Appendix C: Data Sources

EBM Component: Groundfishes

Data for groundfish abundance come from two sources: 1) the Alaska Fisheries Science Center's (AFSC) Pacific West Coast bottom trawl survey of groundfish resources (Weinberg et al. 2002) and 2) the Northwest Fisheries Science Center's (NWFSC) U.S. West Coast bottom trawl survey of groundfish resources off Washington, Oregon, and California (Keller et al. 2008). Important differences exist between the two surveys (e.g., trawl speed, trawl duration, net type) making them not directly comparable (Table 7 and Table 8). Triennial trawl survey data are courtesy of Mark Wilkins, AFSC; NWFSC trawl survey data are courtesy of Beth Horness, NWFSC.

The AFSC survey was conducted triennially from 1977 to 2004 and is generally referred to as the triennial survey. Due to changing objectives, sampling effort with regard to depth and latitude differed among years for the survey (Table 9). The survey was initiated with the goal of providing fishery-independent data on a number of commercially important species including Pacific hake (*Merluccius productus*), sablefish (*Anoplopoma fimbria*) and shelf and slope rockfishes (*Sebastes* spp.). In 1977 sampling occurred between lat 34°00′N and the U.S.-Canada border at 91 to 457 m with sampling stratified by depth. The emphasis of the survey shifted in 1980 to providing better information for two rockfishes: canary (*Sebastes pinniger*) and yellowtail (*S. flavidus*). Effort shifted to the north from lat 36°48′N to 50°00′N. The depth range remained similar at 55–366 m. In 1986 the survey extent was similar but stopped at lat 49°15′N and concentrated on 92–219 m. In 1989 the survey was extended to the south as the objectives of the survey shifted to monitoring a broad range of demersal species and the survey extent shifted to the south (Table 8).

The triennial survey used the standard AFSC Resource Assessment and Conservation Engineering (RACE) Division high-opening Nor'easter trawl with rubber bobbin roller gear. The trawl had a 27.2 m headrope and a 37.4 m foot rope. All trawls were rigged consistently to RACE survey gear standards employing triple 55 m dandy lines (1.59 cm steel cable) connected to each wing and fished with 2.1 × 1.5 m steel V-doors weighing approximately 567 kg each. Nets were hauled at 1.5 m sec^{-1} (3 knots) for 30 minutes. Sampling followed a systematic-random design with tracklines placed across the survey area. Stations were randomly placed along the tracklines at the rate of approximately one station per 7.4 km. For a more detailed description see Weinberg et al. (2002).

The NWFSC survey has been conducted annually since 1998. From 1998 to 2002 the survey covered only the continental slope (≈200–1,200 m). Starting in 2003 the sampling was expanded to include the shelf with the survey covering approximately the area from the U.S.-Mexico border (lat 32°30′N) to Cape Flattery, Washington (lat 48°10′N), depths from 55 to 1,280 m. The most recently available data were for 2009.

The trawls were carried out on four different vessels and used an Aberdeen-style net with a small-mesh liner (5 cm stretched measure) in the cod end to retain smaller specimens. Trawl duration was approximately 15 min at approximately 1.1 m sec^{-1} (2.2 knots).

As of 2003, the NWFSC survey has used a depth-stratified (three zones) random sampling design with trawl locations selected randomly prior to the initiation of the survey. There has been some minor change in the survey design with regard to allocation of sampling effort (Table 10). For a more detailed description, see Keller et al. (2008).

Key Attribute: Population Size

Numbers derived from the trawl surveys are the sole indicator for groundfish population size. Because of differences in sampling design, trawl duration, and net mesh size, the two surveys are not directly comparable. Here the annual means for various metrics (groundfish numbers, size distributions) from the two surveys are plotted on the same figures to allow for comparison, but statistically the two surveys are treated separately. There is overlap between the two surveys in 2004. Comparison of the two surveys in this year reveals wide discrepancies in estimates.

To provide similar coverage of latitudes and depths from the two surveys, a subset of the data was chosen to include trawls falling between lat 34°N–48°N and 50–350 m bottom depth. The first year (1977) of the AFSC survey is generally considered unreliable and not used in stock assessment. These data were not used here. The 1980 data are also somewhat unreliable and though used here should be interpreted with some caution. Since earlier years of the NWFSC survey were limited to the continental slope, only data from 2003 to 2009 were used for consistency in depth coverage between the two surveys. A total of 6,287 trawls (4,017 triennial, 2,270 NWFSC) were used in the following analyses.

Annual coast-wide mean catch per unit effort (CPUE, measured as number per km^2) for each species within survey was estimated using a generalized additive model (GAM) (Hastie and Tibshirani 1999). In the model, year was treated as a categorical, parametric factor while bottom depth, latitude (starting latitude of the trawl), and their interaction were modeled as smoothed terms (continuous, nonlinear covariates). Thin-plate regression splines were used as the base for depth and latitude (Wood 2006a). A tensor product smooth was used to estimate the interaction term since the two variables differed substantially in scale (Wood 2006b). Data were log(x+1) transformed prior to analysis. Display time series are the back transformed estimates of the year intercept + year coefficients.

Key Attribute: Population Condition

Indicator: Size structure

In order to investigate whether size structure of groundfish populations have changed, we compared years within each of the two surveys. We did not make comparisons across surveys because the two surveys used different methods and different-sized nets. These differences will bias the size structure available to be collected and the catchability of many species. However, within each survey, we are able to look for changes in size structure over time.

Similar to population abundance, we investigate changes in size structure in 17 species. These species represent one member from each of the fish functional groups found in the spatially explicit Atlantis ecosystem model of the central California Current (Horne et al. 2010). These species provide insight across a wide range of foraging guilds and trophic levels.

For each species, we calculated the quartiles for length of all individuals collected during the first year of each survey. For the triennial survey, we used 1980, as it is generally accepted that 1977 is not appropriate to use for abundance and biomass estimates. We used 2003 for the NWFSC annual survey. In instances when there were less than 20 individuals of a species measured during a year, we used the first year in which there were greater than 20 individuals.

Next we used these quartiles from the first year's survey for each species to categorize all length measurements for that species into its respective quartile. Counts of individuals in each quartile were summed for each year. We then calculated the proportion of individuals in each quartile each year by dividing the sum of individuals in each quartile by the total number of individuals collected for that year for that species. The proportion of individuals in each quartile was then plotted against year and shown in Figure 13 through Figure 16. In the first year (generally 1980 for triennial and 2003 for NWFSC), the proportion of individuals should be close to 0.25 for each of the quartiles, because each quartile represents 25% of the data for that species. Some values differ from 0.25 in the first year because of the location of the quartile. For example, if 100 sablefish were collected in 2003 and the value of the upper quartile was 52 cm but there were 20 more 52 cm individuals that fell below the quartile line, these individuals would be calculated in the proportion as being in the upper quartile (Quartile 4 on the figures). Thus in this example, Quartile 4 would have a larger proportion of individuals during the first year.

These calculations were then repeated using only data collected in each of the four national marine sanctuaries (figures in Appendix D). In some cases, there was not enough data for some of the 14 species in some national marine sanctuaries to make useful comparisons over time.

Indicator: Spatial structure

Data selection in terms of year, depth, and latitude ranges followed that for estimation of groundfish number time series above. Note that from 1980 to 1986, the triennial survey did not sample south of lat 36°N (Table 9).

Annual distributions were estimated for 1° latitude bins (rounding down) separately for each year and separately for each survey. Thus there are two estimates of distribution for 2004 when the two surveys overlapped temporally. For each year and survey, a separate GAM (Hastie and Tibshirani 1999) was run with latitude as a categorical, parametric variable and depth of the trawl as a continuous nonlinear covariate. A thin-plate regression spline was used to smooth the depth term. All models used an identity link and Gaussian error distribution. Data were log(x+1) transformed prior to analysis, and annual means for each time series are the back-transformed estimates of the intercept + latitude coefficients from the model.

EBM Component: Ecosystem Health

Key Attribute: Community Composition

Indicator: Diversity

Shannon Diversity—The Shannon Diversity Index takes into account the number of species and the evenness of the species. The index is increased either by having additional unique species or by having a more even representation of species (greater evenness).

Data for groundfish diversity come from two sources: 1) the AFSC Pacific West Coast bottom trawl survey of groundfish resources (Weinberg et al. 2002), and 2) the NWFSC U.S. West Coast bottom trawl survey of groundfish resources off Washington, Oregon, and California (Keller et al. 2008). While important differences exist between the two surveys, both contain taxa identified to varying taxonomic levels (some to species, some to family). The analyses here include only those taxa identified to species. A subset of the available data was used including trawls between 50–350 m and lat 34–38°N. Triennial data included the years 1980–2004 (every third year), while NWFSC data included 2003–2009 data. A total of 349 taxa identifiable to the species level was used in the following analyses.

After calculating Shannon Diversity for each trawl, annual means were derived using a GAM (Hastie and Tibshirani 1999) in which year was a parametric, categorical effect. Depth and latitude were included as nonlinear covariates to account for variation with these parameters. Depth and latitude smooths used thin-plate regression splines (Wood 2006a). A tensor product smooth was used for the interaction between depth and latitude because the two variables differed greatly in scale (Wood 2006a, Wood 2006b). GAMs used an identity link and Gaussian error structure. The results shown are the coefficients for year effect derived from the models. Separate GAM models were run for the triennial and NWFSC data because of differing sampling methodologies.

Taxonomic distinctness for groundfishes—West Coast groundfishes: Taxonomic distinctness quantifies diversity as the relatedness of the species within a sample, based on the distances between species in a classification tree (Clarke and Warwick 2001a). Average taxonomic distinctness (Δ^+ or AvTD) is the mean of all species-to-species distances through the tree for all pairs of species within a sample and represents the taxonomic breadth of the sample. The variation in taxonomic distinctness (Λ^+ or VarTD) is the variation in branch lengths among all pairs of species (it is not the variance of AvTD among samples) and is a measure of the irregularities and divergences in the distribution of branch lengths within a sample. Both indices are appealing because they are based on presence/absence data and, unlike many biodiversity measures, neither is affected by the number of species or the sampling effort (Clarke and Warwick 1998b, Clarke and Warwick 2001c).

Data for groundfish come from two sources: 1) the AFSC Pacific West Coast bottom trawl survey of groundfish resources (Weinberg et al. 2002), and 2) the NWFSC West Coast bottom trawl survey of groundfish resources off Washington, Oregon, and California (Keller et al. 2008). While differences exist between the two surveys, both contain taxa identified to varying taxonomic levels (some to species, some to family). For the analyses here, only taxa identified to species were included. A subset of the available data was used including trawls between 50–350 m and lat 34–38°N. Triennial data included the years 1980–2004 (every third year), while NWFSC data included 2003–2009 data. A total of 349 taxa identifiable to the species level was used in the following analyses. A total of 6,287 trawls (4,017 triennial, 2,270 NWFSC) were used in the following analyses.

Equations for the calculation of average taxonomic distinctness and variation in taxonomic distinctness are given by Clarke and Warwick (1998a) and Clarke and Warwick (2001b), respectively. Taxonomic information was derived from (Nelson 2006). The taxonomic hierarchy had eight levels including species, genus, family, order, class, grade, taxa.1, and subphylum. The group taxa.1 distinguished hagfishes and lamprey from the vertebrates. Step lengths in the classification tree varied according to the relative proportional loss of the number of distinct classes.

After calculating AvTD and VarTD for each trawl, annual means were derived using a GAM (Hastie and Tibshirani 1999) in which year was a parametric, categorical effect. Depth and latitude were included as nonlinear covariates to account for variation with these parameters. Depth and latitude smooths used thin-plate regression splines (Wood 2006a). A tensor product smooth was used for the interaction between depth and latitude because the two variable differed greatly in scale (Wood 2006a, Wood 2006b). GAMs used an identity link and Gaussian error structure. The results shown are the coefficients for year effect derived from the models. Separate GAM models were run for the triennial and NWFSC data because of differing sampling methodologies.

Taxonomic distinction for zooplankton—Data for zooplankton are courtesy of Bill Peterson, NWFSC, Newport, Oregon. Also see Peterson et al. (unpubl. manuscr.). Data were collected off Oregon at NH05.

Equations for the calculation of average taxonomic distinctness and variation in taxonomic distinctness for zooplankton are given by Clarke and Warwick (1998a) and Clarke and Warwick (2001b), respectively. The taxonomic hierarchy had seven levels including species, genus, family, order, class, subphylum, and phylum. Step lengths in the classification tree varied according to the relative proportional loss of the number of distinct classes. There were 162 taxa of which 55 were identified to species. Future analyses may wish to more selectively choose those taxa used to calculate taxonomic distinctness metrics.

Seasonal averages for AvTD and VarTD were calculated by first calculating the AvTD or VarTD for each sample and then taking the average of those samples by season. Seasonal averages were then plotted. Seasons were 1) winter: December, January, February; 2) spring: March, April, May; 3) summer: June, July, August; and 4) fall: September, October, November. Winter means include December data from the previous calendar year, that is, winter 1997 is the average of data from December 1996, January 1997, and February 1997.

Indicator: Seabird reproduction indices

Point Reyes Bird Observatory (PRBO) conservation science—Colony based data contain information collected at major seabird colonies and marine mammal rookeries including the Farallon Islands, Alcatraz Island, Año Nuevo Island, and Vandenberg Air Force Base. Information includes annual mean productivity for Ashy storm-petrel (*Oceanodroma homochroa*), Brandt's cormorant (*Phalacrocorax penicillatus*), Cassin's auklet (*Ptychoramphus aleuticus*), common murre (*Uria aalge*), pelagic cormorant (*Phalacrocorax pelagicus*), pigeon guillemot (*Cepphus columba*), rhinoceros auklet (*Cerorhinca monocerata*), and western gull (*Laurus occidentalis*) breeding on the Farallon Islands. See California Avian Data Center; online at http://data.prbo.org/cadc2/index.php?page=marine-data. Data collected by PRBO Conservation Science in collaboration with the U.S. Fish and Wildlife Service.

Bird Research Northwest (formerly Columbia Bird Research)—Ongoing research program investigating the ecology of piscivorous colonial waterbirds (primarily, Caspian terns [*Hydroprogne caspia*], double-crested cormorants [*Phalocrocorax auritis*], American white pelicans [*Pelecanus erythrorhynchos*], and several gull [*Larus*] species) and their impacts on the survival of juvenile salmonids in the Columbia Basin and elsewhere along the Pacific Coast. This research project is a joint, collaborative project between Oregon State University, Real Time Research Inc., and the U.S. Geological Survey's Oregon Cooperative Fish and Wildlife Research Unit. Support for this research project has come from the Bonneville Power Administration; U.S. Army Corps of Engineers, Walla Walla District; U.S. Army Corps of Engineers, Portland District; U.S. Fish and Wildlife Service, Pacific Region, Migratory Birds and Habitat Programs; NMFS; and the Northwest Power and Conservation Council. Bird Research Northwest is online at http://www.birdresearchnw.org/Project-Info/Project-Data/default.aspx.

Triangle Island bird data—Research mainly focuses on Cassin's and rhinoceros auklets, but key demographic parameters are also monitored for pelagic cormorants, Leach's stormpetrels (*Oceanodroma leucorhoa*), glaucous-winged gulls (*Larus glaucescens*), black oystercatchers (*Haematopus bachmani*), tufted puffins (*Fratercula cirrhata*), and common murres. Situated near the northern limits of the California Current oceanographic zone and within the territorial boundaries of the Kwakiutl District Council, the Anne Vallée Ecological Reserve at Triangle Island supports the largest and most diverse seabird colony in British Columbia. During 1994–2003, breeding success (here measured as fledgling production, the mean mass of fledged chick produced per egg laid) of both Cassin's and rhinoceros auklets was lower in years with higher ocean temperatures (SST, sea surface temperature). The birds were affected at all stages of breeding: in warm years, females were less likely to lay eggs, those that did were less likely to hatch their eggs, fewer of the chicks survived to fledge, and the few chicks that did fledge were light in mass (which does not bode well for subsequent survival).

Over the years, the research program at Triangle Island has been funded by the Baillie Foundation, the Canadian Wildlife Service, the Climate Change Action Fund, the Important Bird Areas Community Action Fund, NOAA, the Natural Sciences and Engineering Research Council of Canada, the Nestucca Trust Fund, Simon Fraser University, the Science Horizons Program of Environment Canada, the Vancouver Foundation, and the World Wildlife Fund Canada. Research information is online at http://www.sfu.ca/biology/wildberg/bertram/triangle /climatechange.html. The contact for data is constans@sfu.ca; mark.hipfner@ec.gc.ca.

Washington coastal islands—Rhinoceros auklet reproductive success from three islands for the following years are: Protection Island from 2006 to 2010 (plus published data from the

1970s), Tatoosh Island from 2005 to 2009, and Destruction Island from 2008 to 2010 (plus published data from the 1970s). The contact for data is Dr. Scott Pearson, senior research scientist, Washington Department of Fish and Wildlife, Wildlife Research Division, 1111 Washington Street SE, 5th Floor, Olympia, Washington 98501-2283, telephone (360) 902-2524.

Oregon coast—Central Oregon coast breeding colony reproductive success data for pelagic cormorants were collected over 38 years during the summer by students, and approximately 9 years (1998–2002, 2007–present) on common murres from the Yaquina Head colony. The contacts for data are Rob Suryan, rob.suryan@oregonstate.edu, and Jan Hodder, jhodder@uoregon.edu.

Indicator: The northern copepod biomass anomaly

Data is courtesy of Bill Peterson. Also see Peterson et al. (unpubl. manuscr.). Data were collected off Oregon at NH05.

Indicator: Top predator biomass

Annual means for top predator biomass were derived using a GAM (Hastie and Tibshirani 1999) in which year was a parametric, categorical effect. Depth and latitude were included as nonlinear covariates to account for variation with these parameters. Depth and latitude smooths used thin-plate regression splines (Wood 2006a). A tensor product smooth was used for the interaction between depth and latitude because the two variables differed greatly in scale (Wood 2006a, Wood 2006b). GAMs used an identity link and Gaussian error structure. The results shown are the coefficients for year effect derived from the models. Separate GAM models were run for the triennial and NWFSC data because of differing sampling methodologies.

Key Attribute: Energetics and Material Flows

Indicator: Nutrient levels

Usage permissions: CalCOFI database data is accessible in the CCE LTER data repository supported by the Division of Ocean Sciences, NSF Grant OCE-0417616. Contact: Jim Wilkinson. Data set 82: Conductivity temperature depth bottle data. The survey cruise data set (CalCOFI–SIO) has 800,605 records spanning 1949–2009; parameters are from discrete samples taken from bottles on a hydrographic CTD (conductivity temperature depth) cast. Parameters include depth, temperature, salinity, density (sigma theta), specific volume anomaly, wave height, oxygen, chlorophyll, primary productivity, and nutrients phosphate, nitrate, nitrite, and ammonia.

Filters to CalCOFI data download are: Year, limited to data collected since 1983 (previous to that there are missing years); depth, limited to samples less than 6 m; and seasons, with data binned as 1 equals winter (Jan-Mar), 2 equals spring (Apr-Jun), 3 equals summer (Jul-Sep), and 4 equals fall (Oct-Dec). Geographically the stations are 66.7–136.7 (CalCOFI north to IMECOCAL).

Indicator: Chlorophyll *a*

Chlorophyll *a* (chl *a*) data were collected from the Orbview-2 SeaWiFS and Aqua MODIS (online at http://coastwatch.pfeg.noaa.gov/erddap/index.html). Winter and summer spatial patterns of chl *a* are averages of long-term means from 1999 to 2008 using chl *a* data from SeaWiFS. The time series are constructed from area averages of chl *a* data from MODIS. The area used in the averages is centered on NDBC buoys 46050, 46014, and 46025; the areas have widths extending 50 km from the coast and lengths of 200 km.

Satellite remotely sensed chlorophyll concentration (mg m^{-3}) data were obtained from the Sea-viewing Wide Field-of-View Sensor (SeaWiFS, online at http://oceancolor.gsfc.nasa.gov /SeaWiFS/). Monthly Level 3 mapped 9 km resolution data were provided by the NASA Goddard Space Flight Center (online at http://oceancolor.gsfc.nasa.gov/). We used monthly composites of 9 x 9 km pixels to assess changes in chl *a*; data were processed by Rob Suryan of Oregon State University. Here, we report on chlorophyll concentrations in a 9 x 9 km pixel over the period 1998–2006.

EBM Driver and Pressure: Climate

Several long-term observing programs provide time series of physical, biological, chemical, and fisheries variables within the California Current Large Marine Ecosystem (CCLME) (Peña and Bograd 2007). These include: CalCOFI (Hewitt 1988, Bograd et al. 2003, http://www.calcofi.org/), Line P (Freeland 2007, http://www.pac.dfo-mpo.gc.ca/science /oceans/data-donnees/line-p/index-eng.htm), and U.S. GLOBEC Northeast Pacific Program (Batchelder et al. 2002, http://globec.coas.oregonstate.edu). An abbreviated description of each data set in this IEA is included below.

Large-scale Climate Forcing

PDO

Computation of the Pacific Decadal Oscillation (PDO) index was developed by Zhang et al. (1997). Data were downloaded from the University of Washington Joint Institute for the Study of the Atmosphere and Ocean. Methods and details of computation are online at http:// jisao.washington.edu/pdo/PDO.latest. The PDO reflects SST for the entire North Pacific, including the CCLME, from greater than lat 20°N.

MEI

The Multivariate ENSO Index (MEI) is based on six observed variables over the tropical Pacific. Negative values of the MEI represent the cold ENSO phase, (La Niña), while positive MEI values represent the warm ENSO phase (El Niño). Data were obtained online at http:// www.cdc.noaa.gov/people/klaus.wolter/MEI/table.html from NOAA's Earth System Research Laboratory. In the CCLME, warm ENSO phases (positive MEI values) are associated with strong advection from the south and cold ENSO phases (negative MEI values) with weak northward transport.

NPGO

The North Pacific Gyre Oscillation (NPGO) index, data online at http://eros.eas.gatech .edu/npgo/data/NPGO.txt, emerges from analyses of anomalies of Northeast Pacific SSTs and sea-surface height (Di Lorenzo et al. 2008). Positive values indicate a strong North Pacific gyre and advective transport from the north into the CCLME; negative values indicate a weak gyre and decreased southward transport.

NOI

The Northern Oscillation Index (NOI) is an index of indices of mid-latitude climate fluctuations that show interesting relationships with marine ecosystems and populations. The NOI reflects the variability in equatorial and extratropical teleconnections and represents a wide range of local and remote climate signals (data online at http://coastwatch.pfeg.noaa.gov /erddap/griddap/erdlasNoix.graph).

CUI

The Cumulative Upwelling Index (CUI) is calculated by NOAA's Environmental Research Division from estimates of the magnitude of the offshore component of the Ekman transport driven by wind stress. Positive values indicate upwelling while negative values indicate downwelling (methods and details of computation online at http://www.pfeg.noaa .gov/products/PFEL/modeled/indices/upwelling/NA/how_computed.html).

Large-scale Physical and Biological Conditions

SST

Sea surface temperature (SST) data were collected from the Pathfinder satellite. Area averages were constructed from long term mean from 1999 to 2008 (data online at http:// coastwatch.pfeg.noaa.gov/erddap/griddap/erdPHsstamday.html).

Winds

Meridional winds (north/south) data were collected from the QuikSCAT satellite. Area averages were constructed from long-term mean from 1999 to 2008 (data online at http:// coastwatch.pfeg.noaa.gov/erddap/griddap/erdQSstressmday.html).

SST and meridional winds from buoys were collected from NDBC buoys. We used data from buoys 46023, 46014, 46050 (data online at http://www.ndbc.noaa.gov/).

Sea level

Sea level measurements (mm), compiled by the National Water Level Observation Network, were obtained from the Center for Operational Oceanographic Products and Services (NOS 2008). We used data from San Diego and San Francisco, California, and South Beach, Oregon. Methods and data were downloaded from the University of Hawaii Sea Level Center (http://uhslc.soest.hawaii.edu/).

Hypoxia

The collection and processing of dissolved oxygen data on the shelf off Newport, Oregon, are done by Bill Peterson of NOAA. The data are from the hydrographic sampling station Newport Line (NH) 05 that is located 5 miles off the coast at a depth of 50 m. The dissolved oxygen data taken from a location off the coast of San Diego, California, are from the CalCOFI program (data online at http://www.calcofi.org/data.html). The data are from hydrographic station 93.30 at a depth of 200 m.

OPI

The Oregon Production Index (OPI) is an index to the ocean survival (based on smolt-to-adult returns) for coho salmon (*Oncorhynchus kisutch*) in Oregon. Data were obtained from tables in the Pacific Fishery Management Council's preseason report (http://www.pcouncil.org/salmon/stock-assessment-and-fishery-evaluation-safe-documents/preseason-reports/2010-preseason-report-i/). The percent smolt-adult returns were calculated by the formula SAR = $a/(b \times 1{,}000) \times 100$, where SAR is the percent smolt-adult return, a is the adult OPIH (thousands), and b is the total hatchery smolts released (millions).

CVI

The Central Valley Index (CVI) for Chinook salmon (*O. Tshawytscha*) was obtained from the Pacific Fishery Management Council (http://www.pcouncil.org/salmon/background/document-library/historical-data-of-ocean-salmon-fisheries/). Escapement values for the CVI extend through 2007, but were replaced with a similar Sacramento Index in 2008. Because the two indices are highly correlated, we use a data set compiled of fall escapement values from the CVI from 1970 to 2007, and the fall escapement value from the Sacramento Index for 2008.

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Groundfish, Salmon, Green Sturgeon, and Ecosystem Health

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