data:* Recreational Fisheries Information Network (RecFIN; http://www.recfin.org/)
- **Salmon commercial CA**
  - *About this indicator:* Salmon landings (1000's of metric tons) in California. Salmon landings primarily consist of Chinook (Oncorhynchus tshawytscha), but also includes chum (O. keta), coho (O. kisutch), pink (O. gorbuscha) and sockeye (O. nerka) and steelhead (O. mykiss) .
  - *Source Data:* Pacific Fisheries Information Network (PacFIN; http://pacfin.psmfc.org/)
- **Salmon commercial coastwide**

- *About this indicator:* Salmon landings (1000's of metric tons) on the U.S. West Coast. Salmon landings primarily consist of Chinook (Oncorhynchus tshawytscha), but also includes chum (O. keta), coho (O. kisutch), pink (O. gorbuscha) and sockeye (O. nerka) and steelhead (O. mykiss) .
- *Source Data:* Pacific Fisheries Information Network (PacFIN; http://pacfin.psmfc.org/)

- **Salmon commercial OR**
  - *About this indicator:* Salmon landings (1000's of metric tons) in Oregon. Salmon landings primarily consist of Chinook (Oncorhynchus tshawytscha), but also includes chum (O. keta), coho (O. kisutch), pink (O. gorbuscha) and sockeye (O. nerka) and steelhead (O. mykiss) .
  - *Source Data:* Pacific Fisheries Information Network (PacFIN; http://pacfin.psmfc.org/)

- **Salmon commercial WA**
  - *About this indicator:* Salmon landings (1000's of metric tons) in Washington. Salmon landings primarily consist of Chinook (Oncorhynchus tshawytscha), but also includes chum (O. keta), coho (O. kisutch), pink (O. gorbuscha) and sockeye (O. nerka) and steelhead (O. mykiss) .
  - *Source Data:* Pacific Fisheries Information Network (PacFIN; http://pacfin.psmfc.org/)

- **Salmon recreational CA**
  - *About this indicator:* Salmon landings (1000's of metric tons) in California. Salmon landings primarily consist of Chinook (Oncorhynchus tshawytscha), but also includes chum (O. keta), coho (O. kisutch), pink (O. gorbuscha) and sockeye (O. nerka) and steelhead (O. mykiss) .
  - *Source Data:* Recreational Fisheries Information Network (RecFIN; http://www.recfin.org/)

- **Salmon recreational coastwide**
  - *About this indicator:* Salmon landings (1000's of metric tons) on the U.S. West Coast. Salmon landings primarily consist of Chinook (Oncorhynchus tshawytscha), but also includes chum (O. keta), coho (O. kisutch), pink (O. gorbuscha) and sockeye (O. nerka) and steelhead (O. mykiss) .
  - *Source Data:* Recreational Fisheries Information Network (RecFIN; http://www.recfin.org/)

- **Salmon recreational OR**
  - *About this indicator:* Salmon landings (1000's of metric tons) in Oregon. Salmon landings primarily consist of Chinook (Oncorhynchus tshawytscha), but also includes chum (O. keta), coho (O. kisutch), pink (O. gorbuscha) and sockeye (O. nerka) and steelhead (O. mykiss) .
  - *Source Data:* Recreational Fisheries Information Network (RecFIN; http://www.recfin.org/)

- **Salmon recreational WA**

- *About this indicator:* Salmon landings (1000's of metric tons) in Washington. Salmon landings primarily consist of Chinook (Oncorhynchus tshawytscha), but also includes chum (O. keta), coho (O. kisutch), pink (O. gorbuscha) and sockeye (O. nerka) and steelhead (O. mykiss) .
- *Source Data:* Recreational Fisheries Information Network (RecFIN; http://www.recfin.org/)

- **Shrimp CA**
  - *About this indicator:* Shrimp landings (1000's of metric tons) in California. Shrimp landings consist primarily of Pacific pink shrimp (Pandalus jordani).
  - *Source Data:* Pacific Fisheries Information Network (PacFIN; http://pacfin.psmfc.org/)
- **Shrimp coastwide**
  - *About this indicator:* Shrimp landings (1000's of metric tons) on the U.S. West Coast. Shrimp landings consist primarily of Pacific pink shrimp (Pandalus jordani).
  - *Source Data:* Pacific Fisheries Information Network (PacFIN; http://pacfin.psmfc.org/)
- **Shrimp OR**
  - *About this indicator:* Shrimp landings (1000's of metric tons) in Oregon. Shrimp landings consist primarily of Pacific pink shrimp (Pandalus jordani).
  - *Source Data:* Pacific Fisheries Information Network (PacFIN; http://pacfin.psmfc.org/)
- **Shrimp WA**
  - *About this indicator:* Shrimp landings (1000's of metric tons) in Washington. Shrimp landings consist primarily of Pacific pink shrimp (Pandalus jordani).
  - *Source Data:* Pacific Fisheries Information Network (PacFIN; http://pacfin.psmfc.org/)
- **Total fisheries CA**
  - *About this indicator:* Combined commercial and recreational fisheries landings (1000's of metric tons) in California.
  - *Source Data:* Pacific Fisheries Information Network (PacFIN; http://pacfin.psmfc.org/)
- **Total fisheries coastwide**
  - *About this indicator:* Combined commercial and recreational fisheries landings (1000's of metric tons) on the U.S. West Coast.
  - *Source Data:* Pacific Fisheries Information Network (PacFIN; http://pacfin.psmfc.org/)
- **Total fisheries OR**
  - *About this indicator:* Combined commercial and recreational fisheries landings (1000's of metric tons) in Oregon.
  - *Source Data:* Pacific Fisheries Information Network (PacFIN; http://pacfin.psmfc.org/)
- **Total fisheries WA**

- *About this indicator:* Combined commercial and recreational fisheries landings (1000's of metric tons) in Washington.
- *Source Data:* Pacific Fisheries Information Network (PacFIN; http://pacfin.psmfc.org/)

Component Category: Human Activities

Data Steward: kelly.andrews@noaa.gov

Institution: NOAA NWFSC

Data extraction

ERDDAP™ link: https://oceanview.pfeg.noaa.gov/erddap/tabledap/cciea_AC_landings.html

Data analysis

References

41 Commercial Fishery Revenue

Description Commercial fishery revenue is a direct indicator of ecosystem services provided to coastal economies of the CCE. Commercial revenue data are best summarized by the Pacific Fisheries Information Network (PacFIN; pacfin.psmfc.org). Revenues are calculated based on consumer price indices in current year (e.g., 2024) dollars. Status and trends are estimated relative to a frame of reference of 1991-2020. In most cases, revenue data for the most recent reporting year are only complete through the latter months (e.g., October-December); these data are updated in the next annual cycle.

Commercial revenue data are reported coastwide and by state (CA, OR, WA) by fishery species category.

Indicators

- Species:
  - Coastal pelagic spp, no squid CA
  - Coastal pelagic spp, no squid coastwide
  - Coastal pelagic spp, no squid OR
  - Coastal pelagic spp, no squid WA
  - Commercial fisheries CA
  - Commercial fisheries coastwide
  - Commercial fisheries OR
  - Commercial fisheries WA
  - Crab CA
  - Crab coastwide
  - Crab OR
  - Crab WA
  - Non-whiting groundfish CA
  - Non-whiting groundfish coastwide
  - Non-whiting groundfish OR
  - Non-whiting groundfish WA
  - Highly migratory species CA
  - Highly migratory species coastwide
  - Highly migratory species OR
  - Highly migratory species WA
  - Market squid CA
  - Market squid coastwide

  - Market squid OR
  - Other species CA
  - Other species coastwide
  - Other species OR
  - Other species WA
  - Pacific whiting CA
  - Pacific whiting coastwide
  - Pacific whiting OR
  - Pacific whiting WA
  - Salmon CA
  - Salmon coastwide
  - Salmon OR
  - Salmon WA
  - Shrimp CA
  - Shrimp coastwide
  - Shrimp OR
  - Shrimp WA
- Component Category: Human Activities
- Data Steward: kelly.andrews@noaa.gov
- Institution: NOAA NWFSC
- Source Data: Pacific Fisheries Information Network (PacFIN; http://pacfin.psmfc.org/)
- Additional Calculations: Coastal pelagic species (without market squid (Loligo opalescens)) revenue (millions of 2015 dollars) in California. Coastal pelagic species include Pacific herring (Clupea harengus pallasii), round herring (Etrumeus teres), chub mackerel (Scomber japonicus), jack mackerel (Trachurus symmetricus), northern anchovy (Engraulis mordax), Pacific bonito (Sarda chiliensis), Pacific sardine (Sardinops sagax), and unspecified mackerel.

Data extraction

ERDDAP™ link: https://oceanview.pfeg.noaa.gov/erddap/tabledap/cciea_AC_revenue.html

Data analysis

References

42 Other Human Activities

Description [draw from old reports; this section will require a bit more writing to incorporate evolving approaches and methods]

Indicators

- Species:
  - Bottom trawl contact with seafloor habitat
  - Commercial shipping - distance
  - Finfish Aquaculture
  - Nutrient Input
  - Oil And Gas Activity
  - Seafood consumption (per capita)
  - Seafood consumption (total)
  - Shellfish Aquaculture
- Component Category: Human Activities
- Data Steward: kelly.andrews@noaa.gov
- Institution: NOAA NWFSC
- Source Data: Distances were summed within physiographic depth, habitat and ecoregion categories from logbook data provided by the West Coast Groundfish Observer Program at the Northwest Fisheries Science Center and is comparable to the data developed for NOAA's Essential Fish Habitat 5-year Synthesis Review in 2013 (maps and data available: http://efh-catalog.coas.oregonstate.edu/overview/
- Additional Calculations: Habitat modification was measured using the total distance disturbed by trawling and fixed (longlines and pots) gear. Straight line distances between start and end points for trawling gear and between set and retrieval points for fixed gear were calculated for each gear type and weighted by the gear type's impact to the bottom habitat and by the type of habitat. These weightings come from NOAA's 5-year Synthesis Review of West Coast Groundfish (Supplemental Table A3a.2)

Data extraction

ERDDAP™ link: https://oceanview.pfeg.noaa.gov/erddap/tabledap/cciea_AC_nonfisheries.html

Data analysis

References

43 Spatial Interactions with Ocean-Use Sectors

Below, we describe two portfolios of indicators for i) oceanographic and lower-trophic level productivity and ii) fisheries activity that can help identify ocean areas important to the overall structure and function of the CCE, and that can track potential social-ecological impacts across all stages of OWE development.

Oceanography and Productivity. Six broad-scale indicators of long-term, spatial variation in oceanography and lower-trophic level productivity are being used to inform spatial suitability analyses in areas off northern California being considered for OWE development in 2024. The ecosystem indicators include: 1. Average wind-driven upwelling during March-July, calculated at 40m depth from 1988-2012 using the Regional Ocean Modeling System (Raghukumar et al. 2023); 2. Long-term, spatial variability and hotspots in primary productivity, calculated from a biogeochemistry model as the average concentration of surface phytoplankton in May-July, 1995-2020 (Fiechter et al. 2018); 3. Long-term, spatial variability and hotspots in secondary productivity from May-August, calculated as an ensemble of four different estimates of krill abundance/biomass across the West Coast (Cimino et al. 2020; Fiechter et al. 2020; Messié et al. 2022; Phillips et al. 2022); 4. Long-term, spatial variability and hotspots for young-of-year (YOY) rockfishes during their pelagic juvenile life stage in May-June from 2001-2022 (Field et al. 2021); 5.Long-term, spatial variability and hotspots for YOY Pacific hake in May-June from 2001-2022 (Field et al. 2021); 6. Long-term, spatial variability and hotspots of groundfish nursery habitat on the seafloor, based on summed average densities of juveniles from 13 groundfish species in May-October from 2003-2018 (Tolimieri et al. 2020).

The Bureau of Ocean Energy Management (BOEM) has been using a spatial suitability analysis developed by NOAA's National Centers for Coastal and Ocean Science (NCCOS) to identify areas BOEM may consider for OWE development. In order to inform an analysis of new areas along the northern California coast, we used BOEM's methods to calculate an overall suitability score across the six ecosystem indicators for each grid cell (Riley et al. 2021). Briefly, the raw data for each indicator was cropped to the area-of-interest, interpolated across a 2x2-km spatial grid, transformed using a z-membership function, and then geometrically averaged across all indicators for each grid cell. This geometric mean represents the suitability score of a grid cell for OWE development relative to the importance of these areas to the processes represented by each indicator; thus, a suitability score of '1' is most suitable for OWE, while suitability scores closer to 0 are less suitable. In addition to being applicable to siting of new areas, these indicators could be used to establish baseline conditions that can be used to identify potential effects resulting from OWE development and to identify relevant mitigation strategies.

Fisheries Indicators. We developed seven indicators that describe spatial and temporal variation in groundfish bottom trawling activity from 2002-2021 in the same region being considered for OWE development off the coast of northern California. These indicators were presented in the 2022 ESR and are meant to capture the spatial and temporal variation in fishing effort for the groundfish bottom trawl fishery and to be used in tandem with the ecosystem indicators to identify potential interactions across the entire social-ecological system.

For the groundfish indicators herein, we used logbook set and retrieval coordinates from the limited-entry/catch shares groundfish bottom trawl fisheries to estimate total duration trawled on a 2x2-km grid. These durations were then used to calculate: 1. total duration trawled in the most recent year (2021); 2. the anomaly of the most recent year relative to the entire time series; 3. the most recent 5-year mean (2017-2021); 4. the most recent 5-year trend (2017-2021); 5. the sum of duration trawled across all years; 6. the proportion of years trawled; and 7. the number of years since trawling occurred within each grid cell.

To maintain confidentiality, grid cells with <3 vessels operating within the grid cell across the years associated with the indicator have been removed. The first four indicators are consistent with measuring the 'status' and 'trends' of other ecosystem indicators presented in this report, while the last three have been developed as indicators to use within a risk analysis framework. These indicators account for only federal limited-entry/catch shares groundfish bottom trawl fisheries from 2002-2021, but provide a useful framework for identifying the potential for overlap and conflict between day-to-day fisheries operations and OWE areas. Other fisheries were included in a similar framework and will be added as analyses are completed.

Part V

Human Wellbeing

44 Social Vulnerability

Description The Community Social Vulnerability Index (CSVI) is an indicator of social vulnerability in coastal communities that are dependent upon commercial fishing. To gain further insight into community vulnerability in relation to commercial fishing, fishing dependence, which can be expressed in terms of engagement, reliance, or by a composite of both, can be considered in relation to CSVI. Engagement refers to the total extent of fishing activity in a community; it can be expressed in terms of commercial activity (e.g., landings, revenues, permits, processing, 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.

Similar to the commercial fishing reliance and engagement measures produced as a part of the Community Social Vulnerability Index (CSVI), we have developed index measures for recreational fishing engagement and reliance, absent in prior versions of this report as consistent annual data had not been identified. As with the commercial fishing Index construction, following the method proposed by Jepson and Colburn (2013), data directly linking place-based communities to the economic aspects of recreational fishing, which could be attributed to specific calendar years, were compiled from six distinct sources as inputs for the measures. Charter and guide permit data collected by state managers were obtained and linked to Census-Designated Place (CDP) based communities. Additionally, historic fishing tackle business location data was compiled from Data Axel, the provider of business location data to Environmental Systems Research Institute's (ESRI) business analyst application. Marina business location data was also obtained from ESRI and ESRI's provider. These data enable interannual comparisons and allow for future replicable iterations.

Communities that score highly in either commercial or recreational reliance in addition to higher social vulnerability scores may be especially socially vulnerable to downturns in fishing. Fishing reliance can be volatile: communities can move left on the x-axis in years with reduced landings, and may thus appear to be less dependent on commercial fishing when in fact they have actually just experienced a difficult year; therefore, these results should be interpreted with care. These same qualifications apply to recreational fishing reliance measures, and several communities are among the most reliant in their respective regions for both commercial and recreational fishing. These data are difficult to groundtruth and interpreting trends requires further study.

- Communities (ordered north to south):
    - Bellingham, WA

- Neah Bay, WA
- Anacortes, WA
- La Push, WA
- Westport, WA
- Seattle, WA
- Tokeland, WA
- Shelton, WA
- Bay Center, WA
- Olympia, WA
- Ilwaco, WA
- Chinook, WA
- Astoria, OR
- Garibaldi, OR
- Tillamook, OR
- Beaver, OR
- Cloverdale, OR
- Newport, OR
- Florence, OR
- Coos Bay, OR
- Yachats, OR
- Port Orford, OR
- Winchester Bay, OR
- Brookings, OR
- Crescent City, CA
- Trinidad, CA
- Eureka, CA
- Fields Landing, CA
- Redcrest, CA
- Shelter Cove, CA
- Fort Bragg, CA
- Little River, CA
- Albion, CA
- Point Arena, CA
- Bodega Bay, CA
- Dillon Beach, CA
- Tomales, CA
- Bolinas, CA
- San Francisco, CA
- El Granada, CA
- Half Moon Bay, CA
- Moss Landing, CA
- Monterey, CA
- Morro Bay, CA

  - Avila Beach, CA
  - Santa Barbara, CA
  - Summerland, CA
  - San Buenaventura (Ventura), CA
  - Oxnard, CA
  - Port Hueneme, CA
  - Marina del Rey, CA
  - Los Angeles, CA
  - Dana Point, CA
  - Avalon, CA
  - Del Mar, CA
  - San Diego, CA

- Component Category: Human Wellbeing
- Data Steward: karma.norman@noaa.gov
- Institution: NOAA NWFSC
- Source Data: Community social vulnerability index (CSVI) data were provided by Dr. Karma Norman (NOAA), and are derived from the American Community Survey (ACS) associated with the US Census (http://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml). Although decennial census data represent an estimate at a specific date, the ACS data are period estimates, collected over an entire year and are potentially averaged over varying time periods, depending on the size of the geographic area (U.S. Census Bureau, 2009). Given that communities of interest include geographic areas with populations less than 20,000, ACS data at the Census-Designate Place level or for place-based communities, are averaged over a five-year period. Annual scores are provided as categorical rankings with high representing scores at or above 1 standard deviation, medium high as between .5 and .99 standard deviation, mediam as 0 to .49 standard deviation and low as below 0 standard deviation.

- Additional Calculations: The Community Social Vulnerability Index (CSVI) is derived from social vulnerability indices (e.g., personal disruption, poverty, population composition, housing characteristics, housing disruption, labor force structure, and natural resource labor force).

Data extraction

ERDDAP™ link: https://oceanview.pfeg.noaa.gov/erddap/tabledap/cciea_HD_Soc_Vuln_Indx.html

Data analysis

References

45 Fleet Income Diversification

Description Catches and prices from many fisheries exhibit high interannual variability, leading to high variability in fisher's revenue, but variability can be reduced by diversifying activities across multiple fisheries or regions (Kasperski and Holland 2013). Individuals may have good reasons to specialize, including reduced costs or greater efficiency; thus while diversification may reduce income variation, it does not necessarily promote higher average profitability. We use the Effective Shannon Index (ESI) to examine diversification of fishing revenue for more than 28,000 vessels fishing off the West Coast and Alaska over the last 40 years. The 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; ESI = 3 if revenues are spread evenly across 3 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.

Diversification can take other forms. Spreading effort and catch over the year, or simply fishing more weeks of the year, can both increase revenue and decrease interannual variation of revenue just as species diversification does. In fact, Abbot et al. (2023) showed that reductions in revenue variation associated with species diversification can be explained mainly by increased temporal diversification, which can be achieved by fishing in multiple fisheries but also by fishing for more weeks of the year in a single fishery. Effective Shannon Index can also be used to examine how widely and evenly vessel revenues are spread across weeks of the year as an indicator or temporal diversification. Like the species diversification metric, this index increases the more weeks of the year a vessel has revenue and the more evenly that revenue is distributed across weeks. A vessel fishing 15 weeks of the year with the same revenue each of those weeks would have a temporal ESI of 15, and that number would decline as revenue is spread less evenly over the 15 weeks.

- Indicators:
  - vess_rev_5k
  - vess_rev_5k_fish_2023
  - vess_rev_5k_fish_1981-2023
  - vess_rev_5k_fish_1981
  - vess_rev_5_25k
  - vess_rev_25-100k
  - vess_rev_100k
  - vess_rev_5k_len_40

- vess_rev_5k_len_41-80
- vess_rev_5k_len_81-125
- vess_2023_WA_rev_5k
- vess_2023_OR_rev_5k
- vess_2023_CA_rev_5k
- vess_2023_WC_rev_5k_ave_5k-25k
- vess_2023_WC_rev_5k_ave_25-100k
- vess_2023_WC_rev_5k_ave_100k
- vess_2023_WC_rev_5k_len_40
- vess_2023_WC_rev_5k_len_41-80
- vess_2023_WC_rev_5k_len_81-125
- Port of Bellingham, WA
- Port of Seattle, WA
- Port of Westport, WA
- Port of Ilwaco, WA
- Port of Astoria, OR
- Port of Newport, OR
- Port of Charleston, OR
- Port of Brookings, OR
- Port of Crescent City, CA
- Port of Eureka, CA
- Port of Fort Bragg, CA
- Port of San Francisco, CA
- Port of Moss Landing, CA
- Port of Santa Barbara, CA
- Port of Ventura, CA
- Port of San Pedro, CA

- Component Category: Human Wellbeing
- Data Steward: dan.holland@noaa.gov
- Institution: NOAA NWFSC/AFSC
- Source Data: Data derived from Pacific Fisheries Information Network (PacFIN; http://pacfin.psmfc.org/) and Alaska Fisheries Information Network (AKFIN; http://www.akfin.org/). Fishery diversification estimates provided by D. Holland, NMFS/NWFSC, and S. Kasperski, NMFS/AFSC.
- Additional Calculations: Aggregation and manipulaton of vessel level annual revenue data to create effective shannon index. For details, see: Kasperski, S. and D.S. Holland 2013. Income Diversification and Risk for Fishermen. Proceedings of the National Academy of Science. 100(6):2076-2081. doi: 10.1073/pnas.1212278110; Holland, D.S. and S. Kasperski 2016. The Impact of Access Restrictions on Fishery Income Diversification of US West Coast Fishermen. Forthcoming in Coastal Management.

Data extraction

ERDDAP™ link: https://oceanview.pfeg.noaa.gov/erddap/tabledap/cciea_HD_ESI_VESS.html

Data analysis

References

46 Non-Fishery Income Diversification

Description Compared to many other professions, fishers face unusually high year-to-year variability in their income levels. Diversifying fishing income can help reduce income variability and reduce financial risk, but focusing solely on diversification opportunities within the fishery misses a potentially important form of financial risk reduction - income diversification from non-fishing occupations (i.e., livelihood diversification). Livelihood diversification may actually be a more effective form of financial risk reduction for fishing households if their non-fishing income streams are unaffected by changes in fishery productivity or profitability or if they can be actively increased when fishing income is low.

Levels and trends in non-fishery income diversification have not been presented previously due to a lack of regularly collected data on non-fishery income (NFI). To address this and other informational gaps, the NWFSC began periodically surveying West Coast fishing vessel owners on a triennial basis with surveys carried out in 2017, 2020, and 2023. Surveys were sent to all vessel owners with commercial revenue from West Coast fisheries (federal and state) the prior year. Response rates were around 50% in 2017 and 2020 with over 1400 surveys returned each year. The response rate in 2023 fell to 40% with 1163 surveys returned.

Among other questions, the surveys ask fishing vessel owners what percentage of their household income came from fishing versus non-fishing sources in the prior calendar year (e.g. 2022 for the 2023 survey) and also what percentage of the income they personally contribute to the household is from non-fishery sources. The survey also asks vessel owners that personally contributed NFI to their household what type of non-fishing work they did. Treakle et al. (2023) provides a detailed analysis of the survey data on non-fishing income from the 2017 and 2020 surveys.

Indicator Category Human Wellbeing

Data Steward

Additional Information

Data sources

Data extraction

Data analysis

47 Fishery Revenue Concentration

Description Along with factors like processor availability and local infrastructure influence, variability in port-level landings can impact the overall distribution of fishing revenue along the coast. The Theil Index metric assesses the geographic concentration of fishing revenues, and is used to track progress toward meeting NS-8. The index estimates the difference between observed revenue concentrations and what they would be if they were perfectly equally distributed across ports; higher values indicate greater concentration in a subset of ports. Annually, we calculate the Theil Index for all fisheries and for specific management groups, at the scale of the 21 port groups previously established for the economic Input-Output model for Pacific Coast fisheries (Leonard and Watson 2011).

- Species:
  - All fisheries
  - Coastal pelagics
  - Crab
  - Groundfish
  - Highly migratory species
  - Other species
  - Salmon
  - Shrimp and prawns
- Component Category: Human Wellbeing
- Data Steward: karma.norman@noaa.gov
- Institution: NOAA NWFSC
- Source Data: Theil Index and annual commercial fishery revenue data provided by K. Norman, NMFS/NWFSC, and A. Phillips, PSMFC, with data derived from PacFIN (http://pacfin.psmfc.org).
- Additional Calculations: As a potential indicator to track progress toward meeting NS-8, we use a metric called the Theil Index to assess geographic concentration of fishing revenues. The index estimates the difference between observed revenue concentrations and what they would be if they were perfectly equally distributed across ports; higher values indicate greater concentration in a subset of ports. We calculate the Theil Index for total fisheries and for specific management groups, at the scale of the 21 port groups previously established for the economic Input-Output model for Pacific Coast fisheries (IO-PAC; Leonard and Watson 2011).

Data extraction

ERDDAP™ link: https://oceanview.pfeg.noaa.gov/erddap/tabledap/cciea_HD_THEIL.html

Data analysis

References

48 Fisheries Participation Networks

Description Fisheries participation networks (FPNs) represent how diversified harvest portfolios create connections between fisheries (Fuller et al 2017, Fisher et al 2021). FPNs have shown how West Coast networks change over time, how groundfish fisheries are connected to other fisheries in different IO-PAC port groups (Harvey et al. (2022)), and the vulnerability of West Coast port groups to future shocks to salmon fishing, based on economic dependence (a measure of sensitivity) and a resilience index based on fisheries connectivity (a measure of adaptive capacity) (Harvey et al. 2023). More recently, we compare the number of active salmon vessels and the revenue of commercial salmon vessels between two periods (2017-2022 and 2022-2023) for West Coast port groups.

As fishers diversify their harvest portfolios, they create connections between fisheries, even when ecological links between the target species are weak or absent. In previous reports (Harvey et al. (2021) , Harvey et al. (2022), Harvey et al. 2023, Leising et al. 2024), we used fisheries participation networks (Fuller et al. (2017), M. C. Fisher et al. (2021)) as a way to represent this information about how fisheries are connected through shared participation patterns. In these networks, fisheries are depicted as nodes, and pairs of nodes are connected by lines called 'edges' that integrate information about vessels participating in both fisheries. Changes in network structure over time reflect changes in the ecology of adjacent coastal waters, as well as the legacy of management, markets, and other factors.

Indicator Category Human Wellbeing

Data Steward Samhouri; jameal.samhouri@noaa.gov

Additional Information Vessel-level fisheries participation networks provide a visual representation of the portfolio of fisheries that are economically-important to individual vessels within a port group (Fuller et al. (2017); M. C. Fisher et al. (2021)). The networks are derived from landings receipts and summarized annually from week 46 in one year through week 45 in the following year (e.g., November 2020 to November 2021) to capture the beginning of the Dungeness crab fishing season. Fisheries landings data were retrieved from the Pacific Fisheries Information Network (PacFIN; http://pacfin.psmfc.org) database. We note that in Washington, fish tickets include a port assigned based on the actual port of landing or derived from the license database; prior to 2018, most port data were derived.

Data sources Fisheries landings data were retrieved from the Pacific Fisheries Information Network (PacFIN; http://pacfin.psmfc.org) database. We note that in Washington, fish tickets include a port assigned based on the actual port of landing or derived from the license database; prior to 2018, most port data were derived.

Data extraction To focus the analysis on vessels that derive a substantial amount of income from commercial fishing, we include only vessels that generate at least $5,000 annually in total fisheries revenue. In addition, vessels must generate at least $500 of revenue from a given fishery (node) to be included as participants in that fishery. We assume that economically-important fisheries are those that contribute to at least a median of 10% of the annual revenue of associated vessels. Vessels are represented in all port groups for which their landings meet these conditions. To maintain confidentiality, we include only fisheries with at least three vessels participating in a port group.

In network graphs, node size represents the median proportional contribution of a fishery to annual vessel-level revenue; it is scaled relative to the fishery with the maximum median proportional contribution to annual vessel-level revenue in each network, summarized by port group. Therefore, node sizes are not comparable across port groups, only within them. The edges connecting pairs of nodes indicate that vessels participate in both fisheries, and the widths of these edges scale with the number of vessels exhibiting this behavior, as well as the total amount and evenness of revenue generation from each pair of fisheries. As with node sizes, edge widths are not comparable across port groups, only within them.

Data analysis

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