Agenda Item H.1
Situation Summary
November 2011

INTEGRATED ECOSYSTEM ASSESSMENT (IEA) REPORT

The National Oceanic and Atmospheric Administration (NOAA) has been working on an initiative to incorporate ecosystem principles in ocean and coastal resource management. An integrated ecosystem assessment (IEA) is a synthesis and quantitative analysis of information on relevant natural and socioeconomic factors in relation to specified ecosystem management goals and is an important element in the implementation of ecosystem approaches to management. This is a relatively new assessment tool that is being first applied to the California Current Large Marine Ecosystem (CCLME) as a pilot.

The Council received and overview of the IEA effort at its March 2011 meeting where Council directed the Ecosystem Plan Development Team (EPDT) to work with the IEA team on ways to best focus this pilot effort for use in Council management. Specifically, the EPDT and the IEA team discussed the list of species this initial pilot effort would focus on. The long-term plan is for the IEA to include species from each of the Council's four Fishery Management Plans and across trophic levels. For this initial effort, the IEA team focused on four pilot species, bocaccio, sablefish, Pacific whiting and canary rockfish and explored expanding the analysis to include Sacramento River Chinook salmon, Pacific sardine, and albacore tuna. Additionally, the EPDT and the Ecosystem Subcommittee of the Scientific and Statistical Committee have met with the IEA team and have provided input on the report's development and future work.

At this meeting, Dr. John Stein, Acting Director of the Northwest Fisheries Science Center, and Dr. Cisco Werner, Director of the Southwest Fisheries Science will provide a brief overview of a discussion document (Agenda Item H.1.b, Attachment 1) that assess the status and trends of key climate drivers, predator-prey interactions, and non-fishing pressure for the four focal groundfish species. The Science Centers and the IEA team are interested in Council feedback on ways to expand and improve the format and content of the report so that it is the highest value for use in Council management.

Council Task:

1. Provide feedback on the IEA report.

Reference Materials:

1. Agenda Item H.1.b, Attachment 1: Discussion Document: Development of an Annual Report on Conditions in the California Current Ecosystem (*Introduction and Summary*, *complete document in electronic format only*).

Agenda Order:

a. Agenda Item Overview — Mike Burner
b. IEA Report — John Stein and Cisco Werner
c. Reports and Comments of Advisory Bodies and Management Entities
d. Public Comment
e. Council Discussion

PFMC 10/13/11

DISCUSSION DOCUMENT:

DEVELOPMENT OF AN ANNUAL REPORT ON CONDITIONS IN THE CALIFORNIA CURRENT ECOSYSTEM

PART I. INTRODUCTION AND SUMMARY

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INTRODUCTION

The Pacific Fishery Management Council (Council) has recognized the need for an understanding of the physical, ecological, socioeconomic and management components of the California Current Large Marine Ecosystem (CCLME). The Ecosystem Plan Development Team (EPDT) noted that an integrated ecosystem approach to fishery management can 1) promote sustainable human uses of the CCLME, 2) allow for a coordinated evaluation of ecosystem health, 3) aid in identifying critical data gaps and common ground within and between current FMPs, and 4) allow for evaluation of tradeoffs among fishery sectors or among fisheries and other ecosystem objectives. (EPDT Agenda Item J.1.c Attachment 1, March 2011).

The EPDT envisioned a two-step process to bring ecosystem science into the Council process. First, the EPDT promotes the incorporation of ecosystem science into current Council-related products. Secondly, they advocate a holistic, integrated assessment of the CCLME. This advice is echoed in two SSC recommendations in September 2010:

". . . that a subset of stock assessments be expanded to include ecosystem considerations...The SSC's Ecosystem-Based Management subcommittee should develop guidelines for how ecosystem considerations can be included in stock assessments." (H.1.c., Supplemental SSC Report)

"…The Council should request NMFS to initiate development of an annual report on conditions in the California Current ecosystem. The SSC can provide guidance on the content, review and dissemination of this report…" (H.1.c., Supplemental SSC Report)

In this document, we focus on the first part of this process – providing ecosystem information that could inform stock assessments and single-species management. In their March 2011 report (Agenda Item J.1.c Attachment 1), the EPDT proposed that NMFS invest time to develop a format for and contents of a Council-focused ecosystem considerations report. They then suggested that the NMFS team work iteratively with the Council and its advisory bodies to refine the format and contents of the document. This document represents the outputs of NMFS' initial investment in this process.

Based on discussion with the EPDT, NMFS opted to focus on a limited number of stocks across three FMPs. These are: hake, sablefish, canary rockfish, bocaccio, Chinook salmon, and sardine. This document focuses on the four groundfish (hake, sablefish, canary rockfish, bocaccio) suggested by the EPDT as pilot species.

HOW THIS DOCUMENT IS ORGANIZED

This document is organized around three basic questions:

1) What are the status and trends of key climate/ocean drivers that influence hake, sablefish, canary rockfish, bocaccio, and Sacramento River Chinook salmon?
2) What are the status and trends of important predators and prey that may influence hake, sablefish, canary rockfish, bocaccio, and Sacramento River Chinook salmon?
3) What are the status and trends of non-fisheries pressures that may influence productivity of hake, sablefish, canary rockfish, bocaccio, and Sacramento River Chinook salmon?

Answering these questions required NMFS staff to answer a number of basic questions about the ecology of the focal species. For example, in order to report the status and trends of key climate drivers, it is necessary to understand the relationship between climate and productivity of focal species. Similarly, documenting status and trends of the forage base or predation pressure requires that we know important trophic linkages affecting focal species. Finally, a meaningful report of non-fisheries threats compels us to identify what threats pose the greatest risk to focal species. Thus, this document not only reports status and trends information, but also provides detail about the methods and analyses we used to determine the information presented here.

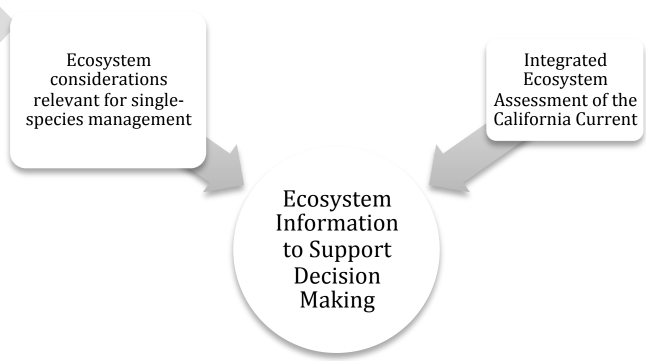


Figure I-1. Effective ecosystem advice for fishery management must include ecosystem considerations that could be used by stock assessors and single-species fisheries management, as well as a holistic, integrated assessment of the entire ecosystem. This document focuses on former—providing information that informs single-species management.

Chapters 1-4 (pp 10-318) are available online and provide the technical underpinnigs of the summaries that follow. **Chapter 1** of this document summarizes what we know about the relationship between climate / ocean conditions and the ecology of focal groundfish species. **Chapter 2** focuses on trophic relationships and reports on the status and trends of key prey and predators. This chapter provides information about how important trophic linkages were identified as well as how data were combined to form predator and prey indices. **Chapter 3** summarizes the state of non-fisheries threats to groundfish species. This chapter synthesizes what we know about the spatial distribution of key threats and fish as well as the susceptibility of fish stocks to different threats. **Chapter 4** summarizes the state of the ecosystem relative to Sacramento River Chinook salmon.

This document is meant to be a discussion document. It is incomplete in its coverage. We hope this document initiates a dialogue that will result in content and format that best serves Council needs. To this end, we have identified a number of "discussion points" throughout the document. These discussion points highlight places in the development of this document that the author team had to make a choice about what information to present, how to analyze this information, or how to best present it. By flagging these choices, we hope that Council and Council advisory body input can shape the final product into one that is of highest value to the Council.

NEXT STEPS

Based on comments and suggestions we receive on this document, the IEA team will:

- Improve the summary presentation
- Adjust the technical analyses that underlie the conclusions about ecosystem status and trends
- Add species, including CPS, HMS, additional salmon, additional groundfish

COMPOSITE VIEW OF THE STATUS & TRENDS OF TROPHIC INTERACTIONS

COMPOSITE VIEW OF THE STATUS & TRENDS OF NON-FISHERIES PRESSURES

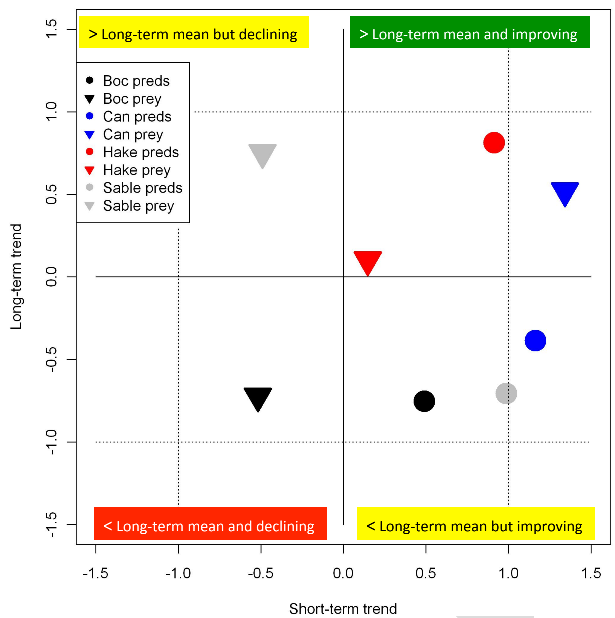


Figure I-2. Status and trends of predators and prey of bocaccio (Boc), canary rockfish (Can), hake, and sablefish (sable). The short-term state indicates the trend over the last five years of the index. The long-term state indicates the difference between the long-term mean (generated from the entire time series) and the mean of the last five years. Values for predators were multiplied by -1 so that increases in predators indicate declining ecosystem state from the perspective of the focal species. Species specific details are provided in the accompanying technical document.

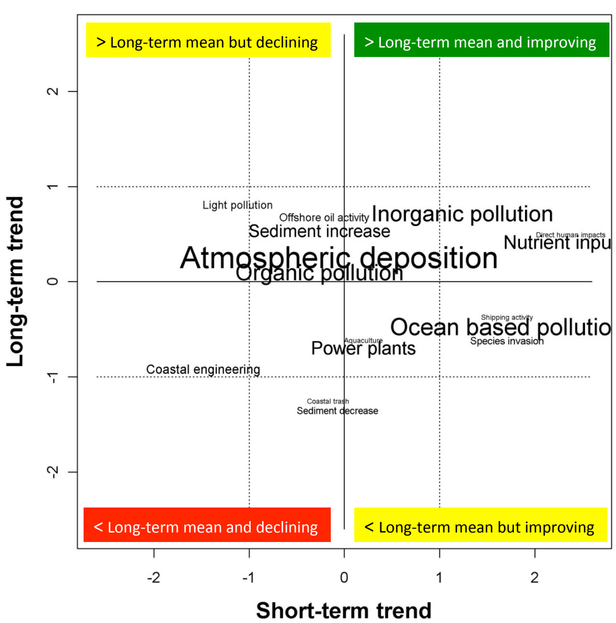
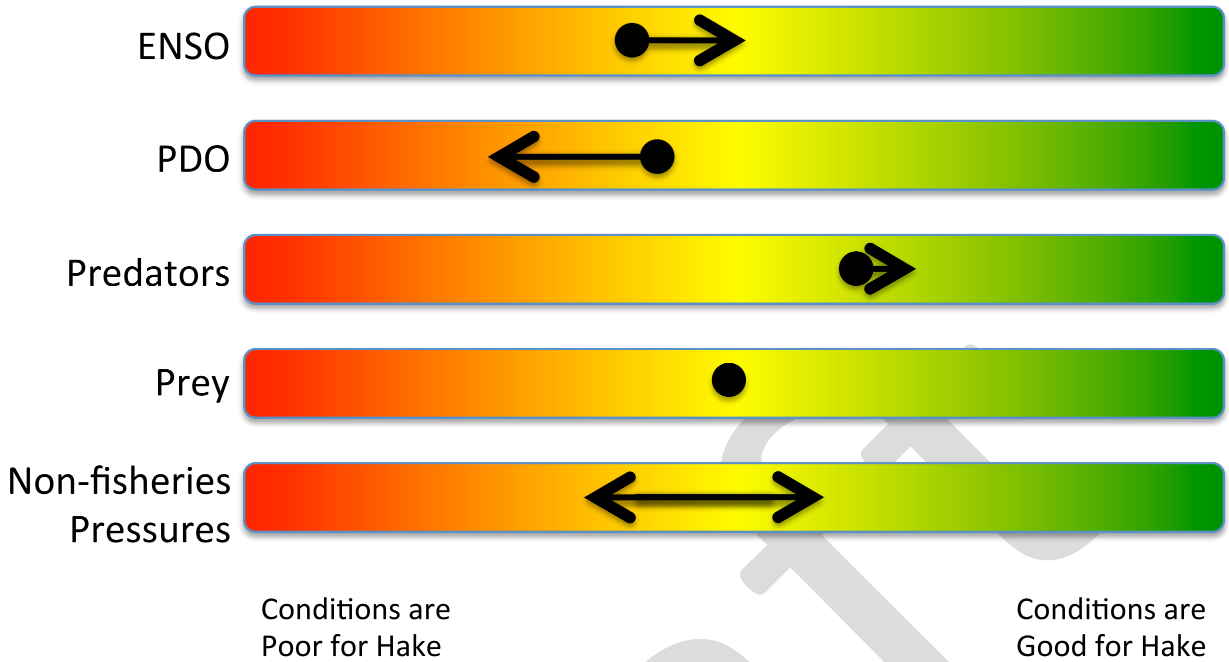


Figure I-3. Status and trends of 16 non-fisheries related pressures. Text size is scaled to the mean risk of the four focal species (bocaccio, canary rockfish, hake, sablefish). The short-term state indicates the trend over the last five years of the index. The long-term state indicates the difference between the long-term mean (generated from the entire time series) and the mean of the last five years. Values for short-term and long-term states were multiplied by -1 so that increases in indices (i.e increases in a pressure) indicate a declining biological environment for each species.



PHYSICAL FORCING

Hake respond strongly to variability in physical forcing. Strong hake year classes are more common El Nino years. Abundance, biomass, and occurrence of Pacific hake are positively correlated with ENSO, and biomass of adults is positively correlated with PDO. The recent five-year trend in ENSO anomalies has been positive, yielding relatively good ocean conditions for Pacific hake; however, PDO has trended downward during this same period. Hake may experience reduced recruitment with long-term warming, unless they continue to expand their spawning grounds to more productive northern waters.

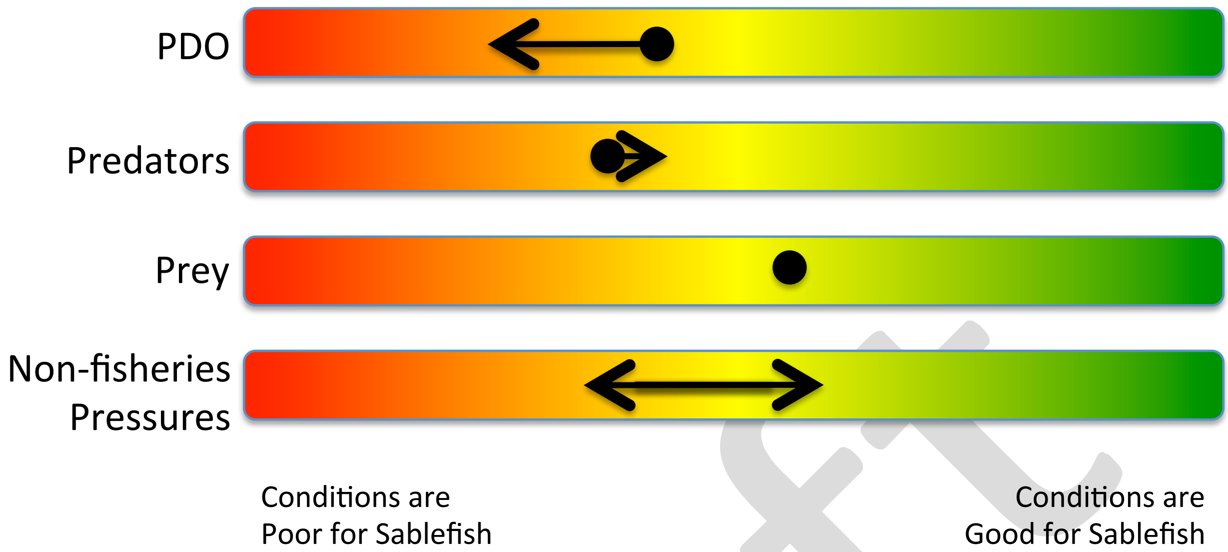
TROPHIC INTERACTIONS

The biological environment for hake is stable. Hake prey (dominated by krill) abundance is average, with no evidence of recent change. The primary hake predators are dogfish, mid-water rockfish, deep large rockfish and other hake. The composite hake predator index showed substantial variation from the late 1950’s until the early 1980’s after which there has been a steady decline. The trend over the last five years shows a decline in predator abundance—an improving condition from the perspective of hake. Note, however, that this composite predator index does not include data on squid, in particular, Humboldt squid.

NON-FISHERIES PRESSURES

The status of most of the 19 non-fisheries pressures on hake is average with no evidence of improving or declining trends. Some non-fisheries pressures are improving (e.g. nutrient inputs), while others (e.g. coastal engineering) are declining. However, in general the highest risk threats, (e.g., atmospheric deposition of pollutants and increases in sediment runoff) show no trend. When placed in context with climate change pressures (e.g. sea surface temperature), most other non-fisheries pressures pose limited risk to the focal species.

SABLEFISH



PHYSICAL FORCING

Strong sablefish year classes occur during periods of more intensive Aleutian Low Pressure and after extended periods of below average SST switched to periods of above average temperatures. ENSO effects on sablefish biomass and abundance are weak. Biomass and occurrence of adult sablefish is positively correlated with PDO. Thus, the recent shift to a cool PDO period (past five years) may yield poorer ocean conditions for sablefish. Long-term warming is hypothesized to yield declines in sablefish populations in the southern CC due to reduced spring productivity and copepod production.

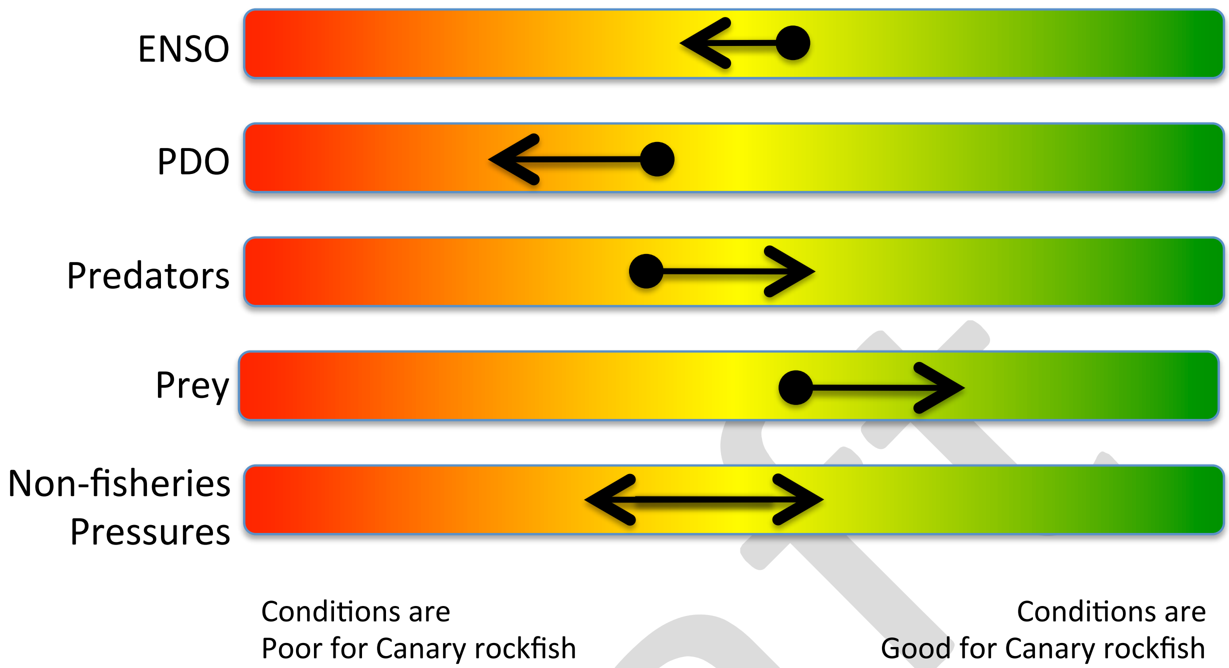
TROPHIC INTERACTIONS

Recent densities of sablefish prey are greater than long term mean but may be declining in recent years. Predator abundance is high, but predator biomass appears to be declining in recent years. However, the trends were within historic norms (but the recent decline of predators is just under one s.d. of the long term mean). The sablefish prey index has shown substantial variation through time with a peak in the mid-2000's. (Note that deposit feeders and cephalopods are not included in the prey index and pelagic sharks are absent from the predator index due to lack of data.

NON-FISHERIES PRESSURES

The status of most of the 19 non-fisheries pressures on sablefish is average with no evidence of improving or declining trends. Some non-fisheries pressures are improving (e.g. nutrient inputs), while others (e.g. coastal engineering) are declining. However, in general the highest risk threats, (e.g., atmospheric deposition of pollutants and increases in sediment runoff) show no trend. When placed in context with climate change pressures (e.g. sea surface temperature), most other non-fisheries pressures pose limited risk to the focal species.

CANARY ROCKFISH



PHYSICAL FORCING

Temperature, atmospheric pressure, and ocean circulation affect growth, survival, and density of rockfishes. Juvenile abundance and egg production is negatively affected by El Nino and adult occurrence is positively related to PDO. Over the past five years, ENSO has trended upward and PDO downward indicating a period of potentially poorer ocean conditions for rockfishes. Long-term warming may result in northerly shifts in distribution decreased maximum size and fecundity, and decreased larval survival.

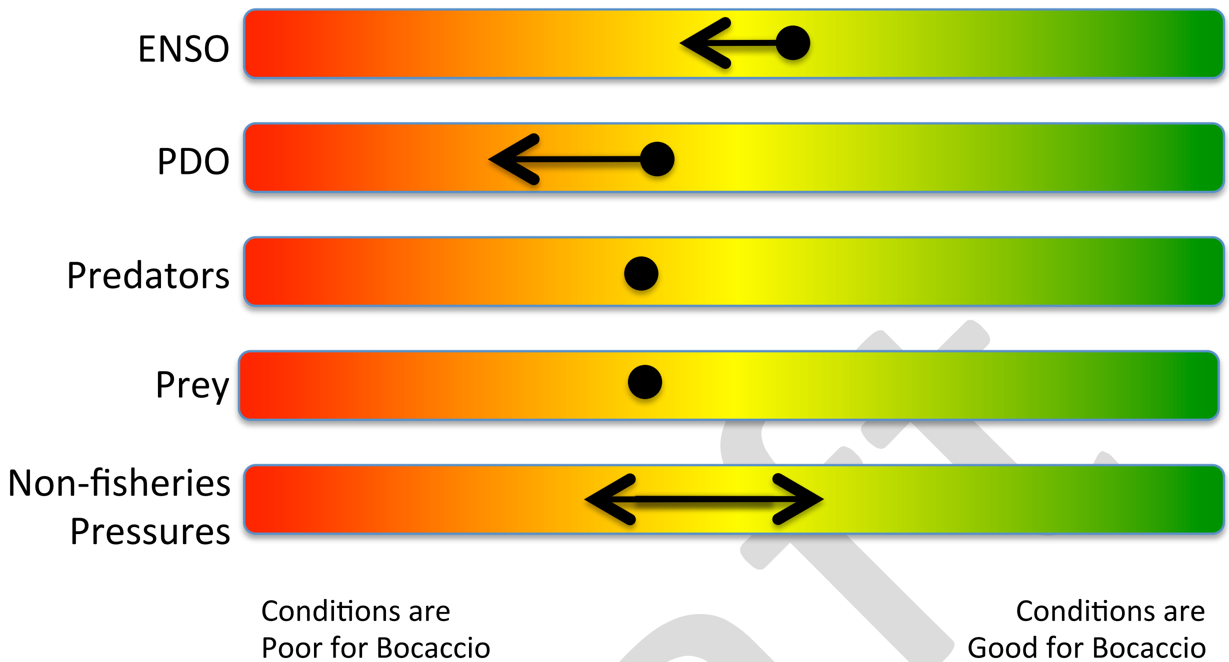
TROPHIC INTERACTIONS

Euphausiids are the primary prey species for canary rockfish (69% of their diet). Canary prey have been variable through time with several years that were substantially better than others. Over the last five years, prey availability has increased. Note, however, that data were not available for deposit feeders and mysids. These groups made up 26% and 13% of the diet respectively. Major predators on canary rockfish include lingcod and dogfish. The canary predator field shows substantial long-term variation. The trend over the last five years has been for a decline in the abundance of predators field.

NON-FISHERIES PRESSURES

The status of most of the 19 non-fisheries pressures on Canary rockfish is average with no evidence of improving or declining trends. Some non-fisheries pressures are improving (e.g. nutrient inputs), while others (e.g. coastal engineering) are declining. However, in general the highest risk threats, (e.g., atmospheric deposition of pollutants and increases in sediment runoff) show no trend. When placed in context with climate change pressures (e.g. sea surface temperature), most other non-fisheries pressures pose limited risk to the focal species.

BOCACCIO



PHYSICAL FORCING

Temperature, atmospheric pressure, and ocean circulation affect growth, survival, and density of rockfishes. Juvenile abundance and egg production is negatively affected by El Nino and adult occurrence is positively related to PDO. Over the past five years, ENSO has trended upward and PDO downward indicating a period of potentially poorer ocean conditions for rockfishes. Long-term warming may result in northerly shifts in distribution decreased maximum size and fecundity, and decreased larval survival.

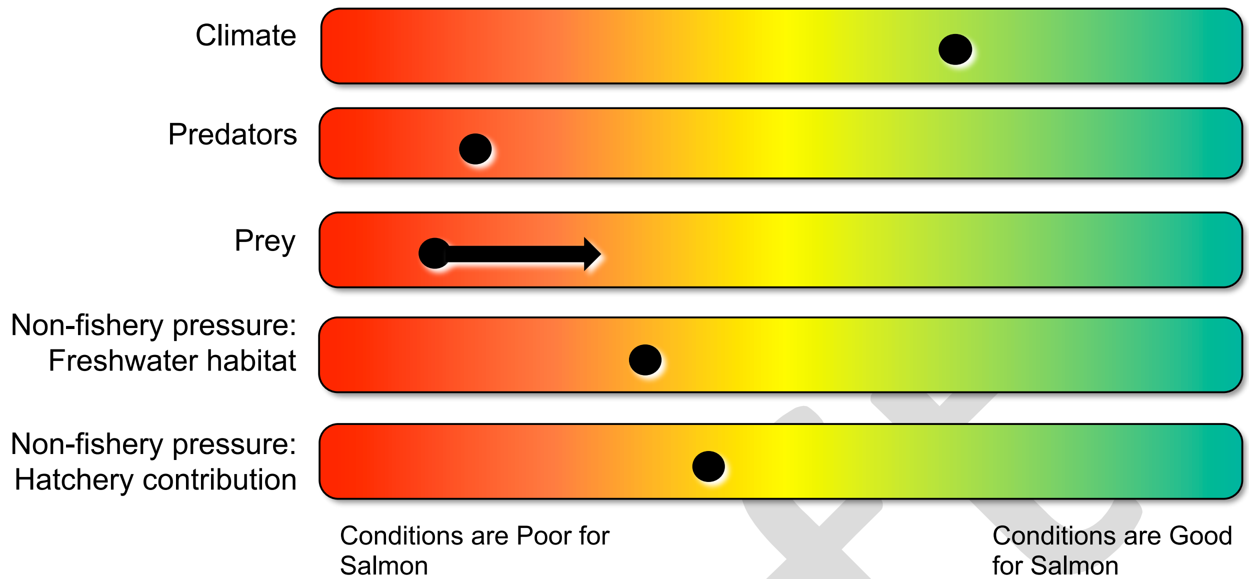
TROPHIC INTERACTIONS

Bocaccio prey have been highly variable over the long term. However, over the last five years, there has been no trend in the bocaccio prey index and the 5-year mean is within one s.d. of the long-term mean. The primary bocaccio predators are mid-water rockfish and lingcod. The bocaccio predator index showed a peak in the mid-2000's and has since declined. Over the last five years, however, the index has been stable.

NON-FISHERIES PRESSURES

The status of most of the 19 non-fisheries pressures on bocaccio is average with no evidence of improving or declining trends. Some non-fisheries pressures are improving (e.g. nutrient inputs), while others (e.g. coastal engineering) are declining. However, in general the highest risk threats, (e.g., atmospheric deposition of pollutants and increases in sediment runoff) show no trend. When placed in context with climate change pressures (e.g. sea surface temperature), most other non-fisheries pressures pose limited risk to the focal species.

SACRAMENTO RIVER CHINOOK SALMON



PHYSICAL FORCING

The ocean condition has been generally in a good state for promoting ecosystem and salmon production. Wells et al 2008 (*Marine Ecology Progress Series* 364:15-29) developed an index of ecosystem productivity based on environmental variables (e.g. wind, temperature) and biological productivity. This index tracked, without modification, the abundance of Chinook salmon 1990-2008. This index can be used as an approximation of the ocean conditions in central California; the region wherein recruitment of salmon juveniles to the adult population is determined.

TROPHIC INTERACTIONS

The forage base for Sacramento River salmon has been restricted in recent years with an increasing trend apparent. We represent forage as the the abundance of krill in the Gulf of the Farallones. As of 2005, the population of California sea lion, a primary predator, was at carrying capacity. Research has shown that California sea lions remove salmon from fishing gear at a rate as great as 30%; the greater the loss to depredation the greater is the true harvest as fish are replaced in the fishery.

NON-FISHERIES PRESSURES

Freshwater habitat: River discharge has been less than optimal for salmon health and productivity. Freshwater flow has been shown to relate to the survival and condition of salmon living in the freshwater environment and moving into the ocean. Hatchery contribution: In the last five years hatchery contribution to the Sacramento River Fall Run Chinook salmon has been approximately 31% with no recent trend. Hatchery contribution represents the proportion of the spawning populations that returns to hatcheries

DISCUSSION DOCUMENT:

DEVELOPMENT OF AN ANNUAL REPORT ON CONDITIONS IN THE CALIFORNIA CURRENT ECOSYSTEM

PART II. TECHNICAL BACKGROUND AND ANALYSES

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CHAPTER 1: PHYSICAL FORCING IN THE CALIFORNIA CURRENT

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THE QUESTION: WHAT ARE THE STATUS AND TRENDS OF KEY CLIMATE/OCEAN DRIVERS THAT INFLUENCE HAKE, SABLEFISH, CANARY ROCKFISH, AND BOCACCIO?

OVERVIEW

The California Current large marine ecosystem (CCLME) is one of five eastern boundary current upwelling regions in the world and extends from southern British Columbia to Baja California. Seasonal variation in ocean circulation, upwelling, and freshwater inputs dictate changes in marine water properties nearshore and translate to patterns of biological productivity in the CCLME. The CCLME is also subject to substantial interannual and decadal-scale climate variability. El Nino Southern Oscillation (ENSO), the dominant source of interannual variability, is triggered by anomalies in the wind field in the western equatorial Pacific. Depressed nitrate, primary production, and chlorophyll levels during El Nino events have led to decreases in fish egg and larvae abundance and variation in zooplankton species dominance. Long periodicity changes in the CCLME include the Pacific Decadal Oscillation (PDO), a low frequency signal in North Pacific sea surface temperatures (SST). Positive PDO anomalies are associated with warmer temperatures, weaker upwelling, and lower primary productivity in the CCLME. In addition to these multiple scales of climate variability, surface waters have warmed in the CCLME over the past 100 years, wind-driven upwelling has increased since the 1940s, and shoaling of hypoxic water has occurred along the coast. Climate model predictions suggest that over the next 50 years the magnitude of ocean warming will surpass the natural variability previously observed in most of the North Pacific. We examined the biological responses of key groundfish species to oceanographic and climate conditions to better understand how they might respond to future climate variability in the CCLME.

Pacific hake

Hake distribution, abundance, and productivity in the CCLME respond strongly to interannual variability in physical forcing. Hake production has been linked to Fraser River flow, the strength of the Aleutian Low Pressure (ALP) system, timing of the spring transition, bottom temperature, wind duration and intensity, and euphausiid abundance. The proportion of strong hake year classes is higher during El Nino years and hake habitat expands under El Nino conditions due to a northward extension of spawning and feeding grounds. Abundance, biomass, and occurrence of juvenile and adult Pacific hake are positively correlated with ENSO and biomass of adults is positively correlated with PDO. The recent five-year trend in ENSO anomalies has been positive, yielding relatively good ocean conditions for Pacific hake; however, PDO has trended downward during this same period. Hake may experience reduced recruitment with long-term warming, unless they continue to expand their spawning grounds to more productive northern waters.

Sablefish

Mechanisms underlying sablefish production in the CCLME include timing of the spring transition, strength of ALP, wind advection, and thermal conditions. Specifically, strong year classes have occurred during periods of more intensive ALP and more frequent southwesterly winds and after extended periods of below average SST switched to periods of above average temperatures. Adult sablefish growth has a negative relationship with El Nino conditions, but ENSO effects on sablefish biomass and abundance are weak. Biomass and occurrence of adult sablefish is positively correlated with PDO. Thus, the recent shift to a cool PDO period (past five years) may yield poorer ocean conditions for sablefish. Long-term warming is hypothesized to yield declines in sablefish populations in the southern CC and potentially decreased year class success due to reduced spring productivity and copepod production. Due to their longevity and high fecundity, sablefish may be able to take advantage of periodic good recruitment conditions, even with increased variability due to climate change.

Rockfishes

Temperature, atmospheric pressure, and ocean circulation affect growth, survival, and density of larval and juvenile rockfishes. The abundance of pelagic juvenile rockfish is strongly correlated with the magnitude of winter southward transport in the CCLME. Rockfish growth and survival may have a dome-shaped response to upwelling (i.e., a range of optimum upwelling exists), because low levels of upwelling result in lower food availability and high levels of upwelling create a more turbulent environment for larvae. Juvenile abundance and adult egg production of rockfishes is negatively affected by El Nino conditions and adult occurrence is positively related to PDO. Over the past five years, ENSO anomalies have trended upward (warm phase) and PDO anomalies downward (cool phase), indicating a period of potentially poorer ocean conditions for rockfishes. Rockfish are predicted to undergo northern shifts in distribution with long-term warming, decreased maximum size and fecundity, and decreased larval survival due to a mismatch with the timing of primary production; however, the longevity and high fecundity of rockfishes may allow them to respond strongly to episodic environmental conditions that are favorable for larval survival.

I. PHYSICAL DOMAIN AND SCALES OF VARIABILITY

The California Current large marine ecosystem (CCLME) is one of five eastern boundary current upwelling regions in the world and extends from the transition zone separating the North Pacific and Alaska Gyres off southern British Columbia to the subtropical waters off Baja California (Hickey 1998, Checkley and Barth 2009; Figure 1). The physical oceanography of the region is characterized by major ocean currents, atmospheric forcing, wind-driven upwelling, and freshwater inputs near the coast (Checkley and Barth 2009). These complex physical features exhibit multiple scales of temporal and spatial variability (Table 1, Figure 1).

I.A PERSISTENT PHYSICAL FEATURES AND SEASONAL VARIATION

Large-scale ocean currents, including the California Current (CC), the California Undercurrent (CU), the Davidson Current (DC), and the coastal jet, vary seasonally and play a dominant role in the physical dynamics of the CCLME (Hickey 1998, Checkley and Barth 2009). The CC is a cool, low-salinity, nutrient-rich mix of Pacific Subarctic and Subtropical Gyre water that flows equatorward, extending from the surface to 500 m and spanning the shelf break to 1000 km offshore (Hickey 1998, Checkley and Barth 2009). The CU carries warm, high-salinity, low oxygen water northward along the continental slope and is narrower than the CC, varying from 10-40 km wide and strongest at depths of 100-300 m (Hickey 1998, Checkley and Barth 2009). The DC is approximately 100 km wide and moves northward from Point Conception to Vancouver Island (Hickey 1998, Checkley and Barth 2009). The coastal jet is a persistent, yet less dominant, feature that meanders equatorward with the CC (Hickey 1998, Checkley and Barth 2009). Alongshore surface currents flow equatorward during spring and summer, when the CC is strongest (Hickey 1998, King et al. 2011). In the summer, a stronger CU maximizes subsurface northward flow and, south of Point Conception, the CC turns north to become the Southern California Eddy (Hickey 1998, King et al. 2011). During the winter, the DC dominates flow over the shelf and beyond the shelf break; south of Point Conception, the CC turns north to become the Southern California Countercurrent (Hickey 1998, King et al. 2011).

The CCLME is characterized by strong seasonal upwelling driven by large-scale alongshore winds associated with atmospheric pressure patterns. During a "spring transition" of currents and water properties over the shelf and slope, weak Aleutian Low Pressure (ALP) and strong North Pacific High Pressure (NPH) systems yield upwelling-favorable (equatorward) winds that drive flow offshore and a decrease in surface temperature and sea level along the coast (Emery and Hamilton 1985, Checkley and Barth 2009). Upwelling of cold, salty, nutrient-rich water continues throughout the summer, leading to increased nutrients and primary productivity near shore (Brodeur et al. 2006, Mackas et al. 2006, Barth et al. 2007, Checkley and Barth 2009). In the fall and winter, the ALP strengthens and NPH weakens, generating poleward winds that cause downwelling, increased water temperature over the continental shelf, and sea level rise near the coast (Hickey 1998, King et al. 2011). The region south of Cape Mendocino diverges from this general seasonal pattern of wind-driven upwelling; there, winds are southward and upwelling-favorable year-round and generally less variable than in the northern CCLME (Huyer 1983, Checkley and Barth 2009). In addition, seasonal upwelling intensity varies along the coast.

Freshwater input to the CCLME varies seasonally, dictating changes in marine water properties nearshore. The Fraser and Columbia Rivers are dominant sources of fresh water to the northern CC (north of Cape Blanco); the Columbia River provides more than 77% of the drainage between the Strait of Juan de Fuca and San Francisco Bay (Barnes et al. 1972, Hickey 1998). Freshwater flows vary with seasonal and interannual variation in rainfall and can have a strong effect on sea surface salinities and temperatures near the coast (Emmett et al. 2006). In addition, the northward DC and downwelling currents drive the Columbia River plume north and onshore in the winter, while upwelling-driven shelf currents move the plume south and offshore in the summer (Barnes et al. 1972).

I.B INTERANNUAL TO DECADAL SCALE CLIMATE VARIABILITY

In addition to seasonal fluctuations, the CCLME is subject to interannual and decadal climate variability (Figure 2). The dominant source of interannual climate variability is the El Nino Southern Oscillation (ENSO), which is triggered by anomalies in the wind field in the western equatorial Pacific and varies between positive and negative phases on five to ten year scales (Mysak 1986, McGowan et al. 1998, Chavez et al. 2002). El Nino (positive ENSO) conditions are associated with an anomalously weak CC (equatorward flow) and strong CU (poleward flow), warmer temperatures in the upper water column, and weaker upwelling intensity (Table 2). There have been at least five El Nino events since 1972, with the strongest occurring in 1957-59, 1982-84 and 1997-98 (Goes et al. 2001, McGowan et al. 2003). Ecosystem responses to El Nino conditions (see next section) may be modulated by the longer-term background climatic state of the Pacific Ocean (Chavez et al. 2002) and, in general, it can be difficult to separate decade-to-century scale variability from interannual variability associated with ENSO (Zhang et al. 1997).

Long periodicity changes in the CCLME have been described using various climate indices, often expressed as anomalies from long term mean conditions (Table 2, Figure 2). Three key basin-scale indices that describe decadal scale variation in oceanographic and atmospheric conditions are the Pacific Decadal Oscillation (PDO; Mantua et al. 1997), the North Pacific Gyre Oscillation (NPGO; DiLorenzo et al. 2008), and the Northern Oscillation Index (NOI; Schwing et al. 2002). The PDO is a low frequency signal in North Pacific sea surface temperatures (SST), derived as the leading principal component of monthly SST anomalies in the North Pacific Ocean poleward of 20° N (Mantua et al. 1997), and accounts for 18-48% of the variability in long-term SST (Field et al. 2006). Positive PDO phases are associated with warmer temperatures, weaker upwelling, and lower primary productivity in the CC (Goes et al. 2001, Bograd and Lynn 2003, McGowan et al. 2003; Table 2). The PDO was predominantly positive between 1925 and 1946, negative between 1947 and 1976, and positive since 1977 (Mantua et al. 1997, Bond et al. 2003). The NPGO is a low frequency signal in sea surface heights over the Northeast Pacific and is defined as the second principal component of sea level pressure over North Pacific (DiLorenzo et al. 2008). Positive values of the NPGO are linked with increased surface salinities, nutrients, and chlorophyll-a values in the CC (DiLorenzo et al. 2008; Table 2). The NOI describes the strength of atmospheric forcing between the equatorial Pacific and the North Pacific and is calculated as the difference in sea level pressure anomalies at the North Pacific High in the northeast Pacific and near Darwin, Australia (Schwing et al. 2002). Positive NOI phases are associated with cooler sea surface temperatures and stronger upwelling-favorable winds along the coast (Schwing et al. 2002; Table 2). The NOI was predominantly positive prior to 1965, during 1970-76 and 1984-91, and after 1998; negative values predominated 1965-70, 1977-83, and 1991-98 (Schwing et al. 2002).

Regime shifts, or abrupt changes in physical conditions that persist for a decade or more, have had dramatic effects on the state of the CCLME (Hare and Mantua 2000). A major regime shift occurred in the North Pacific in 1976-77, during which horizontal advection intensified due to a deepening of the ALP system, the mixed layer deepened, and SST increased in the eastern Pacific (including the CCLME; McGowan et al. 2003). The 1976-77 regime shift marked a transition from a cooler epoch (1960-76) to a warmer one (post-1977; Zhang et al. 1997) and led to an overall decline in system productivity (McGowan et al. 2003); these biotic changes are described in greater detail in section II. Another possible regime shift occurred after the 1997-98 El Nino event, in which upwelling-favorable winds strengthened in the CCLME, coastal waters cooled by several degrees, and PDO reversed sign and remained negative through summer 2002 (Goes et al. 2001).

I.C LONG-TERM TRENDS AND FUTURE PROJECTIONS

In addition to these multiple scales of climate variability, atmospheric and ocean warming has progressed over the past 100 yrs across the world's oceans (Weinheimer et al. 1999, Field et al. 2006, Barron et al. 2010). The integrated heat content of global oceans has increased since the mid-1950s; rapid, unprecedented warming has been attributed to atmospheric forcing associated with accumulating greenhouse gases in the atmosphere (Field et al. 2006; Levitus et al. 2000, 2001). In the CCLME, SST time series showed warming trends of +0.007°C/yr to +0.010°C/yr between 1900 and 2005, slightly higher than the global mean of +0.006°C/yr (Field et al. 2006). Wind-driven upwelling has increased in the CCLME since the 1940s, yielding enhanced summer upwelling and winter downwelling north of 40°N (Hsieh et al. 1995, Snyder et al. 2003). Consistent with enhanced upwelling, SST decreased in northern regions but increased south of 36°N from the 1950s to the 1990s (Schwing et al. 1996). Furthermore, shoaling of hypoxic water along west coast of North America has occurred, possibly due to changes in upwelling and wind forcing (Whitney et al. 2007, Bograd et al. 2008).

Climate model predictions suggest that by 2050, the magnitude of warming due to anthropogenic influences will surpass the natural variability (e.g., PDO) previously observed in most of the North Pacific (Overland and Wang 2007, Wang et al. 2010). Along with increased temperatures, ocean acidification (Feely et al. 2008, Doney et al. 2009) and the frequency of El Nino events are expected to increase (Timmermann et al. 1999). A regional climate model (RCM) developed for the southern CCLME projected that richer atmospheric CO_2 would lead to warmer upper ocean (< 70 m) and increased stratification along the coast that is mitigated by increased upwelling favorable winds (Auad et al. 2006). Upwelling velocities were predicted to be 30% faster near the coast in the spring, yielding stronger offshore advection north of the Santa Barbara Channel, in 2040-2050 compared to observed 1986-1996 values (Auad et al. 2006). The model also indicated that the largest climatological changes would occur north of Point Conception (Auad et al. 2006). Several other climate models developed for the Pacific Northwest projected substantial nearshore ocean warming relative to twentieth century variability, averaging +1.2◦C between 1970-1999 and 2030-2059 periods, but little change in coastal along-shore wind stress and coastal upwelling (Mote and Salathe 2010). In general, there is substantial uncertainty in the intensity of coastal upwelling under different climate scenarios (Bograd et al. 2009, Wang et al. 2010).

II. BIOLOGICAL RESPONSES TO PHYSICAL FORCING

The synergistic effects of environmental and climate variability on the biotic components of the ecosystem are complex. Within a given year, the timing of the spring transition and strength of upwelling-favorable winds have a large effect on ecosystem responses (Barth et al. 2007). Interannual climate variability and decadal scale regime shifts have led to large scale changes in primary production that can propagate throughout food webs (Chavez et al. 2003). For instance, major ecosystem regime shifts have occurred when the PDO and NPGO showed strong, simultaneous, and opposite sign reversals (DiLorenzo et al. 2008). Fish production and recruitment in the Northeast Pacific Ocean have varied in accordance with ENSO and PDO dynamics (Hollowed et al. 2001, Tolimieri and Levin 2005). This section will first describe the biological effects of physical forcing in the CCLME across trophic levels. Next, we develop hypotheses about the sensitivity of four key groundfish species to climate variability and potential impacts of predicted climate change on their productivity and abundance.

II.A. PRIMARY AND SECONDARY PRODUCTION—NUTRIENTS, PHYTOPLANKTON, ZOOPLANKTON

The abundance, distribution, and species composition of primary and secondary producers is dictated by the physical environment. Nutrient input and the timing of the spring transition each year is critical for photosynthesis and productivity of phytoplankton, especially in the northern CCLME (Bograd et al. 2009), and affects the biomass and species composition of zooplankton (Brodeur et al. 2006, Mackas et al. 2006, Barth et al. 2007, King et al. 2011). For example, in 2005 the spring transition occurred approximately 1 month later than average, yielding warmer temperatures, abnormally low upwelling, and negative chlorophyll-*a* anomalies accompanied by a decrease in nitrate concentration in May through mid-July (Barth et al. 2007). As a result, early-season recruitment of mussels and barnacles was exceptionally low, likely due to decreased food supply (Barth et al. 2007). From mid-July onward, upwelling-favorable winds were stronger than average, resulting in higher phytoplankton biomass and a recruitment pulse of mussels and barnacles (Barth et al. 2007). Delayed early-season upwelling and stronger late-season upwelling is consistent with the predicted effects of global warming on coastal upwelling regions (Bakun 1990, Snyder et al. 2003). Upwelling affects planktonic organisms through nutrient enrichment of surrounding waters (MacIsaac et al. 1985, Snyder et al. 2003) and retention of plankton and nutrients in the same areas (Snyder et al. 2003). For instance, decreased upwelling can lead to reduced nutrient supply to phytoplankton (MacIsaac et al. 1985) and reduced offshore transport of phytoplankton, invertebrate larvae, and planktonic fish (Connolly et al. 2001). Thus, changes in the phenology of upwelling translate to variation in the temporal and spatial overlap of predators and prey at higher trophic levels (Beaugrand et al. 2003, Bograd et al. 2009).

Interannual and decadal climate variation affect bottom-up processes that can lead to large ecosystem changes. Depressed nitrate, primary production (carbon), and chlorophyll levels during El Nino events (Chavez et al. 2002) have led to decreases in fish egg and larvae abundance after a several year lag and variation in the dominance of zooplankton and larval fish species (McGowan et al. 2003, Mackas et al. 2006). Stronger upwelling and cooler surface waters after the 1997-98 El Nino led to a doubling of zooplankton biomass in the northern CC and a reversal from warm- to cold-tolerant species dominance (Goes et al. 2001). Copepod biomass was relatively low off the Oregon coast during warm phases of the PDO (1997-8, 2003-5) and high during a cool phase (1999-2002; Brodeur et al. 2008). Following the 1976-77 regime shift, copepod assemblage structure became more variable, productivity decreased across all trophic levels (e.g., zooplankton biomass declined sevenfold; Roemmich and McGowan 1995), and shifts in nearshore fish species richness and dominance occurred (Holbrook et al. 1997, McGowan et al. 2003). Poleward shifts in the centers of abundance for multiple zooplankton species and earlier life cycle timing for a dominant subarctic copepod (*Neocalanus plumchrus*) have been observed during warmer conditions in the CCLME (Mackas et al. 2007). Long-term sea surface warming in the CCLME since 1930 has impacted the composition and abundance of marine plankton communities (Field et el. 2006). An 80% decline in macrozooplankton biomass off southern California from 1951 to 1995 was attributed to warming in the upper water column (>1.5 °C in some places; Roemmich and McGowan 1995).

II.B. FISH

II.B.1 PELAGIC NEKTON

Climate-driven variation in zooplankton composition and abundance has implications for the productivity, survival, and distribution of small pelagic fishes, including herring and juvenile salmon, that provide an important forage base for upper trophic level predators (Tanasichuk 2002, Mackas et al. 2007). Years of low euphausiid concentration off the west coast of Vancouver Island coincided with reduced growth of pre-recruit herring and a shift in adult herring distribution, although adult mortality and recruitment intensity were not related to euphausiid abundance (Tanasichuk 2002). In general, zooplankton production and survival of pelagic fishes have shown relatively strong correlations ($|r| = 0.25–0.8$) with local and basin-scale temperature anomalies in the northern CCLME (Mackas et al. 2007). Following the 1997-1998 El Nino, anchovies and osmeriids increased in abundance and coho and chinook salmon stocks rebounded (Goes et al. 2001).

Pelagic fishes have shown species-specific responses to decadal scale variability. After a 1989 regime shift, Pacific sardines increased in abundance while northern anchovy declined (Emmett and Brodeur 2000). The composition of pelagic nekton assemblages changed with the 1977 regime shift, from a pelagic community dominated by squid, eulachon, and northern anchovy during the cooler pre-1977 period to Pacific sardine, Pacific mackerel, jack mackerel, Pacific hake during the warmer post-1977 period (Emmett and Brodeur 2000). Between 1998 and 2002, pelagic species composition off the Washington and Oregon coasts gradually shifted from predominantly southern species (mackerels, hake) to northern species (squid, smelt, salmon; Brodeur et al. 2005). Pacific herring weight at age, recruitment, and spawning stock biomass off the west coast of Vancouver Island shifted from relatively high levels during the decade prior to the 1976-7 regime shift to relatively low levels by 1989-1999 (Rose et al. 2008).

II.B.2 FOCAL GROUNDFISH SPECIES—PACIFIC HAKE, SABLEFISH, CANARY ROCKFISH, BOCACCIO

Physiology and behavior play an important role in how organisms are affected by their environment, and ultimate population-level responses to climate and ocean conditions may be related strongly to a species' life history and biology (King et al. 2011, Zabel et al. 2011). Physical properties of the environment (e.g., temperature, salinity, circulation) may affect fishes directly, through physiological and behavioral responses, and indirectly, through changes in food supply. For example, temperature affects survival and growth of fishes by dictating metabolic processes and altering the species composition, nutritional quality, and distribution of their prey. Resolving the mechanistic linkages between climate and ocean conditions and groundfish distribution and abundance is challenging, but observed correlations between environmental variables and fish abundance, distribution, and productivity provide the basis for hypotheses about potential species responses to long-term climate change.

PACIFIC HAKE

Pacific hake (*Merluccius productus*, Merlucciidae) occur from the Gulf of California (~25°N) to the Gulf of Alaska (~55°N) and are among the dominant groundfish species in survey and fishery catches along the U.S. west coast. Adult hake undergo large annual migrations from winter (Jan-Mar) spawning grounds off southern California to summer feeding grounds off the west coast of Vancouver Island (Horne and Smith 1997, Agostini et al. 2008, Helser et al. 2008); the timing of these migrations is related to ocean conditions (Benson et al. 2002). Hake achieve maximum lengths of 91 cm and live up to 20 years (Hart 1973). Adults are semi-pelagic and found to depths of 900 m, but most commonly occur between 200-300 m (Hart 1973). Euphausiids are a primary food source for juvenile and adult hake (Benson et al. 2002). Hake production in the CC has been linked to Fraser River flow, strength of ALP, timing of the spring transition, bottom temperature, wind duration and intensity (Hollowed et al. 2008), and euphausiid abundance (Mackas et al. 1997).

Hake distribution, abundance, and productivity in the CC respond strongly to interannual variability in physical forcing. Large-scale ocean circulation, temperature, and upwelling dynamics characterize pelagic habitat and affect hake distribution. Strong poleward flow along the coast near the shelf break (i.e., strong CU, DC) may benefit hake energetically by facilitating migration to highly productive northern feeding grounds (Agostini et al. 2006, Phillips et al. 2007, King et al. 2011) and providing juveniles better access to prey concentrated along shelf edges (Mackas et al. 1997, Agostini et al. 2006). Alternatively, year class strength may be negatively affected by cannibalism (more overlap between adults and juveniles), exposure to a different suite of predators, and stronger advection in the northern CC leading to decreased larval and/or juvenile survival (Agostini et al. 2006, Phillips et al. 2007, King et al. 2011). During warmer years, hake spawning and feeding ranges expand northward (Benson et al. 2002, Emmett et al. 2006, King et al. 2011) and survival of recruits is higher compared to cold years (on average, three times higher; Horne and Smith 1997). In 2003 (warm year), hake were distributed closer to shore (10-20 km) than in 1999 (cold year), when they were less abundant and caught primarily offshore (40-50 km; Emmett et al. 2006). Along the U.S. west coast, large catches of adult hake have been observed in areas of highest chlorophyll-a concentration (42-50 °N; Ware and Thomson 2005).

The effects of upwelling on hake growth, survival, and distribution depend on life history stage and latitudinal region of the CCLME. Regional hake abundance is positively related to euphausiid abundance (Mackas et al. 1997), therefore, upwelling conditions that promote higher euphausiid productivity may benefit hake. Wind-driven upwelling may improve the feeding environment, and therefore growth, of juvenile and adult hake by concentrating euphausiids at the shelf break where they feed (Mackas et al. 1997, King et al. 2011); however, the relationship between euphausiid abundance and upwelling varies along the coast (Benson et al. 2002). In the northern CCLME, euphausiid recruitment was higher during downwelling periods (Mackas et al. 2001), but biomass was positively related to upwelling in the central-southern CCLME (Brodeur and Pearcy 1992). Downwelling, or weak upwelling, conditions favor hake larval survival because strong upwelling causes advection of larvae offshore, away from juvenile nursery areas along the coastal shelf and slope of California and southern Oregon (Phillips et al. 2007, King et al. 2011). In general, annual hake density is strongly related to the timing of the spring transition, with highest average densities nearshore during a late spring transition and warm spring (April–May) temperatures (Brodeur et al. 2006, Emmett et al. 2006).

El Nino conditions (weaker ALP, weaker upwelling, warmer sea surface temperature) are generally favorable for hake in the northern CC. The proportion of strong hake year classes was higher during El Nino years (Hollowed et al. 2001). Hake habitat expands under El Nino conditions (Agostini et al. 2008) due to a northward extension of spawning and feeding grounds (King et al. 2011). After the 1989 regime shift to El Nino conditions, the biomass of hake nearly doubled in Canadian waters (McFarlane et al. 2000) as a result of a northward shift in hake distribution and larger body size of adult hake, possibly due to improved feeding conditions in the north (Benson et al. 2002). Results of a generalized linear model indicated that occurrence of hake in the U.S. west coast survey region (Cape Flattery, WA to U.S.-Mexico border) from 2003 to 2009 was positively related to ENSO, and negatively related to NOI, SST, chl-*a* concentration, and upwelling (see Appendix for statistical methods; Beaudreau and Levin, unpublished). Hake have also responded to decadal-scale and longer term climate change. The biomass of adult hake along the U.S. west coast was significantly and positively related to the PDO (A. Keller, pers. comm., 21 July 11). The quantity of hake larvae decreased in the Southern California Bight after the 1976-77 regime shift to warmer conditions, followed by a slight increase during the 1999-2000 La Nina (Funes-Rodriguez et al. 2009). Overall, there has been a 444 km northward shift in the median latitude of spawning between 1951 and 1984 (Horne and Smith 1997) and a continued poleward extension after the 1989 regime shift (Benson et al. 2002). It has been hypothesized that hake may experience reduced recruitment with long-term warming, unless they continue to expand their spawning grounds to more productive northern waters (King et al. 2011).

SABLEFISH

Sablefish (*Anoplopoma fimbria*, Anoplopomatidae) range from southern Baja California to the north-central Bering Sea and west to the northeastern coast of Japan. Sablefish spawn in deep waters along the continental slope (>500 m) from April to October. Sablefish reach 50% maturity at 55-67 cm in 5-7 years; they can achieve a maximum size of 100 cm and have been aged to 92 years. Adults occur in deep water, commonly between 366 and 915 m, and may undergo extensive migrations of more than 1,000 km. As juveniles, sablefish consume zooplankton (e.g., amphipods, copepods, euphausiids, gelatinous zooplankton) and large planktivores (e.g., herring, sardine, anchovy) and switch to a more piscivorous diet as adults, consuming a variety of fishes including deepwater rockfishes and hake. Mechanisms underlying sablefish production in the CC include timing of the spring transition, strength of ALP, and wind advection (Hollowed et al. 2008).

Rapid growth, mediated by high levels of consumption, is critical for early survival of sablefish (Sogard and Spencer 2004) and results from a bioenergetics model showed increasing sablefish growth efficiencies with increasing temperature (Harvey 2009). Experimental work has also shown that at high temperatures and high rations, juvenile sablefish demonstrated extremely high lipid accumulation in concert with fast growth rates of more than 3mm/day; Sogard and Spencer 2004). In feeding experiments with juvenile sablefish, increasing temperature significantly reduced prey attack and handling times (Stoner and Sterm 2004). A very strong linkage has been observed between thermal conditions in the marine environment and sablefish year class strength. Specifically, strong year classes have consistently occurred after extended periods of below average SST switched to periods of above average temperatures (McFarlane and Beamish 2001).

Stronger year classes have also occurred during periods of more intensive ALP, more frequent southwesterly winds, below average temperatures in the subarctic Pacific and warmer sea surface temperatures in the northern CC (King et al. 2000, McFarlane and Beamish 2001, Hollowed et al. 2008). In addition, strong year classes are closely associated with higher copepod abundance (McFarlane and Beamish 1992, McFarlane and Beamish 2001). The timing of the spring transition affects the spatial and temporal overlap of copepod abundance and first feeding sablefish larvae from January to April (Hollowed et al. 2008), while ALP and wind advection affect the overlap of coastal plankton production with onshore movements of juveniles in the spring and summer (Hollowed et al. 2008). Sea surface height influences the degree to which overall productivity of the CCLME matches the spring period of first feeding (Hollowed et al. 2008). Adult sablefish are associated with upwelling habitats of low SST and high sea surface salinity (Juan-Jorda et al. 2009).

Tagging data from adult sablefish showed that El Nino conditions have a significant negative effect on sablefish growth off the U.S. west coast (Kimura et al. 1998). The biomass of adult sablefish along the U.S. west coast was significantly and positively related to PDO (A. Keller, pers. comm., 21 July 11). During 2003-2009, occurrence of sablefish in the U.S. west coast survey region was positively related to NPGO, and negatively related to NOI, SST, chl-*a* concentration, and upwelling (see Appendix A; Beaudreau and Levin, unpublished). In general, trends in sablefish production are related to patterns of climate and ocean conditions on a decadal scale (Hollowed et al. 2008). Strong year-classes have generally followed large scale shifts to above average SST and more intense ALP in the northern CC (McFarlane and Beamish 2001). Sablefish year classes from 1960 to 1976 were generally below average, followed by an exceptionally large 1977 year class and generally above average recruitment from 1978 to 1990, with subsequent year classes generally below average (King et al. 2000, King et al. 2001). If sufficient food resources are available, juvenile sablefish are capable of tolerating and thriving at increased temperatures up 22°C, beyond which growth and survival are severely compromised (Sogard and Olla 2001). Temperatures in the primary (northern CC) nursery waters for sablefish are not projected to exceed 22°C, therefore, ocean warming may impact sablefish primarily at the southern end of their range (Sogard and Olla 2001). Long-term warming is hypothesized to yield declines in sablefish populations in the southern CC and potentially decreased year class success due to reduced spring productivity and copepod production (King et al. 2011). Due to their longevity and high fecundity, sablefish may be able to take advantage of periodic good recruitment conditions, even with increased variability due to climate change (King et al. 2011).

ROCKFISHES

Rockfishes (*Sebastes* spp., Scorpaenidae) are an ecologically diverse suite of ovoviviparous, sedentary, long-lived species that are dominant in nearshore fish assemblages along the west coast of North America. Distribution of adult rockfishes is structured primarily on the basis of depth, latitude, and structural habitat (Williams and Ralston 2002). We focus on two rockfishes of commercial importance—canary rockfish (*S. pinniger*) and bocaccio (*S. paucispinis*). Canary rockfish are part of a northern assemblage of rockfish (Williams and Ralston 2002) distributed along the continental shelf from northern Baja California to the western Gulf of Alaska, most commonly at depths of 80-200 m. Bocaccio are generally more southern in their distribution (Williams and Ralston 2002), found from central Baja California to southeastern Alaska at depths of 50 to 250 m. Canary and bocaccio females reach 50% maturity at 51 cm and 36 cm, respectively. Canary rockfish achieve a maximum length of 76 cm and longevity of 84 years, while bocaccio can grow to 91 cm and live for over 50 years.

Females of both species undergo parturition during winter months (Dec-Mar), extruding pelagic larvae that settle to kelp canopy habitats in the spring and summer (Apr-Jul) before transitioning to benthic juveniles in fall (Aug-Nov). The concentration of rockfish larvae is highest in January through March off the central coast of Oregon (Brodeur et al. 2008). Spatial synchrony in year class strength has been observed over scales of 500-1000 km for several winter spawning rockfishes in the CCLME (e.g., blue rockfish *S. mystinus*, yellowtail rockfish *S. flavidus*, black rockfish *S. melanops*; Field and Ralston 2005). Spatial variability in year class strength is generally associated with major geographic features, such as Cape Mendocino and Cape Blanco (Field and Ralston 2005). Year class strength in rockfishes may be determined during the larval phase (Laidig et al. 2007).

Relationships between climate and distribution, abundance, and productivity have been poorly studied for individual rockfish species; however, two investigations have revealed linkages between climate variability and bocaccio year class strength. Bocaccio recruitment is highly episodic and controlled by interactions between climate variability and density of conspecifics (i.e., strength of density dependence determined by climate conditions; Zabel et al. 2011). Strong recruitment may only occur when climate acts favorably upon several life stages, including the period prior to parturition of larvae due to potential climate effects on maternal condition (Zabel et al. 2011). Reduced abundance of larval bocaccio has been observed off southern California during anomalously warm periods (Moser et al. 2000, Laidig et al. 2007). Juvenile bocaccio survival was correlated with stronger offshore currents and higher productivity in June preceding parturition, when internal brooding occurs, and a November period of growth following benthic settlement (Zabel et al. 2011). A coupled climate-bocaccio population model revealed that climatic conditions leading to good recruitment years needed to occur more than 90% of the time to achieve positive population growth under historical levels of fishing mortality (Tolimieri and Levin 2005). Boccacio abundance along the U.S. west coast has sharply declined the last 25 years (Zabel et al. 2011), so climate conditions that promote strong recruitment may be particularly important in determining the continued existence of harvested bocaccio populations (Tolimieri and Levin 2005). Specific relationships between climate and population dynamics will be considered for rockfishes as a group due to limited species-specific information.

Temperature, atmospheric pressure, and ocean circulation affect growth, survival, and density of larval and juvenile rockfishes. During spring months (Mar-May), larval drift to nursery areas is affected by wind advection and growth of age-0 individuals is influenced by temperature at 40m below the surface (Hollowed et al. 2008). In the spring and summer (May-Aug), upwelling intensity drives summer prey availability and salinity dictates settlement habitat (Hollowed et al. 2008). The abundance of pelagic juvenile rockfish is strongly correlated with the magnitude of winter southward transport in the CCLME (i.e., stronger equatorward flows; Field and Ralston 2005, Laidig et al. 2007). For three rockfish species (blue rockfish *S. mystinus*, yellowtail rockfish *S. flavidus*, black rockfish *S. melanops*), nearshore temperatures were significantly and negatively correlated with pelagic juvenile abundance from January to June (Laidig et al. 2007). Limited information exists linking temperature with rockfish dynamics at older life stages; however, a bioenergetics model showed that the size of yelloweye rockfish (*S. ruberrimus*) at age 1 increased with increasing temperature (Harvey 2009). For winter spawning rockfishes, large-scale physical forcing mechanisms (1000s of km) may be more important than regional to mesoscale (10s-100s of km) processes in controlling recruitment (Field and Ralston 2005).

The effects of upwelling on larval and juvenile rockfishes are somewhat equivocal, as different studies have yielded alternative conclusions. Coastal upwelling may affect rockfishes during their earliest larval stage, with highest densities of larvae occurring at or near upwelling fronts (Bjorkstedt et al. 2002); however, only weak relationships between upwelling and juvenile rockfish growth, condition, survival, abundance have been observed (Rau et al. 2001, Laidig et al. 2007). For bocaccio, cooler SST and strong upwelling conditions during the period spanning egg production to the end of the larval stage were correlated with higher recruitment on interannual scales (Tolimieri and Levin 2005). Several authors have hypothesized that rockfish growth and survival exhibits a dome-shaped response to upwelling (i.e., a range of optimum upwelling exists), because low levels of upwelling result in lower food availability and high levels of upwelling create a more turbulent environment for larvae (Cury and Roy 1989, Ainley et al. 1993, Ralston 1995, Rau et al. 2001). In hypoxic regions of the CCLME, increased upwelling of oxygen-depleted water could lead to mass mortalities or emigration of adult rockfishes (King et al. 2011).

Rockfishes have shown generally negative responses to El Nino conditions. Anomalously low levels of juvenile rockfish abundance were observed during El Nino events (Laidig et al. 2007) and fewer rockfish occurred in the diet of a generalist predator (common murre *Uria aalge*) during El Nino years (Miller and Sydeman 2004). For bocaccio, it was hypothesized that La Nina conditions prior to settlement should increase the probability of good recruitment (Tolimieri and Levin 2005). A generic rockfish bioenergetics model predicted decreased energy consumption (<4% per individual) and female egg production (<12-19% per individual) during El Nino years compared to baseline conditions (Harvey 2005). Larval rockfish density and occurrence showed nonlinear responses to low-frequency climate signals, with highest levels under normal PDO conditions (i.e., dome-shaped response to PDO anomalies) after a 7-month lag (Miller and Sydeman 2004, Auth et al. 2011). *Sebastes* spp. were among the dominant species in larval fish assemblages off the Oregon coast during a warm PDO phase (2003-2005; Brodeur et al. 2008). Cool, productive conditions (positive NOI) corresponded to a decrease in the magnitude of density-dependent mortality during the settlement period (May-June) for bocaccio (Zabel et al. 2011). Results of a generalized linear model suggested that occurrence of bocaccio and canary rockfish in the U.S. west coast survey region (Cape Flattery, WA to U.S.-Mexico border) from 2003 to 2009 was negatively related to SST and chl-*a* concentration and positively related to PDO (see Appendix A; Beaudreau and Levin, unpublished). Bocaccio and canary rockfish occurrence during 2003-2009 showed weak negative relationships with ENSO (Beaudreau and Levin, unpublished). There was no observed effect of the 1976-77 regime shift on bocaccio recruitment strength or frequency of good recruitment years, which occurred in roughly 13% of years before and after the shift (Tolimieri and Levin 2005). Rockfish are predicted to undergo northern shifts in distribution with long-term warming, decreased maximum size and fecundity, and decreased larval survival due to a mismatch with the timing of primary production; however, the longevity and high fecundity of rockfishes allow them to respond strongly to episodic environmental conditions that are favorable for larval survival (King et al. 2011).

SUMMARY

Biological responses of Pacific hake, sablefish, and rockfishes to physical forcing in the CCLME are summarized in Table 3. Abundance, biomass, and occurrence of juvenile and adult Pacific hake are positively correlated with ENSO and biomass of adults is positively correlated with PDO (i.e., positive phases of ENSO (El Nino) and PDO yield good conditions for hake). Adult sablefish growth has a negative relationship with El Nino conditions, but ENSO effects on sablefish biomass and abundance are weak. Biomass and occurrence of adult sablefish is positively correlated with PDO. Juvenile abundance and adult egg production of rockfishes is negatively affected by El Nino conditions and adult occurrence is positively related to PDO. There has been a positive trend in ENSO anomalies over the past five years, indicating potentially improved conditions for Pacific hake, neutral conditions for sablefish, and worse conditions for rockfishes (Figure 3). During this same period, PDO anomalies have trended downward towards potentially poorer conditions for these species (Figure 3). The relative importance of multi-scale ocean-climate processes and their synergistic effects on groundfish productivity remains a major uncertainty.

APPENDIX A.

Relationships between groundfish occurrence and environmental variables: statistical methods

We evaluated the relationship between occurrence of groundfish species in the U.S. west coast trawl survey (2003-2009) and environmental variables using generalized linear mixed effects models (GLMMs). The probability of capturing a species (i.e., frequency of occurrence in survey tows) was estimated using a GLMM with a binomial error distribution and logit link function (e.g., Helser et al. 2004, Maunder and Punt 2004). The presence/absence of each of four species (Pacific hake, sablefish, bocaccio, and canary rockfish) at each survey tow location was modeled as a function of local environmental variables (latitude, depth, sea surface temperature (SST), chlorophyll-*a* concentration (chl-*a*), upwelling) and climate indices (El Nino Southern Oscillation index (ENSO), Pacific Decadal Oscillation index (PDO), Northern Oscillation Index (NOI), North Pacific Gyre Oscillation (NPGO)). These climate indices were selected because of their known relationships with physical and biological processes in the CCLME (Table 2). Year was included as a random effect to account for potential interannual variation in stock size or spatial changes in fishing effort. Predictor variables showed little covariation at the scale of individual survey tows, however, on larger temporal scales (i.e., month, year) there are strong positive correlations among ENSO, PDO, and SST, which all have strong negative correlations with NOI.

A set of candidate models comprising the null model and all possible combinations of predictor variables were compared using Akaike's information criteria, which balances model complexity (number of estimated parameters) with the goodness of fit, as determined by likelihood (Burnham and Anderson 2002). The ΔAIC was calculated for each model as its AIC minus the lowest AIC across all models; by convention, models with ΔAIC within 2 of the minimum AIC are classified as performing equivalently to the best approximating model (Burnham and Anderson 2002). We calculated the Akaike weight (w_i) for each model, interpreted as the weight of evidence (probability) that model i is the best approximating model from among the set of candidate models (Johnson and Omland 2004). The relative importance of each predictor variable was estimated by summing Akaike weights across all models that included the variable (Burnham and Anderson 2002). The most important predictors of groundfish occurrence and the direction of their effects are reported in the results for each of the four species.

References

Agostini V, Hendrix A, Hollowed A, Wilson C, Pierce S, Francis R (2008) Climate-ocean variability and Pacific hake: a geostatistical modeling approach. Journal of Marine Systems 71: 237-248

Agostini VN, Francis RC, Hollowed AB, Pierce SD, Wilson C, Hendrix AN (2006) The relationship between Pacific hake (*Merluccius productus*) distribution and poleward subsurface flow in the California Current System. Canadian Journal of Fisheries and Aquatic Sciences 63: 2648-2659

Auad G, Miller A, DiLorenzo E (2006) Long-term forecast of oceanic conditions off California and their biological implications. Journal of Geophysical Research 111

Auth TD, Brodeur RD, Soulen HL, Ciannelli L, Peterson WT (2011) The response of fish larvae to decadal changes in environmental forcing factors off the Oregon coast. Fisheries Oceanography 20: 314-328

Bakun A (1990) Global climate change and intensification of coastal ocean upwelling. Science 247: 198-201

Bane J, Levine M, Samelson R, Haines S, Meaux M, Perlin N, Kosro P, Boyd T (2005) Atmospheric forcing of the Oregon coastal ocean during the 2001 upwelling season. Journal of Geophysical Research 110

Bane J, Spitz Y, Letelier R, Peterson W (2007) Intraseasonal oscillations in Oregon's coastal upwelling system: from the jet stream to zooplankton. Proceedings of the National Academy of Sciences, USA 104: 13262-13267

Barnes C, Duxbury A, Morse B (1972) Circulation and selected properties of the Columbia River effluent at sea. In: Pruter AT, Alverson DL (eds) The Columbia River Estuary and Adjacent Ocean Waters. University of Washington Press, Seattle, WA, pp 41-80

Barron J, Bukry D, Field D (2010) Santa Barbara Basin diatom and silicoflagellate response to global climate anomalies during the past 2200 years. Quarternary International 215: 34-44

Barth J, Menge B, Lubchenco J, Chan F, Bane J, Kirincich A, McManus M, Nielsen K, Pierce S, Washburn L (2007) Delayed upwelling alters nearshore coastal ocean ecosystems in the northern California current. Proceedings of the National Academy of Sciences 104: 3719-3724

Beaugrand G, Brander KM, Lindley JA, Souissi S, Reid PC (2003) Plankton effect on cod recruitment in the North Sea. Nature 426: 661-664

Benson AJ, McFarlane GA, Allen SE, Dower JF (2002) Changes in Pacific hake (*Merluccius productus*) migration patterns and juvenile growth related to the 1989 regime shift. Canadian Journal of Fisheries and Aquatic Sciences 59: 1969-1979

Bjorkstedt EP, Rosenfeld LK, Grantham BA, Shkedy Y, Roughgarden J (2002) Distributions of larval rockfishes *Sebastes* spp. across nearshore fronts in a coastal upwelling region. Marine Ecology Progress Series 242: 215-228

Bograd S, Castro C, DiLorenzo E, Palacios D, Bailey H, Gilly W, Chavez F (2008) Oxygen declines and the shoaling of the hypoxic boundary in the California current. Geophysical Research Letters 35: L12607

Bograd S, Lynn R (2003) Long-term variability in the southern California current system. Deep-Sea Research Part II 50: 2355-2370

Bograd SJ, Schroeder I, Sarkar N, Qiu X, Sydeman WJ, Schwing FB (2009) Phenology of coastal upwelling in the California Current. Geophysical Research Letters 36

Bond NA, Overland JE, Spillane M, Stabeno P (2003) Recent shifts in the state of the North Pacific. Geophysical Research Letters 30

Breaker L, Liu P, Torrence C (2001) Intraseasonal oscillations in sea surface temperature, wind stress, and sea level off the central California coast. Continental Shelf Research 21: 727-750

Brodeur R, Pearcy W (1992) Effects of environmental variability on trophic interactions and food web structure in a pelagic upwelling ecosystem. Marine Ecology Progress Series 84: 101-119

Brodeur R, Ralston S, Emmett R, Trudel M, Auth T, Phillips A (2006) Anomalous pelagic nekton abundance, distribution, and apparent recruitment in the northern California current in 2004 and 2005. Geophysical Research Letters 33

Brodeur RD, Peterson WT, Auth TD, Soulen HL, Parnel MM, Emerson AA (2008) Abundance and diversity of coastal fish larvae as indicators of recent changes in ocean and climate conditions in the Oregon upwelling zone. Marine Ecology Progress Series 366: 187-202

Burnham KP, Anderson DR (2002) Model selection and multimodel inference: a practical information-theoretic approach. Springer Science+Business Media, Inc., New York, NY

Chavez F, Collins C, Huyer A, Mackas D (2002) El Niño along the west coast of North America. Progress in Oceanography 54: 1-511

Chavez FP, Ryan J, Lluch-Cota SE, Niquen MC (2003) From anchovies to sardines and back: multidecadal change in the Pacific Ocean. Science 299: 217-221

Checkley J, David M., Barth JA (2009) Patterns and processes in the California Current System. Progress in Oceanography 83: 49-64

Checkley J, DM, Alheit J, Oozeki Y, Roy C (2009) Climate change and small pelagic fish. Cambridge University Press, Cambridge, U.K.

Chelton D, Davis R (1982) Monthly sea-level variability along the west coast of North America. Journal of Physical Oceanography 12: 757-784

Connolly SR, Menge BA, Roughgarden J (2001) A latitudinal gradient in recruitment of intertidal invertebrates in the northeast Pacific Ocean. Ecology 82: 1799-1813

DiLorenzo E, Schneider N, Cobb K, Franks P, Chhak K, Miller A, McWilliams J, Bograd S, Arango H, Curchitser E, Powell T, Riviere P (2008) North Pacific Gyre oscillation links ocean climate and ecosystem change. Geophysical Research Letters 35

Doney S, Fabry V, Feely R, Kleypas J (2009) Ocean acidification: the other CO2 problem. Annual Review of Marine Science 1: 169-192

Emery W, Hamilton K (1985) Atmospheric forcing of interannual variability in the Northeast Pacific Ocean: connections with El Nino. Journal of Geophysical Research 90: 857-868

Emmett R, Krutzikowsky G, Bentley P (2006) Abundance and distribution of pelagic piscivorous fishes in the Columbia River plume during spring/early summer 1998-2003: relationship to oceanographic conditions, forage fishes, and juvenile salmonids. Progress in Oceanography 68: 1-26

Emmett RL, Brodeur RD (2000) Recent changes in the pelagic nekton community off Oregon and Washington in relation to some physical oceanographic conditions. North Pacific Anadromous Fish Commission Bulletin 2: 11-20

Feely R, Sabine C, Feely R, Sabine C, Hernandez-Ayon J, Ianson D, Hales B (2008) Evidence for upwelling of corrosive "acidified" water onto the continental shelf. Science 320: 1490-1492

Field D, Baumgartner T, Charles C, Ferreira-Bartrina V, Ohman M (2006) Planktonic foraminifera of the California current reflect 20th-century warming. Science 311: 63-66

Field JC, Ralston S (2005) Spatial variability in rockfish (*Sebastes* spp.) recruitment events in the California Current System. Canadian Journal of Fisheries and Aquatic Sciences 62: 2199-2210

Funes-Rodriguez R, Elorduy-Garay JF, Hinojosa-Medina A, Zarate-Villafranco A (2009) Interannual distribution of Pacific hake *Merluccius productus* larvae in the southern part of the California Current. Journal of Fish Biology 75: 630-646

Goes JI, Gomes HdR, Limsakul A, Balch WM, Saino T (2001) El Nino related interannual variations in biological production in the North Pacific as evidenced by satellite and ship data. Progress in Oceanography 49: 211-225

Hare S, Mantua N (2000) Empirical evidence for north Pacific regime shifts in 1977 and 1989. Progress in Oceanography 47: 103-145

Hart JL (1973) Pacific Fishes of Canada. Fisheries Research Board of Canada, Ottawa, CA

Harvey CJ (2005) Effects of El Nino events on energy demand and egg production of rockfish (Scorpaenidae: Sebastes): a bioenergetics approach. Fishery Bulletin 103: 71-83

Harvey CJ (2009) Effects of temperature change on demersal fishes in the California Current: a bioenergetics approach. Canadian Journal of Fisheries and Aquatic Sciences 66: 1449-1461

Helser TE, Punt AE, Methot RD (2004) A generalized linear mixed model analysis of a multi-vessel fishery resource survey. Fisheries Research 70:251-264

Helser T, Stewart I, Hamel O (2008) Stock Assessment of Pacific Hake, *Merluccius productus*, (a.k.a. whiting) in US and Canadian Waters in 2008. Northwest Fisheries Science Center, National Oceanic and Atmospheric Administration, Seattle, WA

Hickey B (1998) Coastal oceanography of western North America from the tip of Baja California to Vancouver Island. In: Robinson AR, Brink KH (eds) The Sea, The Global Coastal Ocean, 11. John Wiley & Sons, New York, NY, pp 345-393

Hickey B, McCabe R, Geier S, Dever E, Kachel N (2009) Three interacting freshwater plumes in the northern California current system. Journal or Geophysical Research 114

Holbrook SJ, Schmitt RJ, Stephens J, John S. (1997) Changes in an assemblage of temperate reef fishes associated with a climate shift. Ecological Applications 7: 1299-1310

Hollowed AB, Beamish RJ, Okey TA, Schirripa MJ (2008) Forecasting climate impacts on future production of commercially exploited fish and shellfish, PICES Scientific Report No. 34

Hollowed AB, Hare SR, Wooster WS (2001) Pacific Basin climate variability and patterns of Northeast Pacific marine fish production. Progress in Oceanography 49: 257-282

Horne J, Smith P (1997) Space and time scales in Pacific hake recruitment processes: latitudinal variation over annual cycles. California Cooperative Oceanic Fisheries Investigations Reports 38: 90-102

Hsieh W, Ware D, Thomson R (1995) Wind-induced upwelling along the west coast of North America, 1899-1988. Canadian Journal of Fisheries and Aquatic Sciences 52: 325-334

Huyer A (1983) Coastal upwelling in the California current system. Progress in Oceanography 12: 259-284

Johnson JB, Omland KS (2004) Model selection in ecology and evolution. Trends Ecol Evol 19:101-108

Juan-Jorda MJ, Barth JA, Clarke ME, Wakefield WW (2009) Groundfish species associations with distinct oceanographic habitats in the Northern California Current. Fisheries Oceanography 18: 1-19

Kimura DK, Shimada AM, Shaw FR (1998) Stock structure and movement of tagged sablefish, *Anoplopoma fimbria*, in offshore northeast Pacific waters and the effects of El Nino-Southern Oscillation on migration and growth. Fishery Bulletin 96: 462-481

King J, Agostini V, Harvey C, McFarlane G, Foreman M, Overland J, DiLorenzo E, Bond N, Aydin K (2011) Climate forcing and the California Current ecosystem. ICES Journal of Marine Science

King J, McFarlane G, Beamish R (2000) Decadal-scale patterns in the relative year class success of sablefish (*Anoplopoma fimbria*). Fisheries Oceanography 9: 62-70

King J, McFarlane G, Beamish RJ (2001) Incorporating the dynamics of marine systems into the stock assessment and management of sablefish. Progress in Oceanography 49: 619-639

Laidig TE, Chess JR, Howard DF (2007) Relationship between abundance of juvenile rockfishes (*Sebastes* spp.) and environmental variables documented off northern California and potential mechanisms for the covariation. Fishery Bulletin 105: 39-48

Levitus S, Antonov J, Boyer TP, Stephens C (2000) Warming of the world ocean. Science 287: 2225-2229

Levitus S, Antonov JL, Wang J, Delworth TL, Dixon KW, Broccoli AJ (2001) Anthropogenic warming of Earth's climate system. Science 292: 267-270

MacIsaac J, Dugdale R, Barber R, Blasco D, Packard T (1985) Primary production cycle in an upwelling center. Deep-Sea Research 32: 503-529

Mackas D, Peterson W, Ohman M, Lavaniegos B (2006) Zooplankton anomalies in the California current system before and during the warm ocean conditions of 2005. Geophysical Research Letters 33

Mackas DL, Batten S, Trudel M (2007) Effects on zooplankton of a warmer ocean: Recent evidence from the Northeast Pacific. Progress in Oceanography 75: 223-252

Mackas DL, Kieser R, Saunders M, Yelland DR, Brown RM, Moore DF (1997) Aggregation of euphausiids and Pacific hake (*Merluccius productus*) along the outer continental shelf off Vancouver Island. Canadian Journal of Fisheries and Aquatic Sciences 54: 2080-2096

Mackas DL, Thomson RE, Galbraith M (2001) Changes in the zooplankton community of the British Columbia continental margin, 1985-1999, and their covariation with oceanographic conditions. Canadian Journal of Fisheries and Aquatic Sciences 58: 685-702

Mantua N, Hare S, Zhang Y, Wallace J, Francis R (1997) A Pacific interdecadal climate oscillation with impacts on salmon production. Bulletin of the American Meteorological Society 78: 1069-1079

Maunder MN, Punt AE (2004) Standardizing catch and effort data: a review of recent approaches. Fisheries Research 70:141-159.

McFarlane GA, Beamish RJ (1992) Climatic influence linking copepod production with strong year-classes in sablefish, *Anoplopoma fimbria*. Canadian Journal of Fisheries and Aquatic Sciences 49: 743-753

McFarlane GA, Beamish RJ (2001) The re-occurrence of sardines off British Columbia characterises the dynamic nature of regimes. Progress in Oceanography 49: 151-165

McFarlane GA, King JR, Beamish RJ (2000) Have there been recent changes in climate? Ask the fish. Progress in Oceanography 47: 147-169

McGowan J, Bograd S, Lynn R, Miller A (2003) The biological response to the 1977 regime shift in the California current. Deep-Sea Research Part II 50: 2567-2582

McGowan J, Cayan D, Dorman L (1998) Climate-ocean variability and ecosystem response in the northeast Pacific. Science: 210-217

Miller AK, Sydeman WJ (2004) Rockfish response to low-frequency ocean climate change as revealed by the diet of a marine bird over multiple time scales. Marine Ecology Progress Series 281: 207-216

Moser HG, Charter RL, Watson W, Ambrose DA, Butler JL, Charter SR, Sandknop EM (2000) Abundance and distribution of rockfish (*Sebastes*) larvae in the Southern California Bight in relation to environmental conditions and fishery exploitation. Calif. Coop. Oceanic Fish. Invest. Rep. 41: 132-147

Mote PW, Salathe J, Eric P. (2010) Future climate in the Pacific Northwest. Climate Change 102: 29-50

Mysak L (1986) El Niño, interannual variability and fisheries in the northeast Pacific Ocean. Canadian Journal of Fisheries and Aquatic Sciences 43: 464-497

Overland J, Wang M (2007) Future climate of the North Pacific Ocean. EOS Transactions of the American Geophysical Union 88: 178-182

Phillips AJ, Ralston S, Brodeur RD, Auth TD, Emmett RL, Johnson C (2007) Recent pre-recruit Pacific hake (*Merluccius productus*) occurrences in the northern California Current suggest a northward expansion of their spawning area. California Cooperative Oceanic Fisheries Investigations Reports 48: 215-229

Rau GH, Ralston S, Southon JR, Chavez FP (2001) Upwelling and the condition and diet of juvenile rockfish: A study using 14C, 13C, and 15N natural abundances. Limnology and Oceanography 46: 1565-1570

Roemmich D, McGowan J (1995) Climatic warming and the decline of zooplankton in the California current. Science 267: 1324-1326

Schwing F, Murphree T, Green P (2002) The Northern Oscillation Index (NOI): a new climate index for the northeast Pacific. Progress in Oceanography 53: 115-139

Schwing F, Parrish R, Mendelssohn R (1996) Regional differences in the climate change signal in the California Current system. Eos. Trans. Am. Geophys. Union 1996 Ocean Sciences Meeting Suppl., OS181

Simpson J (1992) Response of the Southern California current system to the mid-latitude North Pacific coastal warming events of 1982-1983 and 1940-1941. Fisheries Oceanography 1: 57-77

Snyder M, Sloan L, Diffenbaugh N, Bell J (2003) Future climate change and upwelling in the California Current. Geophysical Research Letters 30: 18-23

Sogard SM, Olla BL (2001) Growth and behavioral responses to elevated temperatures by juvenile sablefish *Anoplopoma fimbria* and the interactive role of food availability. Marine Ecology Progress Series 217: 121-134

Sogard SM, Spencer ML (2004) Energy allocation in juvenile sablefish: effects of temperature, ration, and body size. Journal of Fish Biology 64: 726-738

Steele J (2004) Regime shifts in the ocean: reconciling observations and theory. Progress in Oceanography 60: 135-141

Stoner AW, Sturm EA (2004) Temperature and hunger mediate sablefish (*Anoplopoma fimbria*) feeding motivation: implications for stock assessment. Canadian Journal of Fisheries and Aquatic Sciences 61: 238-246

Strub P, James C (1988) Atmospheric conditions during the spring and fall transitions in the coastal ocean off western United States. Journal of Geophysical Research 93: 15561-15584

Timmermann A, Oberhuber J, Bacher A, Esch M, Latif M, Roeckner E (1999) Increased El Niño frequency in a climate model forced by future greenhouse warming. Nature 398: 694-697

Tolimieri N, Levin PS (2005) The roles of fishing and climate in the population dynamics of bocaccio rockfish. Ecological Applications 15: 458-468

Tolimieri N, Levin PS (2006) Assemblage structure of Eastern Pacific groundfishes on the U.S. continental slope in relation to physical and environmental variables. Transactions of the American Fisheries Society 135: 317-332

Wang M, Overland J, Bond N (2010) Climate projections for selected large marine ecosystems. Journal of Marine Systems 79: 258-266

Ware D, Thomson R (2005) Bottom up ecosystem trophic dynamics determine fish production in the northeast Pacific. Science 308: 1280-1284

Weinheimer A, Kennett J, Cayan D (1999) Recent increase in surface-water stability during warming off California as recorded in marine sediments. Geology 27: 1019-1022

Whitney F, Freeland H, Robart M (2007) Persistently declining oxygen levels in the interior waters of the eastern subarctic Pacific. Progress in Oceanography 75: 179-199

Williams EH, Ralston S (2002) Distribution and co-occurrence of rockfishes (family: Sebastidae) over trawable shelf and slope habitats of California and southern Oregon. Fishery Bulletin 100: 836-855

Zabel RW, Levin PS, Tolimieri N, Mantua NJ (2011) Interactions between climate and population density in the episodic recruitment of bocaccio, Sebastes paucispinis, a Pacific rockfish. Fisheries Oceanography 20: 294-304

Zhang Y, Wallace JM, Battisti DS (1997) ENSO-like interdecadal variability: 1900-93. Journal of Climate 10: 1004-1020

TABLES AND FIGURES

TABLE 1. TEMPORAL SCALES OF ATMOSPHERIC AND OCEANOGRAPHIC VARIABILITY IN THE CALIFORNIA CURRENT SYSTEM (CCLME).

Scale of variability	**Sources of variability**
Diurnal	• onshore sea breezes, equatorward winds (*5*) • low-pressure systems, storms on ~2-6 day cycle (*1*)
Intraseasonal/Seasonal	• intraseasonal oscillations (ISO): variations in upper-ocean temperatures and currents on 20-40 d period (*2,3*) • large scale atmospheric circulation patterns (*13*) • major current patterns (*7*) • seasonal winds, upwelling (*5*)
Interannual	• El Nino Southern Oscillation (ENSO): dominant source of variation (*4,9,10*)
Multi-decadal	• in-phase coastal sea-level variations, strength of North Pacific Current feeding CC in the north (*5*) • anomalies in the wind field in the western equatorial Pacific (*4,9,10*) • sea surface temperature fluctuations described by the Pacific Decadal Oscillation (PDO) (*8*) • sea level pressure fluctuations described by the North Pacific Gyre Oscillation (NPGO) (*6*) and the Northern Oscillation Index (NOI; ~14-year cycle) (*11*) • regime shifts (*4,12*)

References: [1]Bane et al. 2005, [2]Bane et al. 2007, [3]Breaker et al. 2001, [4]Chavez et al. 2002, [5]Checkley and Barth 2009, [6]DiLorenzo et al. 2008, [7]Hickey 1998, [8]Mantua et al. 1997, [9]McGowan et al. 1998, [10]Mysak 1986, [11]Schwing et al. 2002, [12]Steele 2004, [13]Strub and James 1988

TABLE 2. PHYSICAL AND BIOLOGICAL CONDITIONS IN THE CCLME ASSOCIATED WITH POSITIVE CLIMATE INDEX ANOMALIES (POSITIVE PHASES). INTERANNUAL CLIMATE VARIABILITY IS PRIMARILY DESCRIBED BY EL NINO SOUTHERN OSCILLATION (ENSO). DECADAL SCALE VARIABILITY IS DESCRIBED BY MULTIPLE INDICES, INCLUDING THE PACIFIC DECADAL OSCILLATION (PDO), THE NORTH PACIFIC GYRE OSCILLATION (NPGO), AND THE NORTHERN OSCILLATION INDEX (NOI). CONDITIONS ASSOCIATED WITH NEGATIVE PHASES ARE GENERALLY OPPOSITE THOSE OF POSITIVE PHASES AND ARE NOT SPECIFIED BELOW. CC = CALIFORNIA CURRENT; CU = CALIFORNIA UNDERCURRENT; ALP = ALEUTIAN LOW PRESSURE; NPC = NORTH PACIFIC CURRENT; ACC = ALASKAN COASTAL CURRENT

Feature	**+ ENSO (El Nino)**	**+ PDO**	**+ NPGO**	**+ NOI** associated with - ENSO (La Nina)
atmospheric pressure		ALP deeper, displaced south (*7*)		stronger trade winds (*11*)
large-scale ocean circulation	weaker (equatorward) CC flow, stronger (poleward) CU (*3*)	stronger Alaska Gyre, weaker CC (*4*)	stronger NPC, increase in transport of ACC and CC (*4*)	
sea surface temperature	warmer in upper 500 m (*3*)	warmer (*6,9*)	warmer (weak positive correlation) (*4*)	cooler (*11*)
sea surface salinity			higher (*4*)	
upwelling	delayed, weak upwelling; stronger downwelling (*2*)	weaker (*1,10*)	stronger (*4*)	stronger (*11*)
sea surface height	higher (*7*)	higher (*7*)		
stratification	deeper thermocline & pycnocline (*2*)	stronger (*1,10*)		
freshwater input		lower freshwater input from		

		Columbia and Fraser Rivers (less rainfall) (*9*)		
nutrients, phytoplankton	lower nitrate, primary production (carbon), chlorophyll (*2*)	lower productivity in CC (but higher in Alaska) (*9*)	higher nitrate, phosphate, silicate, oxygen, and chlorophyll-*a* (*4*)	
zooplankton	lower biomass overall (*12*); southern species dominate (*8*)	lower biomass of cold water copepods (*5*)		higher biomass overall (*11*)

References: [1]Bograd and Lynn 2003, [2]Chavez et al. 2002, [3]Chelton and Davis 1982, [4]DiLorenzo et al. 2008, [5]Goes et al. 2001, [6]Hare and Mantua 2000, [7]King et al. 2011, [8]Mackas et al. 2007, [9]Mantua et al. 1997, [10]McGowan et al. 2003, [11]Schwing et al. 2002, [12]Simpson 1992

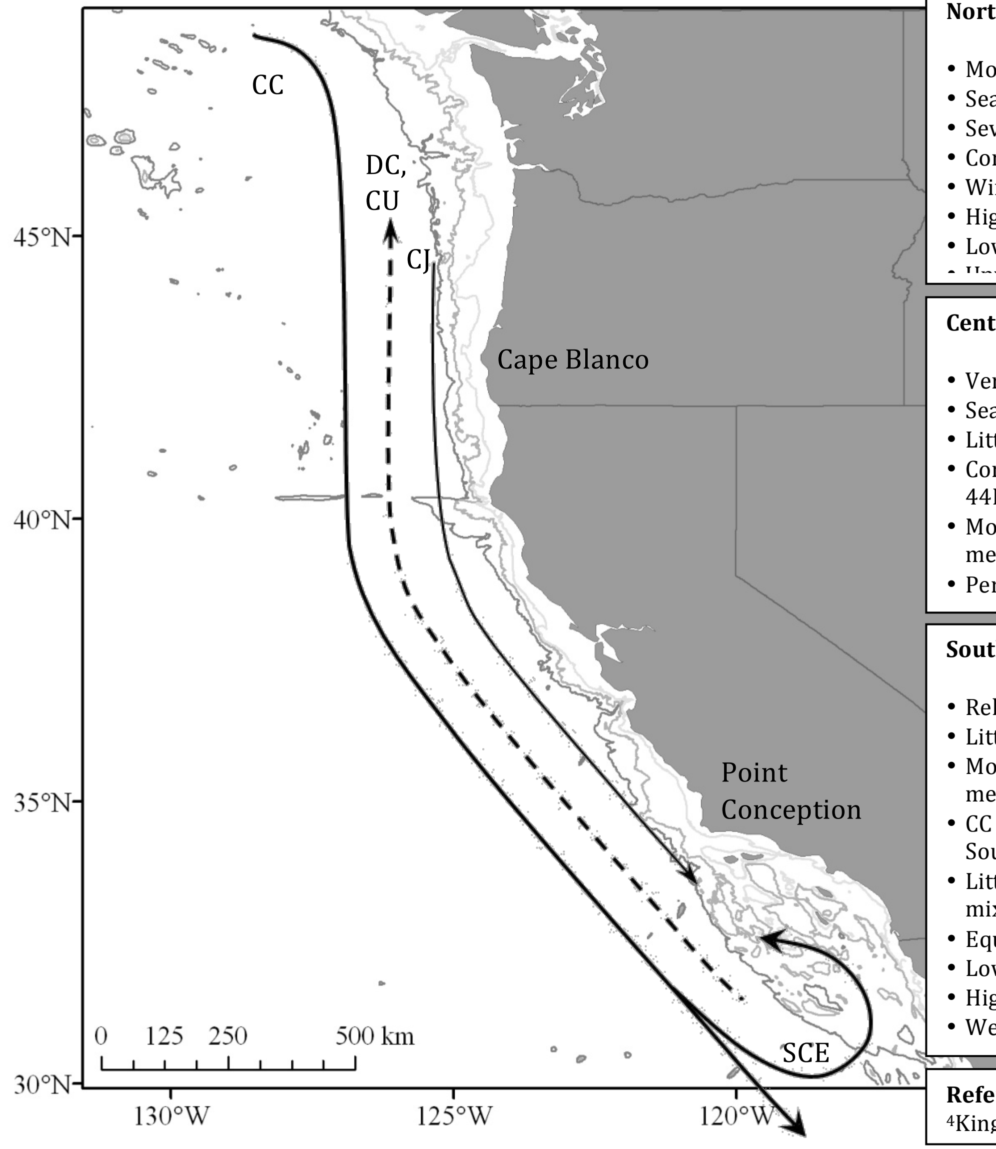
Table 3. Species responses to physical forcing in the CCLME. + and – indicate positive and negative effects, respectively, of environmental factors (column headings and additional descriptors in bold type) on specific biological responses of key groundfish species. ENSO = El Nino Southern Oscillation, PDO = Pacific Decadal Oscillation, NOI = Northern Oscillation Index

	atmospheric conditions / ocean circulation	temperature	upwelling	primary productivity (chl-*a*)	zooplankton	ENSO	PDO	NOI
Pacific hake	**strong poleward flow (DC, CU)**: + adult, juvenile condition (*1,15,17,20*); – larval, juvenile survival (*1*)	+ juvenile survival (*4,6,15*); + abundance nearshore (*6*); + recruitment (*11*)	+ juvenile, adult growth (*17,15*); – larval survival (*15,20*)	+ density (*25*)	**euphausiid abundance**: + juvenile, adult abundance (*17*)	+ recruitment strength (Hollowed et al. 2001); + juvenile, adult abundance, biomass in northern CCLME (*4*); + adult occurrence (*3*)	+ adult biomass (*12*)	
sablefish	**strong ALP**: + recruitment strength (*10,14,18*)	+ growth rate, growth efficiency, lipid accumulation (*8,22,23*);			**copepod abundance**: + recruitment strength (*10*)	– adult growth (*13*)	+ adult occurrence, biomass (*3,12*)	

	atmospheric conditions / ocean circulation	temperature	upwelling	primary productivity (chl-*a*)	zooplankton	ENSO	PDO	NOI
		switch from cool to warm period: + recruitment strength (*18*)						
rockfishes	**strong equatorward flow in winter**: + juvenile abundance (*16*)	– larval, juvenile abundance (*16*); + adult growth (*8*)	+ larval density (*5*); + recruitment strength (*24*); – larval survival if upwelling too strong or weak (*21*)			– juvenile abundance (*16,19*); – recruitment strength (*24*); – adult energy consumption, egg production (*7*)	– larval density (*2,19*); + adult occurrence (*3*)	+ juvenile survival (*26*)

References: [1]Agostini et al. 2006; [2]Auth et al. 2011; [3]Beaudreau and Levin, unpubl.; [4]Benson et al. 2002; [5]Bjorkstedt et al. 2002; [6]Emmett et al. 2006; [7]Harvey 2005; [8]Harvey 2009; [9]Hollowed et al. 2001; [10]Hollowed et al. 2008; [11]Horne and Smith 1997; [12] A. Keller, pers. comm., 21 July 11; [13]Kimura et al. 1998; [14]King et al. 2000; [15]King et al. 2011; [16]Laidig et al. 2007; [17]Mackas et al. 1997; [18]McFarlane and Beamish 2001; [19]Miller and Sydeman 2004; [20]Phillips et al. 2007; [21]Rau et al. 2001; [22]Sogard and Spencer 2004; [23]Stoner and Sterm 2004; [24]Tolimieri and Levin 2005; [25]Ware and Thomson 2005; [26]Zabel et al. 2011

FIGURE 1. SPATIAL VARIATION IN PHYSICAL FORCING IN THE CALIFORNIA CURRENT LARGE MARINE ECOSYSTEM (CCLME), AFTER CHECKLEY AND BARTH 2009, KING ET AL. 2011. CC = CALIFORNIA CURRENT; DC = DAVIDSON CURRENT (SURFACE); CU = CALIFORNIA UNDERCURRENT (SUBSURFACE); CJ = COASTAL JET; SCE = SOUTHERN CALIFORNIA EDDY



Northern CCLME: U.S.-Canada border to Cape Blanco

- Moderately strong, seasonally varying wind (*1*)
- Seasonal upwelling near coast (*1*)
- Several large canyons bisect continental margin (e.g., Astoria Canyon 46N) (*1*)
- Considerable year-round freshwater input from Columbia and Fraser Rivers (*3*)
- Winds poleward, strongest in winter (*3*)
- Higher primary productivity (*5*)
- Lowest temperature, salinity (*3*)
- Upwelling variability most strongly correlated with PDO north of 38N (*2*)

Central CCLME: Cape Blanco to Point Conception

- Very strong, more persistently equatorward wind (*1*)
- Seasonal upwelling near coast; region of cold water extends further offshore (*1*)
- Little summertime freshwater input (*3*)
- Continental margin narrows; presence of submarine banks (e.g., Heceta Bank 44N, Cordell Bank 38N) (*1*)
- More water mass instabilities (e.g., meanders, filaments, eddies); Strong mesoscale eddy activity (*1*)
- Persistent equatorward winds in summer, intermittent and poleward in winter

Southern CCLME: Point Conception to U.S.-Mexico border

- Relatively weak, persistently equatorward wind; weak upwelling (*1*)
- Little summertime freshwater input (*3*)
- More water mass instabilities (e.g., meanders, filaments, eddies); Strong mesoscale eddy activity (*1*)
- CC turns north to become Southern California Countercurrent in winter, Southern California Eddy in summer (*3*)
- Little annual thermocline variability, reduced summer and fall stratification in mixed layer (*4*)
- Equatorward winds, reach max in late spring (*3*)
- Lower primary productivity (*5*)
- Highest temperature, salinity (*3*)
- Weaker seasonal variation (*3*)

References: [1]Checkley and Barth 2009, [2]DiLorenzo et al. 2008, [3]Hickey 1998, [4]King et al. 2011, [5]Ware and Thomson 2005

FIGURE 2. ANNUAL MEAN CLIMATE INDICES IN THE CCLME, 1950-2010. POSITIVE ANOMALIES FROM LONG-TERM MEANS ARE SHOWN IN RED, NEGATIVE ANOMALIES IN BLUE. SST AND CHL-*A* WERE CALCULATED FOR THE AREA BOUNDED BETWEEN 32°N AND 50°N LATITUDE AND 117°W AND 127°W LONGITUDE. SST = SEA SURFACE TEMPERATURE; CHL-A = CHLOROPHYLL-*A* CONCENTRATION; ENSO = EL NINO SOUTHERN OSCILLATION; PDO = PACIFIC DECADAL OSCILLATION; NPGO = NORTH PACIFIC GYRE OSCILLATION; NOI = NORTHERN OSCILLATION INDEX

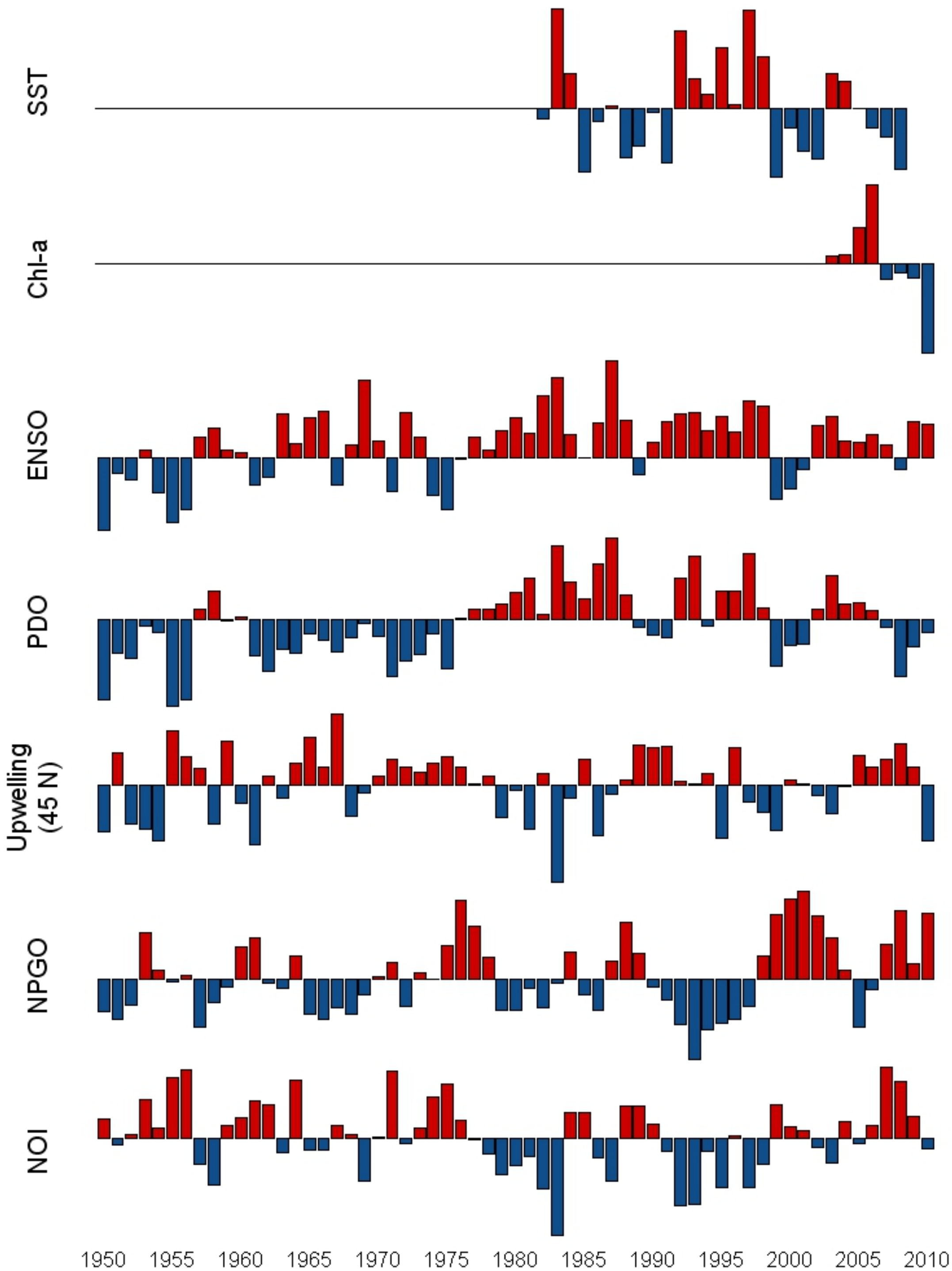
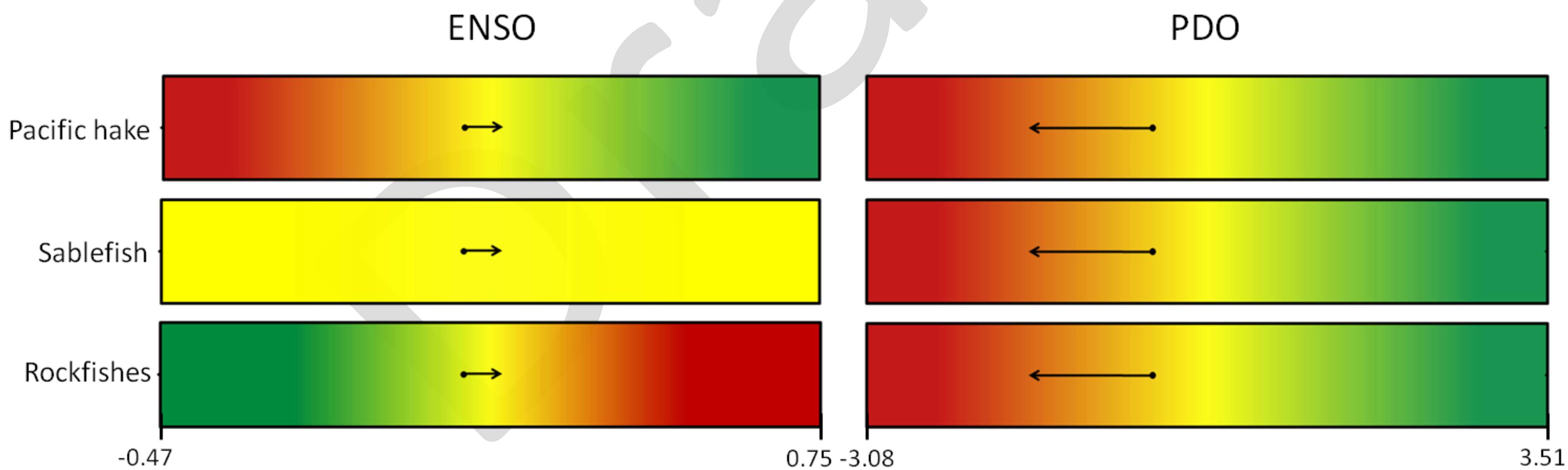

SST
Chl-a
ENSO
PDO
Upwelling (45 N)
NPGO
NOI
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010

FIGURE 3. POTENTIAL RESPONSES OF KEY GROUNDFISH SPECIES TO INTERANNUAL AND DECADAL-SCALE CLIMATE VARIABILITY IN THE CCLME. BARS SHOW THE RANGE OF OBSERVED ENSO AND PDO INDEX VALUES FROM 1950 TO 2010 (LEFT SIDE OF EACH PANEL SET AT MINIMUM OBSERVED INDEX VALUE, RIGHT SIDE SET AT MAXIMUM VALUE). POINTS SHOW THE AVERAGE ENSO OR PDO INDEX VALUE FOR THE LAST 5 YEARS (2005-2010). THE ARROW SHOWS THE DIRECTION OF THE TREND IN MONTHLY INDEX VALUES FROM 2005 TO 2010 AND ITS LENGTH IS PROPORTIONAL TO THE SLOPE OF THE TREND. RED SHADING INDICATES RELATIVELY POOR CONDITIONS FOR PRODUCTIVITY OF PARTICULAR SPECIES, GREEN INDICATES RELATIVELY GOOD CONDITIONS, AND YELLOW INDICATES A NEUTRAL RESPONSE.

ABUNDANCE, BIOMASS, AND OCCURRENCE OF JUVENILE AND ADULT PACIFIC HAKE ARE POSITIVELY CORRELATED WITH ENSO AND BIOMASS OF ADULTS IS POSITIVELY CORRELATED WITH PDO (I.E., POSITIVE PHASES OF ENSO (EL NINO) AND PDO YIELD GOOD CONDITIONS FOR HAKE). ADULT SABLEFISH GROWTH HAS A NEGATIVE RELATIONSHIP WITH EL NINO CONDITIONS, BUT ENSO EFFECTS ON SABLEFISH BIOMASS AND ABUNDANCE ARE WEAK. BIOMASS AND OCCURRENCE OF ADULT SABLEFISH IS POSITIVELY CORRELATED WITH PDO. JUVENILE ABUNDANCE AND ADULT EGG PRODUCTION OF ROCKFISHES IS NEGATIVELY AFFECTED BY EL NINO CONDITIONS AND ADULT OCCURRENCE IS POSITIVELY RELATED TO PDO. SEE TABLE 3 FOR MORE DETAILS.



CHAPTER2: STATUS AND TRENDS OF PREDATORS AND PREY OF FOCAL GROUNDFISH SPECIES

N. Tolimieri - NOAA Northwest Fisheries Science Center

THE QUESTION: WHAT ARE THE STATUS AND TRENDS OF IMPORTANT PREDATORS AND PREY THAT MAY INFLUENCE HAKE, SABLEFISH, CANARY ROCKFISH, AND BOCACCIO?

INTRODUCTION

In this chapter, we evaluated the current biological (prey, predator) environment of four focal groundfish species in the CCLME: bocaccio *Sebastes paucispinis*, canary rockfish *Sebastes pinniger*, Pacific hake *Merluccius productus*, and sablefish *Anoplopoma fimbria*; using time series from a variety of stock assessments, surveys, and other long-term monitoring efforts. Our approach is predicated on an understanding of their important trophic linkages and the assumption that trends in prey and predator populations may help to predict likely areas of future concern or stress for these focal species. This chapter provides information about how important trophic linkages were identified as well as how data were combined to form the predator and prey indices for each focal species.

METHODS

The data sources and detailed methods used to produce the prey and predator indices are described in detail in Appendix B. Briefly, our approach first involved compiling the raw time series data of abundance/biomass for relevant taxa using a linear model to generate an annual mean. Second, a weighted linear mixed model was used to combine the time series into a single, normalized prey or predator index for each focal species. Plots of all time series follow the same format, showing change in number/biomass through time; with lines indicating ± 1.0 SD (standard deviation) over the full time series and the predicted trend over the last five years of the data. 'Performance metrics' on the plots were chosen to represent three types of 'change': 1. the trend over the last five years; 2. the mean of the last five years; and 3. the slope of the last five years. Key discussion points related to time series length and time series inclusion are highlighted in Appendix B. Finally, a quad-plot format was used to represent the short-term and long-term biological environment of each focal species based on prey and predator trends (e.g., good, bad, improving, or declining).

The foundation of our trend analysis was built on an understanding of important trophic linkages for each focal species, and we dedicated considerable effort to clarifying these linkages using multiple approaches, detailed in Appendix C.

RESULTS

For each of the four groundfish focal species, we present three figures: 1. an integrated prey index, 2. an integrated predator index, and 3. a quad-plot that represents the long- and short-term trends of both prey and predators.

Bocaccio

The primary prey of bocaccio are hake and small shallow rockfish (Table B4). The prey index for bocaccio has been variable since 1980 (Fig. 4). After an initial increase to the late 1980's, the prey index declined steadily until around 2000 when it increased until 2006 and then declined again. Over the last five years, there has been no trend in the bocaccio prey index and the 5-year mean is within one SD of the long-term mean.

The primary bocaccio predators are mid-water rockfish and lingcod (Table B4). The index of bocaccio predators showed a peak in the mid-2000's and has since declined (Fig. 5). Over the last five years, however, the index has been stable.

The biological environment of bocaccio appears to be stable at present. The prey index is in the poor-declining quadrant but both the short and long-term trends are within one SD of the full time series (Fig. 6). The predator index is within the poor-improving, but again both the short and long-term trends are within one SD of the full time series.

Canary rockfish

Euphausiids were the primary prey species for canary rockfish making up approximately 69% of their diet (Table B4). Juvenile rockfish also made up a small proportion of their diet. The canary has been variable through time with several years that were substantially better than others (Fig. 7). Over the last five years, prey availability has increase for canary and is presently above one SD of the full time series (Fig. 7). Note, however, that the functional groups 'deposit feeders' and 'shrimp' (mysids etc, not pink shrimp) were not represent in the index due to lack of time series. These groups made up 26% and 13% of the diet respectively.

Major predators on canary included lingcod and dogfish (Table B4). The canary predator field showed substantial variation from 1950 to about 1980 when it slowly declined. It rose again around 2000. The trend over the last five years has been for a decline in the canary predator field. The decline appears to be due to the long- term decline in dogfish abundance (Fig 8) as lingcod have time series show an overall increase in abundance except for a drop in numbers in 2010. Given the overall variability in canary prey this increase may be ephemeral.

The biological environment of canary rockfish is improving for both prey and predators (Fig. 9). Both the prey and predator index are within one SD of the long term trend, but in the near term both indices are improving.

Pacific hake

Euphausiids, gelatinous zooplankton and small planktivores (herring and anchovies) were the primary prey for hake (Table B4) with euphausiids making up about 80% of hake diet. The composite times series of hake prey has been variable since 1950 but is presently stable with no detected increase or decrease (Fig. 10).

The primary hake predators were dogfish, mid-water rockfish, deep large rockfish and other hake (Table B4). The composite hake predator indicator showed substantial variation from the late 1950's until the early 1980's after which there has been a steady decline (Fig. 11). The trend over the last five years shows a decline (significant negative slope) but that decline is within one SD of the full time series. Altering the choice of when to begin the time series might reduce the SD and result in a decline of more than one SD. Note however that this composite predator indicator does not include data on squid, in particular, Humbolt squid (*Dosidicus gigas)*, which may be important hake predators.

The biological environment for hake is stable in terms of long and short term trends (Fig. 12). Both the prey and predator indices are good and improving quadrants but neither has shown change greater than one SD of the long term trend.

Sablefish

Mid-water rockfish were the most important sablefish prey with lingcod also being important (Table B4). The sablefish prey index has shown substantial variation through time with a peak in the mid-2000's (Fig 13). The index has declined from this peak but is currently within one SD of the full time series and shows no trend over the last five years. Note that the functional groups 'deposit feeders' and 'cephalopods' were not represented in this index due to lack of time series data. The groups made up 9% and 6% of sablefish diet respectively.

Skates, rays, and pinnipeds were the most important sablefish predators (Table B4). The composite sable fish predator index showed a steady increase from 1970 until the late 1990's after which it has been stable (Fig. 14). While there was no trend over the last five years, over the last three years of the time series, there has been a substantial drop in the index from an all-time high to more recent levels. Note that the Atlantis model predicts that approximately 11% of sablefish mortality is cause by pelagic sharks, which are not represented in the present index due to lack of time series data.

Sablefish predators and prey showed no short or long-term change (Fig. 15). Prey densities were good relative to the long term trend but the recent trend was for a decline. However, neither short nor long-term trends were greater than one SD. Predators were poor but improving, but again, the trends were within historic norms. Change in the short term trend for predators, however, was just under one SD of the long term mean.

Summary – Integrated Trend of all Focal Species

An integrated summary of all four focal species suggests the biological environment for most species is relatively stable, with both short and long-term trends remaining within 1 SD of the mean (Fig. 16). Canary rockfish represent the single exception to this statement, with both prey and predator trends improving significantly in the near-term.

LIST OF FIGURES

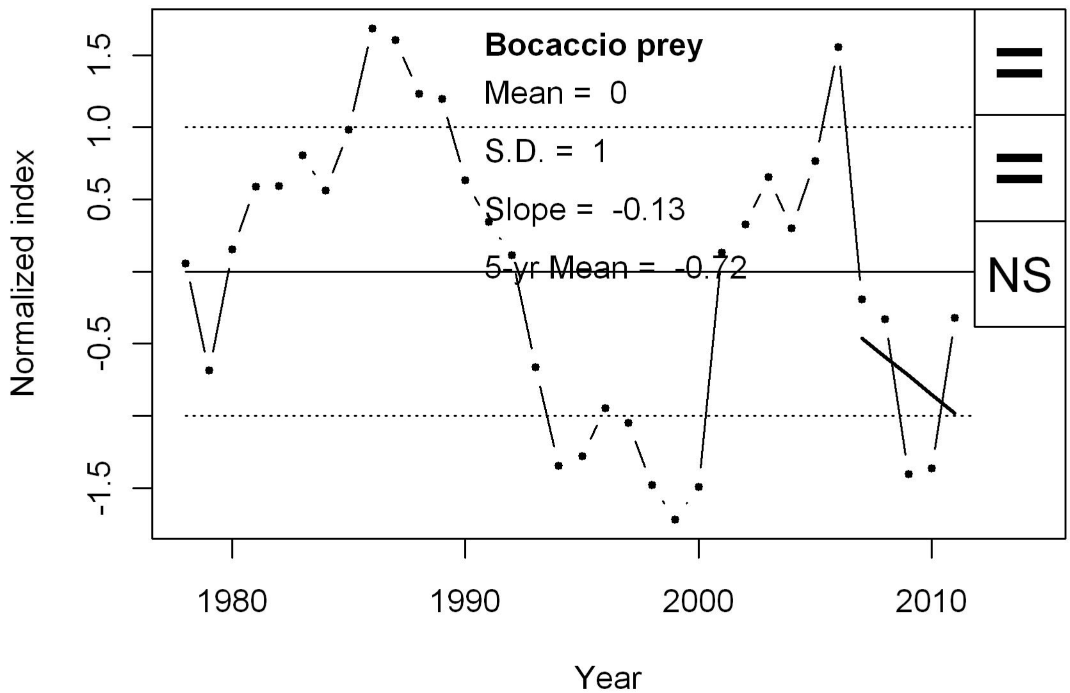


Figure 4. Index of bocaccio prey calculated using the full complement of time series. The solid horizontal line is the mean for the full time series. Dotted lines are +/-1 S.D.. The trend line (thick black) is the over the last five years of data. Slope and 5-yr mean are for the five year trend. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

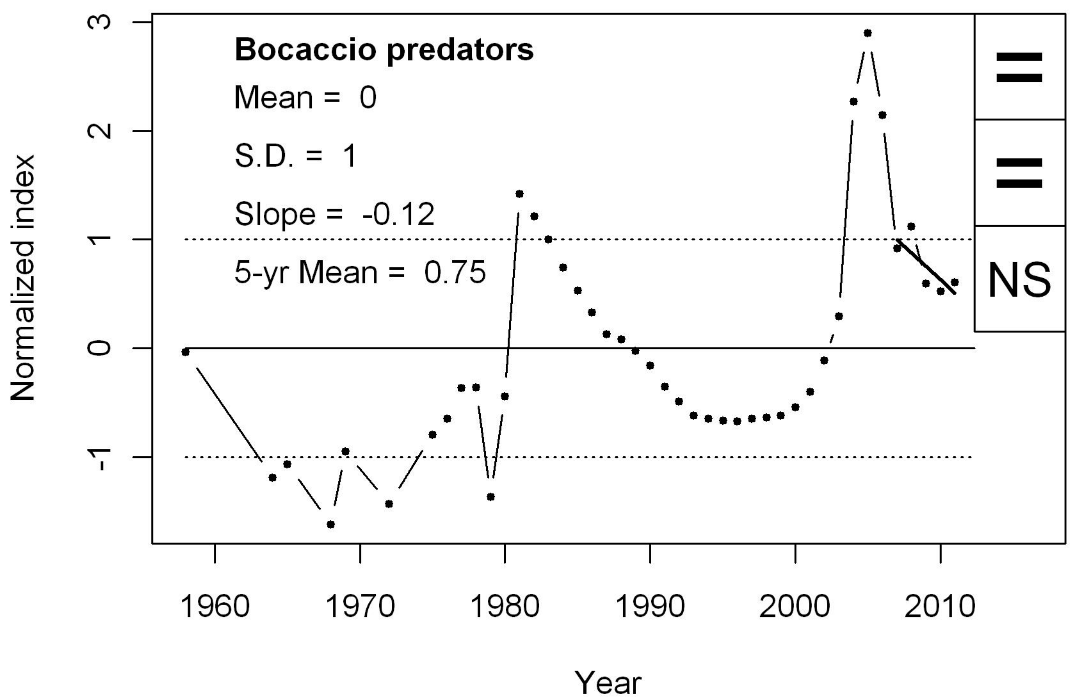


Figure 5. Index of bocaccio predators calculated using the full complement of time series. The solid horizontal line is the mean for the full time series. Dotted lines are +/-1 S.D.. The trend line (thick black) is the over the last five years of data. Slope and 5-yr mean are for the five year trend. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

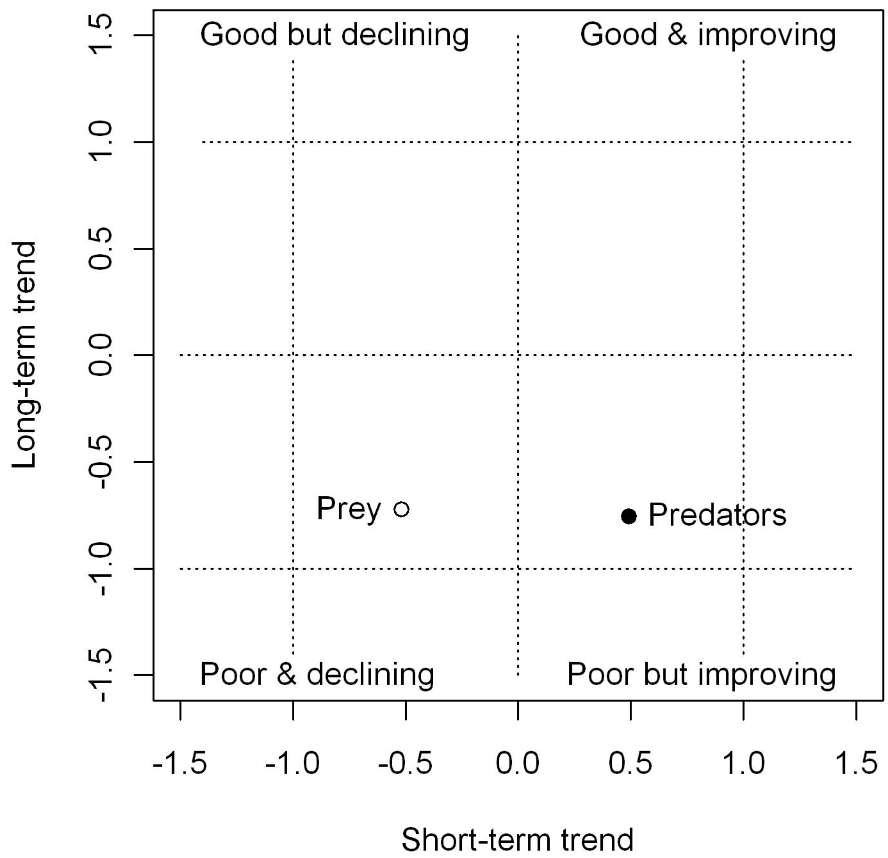


Figure 6 Quad-plot of short-term and long-term states in prey and predator indices for bocaccio. The short-term state indicates the trend over the last five years of the index. The long-term state indicates the difference between the long-term mean and the mean of the last five years. Values for the predator index were multiplied by -1 so that increases in both prey and predator indices indicate an improving biological environment for bocaccio.

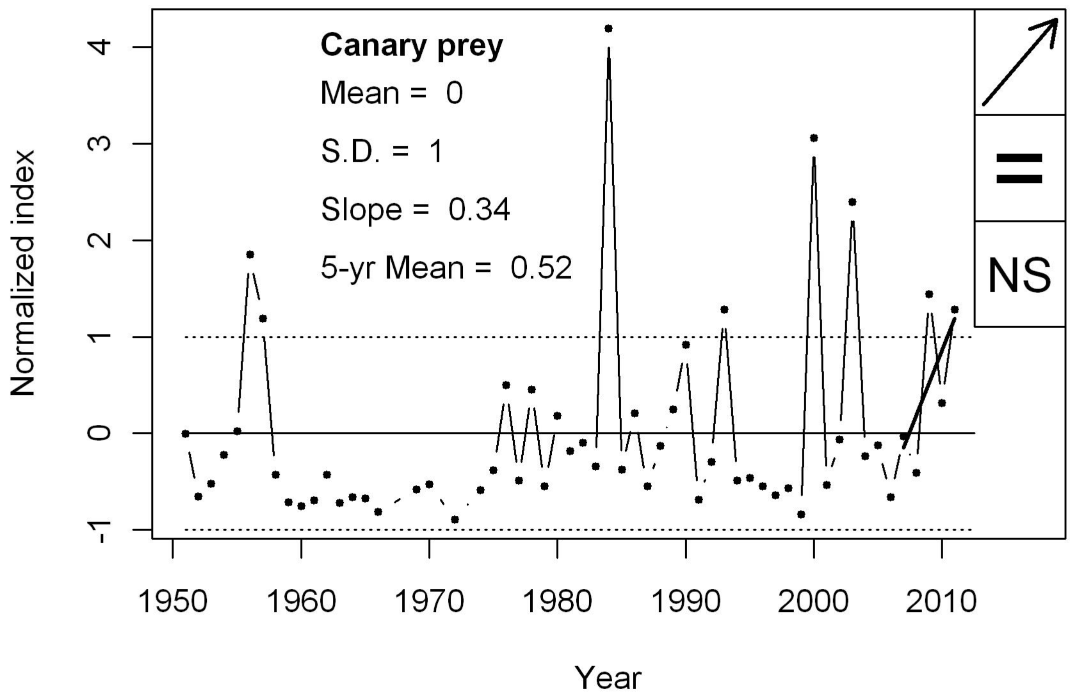


Figure 7. Index of canary prey calculated using the full complement of time series. The solid horizontal line is the mean for the full time series. Dotted lines are +/-1 S.D.. The trend line (thick black) is the over the last five years of data. Slope and 5-yr mean are for the five year trend. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

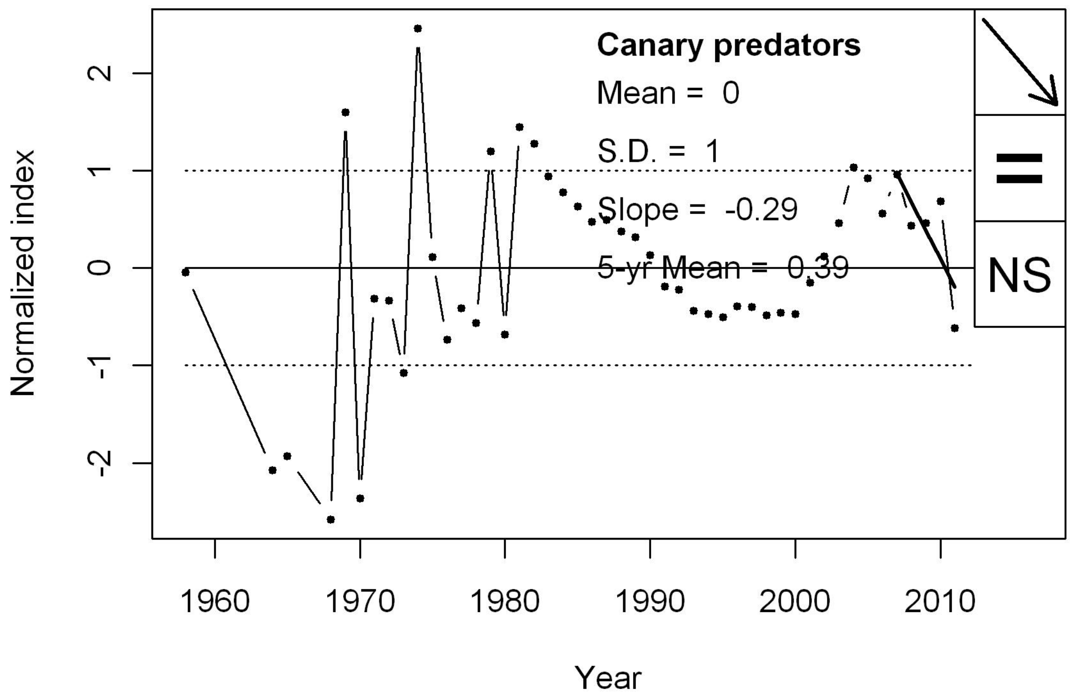


Figure 8. Index of canary predators calculated using the full complement of time series. The solid horizontal line is the mean for the full time series. Dotted lines are +/-1 S.D.. The trend line (thick black) is the over the last five years of data. Slope and 5-yr mean are for the five year trend. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

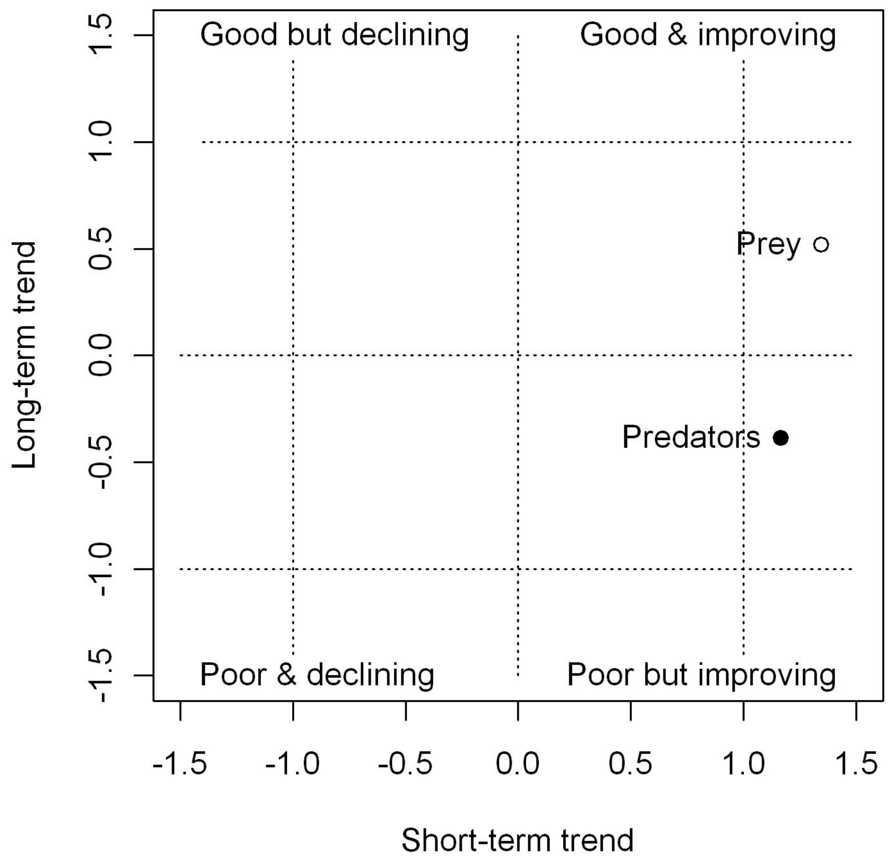


Figure 9 Quad-plot of short-term and long-term states in prey and predator indices for canary rockfish. The short-term state indicates the trend over the last five years of the index. The long-term state indicates the difference between the long-term mean and the mean of the last five years. Values for the predator index were multiplied by -1 so that increases in both prey and predator indices indicate an improving biological environment for canary rockfish.

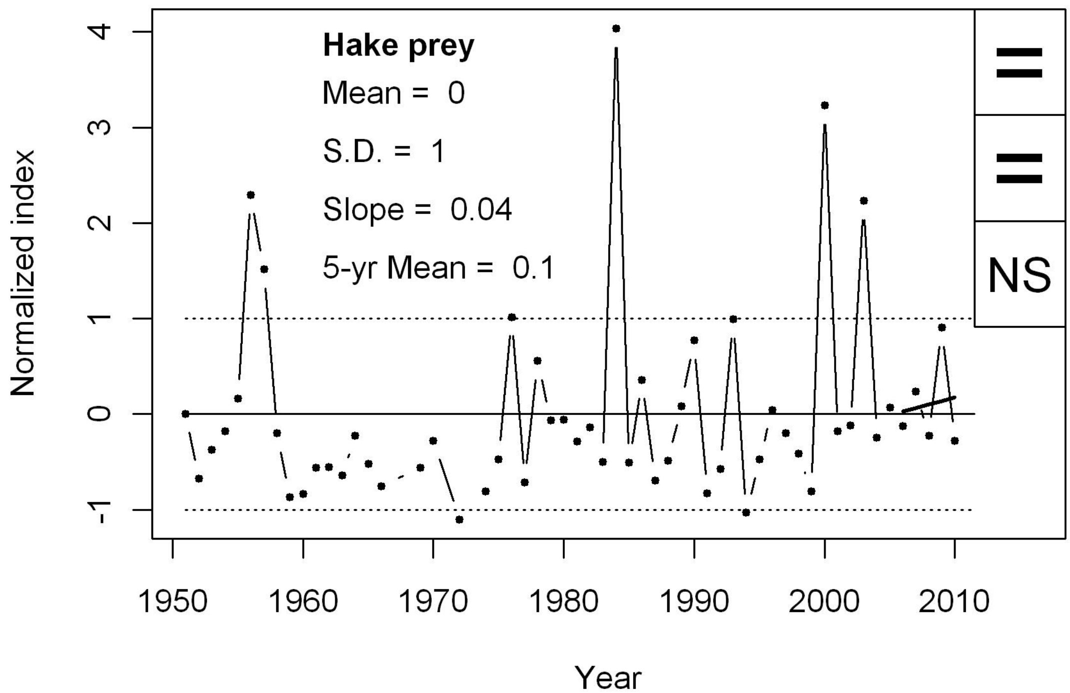


Figure 10. Index of hake prey calculated using the full complement of time series. The solid horizontal line is the mean for the full time series. Dotted lines are +/-1 S.D.. The trend line (thick black) is the over the last five years of data. Slope and 5-yr mean are for the five year trend. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

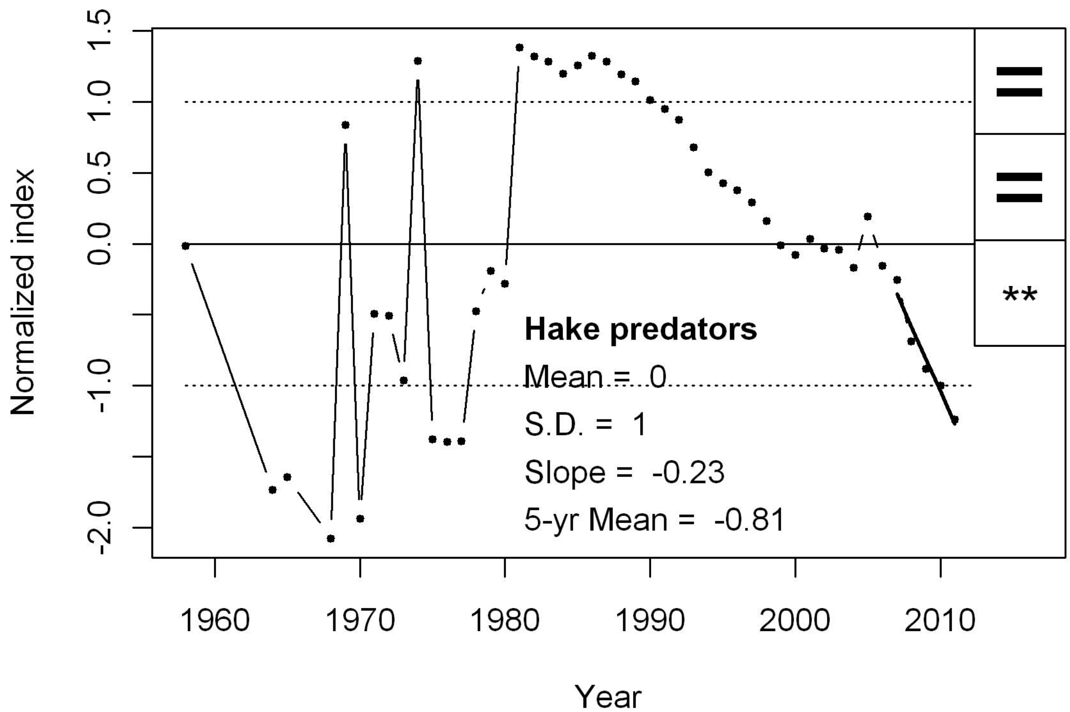


Figure 11. Index of hake predators calculated using the full complement of time series. The solid horizontal line is the mean for the full time series. Dotted lines are +/-1 S.D.. The trend line (thick black) is the over the last five years of data. Slope and 5-yr mean are for the five year trend. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

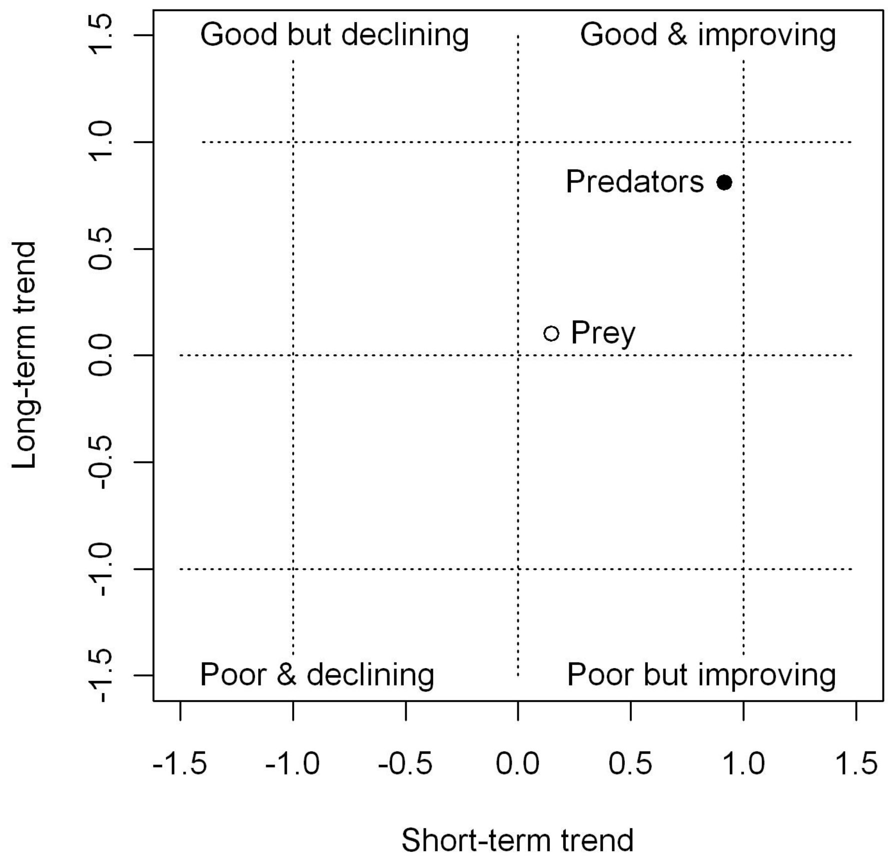


Figure 12 Quad-plot of short-term and long-term states in prey and predator indices for Pacific hake. The short-term state indicates the trend over the last five years of the index. The long-term state indicates the difference between the long-term mean and the mean of the last five years. Values for the predator index were multiplied by -1 so that increases in both prey and predator indices indicate an improving biological environment for Pacific hake.

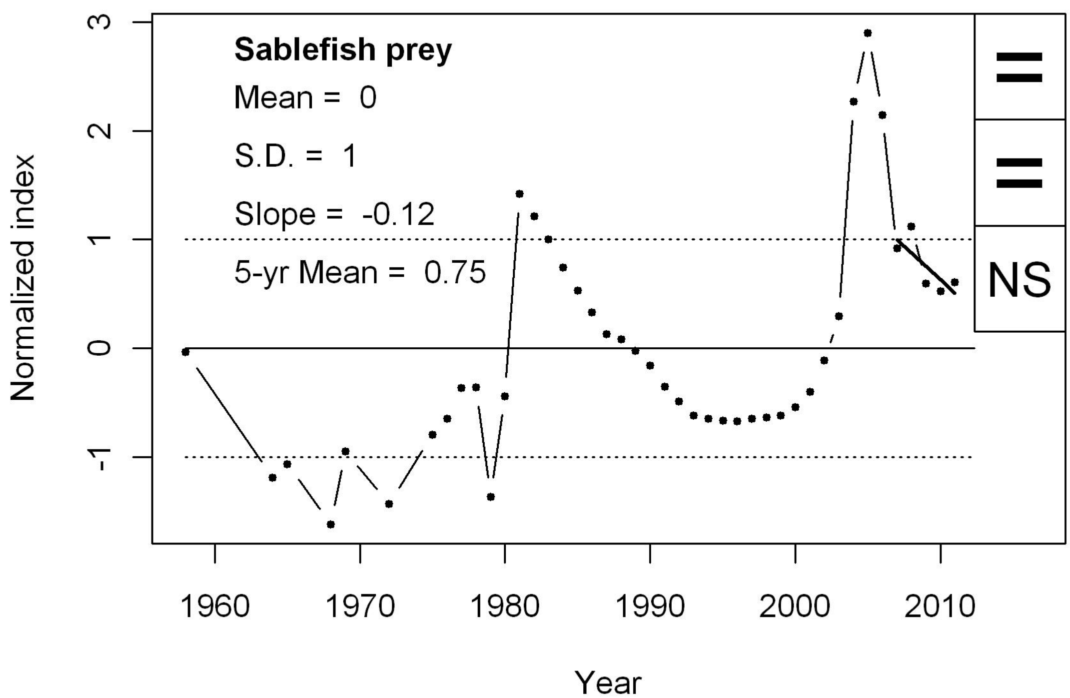


Figure 13. Index of sablefish prey calculated using the full complement of time series. The solid horizontal line is the mean for the full time series. Dotted lines are +/-1 S.D.. The trend line (thick black) is the over the last five years of data. Slope and 5-yr mean are for the five year trend. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

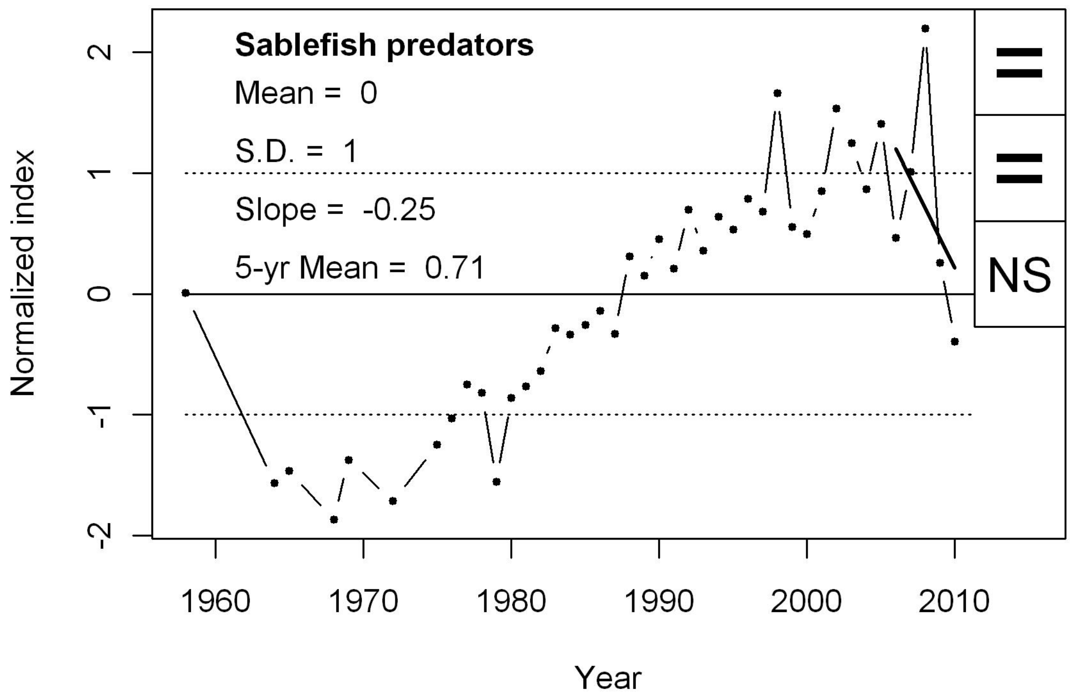


Figure 14. Index of sablefish predators calculated using the full complement of time series. The solid horizontal line is the mean for the full time series. Dotted lines are +/-1 S.D.. The trend line (thick black) is the over the last five years of data. Slope and 5-yr mean are for the five year trend. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

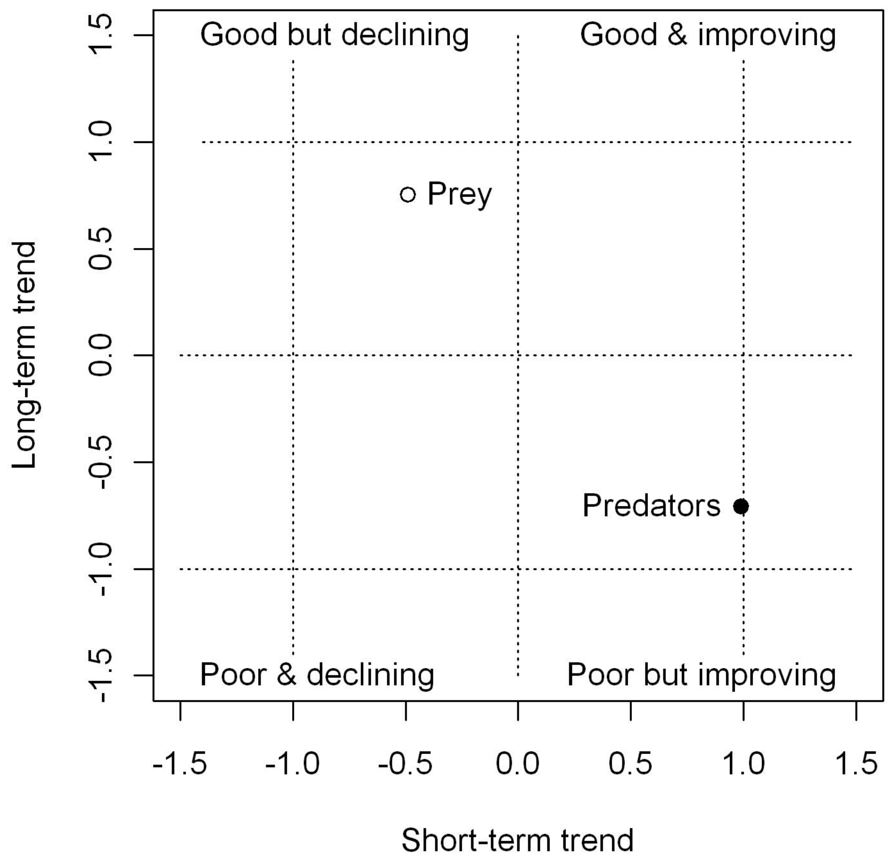


Figure 15 Quad-plot of short-term and long-term states in prey and predator indices for sablefish. The short-term state indicates the trend over the last five years of the index. The long-term state indicates the difference between the long-term mean and the mean of the last five years. Values for the predator index were multiplied by -1 so that increases in both prey and predator indices indicate an improving biological environment for sablefish.

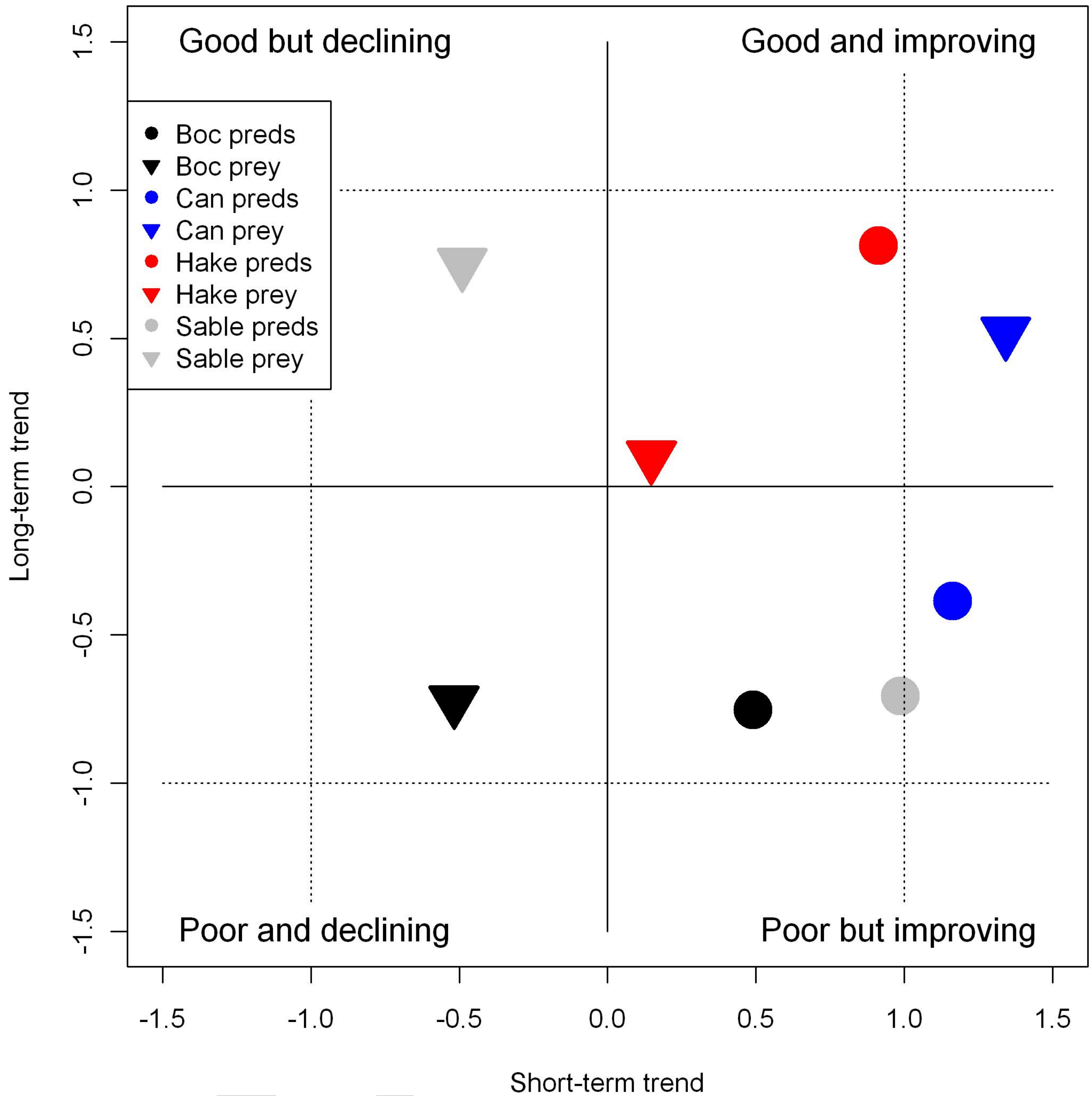


Figure 16. Quad plot of predator and prey trends for the four focal groundfish species.

APPENDIX B:

Data sources and methodology for production of predator and prey indices

Data sources

This document uses 86 time series (Table B1) to evaluate the current biological (predator, prey) environments of the four focal species: hake, sablefish, canary rockfish and bocaccio. The time series data were drawn from a range of sources including stock assessments, surveys and other long-term monitoring (Table B1). For many taxa and functional groups, the West Coast Groundfish Bottom Trawl Survey (WCGFBTS) was a primary source of data. Other time series were taken from published stock assessments, population surveys or long term monitoring projects. With the exception of those times series discussed below, details for each time series are not given here and can be found in the cited references.

Preliminary data analysis: calculation of time series

Many time series were taken directly from stock assessments, population surveys or other long term monitoring projects that reported annual means. For those time series, no initial data analysis was required. However, for several data sets initial data analysis was required to produce yearly means.

Groundfish and crab data from West Coast Groundfish Bottom Trawl Survey (WCGFBTS)

While detailed stock assessments exist for many west coast groundfishes, not all taxa and functional groups have current or recent assessments. Therefore, the WGGFS was used to generate time series for several individual species and relevant groundfish functional groups (Table B2). The WCGFBTS also provides quantitative data for three crab species: Dungeness (*Cancer magister*), Baird's tanner (*Chionoecetes bairdi*), and grooved tanner crabs (*Chionoecetes tanneri*), which are included in the analyses here. For individual species, trends were generated for both biomass and numbers since trends differed to some extent. For groundfish functional groups only biomass time series were generated. For functional groups the biomass of all taxa in that group was summed for each haul prior to analysis, but otherwise the generation of the time series followed the same methodology for that of species biomass or numbers. See below for more information on functional groups.

Trawl survey data were selected to include hauls from 2003 – 2010 between 32° - 48° N and included only those hauls deemed acceptable for fisheries analysis. Hauls from earlier in the time series that were conducted in areas later closed to fishing (and the trawl survey) were excluded from the analyses so as to not bias the data. Data were binned into three depth and four latitude zones prior to analysis. The depth zones and latitude zones were chosen based on previous work on groundfish assemblage structure {Tolimieri, 2007 #260; Tolimieri, 2010 #261; Tolimieri, 2006 #262} and known biogeographic regions. Depth zones included: shelf (<200 m), shallow slope (200-600 m) and deep slope (600-1200 m). Latitude zones included the area south of Point

Conception (32-34.5^{o} N), from Point Conception north to Cape Mendocino (32.4-40.44^{o} N), from Mendocino north to Cape Blanco (40.44-42.84^{o} N) and north to Cape Flattery (~ 48^{o} N). Trawls were binned based on the depth of the trawl and the latitude of the middle of the trawl. Data were converted to catch per unit effort (kg per km^2 or number per km2) by dividing catch by the swept area and $\log_{10}(x+1)$ transformed prior to analysis.

A linear model was used to generate time series for each taxon. Year, depth and latitude were treated as fixed factors in the linear model. Predicted means for each depth and latitude zone then were back transformed to the original data scale and multiplied by the area of that zone and summed to produce an estimate of total biomass for each year. The areal extent of each depth x region bin was calculated from the U.S. Coastal Relief Model (http://www.ngdc.noaa.gov/mgg/coastal/crm.html). The format of these bathymetry data does not conserve area throughout the study region (e.g., a 1 X 1 degree area in the south is larger than a 1 X 1 degree area to the north). To correct this problem, we created a 1/10 degree grid over the sample area and calculated the true area of each 1/10 degree cell. We then re-projected the geographic 1/10 degree grid to a Cylindrical Equal-Area projection (units = meters, projection type = 3, longitude of the center of projection = -122° 0 0.00, latitude of the center of projection = 56° 30 0.000, Azimuth = 120.95, and Scale factor = 1). The new data layer had the correct area for each 1/10 degree latitude/longitude grid cell. The total area of a given depth x region bin was calculated by summing the area of the relevant grid cells. While this calculation accounts for differences in area among the depth x latitude bins, no effort was made to account for catchability.

Salmon

[insert this section]

Zooplankton time series

Annual spring abundance anomalies were calculated for CalCOFI and Central Oregon data as the deviation from the average spring (for CalCOFI; March-June) or growing season (for Oregon; May-September) abundance across the full time series, standardized to the standard deviation of all observations, except for All Vancouver zooplankton anomalies and Central Oregon Northern copepods anomalies, which were calculated as the log biomass anomaly.

<u>Calculation of prey and predator indices</u>

Calculation of the prey and predator indices for each focal species involved several steps. First, time series were allocated to functional groups. Diet data (for prey) and Atlantis {Horne, 2010 #459} output (for predators) were then used to select individual species and functional groups for inclusion in a particular index. A weighted linear mixed model was then used to combine the time series into a single prey or predator index for each focal species. Individual time series used in the analyses are shown in Figures B1-B23.

Functional groups

All functional groups were based on those used in the Atlantis Model of the California Current Ecosystem {Horne, 2010 #459}. Rationale for the development of the specific functional groups can be found therein. In the present analysis, the creation of functional groups was comprised of two separate steps—one involving only the data from the WCGFBTS and the other involving the all time series.

For the WCGFBTS data, individual species were assigned to the Atlantis functional groups (Table B2). The biomass of these species in a trawl was then summed prior to the calculation of the time series for a specific functional group like Mid-water Rockfish. In this analysis only those taxa identified to species were included. Not all species were assigned to a functional group. However, these species were not particularly abundant and over 99% of the biomass identified to species was assigned to a groundfish functional group (Table B3). While most species were assigned to functional groups that included many other species, several species are not lumped into functional groups in the Atlantis model and were allotted to a unique group (within the trawl survey) containing only that species: Dover sole, Pacific hake, sablefish, arrowtooth flounder, canary rockfish, shortbelly rockfish, cowcod, and lingcod. Shortbelly are presented separately in the figures but summed included in the 'small shallow rockfish' functional group for analyses based on the bocaccio diet analyses.

All the time series were then allocated to a functional group to be used in the calculation of prey and predator indices (Table B4). Each functional group contained multiple time series. For example, the 'lingcod' functional group contained a time series of lingcod biomass from the trawl survey, lingcod numbers from the trawl survey, and two estimates of total biomass from the lingcod stock assessment. Similarly the 'hake' functional group was comprised of time series of Pacific hake numbers and biomass from the trawl survey, and the time series from the lingcod stock assessment. The 'hake' functional group also included the total biomass of all hake like fishes (Table B2) in the trawl survey. The functional group pinnipeds included times series of abundance for Stellar's sea lions, California sea lions, harbor seals, and elephant seals among others (Table B4).

Selection of functional groups for inclusion in the prey and predator indices

Species and functional groups were chosen for inclusion in the prey or predator index of a focal species based on diet data or predation effects in the Atlantis model, respectively (Table B4). Diet data are summarized in Dufault {, 2009 #449} with the exception of bocaccio diet. Data on bocaccio diet was provided by J. Buchanan (pers. comm.) based on stomach contents analysis from 2005 – 2008. Diet data are generally proportion of stomach contents by weight {but see / Dufault, 2009 #449}, and are the mean of adult and juvenile diets to provide an estimate of diet across ontogeny. For bocaccio, 16% of the gut contents were unidentified fishes, for which time series could not be produced. This diet item was allocated to the know diet categories (hake, small shallow rockfish, flatfish, small planktivores) based on their relative proportions in bocaccio diets to bring their combined total to 1.0. Predator data are the proportion of a focal species' mortality caused by a predator as derived from Atlantis model predictions. All individual times series within a functional group were given the same diet or predation proportion. These data were later used as weighs when combining the time series.

Data analysis: calculation of indices

To summarize trends in the biological conditions, combined prey and combined predator indices were produced for each focal species. A linear mixed model was used to generate a composite predator or prey index for each of the four focal species. In the model, year was a fixed, categorical effect. Each time series was treated as a random effect. Because the time series were quantified on different scales (biomass, number, CPUE, births etc), they were normalized prior to the analysis. To account for the varying importance of each prey or predator to the focal species, each time series was weighted in the analysis. Prey weights were the proportion of the diet comprised by that prey item and were averaged across juvenile and adult diets. Predator weights were the proportion of total mortality of the focal species for which the predator was responsible (Table B4). In many cases there were multiple times series for a prey or predator. For example, initial analyses used four time series for lingcod: biomass from the WCGFBTS, numbers from the WCGFBTS, and spawning biomass of the northern and southern populations taken from the lingcod stock assessment (Table B4). Likewise there were multiple pinniped species. For these groups the weight for each time series was divided by the number of time series in that functional group, so that groups with numerous time series would not bias the results. This weighting approach does not directly account for differences in biomass or abundance among the prey or predator taxa. However, it does emphasize changes in those groups that were most 'important' (made up the highest proportion of the diet or caused the most mortality) over those that were less important to the focal species.

Discussion Point: *Time series length:*

Some consideration needs to be given to determining the length of the time series to be used. There are at least two points to consider. First, long-time series that have had consistent declines or increases will make it difficult to detect changes relative to SD because SD will be large and recent change may be small but consistent relative to the SD Second, for many of the model derived time series like those from stock assessments, much of the time series can show little real variation and may bias the estimate SD If the goal is to focus on more recent conditions, it may make sense to limit the length of the time series to more recent years.

For many of the stock assessments, the model derived biomass estimates in the early years show little variance and involve model run in times. We excluded these years from the analyses, and selected only data from 1980 onward when better data were available (i.e., the Triennial Survey) and the assessments show more variation. Because the various time series were not of the same length, the series of predicted yearly means did not necessarily have a mean of zero and standard deviation of one. Therefore, the composite predator or prey time series were normalized again prior to presentation.

<u>Time series plots</u>

Plots of all time series follow the same format. The plots show the change in the abundance (however it was measured) through time. The solid horizontal line indicates the mean of the full time series. The two dotted horizontal lines show ± 1.0 standard deviation (SD) of the full time series. The shorter, thick solid line is the predicted trend over the last five years of the data. In the upper right corner of each plot there are three boxes. The upper box indicated whether the trend over the last five years showed an increase (up angled arrow) or decrease (down angled arrow) of more than one standard deviation of the full time series or no change (=). The middle box indicates whether the mean of the last five years was high (+), lower (-) or within (=) one standard deviation of the long term mean. The lower inset box indicates whether the slope of the last five years of data was significantly different from zero. The long-term mean and SD of the time series is also presented on each figure as is the slope over of the trend over the last five years.

The 'performance metrics' on the plots were chosen to represent three types of 'change'. The trend over the last five years indicates whether there has been a fairly rapid and substantial change in the time series in recent years. Judging this change in relation to the long-term SD evaluates 'size' of this change relative to long-term variability. Changes that are within the typical variability of the time series are not, initially at least, considered to be important.

The mean of the last five years provides an indication of the recent state of the time series relative to the long-term status. Thus a stock or indicator might be declining but currently still above the long-term mean, for example. Alternatively, a stock might be stable but below the long-term mean. Again, comparing this five year mean to the SD of the whole time series indicates whether the current state is within or outside of typical variability.

Finally, the slope (whether or not it is significantly different from zero) gives an indication of the current trend of the time series regardless without respect to the overall variability. This information is important especially for those time series that have shown consistent, long-term declines or increases. In these cases, the SD is often high, and evaluating the trend over the last five years relative to the SD will fail to identify cases where the time series is still declining. For example, in the Dover sole stock assessment time series, total biomass has increased steadily for some time, but the increase over the last five years is less than one SD

Effect of time series inclusion

A simple analysis was conducted to determine how (and if) the choice of which time series to include in prey and predator composites affected the outcome. To do so, the results of the 'full' analysis using all available time series was compared to an analysis using a 'reduced' set of time series. For the 'reduced' analysis, stock assessments and some other redundant time series were excluded from the analysis (Table B4). Results for the reduced analysis were subtracted from the full analysis and the results plotted.

Elimination of the stock assessments and other select time series from the calculation of prey and predator indices affected the outcome (Figs. B24 – B32). Bocaccio and sablefish prey indices both showed substantial differences between the full and reduced indices but canary rockfish and hake prey indices did not. Bocaccio, canary rockfish and hake predator indices varied between the full and reduced index, but sablefish showed little difference between the two.

Bocaccio predators, canary rockfish predators and sablefish prey all showed similar trends when full and reduced indices were compared (Fig. B32) with sharp increases in around 1980, declines until approximately 2000 and followed by an increasing trend beginning in 2003. All three indices have lingcod in common, and the inclusion or exclusion of the lingcod stock assessment, which differs in both extent (begins in 1980) and to some level trend versus the trawl data, is the likely cause of these differences between the full and reduced indices.

Canary rockfish and hake prey trends show no difference between the full and reduced because no time series were eliminated from the 'reduced' indices. For the index of hake predators, variability between the full and reduced indices comes from the removal of the dogfish and hake stock assessments. In the case of sablefish predators, the difference between the two indices is fairly minor and may be due to the removal of the lingcod stock assessment. For sablefish lingcod were fairly minor predators compared to the other groups, however, and the effect was not strong.

Discussion Point: *Which time series to include?*

The present analyses make use of multiple time series per functional group for the calculation of the predator and prey indices. In many cases, the time series are somewhat redundant. For example, stock assessment time series are derived in part from the trawl surveys. Similarly, the trawl surveys provide times series of both numbers and biomass. Should all be included? There are advantages and disadvantages to both.

Stock assessments have the advantage of being the most detailed evaluation of a species population trends, but they make a large number of assumptions and are not updated yearly. Trawl survey time series of biomass or numbers have the advantage of being easily update and making fewer assumptions, but are a more cursory look at population trends. Since numbers and biomass trends may differ both may be useful for the production of prey and predator indices.

The intent here is not to provide a full analysis of which time series are appropriate to include but only to highlight the consequences of these decisions. Taken as a whole, these results suggest that careful thought should go into the selection of time series for the calculation of prey and predator indices.

Integrating prey and predator trends

We used the short-term and long-term state for prey and predators of each focal species to clarify the current state of their biological environment (e.g., good, bad, improving, or declining). For the short-term state, we used the difference between the last and first predicted values of the short-term trend line. In cases where data points occur at frequencies other than yearly, we used the last five data points to calculate this term. For the long-term state, we used the difference between the long-term mean and the mean of the last five years. Because an increasing trend for predators represents a potential decrease in 'conditions' for the target species, we multiplied the effect values by -1.

Table B1. Data sources for time series used in the calculation of prey and predator indices. WCGFBTS is the West Coast Groundfish Bottom Trawl Survey conducted by the FRAM division of the Northwest Fisheries Science Center, NOAA Fisheries. For the WCGFBTS all data are biomass (CPUE, kg per km^2) except where noted.

Time series	Data source & notes
Combined hake	WCGFBTS, data courtesy of Beth Horness; beth.horness@noaa.gov, data courtesy of Beth Horness; beth.horness@noaa.gov
Pacific hake biomass	WCGFBTS, data courtesy of Beth Horness; beth.horness@noaa.gov
Pacific hake numbers	WCGFBTS, data courtesy of Beth Horness; beth.horness@noaa.gov
Pacific hake stock assessment	{Stewart, 2011 #491}, Tables 15-126
Arrowtooth flounder biomass	WCGFBTS, data courtesy of Beth Horness; beth.horness@noaa.gov
Arrowtooth flounder numbers	WCGFBTS, data courtesy of Beth Horness; beth.horness@noaa.gov
Arrowtooth stock assessment	{Kaplan, 2007 #485}, Table 7
Dover sole biomass	WCGFBTS, data courtesy of Beth Horness; beth.horness@noaa.gov
Dover sole numbers	WCGFBTS, data courtesy of Beth Horness; beth.horness@noaa.gov
Dover sole stock assessment	{Sampson, 2005 #373}, Table 30
Small flatfish	WCGFBTS, data courtesy of Beth Horness; beth.horness@noaa.gov
Sablefish biomass	WCGFBTS, data courtesy of Beth Horness; beth.horness@noaa.gov
Sablefish numbers	WCGFBTS, data courtesy of Beth Horness; beth.horness@noaa.gov
Sablefish stock assessment	{Stewart, 2011 #492}, Table 10

Spiny dogfish biomass	WCGFBTS, data courtesy of Beth Horness; beth.horness@noaa.gov
Spiny dogfish number	WCGFBTS, data courtesy of Beth Horness; beth.horness@noaa.gov
Spiny dogfish	{Gertseva, 2011 #481}, Table 9
Large demersal sharks	WCGFBTS, data courtesy of Beth Horness; beth.horness@noaa.gov
Skates and rays	WCGFBTS, data courtesy of Beth Horness; beth.horness@noaa.gov

Table B1 (cont). Data sources for time series used in the calculation of prey and predator indices. WCGFBTS is the West Coast Groundfish Bottom Trawl Survey conducted by the FRAM division of the Northwest Fisheries Science Center, NOAA Fisheries. For the WCGFBTS all data are biomass (CPUE, kg per km^2) except where noted.

Lingcod biomass	WCGFBTS, data courtesy of Beth Horness; beth.horness@noaa.gov
Lingcod number	WCGFBTS, data courtesy of Beth Horness; beth.horness@noaa.gov
Lingcod - north	{Hamel, 2009 #482}
Lingcod - south	{Hamel, 2009 #482}
Herring	CDFG 2010
Sardines	Hill et al 2010
Small planktivores	WCGFBTS, data courtesy of Beth Horness; beth.horness@noaa.gov
Large planktivores	WCGFBTS, data courtesy of Beth Horness; beth.horness@noaa.gov
Canary rockfish biomass	WCGFBTS, data courtesy of Beth Horness; beth.horness@noaa.gov
Canary rockfish number	WCGFBTS, data courtesy of Beth Horness; beth.horness@noaa.gov
Canary stock assessment	{Stewart, 2009 #490}, Table 20

Cowcod biomass	WCGFBTS, data courtesy of Beth Horness; beth.horness@noaa.gov
Cowcod number	WCGFBTS, data courtesy of Beth Horness; beth.horness@noaa.gov
Cowcod stock assessment	{Dick, 2009 #480}, Table 3
Yelloweye rockfish biomass	WCGFBTS, data courtesy of Beth Horness; beth.horness@noaa.gov
Yelloweye rockfish number	WCGFBTS, data courtesy of Beth Horness; beth.horness@noaa.gov
Yelloweye stock assessment	{Stewart, 2009 #493}, Table 21
Small shallow rockfish	WCGFBTS, data courtesy of Beth Horness; beth.horness@noaa.gov
Shallow large rockfish	WCGFBTS, data courtesy of Beth Horness; beth.horness@noaa.gov
Mid-water rockfish	WCGFBTS, data courtesy of Beth Horness; beth.horness@noaa.gov
Deep small rockfish	WCGFBTS, data courtesy of Beth Horness; beth.horness@noaa.gov
Deep large rockfish	WCGFBTS, data courtesy of Beth Horness; beth.horness@noaa.gov

Table B1 cont. Data sources for time series used in the calculation of prey and predator indices. WCGFBTS is the West Coast Groundfish Bottom Trawl Survey conducted by the FRAM division of the Northwest Fisheries Science Center, NOAA Fisheries. For the WCGFBTS all data are biomass (CPUE, kg per km^2) except where noted.

Juvenile rockfish	{Sydeman, 2010 #494}, Fig. 14
Rockfish larvae - north	{Sakuma, 2006 #488}, Fig. 5 and Sakuma pers. comm.
Rockfish larvae - core	{Sakuma, 2006 #488}, Fig. 5 and Sakuma pers. comm.
Rockfish larvae - south	{Sakuma, 2006 #488}, Fig. 5 and Sakuma pers. comm.

Shallow misc fish	WCGFBTS, data courtesy of Beth Horness; beth.horness@noaa.gov
Large demersal predators	WCGFBTS, data courtesy of Beth Horness; beth.horness@noaa.gov
Deep demersal fish	WCGFBTS, data courtesy of Beth Horness; beth.horness@noaa.gov
Deep vertical migrators	WCGFBTS, data courtesy of Beth Horness; beth.horness@noaa.gov
Chinook - Klamath in river run size	{PFMC, 2011 #487}, Table II-1
Chinook - Sacramento escapement	{PFMC, 2011 #487}, Table II-1
Chinook - council area catch	{PFMC, 2011 #487}, Table 1-4
Coho - OPI index	{PFMC, 2011 #487}, Tables III-3 - III-30
Coho- council area catch	{PFMC, 2011 #487}, Table 1-4,
Dungeness crab biomass	WCGFBTS, data courtesy of Beth Horness; beth.horness@noaa.gov
Dungeness crab number	WCGFBTS, data courtesy of Beth Horness; beth.horness@noaa.gov
Baird's tanner crab biomass	WCGFBTS, data courtesy of Beth Horness; beth.horness@noaa.gov
Baird's tanner crab number	WCGFBTS, data courtesy of Beth Horness; beth.horness@noaa.gov
Grooved Tanner crab biomass	WCGFBTS, data courtesy of Beth Horness; beth.horness@noaa.gov
Grooved Tanner crab number	WCGFBTS, data courtesy of Beth Horness; beth.horness@noaa.gov
Pink shrimp (number)	{Hannah, 2011 #483}
Pink shrimp (CPUE)	Bob Hannah pers. comm.
Stellar sea lion (all regions)	{Allen, 2011 #477}, Table 4
Stellar sea lion (eastern US stock - BC)	{Allen, 2011 #477}, Table 4
Stellar sea lion (eastern US stock - Southeast AK)	{Allen, 2011 #477}, Table 4

Table B1 cont. Data sources for time series used in the calculation of prey and predator indices. WCGFBTS is the West Coast Groundfish Bottom Trawl Survey conducted by the FRAM division of the Northwest Fisheries Science Center, NOAA Fisheries. For the WCGFBTS all data are biomass (CPUE, kg per km^2) except where noted.

Stellar sea lion (eastern US stock - No.CA/OR)	{Allen, 2011 #477}, Table 4
Stellar sea lion (eastern US stock - Central CA)	{Allen, 2011 #477}, Table 4
Harbor seal (WA stock)	{Carretta, 2011 #478}, Fig. 2
Harbor seal (OR stock)	{Carretta, 2011 #478}, Fig. 2
Harbor seal (CA stock)	{Carretta, 2011 #478}, Fig. 2
Northern fur seal	{Orr, 2011 #486}, Table 22
Northern elephant seal (California breeding stock)	{Carretta, 2011 #478}
California sea lion	{Carretta, 2011 #478}, Fig. 2 & 3
Southern resident orca	{Carretta, 2011 #478}
Gelatinous zooplankton Central OR	CalCOFI-SWFSC (www.oceaninformatics.ucsd.edu). Plankton sample analysis supported by NSF grants to M.D. Ohman, Scripps Institution of Oceanography and by the SIO Pelagic Invertebrates Collection. Contact: Dr. Mark Ohman, mohman@ucsd.edu
Gelatinous zooplankton Central CA	CalCOFI-SWFSC (www.oceaninformatics.ucsd.edu). Plankton sample analysis supported by NSF grants to M.D. Ohman, Scripps Institution of Oceanography and by the SIO Pelagic Invertebrates Collection. Contact: Dr. Mark Ohman, mohman@ucsd.edu
Gelatinous zooplankton Southern CA	CalCOFI-SWFSC (www.oceaninformatics.ucsd.edu). Plankton sample analysis supported by NSF grants to M.D. Ohman, Scripps Institution of Oceanography and by the SIO Pelagic Invertebrates Collection. Contact: Dr. Mark Ohman, mohman@ucsd.edu
Mesozooplankton Central OR	CalCOFI-SWFSC (www.oceaninformatics.ucsd.edu). Plankton sample analysis supported by NSF grants to M.D. Ohman, Scripps Institution of Oceanography and by the SIO Pelagic Invertebrates Collection. Contact: Dr. Mark Ohman, mohman@ucsd.edu

All copepods Central CA	CalCOFI-SWFSC (www.oceaninformatics.ucsd.edu). Plankton sample analysis supported by NSF grants to M.D. Ohman, Scripps Institution of Oceanography and by the SIO Pelagic Invertebrates Collection. Contact: Dr. Mark Ohman, mohman@ucsd.edu

Table B1 cont. Data sources for time series used in the calculation of prey and predator indices. WCGFBTS is the West Coast Groundfish Bottom Trawl Survey conducted by the FRAM division of the Northwest Fisheries Science Center, NOAA Fisheries. For the WCGFBTS all data are biomass (CPUE, kg per km^2) except where noted.

All copepods Southern CA	CalCOFI-SWFSC (www.oceaninformatics.ucsd.edu). Plankton sample analysis supported by NSF grants to M.D. Ohman, Scripps Institution of Oceanography and by the SIO Pelagic Invertebrates Collection. Contact: Dr. Mark Ohman, mohman@ucsd.edu
Transition copepods Central CA	CalCOFI-SWFSC (www.oceaninformatics.ucsd.edu). Plankton sample analysis supported by NSF grants to M.D. Ohman, Scripps Institution of Oceanography and by the SIO Pelagic Invertebrates Collection. Contact: Dr. Mark Ohman, mohman@ucsd.edu
Transition copepods Southern CA	CalCOFI-SWFSC (www.oceaninformatics.ucsd.edu). Plankton sample analysis supported by NSF grants to M.D. Ohman, Scripps Institution of Oceanography and by the SIO Pelagic Invertebrates Collection. Contact: Dr. Mark Ohman, mohman@ucsd.edu
Northern copepods Central OR	Bill Peterson; bill.peterson@noaa
Euphausiid adults Central CA	Data originate from the Brinton-Townsend Euphausiid Database of the Pelagic Invertebrates Collection, Scripps Institution of Oceanography. Database creation supported by NOAA grant NA17RJ1231. Contact: Dr. Mark Ohman, mohman@ucsd.edu
Euphausiid adults Southern CA	Data originate from the Brinton-Townsend Euphausiid Database of the Pelagic Invertebrates Collection, Scripps Institution of Oceanography. Database creation supported by NOAA grant NA17RJ1231. Contact: Dr. Mark Ohman,

	mohman@ucsd.edu
Euphausiid juveniles and eggs Central OR	Newport Line Station 5 (NH05). Contact: from Bill Peterson; bill.peterson@noaa

Table B2. Groundfish functional groups used in the calculation of prey and predator indices. Biomass of all species within the functional group was summed by haul prior to calculating the biomass for that group in a given year. All data from the WCGFBTS.

Functional group	Atlantis abbreviation	Common name	Species
Arrowtooth	FVD	arrowtooth flounder	*Atheresthes stomias*
Canary	FPO	canary rockfish	*Sebastes pinniger*
Cowcod	SHC	cowcod	*Sebastes levis*
Dover sole	FDP	Dover sole	*Microstomus pacificus*
Lingcod	FVS	lingcod	*Ophiodon elongatus*
Sablefish	FMN	sablefish	*Anoplopoma fimbria*
Shortbelly rockfish	FVV	shortbelly rockfish	*Sebastes jordani*
Yelloweye rockfish	SHC	yelloweye rockfish	*Sebastes ruberrimus*
Deep demersal fish	FDD	Pacific grenadier	*Coryphaenoides acrolepis*
		giant grenadier	*Albatrossia pectoralis*
		California slickhead	*Alepocephalus tenebrosus*
		bigfin eelpout	*Lycodes cortezianus*
		Pacific flatnose	*Antimora microlepis*
		twoline eelpout	*Bothrocara brunneum*
		black eelpout	*Lycodes diapterus*
		snakehead eelpout	*Lycenchelys crotalinus*
		blackbelly eelpout	*Lycodes pacificus*
		blacktail snailfish	*Careproctus melanurus*
		California grenadier	*Nezumia stelgidolepis*
		black hagfish	*Eptatretus deani*
		threadfin slickhead	*Talismania bifurcata*

		smooth grenadier	*Nezumia liolepis*
		Pacific hagfish	*Eptatretus stouti*
		ragfish	*Icosteus aenigmaticus*
		wolf-eel	*Anarrhichthys ocellatus*
		blackfin snailfish	*Careproctus cypselurus*
		spotted cusk-eel	*Chilara taylori*
		popeye grenadier	*Coryphaenoides cinereus*
		paperbone cusk-eel	*Lamprogrammus niger*
		hundred fathom codling	*Physiculus rastrelliger*
		California smoothtounge	*Leuroglossus stilbius*
		blackfin poacher	*Bathyagonus nigripinnis*
		fangtooth	*Anoplogaster cornuta*
		blacktip poacher	*Xeneretmus latifrons*

Table B2 cont. Groundfish functional groups used in the calculation of prey and predator indices. Biomass of all species within the functional group was summed by haul prior to calculating the biomass for that group in a given year. All data from the WCGFBTS.

Functional group	**Atlantis abbreviation**	**Common name**	**Species**
Deep demersal fish	FDD	red snailfish	*Paraliparis dactylosus*
		warty poacher	*Chesnonia verrucosa*
		smalldisk snailfish	*Careproctus gilberti*
		bigeye poacher	*Bathyagonus pentacanthus*
		rosy snailfish	*Paraliparis rosaceus*
		blackmouth eelpout	*Lycodapus fierasfer*
		humpback snailfish	*Elassodiscus caudatus*
		sawtooth eel	*Serrivomer sector*

northern smoothtongue	*Leuroglossus schmidti*
black swallower	*Chiasmodon niger*
rubynose brotula	*Cataetyx rubrirostris*
blackline snipe eel	*Avocettina infans*
swellhead snailfish	*Paraliparis cephalus*
soft eelpout	*Bothrocara molle*
broadfin snailfish	*Paraliparis pectoralis*
northern spearnose poacher	*Agonopsis vulsa*
slender snipe eel	*Nemichthys scolopaceus*
blackchin	*Scopelengys tristis*
deepwater eelpout	*Lycodapus endemoscotus*
filamented grenadier	*Coryphaenoides filifer*
longnose snailfish	*Rhinoliparis barbulifer*
pallid eelpout	*Lycodapus mandibularis*
Kamchatka eelpout	*Lycenchelys camchatica*
smooth dreamer	*Chaenophryne draco*
common blackdevil	*Melanocetus johnsonii*
threadfin cusk-eel	*Dicrolene filamentosa*
wattled eelpout	*Lycodes palearis*
Alaska snailfish	*Careproctus colletti*
basketweave cusk-eel	*Ophidion scrippsae*
looseskin eelpout	*Lycodapus dermatinus*
tadpole snailfish	*Nectoliparis pelagicus*
shortfin eelpout	*Lycodes brevipes*

Table B2. Groundfish functional groups used in the calculation of prey and predator indices. Biomass of all species within the functional group was summed by haul prior to calculating the biomass for that group in a given year. All data from the WCGFBTS.

Functional group	Atlantis abbreviation	Common name	Species
Deep large rockfish	FDO	splitnose rockfish	*Sebastes diploproa*
		shortspine thornyhead	*Sebastolobus alascanus*
		blackgill rockfish	*Sebastes melanostomus*
		bank rockfish	*Sebastes rufus*
		redbanded rockfish	*Sebastes babcocki*
Deep small rockfish	FDC	longspine thornyhead	*Sebastolobus altivelis*
		sharpchin rockfish	*Sebastes zacentrus*
		darkblotched rockfish	*Sebastes crameri*
		aurora rockfish	*Sebastes aurora*
Deep vertical migrators	FBP	Pacific viperfish	*Chauliodus macouni*
		longfin dragonfish	*Tactostoma macropus*
		blackbelly dragonfish	*Stomias atriventer*
		shining loosejaw	*Aristostomias scintillans*
		crested bigscale	*Poromitra crassiceps*
		northern lampfish	*Stenobrachius leucopsarus*
		black scabbardfish	*Aphanopus carbo*
		shining tubeshoulder	*Sagamichthys abei*
		Pacific blackdragon	*Idiacanthus antrostomus*
		barreleye	*Macropinna microstoma*
		California headlightfish	*Diaphus theta*
		longnose lancetfish	*Alepisaurus ferox*

duckbill barracudina	*Magnisudis atlantica*
slender hatchetfish	*Argyropelecus affinis*
northern pearleye	*Benthalbella dentata*
highsnout bigscale	*Melamphaes lugubris*
blue lanternfish	*Tarletonbeania crenularis*
longspine hatchetfish	*Sternoptyx diaphana*
scaly paperbone	*Scopelosaurus harryi*
highfin dragonfish	*Bathophilus flemingi*
slender barracudina	*Lestidiops ringens*
Pacific sand lance	*Ammodytes hexapterus*
tropical hatchetfish	*Argyropelecus lychnus*

Table B2 cont. Groundfish functional groups used in the calculation of prey and predator indices. Biomass of all species within the functional group was summed by haul prior to calculating the biomass for that group in a given year. All data from the WCGFBTS.

Functional group	Atlantis abbreviation	Common name	Species
Flatfish	FDF	Pacific sanddab	*Citharichthys sordidus*
		rex sole	*Glyptocephalus zachirus*
		English sole	*Parophrys vetulus*
		slender sole	*Lyopsetta exilis*
		deepsea sole	*Embassichthys bathybius*
		flathead sole	*Hippoglossoides elassodon*
		curlfin sole	*Pleuronichthys decurrens*
		southern rock sole	*Lepidopsetta bilineata*
		starry flounder	*Platichthys stellatus*
		hornyhead turbot	*Pleuronichthys verticalis*
		sand sole	*Psettichthys melanostictus*
		longfin sanddab	*Citharichthys xanthostigma*
		butter sole	*Isopsetta isolepis*
		fantail sole	*Xystreurys liolepis*
		spotted turbot	*Pleuronichthys ritteri*
		California toungefish	*Symphurus atricauda*
		speckled sanddab	*Citharichthys stigmaeus*
Hake	FMM	Pacific hake	*Merluccius productus*
		Pacific cod	*Gadus macrocephalus*
		Pacific hake YOY	*Merluccius productus YOY*
		Pacific tomcod	*Microgadus proximus*

		walleye pollock	*Theragra chalcogramma*
Large demersal predators	FVS	cabezon	*Scorpaenichthys marmoratus*
		red Irish lord	*Hemilepidotus hemilepidotus*
		brown Irish lord	*Hemilepidotus spinosus*
Large demersal sharks	SHD	sixgill shark	*Hexanchus griseus*
Large piscivorous flatfish	FVD	petrale sole	*Eopsetta jordani*
		Pacific halibut	*Hippoglossus stenolepis*
		California halibut	*Paralichthys californicus*
Large planktivores	FPL	jack mackerel	*Trachurus symmetricus*

Table B2 cont. Groundfish functional groups used in the calculation of prey and predator indices. Biomass of all species within the functional group was summed by haul prior to calculating the biomass for that group in a given year. All data from the WCGFBTS.

Functional group	Atlantis abbreviation	Common name	Species
Mid-water rockfish	FDS	chilipepper	*Sebastes goodei*
		yellowtail rockfish	*Sebastes flavidus*
		Pacific ocean perch	*Sebastes alutus*
		bocaccio	*Sebastes paucispinis*
		widow rockfish	*Sebastes entomelas*
		squarespot rockfish	*Sebastes hopkinsi*
		shortraker rockfish	*Sebastes borealis*
		speckled rockfish	*Sebastes ovalis*
		yellowmouth rockfish	*Sebastes reedi*
Pelagic sharks	SHP	soupfin shark	*Galeorhinus galeus*
		blue shark	*Prionace glauca*

Shallow large rockfish	SHR	redstripe rockfish	*Sebastes proriger*
		greenspotted rockfish	*Sebastes chlorostictus*
		silvergray rockfish	*Sebastes brevispinis*
		greenblotched rockfish	*Sebastes rosenblatti*
		copper rockfish	*Sebastes caurinus*
		kelp greenling	*Hexagrammos decagrammus*
		barred sand bass	*Paralabrax nebulifer*
		quillback rockfish	*Sebastes maliger*
		brown rockfish	*Sebastes auriculatus*
		flag rockfish	*Sebastes rubrivinctus*
		pink rockfish	*Sebastes eos*
		starry rockfish	*Sebastes constellatus*
		blue rockfish	*Sebastes mystinus*
		Mexican rockfish	*Sebastes macdonaldi*
		tiger rockfish	*Sebastes nigrocinctus*
		black rockfish	*Sebastes melanops*
		bronzespotted rockfish	*Sebastes gilli*
		olive rockfish	*Sebastes serranoides*
Shallow misc. fish	FDE	white croaker	*Genyonemus lineatus*
		plainfin midshipman	*Porichthys notatus*
		threadfin sculpin	*Icelinus filamentosus*
		longspine combfish	*Zaniolepis latipinnis*
		shortspine combfish	*Zaniolepis frenata*
		Pacific staghorn sculpin	*Leptocottus armatus*

Table B2. Groundfish functional groups used in the calculation of prey and predator indices. Biomass of all species within the functional group was summed by haul prior to calculating the biomass for that group in a given year. All data from the WCGFBTS.

Functional group	Atlantis abbreviation	Common name	Species
Shallow misc. fish	FDE	giant wrymouth	*Cryptacanthodes giganteus*
		blob sculpin	*Psychrolutes phrictus*
		king-of-the-salmon	*Trachipterus altivelis*
		bull sculpin	*Enophrys taurina*
		slim sculpin	*Radulinus asprellus*
		buffalo sculpin	*Enophrys bison*
		medusafish	*Icichthys lockingtoni*
		blackfin sculpin	*Malacocottus kincaidi*
		dusky sculpin	*Icelinus burchami*
		sharpnose sculpin	*Clinocottus acuticeps*
		spotfin sculpin	*Icelinus tenuis*
		queenfish	*Seriphus politus*
		spinyhead sculpin	*Dasycottus setiger*
		sailfin sculpin	*Nautichthys oculofasciatus*
		whitebarred prickleback	*Poroclinus rothrocki*
		roughspine sculpin	*Triglops macellus*
		flabby sculpin	*Zesticelus profundorum*
		thornback sculpin	*Paricelinus hopliticus*
		northern sculpin	*Icelinus borealis*

Shallow small rockfish	FDB	stripetail rockfish	*Sebastes saxicola*
		greenstriped rockfish	*Sebastes elongatus*
		halfbanded rockfish	*Sebastes semicinctus*
		rosethorn rockfish	*Sebastes helvomaculatus*
		swordspine rockfish	*Sebastes ensifer*
		pygmy rockfish	*Sebastes wilsoni*
		honeycomb rockfish	*Sebastes umbrosus*
		rosy rockfish	*Sebastes rosaceus*
		calico rockfish	*Sebastes dalli*
		gopher rockfish	*Sebastes carnatus*
		Puget Sound rockfish	*Sebastes emphaeus*

Table B2. Groundfish functional groups used in the calculation of prey and predator indices. Biomass of all species within the functional group was summed by haul prior to calculating the biomass for that group in a given year. All data from the WCGFBTS.

Functional group	**Atlantis abbreviation**	**Common name**	**Species**
Above 200 m on shelf	FDM	pink seaperch	*Zalembius rosaceus*
		Pacific pompano	*Peprilus simillimus*
		shiner perch	*Cymatogaster aggregata*
		spotfin surfperch	*Hyperprosopon anale*
		barred surfperch	*Amphistichus argenteus*
		white surfperch	*Phanerodon furcatus*
		redtail surfperch	*Amphistichus rhodoterus*
		rubberlip surfperch	*Rhacochilus toxotes*
		striped surfperch	*Embiotoca lateralis*
Skates & rays	SSK	longnose skate	*Raja rhina*

		big skate	*Raja binoculata*
		Bering skate	*Bathyraja kincaidii*
		roughtail skate	*Bathyraja trachura*
		California skate	*Raja inornata*
		Pacific electric ray	*Torpedo californica*
		Bat Ray	*Myliobatis californicus*
		deepsea skate	*Bathyraja abyssicola*
		starry skate	*Raja stellulata*
		Aleutian skate	*Bathyraja aleutica*
Small demersal sharks	SHB	spiny dogfish	*Squalus acanthias*
		spotted ratfish	*Hydrolagus colliei*
		brown cat shark	*Apristurus brunneus*
		filetail cat shark	*Parmaturus xaniurus*
		Pacific angel shark	*Squatina californica*
		longnose cat shark	*Apristurus kampae*
		swell shark	*Cephaloscyllium ventriosum*
Small planktivores	FPS	American shad	*Alosa sapidissima*
		Pacific argentine	*Argentina sialis*
		eulachon	*Thaleichthys pacificus*
		whitebait smelt	*Allosmerus elongatus*
		night smelt	*Spirinchus starksi*
		longfin smelt	*Spirinchus thaleichthys*

Table B3. Total catch and functional groups of all taxa identified to species from 2003 - 2010 in the West Coast Groundfish Bottom Trawl Survey.

Common name	Species	Total biomass(kg)	Proportion	Cumulative proportion	Functional group
Dover sole	*Microstomus pacificus*	232,878	0.173	0.173	Dover sole
Pacific hake	*Merluccius productus*	112,955	0.084	0.257	Hake
longspine thornyhead	*Sebastolobus altivelis*	91,279	0.068	0.325	Deep small rockfish
spiny dogfish	*Squalus acanthias*	80,435	0.060	0.385	Small demersal sharks
sablefish	*Anoplopoma fimbria*	75,144	0.056	0.441	Sablefish
chilipepper	*Sebastes goodei*	58,787	0.044	0.485	Mid-water rockfish
Pacific sanddab	*Citharichthys sordidus*	55,827	0.042	0.526	Flatfish
longnose skate	*Raja rhina*	50,675	0.038	0.564	Skates & rays
rex sole	*Glyptocephalus zachirus*	47,931	0.036	0.600	Flatfish
arrowtooth flounder	*Atheresthes stomias*	46,271	0.034	0.634	Arrowtooth
splitnose rockfish	*Sebastes diploproa*	44,957	0.033	0.667	Deep large rockfish
shortspine thornyhead	*Sebastolobus alascanus*	31,617	0.024	0.691	Deep large rockfish
Pacific grenadier	*Coryphaenoides acrolepis*	27,780	0.021	0.712	Deep demersal fish
sharpchin rockfish	*Sebastes zacentrus*	25,247	0.019	0.730	Deep small rockfish

lingcod	*Ophiodon elongatus*	24,117	0.018	0.748	Lingcod
spotted ratfish	*Hydrolagus colliei*	23,287	0.017	0.766	Small demersal sharks
English sole	*Parophrys vetulus*	23,154	0.017	0.783	Flatfish
shortbelly rockfish	*Sebastes jordani*	23,020	0.017	0.800	Shortbelly rockfish
stripetail rockfish	*Sebastes saxicola*	19,978	0.015	0.815	Shallow small rockfish
yellowtail rockfish	*Sebastes flavidus*	19,176	0.014	0.829	Mid-water rockfish
petrale sole	*Eopsetta jordani*	17,474	0.013	0.842	Large pisc. flatfish
giant grenadier	*Albatrossia pectoralis*	15,481	0.012	0.854	Deep demersal fish

Table B3 (cont.). Total catch and functional groups of all taxa identified to species from 2003 - 2010 in the West Coast Groundfish Bottom Trawl Survey.

Common name	Species	Total biomass(kg)	Proportion	Cumulative proportion	Functional group
greenstriped rockfish	*Sebastes elongatus*	15,185	0.011	0.865	Shallow small rockfish
canary rockfish	*Sebastes pinniger*	14,833	0.011	0.876	Canary
Pacific ocean perch	*Sebastes alutus*	12,331	0.009	0.885	Mid-water rockfish
darkblotched rockfish	*Sebastes crameri*	11,570	0.009	0.894	Deep small rockfish
halfbanded rockfish	*Sebastes semicinctus*	9,317	0.007	0.901	Shallow small rockfish

California slickhead	*Alepocephalus tenebrosus*	9,119	0.007	0.908	Deep demersal fish
big skate	*Raja binoculata*	9,050	0.007	0.914	Skates & rays
slender sole	*Lyopsetta exilis*	8,170	0.006	0.920	Flatfish
redstripe rockfish	*Sebastes proriger*	7,479	0.006	0.926	Shallow large rockfish
Pacific halibut	*Hippoglossus stenolepis*	6,659	0.005	0.931	Large pisc. flatfish
Bering skate	*Bathyraja kincaidii*	6,214	0.005	0.935	Skates & rays
brown cat shark	*Apristurus brunneus*	5,957	0.004	0.940	Small demersal sharks
deepsea sole	*Embassichthys bathybius*	5,409	0.004	0.944	Flatfish
white croaker	*Genyonemus lineatus*	4,631	0.003	0.947	Shallow misc. fish
bigfin eelpout	*Lycodes cortezianus*	4,091	0.003	0.950	Deep demersal fish
aurora rockfish	*Sebastes aurora*	4,044	0.003	0.953	Deep small rockfish
Pacific cod	*Gadus macrocephalus*	3,398	0.003	0.956	Hake
rosethorn rockfish	*Sebastes helvomaculatus*	3,192	0.002	0.958	Shallow small rockfish
filetail cat shark	*Parmaturus xaniurus*	2,980	0.002	0.961	Small demersal sharks
roughtail skate	*Bathyraja trachura*	2,946	0.002	0.963	Skates & rays
Pacific flatnose	*Antimora microlepis*	2,575	0.002	0.965	Deep demersal fish
bocaccio	*Sebastes paucispinis*	2,556	0.002	0.967	Mid-water rockfish

Table B3 (cont.). Total catch and functional groups of all taxa identified to species from 2003 - 2010 in the West Coast Groundfish

Bottom Trawl Survey. Note, Pacific hake YOY are identified separately older hake in the trawl survey. For all analyses here, hake YOY were combined with older individuals for a total pacific hake biomass or number.

Common name	Species	Total biomass(kg)	Proportion	Cumulative proportion	Functional group
twoline eelpout	*Bothrocara brunneum*	2,471	0.002	0.968	Deep demersal fish
blackgill rockfish	*Sebastes melanostomus*	2,411	0.002	0.970	Deep large rockfish
greenspotted rockfish	*Sebastes chlorostictus*	2,000	0.001	0.972	Shallow large rockfish
California skate	*Raja inornata*	1,984	0.001	0.973	Skates & rays
widow rockfish	*Sebastes entomelas*	1,961	0.001	0.975	Mid-water rockfish
pink seaperch	*Zalembius rosaceus*	1,611	0.001	0.976	Shelf - above 200 m
black eelpout	*Lycodes diapterus*	1,593	0.001	0.977	Deep demersal fish
Pacific pompano	*Peprilus simillimus*	1,528	0.001	0.978	Shelf - above 200 m
Pacific sleeper shark	*Somniosus pacificus*	1,428	0.001	0.979	
flathead sole	*Hippoglossoides elassodon*	1,421	0.001	0.980	Flatfish
Pacific electric ray	*Torpedo californica*	1,392	0.001	0.981	Skates & rays
black-spotted/roucheye rockfish	*Sebastes melanostictus / aleutianus*	1,358	0.001	0.982	
plainfin midshipman	*Porichthys notatus*	1,328	0.001	0.983	Shallow misc. fish

snakehead eelpout	*Lycenchelys crotalinus*	1,230	0.001	0.984	Deep demersal fish
American shad	*Alosa sapidissima*	1,179	0.001	0.985	Small planktivores
swordspine rockfish	*Sebastes ensifer*	966	0.001	0.986	Shallow small rockfish
Pacific hake YOY	*Merluccius productus YOY*	938	0.001	0.986	Hake
bank rockfish	*Sebastes rufus*	905	0.001	0.987	Deep large rockfish
squarespot rockfish	*Sebastes hopkinsi*	896	0.001	0.988	Mid-water rockfish
northern anchovy	*Engraulis mordax*	799	0.001	0.988	
pygmy rockfish	*Sebastes wilsoni*	783	0.001	0.989	Shallow small rockfish

Table B3 (cont.). Total catch and functional groups of all taxa identified to species from 2003 - 2010 in the West Coast Groundfish Bottom Trawl Survey.

Common name	Species	Total biomass(kg)	Proportion	Cumulative proportion	Functional group
yelloweye rockfish	*Sebastes ruberrimus*	765	0.001	0.990	Yelloweye rockfish
blackbelly eelpout	*Lycodes pacificus*	754	0.001	0.990	Deep demersal fish
jack mackerel	*Trachurus symmetricus*	736	0.001	0.991	Large planktivores
redbanded rockfish	*Sebastes babcocki*	730	0.001	0.991	Deep large rockfish
blacktail snailfish	*Careproctus melanurus*	699	0.001	0.992	Deep demersal fish

California scorpionfish	*Scorpaena guttata*	649	0.000	0.992	
curlfin sole	*Pleuronichthys decurrens*	637	0.000	0.993	Flatfish
southern rock sole	*Lepidopsetta bilineata*	590	0.000	0.993	Flatfish
Pacific herring	*Clupea pallasi*	465	0.000	0.993	
silvergray rockfish	*Sebastes brevispinis*	411	0.000	0.994	Shallow large rockfish
threadfin sculpin	*Icelinus filamentosus*	402	0.000	0.994	Shallow misc. fish
Bat Ray	*Myliobatis californicus*	324	0.000	0.994	Skates & rays
greenblotched rockfish	*Sebastes rosenblatti*	319	0.000	0.995	Shallow large rockfish
copper rockfish	*Sebastes caurinus*	313	0.000	0.995	Shallow large rockfish
starry flounder	*Platichthys stellatus*	303	0.000	0.995	Flatfish
Pacific angel shark	*Squatina californica*	256	0.000	0.995	Small demersal sharks
California halibut	*Paralichthys californicus*	252	0.000	0.995	Large pisc. flatfish
longnose cat shark	*Apristurus kampae*	245	0.000	0.996	Small demersal sharks
California grenadier	*Nezumia stelgidolepis*	232	0.000	0.996	Deep demersal fish
deepsea skate	*Bathyraja abyssicola*	225	0.000	0.996	Skates & rays
cowcod	*Sebastes levis*	222	0.000	0.996	Cowcod
soupfin shark	*Galeorhinus galeus*	210	0.000	0.996	Pelagic sharks
black hagfish	*Eptatretus deani*	207	0.000	0.996	Deep demersal fish

Table B3 (cont.). Total catch and functional groups of all taxa identified to species from 2003 - 2010 in the West Coast Groundfish Bottom Trawl Survey.

Common name	Species	Total biomass(kg)	Proportion	Cumulative proportion	Functional group
starry skate	*Raja stellulata*	206	0.000	0.997	Skates & rays
bigmouth sole	*Hippoglossina stomata*	203	0.000	0.997	
Pacific tomcod	*Microgadus proximus*	196	0.000	0.997	Hake
threadfin slickhead	*Talismania bifurcata*	186	0.000	0.997	Deep demersal fish
brown smoothhound	*Mustelus henlei*	157	0.000	0.997	
hornyhead turbot	*Pleuronichthys verticalis*	154	0.000	0.997	Flatfish
longspine combfish	*Zaniolepis latipinnis*	147	0.000	0.997	Shallow misc. fish
sand sole	*Psettichthys melanostictus*	142	0.000	0.997	Flatfish
arrowtail	*Melanonus zugmayeri*	134	0.000	0.998	
smooth grenadier	*Nezumia liolepis*	129	0.000	0.998	Deep demersal fish
kelp greenling	*Hexagrammos decagrammus*	122	0.000	0.998	Shallow large rockfish
shiner perch	*Cymatogaster aggregata*	122	0.000	0.998	Shelf - above 200 m
honeycomb rockfish	*Sebastes umbrosus*	122	0.000	0.998	Shallow small rockfish

walleye pollock	*Theragra chalcogramma*	119	0.000	0.998	Hake
shortraker rockfish	*Sebastes borealis*	116	0.000	0.998	Mid-water rockfish
speckled rockfish	*Sebastes ovalis*	114	0.000	0.998	Mid-water rockfish
Aleutian skate	*Bathyraja aleutica*	108	0.000	0.998	Skates & rays
yellowmouth rockfish	*Sebastes reedi*	104	0.000	0.998	Mid-water rockfish
longfin sanddab	*Citharichthys xanthostigma*	100	0.000	0.998	Flatfish
chinook salmon	*Oncorhynchus tshawytscha*	91	0.000	0.998	

Table B3 (cont.). Total catch and functional groups of all taxa identified to species from 2003 - 2010 in the West Coast Groundfish Bottom Trawl Survey.

Common name	Species	Total biomass(kg)	Proportion	Cumulative proportion	Functional group
sixgill shark	*Hexanchus griseus*	90	0.000	0.999	Large demersal sharks
butter sole	*Isopsetta isolepis*	86	0.000	0.999	Flatfish
Pacific hagfish	*Eptatretus stouti*	76	0.000	0.999	Deep demersal fish
ragfish	*Icosteus aenigmaticus*	68	0.000	0.999	Deep demersal fish
California lizardfish	*Synodus lucioceps*	68	0.000	0.999	

Pacific argentine	*Argentina sialis*	67	0.000	0.999	Small planktivores
barred sand bass	*Paralabrax nebulifer*	67	0.000	0.999	Shallow large rockfish
quillback rockfish	*Sebastes maliger*	66	0.000	0.999	Shallow large rockfish
swell shark	*Cephaloscyllium ventriosum*	65	0.000	0.999	Small demersal sharks
Pacific sardine	*Sardinops sagax*	65	0.000	0.999	
shortspine combfish	*Zaniolepis frenata*	64	0.000	0.999	Shallow misc. fish
brown rockfish	*Sebastes auriculatus*	60	0.000	0.999	Shallow large rockfish
wolf-eel	*Anarrhichthys ocellatus*	59	0.000	0.999	Deep demersal fish
blackfin snailfish	*Careproctus cypselurus*	57	0.000	0.999	Deep demersal fish
rosy rockfish	*Sebastes rosaceus*	53	0.000	0.999	Shallow small rockfish
flag rockfish	*Sebastes rubrivinctus*	53	0.000	0.999	Shallow large rockfish
Pacific staghorn sculpin	*Leptocottus armatus*	48	0.000	0.999	Shallow misc. fish
eulachon	*Thaleichthys pacificus*	41	0.000	0.999	Small planktivores
spotted cusk-eel	*Chilara taylori*	40	0.000	0.999	Deep demersal fish
whitebait smelt	*Allosmerus elongatus*	39	0.000	0.999	Small planktivores
pink rockfish	*Sebastes eos*	38	0.000	0.999	Shallow large rockfish
gray smoothhound	*Mustelus californicus*	37	0.000	0.999	

Table B3 (cont.). Total catch and functional groups of all taxa identified to species from 2003 - 2010 in the West Coast Groundfish Bottom Trawl Survey.

Common name	Species	Total biomass(kg)	Proportion	Cumulative proportion	Functional group
popeye grenadier	*Coryphaenoides cinereus*	37	0.000	0.999	Deep demersal fish
giant wrymouth	*Cryptacanthodes giganteus*	34	0.000	0.999	Shallow misc. fish
Pacific viperfish	*Chauliodus macouni*	34	0.000	1.000	Deep vertical migrators
paperbone cusk-eel	*Lamprogrammus niger*	33	0.000	1.000	Deep demersal fish
blob sculpin	*Psychrolutes phrictus*	33	0.000	1.000	Shallow misc. fish
pinkrose rockfish	*Sebastes simulator*	32	0.000	1.000	
chub mackerel	*Scomber japonicus*	31	0.000	1.000	
king-of-the-salmon	*Trachipterus altivelis*	30	0.000	1.000	Shallow misc. fish
calico rockfish	*Sebastes dalli*	27	0.000	1.000	Shallow small rockfish
hundred fathom codling	*Physiculus rastrelliger*	26	0.000	1.000	Deep demersal fish
blue shark	*Prionace glauca*	23	0.000	1.000	Pelagic sharks
longfin dragonfish	*Tactostoma macropus*	19	0.000	1.000	Deep vertical migrators
combtooth dogfish	*Centroscyllium nigrum*	18	0.000	1.000	

smooth stargazer	*Kathetostoma averruncus*	18	0.000	1.000	
blackbelly dragonfish	*Stomias atriventer*	17	0.000	1.000	Deep vertical migrators
robust blacksmelt	*Bathylagus milleri*	17	0.000	1.000	
starry rockfish	*Sebastes constellatus*	17	0.000	1.000	Shallow large rockfish
California smoothtounge	*Leuroglossus stilbius*	17	0.000	1.000	Deep demersal fish
blackfin poacher	*Bathyagonus nigripinnis*	16	0.000	1.000	Deep demersal fish
bull sculpin	*Enophrys taurina*	15	0.000	1.000	Shallow misc. fish
fantail sole	*Xystreurys liolepis*	14	0.000	1.000	Flatfish
blue rockfish	*Sebastes mystinus*	13	0.000	1.000	Shallow large rockfish

Table B3 (cont.). Total catch and functional groups of all taxa identified to species from 2003 - 2010 in the West Coast Groundfish Bottom Trawl Survey.

Common name	Species	Total biomass(kg)	Proportion	Cumulative proportion	Functional group
night smelt	*Spirinchus starksi*	12	0.000	1.000	Small planktivores
spotted turbot	*Pleuronichthys ritteri*	12	0.000	1.000	Flatfish
Pacific blacksmelt	*Bathylagus pacificus*	11	0.000	1.000	
freckled rockfish	*Sebastes lentiginosus*	10	0.000	1.000	

lumptail searobin	*Prionotus stephanophrys*	8	0.000	1.000	
Mexican rockfish	*Sebastes macdonaldi*	8	0.000	1.000	Shallow large rockfish
spotfin surfperch	*Hyperprosopon anale*	6	0.000	1.000	Shelf - above 200 m
silver scabbardfish	*Lepidopus xantusi*	6	0.000	1.000	
northern rock sole	*Lepidopsetta polyxystra*	6	0.000	1.000	
tiger rockfish	*Sebastes nigrocinctus*	6	0.000	1.000	Shallow large rockfish
fangtooth	*Anoplogaster cornuta*	5	0.000	1.000	Deep demersal fish
blacktip poacher	*Xeneretmus latifrons*	5	0.000	1.000	Deep demersal fish
cabezon	*Scorpaenichthys marmoratus*	5	0.000	1.000	Large demersal predators
broadfin sculpin	*Bolinia euryptera*	5	0.000	1.000	
shining loosejaw	*Aristostomias scintillans*	4	0.000	1.000	Deep vertical migrators
crested bigscale	*Poromitra crassiceps*	4	0.000	1.000	Deep vertical migrators
fringed sculpin	*Icelinus fimbriatus*	4	0.000	1.000	
red snailfish	*Paraliparis dactylosus*	4	0.000	1.000	Deep demersal fish
ocean sunfish	*Mola mola*	4	0.000	1.000	
black rockfish	*Sebastes melanops*	4	0.000	1.000	Shallow large rockfish
banded guitarfish	*Zapteryx exasperata*	4	0.000	1.000	
surf smelt	*Hypomesus pretiosus*	4	0.000	1.000	

Table B3 (cont.). Total catch and functional groups of all taxa identified to species from 2003 - 2010 in the West Coast Groundfish Bottom Trawl Survey.

Common name	Species	Total biomass(kg)	Proportion	Cumulative proportion	Functional group
warty poacher	*Chesnonia verrucosa*	4	0.000	1.000	Deep demersal fish
northern lampfish	*Stenobrachius leucopsarus*	4	0.000	1.000	Deep vertical migrators
bronzespotted rockfish	*Sebastes gilli*	3	0.000	1.000	Shallow large rockfish
black scabbardfish	*Aphanopus carbo*	3	0.000	1.000	Deep vertical migrators
barred surfperch	*Amphistichus argenteus*	3	0.000	1.000	Shelf - above 200 m
smalldisk snailfish	*Careproctus gilberti*	3	0.000	1.000	Deep demersal fish
shining tubeshoulder	*Sagamichthys abei*	2	0.000	1.000	Deep vertical migrators
roughback sculpin	*Chitonotus pugetensis*	2	0.000	1.000	
bigeye poacher	*Bathyagonus pentacanthus*	2	0.000	1.000	Deep demersal fish
slim sculpin	*Radulinus asprellus*	2	0.000	1.000	Shallow misc. fish
Pacific blackdragon	*Idiacanthus antrostomus*	2	0.000	1.000	Deep vertical migrators
rosy snailfish	*Paraliparis rosaceus*	2	0.000	1.000	Deep demersal fish
red Irish lord	*Hemilepidotus*	2	0.000	1.000	Large demersal predators

	hemilepidotus				
buffalo sculpin	*Enophrys bison*	2	0.000	1.000	Shallow misc. fish
blackmouth eelpout	*Lycodapus fierasfer*	2	0.000	1.000	Deep demersal fish
arctic staghorn sculpin	*Gymnocanthus tricuspis*	2	0.000	1.000	
humpback snailfish	*Elassodiscus caudatus*	2	0.000	1.000	Deep demersal fish
sawtooth eel	*Serrivomer sector*	2	0.000	1.000	Deep demersal fish
medusafish	*Icichthys lockingtoni*	2	0.000	1.000	Shallow misc. fish
pile perch	*Damalichthys vacca*	2	0.000	1.000	
barreleye	*Macropinna microstoma*	2	0.000	1.000	Deep vertical migrators

Table B3 (cont.). Total catch and functional groups of all taxa identified to species from 2003 - 2010 in the West Coast Groundfish Bottom Trawl Survey.

Common name	Species	Total biomass(kg)	Proportion	Cumulative proportion	Functional group
gopher rockfish	*Sebastes carnatus*	2	0.000	1.000	Shallow small rockfish
northern smoothtongue	*Leuroglossus schmidti*	2	0.000	1.000	Deep demersal fish
blackfin sculpin	*Malacocottus kincaidi*	2	0.000	1.000	Shallow misc. fish
northern ronquil	*Ronquilus jordani*	2	0.000	1.000	

California headlightfish	*Diaphus theta*	2	0.000	1.000	Deep vertical migrators
Pacific longnose chimaera	*Harriotta raleighana*	2	0.000	1.000	
red brotula	*Brosmophycis marginata*	2	0.000	1.000	
longnose lancetfish	*Alepisaurus ferox*	2	0.000	1.000	Deep vertical migrators
sunset rockfish	*Sebastes crocotulus*	2	0.000	1.000	
brown Irish lord	*Hemilepidotus spinosus*	2	0.000	1.000	Large demersal predators
dusky sculpin	*Icelinus burchami*	2	0.000	1.000	Shallow misc. fish
black swallower	*Chiasmodon niger*	2	0.000	1.000	Deep demersal fish
coho salmon	*Oncorhynchus kisutch*	1	0.000	1.000	
longfin smelt	*Spirinchus thaleichthys*	1	0.000	1.000	Small planktivores
rubynose brotula	*Cataetyx rubrirostris*	1	0.000	1.000	Deep demersal fish
blackline snipe eel	*Avocettina infans*	1	0.000	1.000	Deep demersal fish
white surfperch	*Phanerodon furcatus*	1	0.000	1.000	Shelf - above 200 m
swellhead snailfish	*Paraliparis cephalus*	1	0.000	1.000	Deep demersal fish
duckbill barracudina	*Magnisudis atlantica*	1	0.000	1.000	Deep vertical migrators
sharpnose sculpin	*Clinocottus acuticeps*	1	0.000	1.000	Shallow misc. fish
soft eelpout	*Bothrocara molle*	1	0.000	1.000	Deep demersal fish

Table B3 (cont.). Total catch and functional groups of all taxa identified to species from 2003 - 2010 in the West Coast Groundfish

Bottom Trawl Survey.

Common name	Species	Total biomass(kg)	Proportion	Cumulative proportion	Functional group
longfin sculpin	*Jordania zonope*	1	0.000	1.000	
dogface witch-eel	*Facciolella gilbertii*	1	0.000	1.000	
Panama snaggletooth	*Borostomias panamensis*	1	0.000	1.000	
broadfin snailfish	*Paraliparis pectoralis*	1	0.000	1.000	Deep demersal fish
slender hatchetfish	*Argyropelecus affinis*	1	0.000	1.000	Deep vertical migrators
sharpchin slickhead	*Bajacalifornia burragei*	1	0.000	1.000	
whipnose	*Gigantactis vanhoeffeni*	1	0.000	1.000	
olive rockfish	*Sebastes serranoides*	1	0.000	1.000	Shallow large rockfish
northern pearleye	*Benthalbella dentata*	1	0.000	1.000	Deep vertical migrators
highsnout bigscale	*Melamphaes lugubris*	1	0.000	1.000	Deep vertical migrators
northern spearnose poacher	*Agonopsis vulsa*	1	0.000	1.000	Deep demersal fish
slender snipe eel	*Nemichthys scolopaceus*	1	0.000	1.000	Deep demersal fish
Pacific lamprey	*Lampetra tridentata*	1	0.000	1.000	
blackchin	*Scopelengys tristis*	1	0.000	1.000	Deep demersal fish

slender codling	*Halargyreus johnsoni*	1	0.000	1.000	
deepwater eelpout	*Lycodapus endemoscotus*	1	0.000	1.000	Deep demersal fish
spotfin sculpin	*Icelinus tenuis*	1	0.000	1.000	Shallow misc. fish
rainbow smelt	*Osmerus mordax*	1	0.000	1.000	
broadfin lanternfish	*Nannobrachium ritteri*	1	0.000	1.000	
scabbardfish	*Lepidopus fitchi*	1	0.000	1.000	
filamented grenadier	*Coryphaenoides filifer*	0	0.000	1.000	Deep demersal fish
longnose snailfish	*Rhinoliparis barbulifer*	0	0.000	1.000	Deep demersal fish

Table B3 (cont.). Total catch and functional groups of all taxa identified to species from 2003 - 2010 in the West Coast Groundfish Bottom Trawl Survey.

Common name	Species	Total biomass(kg)	Proportion	Cumulative proportion	Functional group
blue lanternfish	*Tarletonbeania crenularis*	0	0.000	1.000	Deep vertical migrators
queenfish	*Seriphus politus*	0	0.000	1.000	Shallow misc. fish
pallid eelpout	*Lycodapus mandibularis*	0	0.000	1.000	Deep demersal fish
shoulder spot grenadier	*Coelorinchus scaphopsis*	0	0.000	1.000	
splitnose searobin	*Bellator xenisma*	0	0.000	1.000	

manefish	*Caristius macropus*	0	0.000	1.000	
Kamchatka eelpout	*Lycenchelys camchatica*	0	0.000	1.000	Deep demersal fish
California lanternfish	*Symbolophorus californiensis*	0	0.000	1.000	
smooth dreamer	*Chaenophryne draco*	0	0.000	1.000	Deep demersal fish
sharpnose surfperch	*Phanerodon atripes*	0	0.000	1.000	
Puget Sound rockfish	*Sebastes emphaeus*	0	0.000	1.000	Shallow small rockfish
pale snipe eel	*Nemichthys larseni*	0	0.000	1.000	
	Podothecus acipenserinus	0	0.000	1.000	
	Venefica tentaculata	0	0.000	1.000	
redtail surfperch	*Amphistichus rhodoterus*	0	0.000	1.000	Shelf - above 200 m
smootheye poacher	*Xeneretmus leiops*	0	0.000	1.000	
spinyhead sculpin	*Dasycottus setiger*	0	0.000	1.000	Shallow misc. fish
common blackdevil	*Melanocetus johnsonii*	0	0.000	1.000	Deep demersal fish
sailfin sculpin	*Nautichthys oculofasciatus*	0	0.000	1.000	Shallow misc. fish
crossthroat snipe eel	*Serrivomer jesperseni*	0	0.000	1.000	
spiny dreamer	*Oneirodes acanthias*	0	0.000	1.000	

Table B3 (cont.). Total catch and functional groups of all taxa identified to species from 2003 - 2010 in the West Coast Groundfish

Bottom Trawl Survey.

Common name	Species	Total biomass(kg)	Proportion	Cumulative proportion	Functional group
longspine hatchetfish	*Sternoptyx diaphana*	0	0.000	1.000	Deep vertical migrators
ribbon barracudina	*Arctozenus risso*	0	0.000	1.000	
	Maulisia mauli	0	0.000	1.000	
smalleye squaretail	*Tetragonurus cuvieri*	0	0.000	1.000	
California toungefish	*Symphurus atricauda*	0	0.000	1.000	Flatfish
threadfin cusk-eel	*Dicrolene filamentosa*	0	0.000	1.000	Deep demersal fish
bluethroat argentine	*Nansenia candida*	0	0.000	1.000	
triplewart sea devil	*Cryptopsaras couesii*	0	0.000	1.000	
slim snailfish	*Rhinoliparis attenuatus*	0	0.000	1.000	
scaly paperbone	*Scopelosaurus harryi*	0	0.000	1.000	Deep vertical migrators
shortnose swallower	*Kali indica*	0	0.000	1.000	
highfin dragonfish	*Bathophilus flemingi*	0	0.000	1.000	Deep vertical migrators
	Oneirodes thompsoni	0	0.000	1.000	
whitebarred prickleback	*Poroclinus rothrocki*	0	0.000	1.000	Shallow misc. fish

wattled eelpout	*Lycodes palearis*	0	0.000	1.000	Deep demersal fish
grunt sculpin	*Rhamphocottus richardsoni*	0	0.000	1.000	
slender barracudina	*Lestidiops ringens*	0	0.000	1.000	Deep vertical migrators
rubberlip surfperch	*Rhacochilus toxotes*	0	0.000	1.000	Shelf - above 200 m
Fanfin seadevil	*Caulophryne jordani*	0	0.000	1.000	
persimmon eelpout	*Maynea californica*	0	0.000	1.000	
tree rockfish	*Sebastes serriceps*	0	0.000	1.000	
Alaska snailfish	*Careproctus colletti*	0	0.000	1.000	Deep demersal fish

Table B3 (cont.). Total catch and functional groups of all taxa identified to species from 2003 - 2010 in the West Coast Groundfish Bottom Trawl Survey.

Common name	Species	Total biomass(kg)	Proportion	Cumulative proportion	Functional group
striped surfperch	*Embiotoca lateralis*	0	0.000	1.000	Shelf - above 200 m
blacklip snailfish	*Elassodiscus tremebundus*	0	0.000	1.000	
	Bajacalifornia erimoensis	0	0.000	1.000	
slipskin snailfish	*Liparis fucensis*	0	0.000	1.000	

Pacific sandfish	*Trichodon trichodon*	0	0.000	1.000	
basketweave cusk-eel	*Ophidion scrippsae*	0	0.000	1.000	Deep demersal fish
roughspine sculpin	*Triglops macellus*	0	0.000	1.000	Shallow misc. fish
Pacific sand lance	*Ammodytes hexapterus*	0	0.000	1.000	Deep vertical migrators
bearded eelpout	*Lycodema barbatum*	0	0.000	1.000	
midwater eelpout	*Melanostigma pammelas*	0	0.000	1.000	
flabby sculpin	*Zesticelus profundorum*	0	0.000	1.000	Shallow misc. fish
needletooth swallower	*Kali normani*	0	0.000	1.000	
spinynose Sculpin	*Radulinus taylori*	0	0.000	1.000	
southern spearnose poacher	*Agonopsis sterletus*	0	0.000	1.000	
speckled sanddab	*Citharichthys stigmaeus*	0	0.000	1.000	Flatfish
dwarf wrymouth	*Lyconectes aleutensis*	0	0.000	1.000	
abyssal snailfish	*Careproctus ovigerum*	0	0.000	1.000	
javelin spookfish	*Bathylychnops exilis*	0	0.000	1.000	
thornback sculpin	*Paricelinus hopliticus*	0	0.000	1.000	Shallow misc. fish
showy snailfish	*Liparis pulchellus*	0	0.000	1.000	

Table B3 (cont.). Total catch and functional groups of all taxa identified to species from 2003 - 2010 in the West Coast Groundfish Bottom Trawl Survey.

Common name	Species	Total biomass(kg)	Proportion	Cumulative proportion	Functional group
pygmy poacher	*Odontopyxis trispinosa*	0	0.000	1.000	
looseskin eelpout	*Lycodapus dermatinus*	0	0.000	1.000	Deep demersal fish
tadpole snailfish	*Nectoliparis pelagicus*	0	0.000	1.000	Deep demersal fish
tropical hatchetfish	*Argyropelecus lychnus*	0	0.000	1.000	Deep vertical migrators
	Howella sherborni	0	0.000	1.000	
tadpole sculpin	*Psychrolutes paradoxus*	0	0.000	1.000	
northern sculpin	*Icelinus borealis*	0	0.000	1.000	Shallow misc. fish
pelagic basset	*Howella brodiei*	0	0.000	1.000	
striped kelpfish	*Gibbonsia metzi*	0	0.000	1.000	
shortfin eelpout	*Lycodes brevipes*	0	0.000	1.000	Deep demersal fish
	Chaenophryne longiceps	0	0.000	1.000	
topsmelt	*Atherinops affinis*	0	0.000	1.000	

Table B4. Species, functional groups used in the calculation of prey and predator indices of each focal species. For prey items, weights are the proportion by weight of diet based on analysis of gut contents {Buchanan, pers. comm.., Dufault, 2009 #449}. For prey, weights are the mean of juvenile and adult diets. Predator weights are proportion of total mortality caused by that predator as estimated in the Atlantis model of the California Current Ecosystem. Full/reduced indicates which species were included in the reduced model or only in the full models for estimating prey and predator indices. GFS indicate the West Coast Groundfish Bottom Trawl Survey. "bio." indicates catch per unit effort (CPUE) in biomass per km2. 'no.' indicates CPUE in number per km2. 'SA' indicates stock assessment.

Time series	Functional group	Reduced/ Full	Bocaccio		Canary rockfish		Hake		Sablefish	
			Predators	Prey	Predators	Prey	Predators	Prey	Predators	Prey
Combined hake	Hake	full		0.385			0.119			
Pacific hake - GFS bio.	Hake	reduced		0.385			0.119			
Pacific hake - GFS no.	Hake	reduced		0.385			0.119			
Pacific hake - SA	Hake	full		0.385			0.119			
Arrowtooth - GFS bio.	Arrowtooth	reduced	0.006							0.006
Arrowtooth - GFS no.	Arrowtooth	reduced	0.006							0.006
Arrowtooth - SA	Arrowtooth	full	0.006							0.006
Dover sole - GFS bio.	Small flatfish	reduced		0.054				0.001		
Dover sole - GFS no.	Small flatfish	reduced		0.054				0.001		
Dover sole - SA	Small flatfish	full		0.054				0.001		
Small flatfish	Small flatfish	reduced		0.054				0.001		
Sablefish - GFS bio.	Sablefish	reduced	0.012		0.015					0.012

Sablefish - GFS no.	Sablefish	reduced	0.012		0.015					0.012
Sablefish - SA	Sablefish	full	0.012		0.015					0.012
Spiny dogfish - GFS bio.	Dogfish	reduced			0.244		0.406			
Spiny dogfish - GFS no.	Dogfish	reduced			0.244		0.406			
Spiny dogfish - SA	Dogfish	full			0.244		0.406			
LargeDemersalSharks	Large demersal Sharks	reduced								
Skates and rays	Skates	reduced	0.084		0.058		0.009		0.587	0.084
Lingcod - GFS bio.	Lingcod	reduced	0.152		0.536		0.002			0.152
Lingcod - GFS no.	Lingcod	reduced	0.152		0.536		0.002			0.152

Table B4 (cont.). Species, functional groups used in the calculation of prey and predator indices of each focal species. For prey items, weights are the proportion by weight of diet based on analysis of gut contents {Buchanan, pers. comm.., Dufault, 2009 #449}. For prey, weights are the mean of juvenile and adult diets. Predator weights are proportion of total mortality caused by that predator as estimated in the Atlantis model of the California Current Ecosystem. Full/reduced indicates which species were included in the reduced model or only in the full models for estimating prey and predator indices. GFS indicate the West Coast Groundfish Bottom Trawl Survey. "bio." indicates catch per unit effort (CPUE) in biomass per km2. 'no.' indicates CPUE in number per km2. 'SA' indicates stock assessment.

		Reduced/ Full	Bocaccio		Canary rockfish		Hake		Sablefish	
Time series	Functional group		Predators	Prey	Predators	Prey	Predators	Prey	Predators	Prey
Lingcod - SA north	Lingcod	full	0.152		0.536		0.002			0.152
Lincod - SA south	Lingcod	full	0.152		0.536		0.002			0.152

Herring	Small planktivores	reduced		0.042	0.002	0.142	
Sardines	Small planktivores	reduced		0.042	0.002	0.142	
Small planktivores	Small planktivores	reduced		0.042	0.002	0.142	
Large planktivores	Large planktivores	reduced				0.006	
Canary rockfish - GFS bio.	Canary rockfish	reduced					
Canary rockfish - GFS no.	Canary rockfish	reduced					
Canary - SA	Canary rockfish	full					
Cowcod - GFS bio.	Cowcod	reduced	0.003				0.003
Cowcod - GFS no.	Cowcod	reduced	0.003				0.003
Cowcod - SA	Cowcod	full	0.003				0.003
Yelloweye rockfish - GFS bio.	Yelloweye	reduced	0.003				0.003
Yelloweye rockfish - GFS no.	Yelloweye	reduced	0.003				0.003
Yelloweye - SA	Yelloweye	full	0.003				0.003
Small shallow rockfish	Shallow small rockfish	reduced		0.518			
Shallow large rockfish	Shallow large	reduced					

Table B4 (cont.). Species, functional groups used in the calculation of prey and predator indices of each focal species. For prey items, weights are the proportion by weight of diet based on analysis of gut contents {Buchanan, pers. comm.., Dufault, 2009 #449}. For prey, weights are the mean of juvenile and adult diets. Predator weights are proportion of total mortality caused by that predator as estimated in the Atlantis model of the California Current Ecosystem. Full/reduced indicates which species were included in the reduced model or only in the full models for estimating prey and predator indices. GFS indicate the West Coast Groundfish Bottom Trawl Survey. "bio." indicates catch per unit effort (CPUE) in biomass per km2. 'no.' indicates CPUE in number per km2. 'SA' indicates stock assessment.

		Reduced/ Full	Bocaccio		Canary rockfish		Hake		Sablefish	
Time series	Functional group		Predators	Prey	Predators	Prey	Predators	Prey	Predators	Prey
Mid-water rockfish	Mid-water rockfish	reduced	0.613				0.228			0.613
Deep small rockfish	Deep small rockfish	reduced								
Deep large rockfish	deep large rockfish	reduced	0.088		0.029		0.214			0.088
Juvenile rockfish	Juvenile rockfish	reduced				0.100				
Rockfish larvae - north	Juvenile rockfish	reduced				0.100				
Rockfish larvae - core	Juvenile rockfish	reduced				0.100				
Rockfish larvae - south	Juvenile rockfish	reduced				0.100				
Shallow misc fish	Shallow misc. fish	reduced								
Large demersal predators	Large demersal predators	reduced								

Deep demersal fish	Deep demersal fish	reduced								
Deep vertical migrators	Deep vertical migrators	reduced				0.010		0.038		
Chinook - Klamath in river run size	Salmon	reduced			0.073		0.004			
Chinook - Sacramento escapement	Salmon	reduced			0.073		0.004			
Chinook - council area catch	Salmon	reduced			0.073		0.004			
Coho - OPI index	Salmon	reduced			0.073		0.004			
Coho- council area catch	Salmon	reduced			0.073		0.004			
Dungeness crab - GFS bio.	Megazoobenthose	reduced		0.000				0.001	0.072	

Table B4 (cont.). Species, functional groups used in the calculation of prey and predator indices of each focal species. For prey items, weights are the proportion by weight of diet based on analysis of gut contents {Buchanan, pers. comm.., Dufault, 2009 #449}. For prey, weights are the mean of juvenile and adult diets. Predator weights are proportion of total mortality caused by that predator as estimated in the Atlantis model of the California Current Ecosystem. Full/reduced indicates which species were included in the reduced model or only in the full models for estimating prey and predator indices. GFS indicate the West Coast Groundfish Bottom Trawl Survey. "bio." indicates catch per unit effort (CPUE) in biomass per km2. 'no.' indicates CPUE in number per km2. 'SA' indicates stock assessment.

		Reduced/ Full	Bocaccio		Canary rockfish		Hake		Sablefish	
Time series	Functional group		Predators	Prey	Predators	Prey	Predators	Prey	Predators	Prey
Dungeness crab	Megazoobenthose	reduced		0.000				0.001	0.072	

Bairds tanner crab - GFS bio.	Megazoobenthos e	reduced	0.000			0.001	0.072
Bairds tanner crab	Megazoobenthos e	reduced	0.000			0.001	0.072
Grooved Tanner crab - GFS bio.	Megazoobenthos e	reduced	0.000			0.001	0.072
Grooved Tanner crab	Megazoobenthos e	reduced	0.000			0.001	0.072
Pink shrimp (number)	BenHerbGrazers	reduced			0.014	0.017	
Pink shrimp (CPUE)	BenHerbGrazers	reduced			0.014	0.017	
Stellar sea lion (all regions)	Pnnipeds	reduced		0.046			0.233
Stellar sea lion (eastern US stock - BC)	Pinnipeds	full		0.046			0.233
Stellar sea lion (eastern US stock - Southeast AK)	Pinnipeds	full		0.046			0.233
Stellar sea lion (eastern US stock - No.CA/OR)	Pinnipeds	full		0.046			0.233
Stellar sea lion (eastern US stock - Central CA)	Pinnipeds	full		0.046			0.233
Harbor seal (WA stock)	Pinnipeds	reduced		0.046			0.233
Harbor seal (OR stock)	pinnipeds	reduced		0.046			
Harbor seal (CA stock)	pinnipeds	reduced		0.046			0.233

Northern fur seal	pinnipeds	reduced			0.046				0.233	
Northern elephant seal (California breeding stock)	pinnipeds	reduced			0.046				0.233	
California sea lion	pinnipeds	reduced			0.046				0.233	

Table B4 (cont.). Species, functional groups used in the calculation of prey and predator indices of each focal species. For prey items, weights are the proportion by weight of diet based on analysis of gut contents {Buchanan, pers. comm.., Dufault, 2009 #449}. For prey, weights are the mean of juvenile and adult diets. Predator weights are proportion of total mortality caused by that predator as estimated in the Atlantis model of the California Current Ecosystem. Full/reduced indicates which species were included in the reduced model or only in the full models for estimating prey and predator indices. GFS indicate the West Coast Groundfish Bottom Trawl Survey. "bio." indicates catch per unit effort (CPUE) in biomass per km2. 'no.' indicates CPUE in number per km2. 'SA' indicates stock assessment.

		Reduced/ Full	Bocaccio		Canary rockfish		Hake		Sablefish	
Time series	Functional group		Predators	Prey	Predators	Prey	Predators	Prey	Predators	Prey
Southern resident orca	toothed whales	reduced					0.010			
Gelatinous zooplankton Central OR	Gelatinous zooplankton	reduced						0.104		
Gelatinous zooplankton Central CA	Gelatinous zooplankton	reduced						0.104		
Gelatinous zooplankton Southern CA	Gelatinous zooplankton	reduced						0.104		
Mesozooplankton Central OR	Mesozooplankton	reduced						0.075		

All copepods Central CA	Mesozooplankton	reduced		0.075
All copepods Southern CA	Mesozooplankton	reduced		0.075
Transition copepods Central CA	Mesozooplankton	reduced		0.075
Transition copepods Southern CA	Mesozooplankton	reduced		0.075
Northern copepods Central OR	Mesozooplankton	reduced		0.075
Euphausiid adults Central CA	Large zooplankton	reduced	0.629	0.793
Euphausiid adults Southern CA	Large zooplankton	reduced	0.629	0.793
Euphausiid juveniles and eggs Central OR	Large zooplankton	reduced	0.629	0.793

LIST OF APPENDIX B. FIGURES

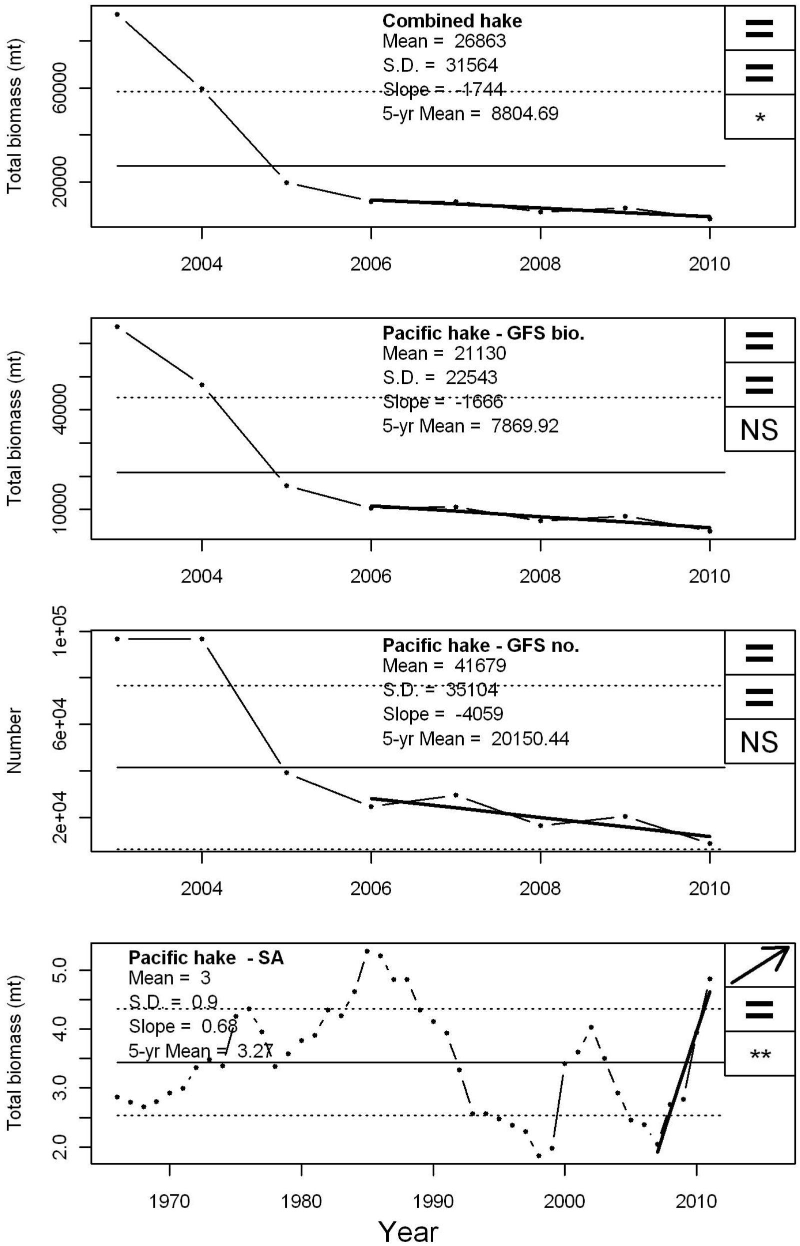


Figure B1. Hake time series used in the analyses. The solid horizontal line is the mean for the full time series. Dotted lines are +/-1 S.D.. The trend line (thick black) is the over the last five years of data. Mean and S.D. are the mean and standard deviation of the full time series. Slope and 5-yr mean are for the five year trend. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

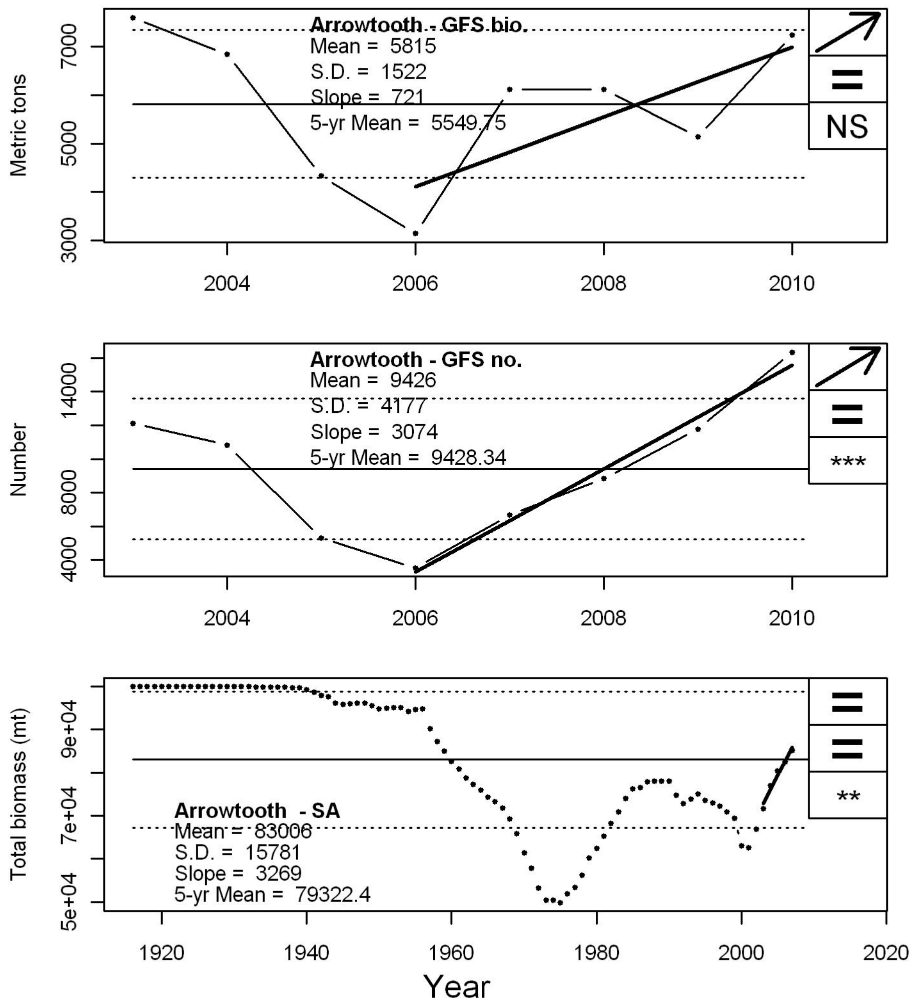


Figure B2. Arrowtooth flounder time series used in the analyses. The solid horizontal line is the mean for the full time series. Dotted lines are +/-1 S.D.. The trend line (thick black) is the over the last five years of data. Mean and S.D. are the mean and standard deviation of the full time series. Slope and 5-yr mean are for the five year trend. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

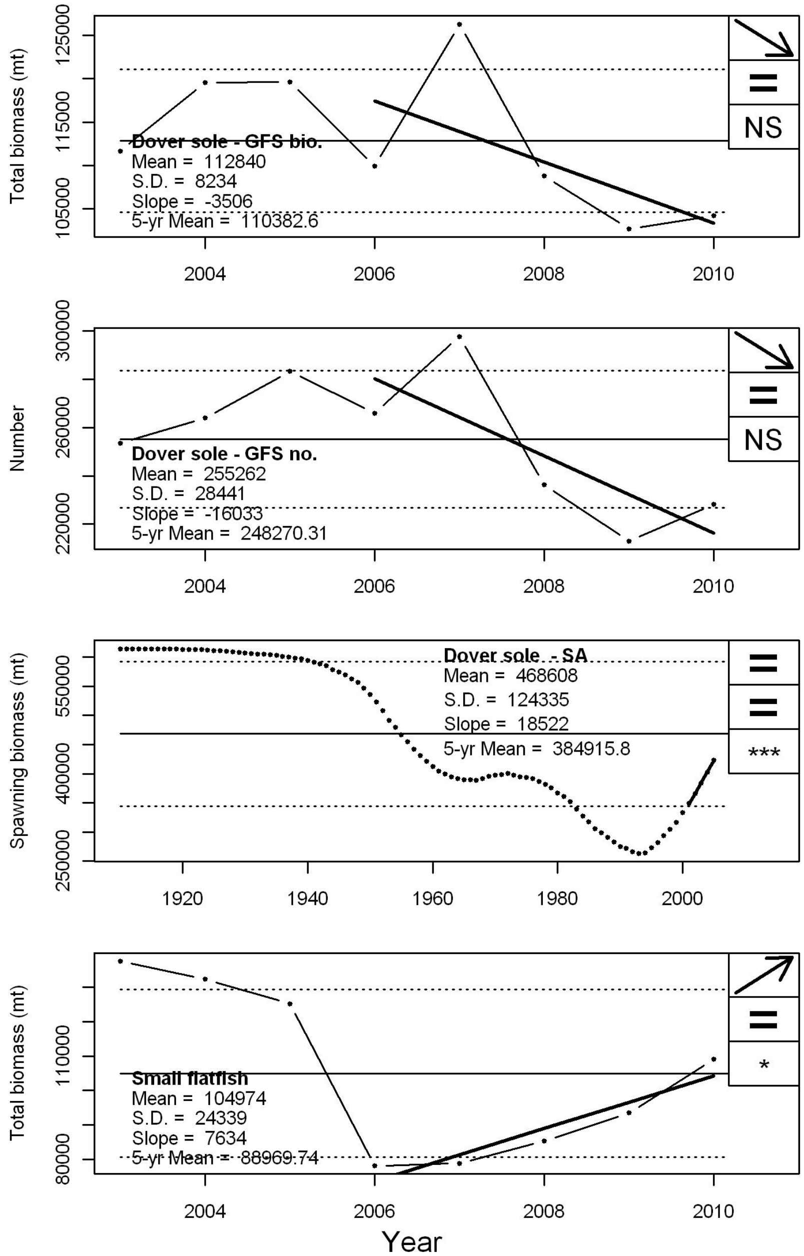


Figure B3. Dover sole and small flatfish time series used in the analyses. The solid horizontal line is the mean for the full time series. Dotted lines are +/-1 S.D.. The trend line (thick black) is the over the last five years of data. Mean and S.D. are the mean and standard deviation of the full time series. Slope and 5-yr mean are for the five year trend. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

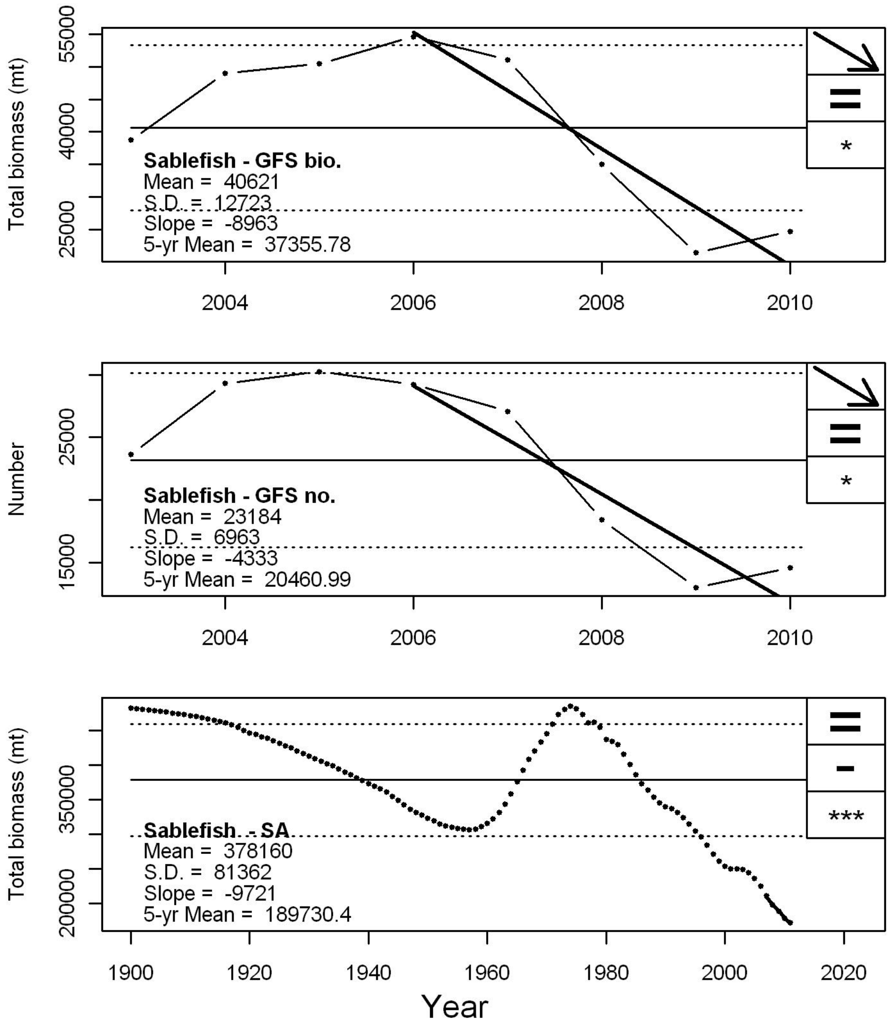


Figure B4. Sablefish time series used in the analyses. The solid horizontal line is the mean for the full time series. Dotted lines are +/-1 S.D.. The trend line (thick black) is the over the last five years of data. Mean and S.D. are the mean and standard deviation of the full time series. Slope and 5-yr mean are for the five year trend. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

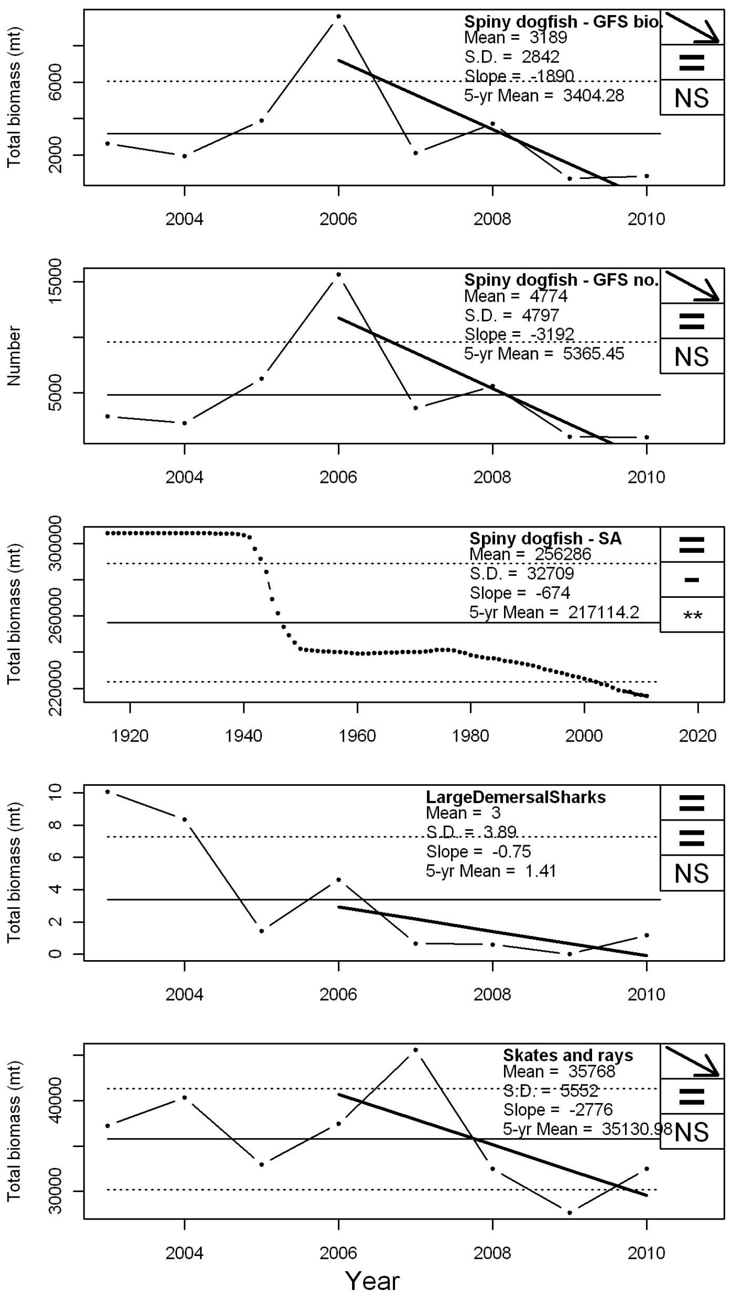


Figure B5. Dogfish, demersal sharks and, skates and rays time series used in the analyses. The solid horizontal line is the mean for the full time series. Dotted lines are +/-1 S.D.. The trend line (thick black) is the over the last five years of data. Mean and S.D. are the mean and standard deviation of the full time series. Slope and 5-yr mean are for the five year trend. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

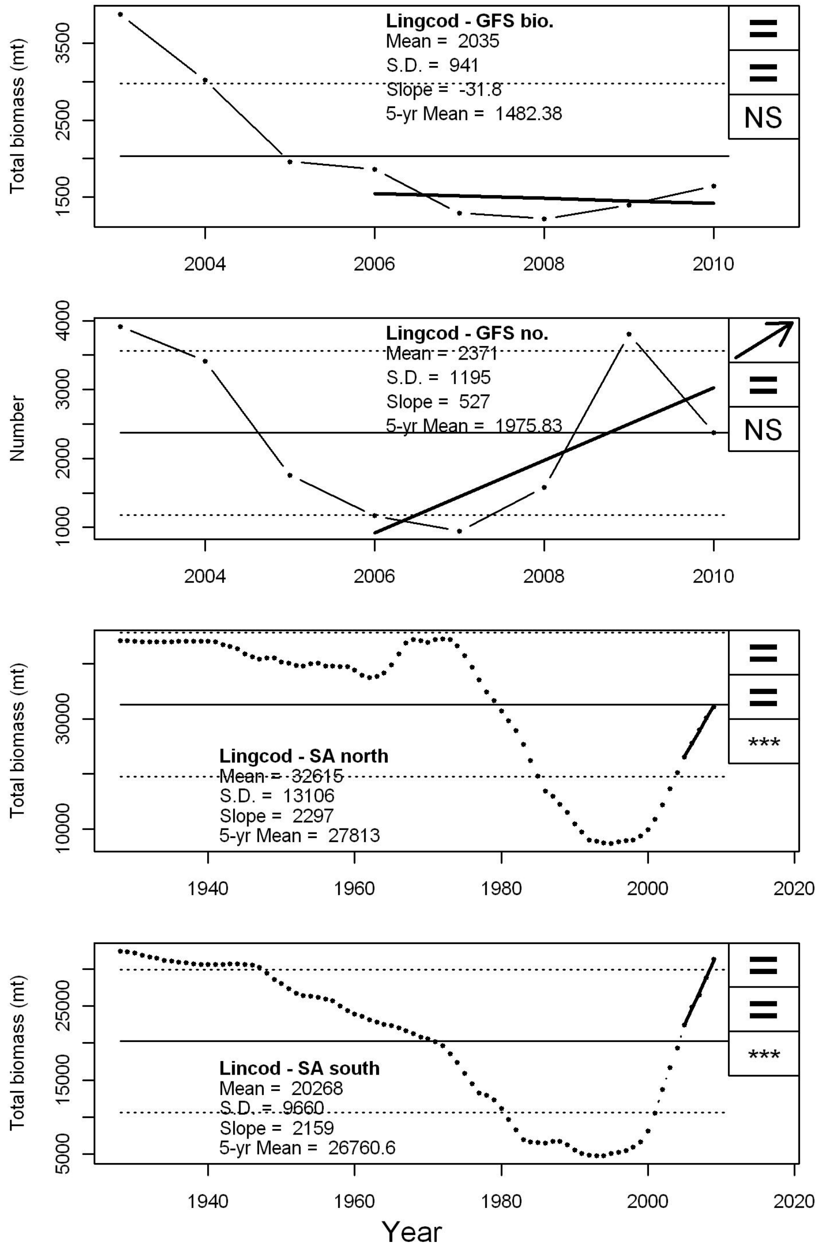


Figure B6. Lingcod time series used in the analyses. The solid horizontal line is the mean for the full time series. Dotted lines are +/-1 S.D.. The trend line (thick black) is the over the last five years of data. Mean and S.D. are the mean and standard deviation of the full time series. Slope and 5-yr mean are for the five year trend. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

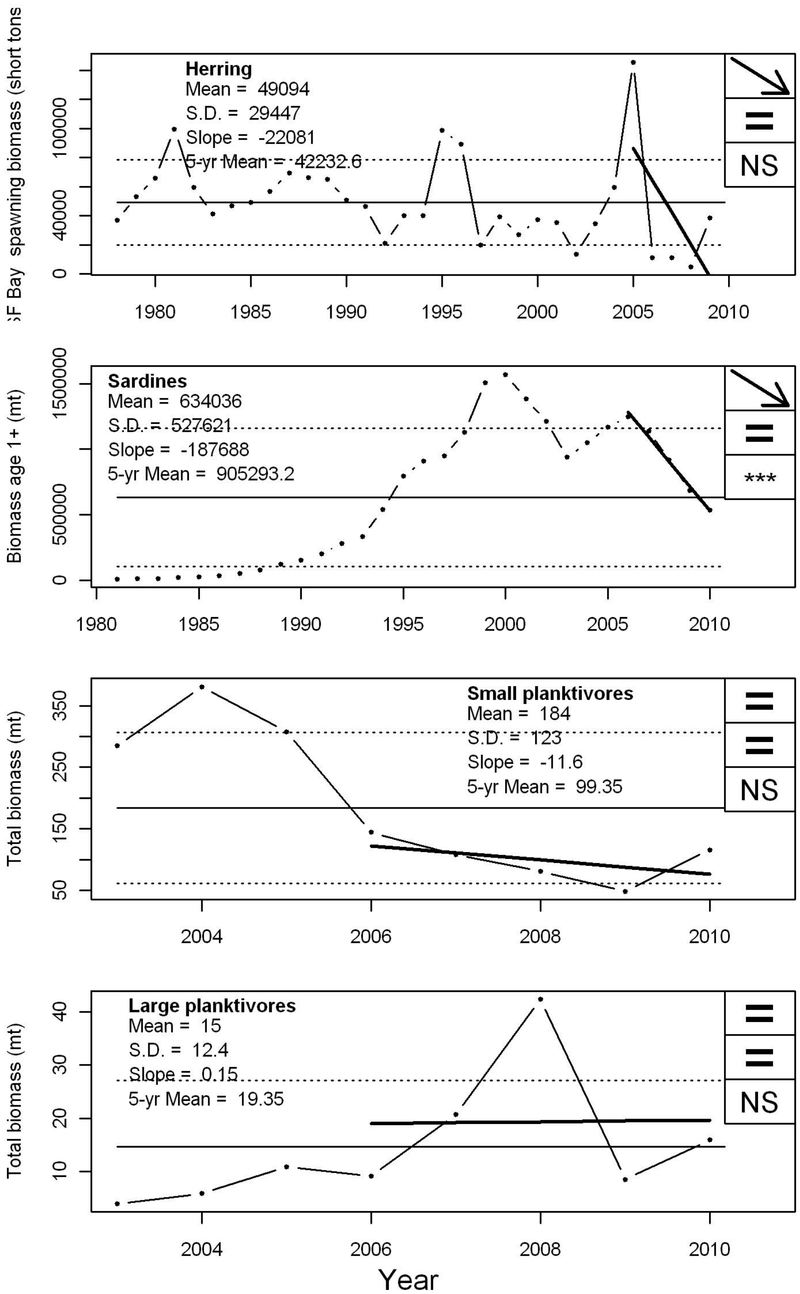


Figure B7. Herring, sardine and other planktivore time series used in the analyses. The solid horizontal line is the mean for the full time series. Dotted lines are +/-1 S.D.. The trend line (thick black) is the over the last five years of data. Mean and S.D. are the mean and standard deviation of the full time series. Slope and 5-yr mean are for the five year trend. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

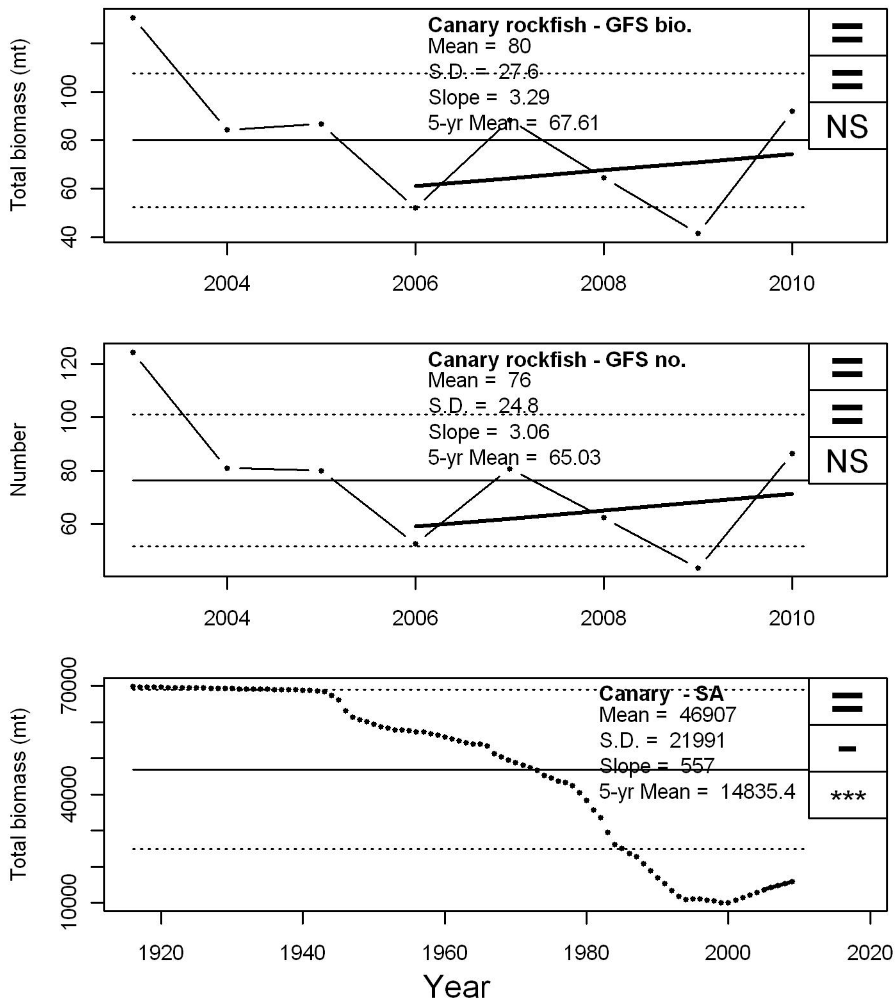


Figure B8. Canary rocfish time series used in the analyses. The solid horizontal line is the mean for the full time series. Dotted lines are +/-1 S.D.. The trend line (thick black) is the over the last five years of data. Mean and S.D. are the mean and standard deviation of the full time series. Slope and 5-yr mean are for the five year trend. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

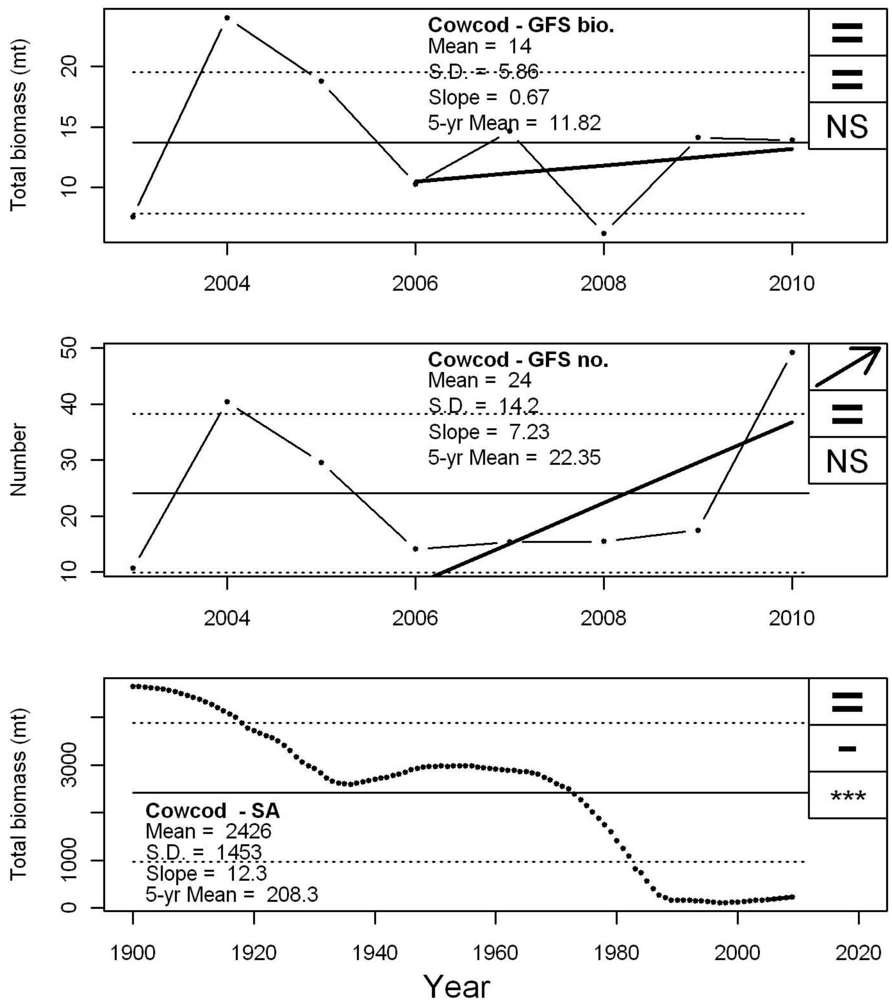


Figure B9. Cowcod time series used in the analyses. The solid horizontal line is the mean for the full time series. Dotted lines are +/-1 S.D.. The trend line (thick black) is the over the last five years of data. Mean and S.D. are the mean and standard deviation of the full time series. Slope and 5-yr mean are for the five year trend. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

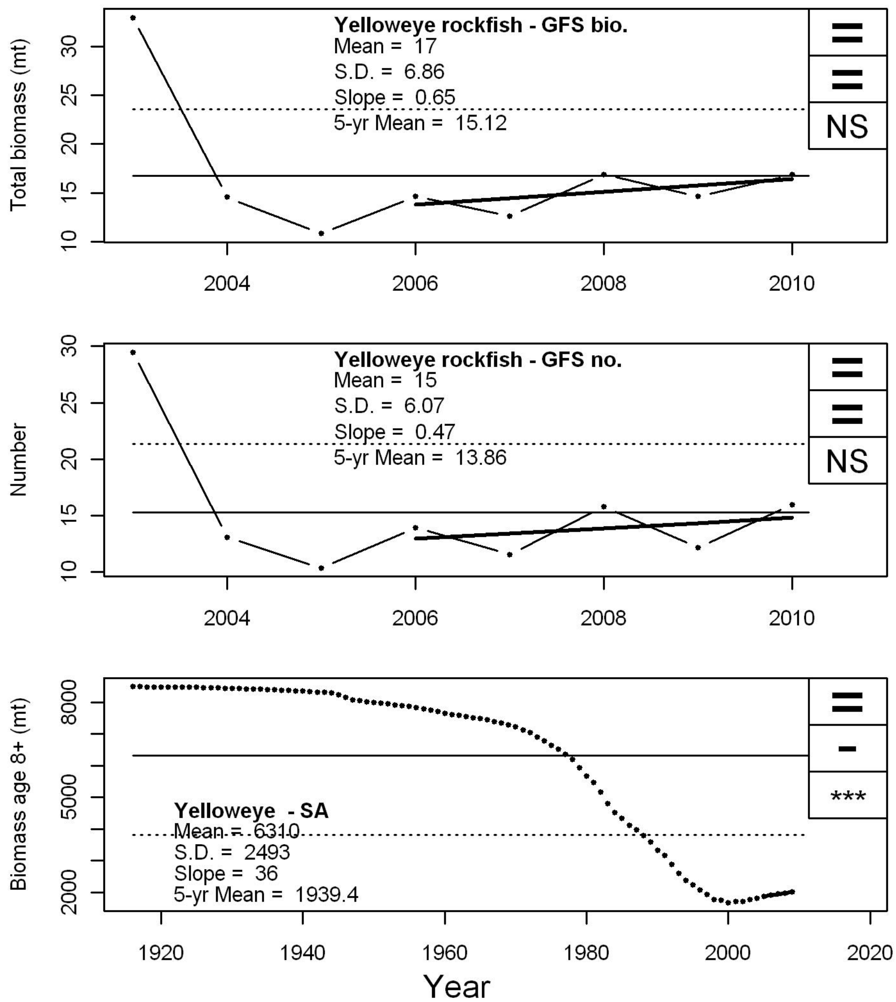


Figure B10. Yelloweye rockfish time series used in the analyses. The solid horizontal line is the mean for the full time series. Dotted lines are +/-1 S.D.. The trend line (thick black) is the over the last five years of data. Mean and S.D. are the mean and standard deviation of the full time series. Slope and 5-yr mean are for the five year trend. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

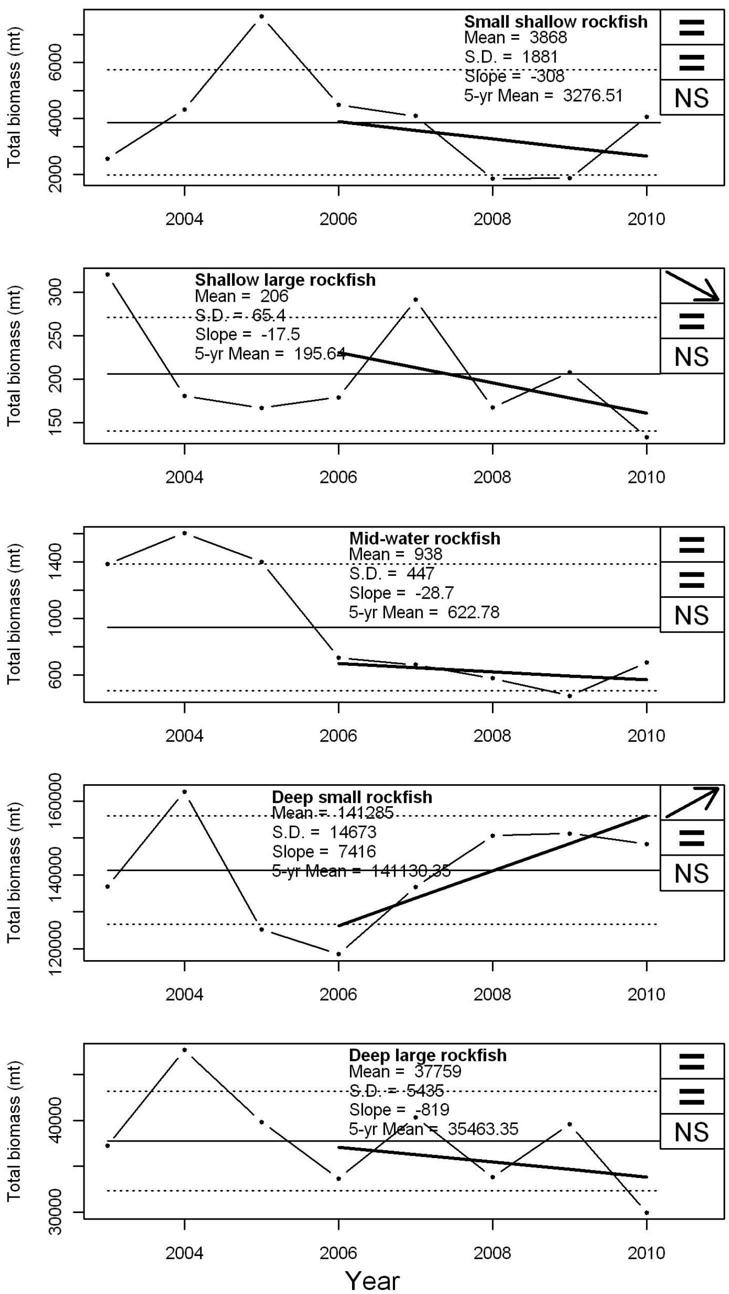


Figure B11. Small shallow rockfish, shallow large rockfish, mid-water rockfish, deep small rockfish and deep large rockfish time series used in the analyses. The solid horizontal line is the mean for the full time series. Dotted lines are +/-1 S.D.. The trend line (thick black) is the over the last five years of data. Mean and S.D. are the mean and standard deviation of the full time series. Slope and 5-yr mean are for the five year trend. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was

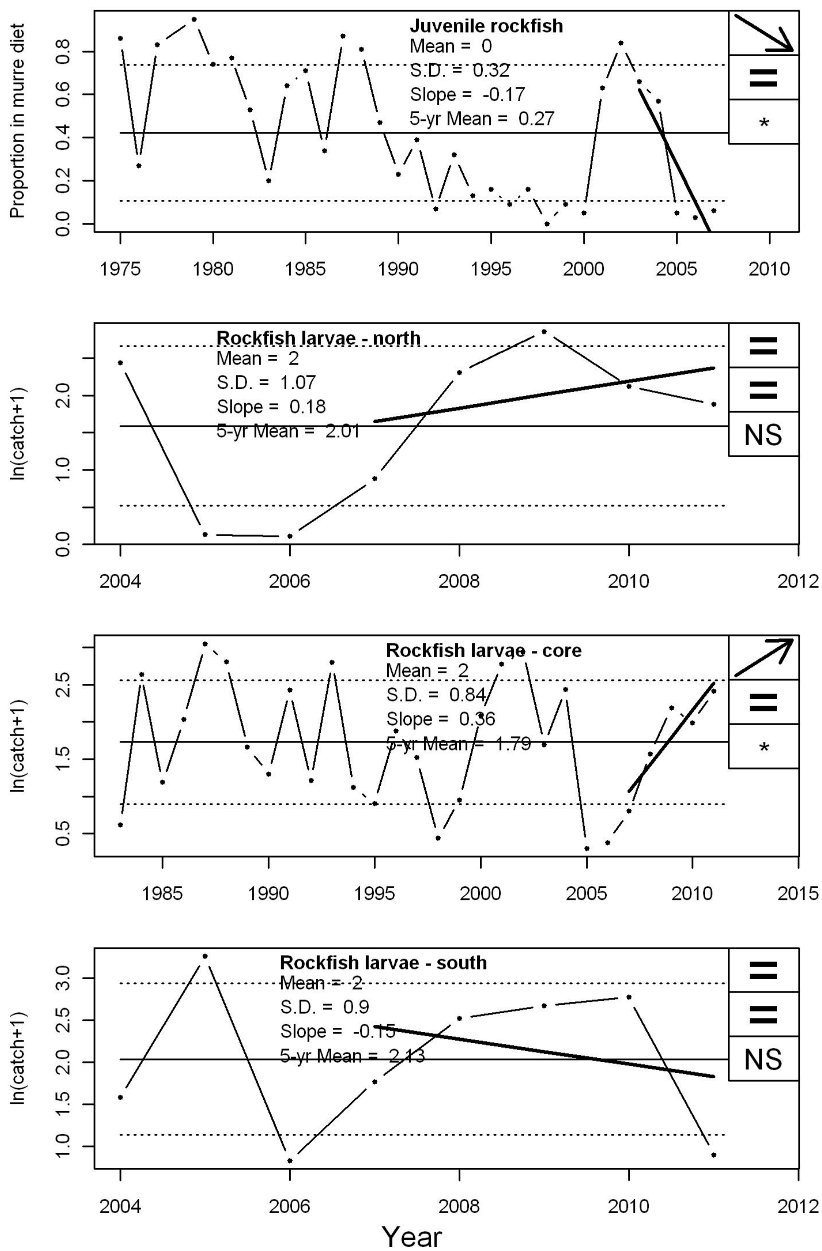


Figure B12. Juvenile and larval rockfish time series used in the analyses. The solid horizontal line is the mean for the full time series. Dotted lines are +/-1 S.D.. The trend line (thick black) is the over the last five years of data. Mean and S.D. are the mean and standard deviation of the full time series. Slope and 5-yr mean are for the five year trend. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

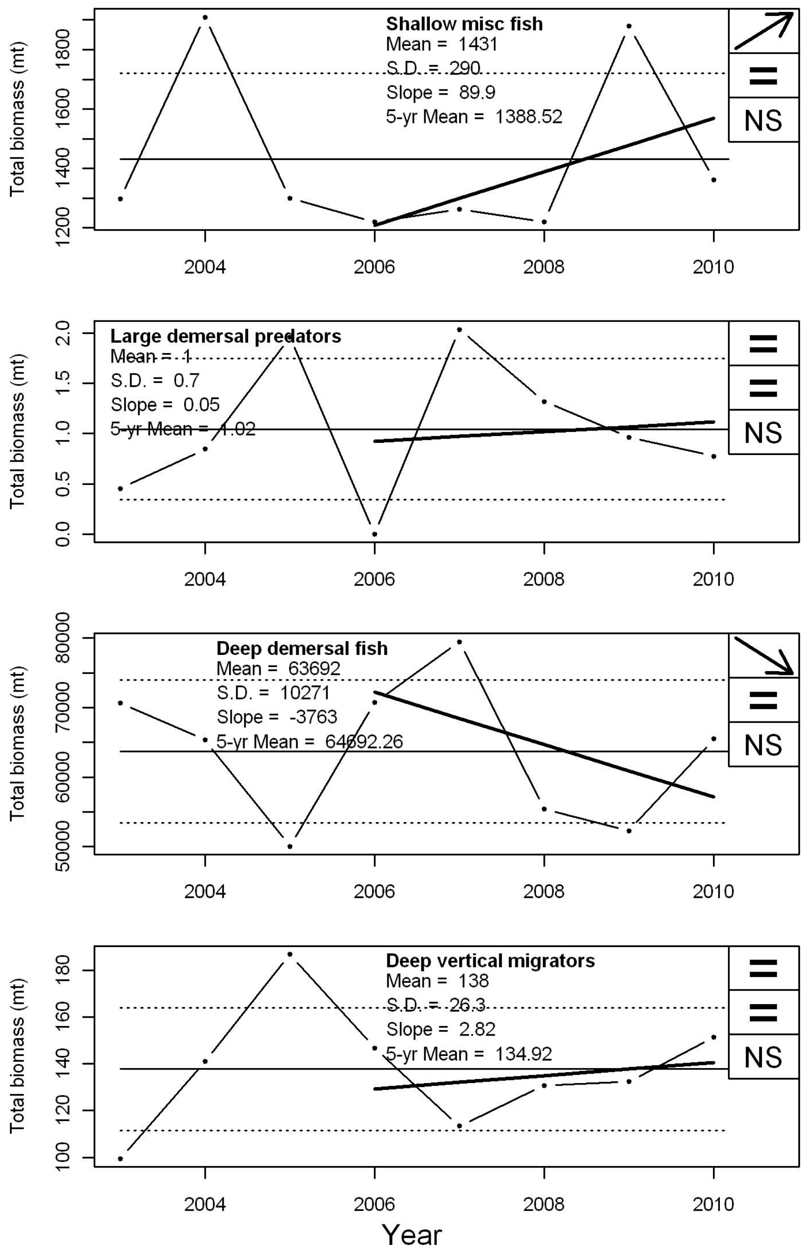


Figure B13. Shallow misc. fish, large demersal predators, deep demersal fish and deep vertical migrators time series used in the analyses. The solid horizontal line is the mean for the full time series. Dotted lines are +/-1 S.D.. The trend line (thick black) is the over the last five years of data. Mean and S.D. are the mean and standard deviation of the full time series. Slope and 5-yr mean are for the five year trend. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

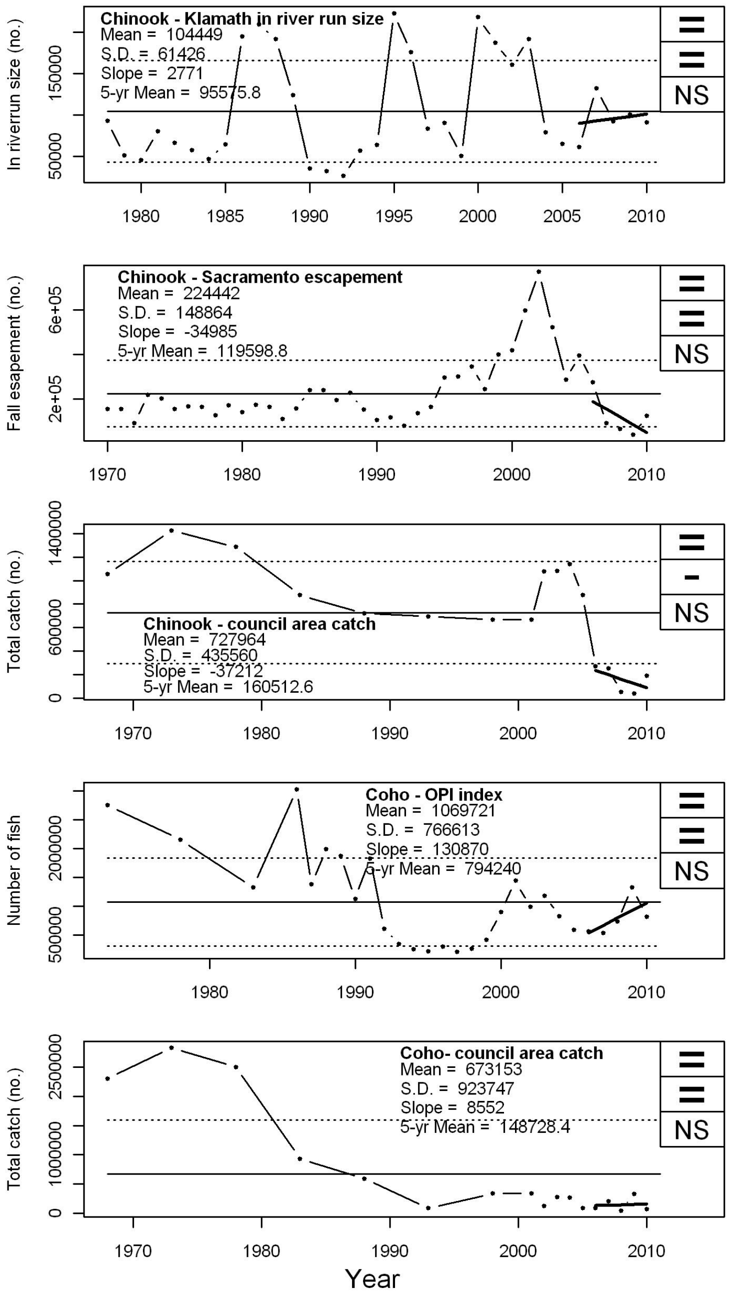


Figure B14. Chinook and coho salmon time series used in the analyses. The solid horizontal line is the mean for the full time series. Dotted lines are +/-1 S.D.. The trend line (thick black) is the over the last five years of data. Mean and S.D. are the mean and standard deviation of the full time series. Slope and 5-yr mean are for the five year trend. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

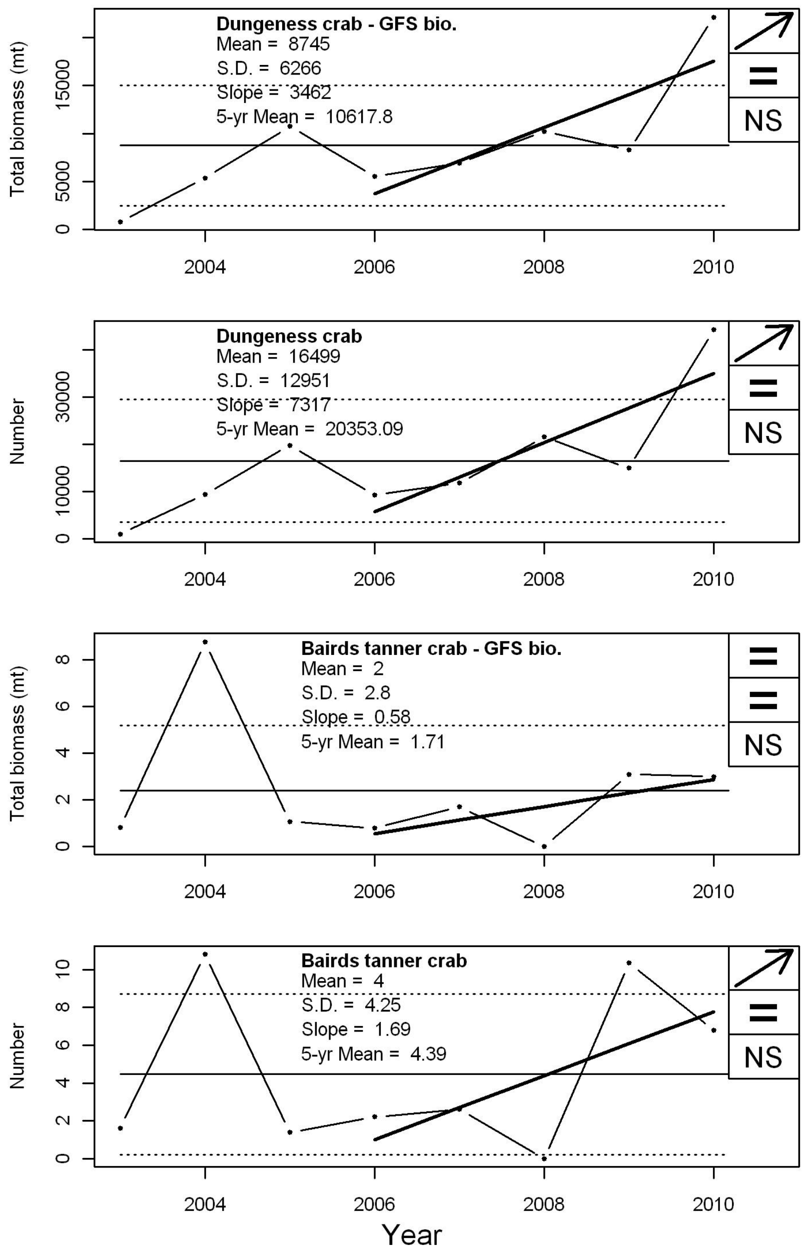


Figure B15. Dungeoness and Baird's tanner crab time series used in the analyses. The solid horizontal line is the mean for the full time series. Dotted lines are +/-1 S.D.. The trend line (thick black) is the over the last five years of data. Mean and S.D. are the mean and standard deviation of the full time series. Slope and 5-yr mean are for the five year trend. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

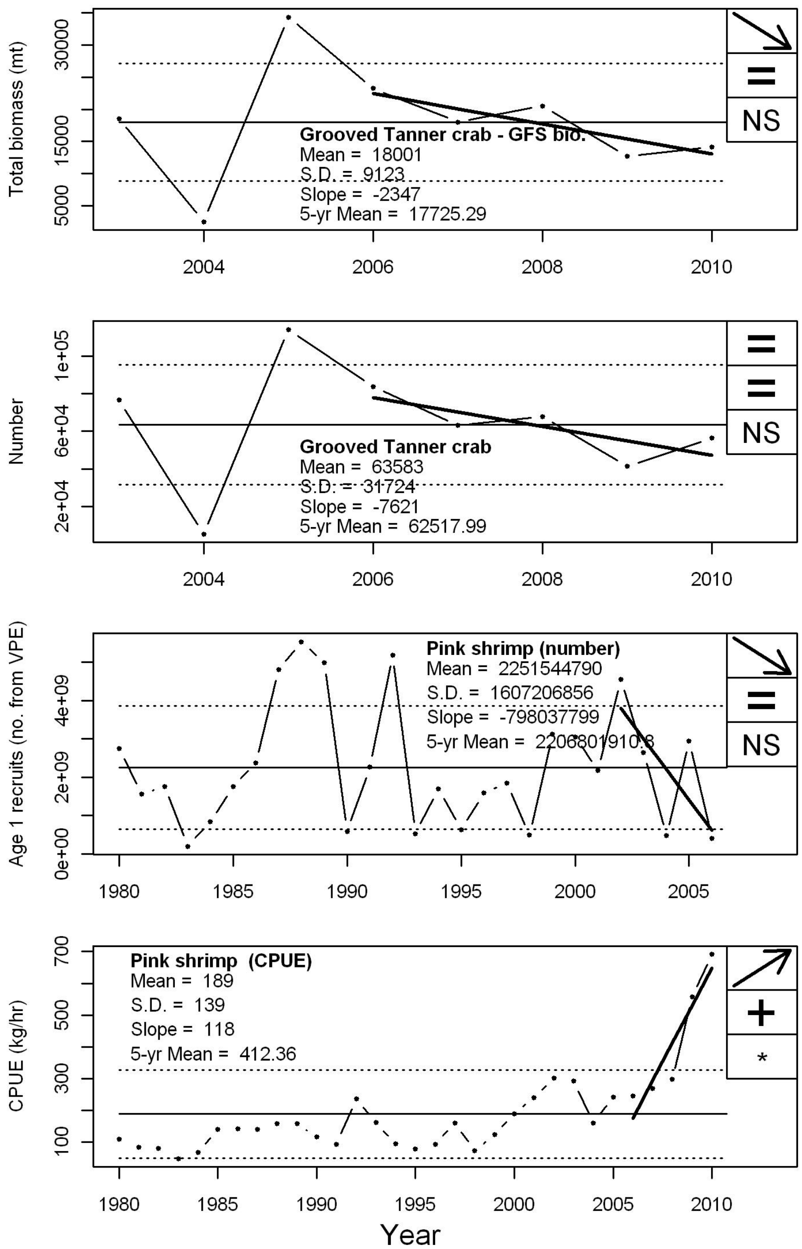


Figure B16. Grooved tanner crab and pink shrimp time series used in the analyses. The solid horizontal line is the mean for the full time series. Dotted lines are +/-1 S.D.. The trend line (thick black) is the over the last five years of data. Mean and S.D. are the mean and standard deviation of the full time series. Slope and 5-yr mean are for the five year trend. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

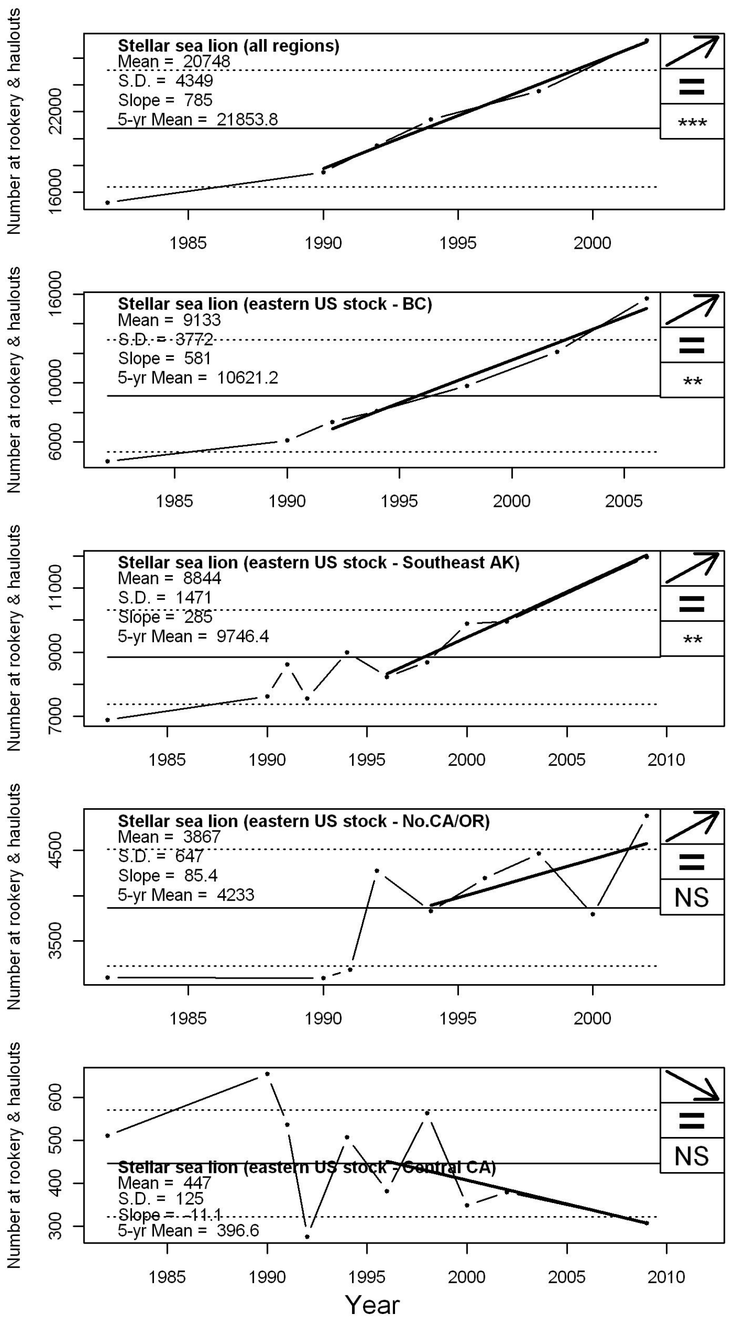


Figure B17. Stellar's sea lion time series used in the analyses. The solid horizontal line is the mean for the full time series. Dotted lines are +/-1 S.D.. The trend line (thick black) is the over the last five years of data. Mean and S.D. are the mean and standard deviation of the full time series. Slope and 5-yr mean are for the five year trend. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

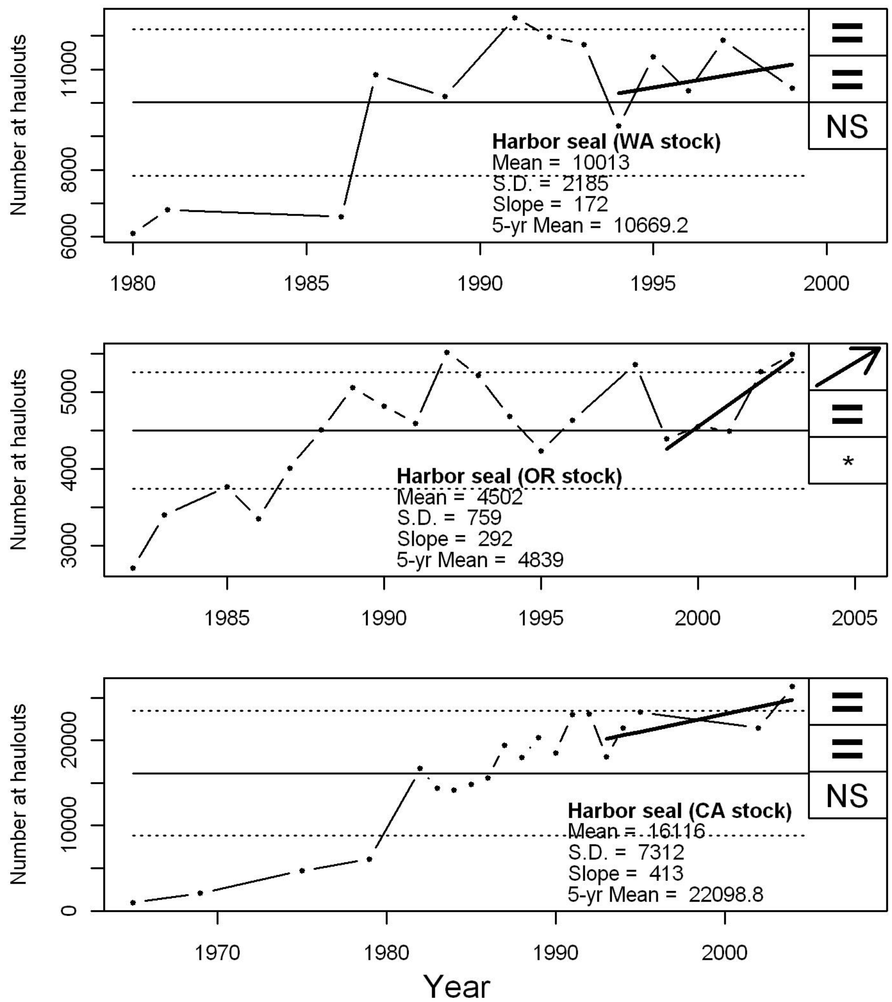


Figure B18. Harbor seal time series used in the analyses. The solid horizontal line is the mean for the full time series. Dotted lines are +/-1 S.D.. The trend line (thick black) is the over the last five years of data. Mean and S.D. are the mean and standard deviation of the full time series. Slope and 5-yr mean are for the five year trend. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

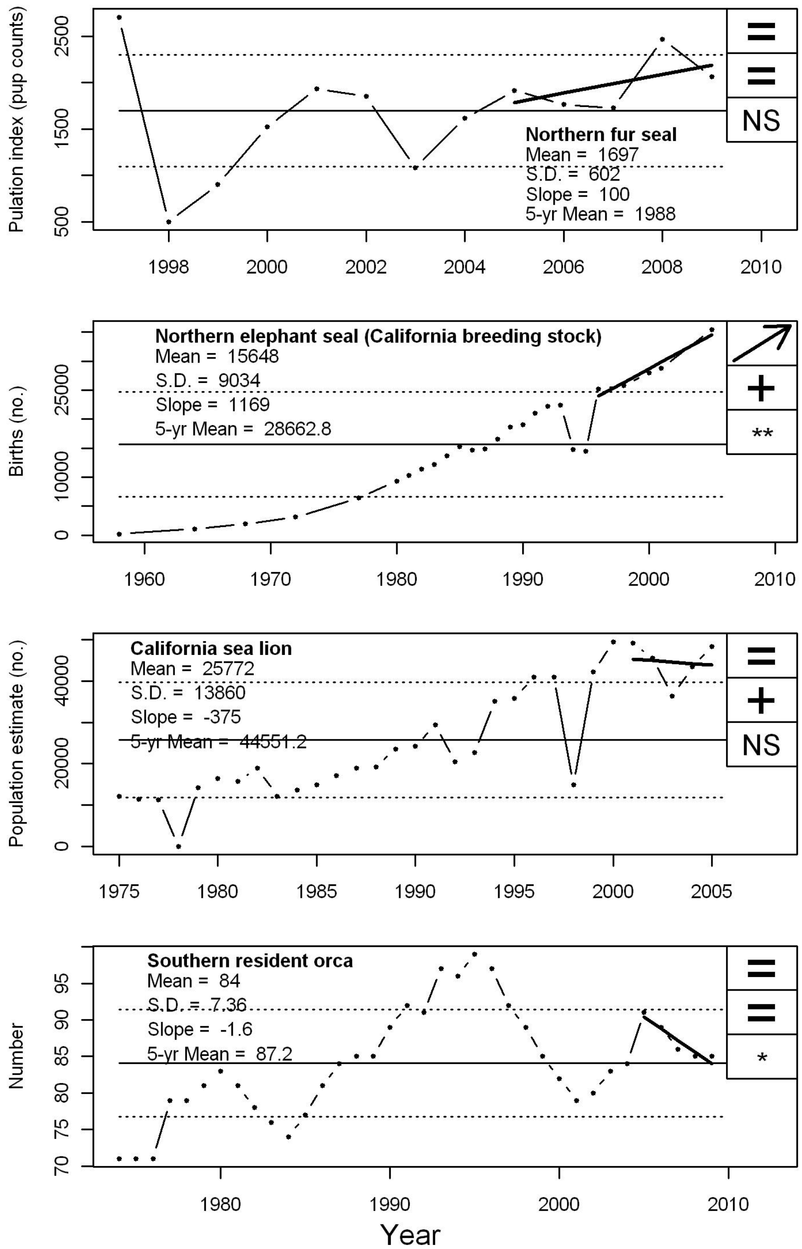


Figure B19. Northern fur seal, northern elephan seal, California sea lion and southern resident orca time series used in the analyses. The solid horizontal line is the mean for the full time series. Dotted lines are +/-1 S.D.. The trend line (thick black) is the over the last five years of data. Mean and S.D. are the mean and standard deviation of the full time series. Slope and 5-yr mean are for the five year trend. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

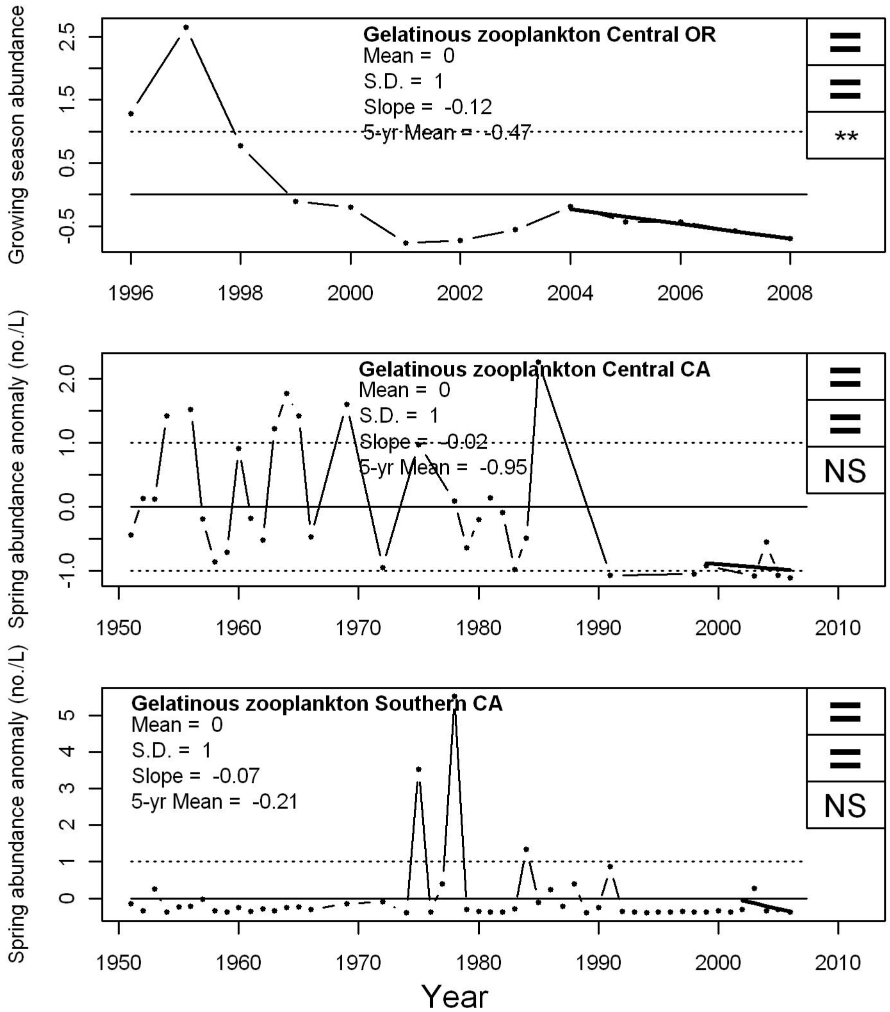


Figure B20. Gelatinous zooplankton time series used in the analyses. The solid horizontal line is the mean for the full time series. Dotted lines are +/-1 S.D.. The trend line (thick black) is the over the last five years of data. Mean and S.D. are the mean and standard deviation of the full time series. Slope and 5-yr mean are for the five year trend. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

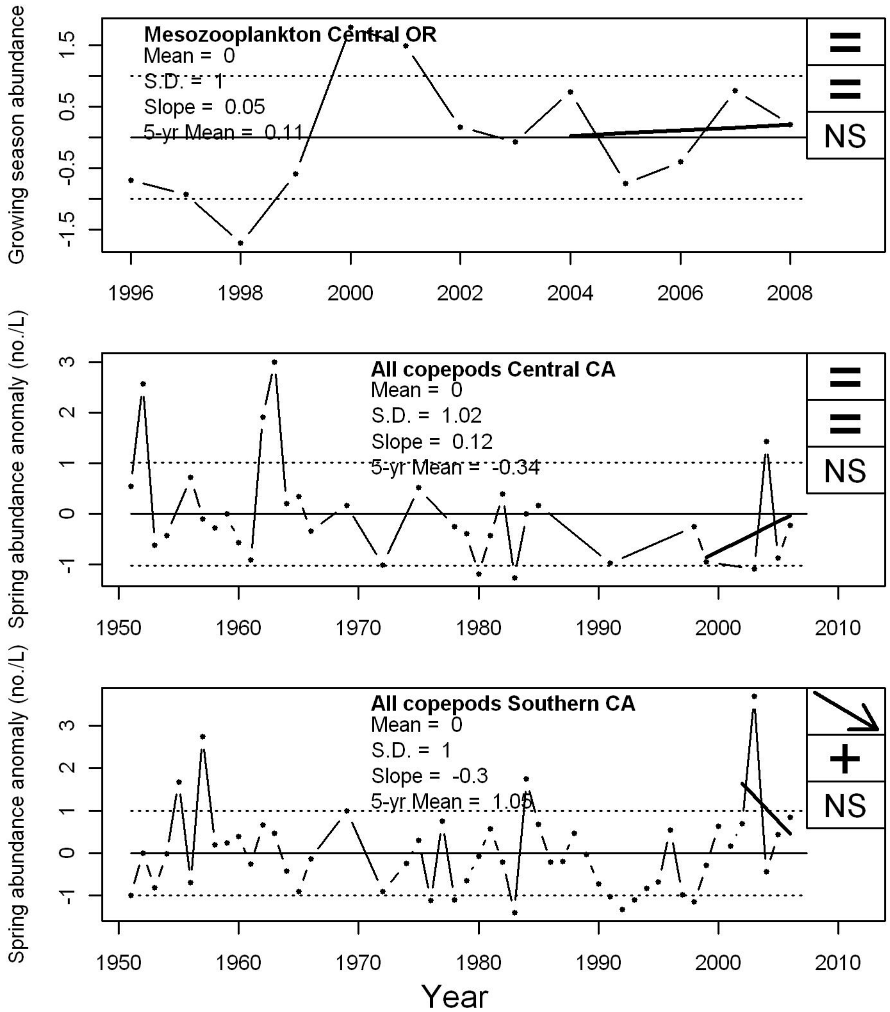


Figure B21. Mesozooplankton and copepod time series used in the analyses. The solid horizontal line is the mean for the full time series. Dotted lines are +/-1 S.D.. The trend line (thick black) is the over the last five years of data. Mean and S.D. are the mean and standard deviation of the full time series. Slope and 5-yr mean are for the five year trend. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

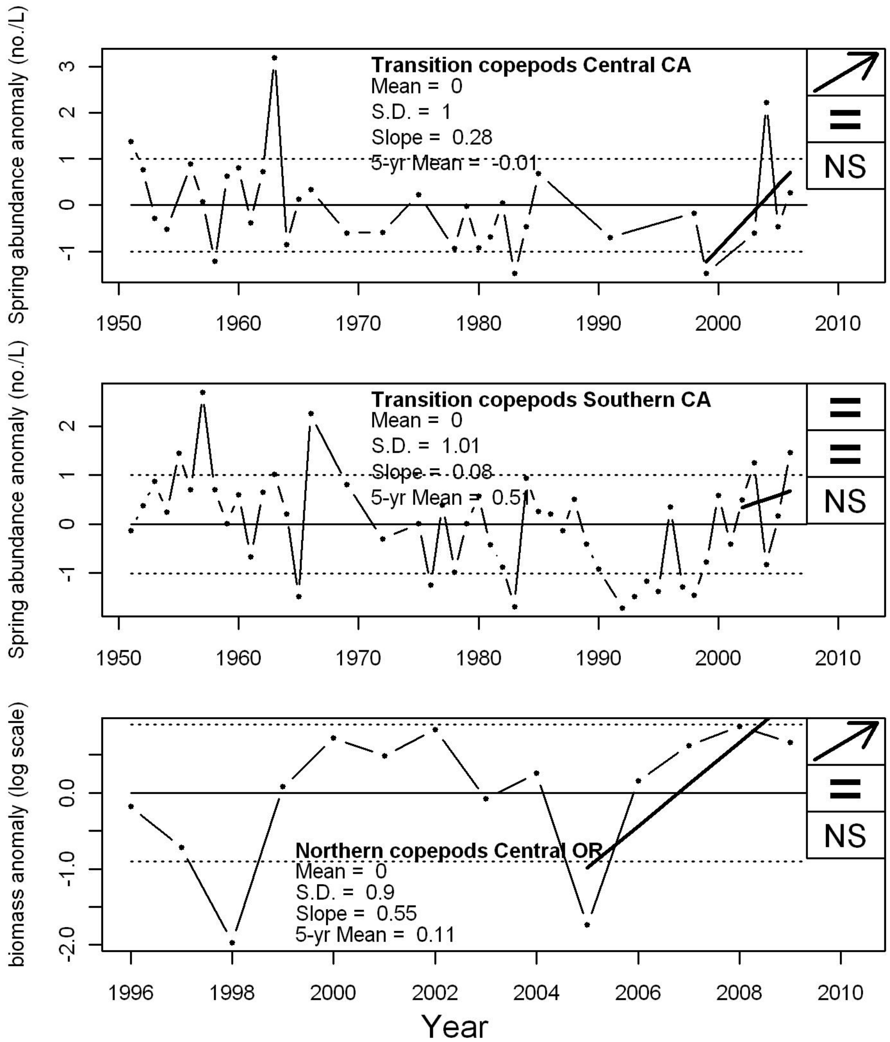


Figure B22. Copepod time series used in the analyses. The solid horizontal line is the mean for the full time series. Dotted lines are +/-1 S.D.. The trend line (thick black) is the over the last five years of data. Mean and S.D. are the mean and standard deviation of the full time series. Slope and 5-yr mean are for the five year trend. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

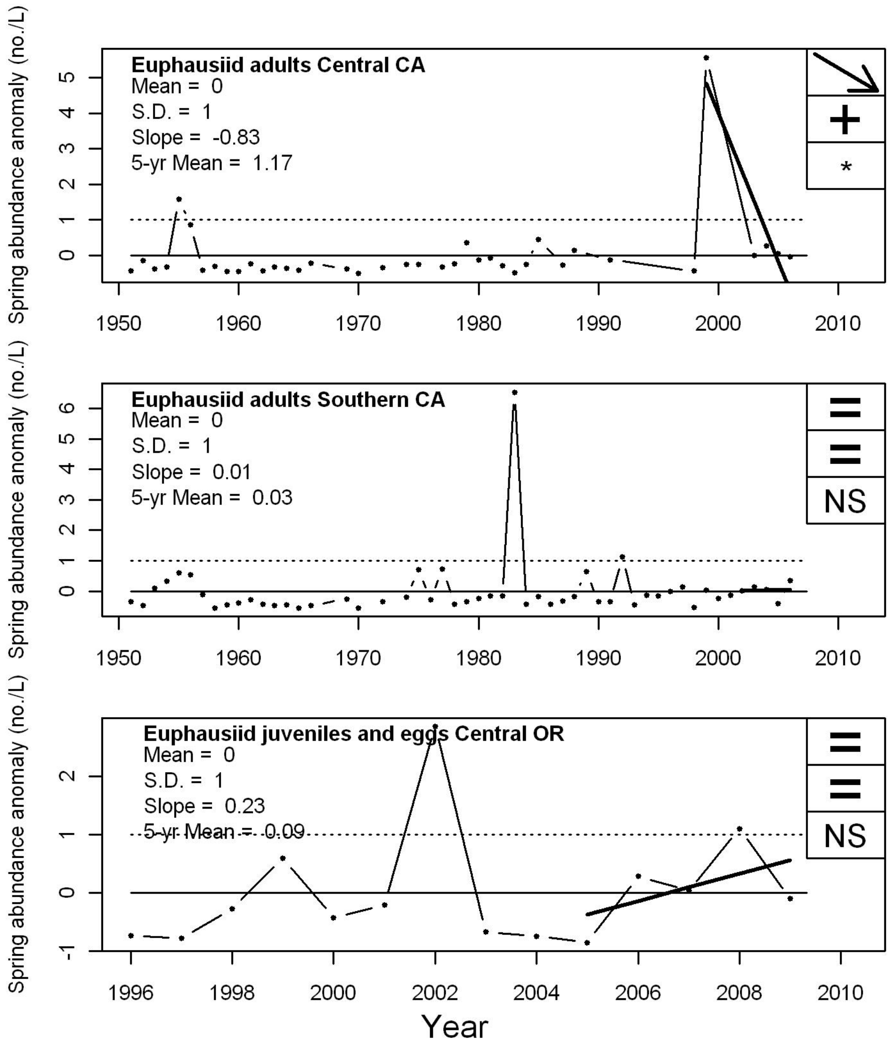


Figure B23. Euphausiids time series used in the analyses. The solid horizontal line is the mean for the full time series. Dotted lines are +/-1 S.D.. The trend line (thick black) is the over the last five years of data. Mean and S.D. are the mean and standard deviation of the full time series. Slope and 5-yr mean are for the five year trend. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

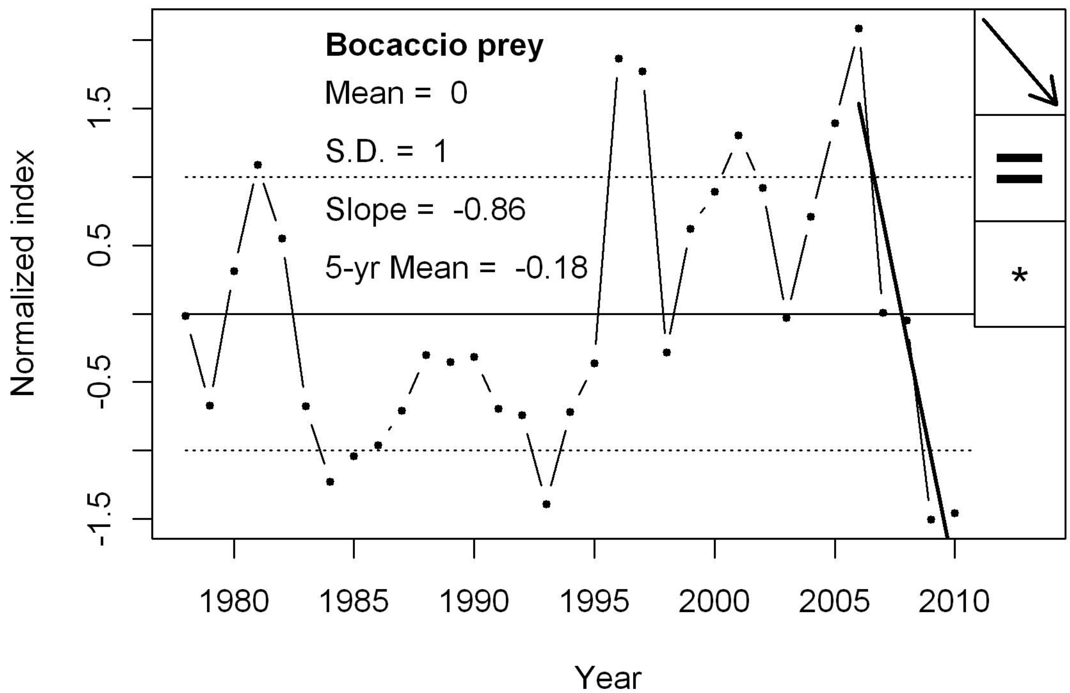


Figure B24. Index of bocaccio prey calculated using the reduced complement of time series. The solid horizontal line is the mean for the full time series. Dotted lines are +/-1 S.D.. The trend line (thick black) is the over the last five years of data. Slope and 5-yr mean are for the five year trend. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

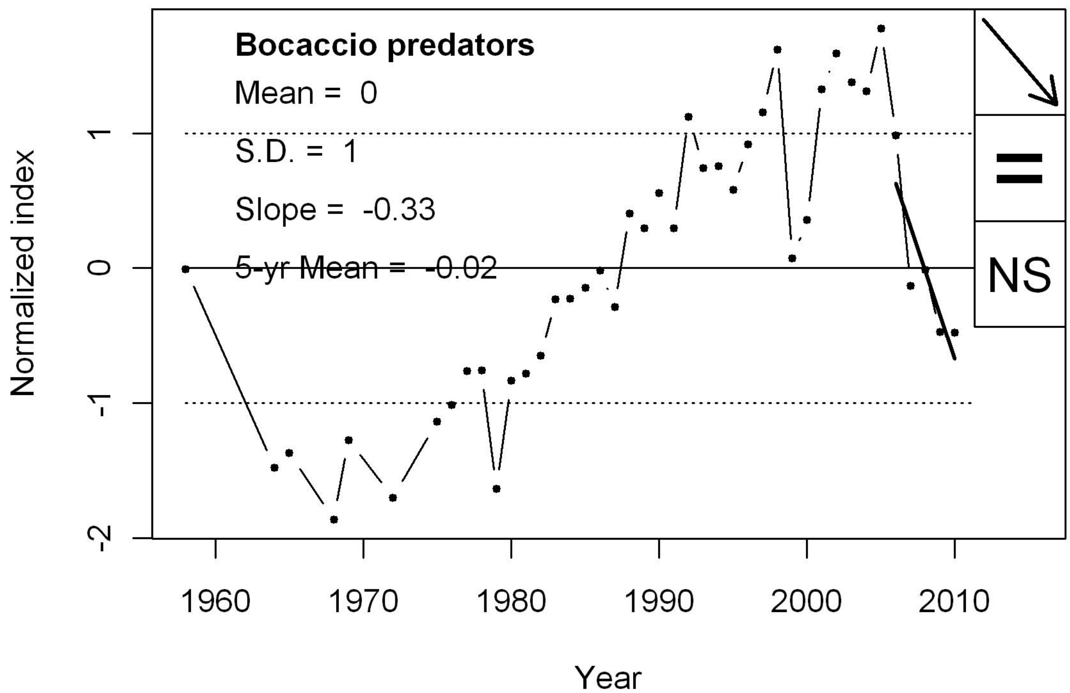


Figure B25. Index of bocaccio predators calculated using the reduced complement of time series. The solid horizontal line is the mean for the full time series. Dotted lines are +/-1 S.D.. The trend line (thick black) is the over the last five years of data. Slope and 5-yr mean are for the five year trend. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

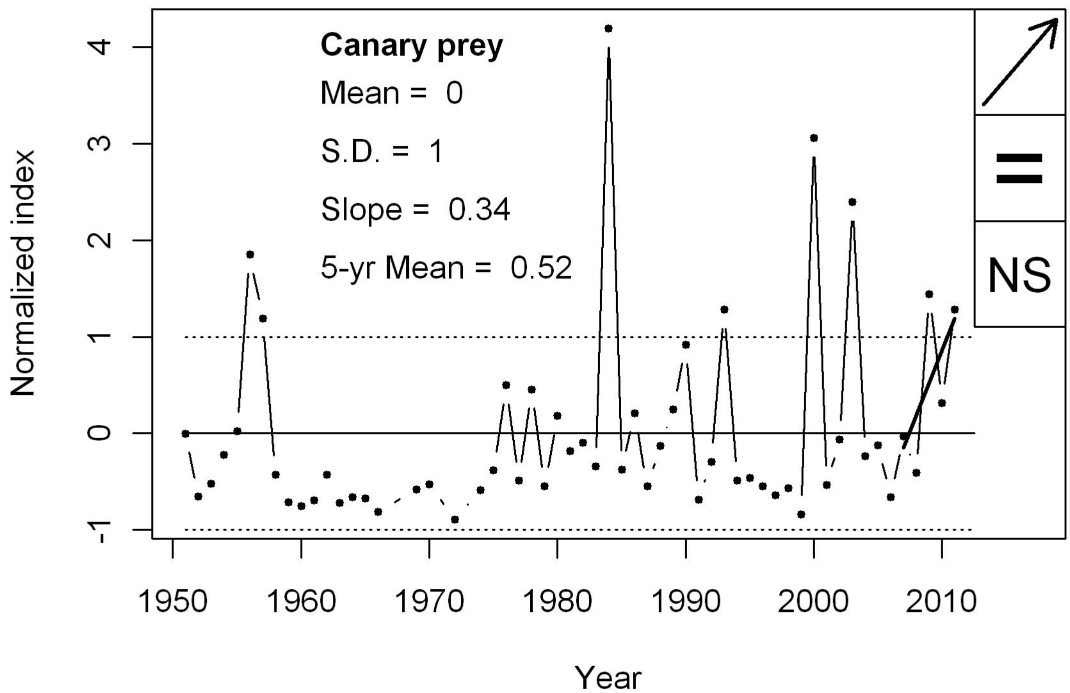


Figure B26. Index of canary prey calculated using the reduced complement of time series. The solid horizontal line is the mean for the full time series. Dotted lines are +/-1 S.D.. The trend line (thick black) is the over the last five years of data. Slope and 5-yr mean are for the five year trend. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

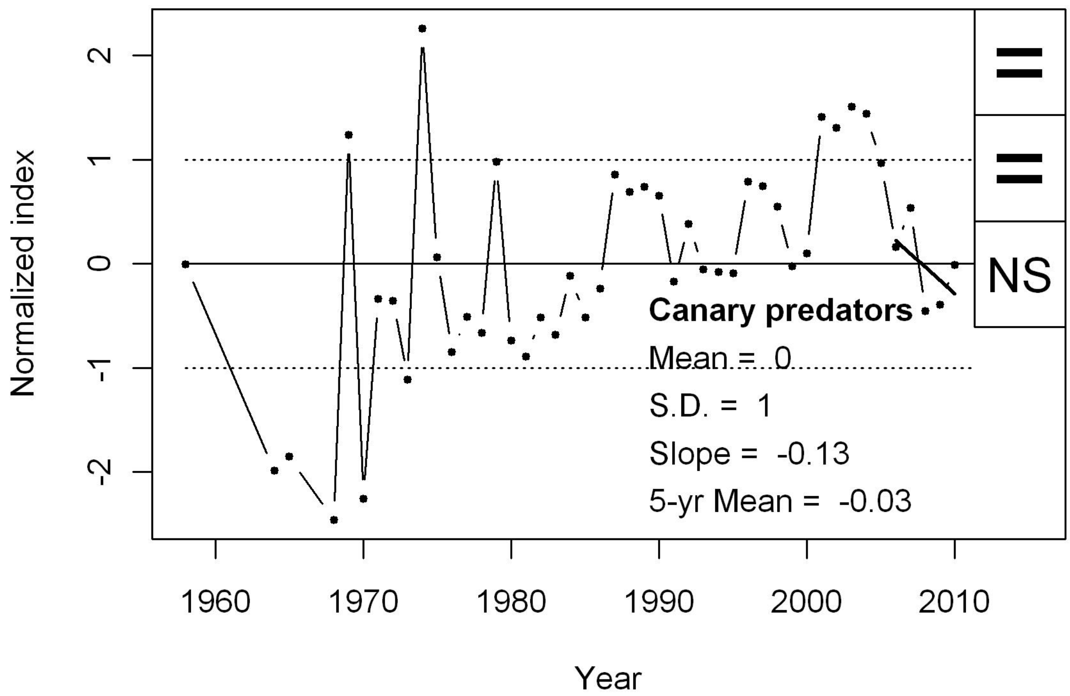


Figure B27. Index of canary predators calculated using the reduced complement of time series. The solid horizontal line is the mean for the full time series. Dotted lines are +/-1 S.D.. The trend line (thick black) is the over the last five years of data. Slope and 5-yr mean are for the five year trend. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

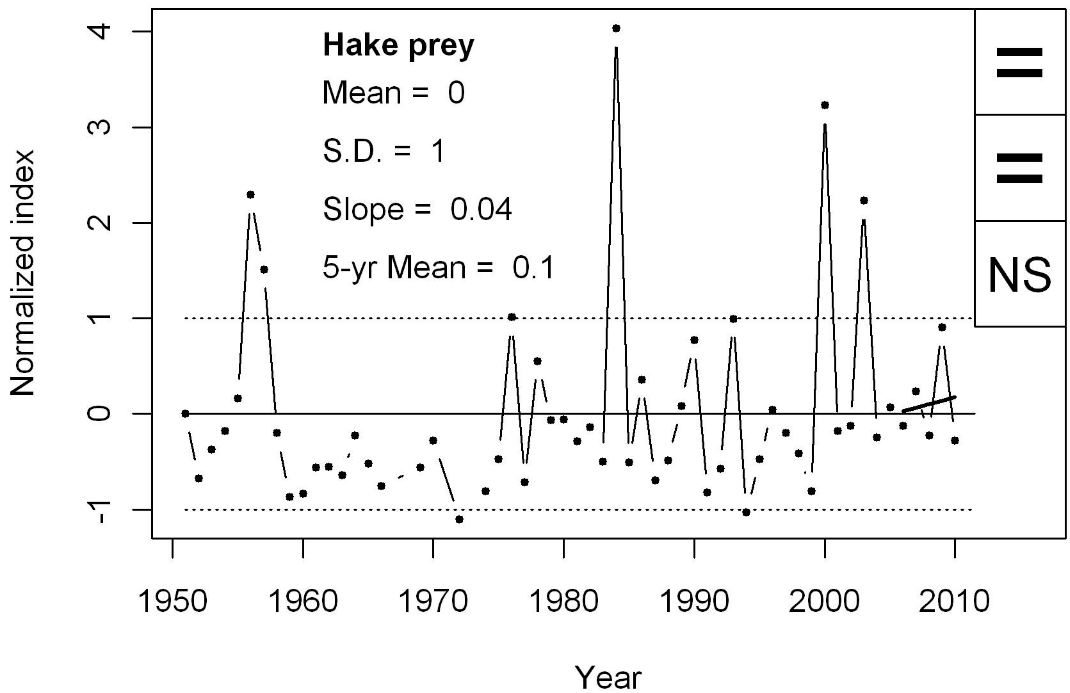


Figure B28. Index of hake prey calculated using the reduced complement of time series. The solid horizontal line is the mean for the full time series. Dotted lines are +/-1 S.D.. The trend line (thick black) is the over the last five years of data. Slope and 5-yr mean are for the five year trend. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

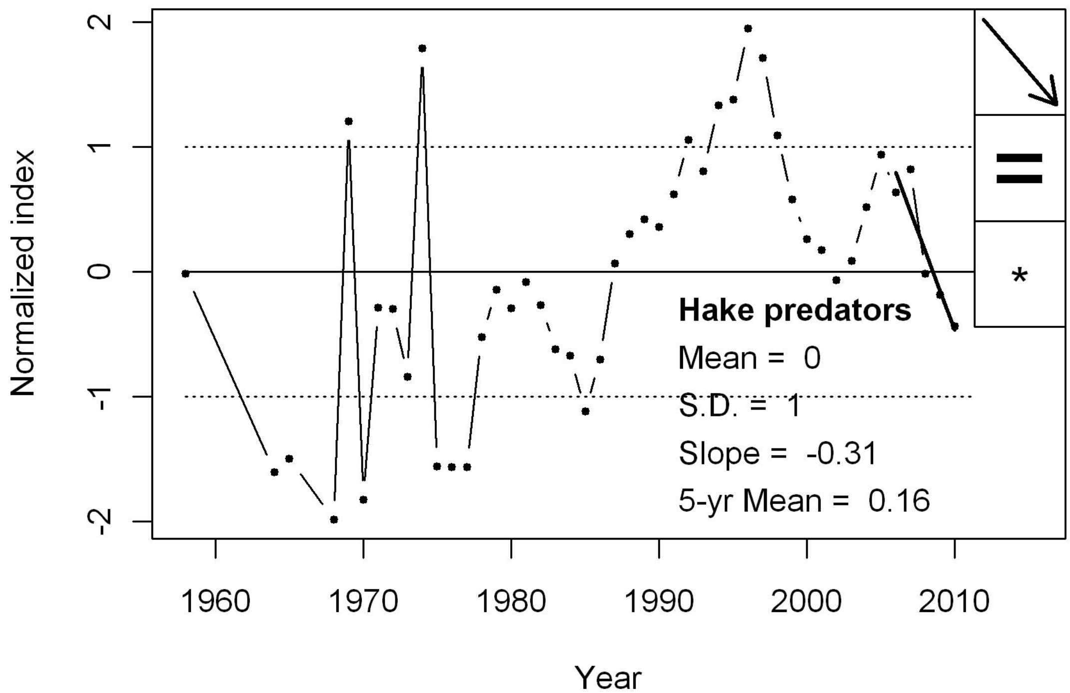


Figure B29. Index of hake predators calculated using the reduced complement of time series. The solid horizontal line is the mean for the full time series. Dotted lines are +/-1 S.D.. The trend line (thick black) is the over the last five years of data. Slope and 5-yr mean are for the five year trend. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

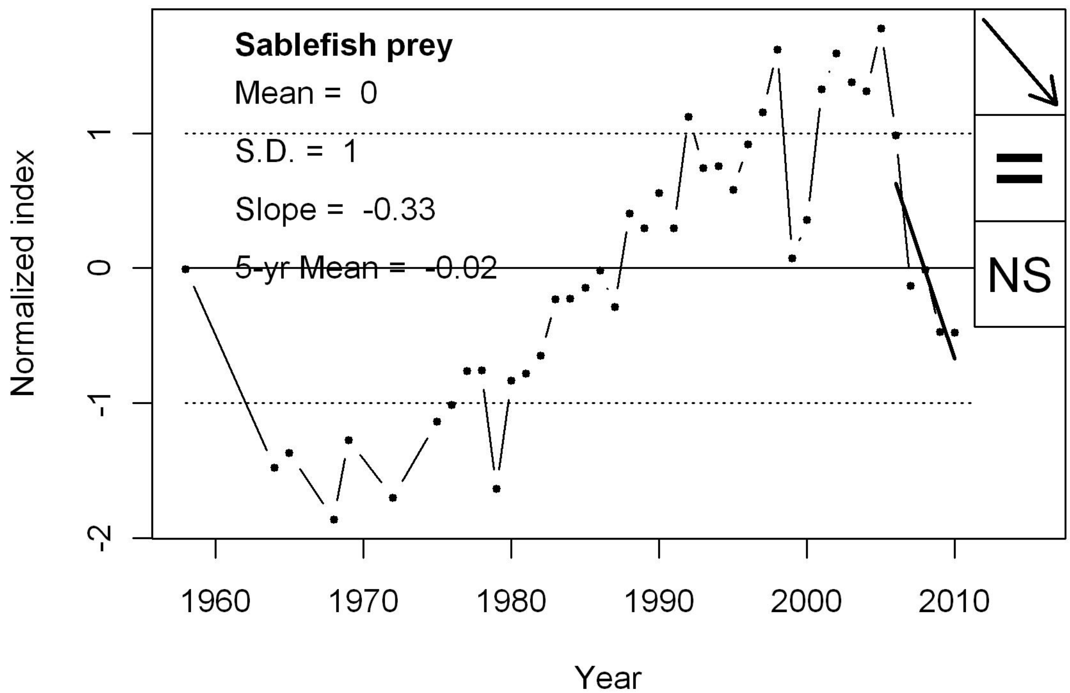


Figure B30. Index of sablefish prey calculated using the reduced complement of time series. The solid horizontal line is the mean for the full time series. Dotted lines are +/-1 S.D.. The trend line (thick black) is the over the last five years of data. Slope and 5-yr mean are for the five year trend. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

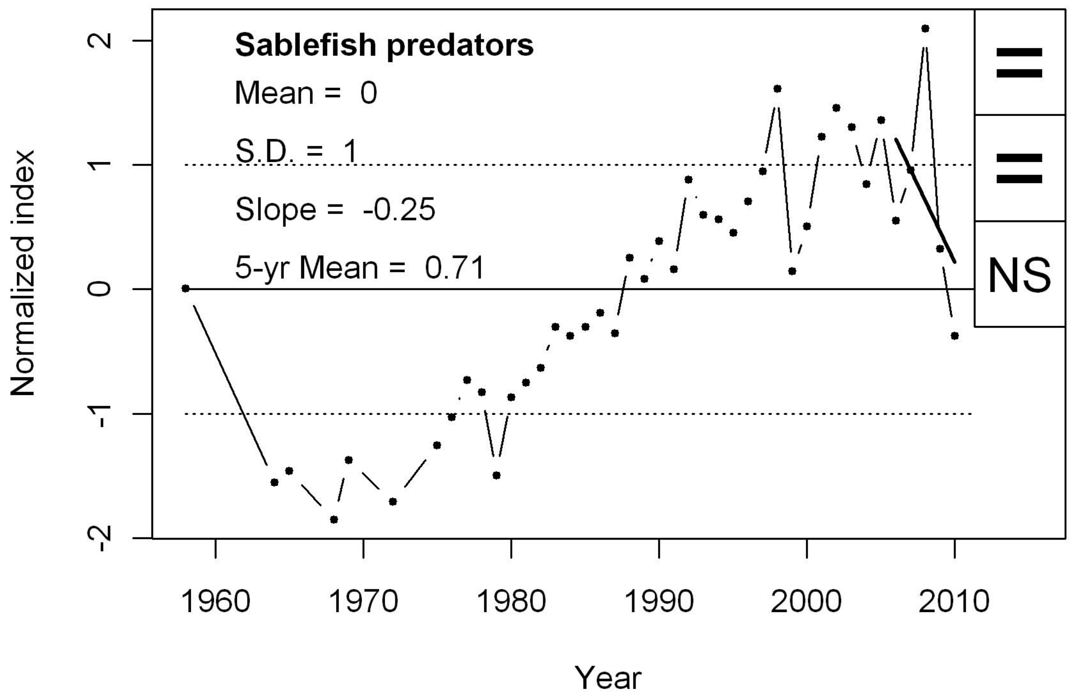


Figure B31. Index of sablefish predators calculated using the reduced complement of time series. The solid horizontal line is the mean for the full time series. Dotted lines are +/-1 S.D.. The trend line (thick black) is the over the last five years of data. Slope and 5-yr mean are for the five year trend. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

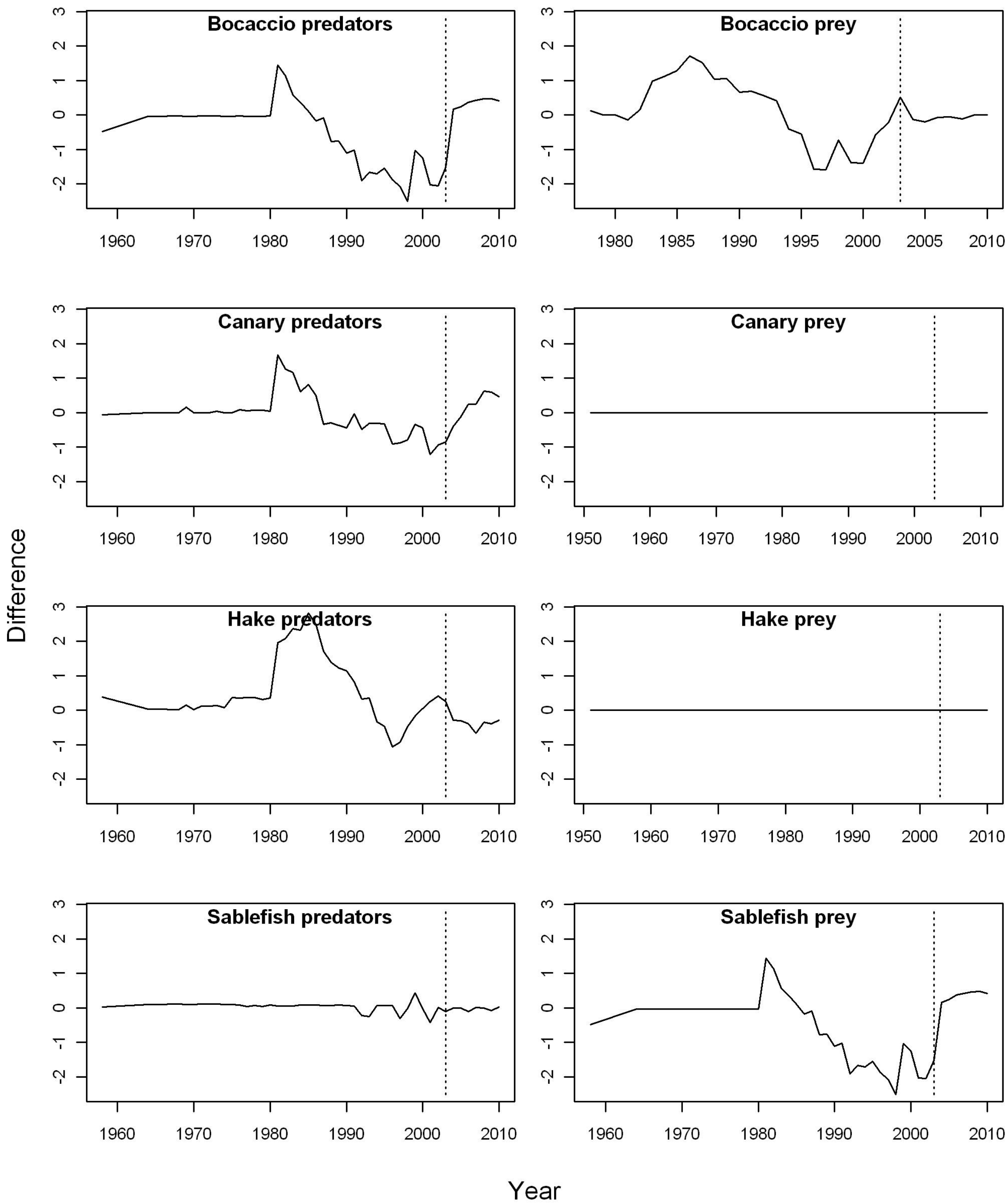


Figure B32. Difference betweeen prey and predator indices for focal species using all time series for that focal species and the reduced times series set. Vertical dotted line indicates 1980.

CHAPTER 2, APPENDIX C:

PREDATORS AND PREY OF SABLEFISH, PACIFIC HAKE, BOCACCIO, AND CANARY ROCKFISH

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OVERVIEW

As a first step toward considering food web interactions that influence groundfish stocks, we identified major predators and prey of sablefish (*Anoplopoma fimbria*), Pacific hake (*Merluccius productus*), bocaccio (*Sebastes* paucispinis), and canary rockfish (*Sebastes pinniger*). Rather than relying on a single analysis, we applied three approaches: diet composition, qualitative modeling, and a full ecosystem model. Below, we first identify the food webs that derive from a consensus between these approaches. We then detail the methodology behind the three approaches. Overall, our goal is to identify a narrow set of predators and prey that account for the bulk of the forage base for, and predation pressure on, these four groundfish stocks.

In the consensus food web diagrams we developed for the four focal groundfish species (Fig. C1-C4), the focal group is in red, major prey items are in green, and major predators are in dark blue. Turquoise colored groups are both prey and predators of the focal group (for instance, juveniles of the focal group may be eaten by turquoise-colored adults, but adults of the focal species may eat the other group). Position in the y-direction is approximately related to trophic level. Size of the box is related to biomass of the group. Links between boxes represent links in the food web; most diet information depicted here involves adult predators. The diagrams exclude minor prey items and predators that inflict small proportions of predation mortality on the focal group. Food web visualization software (Ecoviz 2.3.6) was provided by Dr. Kerim Aydin, NOAA AFSC.

PART I: IDENTIFYING PREY VIA SYNTHESIS OF DIET INFORMATION

METHODS

We first identified key prey items for canary rockfish, sablefish, Pacific hake, and bocaccio from published literature related to stomach contents. For the first three of these species, information was derived from Dufault et al. (2009), which summarizes over 75 reports on diets of marine species in the California Current. In Dufault et al. (2009), prey items are identified at the functional group level. For instance, prey are listed as large zooplankton or small planktivores, rather than by species. A full list of species in each functional group is contained in Horne et al. (2010). Dufault et al. (2009) lacks information on adult bocaccio diets, and therefore prey items of bocaccio are based on preliminary adult boccacio data from 39 fish sampled by John Buchanan (pers. comm. NOAA NWFSC, Newport, OR), and qualitative reports of diet composition from DFO(2009).

Overall, major prey items of these four groundfish included:

- Large zooplankton (krill)
- Small planktivores (forage fish)
- Mesozooplankton (copepods)
- Gelatinous zooplankton (jellyfish)
- Cephalopods
- Hake
- Deposit feeders (amphipods, isopods, snails, worms)
- Shrimp

Based on the very limited data for bocaccio diets, the following three prey groups may also be important:

- Shallow small rockfish
- Canary rockfish
- Midwater rockfish

Summary diet compositions for adult and juvenile canary rockfish, sablefish, Pacific hake, and bocaccio, respectively (Fig. C5-C12). Prey groups that comprise less than 2% of juvenile diets and less than 2% of adult diets are not shown.

PART II: IDENTIFYING PREDATORS VIA ECOSYSTEM MODEL ESTIMATES OF PREDATION MORTALITY

METHODS

Ecosystem models allow quantitative estimation of the predation mortality inflicted on groundfish stocks by predators in the California Current. The Atlantis framework (Fulton, 2004; Fulton et al., 2011) is one such ecosystem model, and accounts for not only predator diets but also predator biomass, consumption rate, ontogenetic changes in diet, and annual migrations of predators such as hake. The Central California Atlantis Model (Horne et al., 2010) includes the full food web of the California Current, from Point Conception to the Canadian border and out to 1200 m depth. Diet information is based primarily on Dufault et al. (2009), the same source used above to identify key prey of the four groundfish. We used the model to estimate initial predation mortality on the four groundfish at the start of a simulation beginning in June 2008.

The method allowed us to identify 12 main predator groups with substantial predation mortality on one or more of the four groundfish species of interest. These predator groups are:

- Lingcod (*Ophiodon elongatus*)
- Dogfish (*Squalus acanthias*)
- Salmon
- Skates
- Pinnipeds
- Deep large rockfish (shortspine thornyhead, *Sebastolobus alascanus*)

- Sablefish
- Midwater rockfish
- Pacific hake
- Toothed whales
- Pelagic sharks
- Large flatfish (such as arrowtooth flounder *Atheresthes stomias*)

A detailed list of predators on each of the four groups is shown in Table C1. Note that since bocaccio are not modeled as an individual species in the Atlantis model, here we identify predators on a midwater rockfish functional group, which contains bocaccio and other species.

PART III: QUALITATIVE MODELING

OVERVIEW

The key prey and predator taxa of the four focal species (hake, sablefish, bocaccio and canary rockfish) were further identified using qualitative food web modeling. Using information about community structure derived from diet data, we quantified interaction links between all pairs of species/guilds. A community matrix, comprised of direct qualitative links (as +, - or 0) between species/guild pairs, was used to quantify direct and indirect relationships between all food web constituents. These relationships were then used to predict the effects of a press perturbation to one community constituent, i.e., an increase/decrease in abundance, birth rate, etc., on each other community constituent.

INTRODUCTION

Qualitative food web modeling can be used to describe indirect linkages and the effects of changes in species abundance that are otherwise difficult to describe, owing to food web complexity or limited quantitative information about linkages (Puccia and Levins 1985). Qualitative models are mathematically rigorous approaches to describing general relationships and trends in complex ecosystems in the absence of interaction strengths, information that is often lacking or imprecise, particularly in marine ecosystems. The emphasis in qualitative models on food web structure, defined by the relationships of interacting species, is particularly useful in a fisheries management context, where recent efforts to move away from the classic single-stock analysis and towards ecosystem-based models can be hampered by a lack of detailed information about interactions among all the food web constituents (Dambacher, Gaughan et al. 2009). Here, qualitative food web analysis makes use of fundamental information about relationships among species (e.g., diet information) to describe the effects of a change in the abundance of one species on the rest of the community (Dambacher, Li et al. 2002), critical information in an ecosystem-based management context.

We used fish diet information compiled for the California Current (Dufault, Marshall et al. 2009; Figs. C5-C12) to construct a diet matrix of the full California Current ecosystem. The exception for this was for bocaccio, where diet information was based on two additional sources (DFO 2009; Buchanan 2011). This 75 x 75 matrix was then reduced to a smaller diet matrix (24 taxonomic groups) focused on the food webs of the four focal species, by including only those taxa connected to the focal species via trophic interactions, and only taxa that represented ≥10% of diet composition. For example, the smaller diet matrix included canary rockfish, the predators and prey (≥10% of diet) of canary rockfish, the predators of canary rockfish predators, and the prey of canary rockfish prey, and so on, until reaching the base and top of the food web. To this matrix were added similar trophic webs centered on the remaining three focal species. This resulted in a 28 x 28 diet matrix (Table C2). To accommodate the computational limitations of the model, we constructed individual diet matrices for each of the focal groundfish species in the same fashion (Figs C13-C16; Tables C3-C6).

Discussion Point*: How to define predators?*

The present analysis defined predators of focal species as those species/guilds whose diet was at least 10% comprised of the focal species. Alternative methods for defining predators include scaling predator diets by predator biomass or abundance, to calculate relative predation pressure on each focal species, and then ranking predators by this predation pressure. The current method considers the predation threat to be equal among all potential predators of the focal species. For example, bocaccio predation on Pacific hake is considered to be as important as pinniped predation on Pacific hake, despite their low abundance. Alternative methods may produce different lists of key predators.

We next converted the diet matrices into qualitative community matrices ($^\circ\mathbf{A}$) containing all the direct effects in the food web (Tables C7-C10; Puccia and Levins 1985; Dambacher, Li et al. 2002). This was done by transferring each diet entry from the diet matrix to the community matrix, converting diet proportions to $^\circ a_{ij} = +1$ (prey-to-predator link) and $^\circ a_{ji} = -1$ (predator-to-prey link). The exception to this was we assumed no top-down effect on phytoplankton, i.e., no negative effect on phytoplankton by grazers. We also set each cell corresponding to the effect of adults on juveniles within taxa $^\circ a_{ij}$=+1 and each $^\circ a_{ii} = -1$ (self-regulation; Dambacher, Young et al. 2010). For species at very low population levels (e.g., bocaccio) not expected to experience self-damping effects, we tested the effects of setting $^\circ a_{ii}$ to 0 or +1 instead of -1, and found no changes to the results, and therefore left $^\circ a_{ii}$ for bocaccio at -1 to maintain food web stability (Dambacher, Young et al. 2010).

Using qualitative community matrices, we calculated how a press perturbation to each species, i.e., an increase or decrease in abundance, would affect every other species. These effects are based on an analysis of the adjoint of the negative community matrix (adj $-^\circ\mathbf{A}$), the elements of which represent a summation of all direct and indirect cycles connecting each species pair (Dambacher et al. 2002), and thereby provide a prediction of the directional response of each species to a press perturbation (Tables C11-C14). A matrix of "weighted predictions" (**W**), contributes a measure of the reliability of the predicted responses by weighting each element of the adj $-^\circ\mathbf{A}$ by the total number of feedback cycles contributing to it (Dambacher et al. 2002).

Weighted prediction (**W**) values scale by food web size and connectance such that as the number of nodes (species) in a food web or the number of links between nodes increases, **W** values decrease.

The reliability of sign determinancy of the adj $-{}^{\circ}\mathbf{A}$ is >0.95 for **W** values >0.5 (Dambacher, Li et al. 2002). We compared the adj $-{}^{\circ}\mathbf{A}$ of larger food webs (16-20 species) to the corresponding adj $-{}^{\circ}\mathbf{A}$ values of smaller food webs (5-10 species), focusing on entries corresponding to **W** values >0.5 for the smaller food webs. We found 100% sign consistency between adj $-{}^{\circ}\mathbf{A}$ matrices for all entries with corresponding **W** values >0.1. We therefore used a **W** threshold value of 0.1 for selecting key interactors with the focal species.

Key prey and predators of each focal species were defined as those prey and predator species/guilds that, when perturbed, had a positive or negative effect on the focal species. In addition, we defined indirect interactors as all other species/guilds besides predators or prey that, when perturbed, had positive or negative effects on the focal species.

RESULTS – KEY PREDATORS/PREY AND INDIRECT INTERACTIONS

BOCACCIO

1. PREY

The qualitative model of the bocaccio food web did not identify any prey species that, when perturbed, caused a response in bocaccio populations, according to our threshold of reliability. However, it should be noted that bocaccio diet data information is sparse; this is a major data gap. The data we use to inform this food web model come from only two reports: one reporting diet proportions from bocaccio sampled off the coast of California (pers comm. D. Buchanan 2011), and one describing, generally, prey species of fish caught off the coast of British Columbia and California (DFO 2009).

> ***Discussion point:*** *Lack of data for Bocaccio Diets*
>
> Our ability to identify the key prey for bocaccio was substantially limited by a dearth of diet information on bocaccio. Our diet information was limited to one personal communication and one Department of Fisheries and Oceans, Canada (DFO) report. This is a major data gap that should be filled, particularly considering the depleted status of bocaccio.

2. Predators

Bocaccio did not comprise more than 10% of any predator's diet, and therefore no predators were included in the qualitative model of bocaccio.

3. Indirect interactions

Large planktivores (mackerel) had an indirect negative effect on adult bocaccio, likely through competition for krill, a major prey for adult bocaccio prey fish, such as rockfish and hake (Fig. C13). Likewise, krill had an indirect positive effect on adult bocaccio, via the same trophic links. Shrimp had an indirect negative effect on adult bocaccio, via predation on deposit feeders, which are prey for rockfish (bocaccio prey), or as prey for mackerel, which have a negative indirect effect on adult bocaccio. Gelatinous zooplankton had a negative indirect effect on juvenile bocaccio, likely via competition for krill.

CANARY ROCKFISH

1. PREY

Krill were the major key prey for adult canary rockfish. Deposit feeders (amphipods, isopods, small crustacea) were the major prey species for juvenile canary rockfish.

2. PREDATORS

Adult bocaccio were the only canary rockfish predators in the model, and they were highlighted as having a negative effect on canary.

3. INDIRECT INTERACTIONS

Meiobenthos (flagellates, ciliates, nematodes) and benthic carnivores (polychaetes, nematodes, peanut worms, flatworms) had negative indirect effect on juvenile canary rockfish, likely to their role in reducing deposit feeders, a juvenile canary prey item (Fig. C14). Krill had indirect positive effects on juvenile canary rockfish, owing to their role as prey for adult Canary rockfish. Bottom-up effects of phytoplankton, included in this model, were highlighted for adult and juvenile canary rockfish.

PACIFIC HAKE

1. PREY

Krill were the only prey highlighted for adult hake, while copepods were key prey for juvenile hake.

2. PREDATORS

The key predators for adult Pacific hake were adult bocaccio, large flatfish (Arrowtooth flounder, Pacific halibut), pinnipeds and sablefish. Pinnipeds and small demersal sharks (spiny dogfish, spotted ratfish) were key predators on juvenile Pacific hake.

3. INDIRECT INTERACTIONS

Small planktivores (Northern anchovy, Pacific sardine) had a negative indirect effect on juvenile Pacific hake, likely owing to competition for krill (Fig. C15). Adult and juvenile Chinook salmon had positive indirect effects on juvenile Pacific hake, owing to their predation on anchovies and sardines.

SABLEFISH

1. PREY

Deep small rockfish (Longspine thornyhead, Sharpchin rockfish) and Pacific hake were identified as key prey for sablefish. Key prey for juvenile sablefish were small planktivores (sardines, anchovies), deposit feeders (amphipods, isopods, small crustacea), krill and gelatinous zooplankton.

2. PREDATORS

No Sablefish predators were included in the Sablefish model, because there were no predators with >10% of their diet comprised of Sablefish.

3. INDIRECT INTERACTIONS

Deposit feeders had an indirect positive effect on adult sablefish, likely via their role as prey for deep small rockfish, a key sablefish prey group (Fig. C16). Gelatinous zooplankton had negative indirect effects on both juvenile and adult sablefish, despite being a juvenile sablefish prey item, perhaps resulting from competition for krill. Krill had indirect positive effects on adult sablefish, in its role as prey for sablefish prey species. Copepods also had positive indirect effects on both juvenile and adult sablefish, while microzooplankton had both negative (on adults) and positive (on juveniles) effects on sablefish, owing to their role as prey for both copepods and gelatinous zooplankton.

RESULTS – PERTURBATIONS

Qualitative models showed that a decrease in small planktivorous forage fish (sardines, anchovies) affects multiple taxa throughout the groundfish food webs, and that the focal groundfish species had varying responses to a reduction in forage fish (Fig. C17). Small planktivores are included in the food web models for bocaccio, Pacific hake, and sablefish. Qualitative analysis of all three food webs showed that Pacific hake and juvenile sablefish decreased with a decrease in small planktivores, and that Canary rockfish, juvenile Pacific hake and juvenile bocaccio increased with a decrease in small planktivores. A decrease in small planktivores resulted in an increase in krill, owing to release of predation pressure by small planktivores, and a cascading decrease in copepods (Fig. C17). Pelagic sharks, pinnipeds, and Chinook salmon (adults and juveniles) also decreased in response to a decrease in small planktivores, associated with the loss of an important prey species. Species responding positively to a decrease in small planktivores included krill, deep small rockfish, and gelatinous zooplankton. These positive responses were mostly owing to an increase in krill abundance resulting from the decrease in predation pressure by small planktivores.

Qualitative models showed that a decrease in krill (euphausiids) results in a decrease in each of the four focal groundfish species (Fig. C18). Negative responses were also shown for large flatfish (Arrowtooth flounder), juvenile small demersal sharks, and filter feeders. Interestingly, Chinook salmon decreased in response to a decrease in krill, and also was predicted to decrease with a decrease in small planktivores, even though small planktivores and euphausiids consistently have opposing responses in the qualitative food web models. The Chinook salmon response indicates that a decrease in either of its prey species has negative effects on Chinook populations.

Species/guilds that increased in response to a decrease in krill included pinnipeds, deposit feeders, microzooplankton, and copepods. Species with ambiguous responses, that is, having a response to a krill perterbation that varied by food web, included shrimp, juvenile Canary rockfish and small planktivores. This ambiguous response was likely owing to variation in which predators and/or prey of those species were included in each groundfish food web.

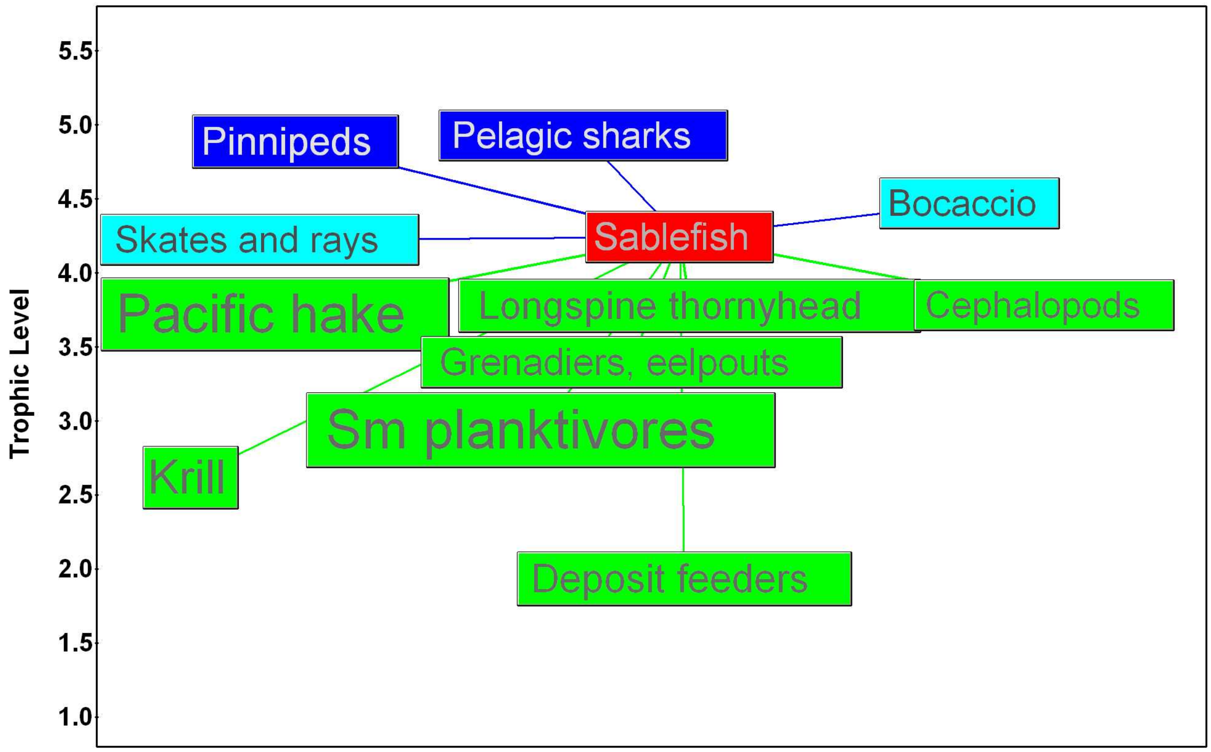


Figure C1. Primary food web of sablefish. In addition to the predator-prey links shown here, qualitative modeling suggests that bocaccio have non-trophic negative interactions (e.g. food competition) with sablefish.

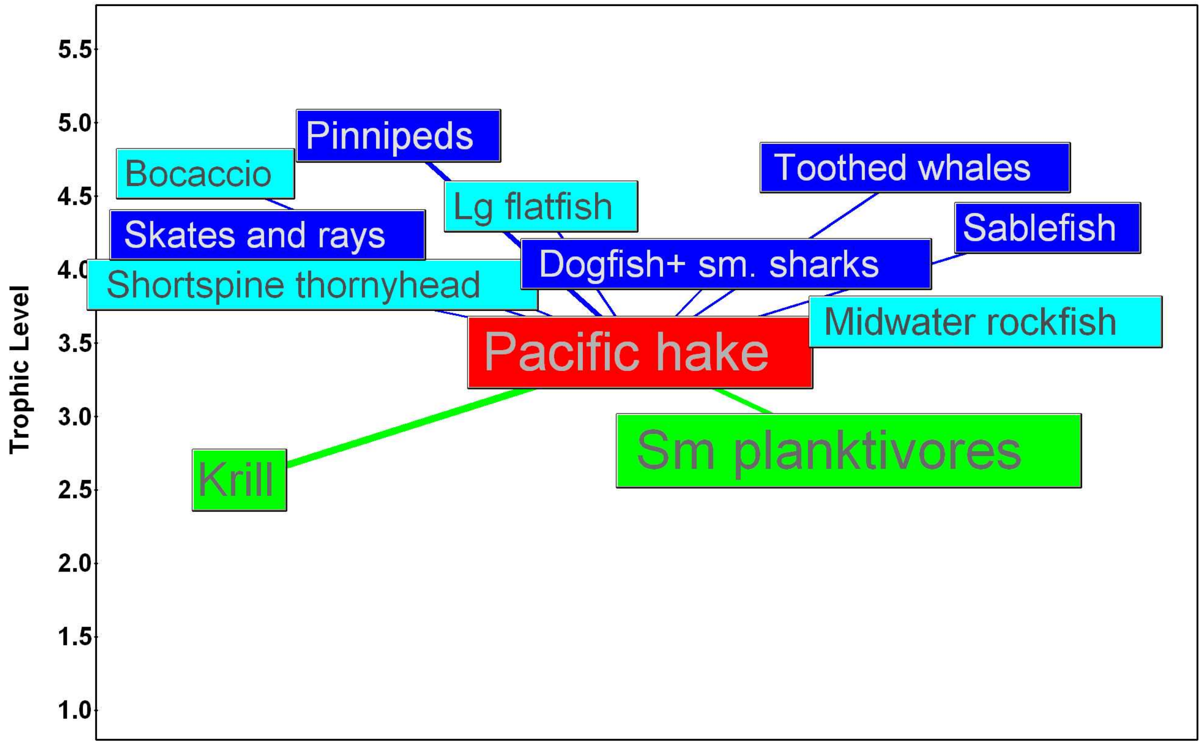


Figure C2. Primary food web of Pacific hake. Note that this diagram is based on adult hake data. Juvenile hake also feed on copepods, and this is identified as a strong link in qualitative modeling. Qualitative modeling also identified non-trophic negative relationships between hake and small planktivores, and positive relationships with chinook salmon.

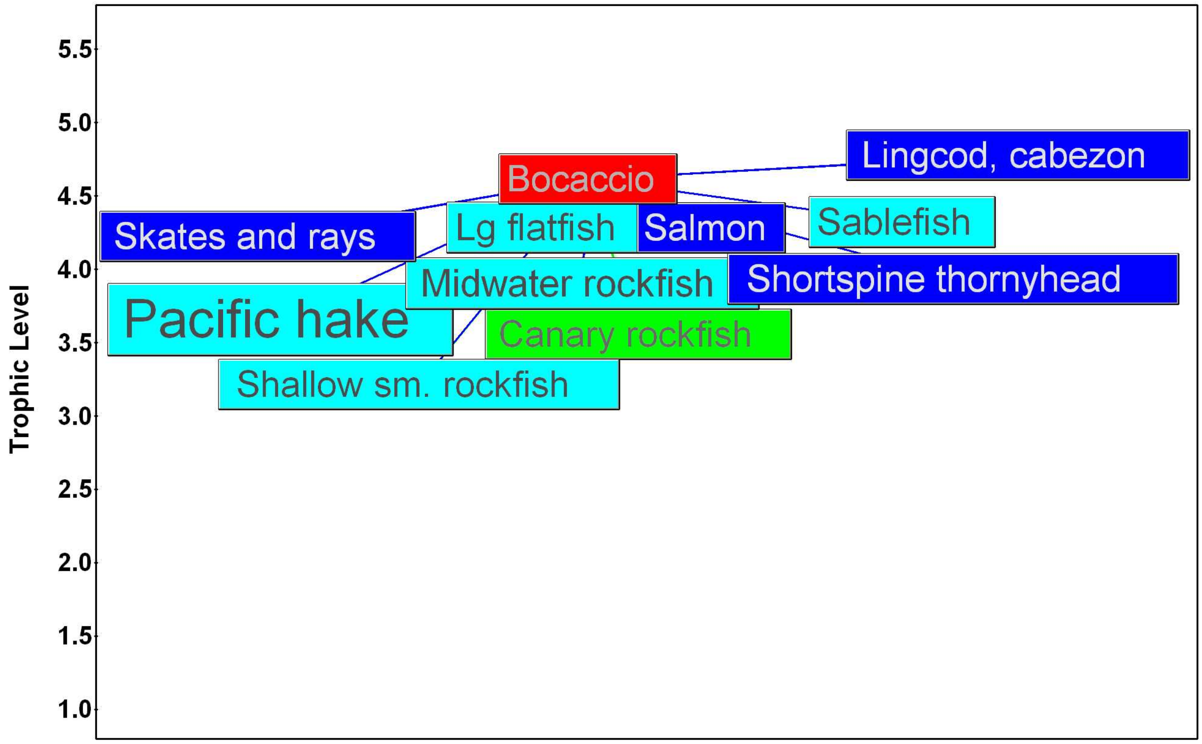


Figure C3. Primary food web for bocaccio. As discussed below, data for bocaccio are poor -- this is a major data gap. The available data suggest that bocaccio feed on juveniles of many species at trophic level 3.5-4.5, and that juvenile bocaccio in turn are consumed by adults of these species. Note that juvenile bocaccio diets are not incorporated into this figure, but would include euphausiids (krill). Qualitative modeling suggests that bocaccio have non-trophic negative interactions (e.g. food competition) with sablefish, in addition to the trophic effects shown here.

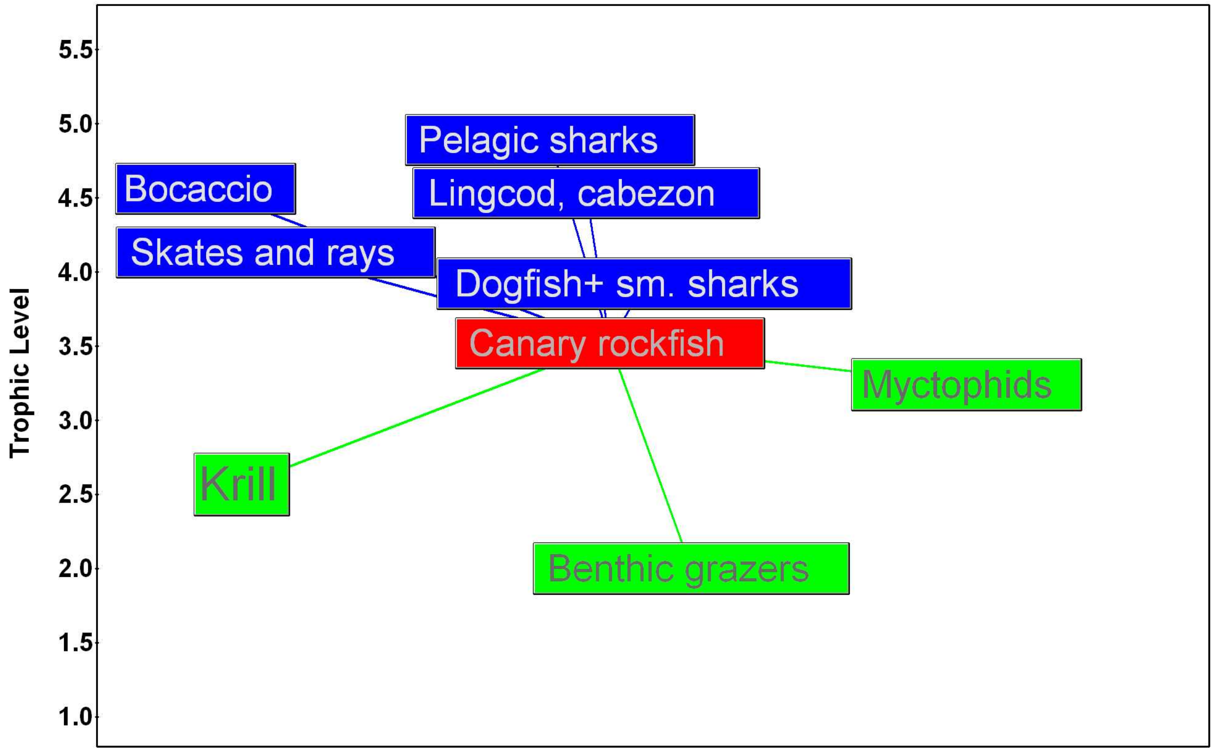


Figure C4. The primary food web for canary rockfish. Note that this diagram is based on adult diet data; juvenile canary also prey upon deposit feeders such as snails, amphipods and isopods, and this is a strong link identified by qualitative modeling.

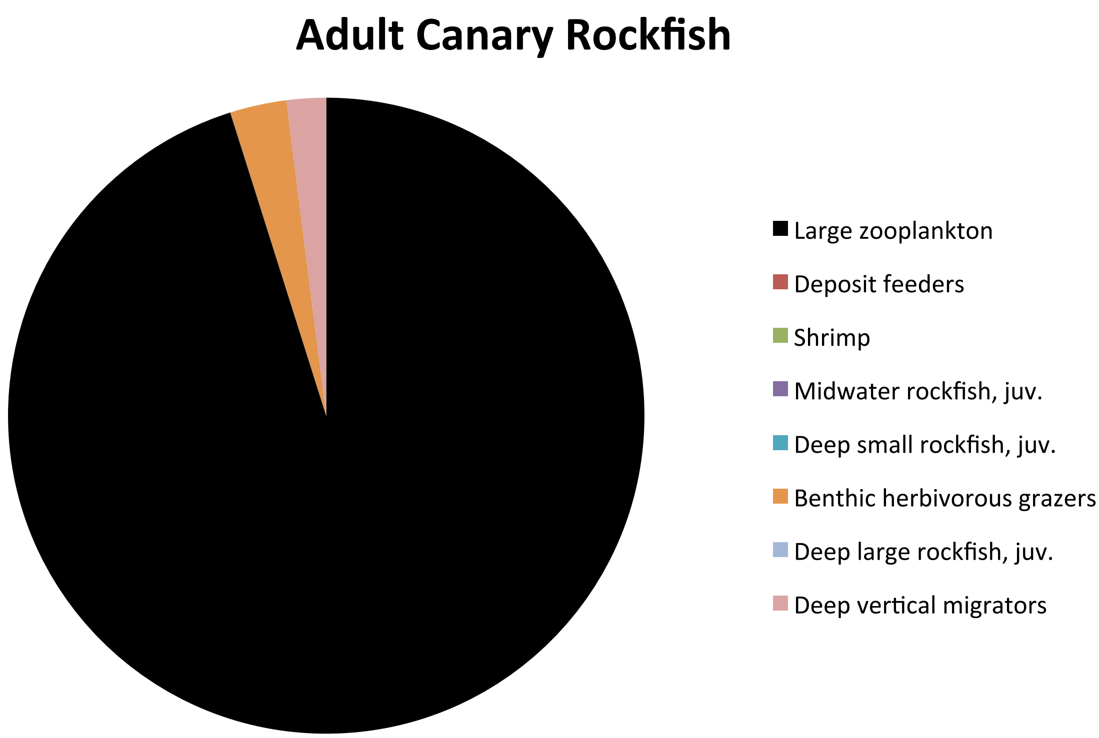


Figure C5. Diets of adult canary rockfish. Major prey items include large zooplankton (euphausiids), benthic grazers (such as pandalid shrimp and some snails), and deep vertically migrating fish (myctophids).

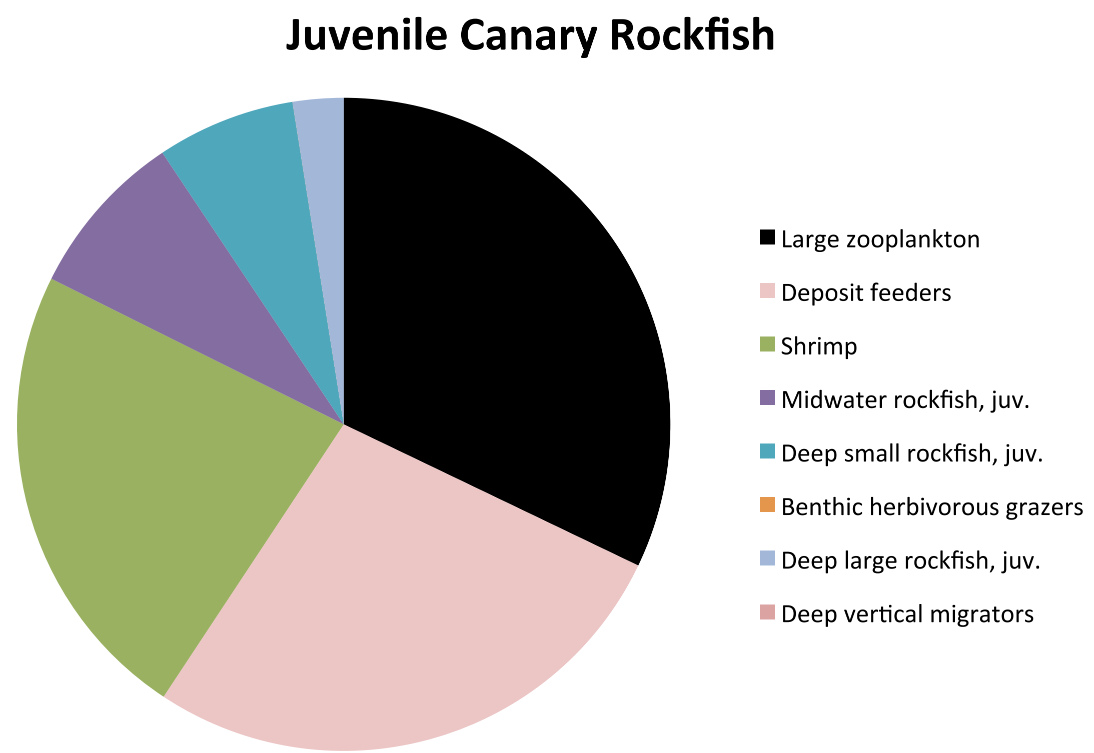


Figure C6. Diets of juvenile canary rockfish. Major prey items include large zooplankton (euphausiids), deposit feeders (e.g. amphipods, isopods), shrimp, and juvenile rockfish.

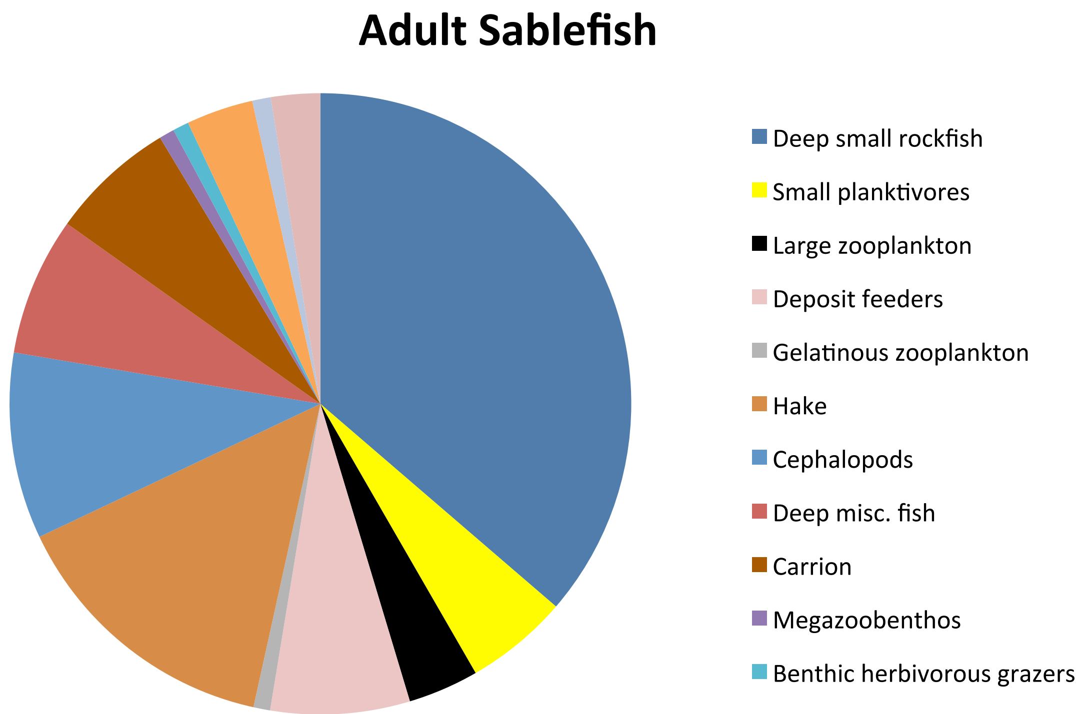


Figure C7. Diets of adult sablefish. Major prey items include deep small rockfish (e.g. longspine thornyhead, *Sebastolobus altivelis*), hake, cephalopods, deposit feeders (amphipods, isopods, snails), small plantivorous fish, large zooplankton (euphausiids), deep miscellaneous fish (eelpouts and grenadiers), and carrion.

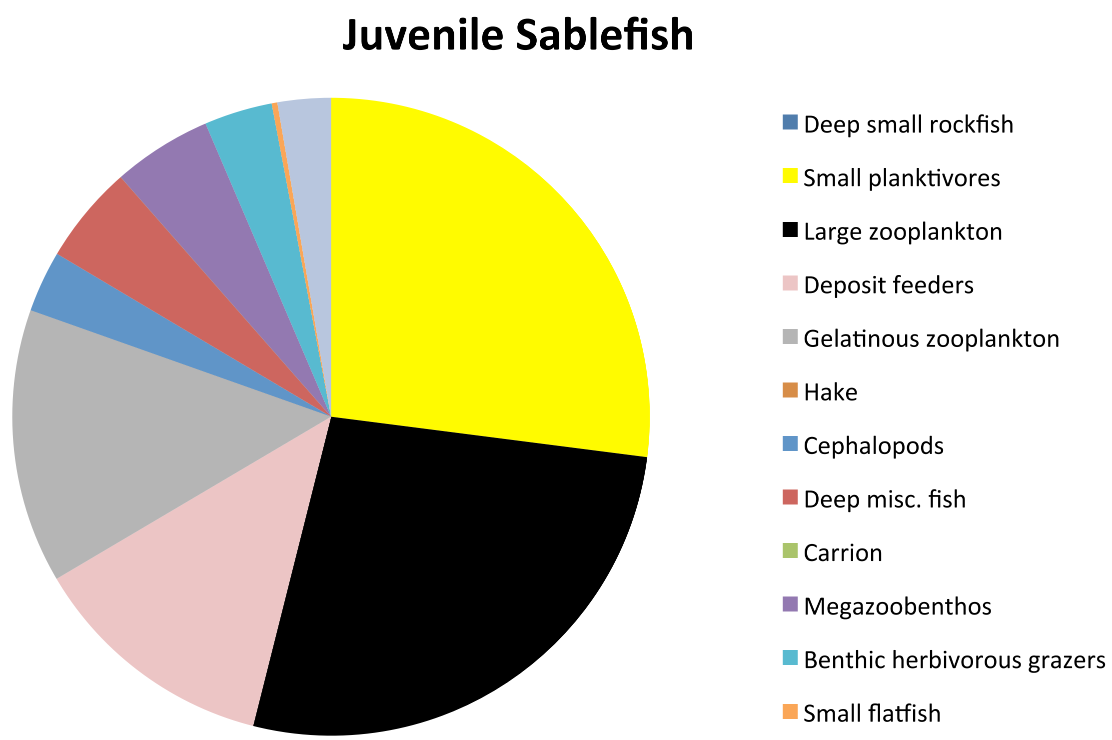


Figure C8. Diets of juvenile sablefish. Major prey items include small planktivorous fish, large zooplankton (euphausiids), deposit feeders (amphipods, isopods, etc.), and gelatinous zooplankton.

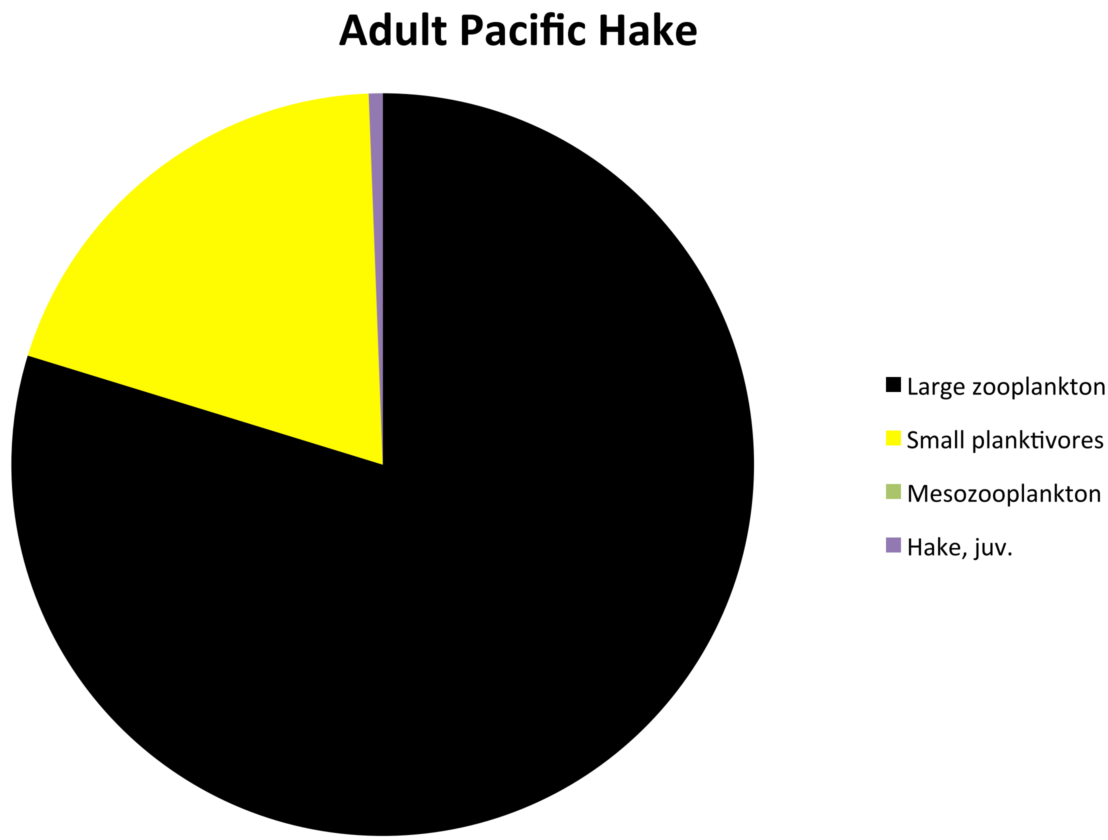


Figure C9. Diets of adult hake. Major prey items include large zooplankton (euphausiids) and small planktivorous fish. Approximately 1% of the adult diet is juvenile hake.

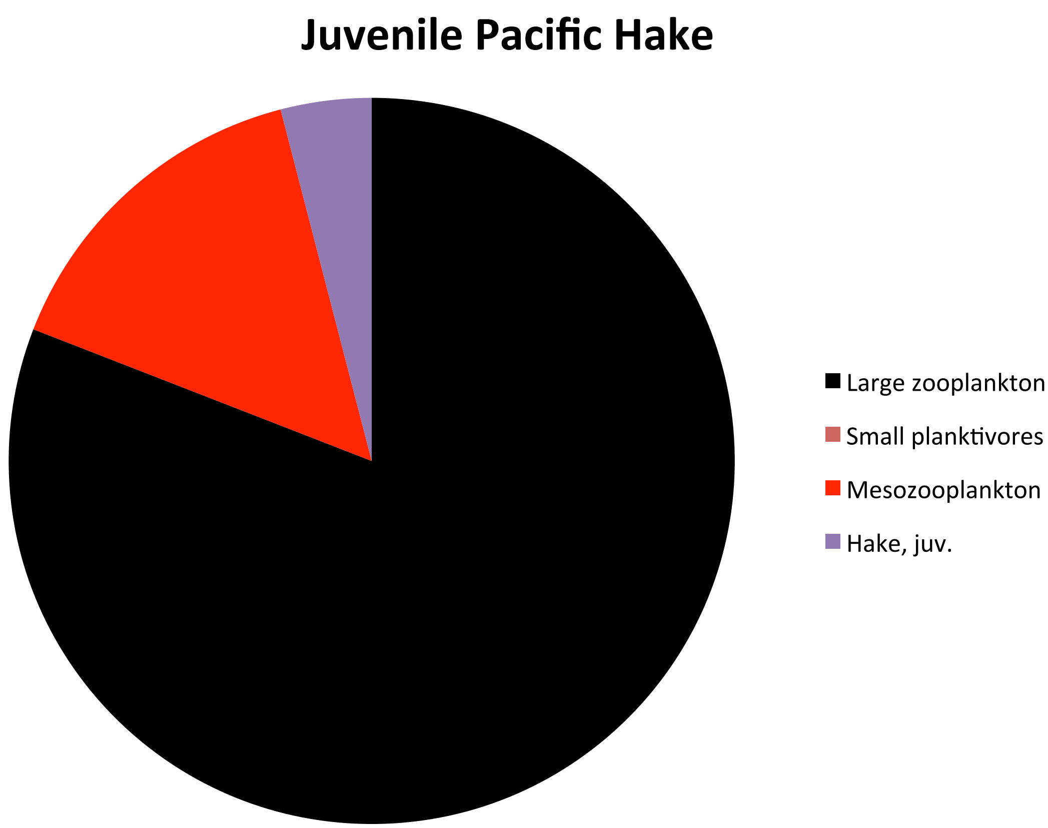


Figure C10. Diets of juvenile hake. Major prey items include large zooplankton (euphausiids) and mesozooplankton (copepods), as well as some juvenile hake (cannibalism).

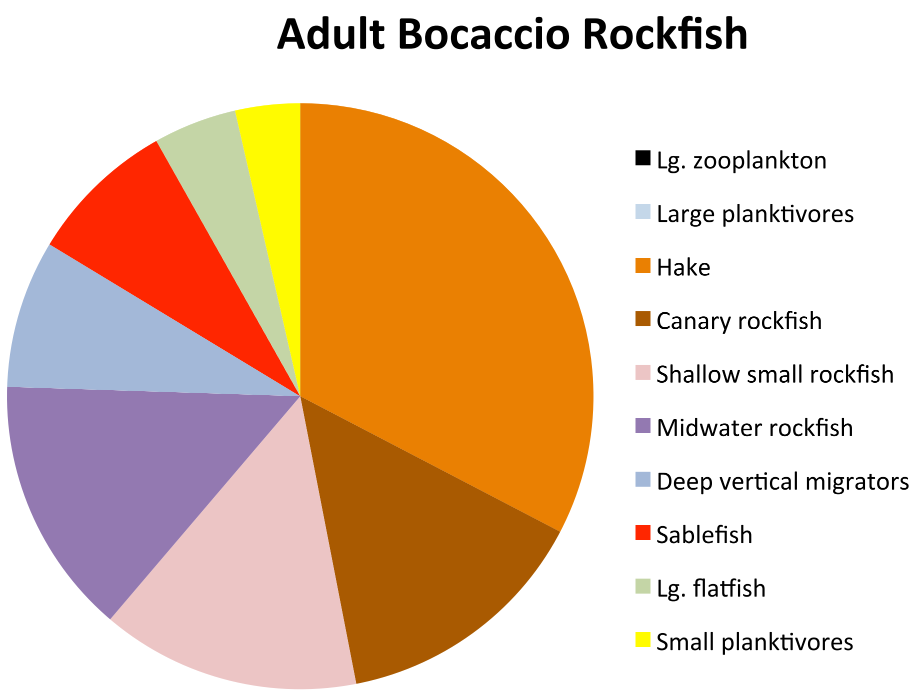


Figure C11. Diets of adult bocaccio, based on very limited data available from NOAA NWFSC Newport and DFO(2009). Major diet items include hake and other rockfish.

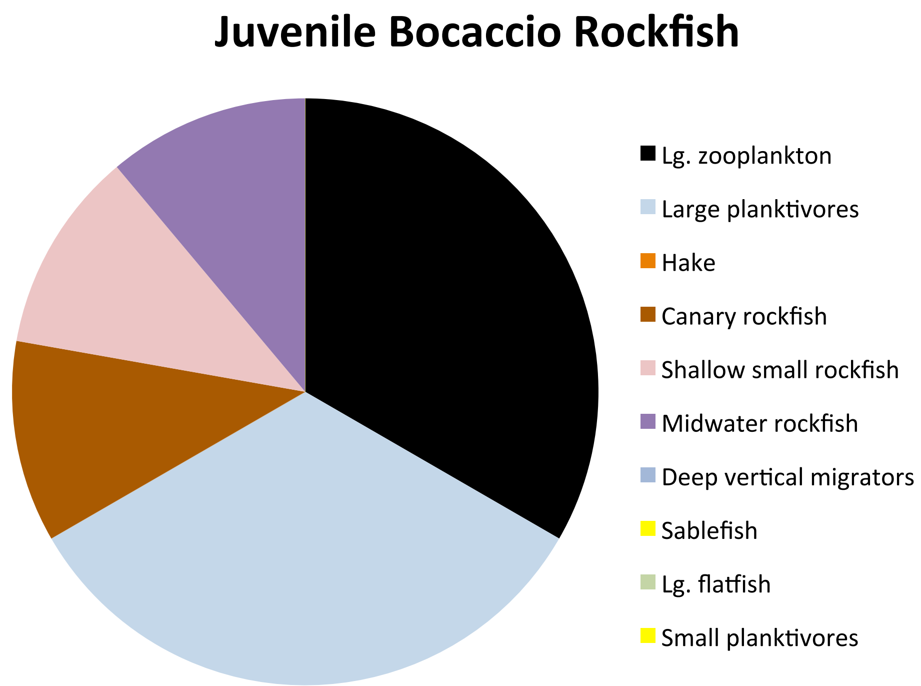


Figure C12. Diets of juvenile bocaccio, based on very limited data available from DFO(2009). Major diet items include large zooplankton (euphausiids), large planktivores (mackerel), and rockfish.

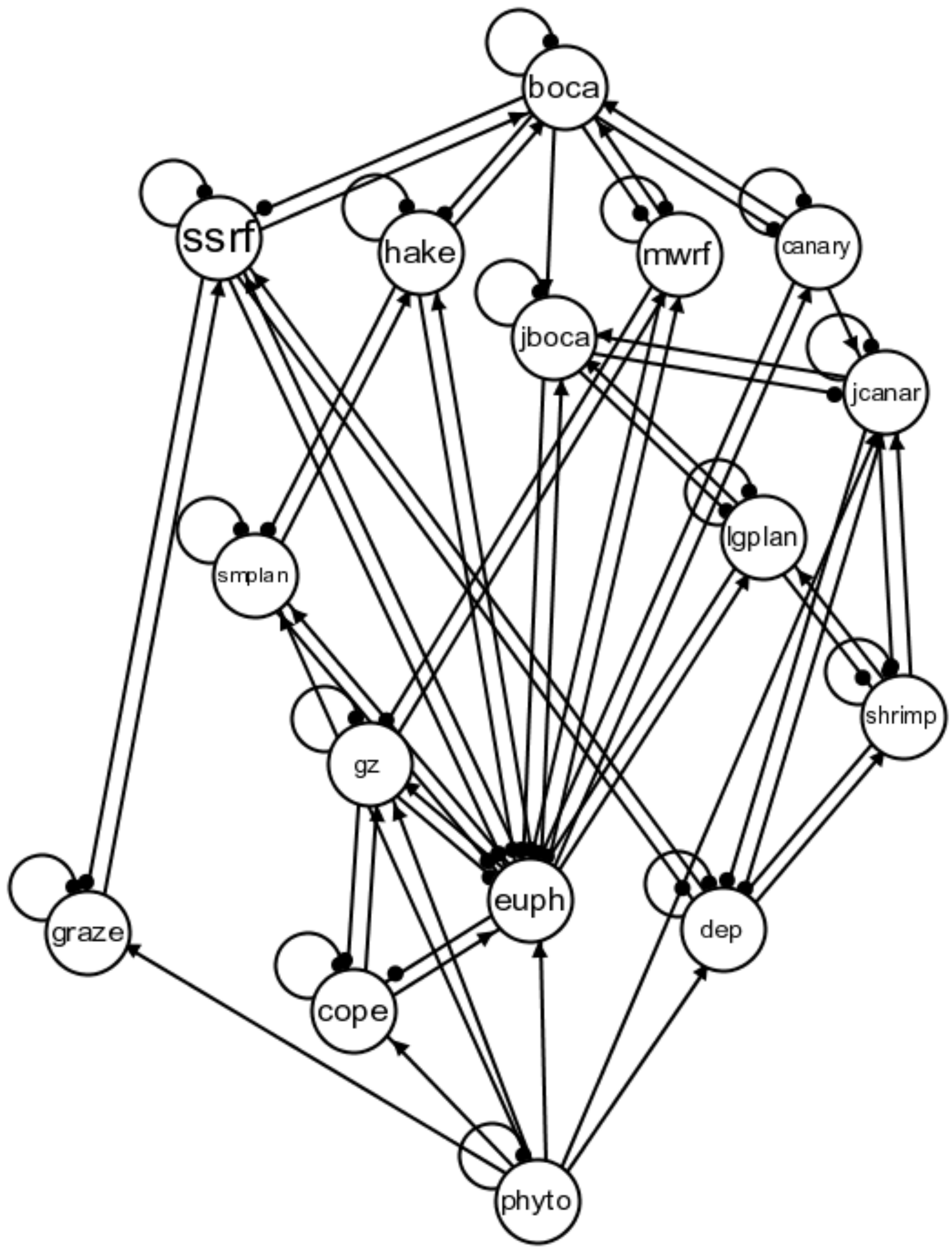


Figure C13. Bocaccio food-web digraph. Arrow ends indicate prey-predator (+1) interaction; circle ends indicate predator-prey or self-damping (-1) interactions. Abbreviate names are as follows: boca=bocaccio; ssrf=small shallow rockfish; jboca=juvenile bocaccio; mwrf = Midwater rockfish; jcanary = juvenile canary rockfish; lgplan = large planktivores; smplan = small planktivores; gz = gelatinous zooplankton; euph = euphausiids; dep = deposit feeders; cope = copepods; graze = benthic herbivorous grazers; phyto = phytoplankton.

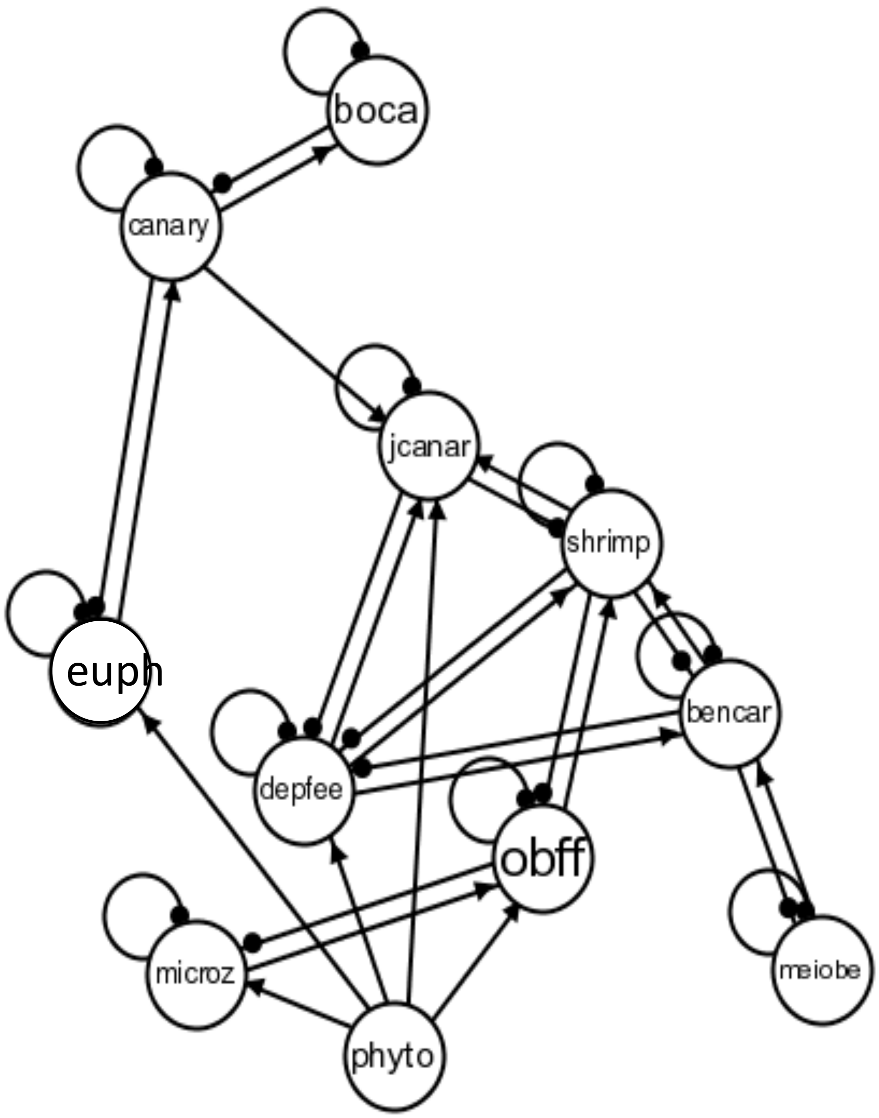


Figure C14. Canary rockfish food-web digraph. Arrow ends indicate prey-predator (+1) interaction; circle ends indicate predator-prey or self-damping (-1) interactions. Abbreviate names are as follows: boca=bocaccio; ssrf=small shallow rockfish; jboca=juvenile bocaccio; mwrf = Midwater rockfish; jcanary = juvenile canary rockfish; lgplan = large planktivores; smplan = small planktivores; gz = gelatinous zooplankton; euph = Euphausiids; dep = deposit feeders; cope = copepods; graze = benthic herbivorous grazers; phyto = phytoplankton.

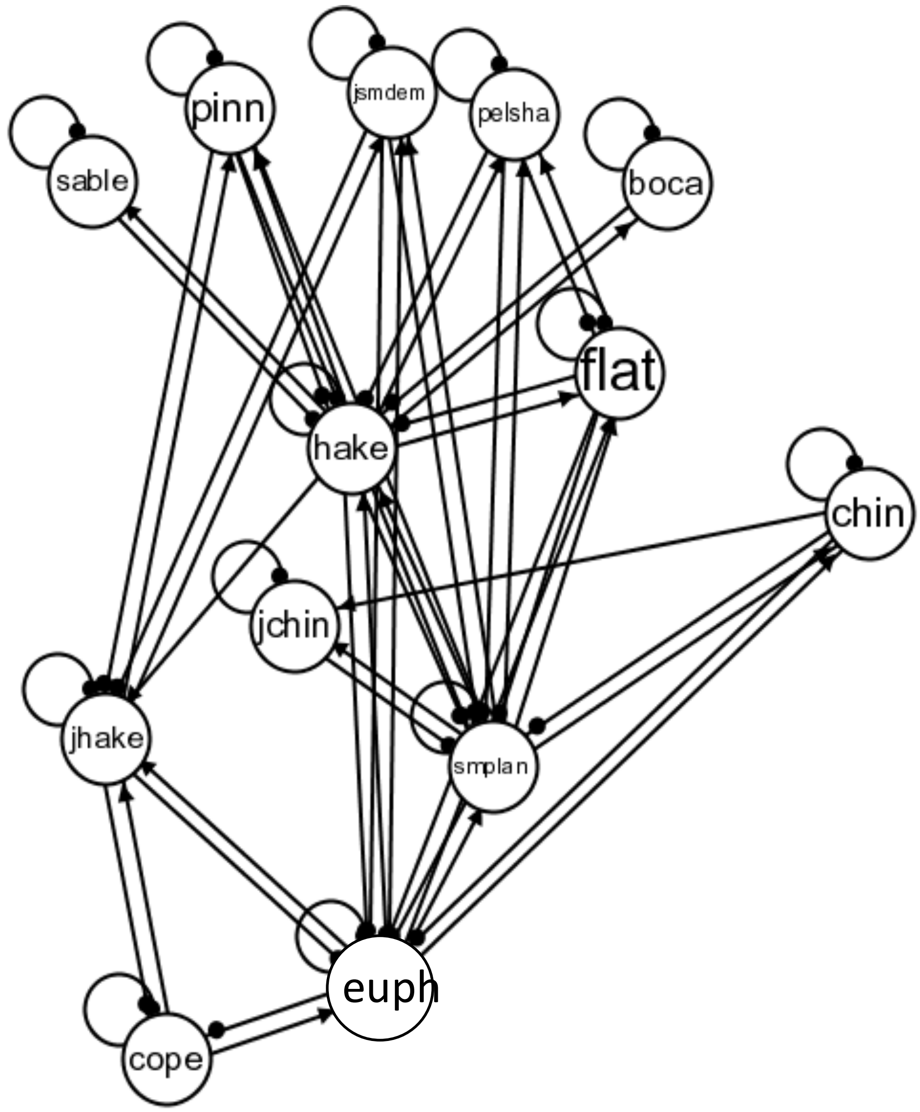


Figure C15. Hake food-web digraph. Arrow ends indicate prey-predator (+1) interaction; circle ends indicate predator-prey or self-damping (-1) interactions. Abbreviate names are as follows: pinn = pinnipeds, jsmdem = juvenile small demersal sharks; pelsha = pelagic sharks; sable = sablefish; boca = bocaccio; flat = large flatfish; jchin = juvenile Chinook salmon; chin = Chinook salmon; jhake = juvenile hake; smplan = small planktivores; lgzoo = large zooplankton; cope = copepods.

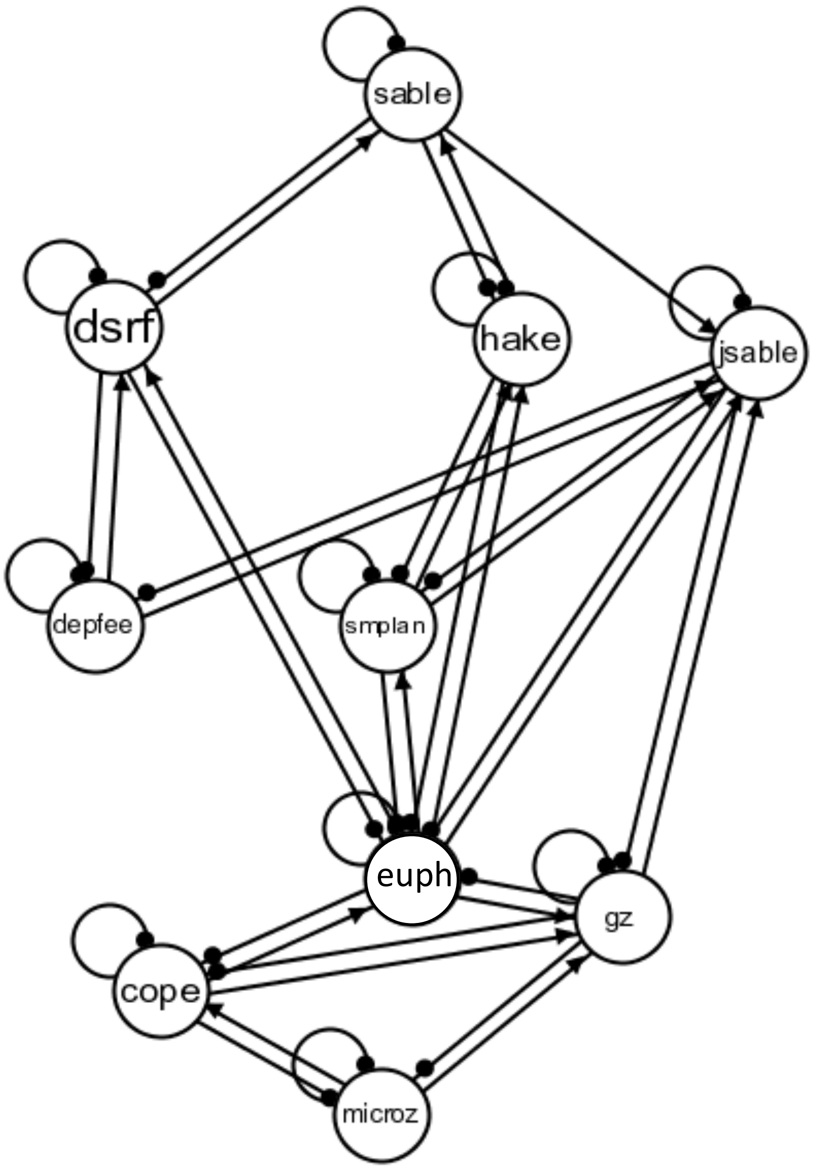
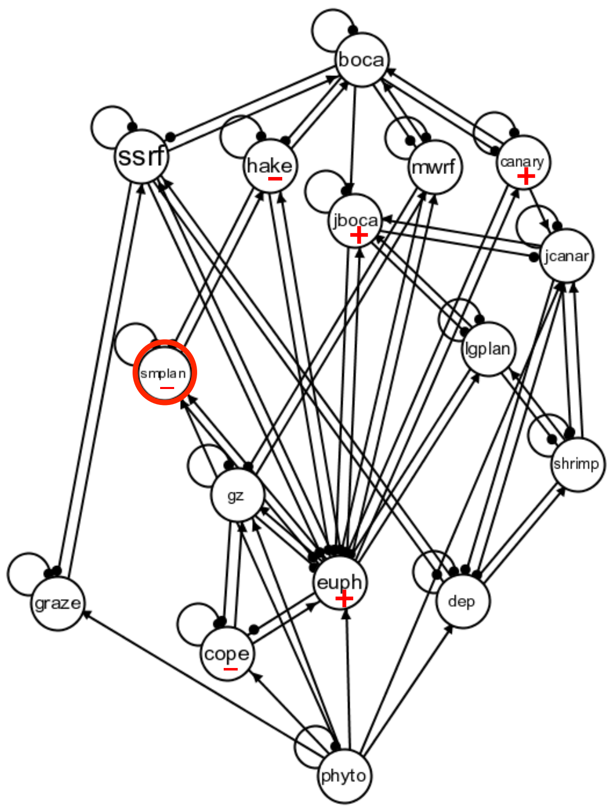
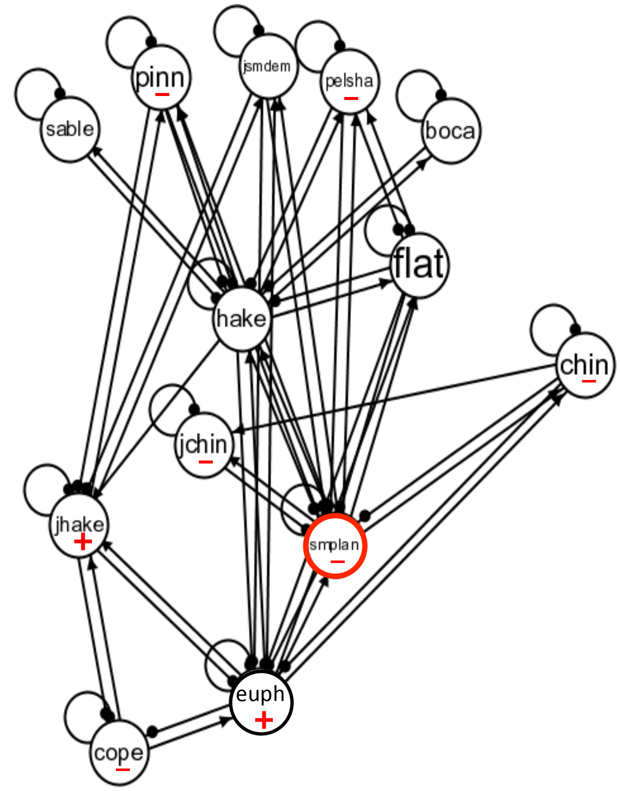


Figure C16. Sablefish food-web digraph. Arrow ends indicate prey-predator (+1) interaction; circle ends indicate predator-prey or self-damping (-1) interactions. Abbreviate names are as follows: sable = sablefish; dsrf = deep small rockfish; jsable = juvenile sablefish; depfee = deposit feeders; smplan = small planktivores; lgzoo = large zooplankton; gz = gelatinous zooplankton; cope = copepods; microz = microzooplankton.


boca
ssrf
hake
mwrf
canary
jboca
jcanar
lgplan
smplan
shrimp
gz
euph
dep
graze
cope
phyto


pinn
jsmdem
pelsha
sable
boca
flat
hake
chin
jchin
jhake
smplan
euph
cope

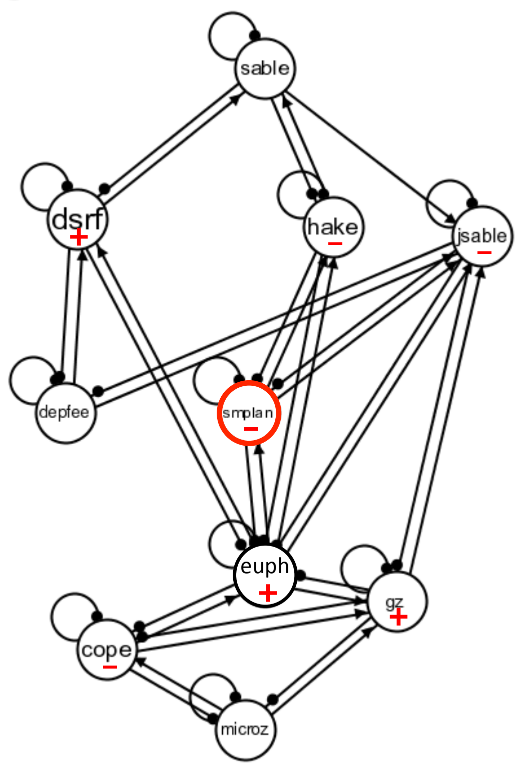

sable
dsrf
hake
jsable
depfee
smplan
euph
gz
cope
microz

Figure C16 (prev. page). Effects of a decrease in small planktivores (sardines, anchovies) on other species in each food web (excluding the sablefish food web, which does not include small planktivores). Positive (+) and negative (-) effects that exceed the reliability threshold are shown inside species nodes. Species names as follows: boca = bocaccio; chin = Chinook salmon; cope = copepods; dep = deposit feeders; dsrf = deep small rockfish; euph = euphausiids; flat = flatfish; gz = gelatinous zooplankton; graze = benthic herbivorous grazers; jboca = juvenile bocaccio; jcanar = juvenile canary rockfish; jchin = juvenile Chinook salmon; lgplan = large planktivores; microz = microzooplankton; mwrf = midwater rockfish; pelsha = pelagic sharks; phyto = phytoplankton; pinn = pinnipeds; smdem = small demersal sharks; smplan = small planktivores; ssrf = shallow small rockfish. See Table 1 for complete list of species included in each guild.

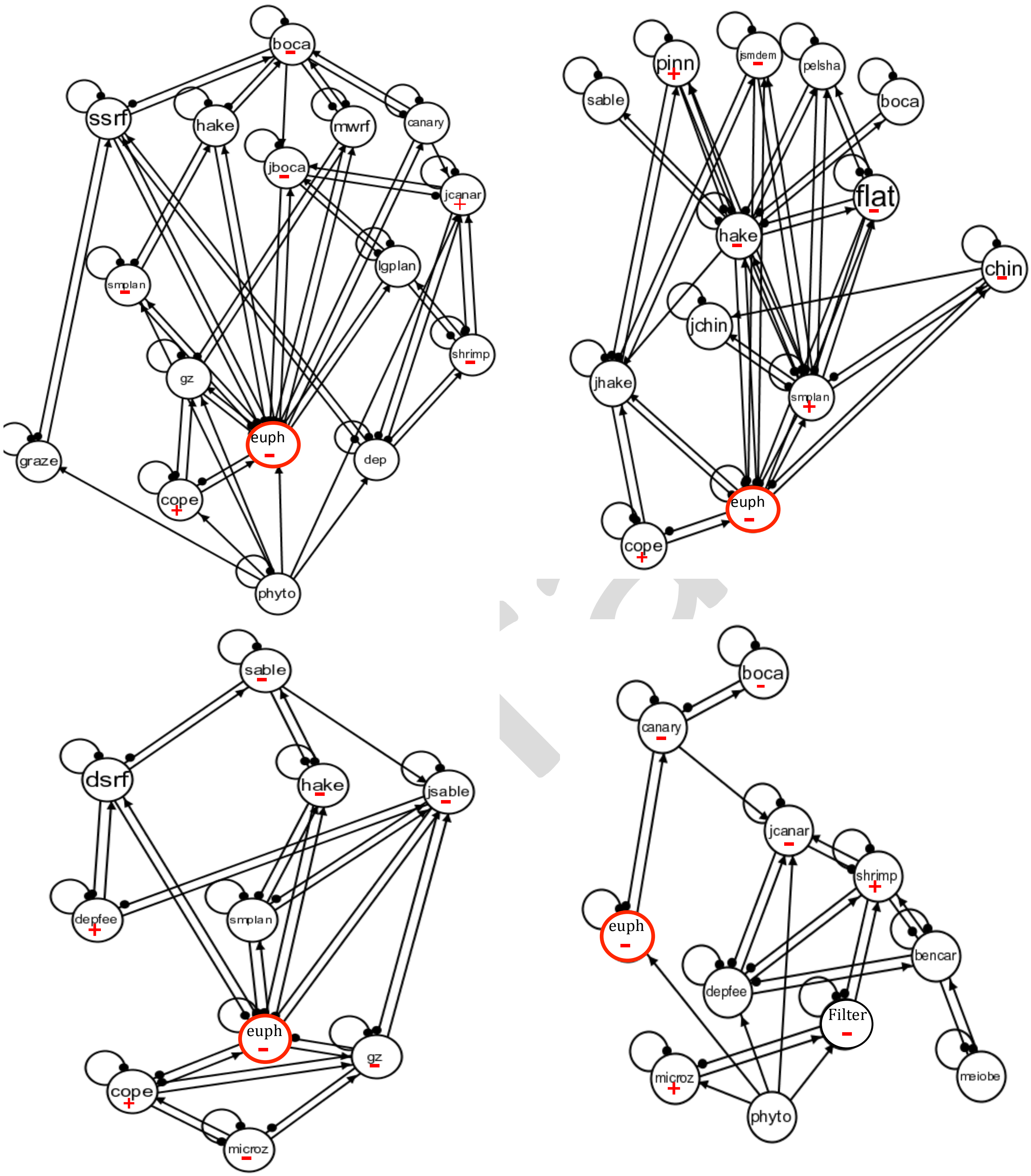

boca
ssrf
hake
mwrf
canary
jboca
jcanar
lgplan
smplan
shrimp
gz
euph
dep
graze
cope
phyto
pinn
jsmdem
pelsha
sable
boca
flat
hake
chin
jchin
jhake
smplan
euph
cope
sable
dsrf
hake
jsable
depfee
smplan
euph
gz
cope
microz
boca
canary
jcanar
shrimp
euph
bencar
depfee
Filter
microz
meiobe
phyto

Figure C17 (previous page). Effects of a decrease in Euphausiids (krill) on other species in each food web. Positive (+) and negative (-) effects that exceed the reliability threshold are shown inside species nodes. Species names as follows: boca = bocaccio; chin = Chinook salmon; cope = copepods; dep = deposit feeders; dsrf = deep small rockfish; euph = euphausiids; flat = flatfish; gz = gelatinous zooplankton; graze = benthic herbivorous grazers; jboca = juvenile bocaccio; jcanar = juvenile canary rockfish; jchin = juvenile Chinook salmon; lgplan = large planktivores; microz = microzooplankton; mwrf = midwater rockfish; pelsha = pelagic sharks; phyto = phytoplankton; pinn = pinnipeds; smdem = small demersal sharks; smplan = small planktivores; ssrf = shallow small rockfish. See Table 1 for complete list of species included in each guild.

Table C1. Predators on four groundfish species, based on Horne et al. (2010) Atlantis ecosystem model. Predators listed here consume either juveniles or adults of the four groundfish. Predators that account for 1 % or more of total predation mortality are in bold.

Canary rockfish	Hake	Sablefish	Midwater rockfish (including bocaccio)
lingcod	**dogfish**	**skates**	**midwater rockfish**
dogfish	**midwater rockfish**	**pinnipeds**	**lingcod**
salmon	**deep large rockfish**	**pelagic sharks**	**deep large rockfish**
skates	**hake**	**crabs**	**skates**
pinnipeds	**toothed whales**		**salmon**
deep large rockfish	**skates**		**sablefish**
sablefish	small toothed whales		**arrowtooth**
pelagic sharks	salmon		yelloweye and cowcod
	lingcod		pinnipeds
	pinnipeds		dogfish
	pelagic sharks		crabs
	arrowtooth		canary rockfish
	deep demersal fish		pelagic sharks
	canary rockfish		
	large demersal sharks		

Table C2. Species associated with each guild used in qualitative modeling, and proportional representation of each. Proportions are given for adult vertebrates only. (Adapted from Dufault et al. 2009, Table 1)

Guild	Species (Common name)	Proportion
Transient orcas	Transient orca	1.0
Bocaccio	Bocaccio	1.0
Canary rockfish	Canary rockfish	1.0
Chinook salmon	Chinook salmon	1.0
Deep small rockfish	Longspine thornyhead	0.63
	Sharpchin rockfish	0.20
	Splitnose rockfish	0.17
Diving seabirds	Common murre	0.59
	Rhinoceros auklet	0.19
	Cormorants, shags	0.16
Large flatfish	Arrowtooth flounders	0.71
	Pacific halibut	0.15
	Petrale sole	0.14
Midwater rockfish	Widow rockfish	0.43
	Pacific ocean perch	0.34
	Yellowtail rockfish	0.23
Pacific hake	Pacific hake	1.0
Pelagic sharks	Soupfin sharks	1.0
Pinnipeds	Northern elephant seal	0.32
	California sea lion	0.27
	Northern fur seal	0.25
	Harbor seal	0.15
Shallow small rockfish	Rosethorn rockfish	0.71
	Greenstriped rockfish	0.24

	Pygmy rockfish	0.06
Large planktivores	Pacific mackerel	0.59
	Jack mackerel	0.41
Small planktivores	Northern anchovy	0.59
	Pacific sardine	0.39
	Pacific herring	0.02
Small demersal sharks	Spiny dogfish	0.81
	Spotted ratfish	0.19
Deposit feeders	Amphipods, isopods, small crustacea, snails, ghost shrimp, sea cucumbers, worms, sea mouse, sea slugs, barnacles, solenogaster, hermit crabs	
Benthic filter feeders	Geoduck, barnacles, razor clam, littleneck clam, Manila clam, miscellaneous bivalves, Vancouver scallop, glass scallop, green sea urchin, red sea urchin	
Benthic grazers	Snails, abalone, nudibranchs, sand dollars, naked solarelle, dorid nudibranchs, limpets, heart sea urchin, spot prawns, pandalid shrimps	
Meiobenthos	Flagellates, ciliates, nematodes	
Gelatinous zooplankton	Salps, jellyfish, ctenophores, comb jellies	
Mesozooplankton	Copepods, cladocera	
Benthic carnivores	Polychaetes, nematodes, burrowing crustacea, peanut worms, flatworms	
Microzooplankton	Ciliates, dinoflagellates, nanoflagellates, gymnodinoids, protozoa	
Shrimp	Crangon and mysid shrimps	

Table C3. Diet matrix for bocaccio. Predators are in rows, prey are in columns. Values represent the proportional diet composition of each prey for each predator. Species names are as follows: 1: Bocaccio; 2: Canary rockfish; 3: Large planktivores; 4: Midwater rockfish; 5: Pacific hake; 6: Shallow small rockfish; 7: Small planktivores; 8: Benthic herbivorous grazers; 9: Deposit feeders; 10: Gelatinous zooplankton; 11: Juvenile bocaccio; 12: Juvenile Canary rockfish; 13: Phytoplankton; 14: Large zooplankton; 15: Mesozooplankton; 16: Shrimp.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	0	0.14	0	0.14	0.32	0.14	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0.95	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0.60	0	0.14
4	0	0	0	0	0	0	0	0	0	0.24	0	0	0	0.38	0	0
5	0	0	0	0	0	0	0.19	0	0	0	0	0	0	0.78	0	0
6	0	0	0	0	0	0	0	0.26	0.34	0	0	0	0	0.27	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0.26	0.61	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0.14	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0.31	0.33	0.16	0
11	0	0	0.33	0	0	0	0	0	0	0	0	0.11	0	0.33	0	0
12	0	0	0	0	0	0	0	0	0.26	0	0	0	0.31	0	0	0.22
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0.56	0.14	0.20	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0
16	0	0	0	0	0	0	0	0	0.38	0	0	0	0	0	0	0

Table C4. Diet matrix for canary rockfish. Predators are in rows, prey are in columns. Values represent the proportional diet composition of each prey for each predator. Species names are as follows: 1: Bocaccio; 2: Canary rockfish; 3: Benthic carnivores; 4: Deposit feeders; 5: Juvenile Canary rockfish; 6: Large zooplankton; 7: Meiobenthos; 8: Microzooplankton; 9: Other benthic filter feeders; 10: Phytoplankton; 11: Shrimp.

	1	2	3	4	5	6	7	8	9	10	11
1	0	0.14	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0.95	0	0	0	0	0
3	0	0	0	0.5	0	0	0.3	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0.14	0
5	0	0	0	0.26	0	0	0	0	0	0.31	0.22
6	0	0	0	0	0	0.14	0	0	0	0.56	0
7	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0.75	0
9	0	0	0	0	0	0	0	0.25	0	0.5	0
10	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0.16	0.38	0	0	0	0	0.1	0	0

Table C5. Diet matrix for Pacific hake. Predators are in rows, prey are in columns. Values represent the proportional diet composition of each prey for each predator. Species names are as follows: 1: Bocaccio; 2: Chinook salmon; 3: Large flatfish; 4: Pacific hake; 5: Pelagic sharks; 6: Pinnipeds; 7: Sablefish; 8: Small planktivores; 9: Juvenile Chinook salmon; 10: Juvenile Pacific hake; 11: Juvenile small demersal sharks; 12: Large zooplankton; 13: Mesozooplankton.

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	0	0	0	0.32	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0.48	0	0	0	0.26	0
3	0	0	0	0.38	0	0	0	0.12	0	0	0	0.10	0
4	0	0	0	0	0	0	0	0.19	0	0	0	0.78	0
5	0	0	0.10	0.12	0	0	0	0.26	0	0	0	0	0
6	0	0	0	0.10	0	0	0	0.12	0	0.10	0	0	0
7	0	0	0	0.13	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0.61	0
9	0	0	0	0	0	0	0	0.48	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0.80	0.15
11	0	0	0	0	0	0	0	0.19	0	0.21	0	0.59	0
12	0	0	0	0	0	0	0	0	0	0	0	0.14	0.20
13	0	0	0	0	0	0	0	0	0	0	0	0	0

Table C6. Diet matrix for Sablefish. Predators are in rows, prey are in columns. Values represent the proportional diet composition of each prey for each predator. Species names are as follows: 1: Deep small rockfish; 2: Pacific hake; 3: Sablefish; 4: Small planktivores; 5: Deposit feeders; 6: Gelatinous zooplankton; 7: Juvenile Sablefish; 8: Large zooplankton; 9: Mesozooplankton; 10: Microzooplankton.

	1	2	3	4	5	6	7	8	9	10
1	0	0	0	0	0.3	0	0	0.1	0	0
2	0	0	0	0.19	0	0	0	0.78	0	0
3	0.34	0.13	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0.61	0	0
5	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0.33	0.16	0.17
7	0	0	0	0.25	0.12	0.13	0	0.25	0	0
8	0	0	0	0	0	0	0	0.14	0.2	0
9	0	0	0	0	0	0	0	0	0	0.2
10	0	0	0	0	0	0	0	0	0	0

Table C7. Community matrix for bocaccio food web. Species names are as follows: 1: Bocaccio; 2: Canary rockfish; 3: Large planktivores; 4: Midwater rockfish; 5: Pacific hake; 6: Shallow small rockfish; 7: Small planktivores; 8: Benthic herbivorous grazers; 9: Deposit feeders; 10: Gelatinous zooplankton; 11: Juvenile bocaccio; 12: Juvenile Canary rockfish; 13: Phytoplankton; 14: Large zooplankton; 15: Mesozooplankton; 16: Shrimp.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	-1	-1	0	-1	-1	-1	0	0	0	0	1	0	0	0	0	0
2	1	-1	0	0	0	0	0	0	0	0	0	1	0	-1	0	0
3	0	0	-1	0	0	0	0	0	0	0	1	0	0	-1	0	-1
4	1	0	0	-1	0	0	0	0	0	-1	0	0	0	-1	0	0
5	1	0	0	0	-1	0	-1	0	0	0	0	0	0	-1	0	0
6	1	0	0	0	0	-1	0	-1	-1	0	0	0	0	-1	0	0
7	0	0	0	0	1	0	-1	0	0	0	0	0	0	-1	0	0
8	0	0	0	0	0	1	0	-1	0	0	0	0	0	0	0	0
9	0	0	0	0	0	1	0	0	-1	0	0	1	0	0	0	1
10	0	0	0	1	0	0	0	0	0	-1	0	0	0	-1	-1	0
11	0	0	-1	0	0	0	0	0	0	0	-1	-1	0	-1	0	0
12	0	0	0	0	0	0	0	0	-1	0	1	-1	0	0	0	-1
13	0	0	0	0	0	0	1	1	1	1	0	1	-1	1	1	0
14	0	1	1	1	1	1	1	0	0	1	1	0	0	-1	-1	0
15	0	0	0	0	0	0	0	0	0	1	0	0	0	1	-1	0
16	0	0	1	0	0	0	0	0	-1	0	0	1	0	0	0	-1

Table C8. Community matrix for canary rockfish food web. Species names are as follows: 1: Bocaccio; 2: Canary rockfish; 3: Benthic carnivores; 4: Deposit feeders; 5: Juvenile Canary rockfish; 6: Large zooplankton; 7: Meiobenthos; 8: Microzooplankton; 9: Other benthic filter feeders; 10: Phytoplankton; 11: Shrimp.

	1	2	3	4	5	6	7	8	9	10	11
1	-1	-1	0	0	0	0	0	0	0	0	0
2	1	-1	0	0	1	-1	0	0	0	0	0
3	0	0	-1	-1	0	0	-1	0	0	0	1
4	0	0	1	-1	1	0	0	0	0	0	1
5	0	0	0	-1	-1	0	0	0	0	0	-1
6	0	1	0	0	0	-1	0	0	0	0	0
7	0	0	1	0	0	0	-1	0	0	0	0
8	0	0	0	0	0	0	0	-1	1	0	0
9	0	0	0	0	0	0	0	-1	-1	0	1
10	0	0	0	1	1	1	0	1	1	-1	0
11	0	0	-1	-1	1	0	0	0	-1	0	-1

Table C9. Community matrix for Pacific hake food web. Species names are as follows: 1: Bocaccio; 2: Chinook salmon; 3: Large flatfish; 4: Pacific hake; 5: Pelagic sharks; 6: Pinnipeds; 7: Sablefish; 8: Small planktivores; 9: Juvenile Chinook salmon; 10: Juvenile Pacific hake; 11: Juvenile small demersal sharks; 12: Large zooplankton; 13: Mesozooplankton.

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	-1	0	0	-1	0	0	0	0	0	0	0	0	0
2	0	-1	0	0	0	0	0	-1	1	0	0	-1	0
3	0	0	-1	-1	1	0	0	-1	0	0	0	-1	0
4	1	0	1	-1	1	1	1	-1	0	1	0	-1	0
5	0	0	-1	-1	-1	0	0	-1	0	0	0	0	0
6	0	0	0	-1	0	-1	0	-1	0	-1	0	0	0
7	0	0	0	-1	0	0	-1	0	0	0	0	0	0
8	0	1	1	1	1	1	0	-1	1	0	1	-1	0
9	0	0	0	0	0	0	0	-1	-1	0	0	0	0
10	0	0	0	0	0	1	0	0	0	-1	1	-1	-1
11	0	0	0	0	0	0	0	-1	0	-1	-1	-1	0
12	0	1	1	1	0	0	0	1	0	1	1	-1	-1
13	0	0	0	0	0	0	0	0	0	1	0	1	-1

Table C10. Community matrix for sablefish food web. Species names are as follows: 1: Deep small rockfish; 2: Pacific hake; 3: Sablefish; 4: Small planktivores; 5: Deposit feeders; 6: Gelatinous zooplankton; 7: Juvenile Sablefish; 8: Large zooplankton; 9: Mesozooplankton; 10: Microzooplankton.

	1	2	3	4	5	6	7	8	9	10
1	-1	0	1	0	-1	0	0	-1	0	0
2	0	-1	1	-1	0	0	0	-1	0	0
3	-1	-1	-1	0	0	0	1	0	0	0
4	0	1	0	-1	0	0	1	-1	0	0
5	1	0	0	0	-1	0	1	0	0	0
6	0	0	0	0	0	-1	1	-1	-1	-1
7	0	0	0	-1	-1	-1	-1	-1	0	0
8	1	1	0	1	0	1	1	-1	-1	0
9	0	0	0	0	0	1	0	1	-1	-1
10	0	0	0	0	0	1	0	0	1	-1

Table C11. Bocaccio food web adjoint (**-A**) matrix. Signs represent predicted directional responses of row species to positive press perturbation of column species. Highlighted cells correspond to **W** values >0.1. Boxes are drawn around effects on bocaccio and juvenile bocaccio. Species names are as follows: 1: Bocaccio; 2: Canary rockfish; 3: Large planktivores; 4: Midwater rockfish; 5: Pacific hake; 6: Shallow small rockfish; 7: Small planktivores; 8: Benthic herbivorous grazers; 9: Deposit feeders; 10: Gelatinous zooplankton; 11: Juvenile bocaccio; 12: Juvenile Canary rockfish; 13: Phytoplankton; 14: Large zooplankton; 15: Mesozooplankton; 16: Shrimp.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	702	318	-420	468	351	120	-147	120	-36	-264	-192	114	519	498	234	-270
2	-594	1551	-141	-396	-297	-267	-372	-267	-135	-273	-3	69	-1101	75	-198	63
3	108	-760	1112	72	54	92	-41	92	-171	-59	-434	-773	-821	95	36	510
4	-396	-400	-94	1170	-198	-178	-248	-178	-90	535	-2	46	700	50	585	42
5	-243	-441	-351	-162	954	-207	630	-207	-153	-405	-99	126	234	324	-81	-72
6	-216	-392	166	-144	-108	772	-157	772	342	-121	-88	-127	686	49	-72	-303
7	351	159	-210	234	-900	60	1002	60	-18	-132	-96	57	1335	249	117	-135
8	216	392	-166	144	108	-772	157	1379	-342	121	88	127	1465	-49	72	303
9	162	-184	473	108	81	-340	58	-340	819	31	-173	-323	322	23	54	-669
10	198	200	47	-585	99	89	124	89	45	808	1	-23	1801	-25	783	-21
11	486	165	-15	324	243	-303	-543	-303	306	-624	915	465	249	786	162	144
12	-432	889	-146	-288	-216	-368	164	-368	684	236	-415	941	1133	-380	-144	111
13	0	0	0	0	0	0	0	0	0	0	0	0	2151	0	0	0
14	108	-282	-561	72	54	-147	-519	-147	-171	-537	-195	183	-582	573	36	-207
15	-306	82	514	513	-153	58	395	58	126	-271	194	-160	932	-548	1332	228

16	486	-313	-493	324	243	-64	-65	-64	306	-146	676	-491	10	308	162	861

Table C12. Canary rockfish food web adjoint (-**A**) matrix. Signs represent predicted directional responses of row species to positive press perturbation of column species. Highlighted cells correspond to **W** values >0.1. Boxes are drawn around effects on Canary rockfish and juvenile Canary rockfish. 1: Bocaccio; 2: Canary rockfish; 3: Benthic carnivores; 4: Deposit feeders; 5: Juvenile Canary rockfish; 6: Large zooplankton; 7: Meiobenthos; 8: Microzooplankton; 9: Other benthic filter feeders; 10: Phytoplankton; 11: Shrimp.

	1	2	3	4	5	6	7	8	9	10	11
1	66	33	0	0	0	33	0	0	0	33	0
2	-33	33	0	0	0	33	0	0	0	33	0
3	-3	3	30	15	9	3	30	-12	-12	3	-24
4	6	-6	-27	36	-18	-6	-27	-9	-9	-6	-18
5	-15	15	-15	42	45	15	-15	6	6	114	12
6	33	-33	0	0	0	66	0	0	0	66	0
7	3	-3	-30	-15	-9	-3	69	12	12	-3	24
8	6	-6	6	3	-18	-6	6	57	-42	-6	15
9	-6	6	-6	-3	18	6	-6	42	42	105	-15
10	0	0	0	0	0	0	0	0	0	99	0
11	12	-12	12	6	-36	-12	12	15	15	-12	30

Table C13. Pacific hake food web adjoint (-A) matrix. Signs represent predicted directional responses of row species to positive press perturbation of column species. Highlighted cells correspond to **W** values >0.1. Boxes are drawn around effects on Pacific hake and juvenile Pacific hake. Species names are as follows: 1: Bocaccio; 2: Chinook salmon; 3: Large flatfish; 4: Pacific hake; 5: Pelagic sharks; 6: Pinnipeds; 7: Sablefish; 8: Small planktivores; 9: Juvenile Chinook salmon; 10: Juvenile Pacific hake; 11: Juvenile small demersal sharks; 12: Large zooplankton; 13: Mesozooplankton.

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	568	14	-143	150	11	-87	-150	-18	18	-45	41	22	-23
2	82	404	-75	-82	61	105	82	96	-96	-119	-99	122	3
3	6	-58	336	-6	-302	104	6	-28	28	-70	-16	114	44
4	-150	14	-143	150	11	-87	-150	-18	18	-45	41	22	-23
5	-74	-242	164	74	374	-86	-74	106	-106	-94	-42	30	-64
6	-118	-56	-146	118	-44	348	-118	72	-72	180	-164	-88	92
7	-150	14	-143	150	11	-87	568	-18	18	-45	41	22	-23
8	70	-198	-29	-70	-53	-103	70	152	-152	21	-67	-106	-85
9	152	206	-104	-152	8	2	152	248	470	-98	-166	16	-82
10	-38	128	26	38	-2	-180	-38	-62	62	204	-138	-4	200
11	44	-186	-49	-44	59	-75	44	34	-34	85	481	118	203
12	12	-116	-46	-12	114	208	12	-56	56	-140	-32	228	88
13	26	-12	20	-26	-112	-28	26	118	-118	-64	170	-224	430

Table C14. Sablefish food web adjoint (-A) matrix. Signs represent predicted directional responses of row species to positive press perturbation of column species. Highlighted cells correspond to **W** values >0.1. Boxes are drawn around effects on Pacific hake and juvenile Pacific hake. Species names are as follows: 1: Deep small rockfish; 2: Pacific hake; 3: Sablefish; 4: Small planktivores; 5: Deposit feeders; 6: Gelatinous zooplankton; 7: Juvenile Sablefish; 8: Large zooplankton; 9: Mesozooplankton; 10: Microzooplankton.

	1	2	3	4	5	6	7	8	9	10
1	117	-39	-102	-57	93	-6	-24	-6	-3	-9
2	-57	121	-68	67	-61	-52	-4	50	25	-27
3	60	82	136	10	32	-58	-28	44	22	-36
4	45	-117	0	135	-27	-18	-72	-18	-9	-27
5	-87	29	-34	11	127	28	-92	-74	-37	-9
6	-6	2	-34	-52	-44	118	-38	16	8	126
7	-30	10	136	46	86	-22	116	80	40	18
8	-42	14	68	-58	-2	-92	40	112	56	-36
9	27	-9	0	81	45	-72	18	-72	117	45
10	-21	7	34	-29	-1	-46	20	56	-125	135

References

Buchanan, J., 2011.

Dambacher, J. M., D. J. Gaughan, et al., 2009. "Qualitative modelling and indicators of exploited ecosystems." Fish and Fisheries 10(3): 305-322.

Dambacher, J. M., H. W. Li, et al., 2002. "Relevance of community structure in assessing indeterminacy of ecological predictions." Ecology 83(5): 1372-1385.

Dambacher, J. M., J. W. Young, et al., 2010. "Analyzing pelagic food webs leading to top predators in the Pacific Ocean: A graph-theoretic approach." Progress in Oceanography 86(1-2): 152-165.

DFO Canada. 2009. Recovery Potential Assessment of Bocaccio in British Columbia waters. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. No. 2009/040.

Dufault, A.M., K. Marshall, I.C. Kaplan, 2009. A synthesis of diets and trophic overlap of marine species in the California Current. NOAA Tech. Memo. NMFS-NWFSC-103. Available online: http://www.nwfsc.noaa.gov/assets/25/7024_12212009_134730_DietsCalCurrentTM103WebFinal.pdf

Fulton, E., 2004. Biogeochemical marine ecosystem models II: the effect of physiological detail on model performance. Ecological Modelling 173, 371-406.

Fulton, E.A., J.S. Link, I.C. Kaplan, M. Savina-Rolland, P. Johnson, C. Ainsworth, P. Horne, R. Gorton, R.J. Gamble, A.D.M. Smith, D.C. Smith. 2011. Lessons in modeling and management of marine ecosystems: the Atlantis experience. Fish and Fisheries 12(2), 171–188.

Horne, P.J., I.C. Kaplan, K.N. Marshall, P.S. Levin, C.J. Harvey, A.J. Hermann, E.A. Fulton. 2010. Design and Parameterization of a Spatially Explicit Ecosystem Model of the Central California Current. NOAA Tech. Memo. NMFS-NWFSC-104. Available online: http://www.nwfsc.noaa.gov/assets/25/7048_03232010_145542_ModelCalCurrentTM104WebFinal.pdf

Puccia, C. J. and R. Levins 1985. Qualitative modeling of complex systems: An introduction to loop analysis and time averaging. Cambridge, MA, Harvard University Press.

CHAPTER 3: RELATIVE RISK ASSOCIATED WITH NON-FISHERIES THREATS TO FOUR FOCAL GROUNDFISH SPECIES IN THE CALIFORNIA CURRENT.

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THE QUESTION: WHAT ARE THE STATUS AND TRENDS OF NON-FISHERIES PRESSURES THAT MAY INFLUENCE PRODUCTIVITY OF HAKE, SABLEFISH, CANARY ROCKFISH, AND BOCACCIO?

INTRODUCTION

With the rise of ecosystem-based approaches to ocean management, recent studies have focused on calculating human impact, vulnerability and risk of marine ecosystems to a variety of threats (Halpern et al. 2008; Halpern et al. 2009a; Teck et al. 2010; Samhouri and Levin In review). These studies begin to put multiple threats into relative context with one another such that managers and policymakers can prioritize threats to be addressed with limited resources (Bottrill et al. 2008).

Most of the threats to marine ecosystems are the result of human-related activities that occur both in the ocean (e.g. fishing & shipping activity) and on land (e.g. pollutants and runoff from agricultural activities). The ability to assess threats originating on land and in the sea is a major obstacle to marine ecosystem management.

Risk assessment is a general analytical approach for describing the likelihood of adverse consequences due to exposure to particular threats. It is particularly common in the field of ecotoxicology, where risk is described based on the response (or sensitivity) of a species to different levels of exposure to a threat (typically a chemical contaminant) (Suter 2007). Risk assessment has also entered the parlance of fisheries management in the form of productivity-susceptibility analyses (PSA), which have been used to determine the vulnerability of fish stocks (especially those that are data-poor) to current fisheries management practices, based on their susceptibility to the fishery and knowledge of a suite of life history traits (Patrick et al. 2010, Hobday et al. 2011). The virtue of the ecotoxicological and PSA risk approaches is that they allow an evaluation of the probability of adverse effects given information about exposure to a stressor (i.e., a contaminant or fishery) while taking into account species-specific variation in responses to the stressor. These approaches do not, however, provide information about the trajectory of threat intensity over multiyear time scales. Such information is critical to understanding whether management actions to diminish threat intensity have been taken in the recent or distant past.

In this paper, we first use an exposure-sensitivity framework to analyze the relative risk posed by 19 non-fisheries related threats to four groundfish species in the California Current. We then describe the short-term and long-term trends of these threats and put them into a framework that may help managers and policy makers prioritize which threats are in need of active management in the California Current.

METHODS

FOCAL SPECIES

We examined the relative risk of 19 non-fisheries related threats to four groundfish species in the California Current: bocaccio *Sebastes paucispinis* and canary *Sebastes pinniger* rockfish, Pacific hake *Merluccius productus*, and sablefish *Anoplopoma fimbria*. Each species is managed under the Pacific Fishery Management Council's groundfish Fishery Management Plan. There are over 90 species of groundfish managed under this FMP, and the four species we examined represent species of high value (Pacific hake and Sablefish) and species that are of high concern due to depleted stock levels (bocaccio and canary rockfish).

Bocaccio juveniles are generally associated with inshore benthic habitats, rocks with algae, and sandy zones with eelgrass or drift algae. Juveniles gradually shift to deeper high-relief rocky habitats at depths of ~50 – 250 m; however, max depths have been reported to 478 m (Love et al. 2002).

Canary rockfish juveniles are generally associated with benthic habitats, tide pools, kelp beds, and the interface between sand and rock outcrops at depths of ~15-20 m. Juveniles shift to deeper habitat at the end of the summer and adults are commonly found near pinnacles and high-relief rocky habitats with high currents at depths of ~80 – 200m with max depths to 838 m. Canary rockfish commonly school near but not on bottom (Love et al. 2002).

Pacific hake live in shallow coastal waters, bays, and estuaries (Bailey 1981, Bailey et al. 1982, Dark 1975, Dark and Wilkins 1994, Dorn 1995, NOAA 1990, Sakuma and Ralston 1995, Smith 1995), and move to deeper water as they get older (NOAA 1990). Pacific hake school at depth during the day, then move to the surface and disband at night for feeding (McFarlane and Beamish 1986, Sumida and Moser 1980, Tanasich et al. 1991). Adults are epi-mesopelagic (Bailey et al. 1982, NOAA 1990, Sumida and Moser 1980). Highest densities of Pacific hake are usually found between 50 and 500 m, but adults occur as deep as 920 m and as far offshore as 400 km (Bailey 1982, Bailey et al. 1982, Dark and Wilkins 1994, Dorn 1995, Hart 1973, NOAA 1990, Stauffer 1985). Spawning is greatest at depths between 130 and 500 m (Bailey et al. 1982, NOAA 1990, Smith 1995).

As juveniles, sablefish are generally found in schools near surface offshore and then migrate to inshore waters after several months (Hart 1973). As sablefish mature, they migrate offshore and live near bottom at depths to 1500 m, but are most commonly found between 366 – 915 m (Hart 1973, Schirripa 2007).

NON-FISHERIES THREATS

We focused on 19 non-fisheries related threats used in Halpern et al (2009a): aquaculture, atmospheric deposition, coastal engineering, direct human impacts, inorganic pollution, light pollution, nutrient input, ocean-based pollution, offshore oil activity, organic pollution, power plants, sediment runoff decrease, sediment runoff increase, shipping activity, species invasions, coastal trash, ocean acidification, sea-surface temperature anomalies, and UV radiation. These data describe the relative spatial intensity of each threat within 1-km^2 grid cells of the California

Current. Data were downloaded from the National Center for Ecological Analysis and Synthesis website (http://www.nceas.ucsb.edu/globalmarine/ca_current_data). Each threat is described in detail in Appendix E and in the supporting material of Halpern et al (2008; 2009a).

This analysis represents a first attempt to synthesize and describe spatial and temporal variation in the intensity of these threats as they relate to the four groundfish species. We have highlighted particular areas (data sources, etc.) which could be improved or enhanced given sufficient time.

OVERVIEW OF RISK CALCULATION

We assessed the risk that various non-fisheries threats will lead to negative effects on the adult and juvenile populations of bocaccio, canary rockfish, sablefish, and Pacific hake within the U.S. borders of the California Current Large Marine Ecosystem. We evaluated risk over the next 5 – 10 years, assuming management practices continue unchanged, based on two axes of information. The first axis was related to the exposure *E* of a species to the non-fisheries threats, and the other axis was a conditional probability related to the sensitivity *S* of the population to the threats, given its exposure (Fig. 17). Though we refer to risk to each species, the assessment is focused on the risk of decline of each stock within the U.S. California Current, rather than the risk of extinction of each species throughout its range. More details about the mechanics of the framework are provided in Samhouri and Levin (in review).

The relative risk R_{ij} to species i, life-history stage j was calculated as:

$$R_{ij} = \sqrt{(E-1)^2 + (S-1)^2} \qquad (1)$$

Under this framework, the risk to a species increased with Euclidean distance from the origin and each axis received equivalent weight in estimating risk.

Values of E and S were determined for each life-history stage of each species by assigning a score ranging from one to three for a standardized set of criteria (see Table 4), and then averaging the scores to create exposure and sensitivity indices.

Discussion Point: The Euclidean distance is one of several ways that risk could be calculated. For instance, it could be calculated as the product of the Exposure and Sensitivity scores. The latter approach would lead to a higher estimation of risk when E and S scores are similar than the Euclidean distance calculation. The Euclidean distance calculation is much more conservative (i.e. risk is higher) when E and S have very different values. Which approach does the SSC prefer?

EXPOSURE AXIS

The exposure axis was scored based on a single criterion: spatial intensity. This criterion described the overlap of a species' spatial distribution and the relative intensity of each threat (Fig. 17). In order to calculate the spatial intensity of each threat across each species distribution, we took advantage of two published GIS data sets.

First, we used Habitat Suitability Probabilities to describe the distribution of each species/life-history stage (Figs. 18 – 25). HSP values describe the probability of occurrence of each species/life-history stage within the U.S. boundaries of the California Current. Briefly, the HSP values were calculated for the National Marine Fisheries Service (NMFS) Northwest Region and the Pacific Fishery Management Council in support of an Environmental Impact Statement (EIS) to consider the designation and conservation of Essential Fish Habitat (EFH) for Pacific Coast Groundfish (http://www.nwr.noaa.gov/Groundfish-Halibut/Groundfish-Fishery-Management/NEPA-Documents/EFH-Final-EIS.cfm). HSP values were generated from merged habitat and bathymetry GIS data and a Bayesian Network model that incorporated information about species' habitat preferences (bottom type and depth preferences) from NMFS trawl surveys and the Habitat Use Database (see Appendix D for more details). We used data if HSP values were ≥ 0.01 because HSP values for habitat < 0.01 were not retained during the modeling.

Second, we used data from Halpern et al (2009a) to describe the spatial intensity of each threat throughout the distribution of each species/life-history stage. These data layers provide a relative score for the intensity of each threat (scaled between 0 and 1) in 1-km^2 grid cells across the entire California Current. The data sources and calculations for each threat are described in detail in the supporting materials of Halpern et al (2008; 2009a), and briefly outlined in Appendix E.

HSP data layers for each species/life-history stage and the 19 threat data layers were brought into ArcView version 9.3 for analysis. We then multiplied the HSP data layer by each threat data layer to calculate the exposure intensity (ei) for each threat across the distribution of each species/life-history stage (n = 152; Fig. 17). Thus, the threat k intensity scores were weighted by the probability of species i /life-history stage j occurring in each 1-km^2 cell.

$$ei_{ijk} = HSP_{ij} * \text{threat}_k \text{ intensity for each 1-km}^2 \text{ grid cell} \qquad (2)$$

For visual representation, we classified the distribution of ei_{ijk} values into three terciles (high, medium, and low), although offshore oil activity data was divided into only high and low categories based on the median value because there were so few unique values.

For the final Exposure score, we summed all exposure intensity values for each species/life-history stage/threat (Table 5). We then standardized the sums across all 19 threats within each species/life-history stage to values between 1 and 3 (Table 6) to keep them on the same scale as the Sensitivity criteria.

Discussion Point: We decided to use the "sum" of all exposure intensity values as the metric to measure the criterion Spatial intensity. An alternative approach would be to use the "mean" of all exposure intensity scores. A preliminary analysis showed that when the "mean" of all exposure intensity values is calculated for each species/life-history stage/threat and then standardized between 1 – 3, the resulting scores are nearly identical to the standardized sum scores. Another alternative approach, which was used by Samhouri and Levin (in review), is to scale the species probability value (HSP value in our case) and the threat intensity value for each grid cell between 1 – 3 first. These two standardized values were averaged for each grid cell and then all grid cells were averaged to get the spatial intensity final score. Which approach does the SSC prefer?

SENSITIVITY CRITERIA

The sensitivity criteria were divided into those that influenced a species' resistance to a threat and those that affected its recovery from a threat (Table 4). Resistance factors were threat-specific, and included one criterion that described the mortality induced by a threat and one criterion that described the behavioral or physiological response to a threat. Recovery factors did not vary across non-fisheries threats. They included one criterion related to a species' life history traits, based on an average score for fecundity, age at maturity, reproductive strategy, and population connectivity, and one criterion related to the current status of the stock. We used the definitions in Table 4 to score each criterion (Table 7). Scoring for all criteria was based on the primary literature and is addressed in detail in Appendix E. The four criteria were then averaged for each threat for each species/life-history stage to get the final Sensitivity score (Table 8). The final scores for Exposure and Sensitivity were used to calculate the relative risk among all non-fisheries threats within each species/life-history stage.

Discussion Point:: We decided to average the 4 life history traits to create a single criterion. This approach results in a total of 4 criteria for the sensitivity axis and provides for the same number of criteria within the Recovery and Resistance factors groups (2 each). An alternative approach would be to include each life history trait as individual criteria, which would result in a total of 7 sensitivity criteria. The more criteria used to score the sensitivity axis, the more robust the score is and the less responsive it is to threat-specific effects on recovery factors (Azose and Samhouri unpublished). Which approach does the SSC prefer?

STATUS AND TRENDS OF NON-FISHERIES THREATS

TIME SERIES DATA

In order to determine the relative status and trend of each threat, we searched for time series data in the primary literature and in online databases. Data collected were from numerous sources (Table 9; and in more detail in Appendix E). Each dataset varies in the spatio-temporal scale of sampling. We did not include time series data on the climate change threats (ocean acidification, sea surface temperature, and UV radiation) in this analysis because these threats are dealt with separately in other chapters.

For each dataset, we normalized the time series by subtracting the mean and dividing by the standard deviation. This put all threat data onto the same scale (mean = 0, SD= 1) which we could use later to compare trends among threats.

Discussion Point: At this point, we have used all the years for each of the datasets in calculating summary statistics that are later compared among threats. This may lead to spurious interpretations when data from different time periods measured at different sampling frequencies are compared. However, some threats have very limited years of data that are applicable to the entire California Current, thus much of the data would be eliminated if we only compare time periods that we have data for all threats. Does the SSC feel this is an issue that needs to be addressed and if so, does the SSC have any suggestions as to how to address this potential shortcoming with our analysis?

TIME SERIES ANALYSIS AND PLOTS

Each normalized time series of data was analyzed using linear mixed models to produce four 'performance metrics' of interest: the long-term mean and standard deviation of the entire time series, and the short-term mean and slope of the last five years of data. See Appendix D: *Status and trends of non-fisheries threats* for details on the decisions and rationale to use these metrics.

Plots of all time-series follow the same format. The plots show the change in the threat (however it was measured) through time. The solid horizontal line indicates the mean of the full time series. The two dotted horizontal lines show ± 1.0 standard deviation of the full time series. The shorter, thick solid line is the predicted trend over the last five years of the data. In the upper right corner of each plot there are three boxes. The upper box indicated whether the trend over the last five years showed an increase (up angled arrow) or decrease (down angled arrow) of more than one standard deviation of the full time series or no change (=). The middle box indicates whether the mean of the last five years was higher (+), lower (-) or within (=) one standard deviation of the long term mean. The lower inset box indicates whether the slope of the last five years of data was significantly different from zero.

COMPARISON OF THREATS

Using the performance metrics from above, we calculated a short-term and long-term state for each threat in order to compare which threats were relatively good or bad and improving or declining. For the short-term state, we used the difference between the last and first predicted values of the short-term trend line. In cases where data points occur at frequencies other than yearly, we used the last five data points to calculate this term. For the long-term state, we used the difference between the long-term mean and the mean of the last five years. Because an increasing trend for threats represents a potential decline in the environment for the species, we multiplied each of the states by -1. To emphasize threats that are of higher risk, we used the mean relative risk score for adults across all species and the mean relative risk score for juveniles across all species to weight the text size of each threat.

RESULTS

EXPOSURE INTENSITY

The calculated exposure intensity index for each species/life-history stage/threat varied throughout the distribution of each species for most threats. As examples, figures 26 – 44 show the exposure intensity for Pacific hake adults for each of the 19 threats. There are several threats that show very little overlap with hake adult habitats, e.g. aquaculture (fish farms), coastal engineering, direct human impacts (trampling), offshore oil activities, power plants, and coastal trash (Figs. 26, 28, 29, 34, 36, & 41, respectively). Spatially expansive threats affect nearly the entire distribution of adult hake, e.g. atmospheric deposition, ocean-based pollution, shipping, and the three climate change threats – ocean acidification, sea surface temperature, and UV radiation (Figs. 27, 33, 39, 42 – 44, respectively). Threats that occur as point-sources show relatively high exposure intensity in coastal areas and low or no exposure in offshore portions of their distribution, e.g. inorganic pollution, light pollution, nutrient input, organic pollution, sediment runoff decrease and increase, and species invasions (Figs. 30 – 32, 35, 37 – 38, and 40, respectively).

Across species/life history stages, exposure intensity generally varies in relation to the offshore distribution of adult habitats and the nearshore concentration of juvenile habitats. Thus, juveniles of most species tend to be exposed to higher intensities of point-source threats because of their higher probabilities of occurrence in nearshore habitats, while adults tend to have much broader exposure to spatially expansive threats, such as atmospheric deposition or the climate change threats. One generality among these four species may be that in the waters off Oregon and Washington, we found higher exposure intensities for juveniles as a result of their nearshore habitat, while adults experience broader, higher exposure intensities in waters off California due to broader habitat occurrence (compare Figs. 45 & 46, 47 & 48, and 50 & 51).

RELATIVE RISK

In general, we found that the most spatially expansive threats were of greater relative risk to each of the four species than threats related to point-sources (Figs. 52 – 59). The climate change threats and atmospheric deposition of pollutants have the highest risk for each of the species/life-history stages. Aquaculture, direct human impacts, shipping activity and coastal trash generally had the lowest relative risk for each species/life-history stage.

STATUS AND TRENDS OF NON-FISHERIES THREATS

The trend of each threat is shown in Figures 60 – 75. Based on the indices used for each threat, we found that the status and trend of many threats are within the boundaries of 1 SD (the dotted lines on Figs. 76 & 77) for both short-term and long-term states. We found that direct human impacts and nutrient input are improving the most on the short-term scale relative to the other threats, while light pollution and coastal engineering are declining the most (Figs. 76-77). Coastal trash and sediment decrease are in the poorest condition compared to their long-term trend, while light pollution, offshore oil activity, and inorganic pollution are in the best condition compared to their long-term trend. Thus, threats beyond or near the 1 SD lines in the poor or declining directions may be threats to prioritize for marine species in general. However, the risk of these particular threats to the four focal species was not very high, as indicated by their small text sizes in Figs. 76-77. The highest risk threats, such as atmospheric deposition and sediment runoff increases shown in the largest text sizes on Figs. 76-77, are neither improving nor declining.

CONCLUSIONS

Our analysis builds on the risk assessment framework of others that will allow for comparison of relative risk among multiple non-fisheries threats. This framework shows which threats are relevant to focal species and provides a basis for prioritizing which threats are in need of management actions. Rapid assessments of other species can be easily integrated into this framework. We expect that a few of the data sets we used to estimate status and trends of specific threats will be improved with further input and collaboration from researchers in the specific fields of study, which may alter their ultimate categorical trends.

Table 4. Definitions and scoring bins for the exposure and sensitivity criteria used in the risk assessment.

Discussion Point:: We believe that the #2(alt.) sensitivity scoring categories for behavioral/physiological response may be better reflective of the desired "Low", "Moderate", and "High" scoring categories. The current scoring definitions may be more subjective, i.e. distinguishing between what is a "moderate" effect versus what is a "severe" effect is subjective. We plan to re-score the Sensitivity values for "Behavioral/physiological" criteria using the #2(alt) scoring definitions, which may change the ultimate scores in later iterations. Can the SSC comment/weigh in on which definitions it believes are more appropriate?

Criteria	Explanation of criteria	Exposure		
1. Spatial intensity	The overlap between the probability of species occurrence (HSP) and the relative intensity of a threat.	Standardized distribution (scale=1-3) of the sum of species-specific exposure intensity values.		
		Sensitivity		
Low resistance factors		Low (1)	Moderate(2)	High(3)
1. Mortality	Direct effect of threat on population-wide average mortality rate of a species	Negligible	Sub-lethal	Lethal
2. Behavioral/physiological response	Population-wide effect of threat on behavior or physiology of a species	Negligible behavioral or physiological response	Moderate behavioral or physiological response	Severe behavioral or physiological response
2(alt). Behavioral/physiological response	Population-wide effect of threat on behavior or physiology of a species	Response reduces sensitivity	Response does not change sensitivity	Response increases sensitivity
Slow recovery factors				
3. Current status	Status of the species based on management targets, i.e. x > or < B_{40}	X > B_{40}	B_{40} > X > B_{25}	X < B_{25}
4. Life –history characteristics				
a. Fecundity	The population-wide average number of offspring produced by a female each year	> 10^3	> 10^2 - 10^3	< 10^2
b. Age at maturity	Population-wide average age at maturity;	< 2 years	2 – 4 years	> 4 years

Criteria	Explanation of criteria	Exposure		
	greater age at maturity corresponds to longer generation times and lower productivity			
c. Reproductive strategy	The extent to which a species protects and nourishes its offspring	Internal fertilization and parental care	Internal fertilization or parental care but not both	External fertilization and no parental care
d. Population connectivity	Realized exchange with other populations based on spatial patchiness of distribution, degree of isolation, and potential dispersal capability	Regular movement/exchange within the California Current	Occasional movement/exchange within the California Current	Negligible movement/exchange within the California Current

Table 5. Sums of exposure intensity values. Boc = bocaccio *Sebastes paucispinis*; Can = canary rockfish *Sebastes pinniger*; Hake = Pacific hake *Merluccius productus*; Sable = Sablefish *Anoplopoma fimbria*; Ad = adult; Juv = juvenile.

Threat	Boc Ad	Boc Juv	Can Ad	Can Juv	Hake Ad	Hake Juv	Sable Ad	Sable Juv
Aquaculture	0	0	0	0	2	0	2	0
Atmospheric deposition	2866	9481	4180	11092	42572	55	70199	25431
Coastal engineering	2	105	2	263	377	0	224	11
Direct human impacts	1	121	1	100	170	0	63	51
Inorganic pollution	143	935	202	1505	1977	7	1142	421
Light pollution	173	913	189	1859	2657	7	2549	681
Nutrient input	473	2482	883	3629	5100	14	3221	1597
Ocean-based pollution	1314	4525	2081	6678	14625	19	18549	6883
Offshore oil activities	1	2	1	6	6	0	4	0
Organic pollution	416	2568	969	3743	4838	10	2737	1488
Power plants	2	30	2	51	43	0	25	0
Sediment decrease	689	3332	1282	5095	7562	18	5450	2427
Sediment increase	1786	7384	3298	10506	16773	18	11868	5975
Shipping activity	6	254	8	397	2359	0	132	89
Species invasions	932	4231	1443	5359	10043	16	6715	3327
Coastal trash	3	219	3	408	266	1	94	41
Ocean Acidification	4579	12840	7778	20410	59300	65	104895	36161
Sea Surface Temperature	2352	8710	4947	10870	32291	38	49054	20411
UV radiation	4411	12526	7354	19374	57542	66	100313	34891

Table 6. Final exposure scores after sums of exposure intensity values were standardized between 1 and 3. Boc = bocaccio *Sebastes paucispinis*; Can = canary rockfish *Sebastes pinniger*; Hake = Pacific hake *Merluccius productus*; Sable = Sablefish *Anoplopoma fimbria*; Ad = adult; Juv = juvenile.

Threat	Boc Ad	Boc Juv	Can Ad	Can Juv	Hake Ad	Hake Juv	Sable Ad	Sable Juv
Aquaculture	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Atmospheric deposition	2.25	2.48	2.07	2.09	2.44	2.69	2.34	2.41
Coastal engineering	1.00	1.02	1.00	1.03	1.01	1.00	1.00	1.00
Direct human impacts	1.00	1.02	1.00	1.01	1.01	1.00	1.00	1.00
Inorganic pollution	1.06	1.15	1.05	1.15	1.07	1.22	1.02	1.02
Light pollution	1.08	1.14	1.05	1.18	1.09	1.20	1.05	1.04
Nutrient input	1.21	1.39	1.23	1.36	1.17	1.42	1.06	1.09
Ocean-based pollution	1.57	1.70	1.54	1.65	1.49	1.59	1.35	1.38
Offshore oil activities	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Organic pollution	1.18	1.40	1.25	1.37	1.16	1.29	1.05	1.08
Power plants	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Sediment decrease	1.30	1.52	1.33	1.50	1.25	1.55	1.10	1.13
Sediment increase	1.78	2.15	1.85	2.03	1.57	1.54	1.23	1.33
Shipping activity	1.00	1.04	1.00	1.04	1.08	1.00	1.00	1.00
Species invasions	1.41	1.66	1.37	1.53	1.34	1.49	1.13	1.18
Coastal trash	1.00	1.03	1.00	1.04	1.01	1.02	1.00	1.00
Ocean Acidification	3.00	3.00	3.00	3.00	3.00	2.97	3.00	3.00
Sea Surface Temperature	2.03	2.36	2.27	2.07	2.09	2.16	1.94	2.13
UV radiation	2.93	2.95	2.89	2.90	2.94	3.00	2.91	2.93

Table 7. Raw sensitivity scores based on literature review (see Table 4for definitions of factors and scoring bins; see Appendix E for details and rationale for scoring). Boc = bocaccio *Sebastes paucispinis*; Can = canary rockfish *Sebastes pinniger*; Hake = Pacific hake *Merluccius productus*; Sable = Sablefish *Anoplopoma fimbria*; Ad = adult; Juv = juvenile.

Criterion	Boc Ad	Boc Juv	Can Ad	Can Juv	Hake Ad	Hake Juv	Sable Ad	Sable Juv
Low resistance factors								
1. Mortality								
Aquaculture	1	1	1	1	1	1	1	1
Atmospheric deposition	2	3	2	3	2	3	2	3
Coastal engineering	1	1	1	1	1	1	1	1
Direct human impacts	1	1	1	1	1	1	1	1
Inorganic pollution	2	3	2	3	2	3	2	3
Light pollution	1	1	1	1	1	1	1	1
Nutrient input	1	2	1	2	1	2	1	2
Ocean-based pollution	2	3	2	3	2	3	2	3
Offshore oil activities	2	2	2	2	1	1	1	1
Organic pollution	2	3	2	3	2	3	2	3
Power plants	1	3	1	3	1	3	1	3
Sediment decrease	1	1	1	1	1	1	1	1
Sediment increase	1	1	1	1	1	1	1	1
Shipping activity	1	1	1	1	1	1	1	1
Species invasions	1	1	1	1	1	1	1	1
Coastal trash	1	1	1	1	1	1	1	1
Ocean Acidification	2	3	2	3	2	3	2	3
Sea Surface Temperature	2	2	2	2	2	2	2	2
UV radiation	1	3	1	3	1	3	1	3
2. Behavioral/physiological response								
Aquaculture	1	1	1	1	1	1	1	1
Atmospheric deposition	2	3	2	3	2	3	2	3
Coastal engineering	3	3	3	3	2	3	2	3
Direct human impacts	1	1	1	1	1	1	1	1
Inorganic pollution	2	3	2	3	2	3	2	3

Criterion	Boc Ad	Boc Juv	Can Ad	Can Juv	Hake Ad	Hake Juv	Sable Ad	Sable Juv
Light pollution	1	2	1	2	1	2	1	2
Nutrient input	2	3	2	3	2	3	2	3
Ocean-based pollution	2	3	2	3	2	3	2	3
Offshore oil activities	2	2	2	2	1	1	1	1
Organic pollution	2	3	2	3	2	3	2	3
Power plants	2	2	2	2	2	2	2	2
Sediment decrease	1	1	1	1	1	1	1	1
Sediment increase	3	3	3	3	2	2	2	2
Shipping activity	1	1	1	1	1	1	1	1
Species invasions	1	1	1	1	1	1	1	1
Coastal trash	1	1	1	1	1	1	1	1
Ocean Acidification	2	3	2	3	2	3	2	3
Sea Surface Temperature	3	3	3	3	3	3	3	3
UV radiation	1	2	1	2	2	2	2	2
Slow recovery factors								
3. Current status	3	3	2	2	2	2	2	2
4. Life history characteristics								
a. Fecundity	1	1	1	1	1	1	1	1
b. Age at maturity	2	2	3	3	2	2	2	2
c. Reproductive strategy	2	2	2	2	1	1	1	1
d. Population connectivity	2	2	2	2	1	1	3	3

Table 8. Final sensitivity scores after averaging across each of the four sensitivity criteria. Boc = bocaccio *Sebastes paucispinis*; Can = canary rockfish *Sebastes pinniger*; Hake = Pacific hake *Merluccius productus*; Sable = Sablefish *Anoplopoma fimbria*; Ad = adult; Juv = juvenile.

Threat	Boc Ad	Boc Juv	Can Ad	Can Juv	Hake Ad	Hake Juv	Sable Ad	Sable Juv
Aquaculture	.69	.69	.50	.50	.31	.31	.44	.44
Atmospheric deposition	.19	.69	.00	.50	.81	.31	.94	.44
Coastal engineering	.19	.19	.00	.00	.56	.56	.69	.69
Direct human impacts	.69	.69	.50	.50	.31	.31	.44	.44
Inorganic pollution	.19	.69	.00	.50	.81	.31	.94	.44
Light pollution	.69	.94	.50	.75	.31	.56	.44	.69
Nutrient input	.94	.44	.75	.25	.56	.06	.69	.19
Ocean-based pollution	.19	.69	.00	.50	.81	.31	.94	.44
Offshore oil activities	.19	.19	.00	.00	.31	.31	.44	.44
Organic pollution	.19	.69	.00	.50	.81	.31	.94	.44
Power plants	.94	.44	.75	.25	.56	.06	.69	.19
Sediment decrease	.69	.69	.50	.50	.31	.31	.44	.44
Sediment increase	.19	.19	.00	.00	.56	.56	.69	.69
Shipping activity	.69	.69	.50	.50	.31	.31	.44	.44
Species invasions	.69	.69	.50	.50	.31	.31	.44	.44
Coastal trash	.69	.69	.50	.50	.31	.31	.44	.44
Ocean Acidification	.19	.69	.00	.50	.81	.31	.94	.44
Sea Surface Temperature	.44	.44	.25	.25	.06	.06	.19	.19
UV radiation	.69	.44	.50	.25	.56	.06	.69	.19

Table 9. Data used for each non-fisheries threat index.

Discussion Point: Several time series (e.g., Aquaculture, Coastal Engineering, Nutrient Input) rely on proxies, require further processing, or are based on older datasets. This data will be updated as more refined datasets of the West Coast can be accessed. Conclusions based on reported trends are therefore subject to change.

Threat	**Index metric**	**Definition and source of data**	**Time series**	**Sampling period**
Aquaculture	Aquaculture production	Total U.S. aquaculture production including all categories except catfish and trout; Fisheries of the United States 2009. NMFS Office of Science and Technology. Current Fishery Statistics No. 2009. US Dept Comm.	1985 – 2008	yearly
Atmospheric deposition	Atmospheric deposition of sulfate	Sulfate was used as a proxy for all atmospheric pollutants (Halpern et a. 2009) measured at sites within CA, OR, and WA; National Atmospheric Deposition Program (http://nadp.sws.uiuc.edu/data/ntndata.aspx)	1985 – 2010	yearly
Coastal engineering	Human population	Population size of West coast states (CA, OR, WA); United States Census 2010 (http://2010.census.gov/2010census/data/apportionment-pop-text.php)	1910 – 2010	decadal
Direct human impacts	Beach attendance	Total visitor attendance at 48 California state parks identified as “State Beach”; California State Park System Annual Statistical Reports: 2001 -2010 (http://www.parks.ca.gov/?page_id=23308)	2002 – 2010	yearly
Inorganic pollution	Total inorganic pollutants (lbs)	Total pounds of inorganic pollutants disposed of or otherwise released on site to the ground or water for ‘1988 core chemicals’;Environmental Protection Agency, Toxics Release Inventory (http://www.epa.gov/tri/)	1988 – 2009	yearly
Light pollution	Average visible light	Data are cloud-free composites of average visible light made using all the available archived DMSP-OLS smooth resolution data for each calendar year. Data grid cell size is 1 km^2 at the equator ; NOAA’s National Geophysical Data Center’s Version 4 DMSP-OLS Nighttime Lights Time Series Average Lights X Pct (http://www.ngdc.noaa.gov/dmsp/downloadV4composites.html)	1992 – 2009	yearly
Nutrient input	Mean nitrogen	Mean nitrogen (nitrite + nitrate) in surface water samples, all land use types for Pacific coastal basins; US Geological Survey National Water Quality Assessment Data Warehouse (http://infotrek.er.usgs.gov/apex/f?p=NAWQA:HOME:5572182579967972)	1992 – 2011	yearly
Ocean-based pollution	Tons of cargo	Total tons of cargo moved through ports on the U.S. West Coast using waterway codes for CA, OR and WA; Data from US Army Corps of Engineers Navigation Data Center (http://www.ndc.iwr.usace.army.mil/data/datawcus.htm)	1993 – 2009	yearly
Organic pollution	Concentrations of pesticides	Data are normalized grand mean concentrations of 13 pesticides and 3 degradates measured in 3,033 water samples from 27 stream-water sites along the West Coast; U.S. Geological Survey Scientific Investigations Report 2010-5139 (http://pubs.usgs.gov/sir/2010/5139/)	1993 – 2008	yearly

Threat	Index metric	Definition and source of data	Time series	Sampling period
Offshore oil activities	Offshore oil & gas wells	Data are the number of offshore oil and gas producing wells in state and federal waters; Annual reports - CA Dept of Conservation; Division of oil, gas, and geothermal resources (ftp://ftp.consrv.ca.gov/../pub/oil/annual_reports/)	1981 – 2009	yearly
Power plants	Thermoelectric power saline water withdrawals	Gallons of saline water withdrawn by electric power plants in coastal states (CA, OR, WA); http://pubs.usgs.gov/circ/2004/circ1268/htdocs/table13.html; http://pubs.usgs.gov/circ/2004/circ1268/htdocs/figure14.html.	1950 – 2000	Every 5 years
Sediment decrease	Total reservoir storage area	Total reservoir storage area in CA and Pacific Northwest water resource regions; data from Figure 4 in Graf (1999) based on data from US Army Corps of Engineers from 1996.	1910 – 1993	varies
Sediment increase	Suspended sediment (mg/L)	Suspended sediment levels [mg/L] from Pacific coastal basins, all land use classes; USGS surface water database http://infotrek.er.usgs.gov/apex/f?p=NAWQA:HOME:5572182579967972	1991 – 2010	yearly
Shipping activity	Tons of cargo	Total tons of cargo moved through ports on the U.S. West Coast using waterway codes for CA, OR and WA; Data from US Army Corps of Engineers Navigation Data Center (http://www.ndc.iwr.usace.army.mil/data/datawcus.htm)	1993 – 2009	yearly
Species invasions	Tons of cargo	Total tons of cargo moved through ports on the U.S. West Coast using waterway codes for CA, OR and WA; Data from US Army Corps of Engineers Navigation Data Center (http://www.ndc.iwr.usace.army.mil/data/datawcus.htm)	1993 – 2009	yearly
Coastal Trash	Beach trash	Counts of trash picked up off of California beaches; California Coastal Commission's Public Education Program (www.coastal.ca.gov/publiced/ccd/data.xls)	1989 – 2010	yearly

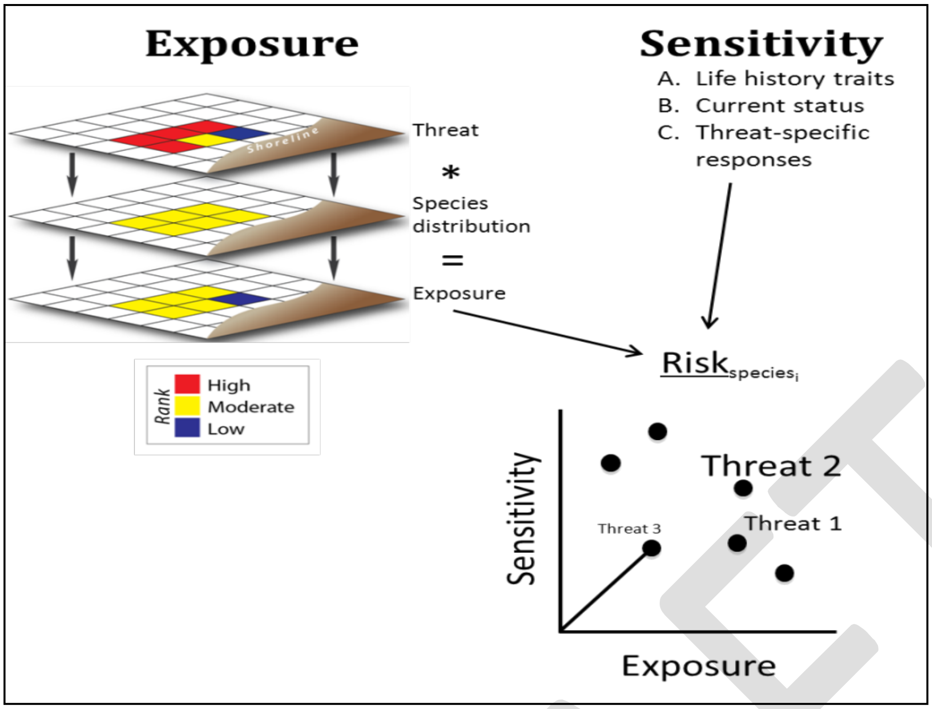


Figure 17. Schematic of relative risk score calculation.
Exposure layer diagram courtesy of J. Davies, NOAA.

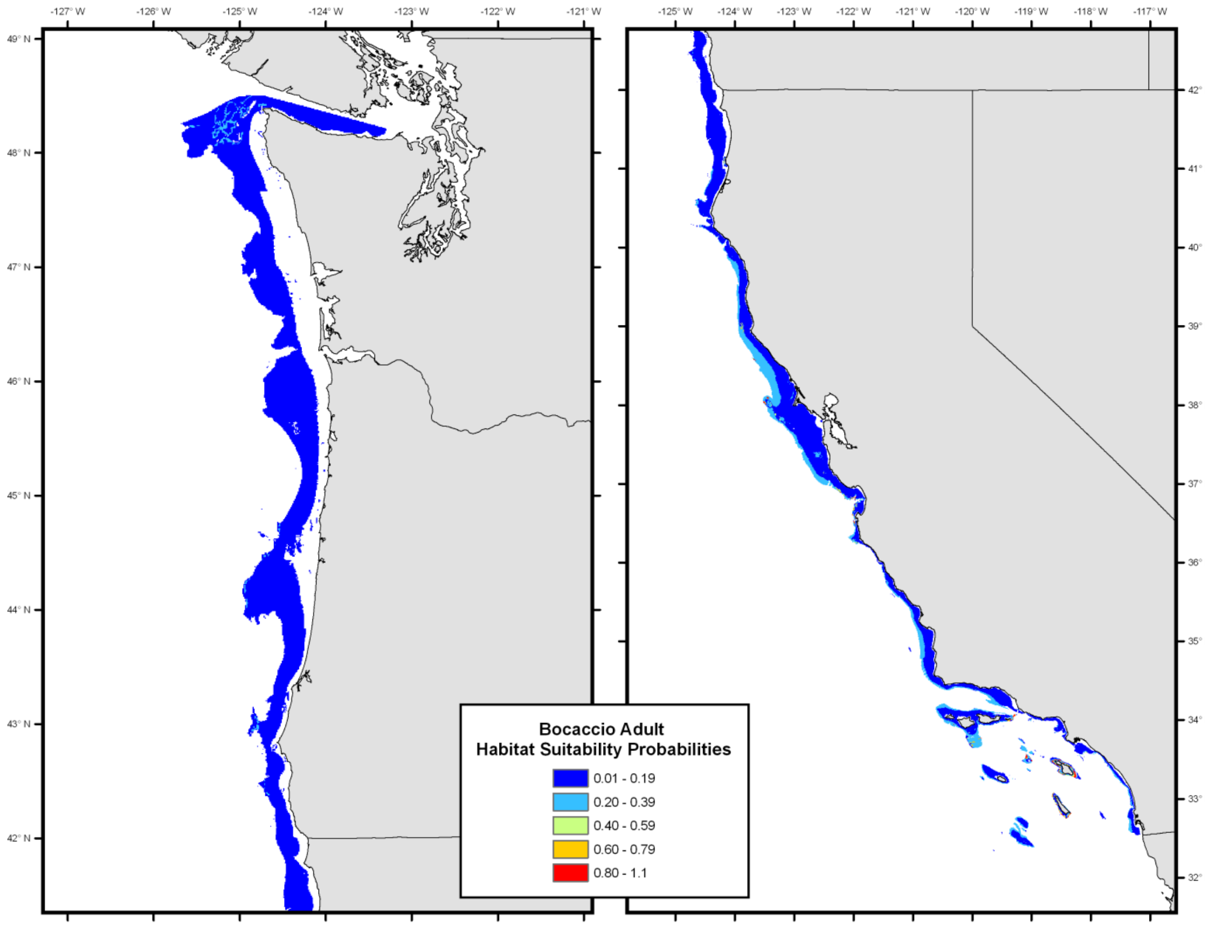


Figure 18. Habitat Suitability Probabilities for bocaccio *Sebastes paucispinis* adult. Data from 2005 Essential Fish Habitat Final Environmental Impact Statement.

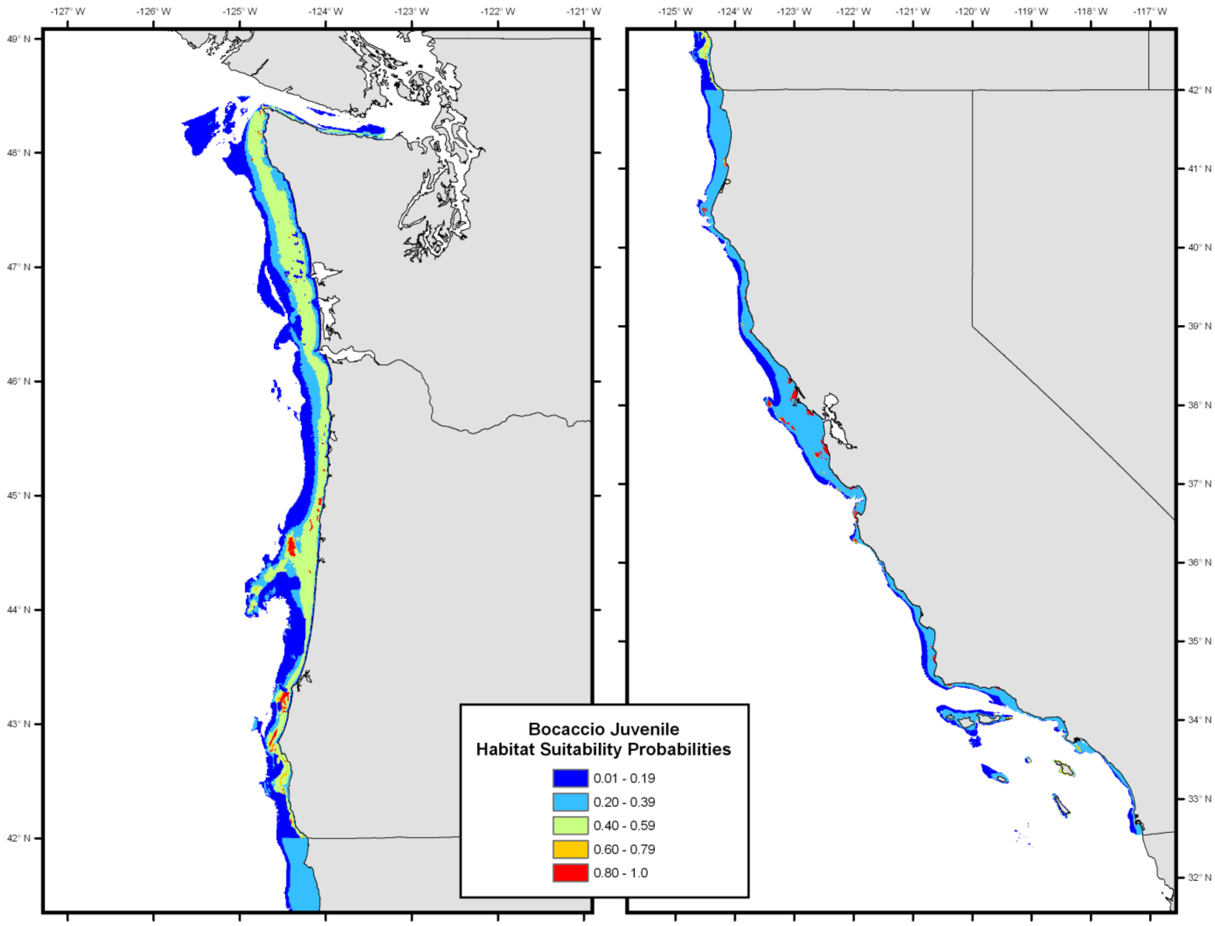


Figure 19. Habitat Suitability Probabilities for bocaccio *Sebastes paucispinis* juvenile. Data from 2005 Essential Fish Habitat Final Environmental Impact Statement.

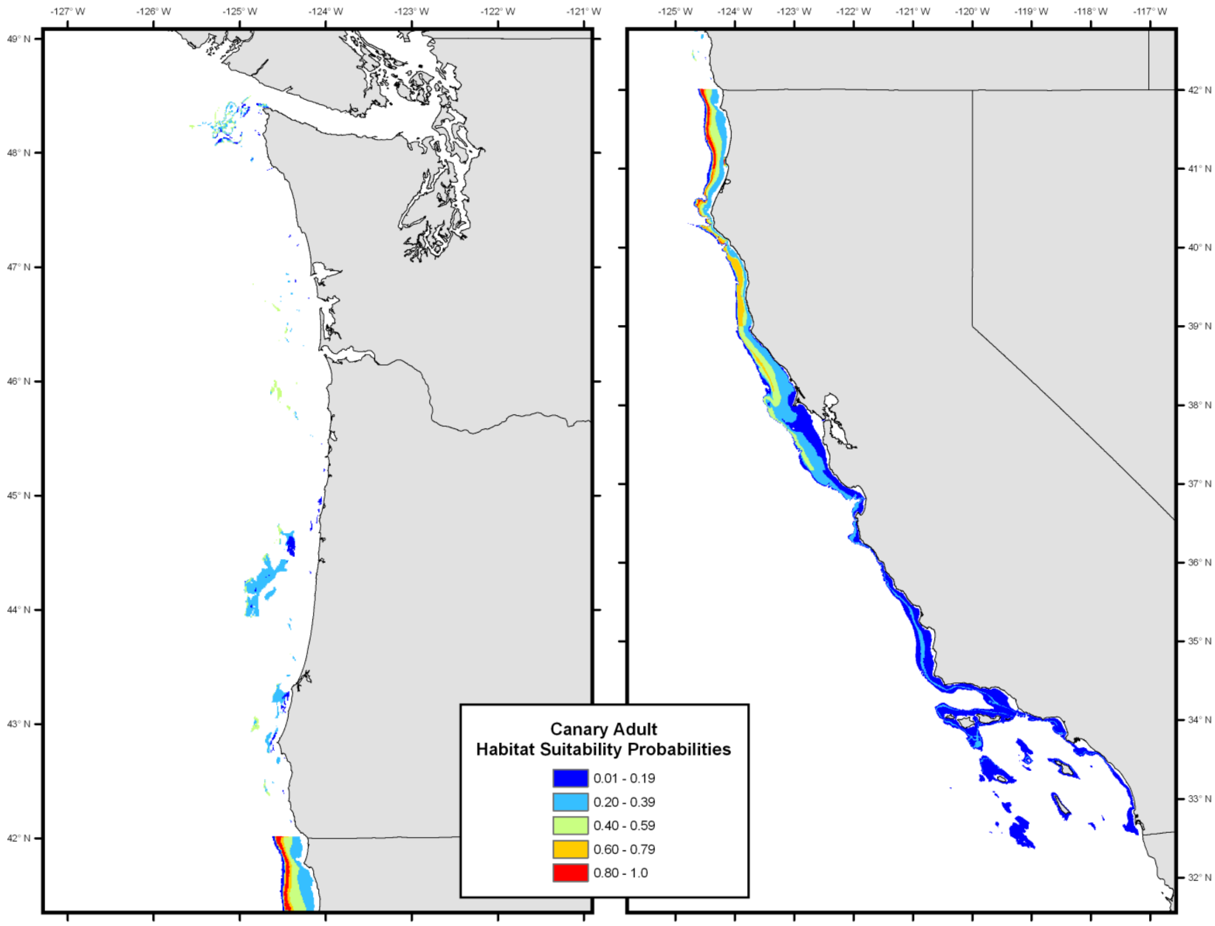


Figure 20. Habitat Suitability Probabilities for canary *Sebastes pinniger* adult. Data from 2005 Essential Fish Habitat Final Environmental Impact Statement.

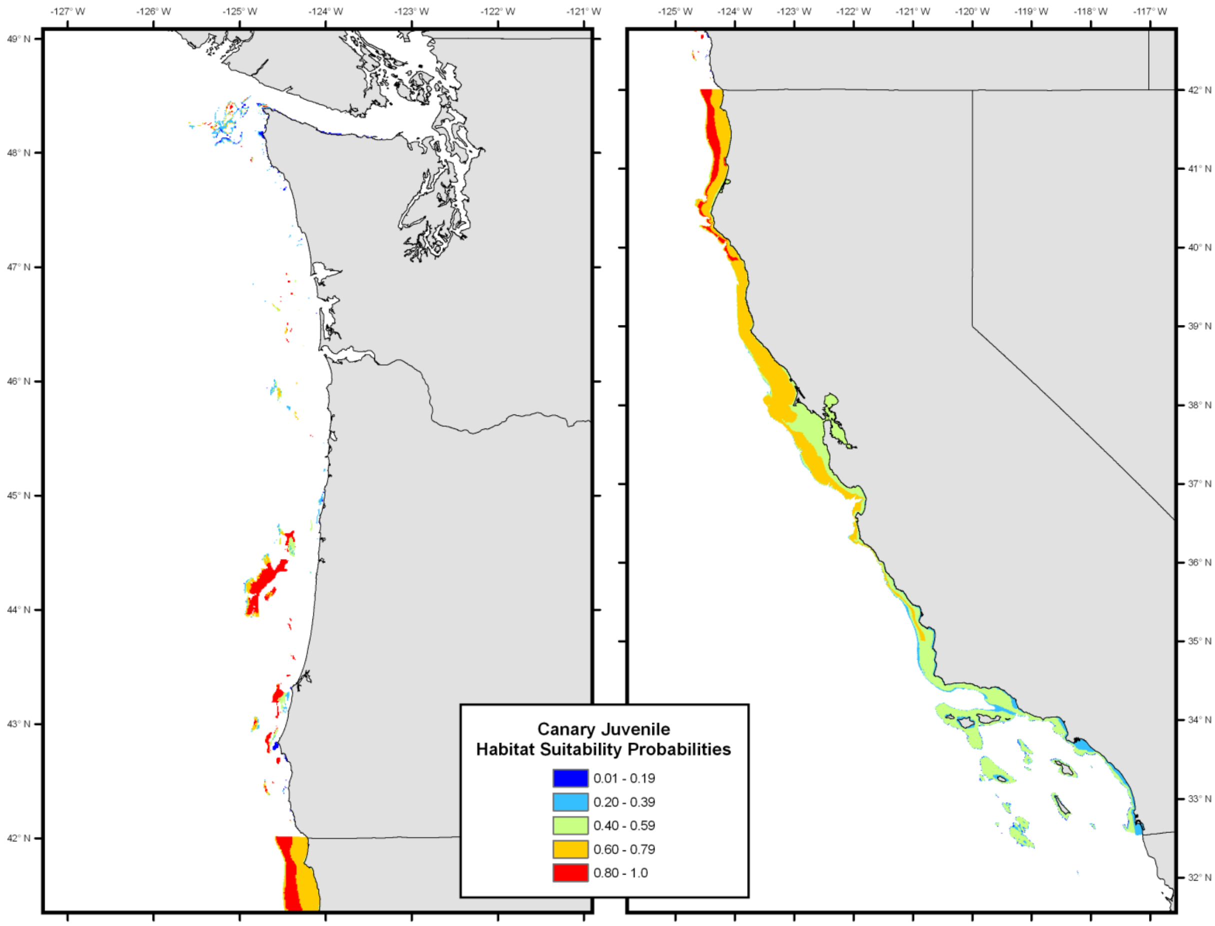


Figure 21. Habitat Suitability Probabilities for canary *Sebastes pinniger* juvenile. Data from 2005 Essential Fish Habitat Final Environmental Impact Statement.

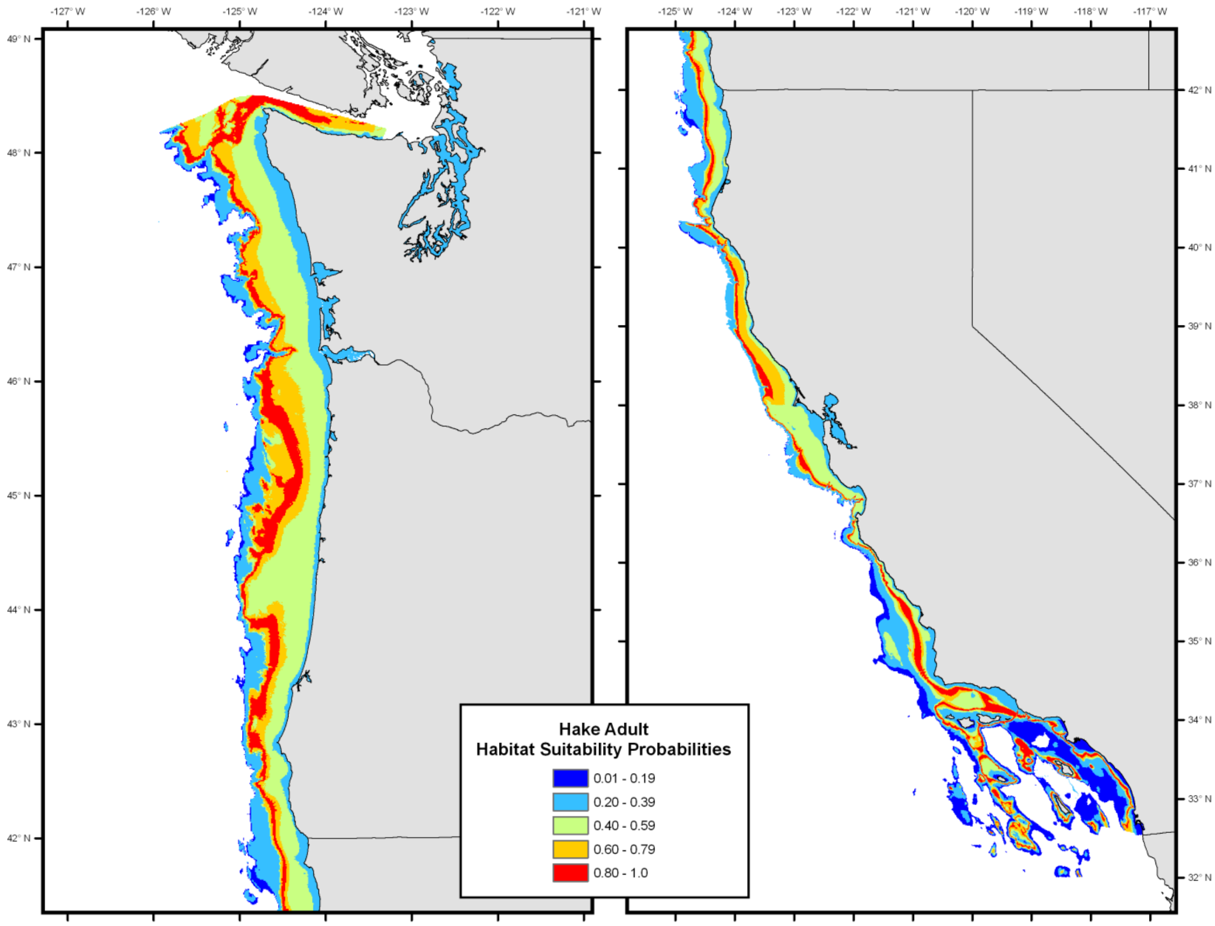


Figure 22. Habitat Suitability Probabilities for Pacific hake *Merluccius productus* adult. Data from 2005 Essential Fish Habitat Final Environmental Impact Statement.

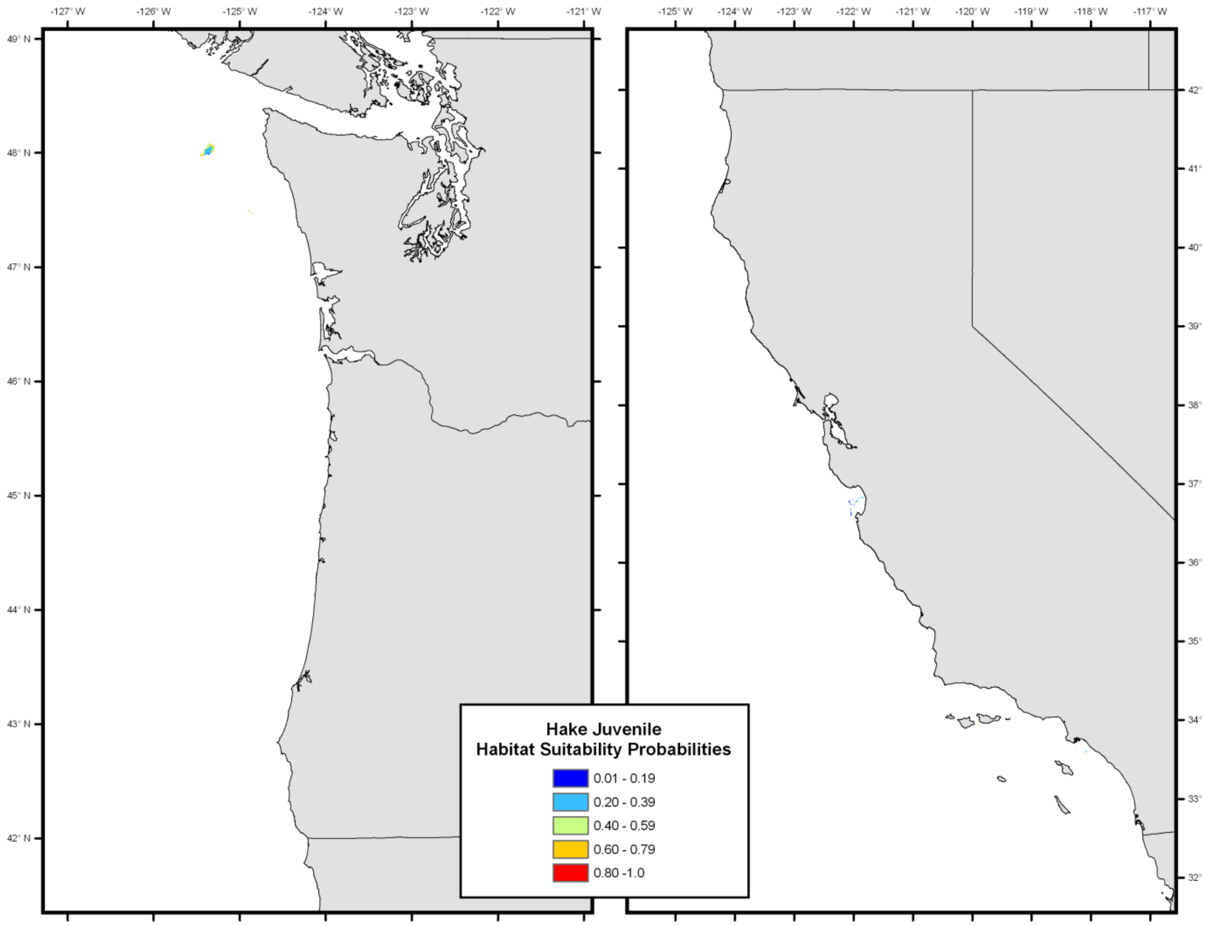


Figure 23. Habitat Suitability Probabilities for Pacific hake *Merluccius productus* juvenile. Data from 2005 Essential Fish Habitat Final Environmental Impact Statement.

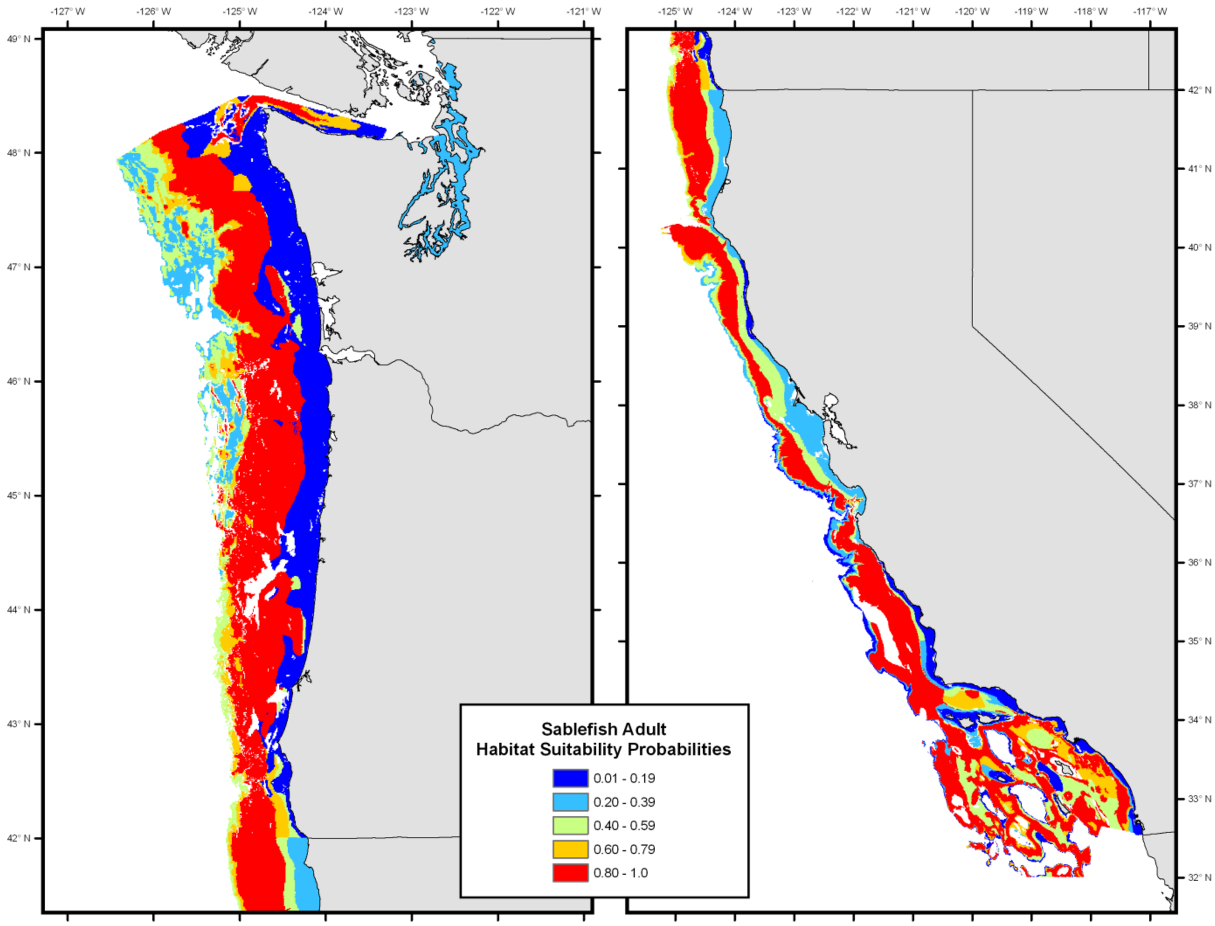


Figure 24. Habitat Suitability Probabilities for Sablefish *Anoplopoma fimbria* adult. Data from 2005 Essential Fish Habitat Final Environmental Impact Statement.

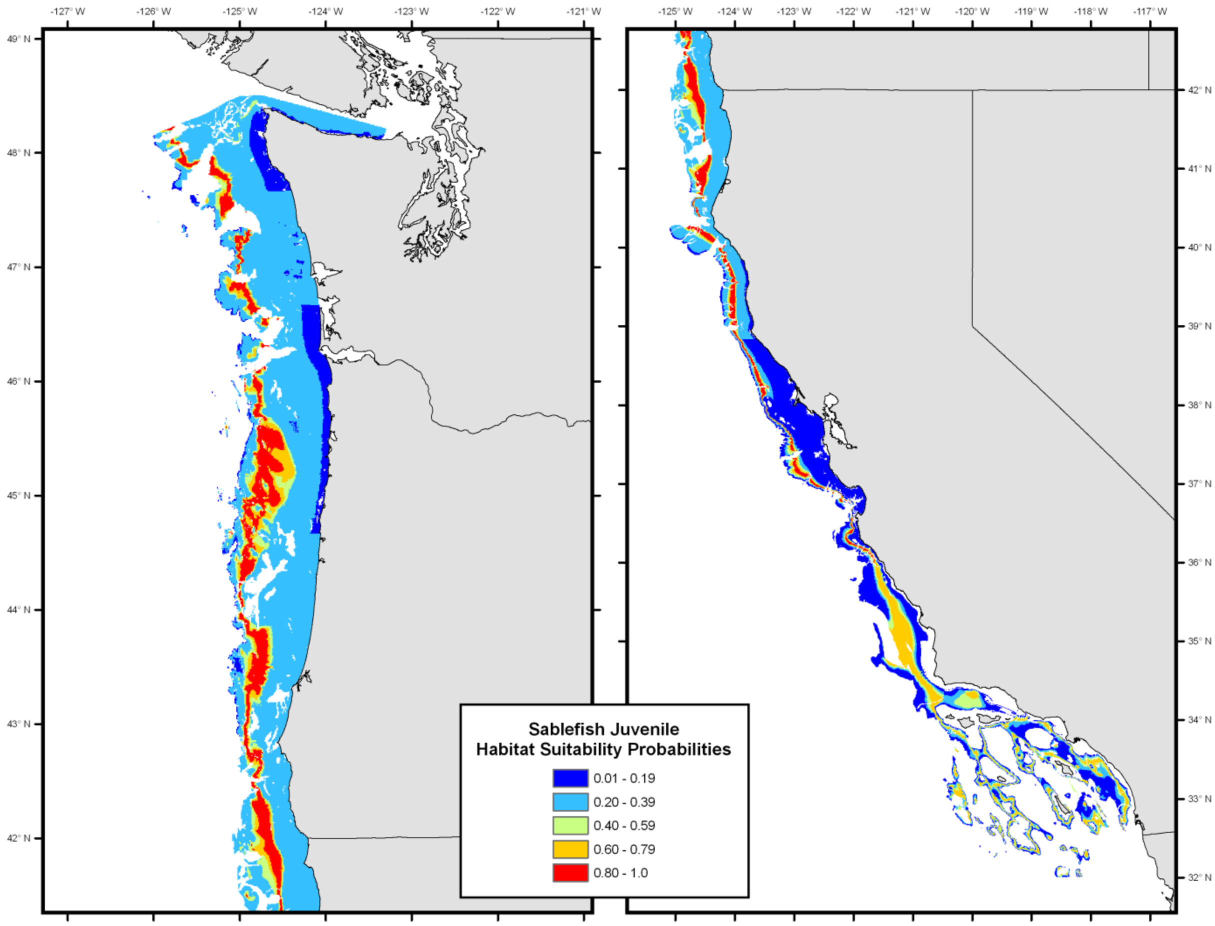


Figure 25. Habitat Suitability Probabilities for Sablefish *Anoplopoma fimbria* juvenile. Data from 2005 Essential Fish Habitat Final Environmental Impact Statement.

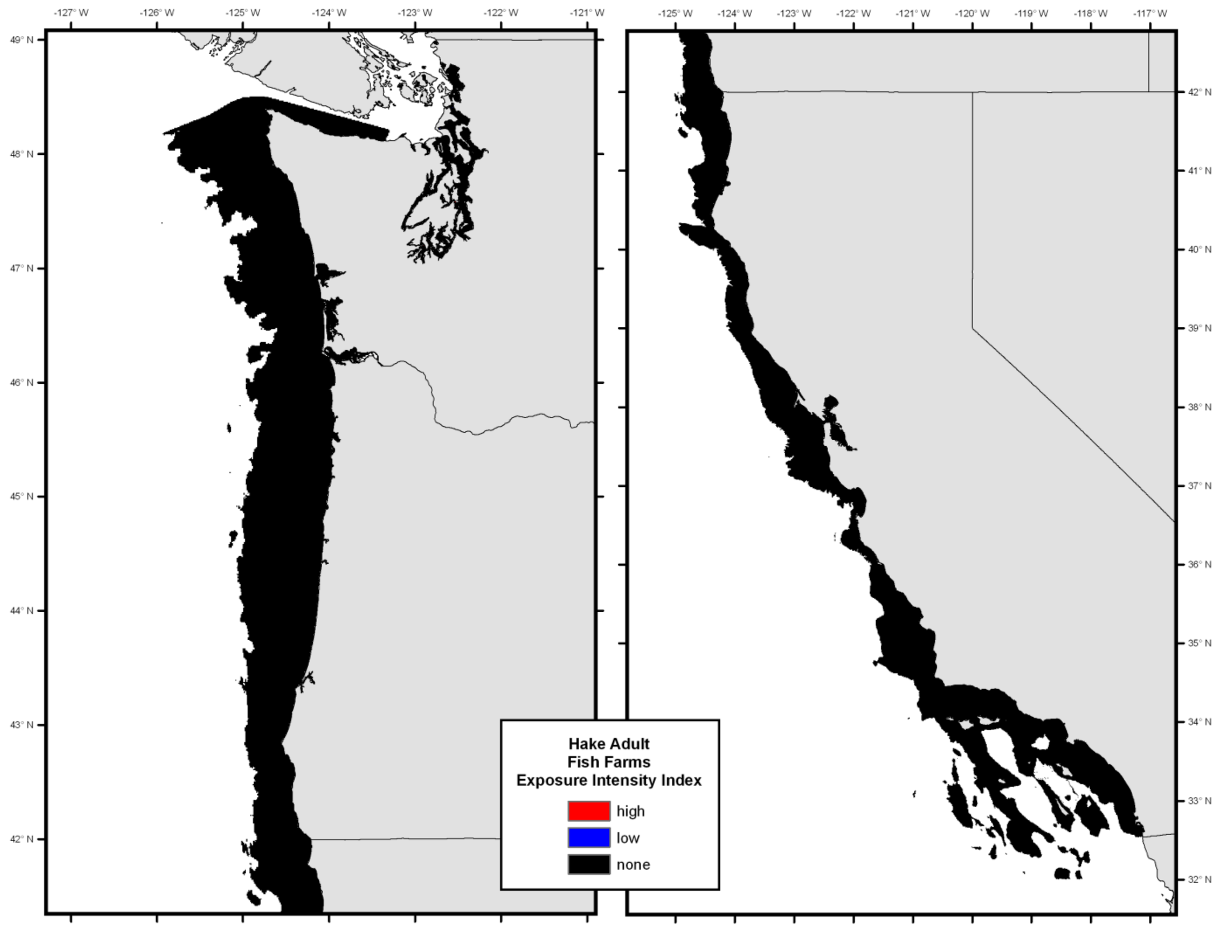


Figure 26. Exposure intensity index of aquaculture for Pacific hake *Merluccius productus* adult. High = upper bicile, and low = lower bicile.

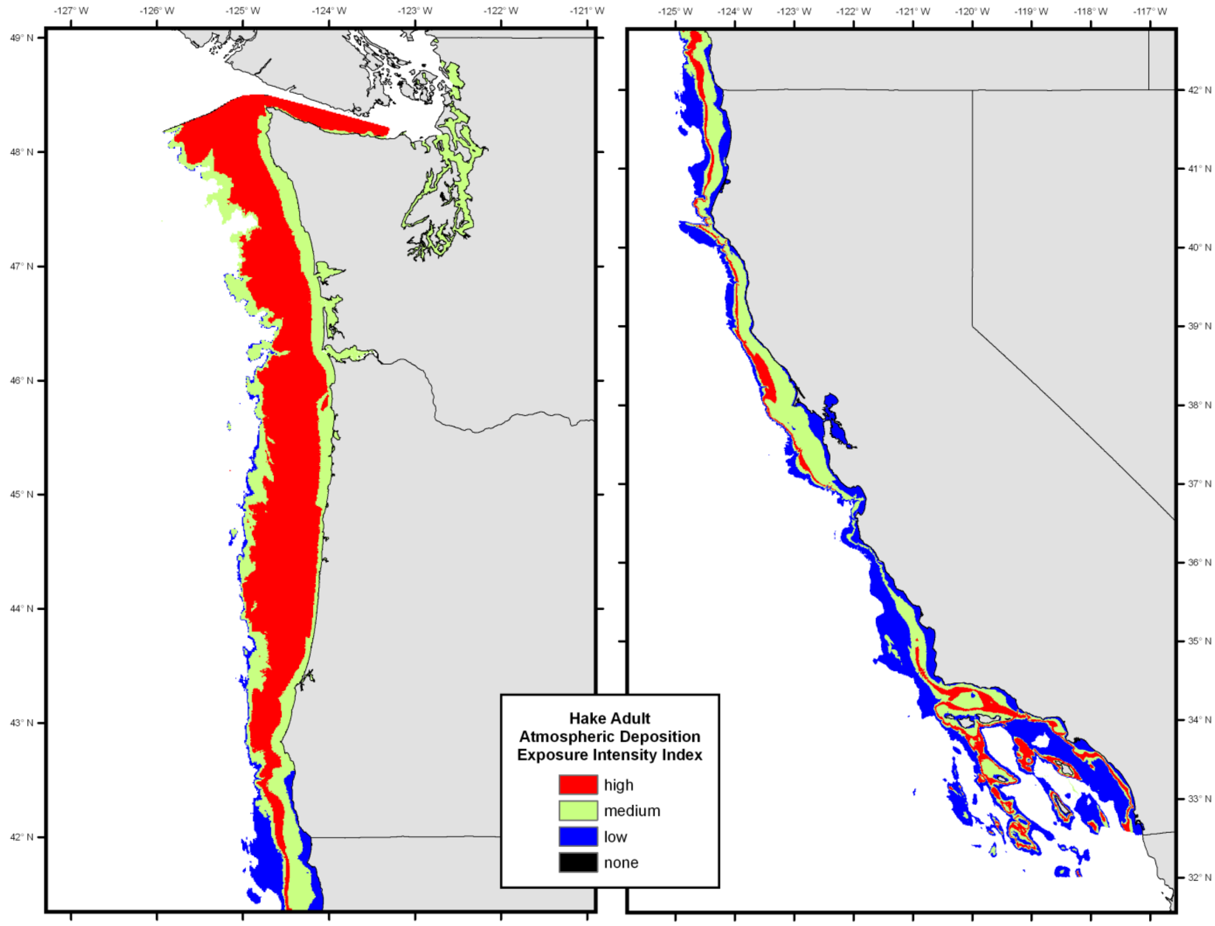


Figure 27. Exposure intensity index of atmospheric deposition of pollutants for Pacific hake *Merluccius productus* adult. High = upper tercile, Medium = middle tercile, low = lower tercile.

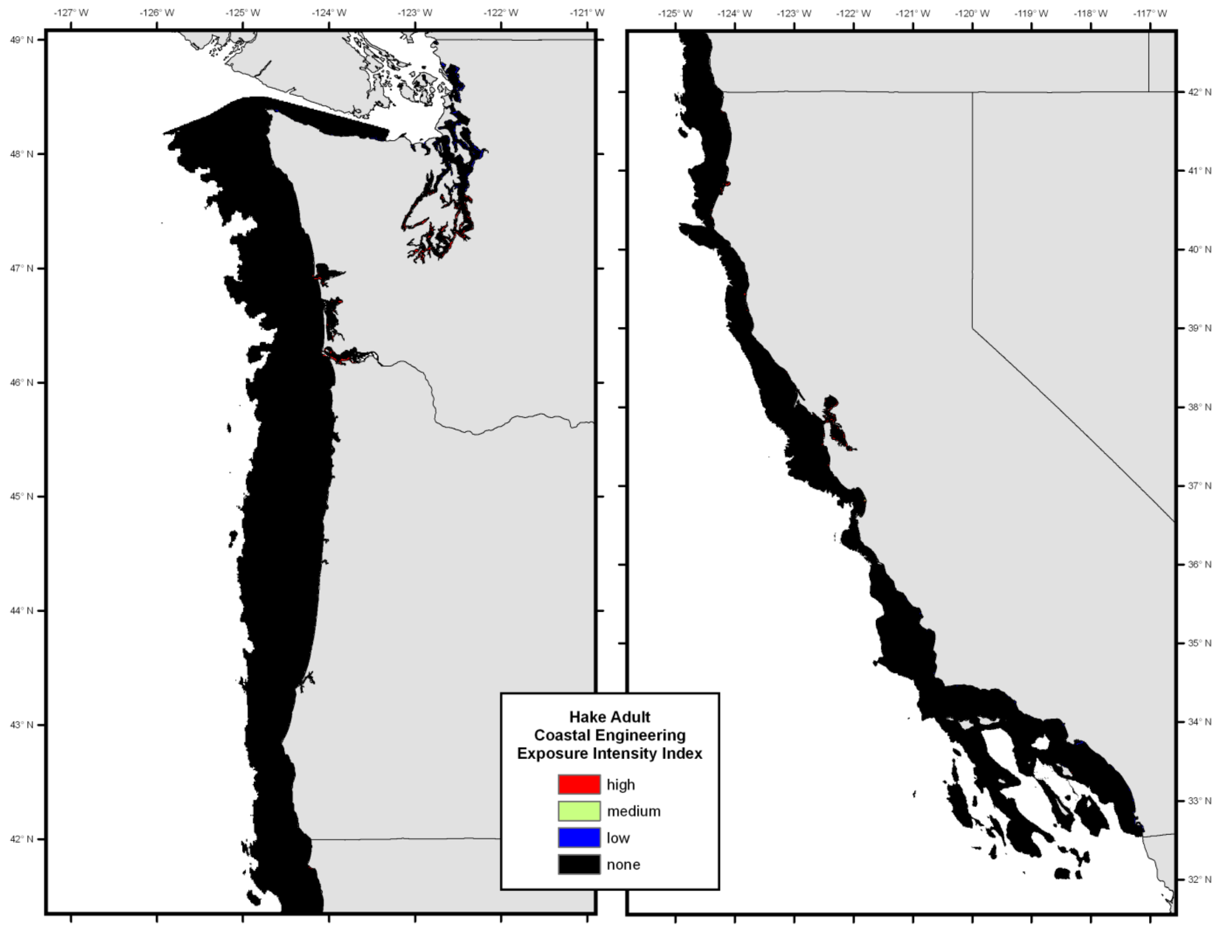


Figure 28. Exposure intensity index of coastal engineering for Pacific hake *Merluccius productus* adult. High = upper tercile, Medium = middle tercile, low = lower tercile.

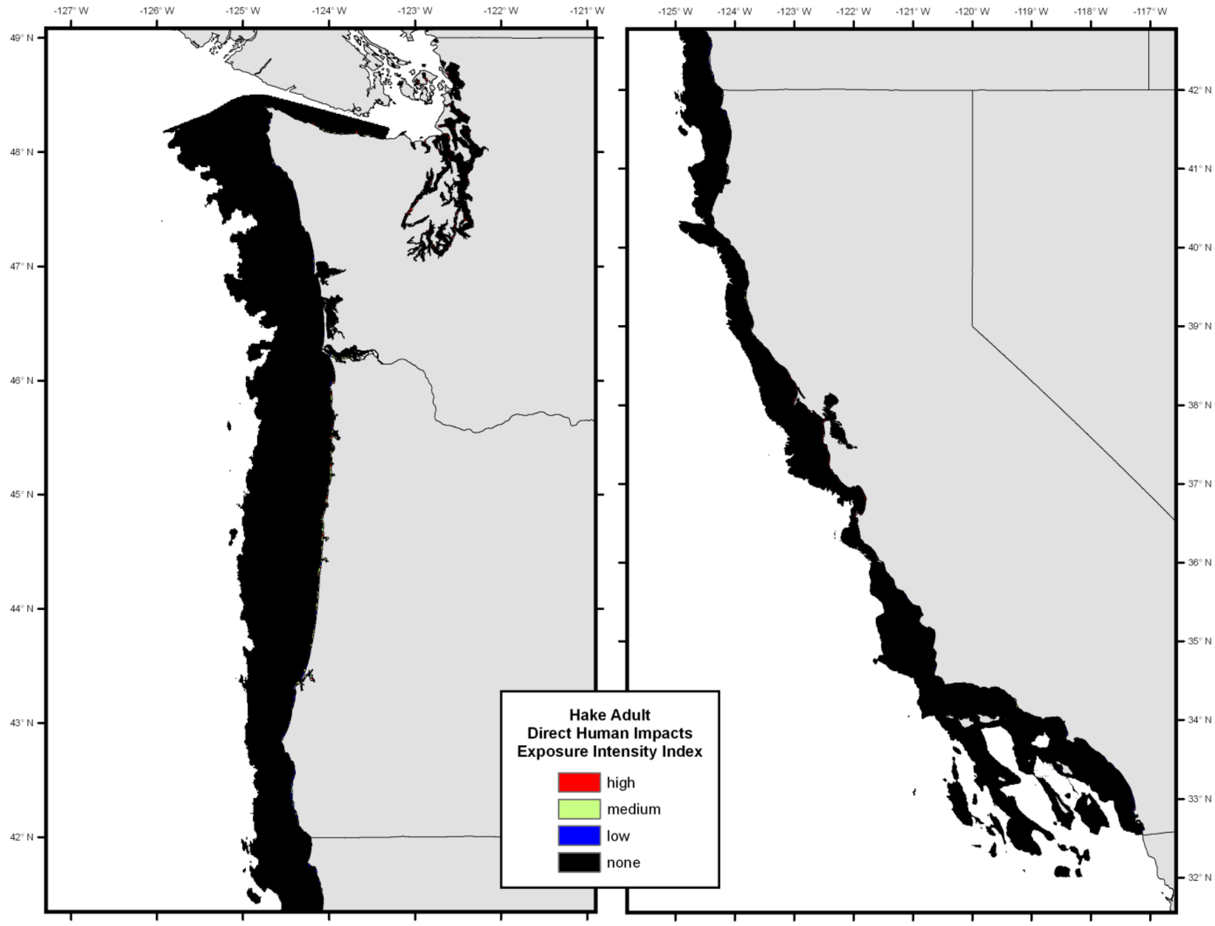


Figure 29. Exposure intensity index of direct human impacts (beach trampling) for Pacific hake *Merluccius productus* adult. High = upper tercile, Medium = middle tercile, low = lower tercile.

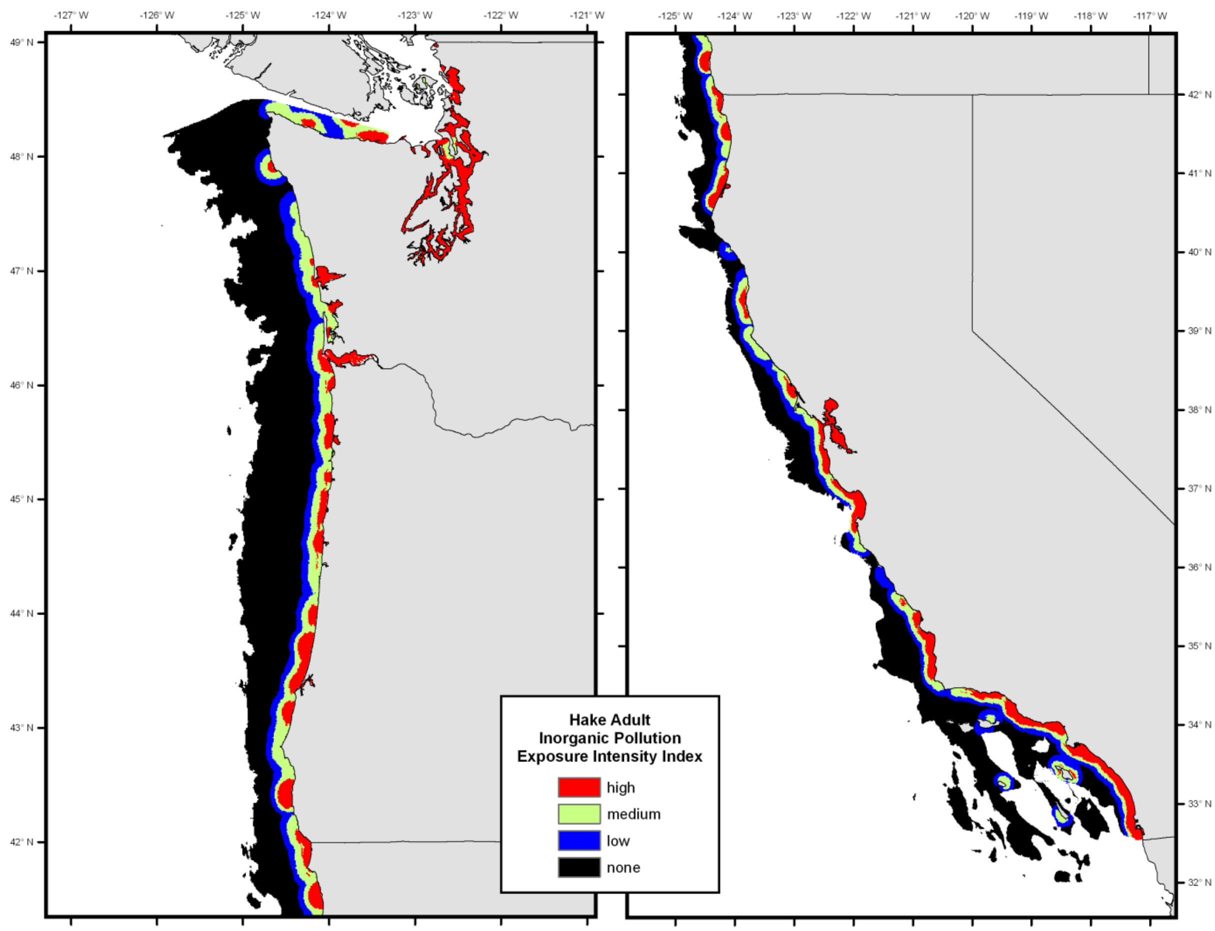


Figure 30. Exposure intensity index of inorganic pollution for Pacific hake *Merluccius productus* adult. High = upper tercile, Medium = middle tercile, low = lower tercile.

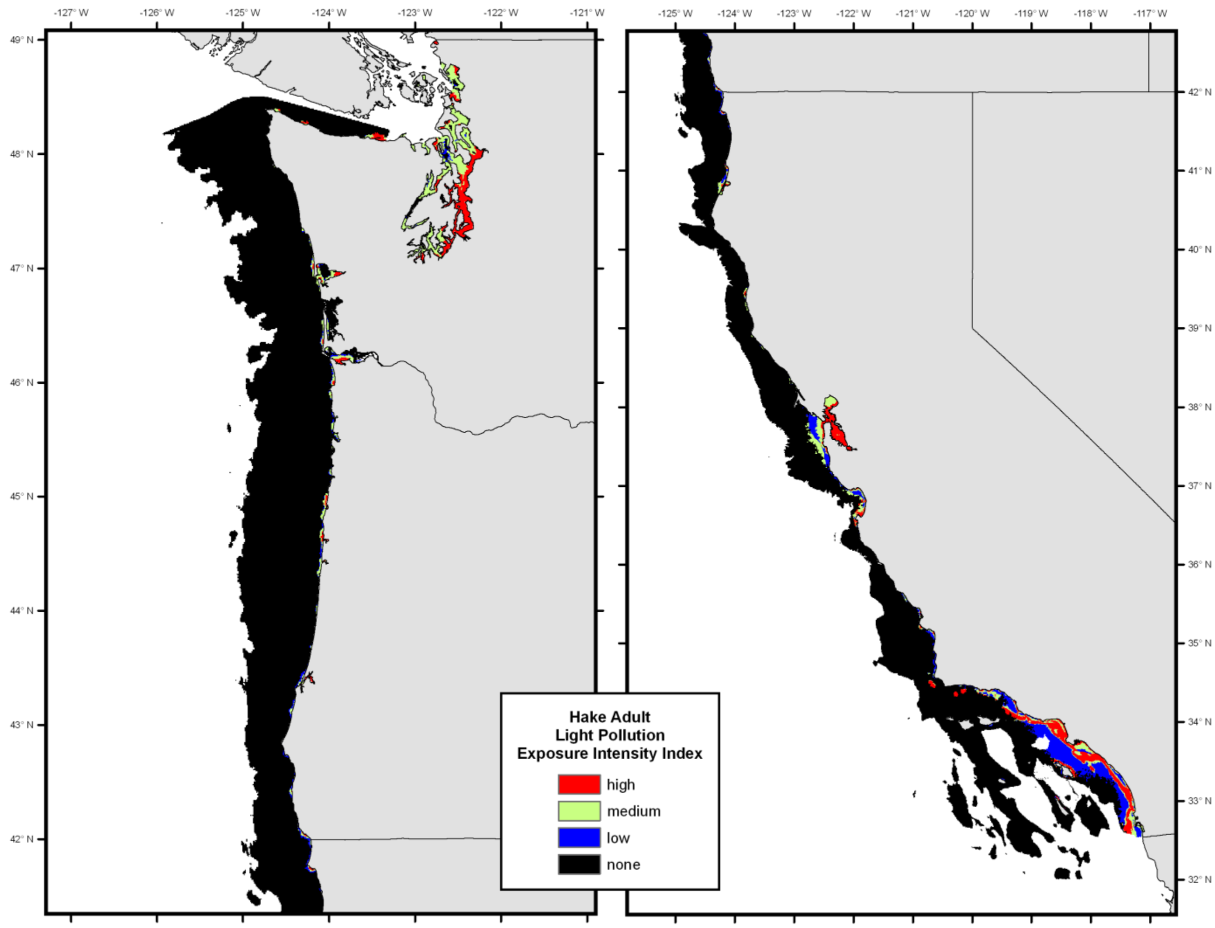


Figure 31. Exposure intensity index of light pollution for Pacific hake *Merluccius productus* adult. High = upper tercile, Medium = middle tercile, low = lower tercile.

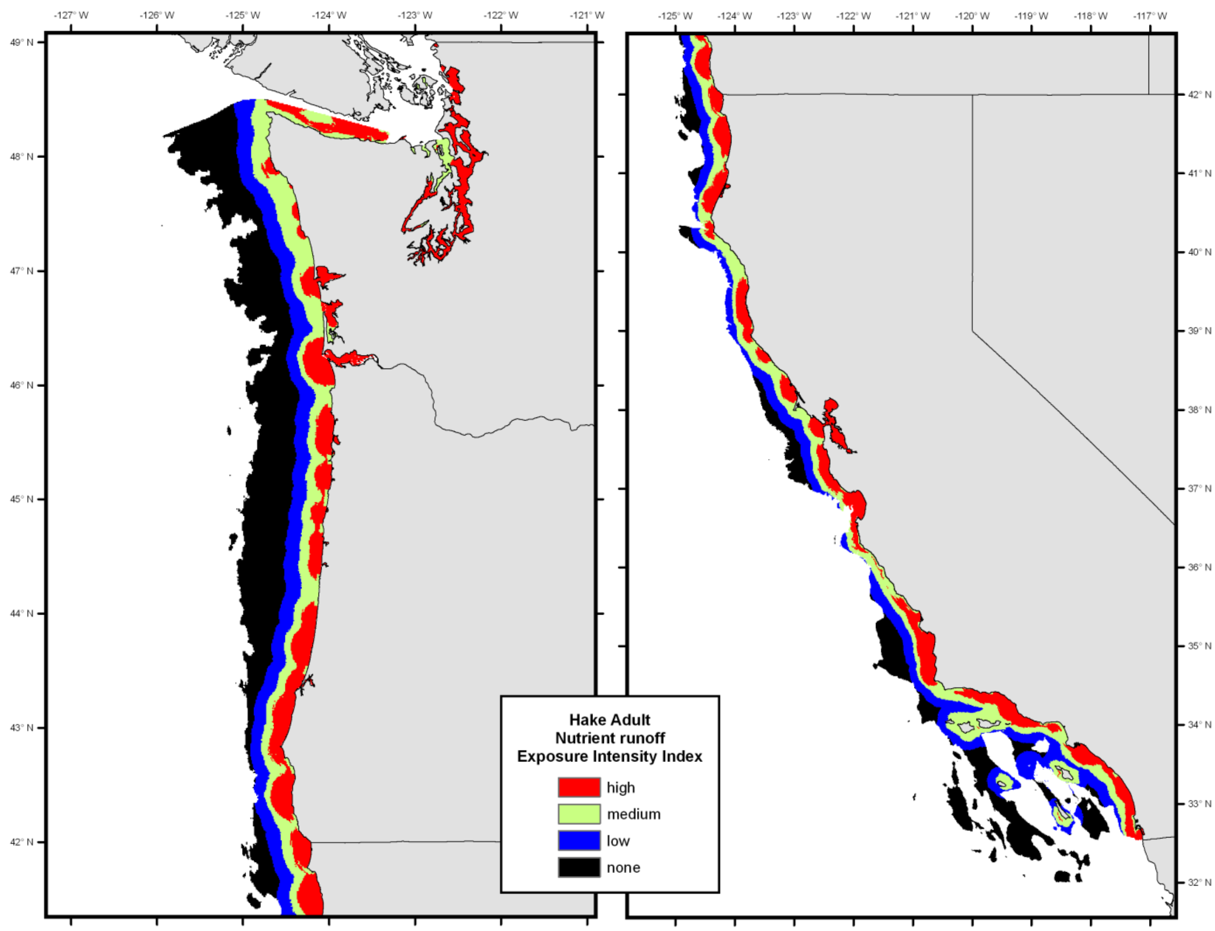


Figure 32. Exposure intensity index of nutrient runoff for Pacific hake *Merluccius productus* adult. High = upper tercile, Medium = middle tercile, low = lower tercile.

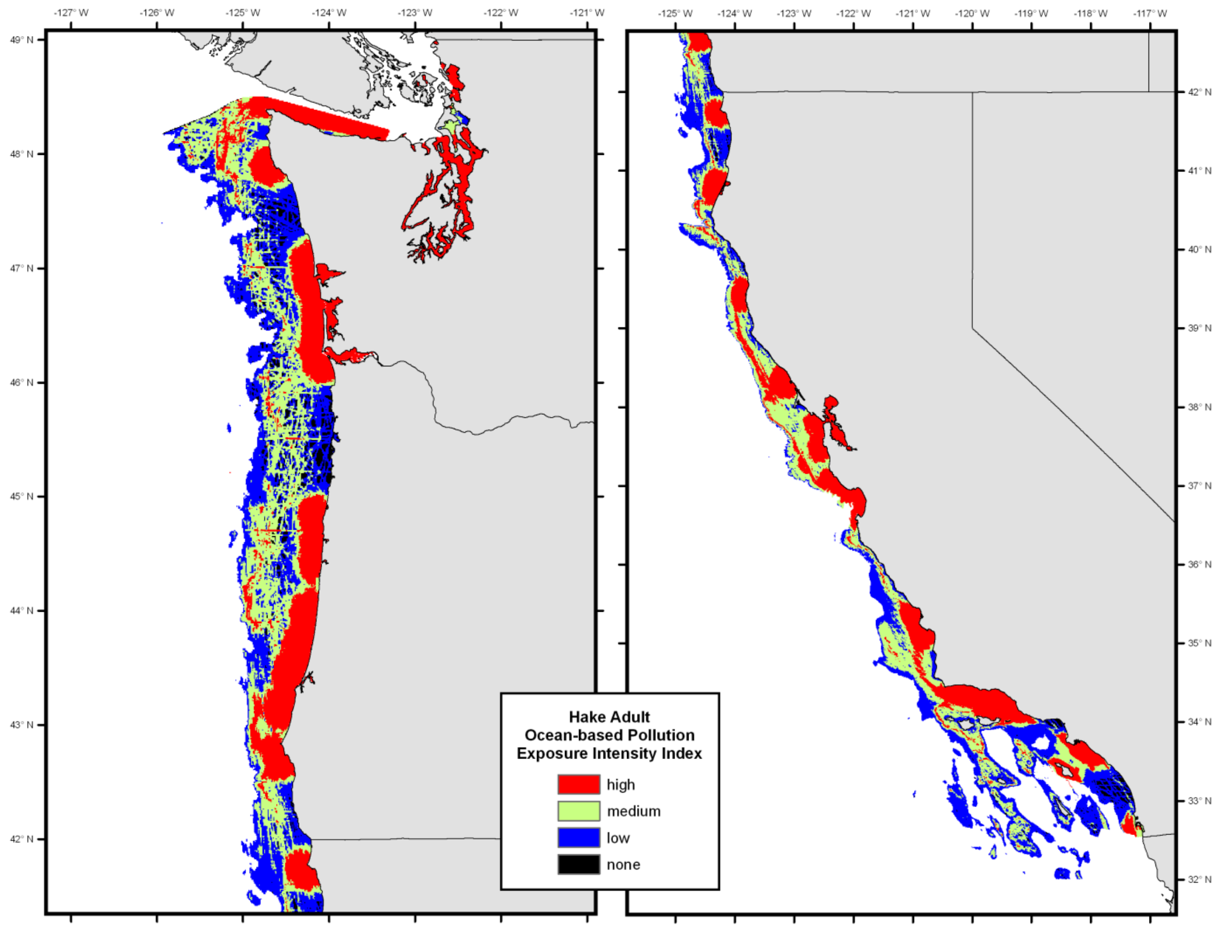


Figure 33. Exposure intensity index of ocean-based pollution for Pacific hake *Merluccius productus* adult. High = upper tercile, Medium = middle tercile, low = lower tercile.

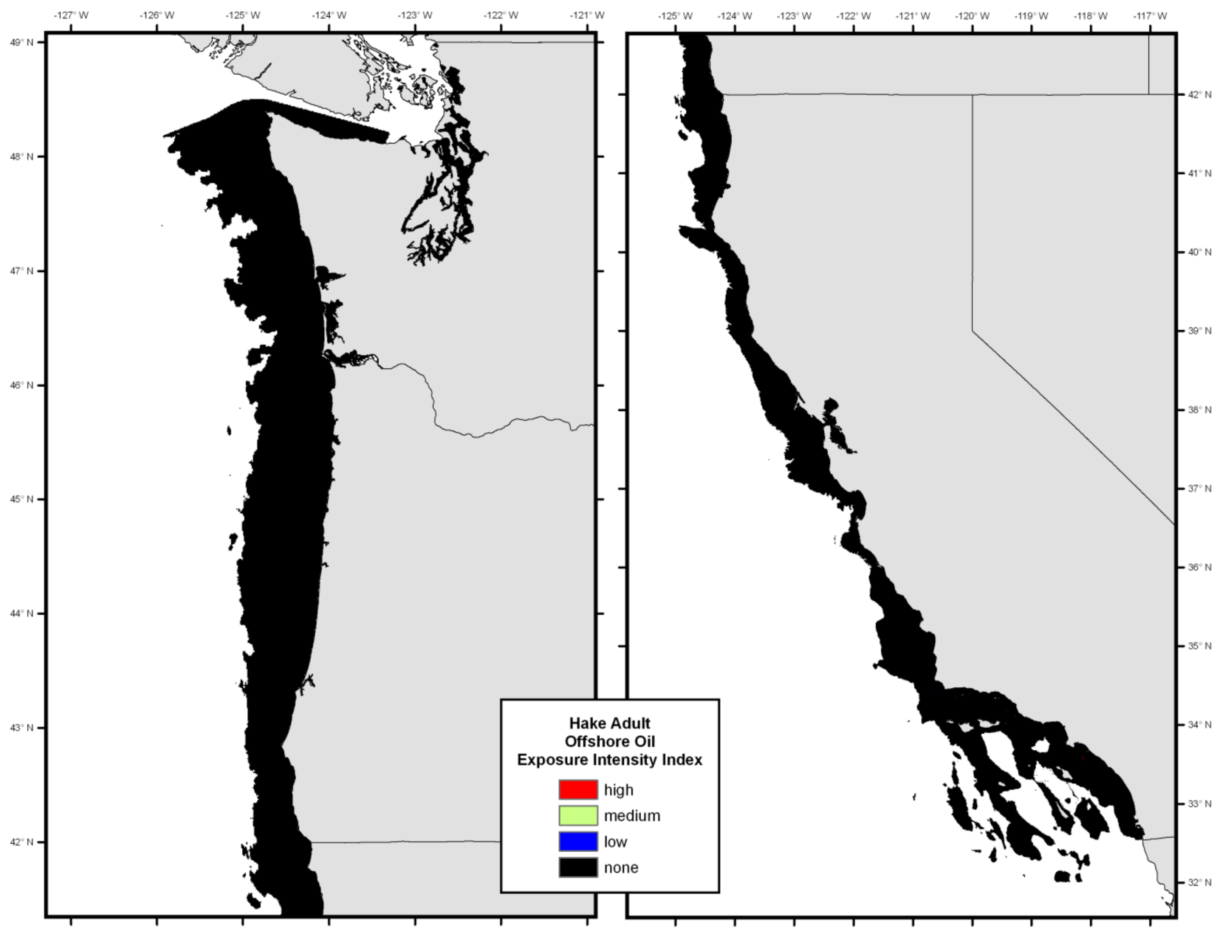


Figure 34. Exposure intensity index of offshore oil activities for Pacific hake *Merluccius productus* adult. High = upper tercile, Medium = middle tercile, low = lower tercile.

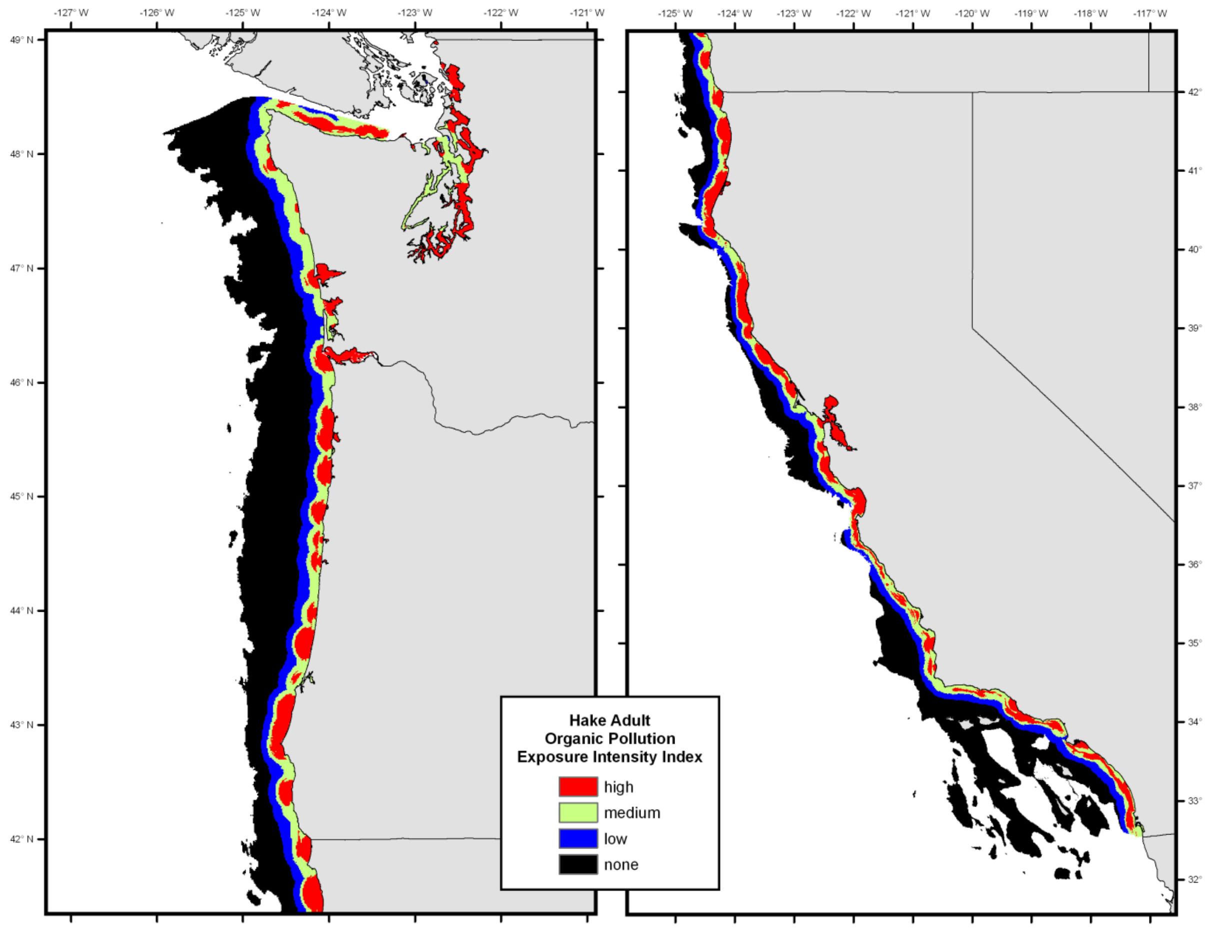


Figure 35. Exposure intensity index of organic pollution for Pacific hake *Merluccius productus* adult. High = upper tercile, Medium = middle tercile, low = lower tercile.

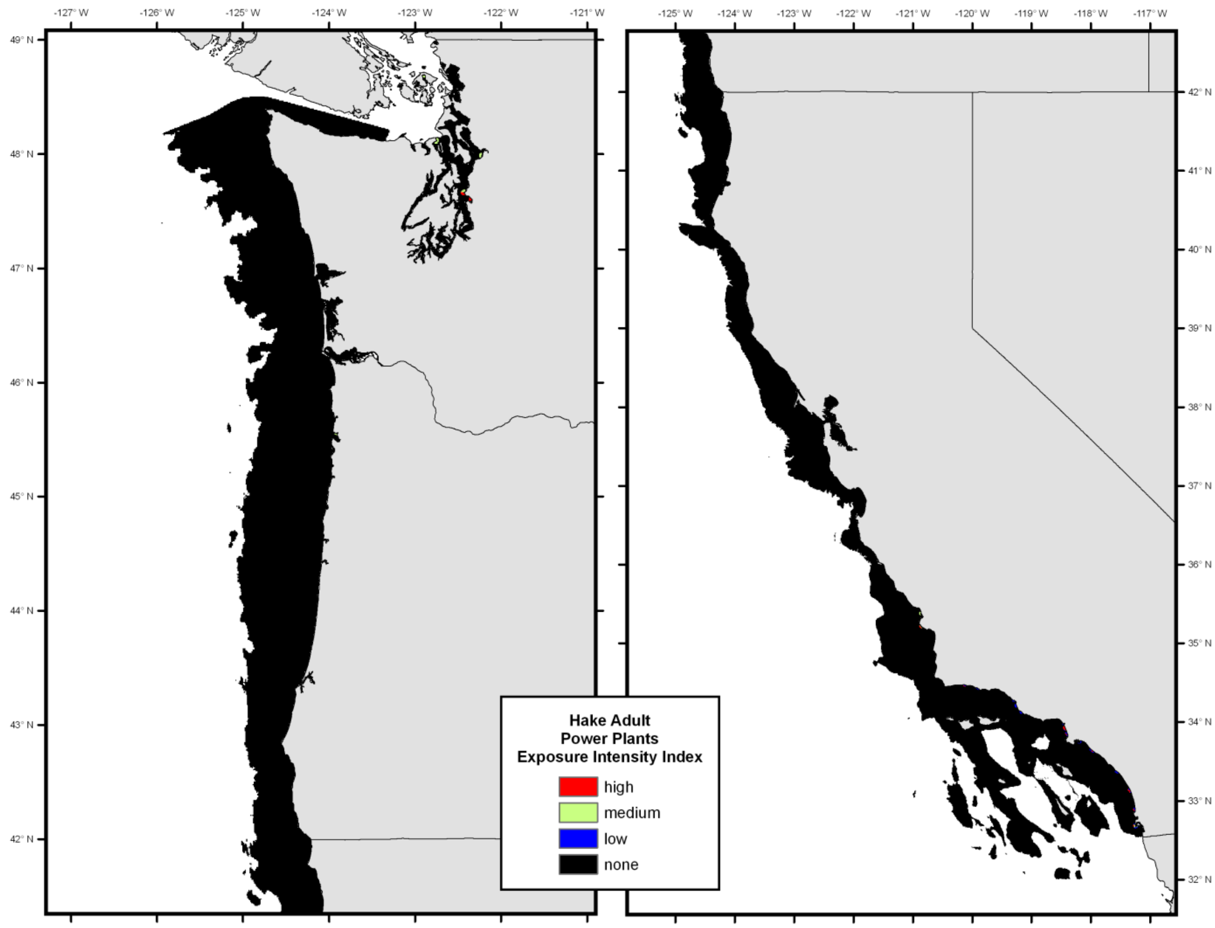


Figure 36. Exposure intensity index of power plant activity for Pacific hake *Merluccius productus* adult. High = upper tercile, Medium = middle tercile, low = lower tercile.

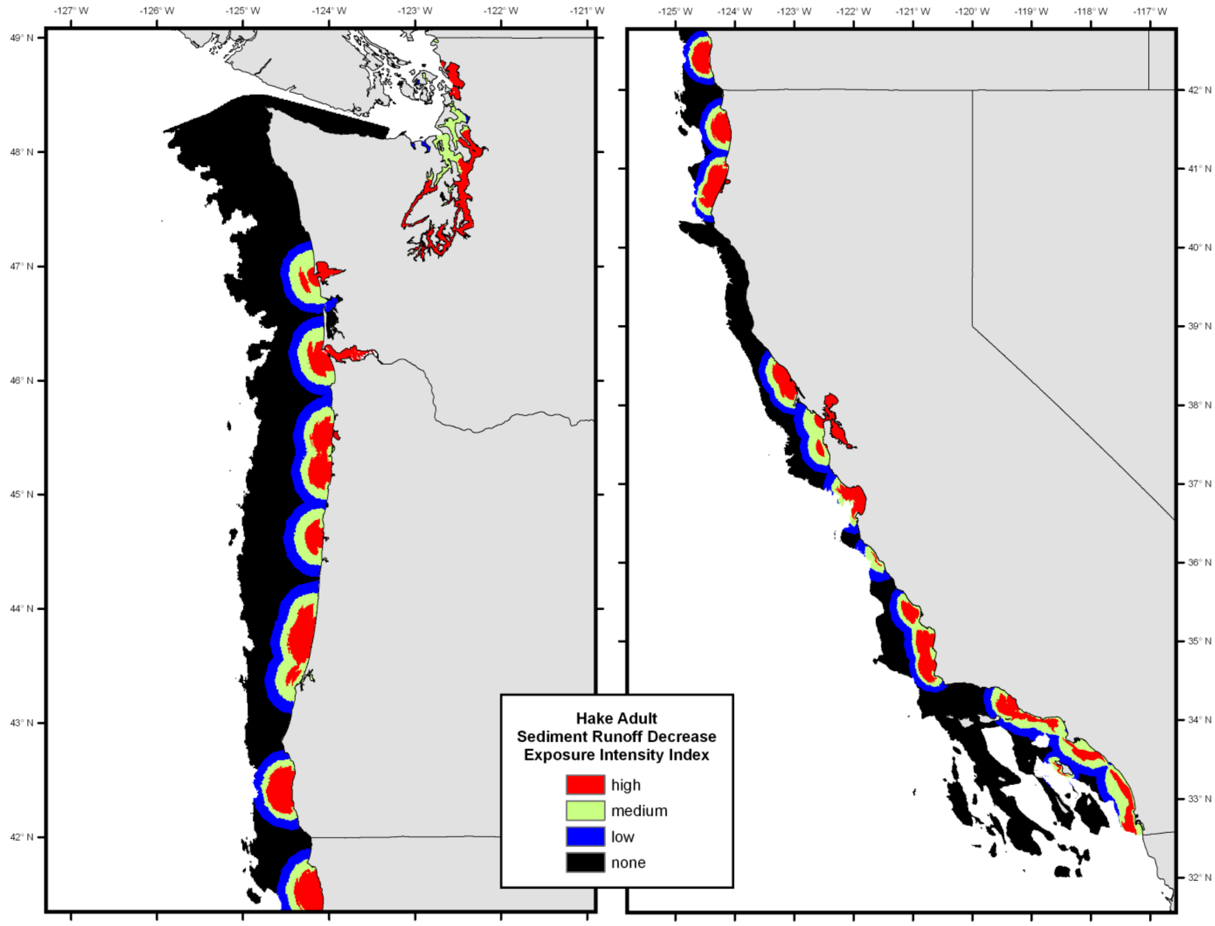


Figure 37. Exposure intensity index of sediment runoff decrease for Pacific hake *Merluccius productus* adult. High = upper tercile, Medium = middle tercile, low = lower tercile.

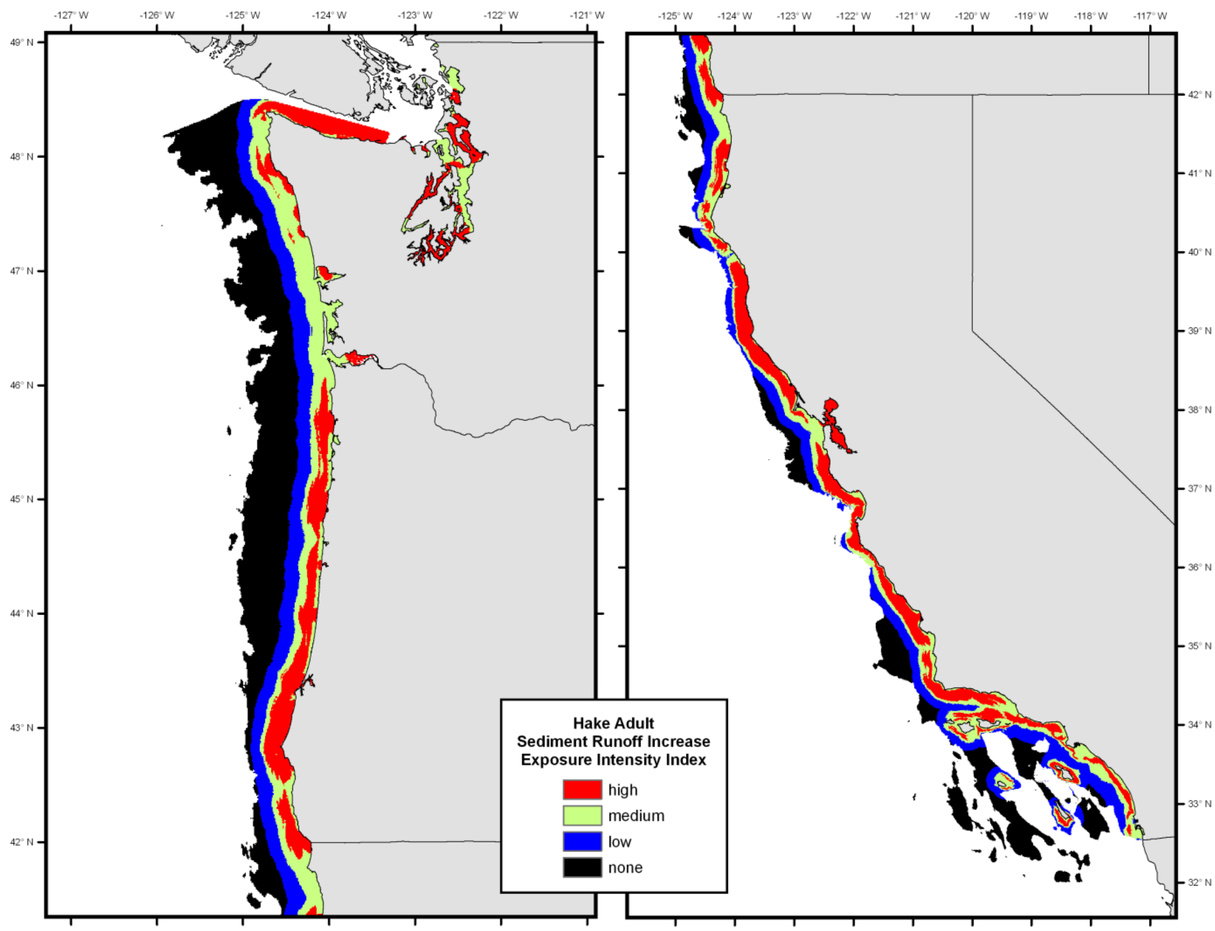


Figure 38. Exposure intensity index of sediment runoff increase for Pacific hake *Merluccius productus* adult. High = upper tercile, Medium = middle tercile, low = lower tercile.

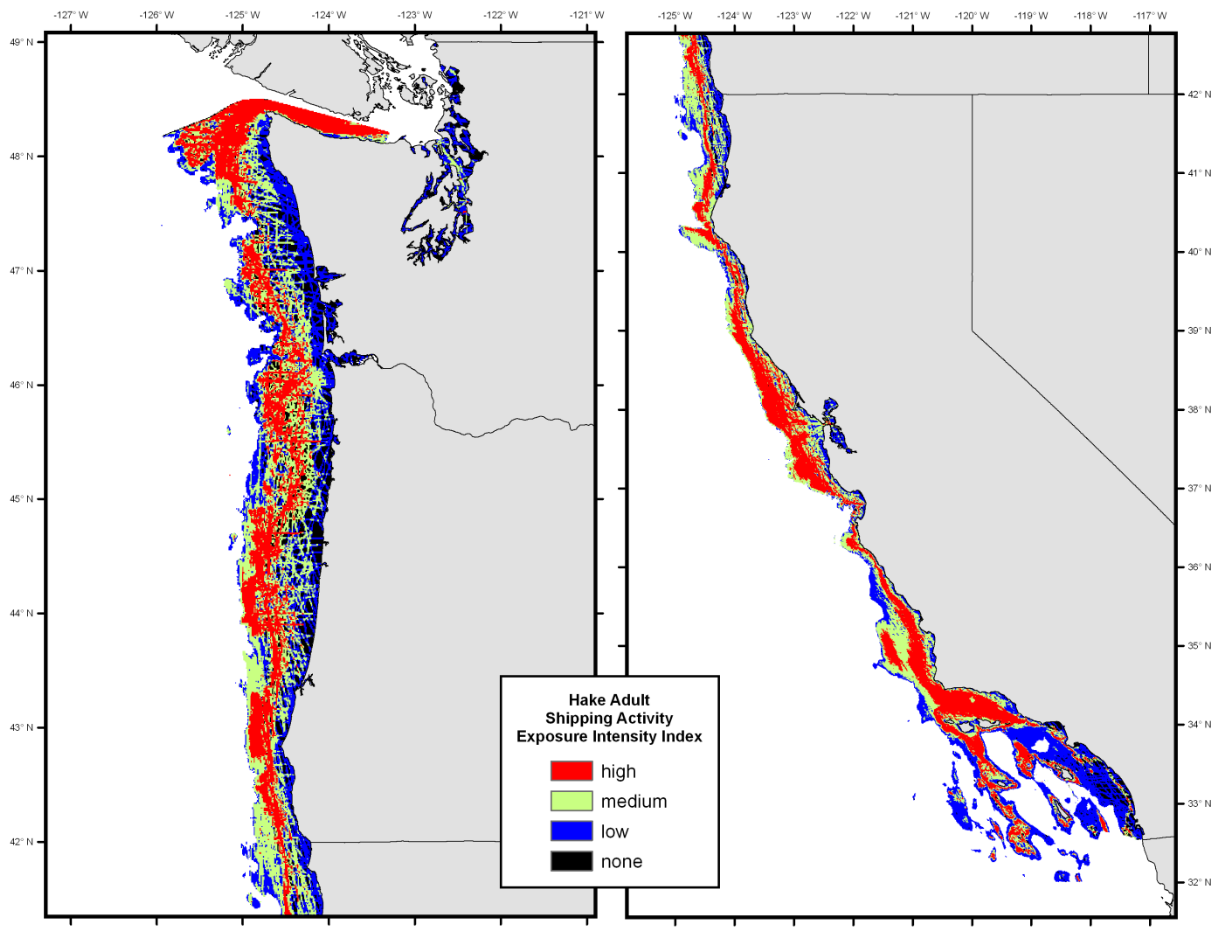


Figure 39. Exposure intensity index of shipping activity for Pacific hake *Merluccius productus* adult. High = upper tercile, Medium = middle tercile, low = lower tercile.

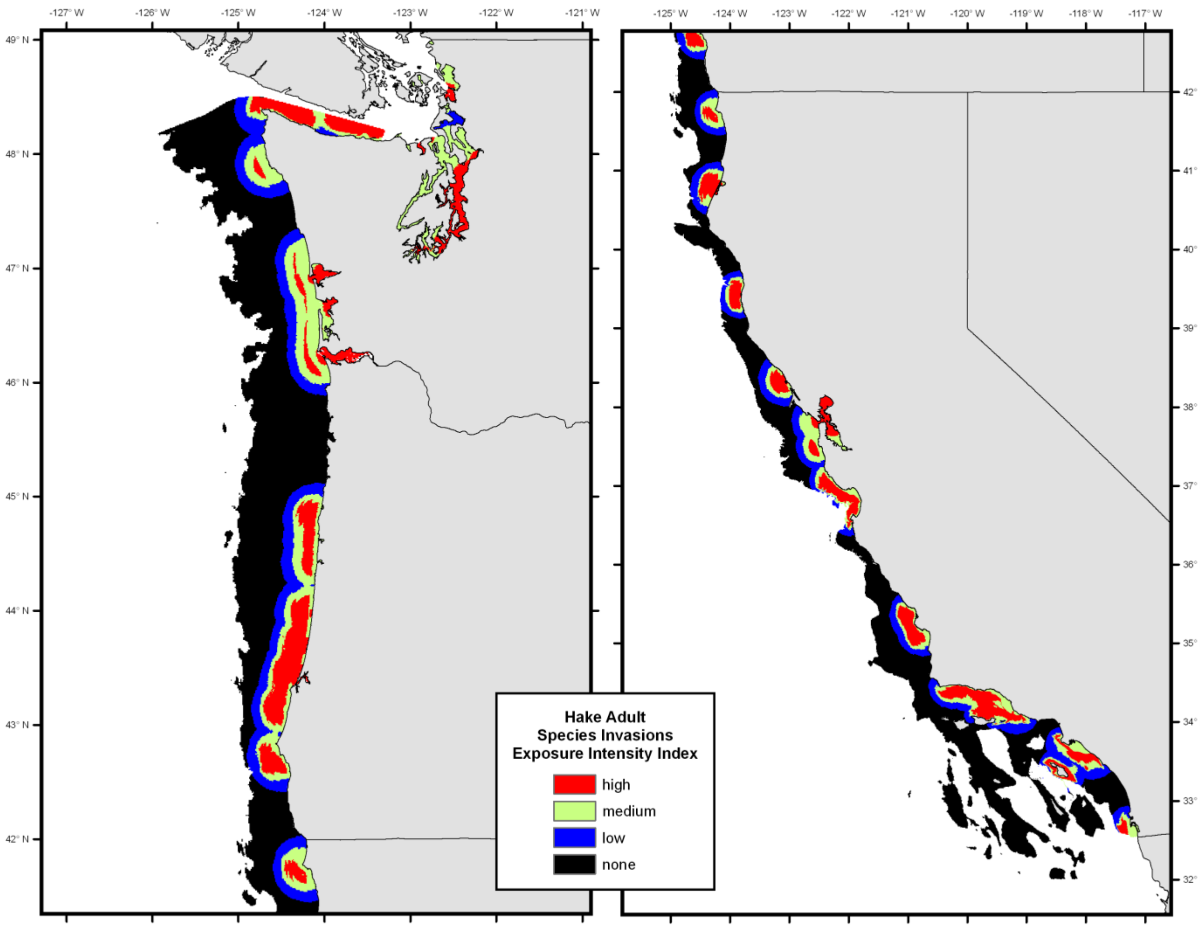


Figure 40. Exposure intensity index of species invasions for Pacific hake *Merluccius productus* adult. High = upper tercile, Medium = middle tercile, low = lower tercile.

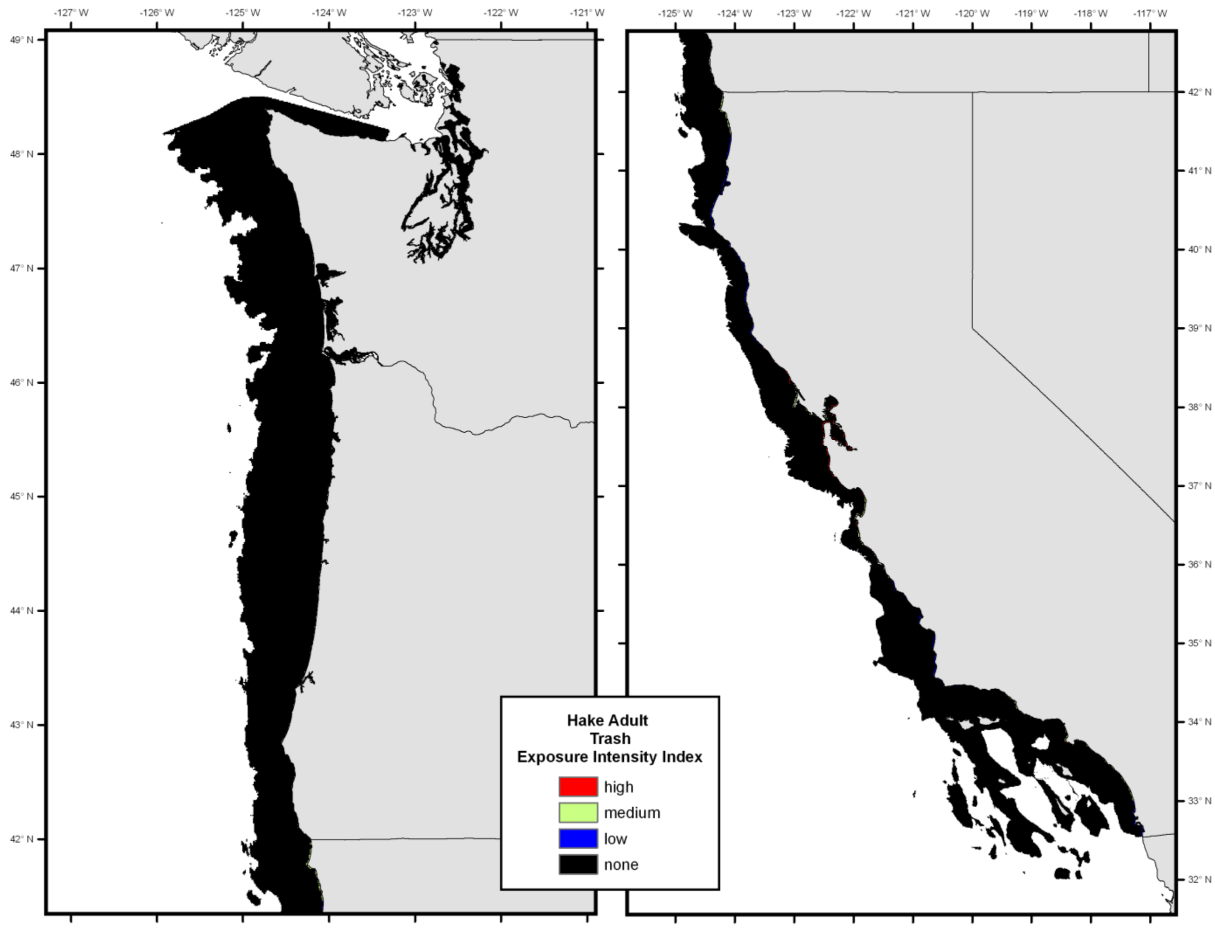


Figure 41. Exposure intensity index of coastal trash for Pacific hake *Merluccius productus* adult. High = upper tercile, Medium = middle tercile, low = lower tercile.

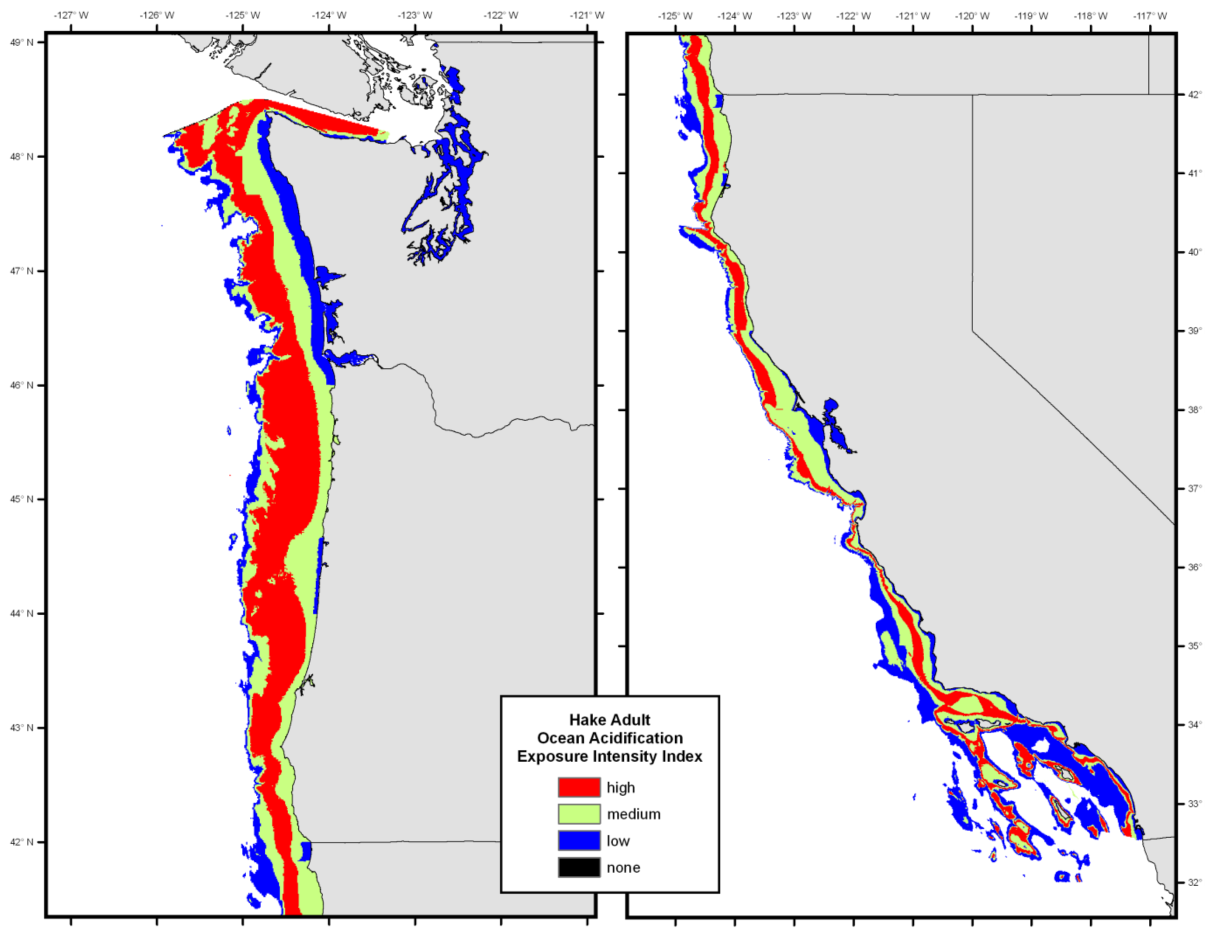


Figure 42. Exposure intensity index of ocean acidification for Pacific hake *Merluccius productus* adult. High = upper tercile, Medium = middle tercile, low = lower tercile.

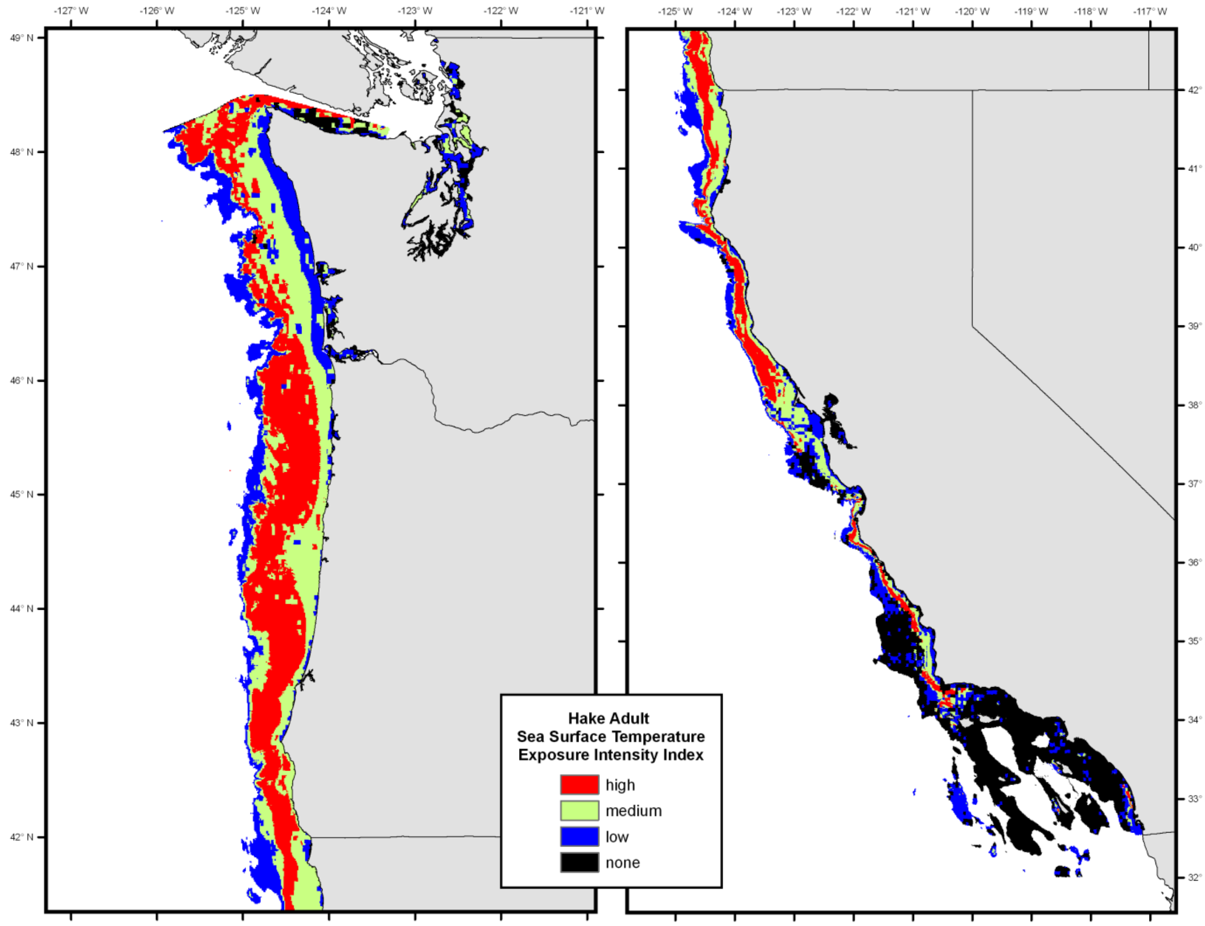


Figure 43. Exposure intensity index of sea-surface temperature for Pacific hake *Merluccius productus* adult. High = upper tercile, Medium = middle tercile, low = lower tercile.

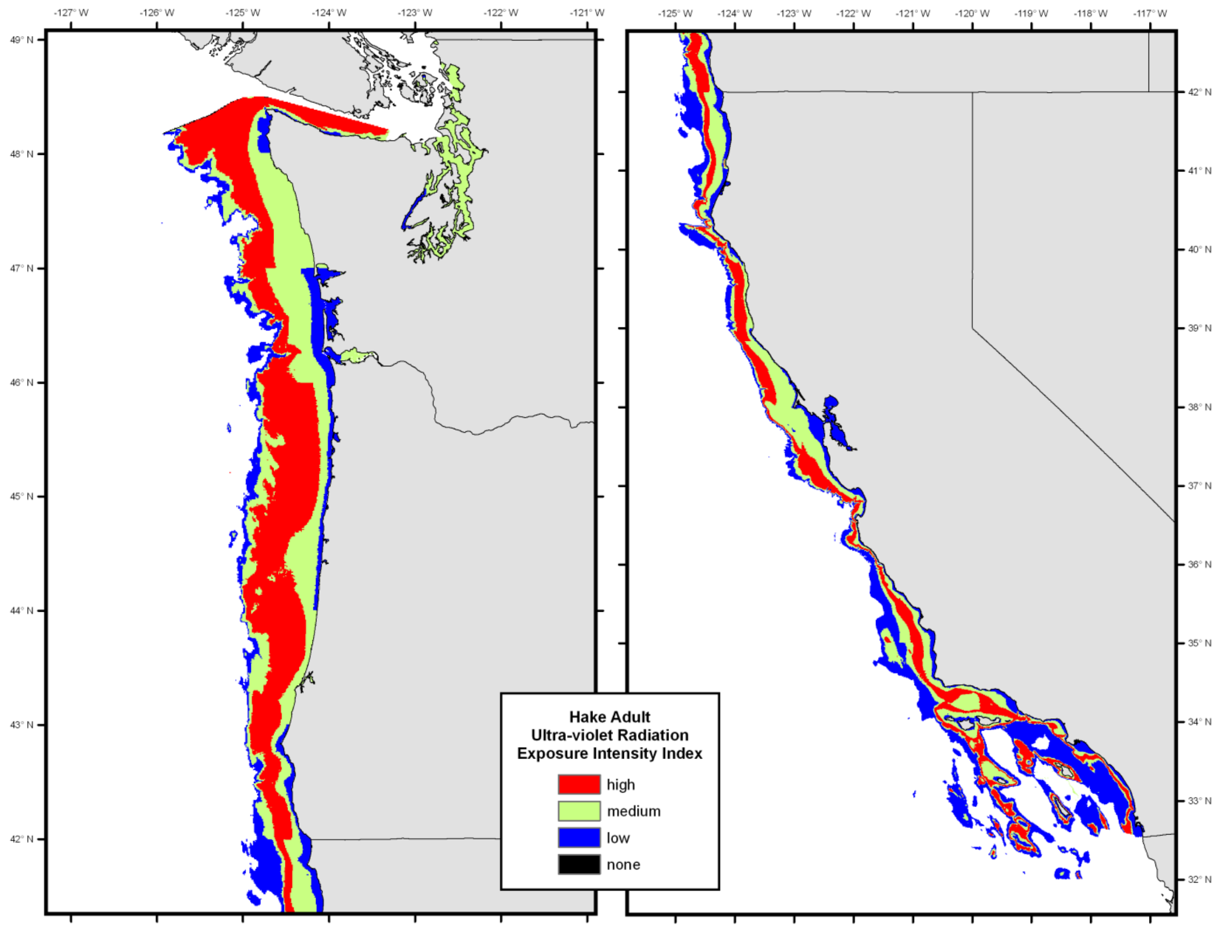


Figure 44. Exposure intensity index of ultra-violet radiation for Pacific hake *Merluccius productus* adult. High = upper tercile, Medium = middle tercile, low = lower tercile.

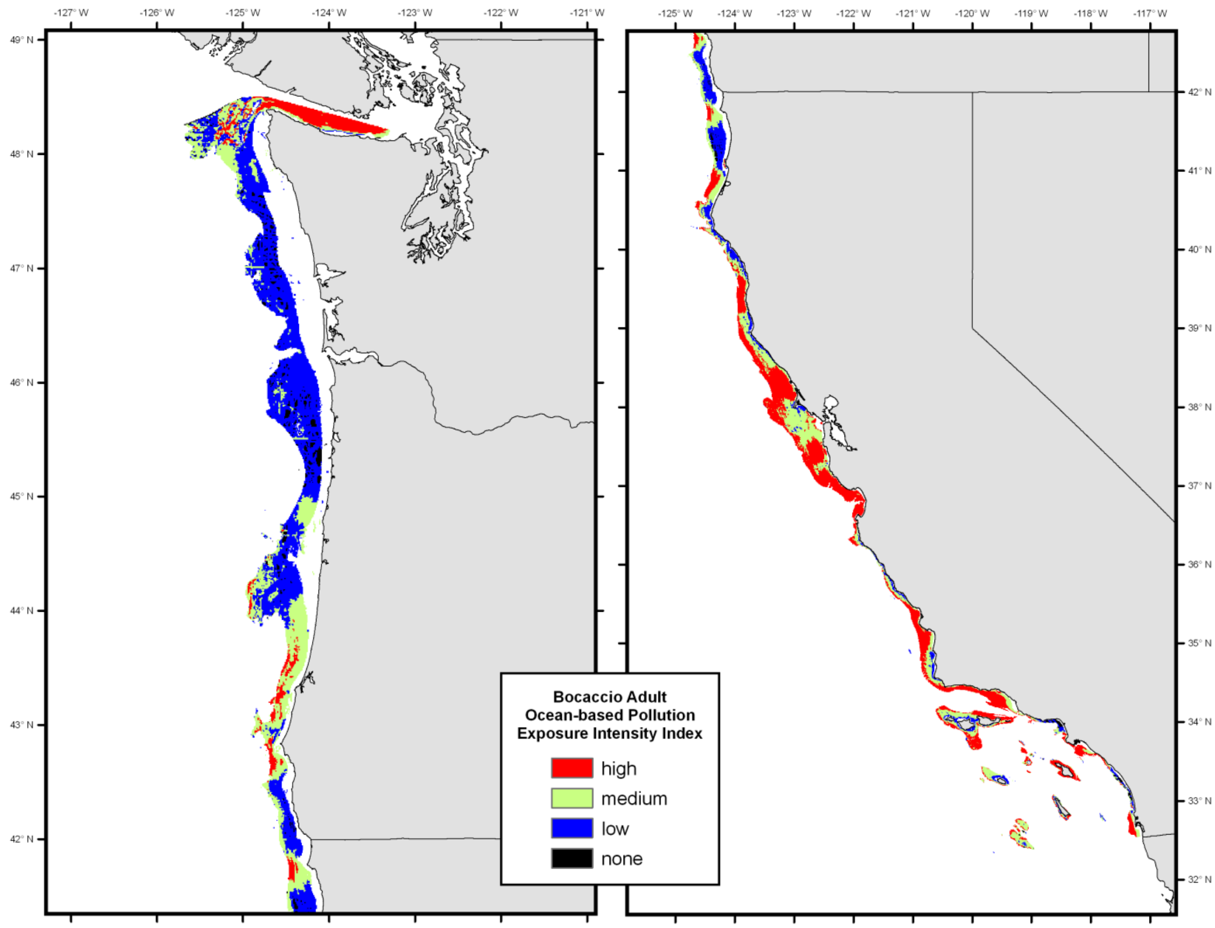


Figure 45. Exposure intensity index of ocean-based pollution for bocaccio *Sebastes paucispinis* rockfish adults. High = upper tercile, Medium = middle tercile, low = lower tercile.

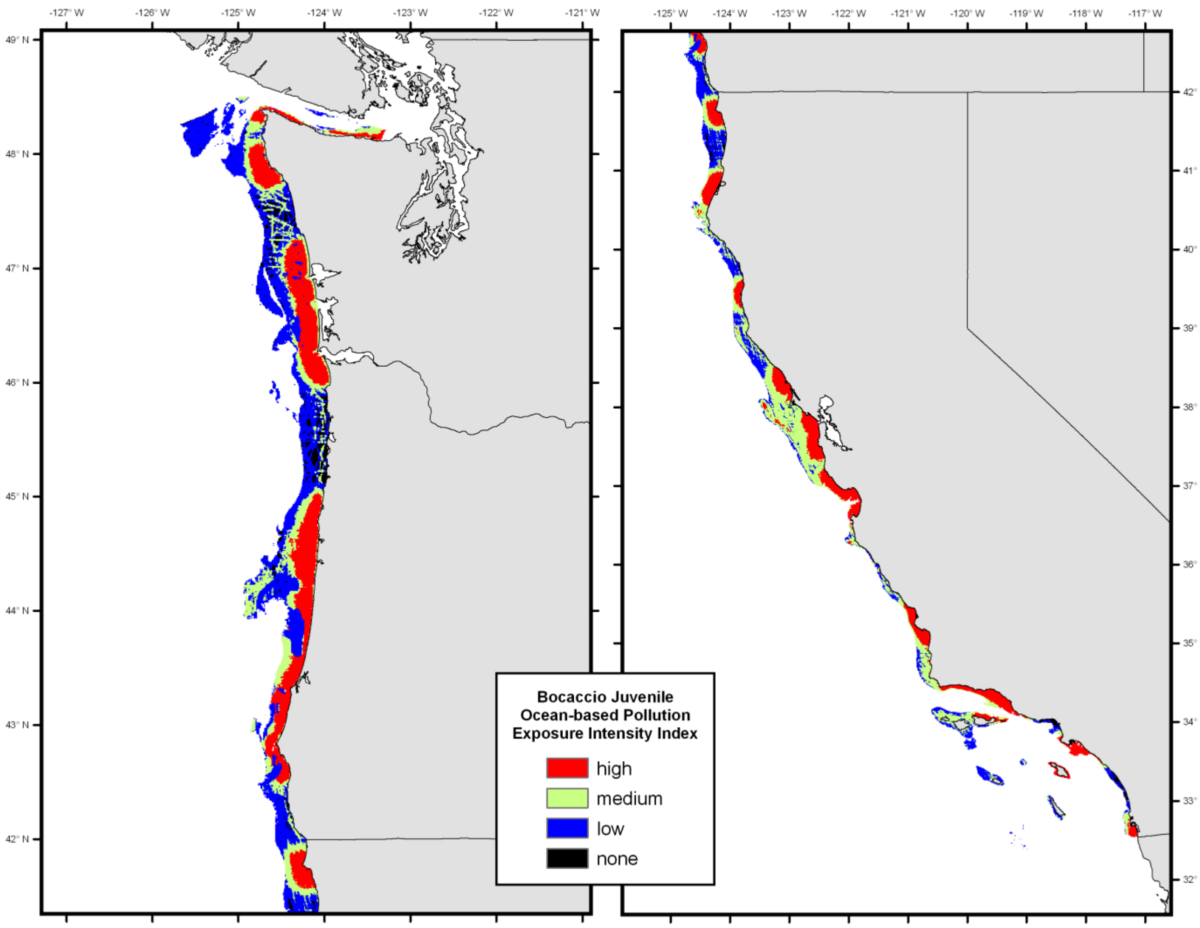


Figure 46. Exposure intensity index of ocean-based pollution for bocaccio *Sebastes paucispinis* rockfish juveniles. High = upper tercile, Medium = middle tercile, low = lower tercile.

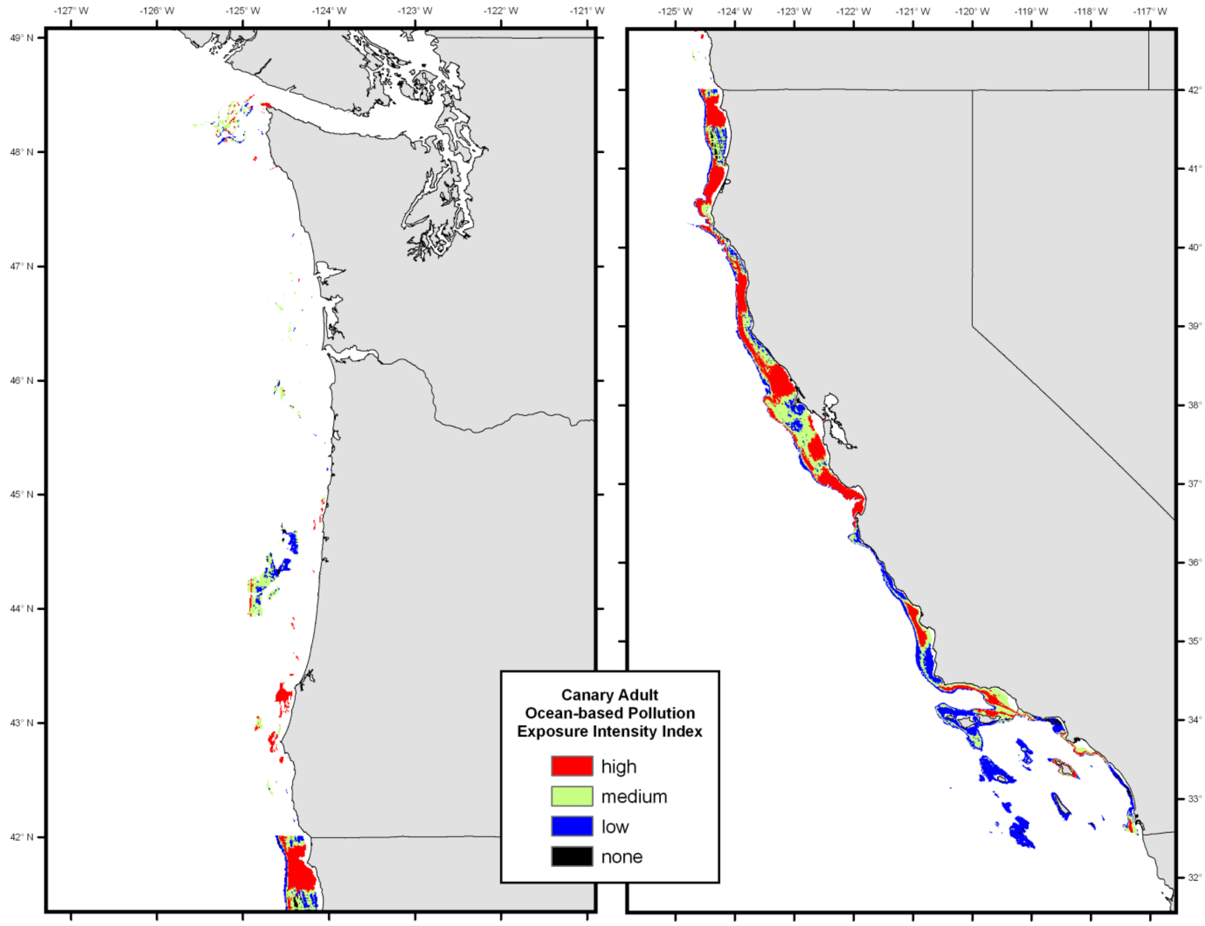


Figure 47. Exposure intensity index of ocean-based pollution for canary *Sebastes pinniger* rockfish adults. High = upper tercile, Medium = middle tercile, low = lower tercile.

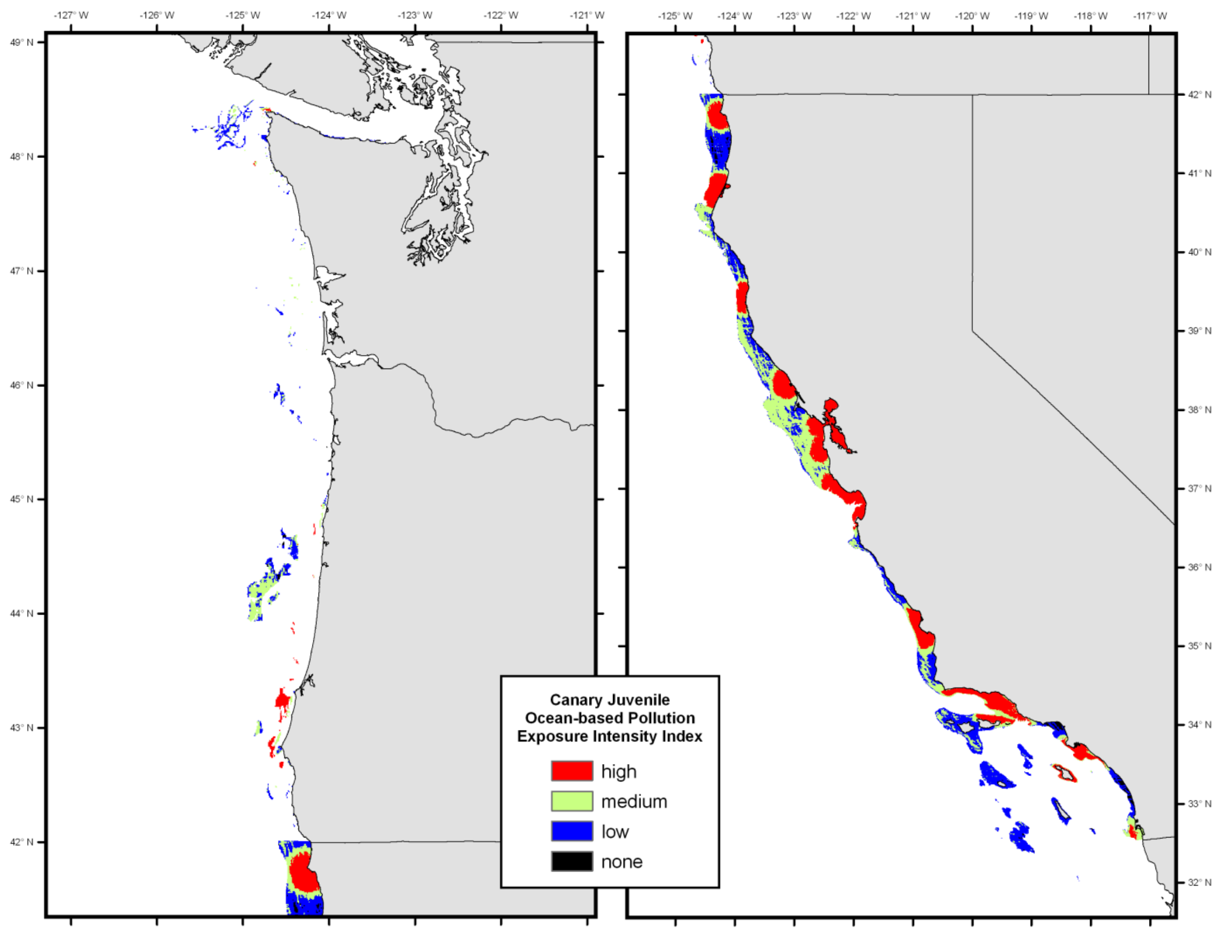


Figure 48. Exposure intensity index of ocean-based pollution for canary *Sebastes pinniger* rockfish juveniles. High = upper tercile, Medium = middle tercile, low = lower tercile.

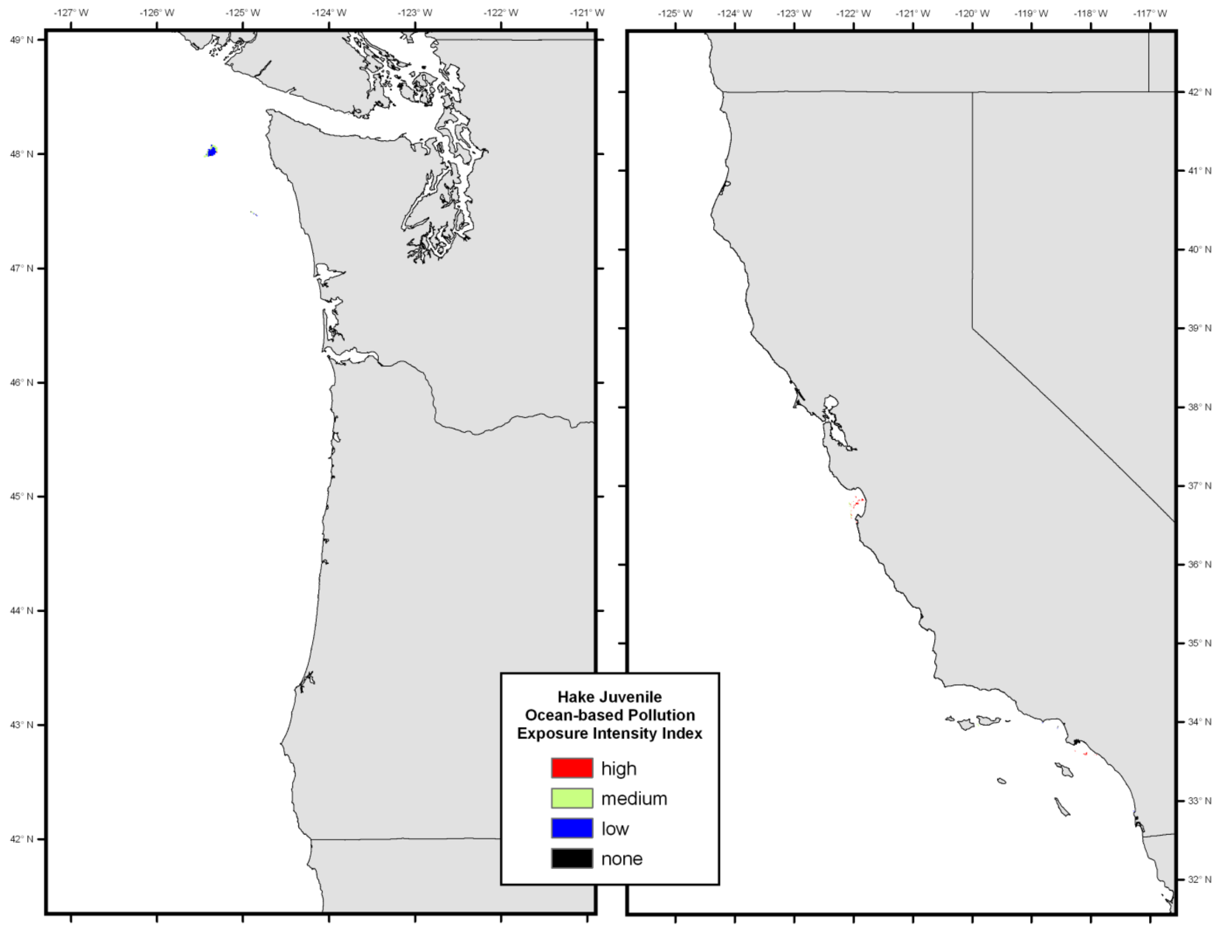


Figure 49. Exposure intensity index of ocean-based pollution for Pacific hake *Merluccius productus* juveniles. High = upper tercile, Medium = middle tercile, low = lower tercile.

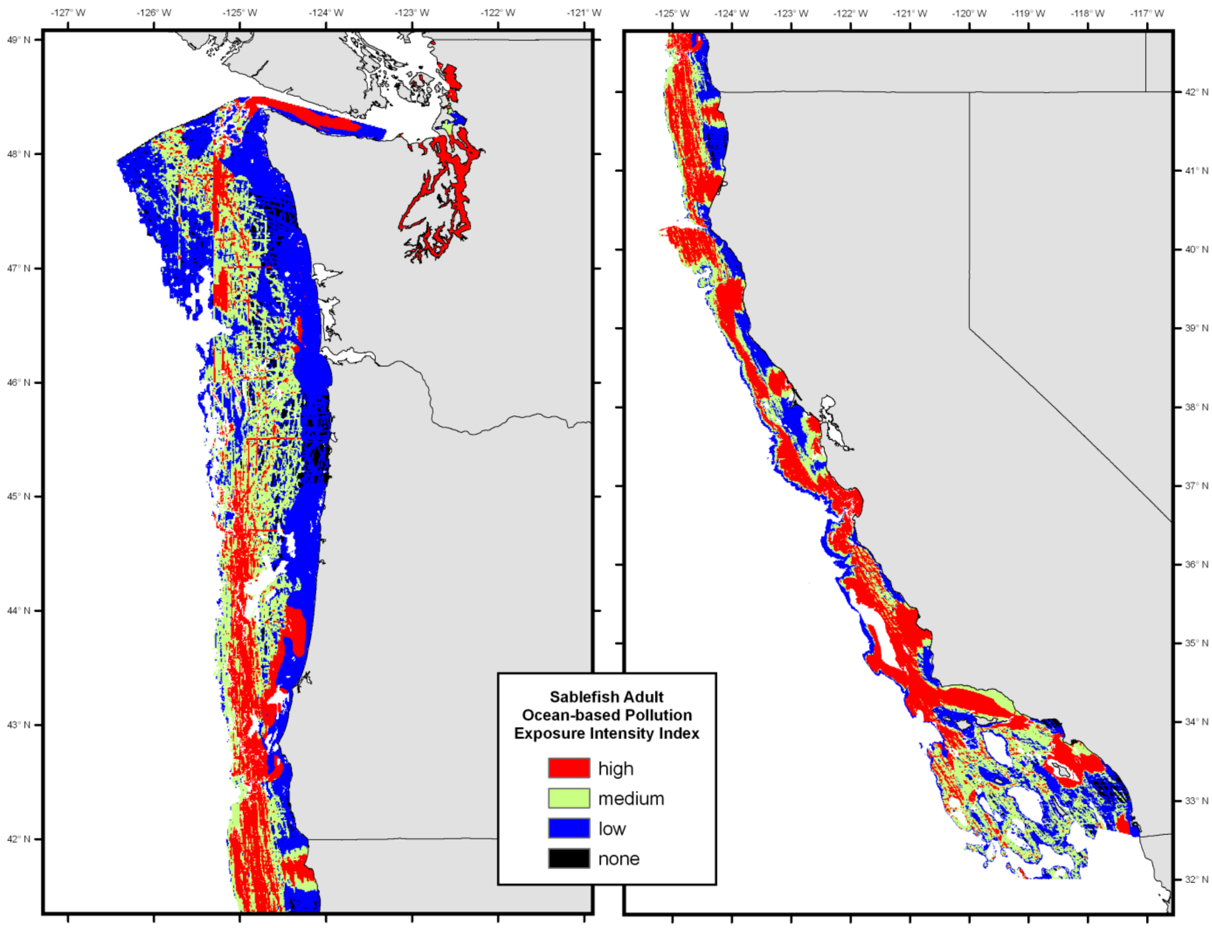


Figure 50. Exposure intensity index of ocean-based pollution for sablefish *Anoplopoma fimbria* adults. High = upper tercile, Medium = middle tercile, low = lower tercile.

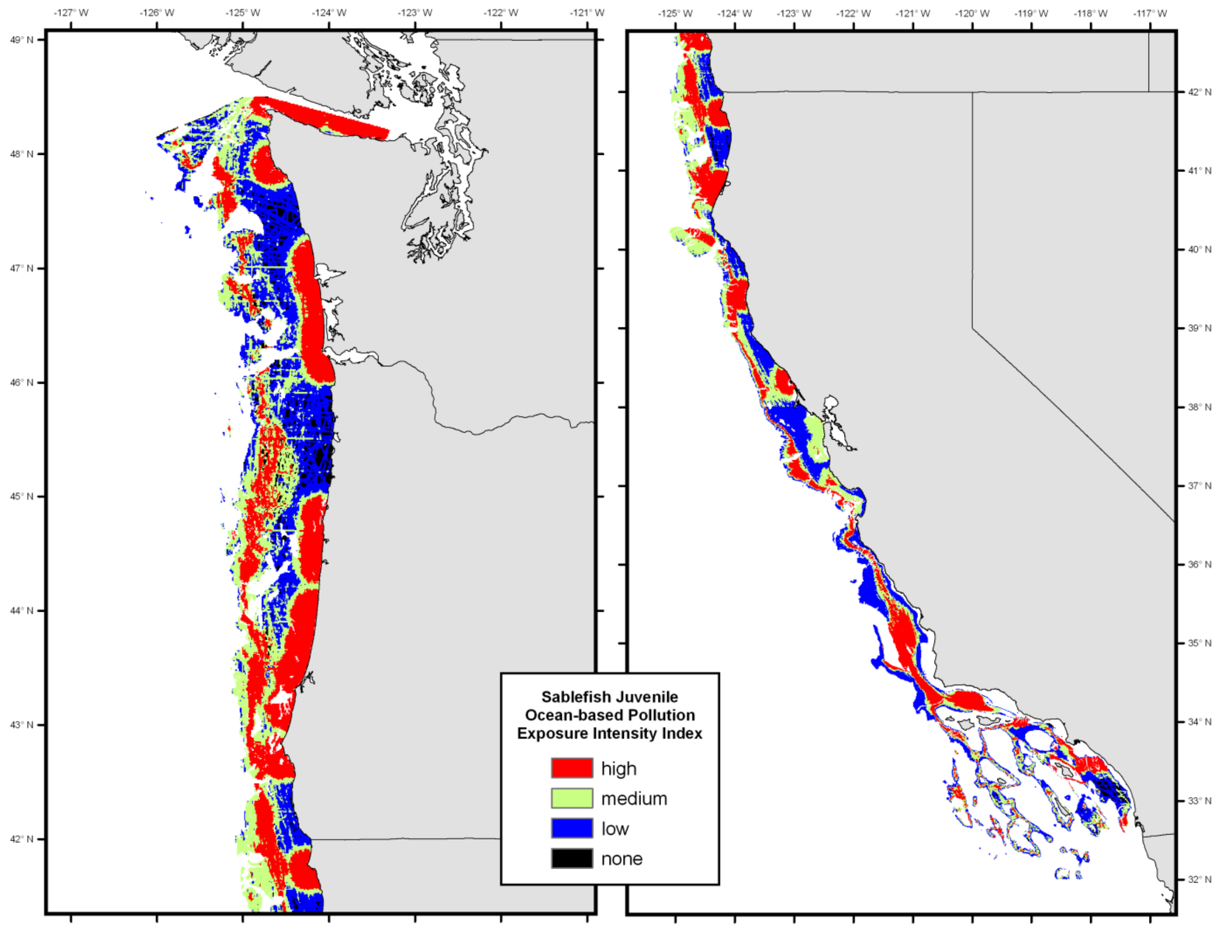
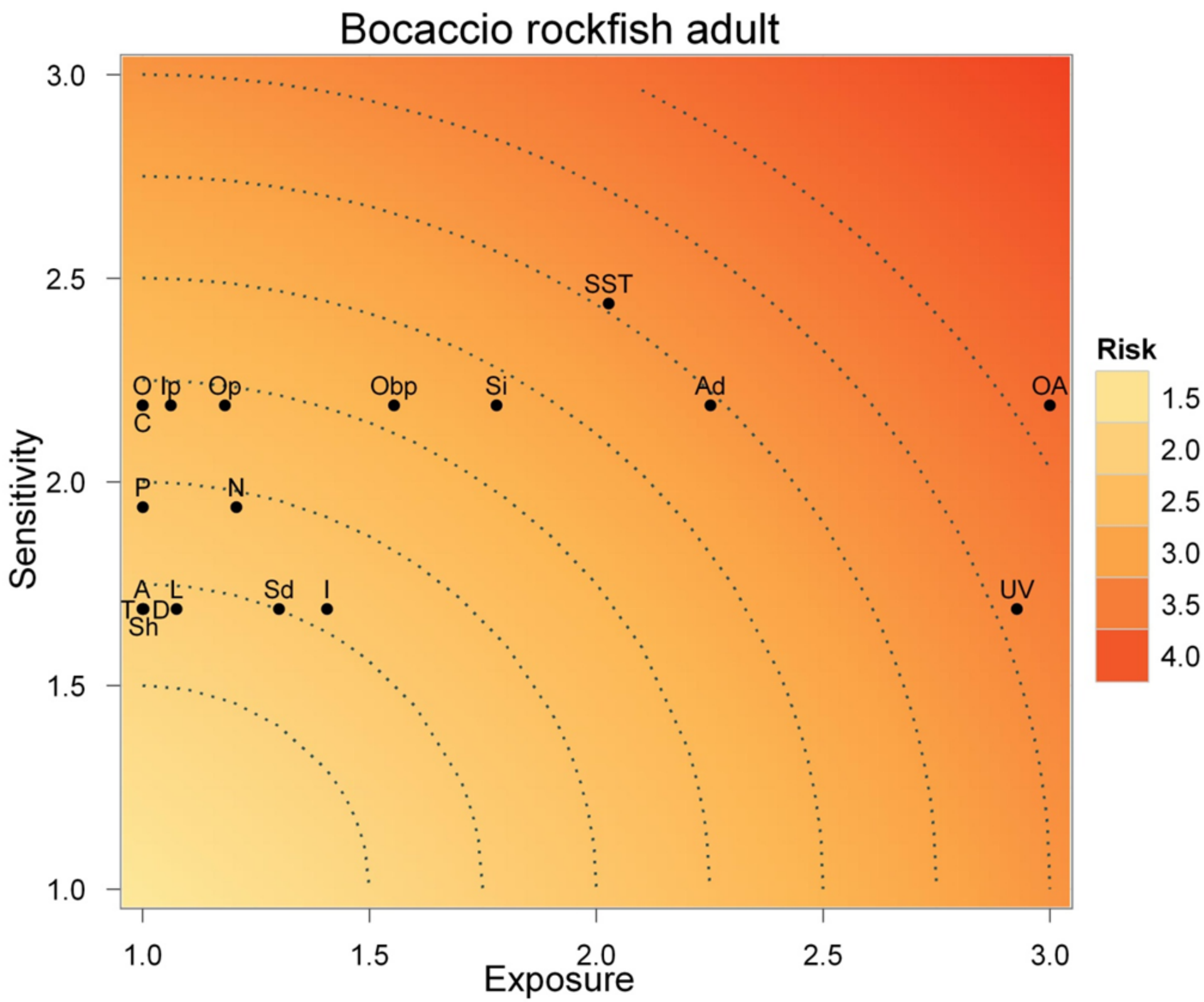
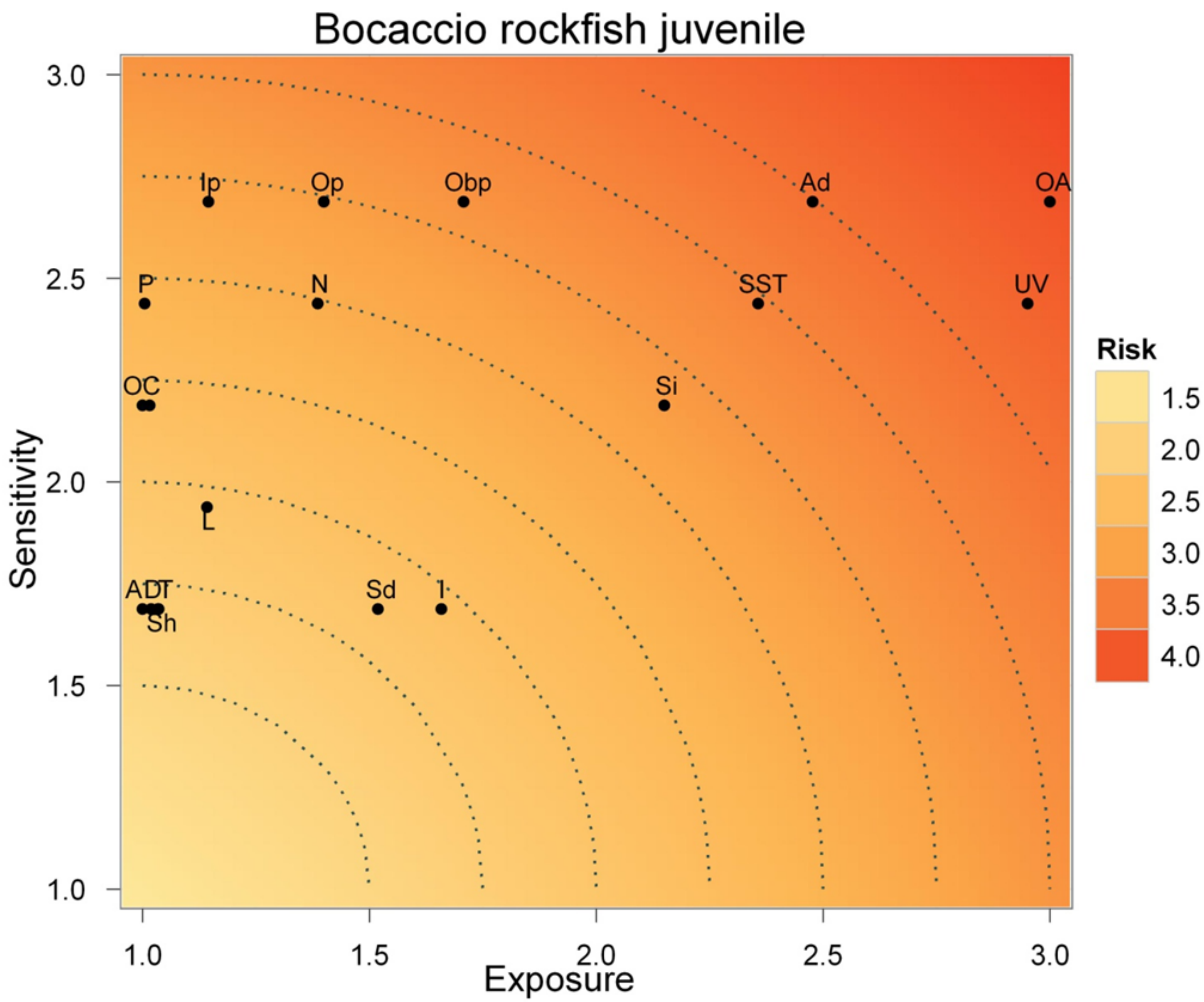


Figure 51. Exposure intensity index of ocean-based pollution for sablefish *Anoplopoma fimbria* juveniles. High = upper tercile, Medium = middle tercile, low = lower tercile.



<u>Non-fisheries threats</u>
A – Aquaculture
Ad – Atmospheric deposition
C – Coastal engineering
D – Direct human impacts
Ip – Inorganic pollution
L – Light pollution
N – Nutrient input
Obp – Ocean based pollution
Op – Organic pollution
O – Oil rigs
P – Power plants
Sd – Sediment decrease
Si – Sediment increase
Sh – Shipping activity
I – Species invasions
T – Trash
OA – Ocean Acidification
SST – Sea Surface Temp
UV – UV Radiation

Figure 52. Relative risk of bocaccio *Sebastes paucispinis* adults to 19 non-fisheries related threats. .



Non-fisheries threats
A – Aquaculture
Ad – Atmospheric deposition
C – Coastal engineering
D – Direct human impacts
Ip – Inorganic pollution
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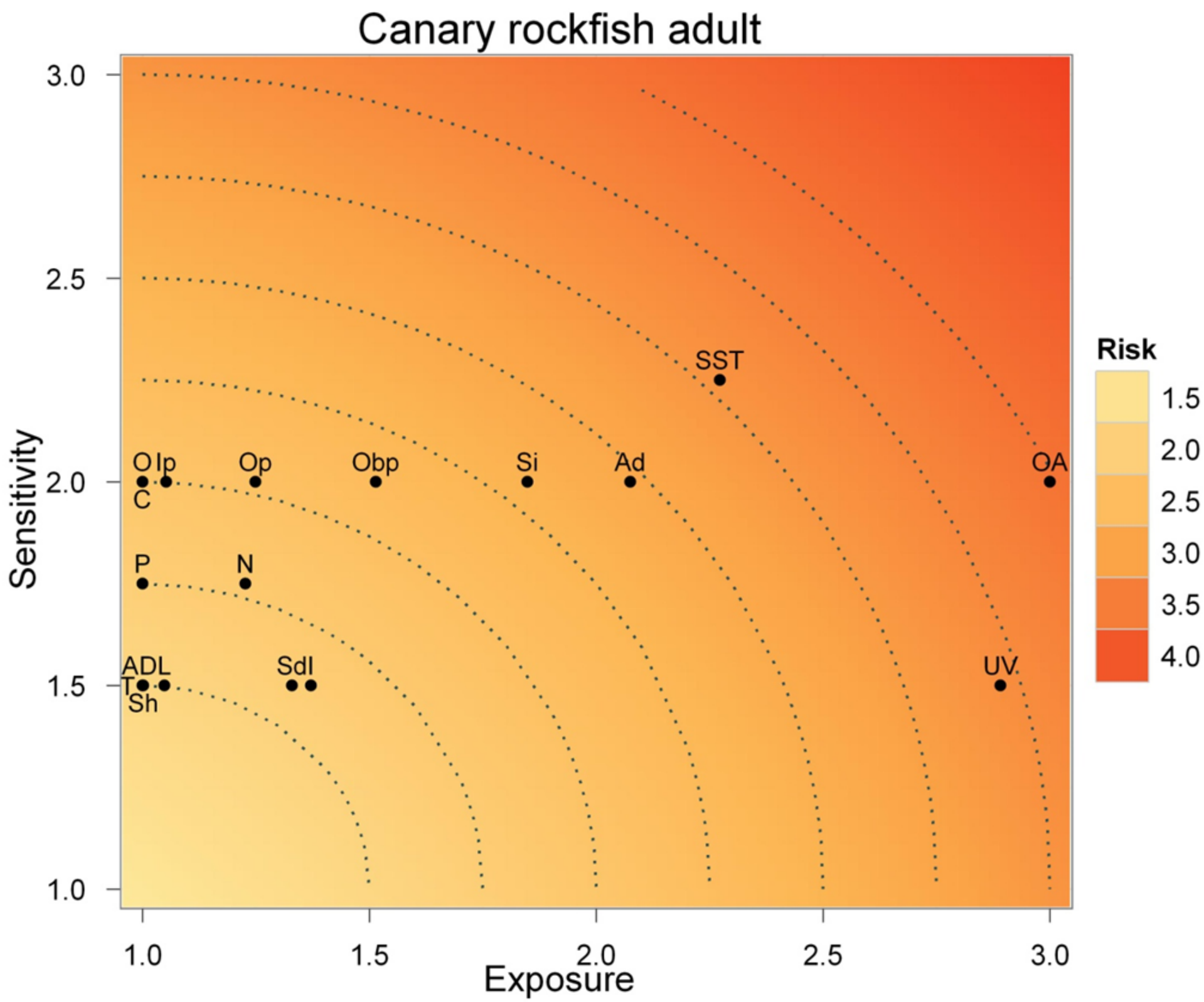
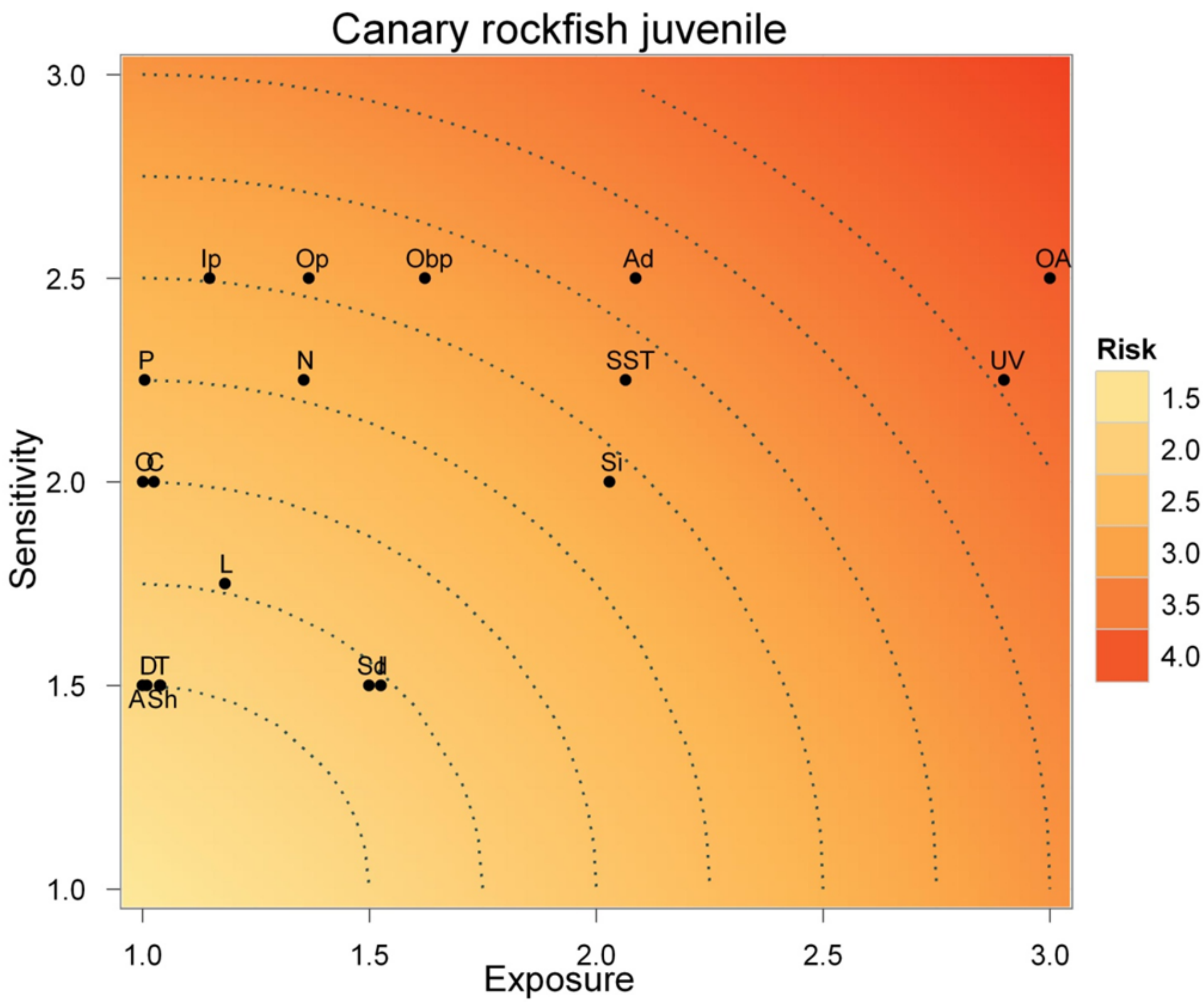
O – Oil rigs
P – Power plants
Sd – Sediment decrease
Si – Sediment increase
Sh – Shipping activity
I – Species invasions
T – Trash
OA – Ocean Acidification
SST – Sea Surface Temp
UV – UV Radiation

Figure 53. Relative risk of bocaccio *Sebastes paucispinis* juveniles to 19 non-fisheries related threats.



Non-fisheries threats
A – Aquaculture
Ad – Atmospheric deposition
C – Coastal engineering
D – Direct human impacts
Ip – Inorganic pollution
L – Light pollution
N – Nutrient input
Obp – Ocean based pollution
Op – Organic pollution
O – Oil rigs
P – Power plants
Sd – Sediment decrease
Si – Sediment increase
Sh – Shipping activity
I – Species invasions
T – Trash
OA – Ocean Acidification
SST – Sea Surface Temp
UV – UV Radiation

Figure 54. Relative risk of canary rockfish *Sebastes pinniger* adults to 19 non-fisheries related threats.



Non-fisheries threats
A – Aquaculture
Ad – Atmospheric deposition
C – Coastal engineering
D – Direct human impacts
Ip – Inorganic pollution
L – Light pollution
N – Nutrient input
Obp – Ocean based pollution
Op – Organic pollution
O – Oil rigs
P – Power plants
Sd – Sediment decrease
Si – Sediment increase
Sh – Shipping activity
I – Species invasions
T – Trash
OA – Ocean Acidification
SST – Sea Surface Temp
UV – UV Radiation

Figure 55. Relative risk of canary rockfish *Sebastes pinniger* juveniles to 19 non-fisheries related threats.

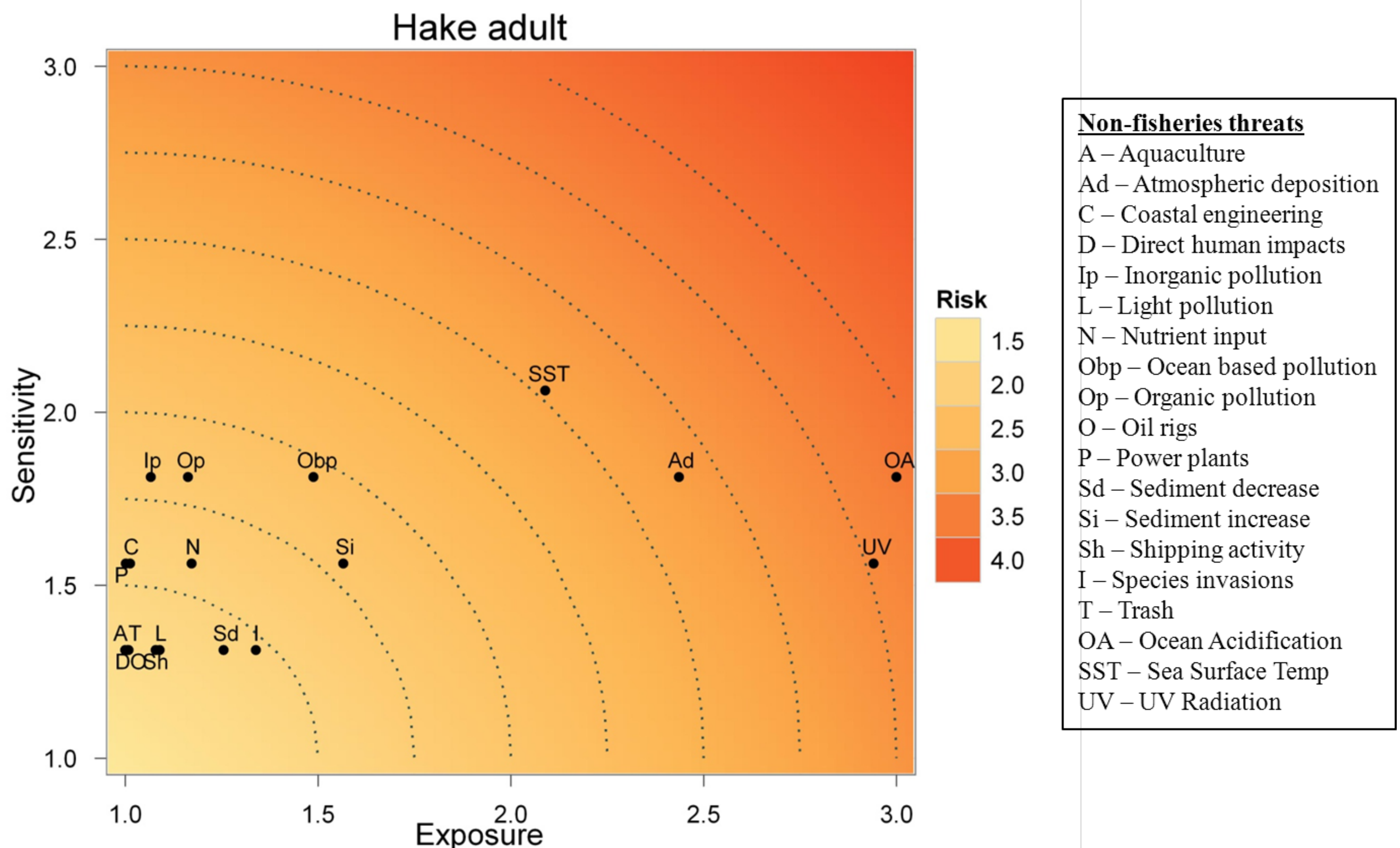


Figure 56. Relative risk of Pacific hake *Merluccius productus* adults to 19 non-fisheries related threats.

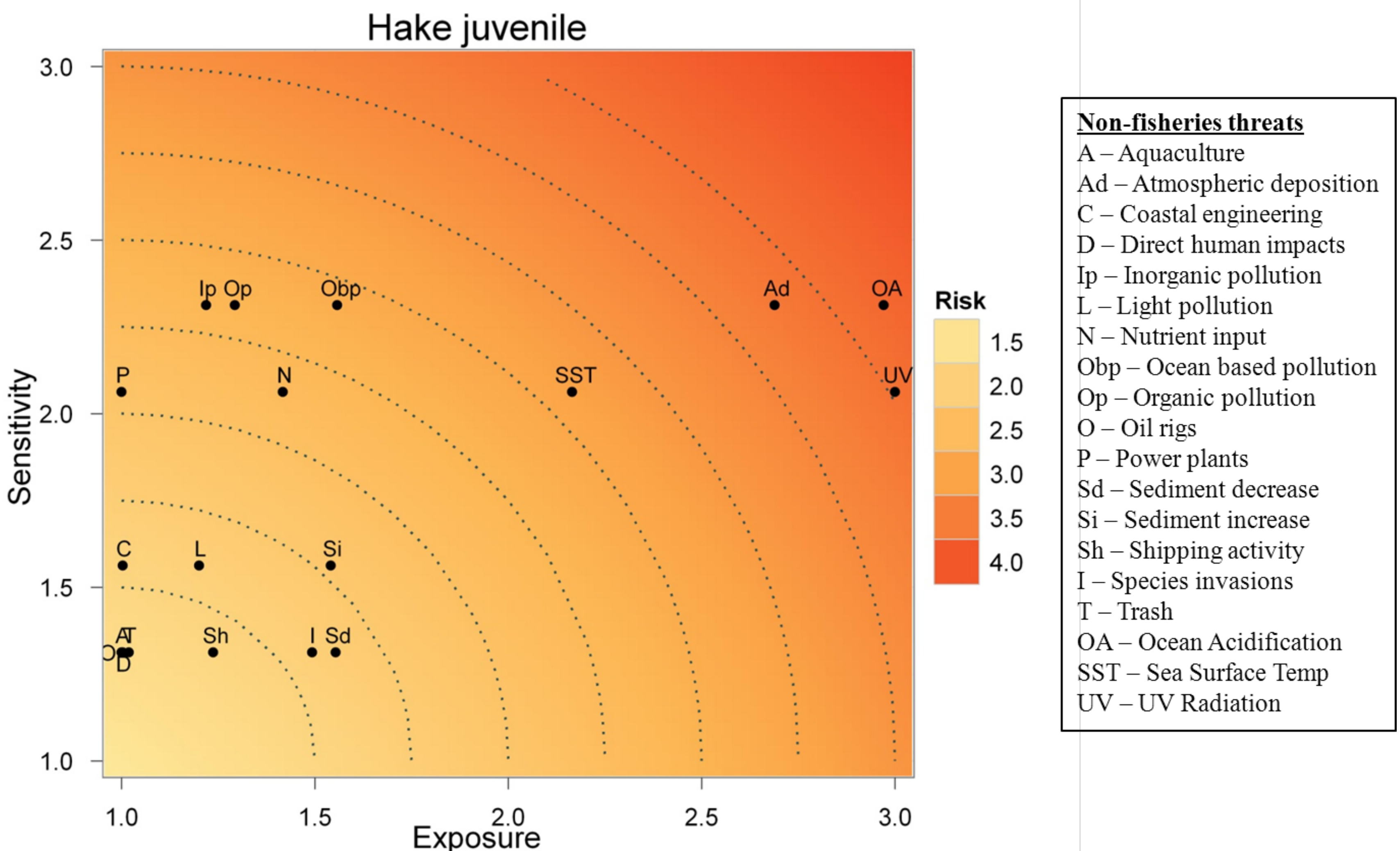
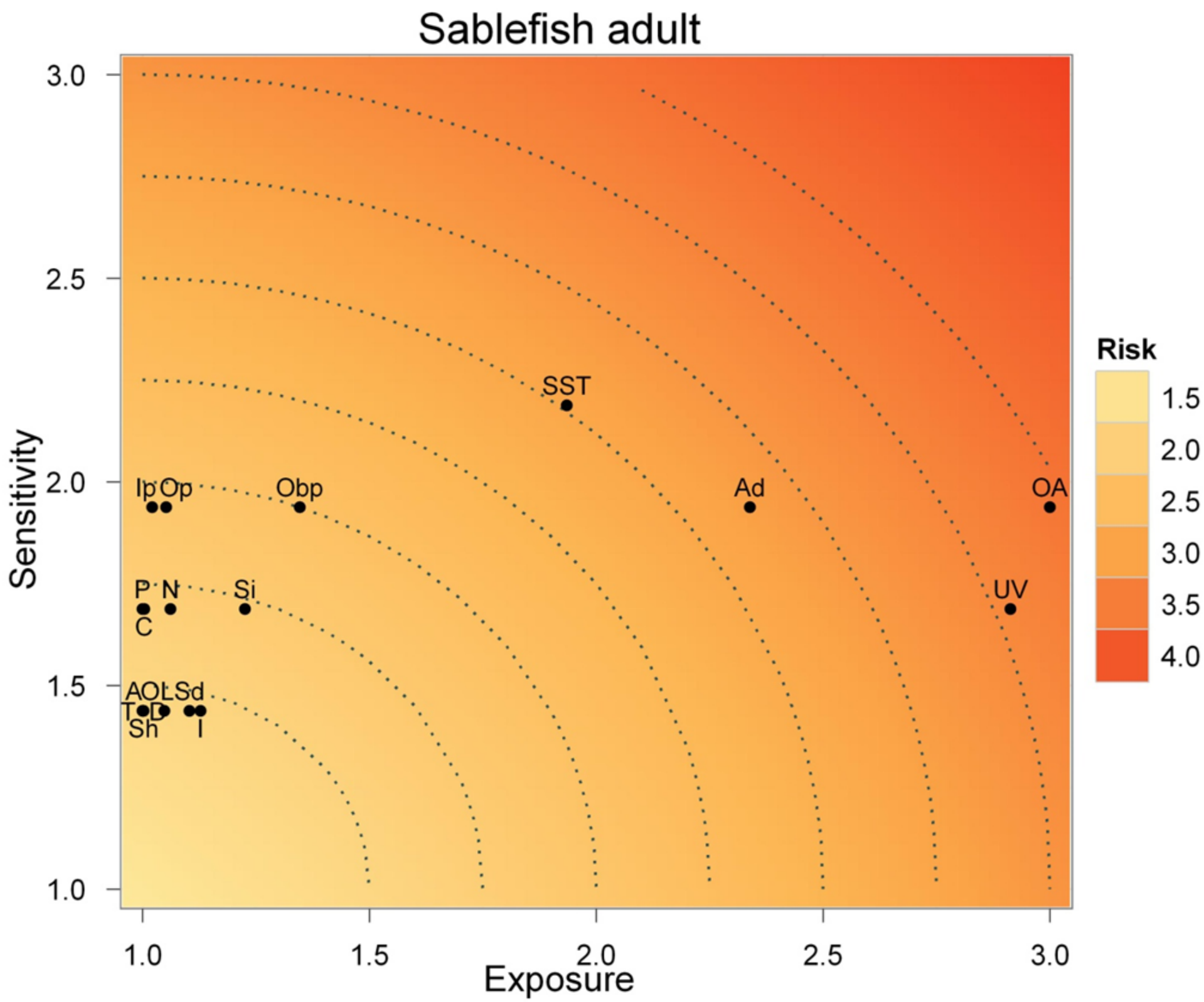
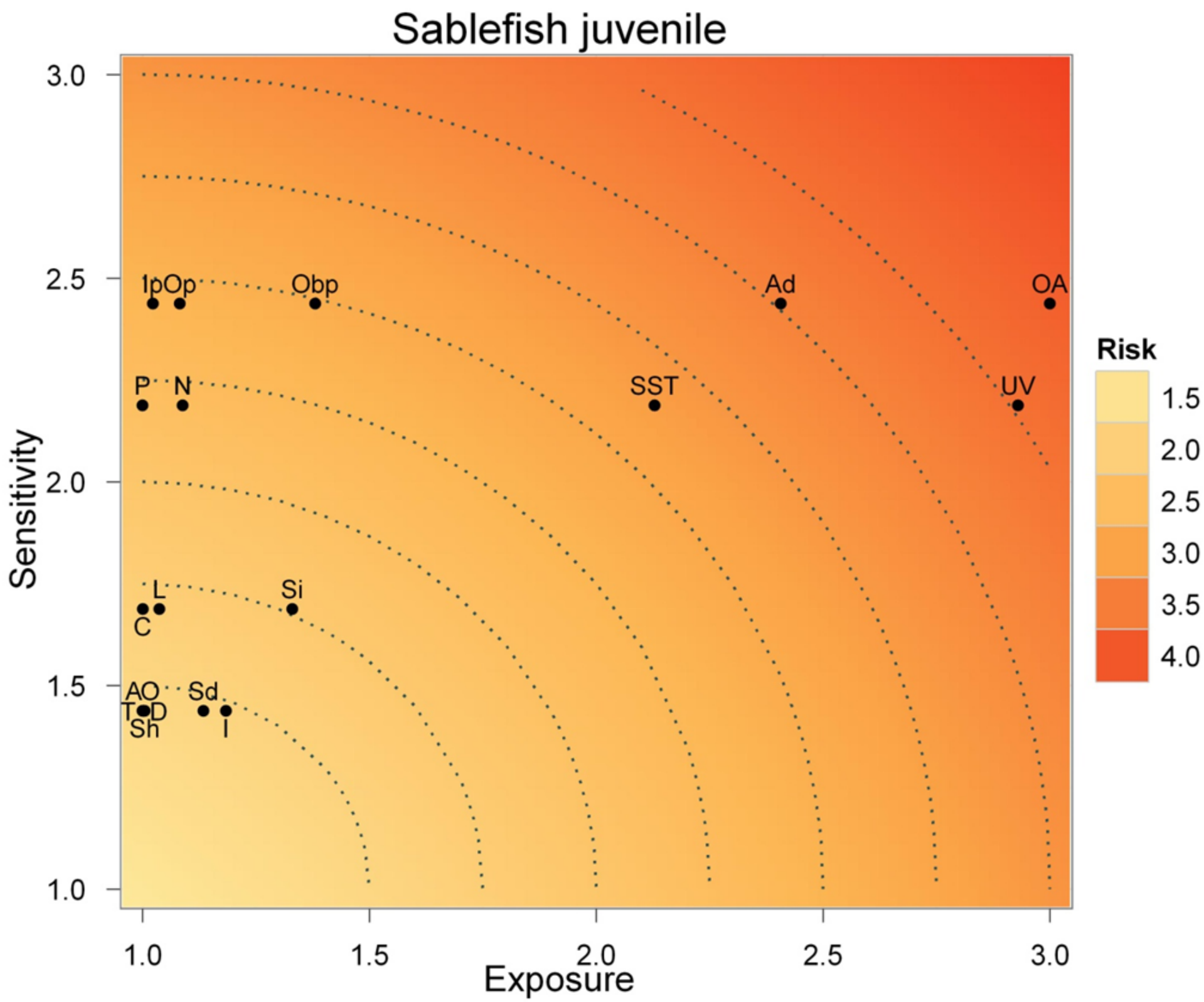


Figure 57. Relative risk of Pacific hake *Merluccius productus* juveniles to 19 non-fisheries related threats.



Non-fisheries threats
A – Aquaculture
Ad – Atmospheric deposition
C – Coastal engineering
D – Direct human impacts
Ip – Inorganic pollution
L – Light pollution
N – Nutrient input
Obp – Ocean based pollution
Op – Organic pollution
O – Oil rigs
P – Power plants
Sd – Sediment decrease
Si – Sediment increase
Sh – Shipping activity
I – Species invasions
T – Trash
OA – Ocean Acidification
SST – Sea Surface Temp
UV – UV Radiation

Figure 58. Relative risk of sablefish *Anoplopoma fimbria* adults to 19 non-fisheries related threats.



Non-fisheries threats
A – Aquaculture
Ad – Atmospheric deposition
C – Coastal engineering
D – Direct human impacts
Ip – Inorganic pollution
L – Light pollution
N – Nutrient input
Obp – Ocean based pollution
Op – Organic pollution
O – Oil rigs
P – Power plants
Sd – Sediment decrease
Si – Sediment increase
Sh – Shipping activity
I – Species invasions
T – Trash
OA – Ocean Acidification
SST – Sea Surface Temp
UV – UV Radiation

Figure 59. Relative risk of sablefish *Anoplopoma fimbria* juveniles to 19 non-fisheries related threats.

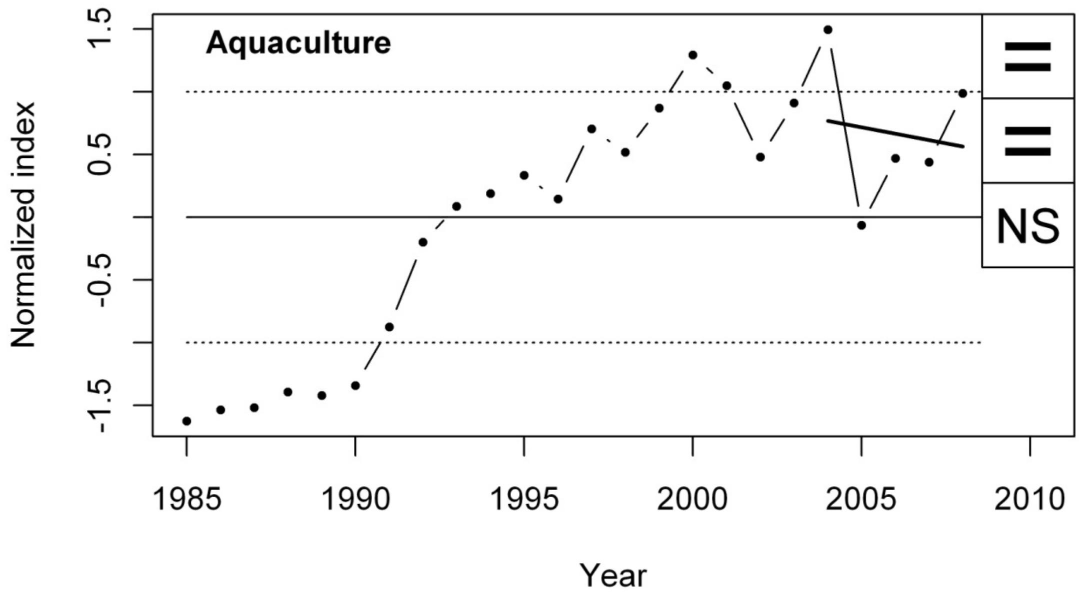


Figure 60. Index of aquaculture. See Table 9 for time series specifics. Dotted lines are +/- 1 S.D.. The thick black line is the short-term trend for the last five years of data. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of the full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

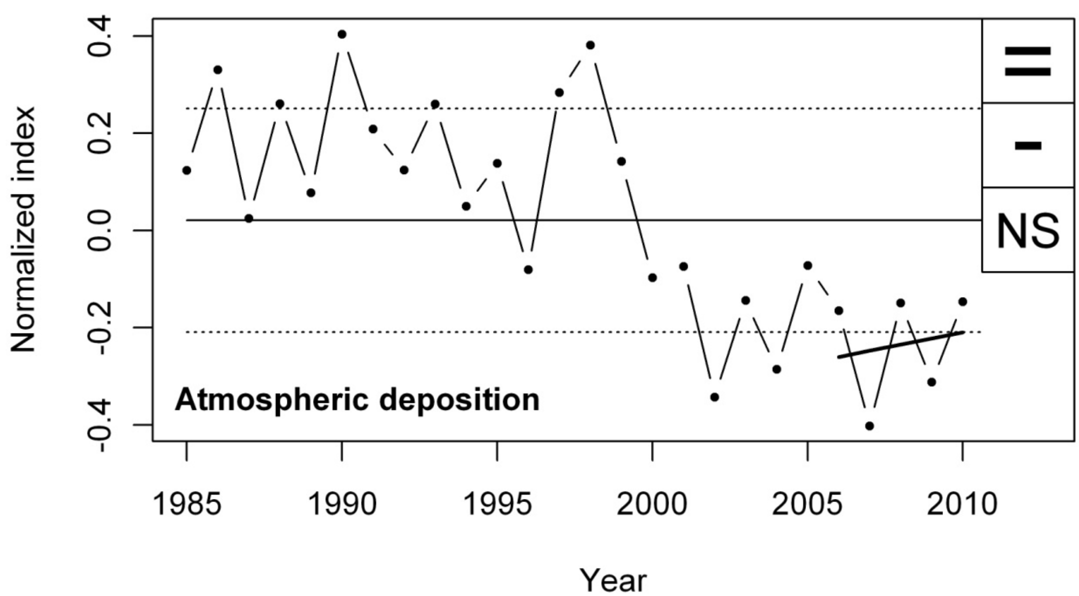


Figure 61. Index of atmospheric deposition. See Table 9 for time series specifics. Dotted lines are +/- 1 S.D.. The thick black line is the short-term trend for the last five years of data. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of the full time series. The middle inset box indicates whether the mean of the last five years was

greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

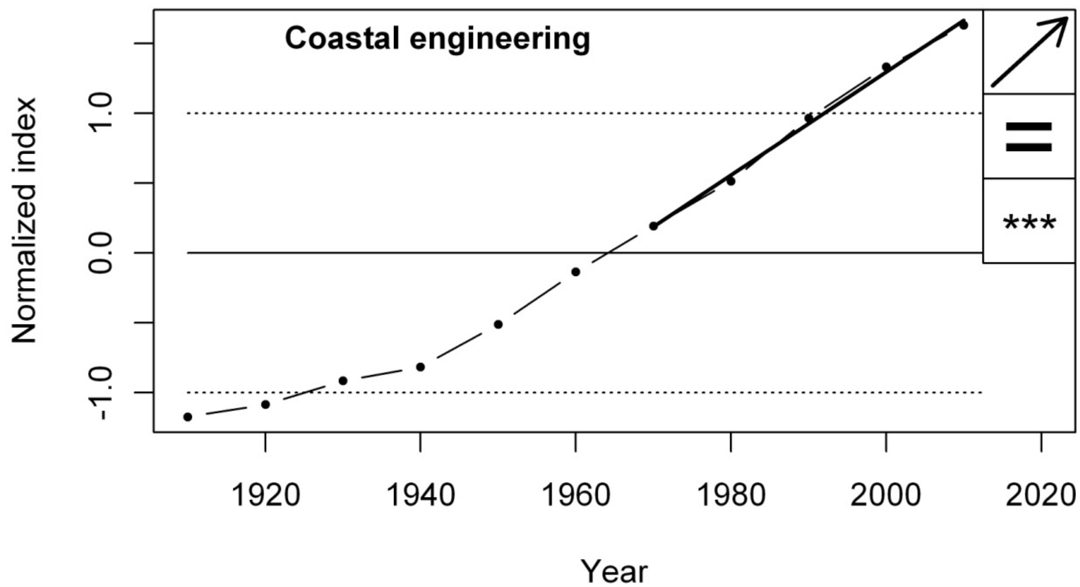


Figure 62. Index of coastal engineering. See Table 9 for time series specifics. Dotted lines are +/- 1 S.D.. The thick black line is the short-term trend for the last five data points. The upper inset box indicates whether the short-term trend increased, decreased, or showed no change relative to 1 S.D. of the full time series. The middle inset box indicates whether the mean of the short-term trend was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope of the short-term trend was significant or not.

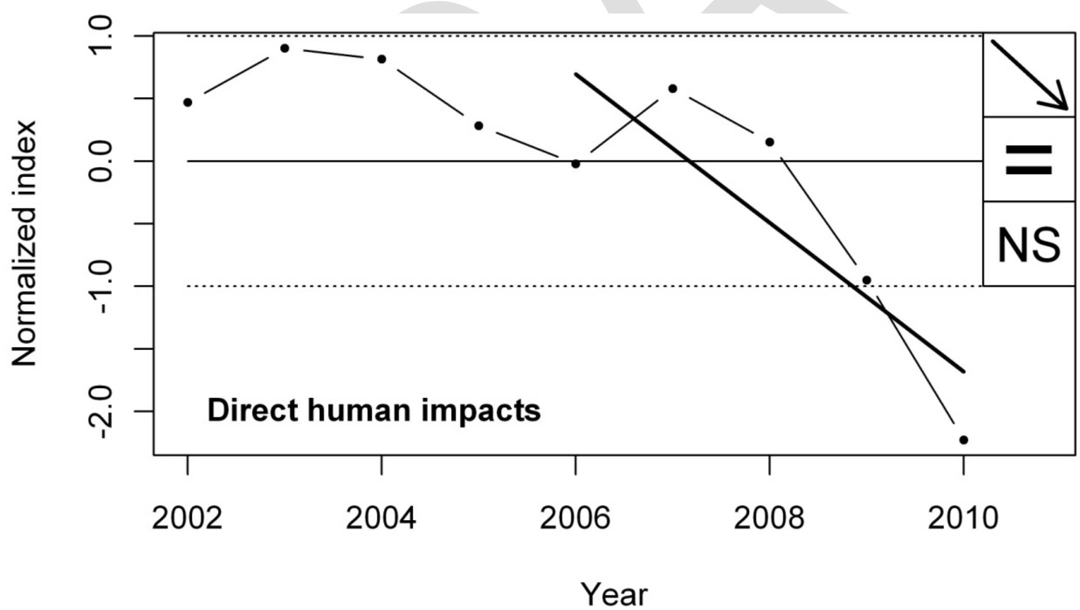


Figure 63. Index of direct human impacts. See Table 9 for time series specifics. Dotted lines are +/- 1 S.D.. The thick black line is the short-term trend for the last five years of data. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of the full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

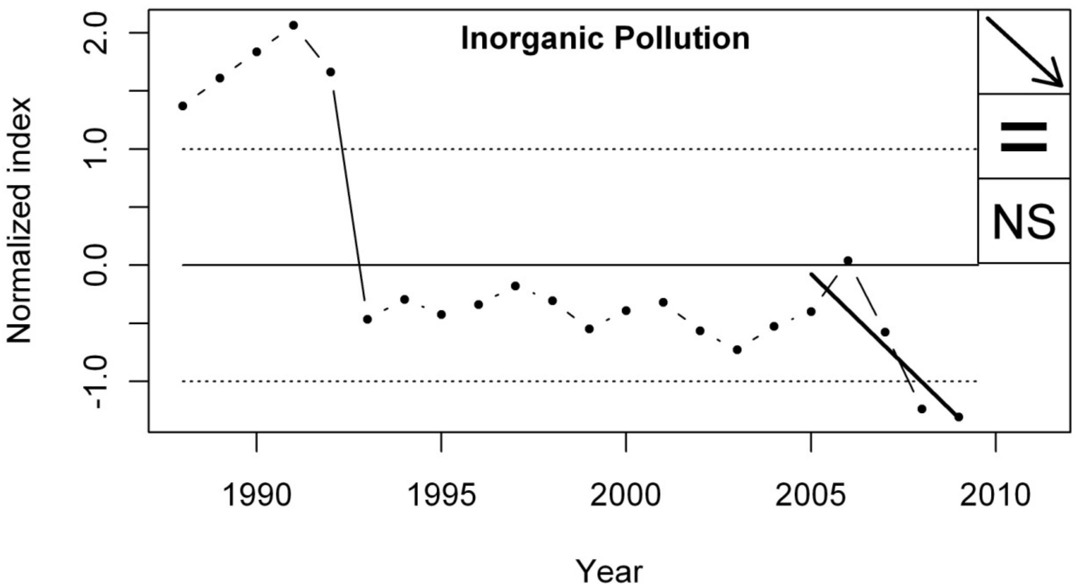


Figure 64. Index of inorganic pollution. See Table 9 for time series specifics. Dotted lines are +/- 1 S.D.. The thick black line is the short-term trend for the last five years of data. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of the full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

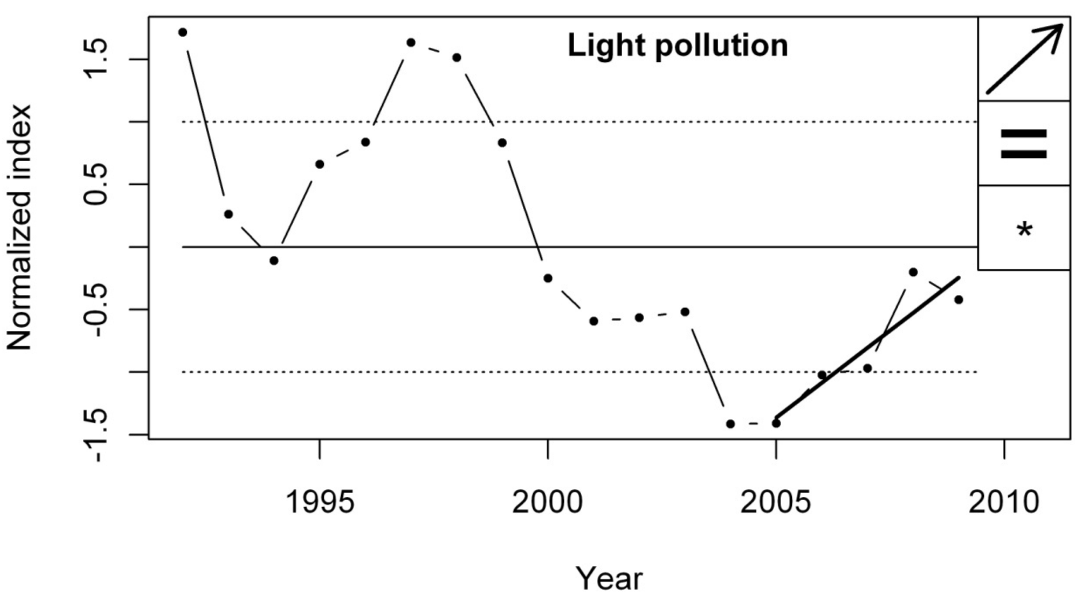


Figure 65. Index of light pollution. See Table 9 for time series specifics. Dotted lines are +/- 1 S.D.. The thick black line is the short-term trend for the last five years of data. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of the full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

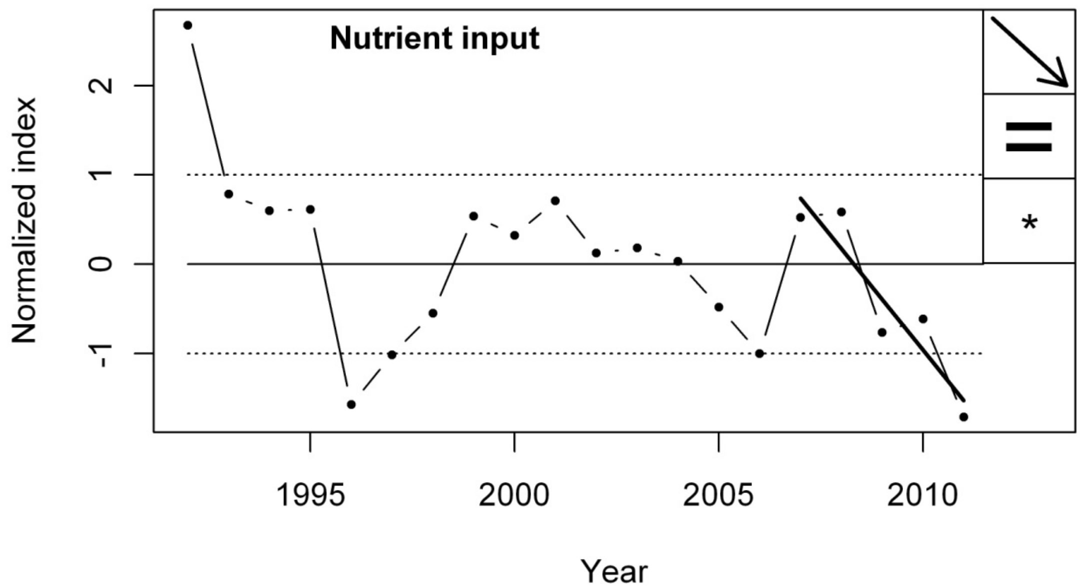


Figure 66. Index of nutrient input. See Table 9 for time series specifics. Dotted lines are +/- 1 S.D.. The thick black line is the short-term trend for the last five years of data. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of the full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

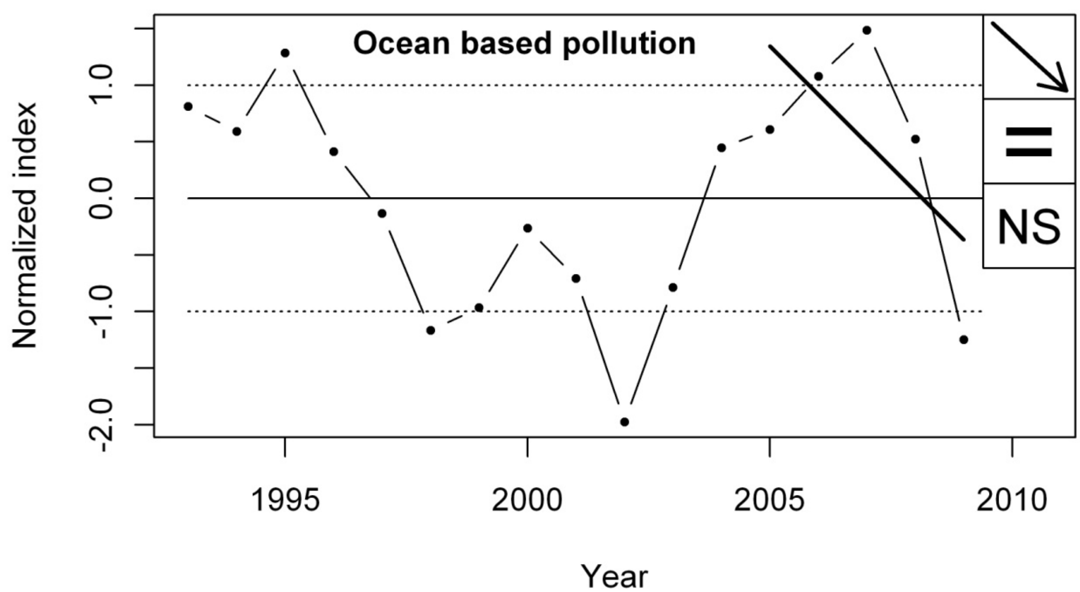


Figure 67. Index of ocean-based pollution. See Table 9 for time series specifics. Dotted lines are +/- 1 S.D.. The thick black line is the short-term trend for the last five years of data. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of the full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

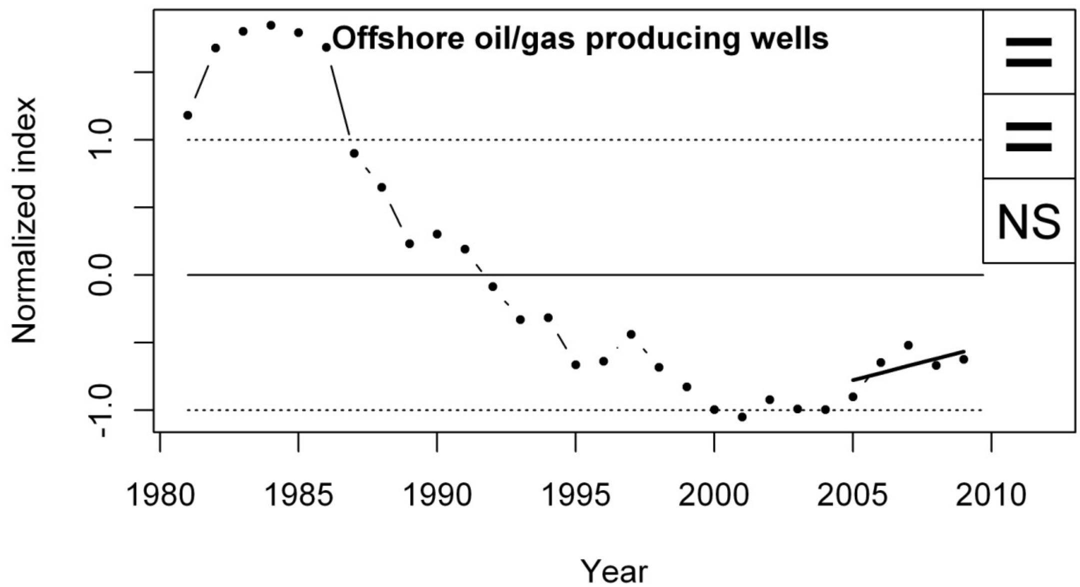


Figure 68. Index of offshore oil activities. See Table 9 for time series specifics. Dotted lines are +/- 1 S.D.. The thick black line is the short-term trend for the last five years of data. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of the full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

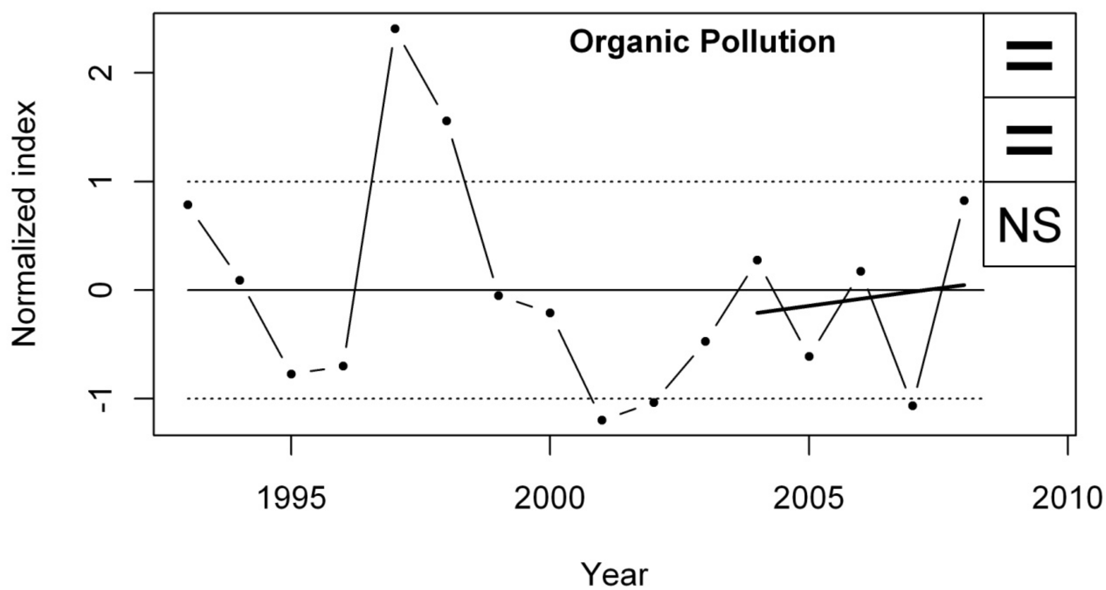


Figure 69. Index of organic pollution. See Table 9 for time series specifics. Dotted lines are +/- 1 S.D.. The thick black line is the short-term trend for the last five years of data. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of the full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

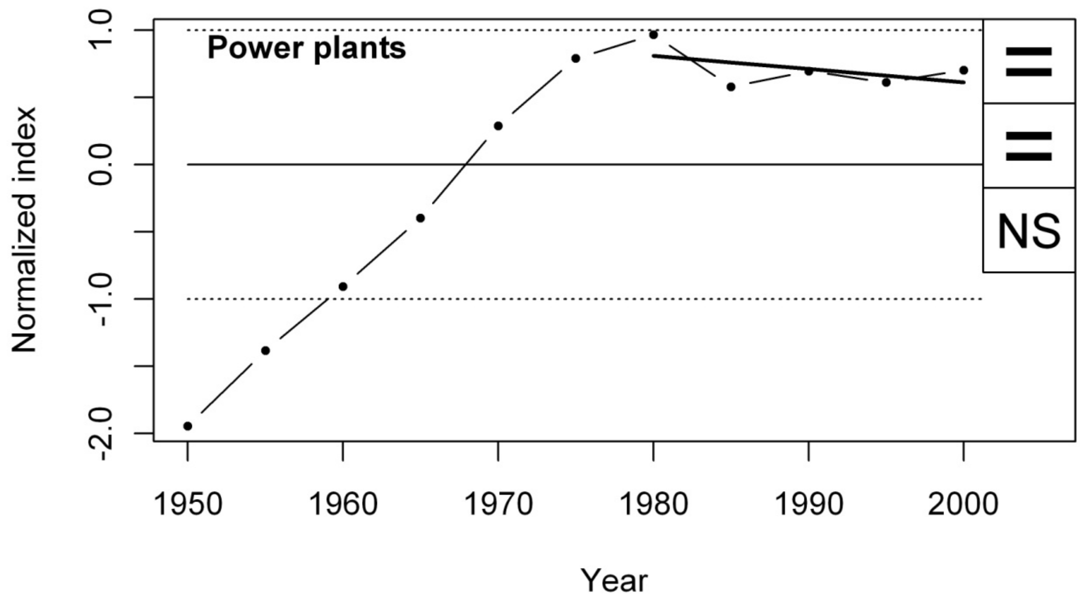


Figure 70. Index of power plants. See Table 9 for time series specifics. Dotted lines are +/- 1 S.D.. The thick black line is the short-term trend for the last five data points. The upper inset box indicates whether the short-term trend increased, decreased, or showed no change relative to 1 S.D. of the full time series. The middle inset box indicates whether the mean of the short-term trend was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope of the short-term trend was significant or not.

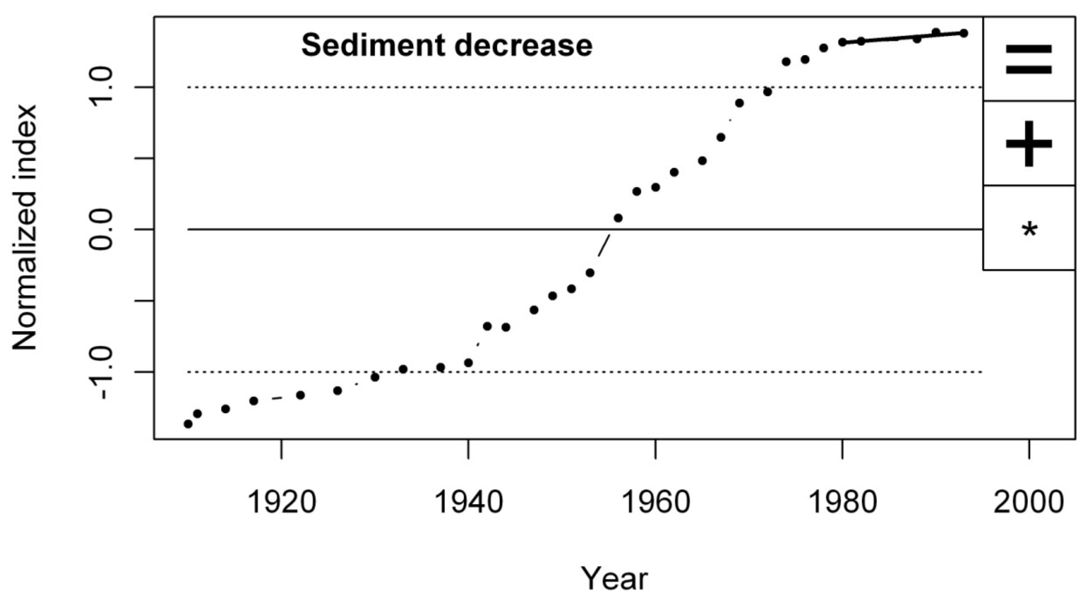


Figure 71. Index of sediment decrease. See Table 9 for time series specifics. Dotted lines are +/- 1 S.D.. The thick black line is the short-term trend for the last five data points. The upper inset box indicates whether the short-term trend increased, decreased, or showed no change relative to 1 S.D. of the full time series. The middle inset box indicates whether the mean of the short-term trend was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope of the short-term trend was significant or not.

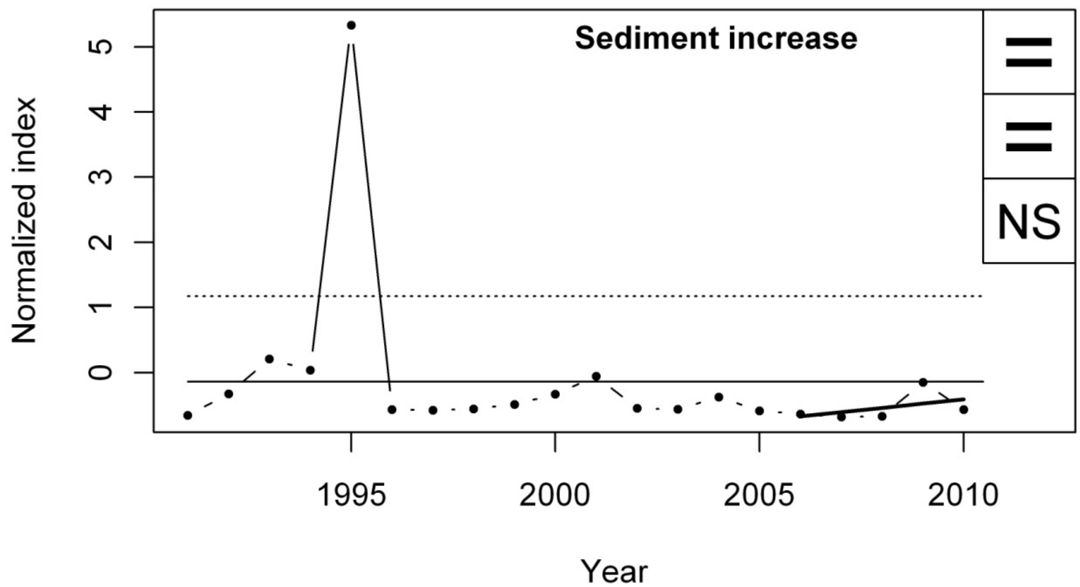


Figure 72. Index of sediment increase. See Table 9 for time series specifics. Dotted lines are +/- 1 S.D.. The thick black line is the short-term trend for the last five years of data. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of the full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

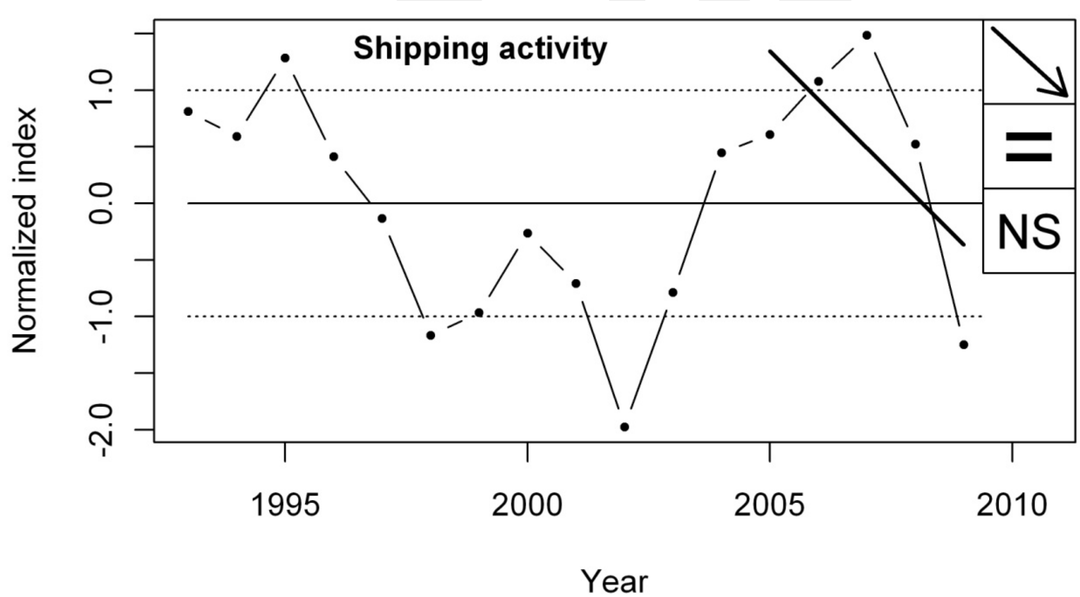


Figure 73. Index of shipping activity. See Table 9 for time series specifics. Dotted lines are +/- 1 S.D.. The thick black line is the short-term trend for the last five years of data. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of the full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

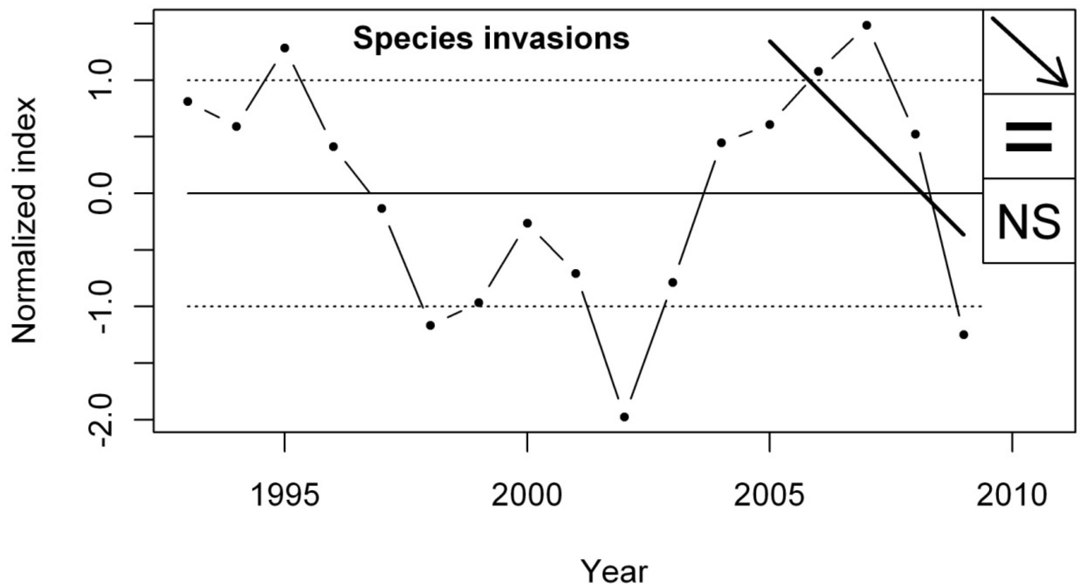


Figure 74. Index of species invasions. See Table 9 for time series specifics. Dotted lines are +/- 1 S.D.. The thick black line is the short-term trend for the last five years of data. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of the full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

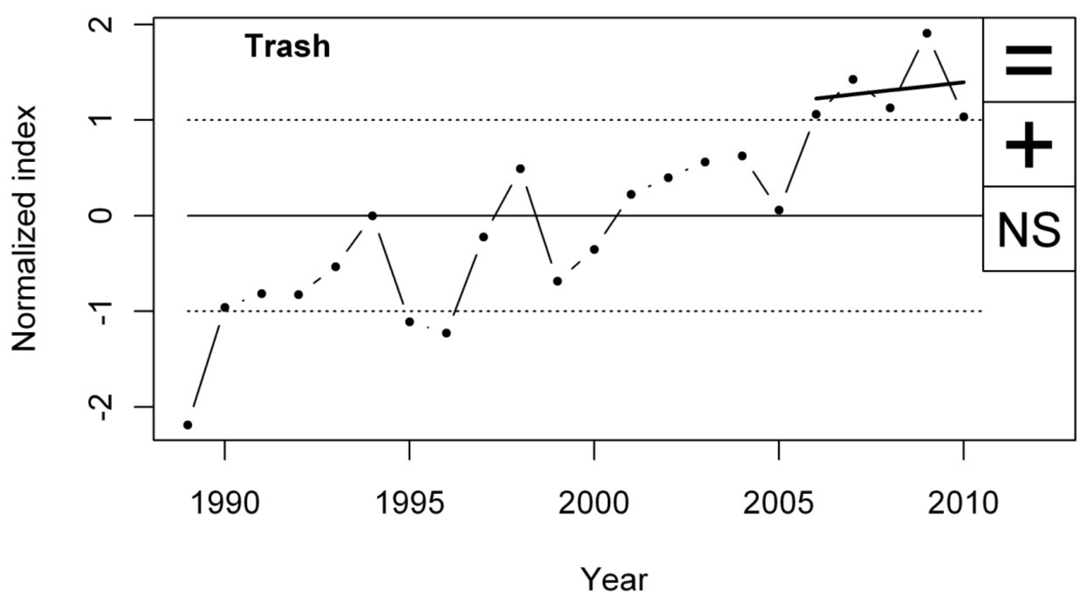


Figure 75. Index of trash. See Table 9 for time series specifics. Dotted lines are +/- 1 S.D.. The thick black line is the short-term trend for the last five years of data. The upper inset box indicates whether the 5-year trend increased, decreased, or showed no change relative to 1 S.D. of the full time series. The middle inset box indicates whether the mean of the last five years was greater than, lesser than or within 1 S.D. of the full time series mean. The lower inset box indicates whether the slope over the last five years was significant or not.

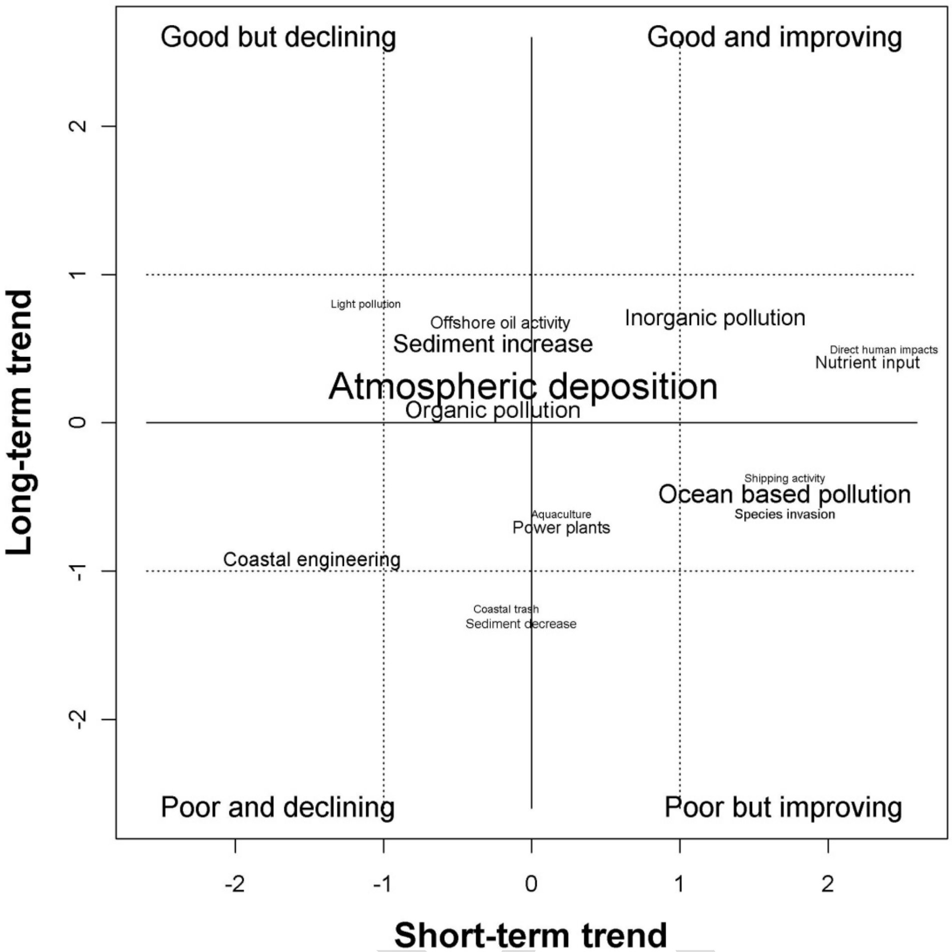


Figure 76. Quad-plot of short-term and long-term states of non-fisheries threat indices. Text size is scaled to the mean risk across all species adult life stages. The short-term state indicates the trend over the last five years of the index. The long-term state indicates the difference between the long-term mean and the mean of the last five years. Values for short-term and long-term states were multiplied by -1 so that increases in indices (i.e increases in a threat) indicate a declining biological environment for each species.

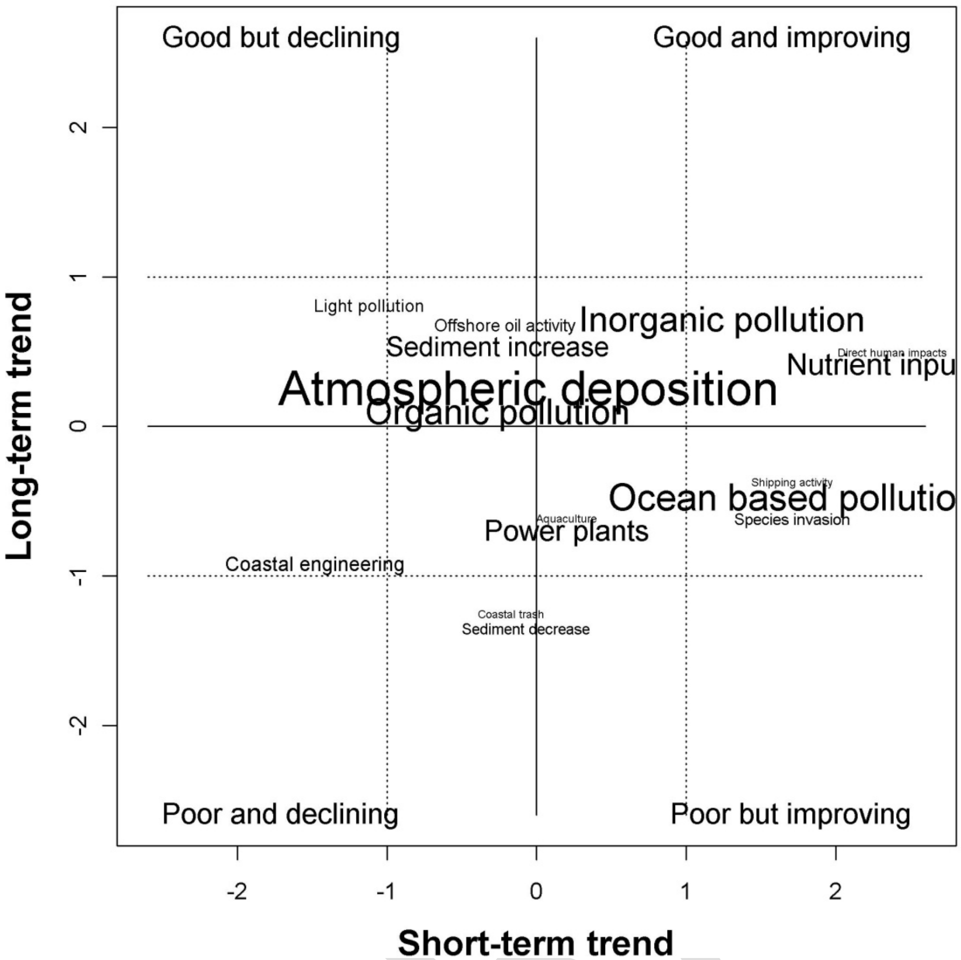


Figure 77. Quad-plot of short-term and long-term states of non-fisheries threat indices. Text size is scaled to the mean risk across all species juvenile life stages. The short-term state indicates the trend over the last five years of the index. The long-term state indicates the difference between the long-term mean and the mean of the last five years. Values for short-term and long-term states were multiplied by -1 so that increases in indices (i.e increases in a threat) indicate a declining biological environment for each species.

APPENDIX D.

HABITAT SUITABILITY PROBABILITIES

The HSP that we used were developed during the 2005 EFH EIS process. This work is scheduled to be updated every 5 years, so the HSP data that we used in this analysis may be updated in the near future that would improve the underlying data. Of particular interest is the HSP for juvenile Pacific hake (Fig. 6). Currently, the habitat is limited to a few locations. Depending on the definition of 'juvenile', the habitat identified for juvenile hake may be much more expansive than the current analysis.

Detailed information about the development of the data and analytical procedures used to produce the HSPs are described in the document: *Pacific States Marine Fisheries Commission. 2004. Risk Assessment for the Pacific Groundfish FMP*, which is included as Appendix A to the FEIS. Additionally, Appendix D of this document includes a *Report on Updates Made to the Production of Essential Fish Habitat Suitability Probability Maps* (http://www.nwr.noaa.gov/Groundfish-Halibut/Groundfish-Fishery-Management/NEPA-Documents/EFH-Final-EIS.cfm).

The shape files (GIS compatible files) for each species/life-history stage are separated into five geographic regions along the U.S. West Coast due to computer processing limitations during the analysis. We used the 'merge' command in ArcView version 9.3 to combine all regions into one combined data layer. In some of the shape files, polygons were created where HSP equaled 0. This appeared to be due to a few geographic border lines drawn that do not represent changes in HSP values. In order to keep these cells from showing up as habitat ('none' category for exposure intensity index) in further analyses, we changed all the 0 values in each HSP data layer to -9999 (represents 'no data').

NON-FISHERIES THREATS DATA

First, we downloaded the GeoTiff files projected in Arc System Zone 2 for each of the 19 non-fisheries related threats (or impacts) from the National Center for Ecological Analysis and Synthesis's website (http://www.nceas.ucsb.edu/globalmarine/ca_current_data). We created pyramids for each of the files using ArcCatalog version 9.3 and then brought each of the files into ArcView. Each file was then converted into a GRID file using the RasterToOther Conversion tool in the ArcView Toolbox.

For all threats except shipping, we assumed that the threat affected all depths of the water column. For example, if a grid cell had a value of 0.5 for organic pollution, we assumed this threat affected species inhabiting the water column at all depths including the bottom. For shipping, we made a correction to the threat value to take into account that shipping most likely affects the top 20 m of the water column, such that individuals on the bottom are not exposed to this threat. So, we limited the shipping data to depths of 20m or less for bocaccio, canary and sablefish, i.e. for grid cells that were at depths > 20 m, we multiplied the threat value by 0. For Pacific hake, we estimated a proportion of the population that migrates up into the water column at depths less than 20m based on primary literature because most surveys of hake populations do not measure the top 50 m of the water column (D. Chu, Northwest Fisheries Science Center, *pers comm*.). Juvenile hake show vertical distribution into shallow depths of the water column, particularly at night. Sakuma & Ralston (1997) present data showing that ~1/3 of juveniles collected were at 10 m, 1/3 were at 40 m, and 1/3 were found at 100 m); thus, we multiplied the threat value by 0.334 as an estimate of the proportion of juveniles that would be exposed to shipping*. .For adults, some small proportion of adult hake migrate into this depth zone (0-20m) at night, typically feeding on euphausiid populations which are vertically migrating and concentrate near 20 m between 2400-0200 hrs (Alverson & Larkins 1969). Adult hake migrate on a diurnal schedule: fish are dispersed from near surface to 20- m depth at night (10 p.m. to 3 a.m.), descend quickly at dawn and form schools; and rise to the surface at night in 30-40 min (Nelson and Larkins 1970; Ermakov 1974). These diurnal migrations have been compared to the migrations of their primary prey, euphausiids, as a causal mechanism (Alton and Nelson 1970). Because juveniles are most likely found in the upper water column at greater proportions, we used an estimate of 10% for the proportion of adult hake that migrate into the top 20m of the water column at some point*; therefore, we multiplied the shipping threat values by 0.1 in order to account for this level of exposure.

*Decision Point: If there are other estimates for this value, we would be happy to compare and discuss.

STATUS AND TRENDS OF NON-FISHERIES THREATS

The ‘performance metrics’ on the plots were chosen to represent three types of ‘change’. The trend over the last five years indicates whether there has been a fairly rapid and substantial change in the time series in recent years. Judging this change in relation to the long-term s.d. evaluates ‘size’ of this change relative to long-term variability. Changes that are within the typical variability of the time series are not, initially at least, considered to be important.

The mean of the last five years provides an indication of the recent state of the time series relative to the long-term status. Thus, a threat might be declining but currently still above the long-term mean, for example. Alternatively, a threat might be stable but below the long-term mean. Again, comparing this five year mean to the s.d. of the whole time series indicates whether the current state is within or outside of typical variability.

Finally, the slope (whether or not it is significantly different from zero) gives an indication of the current trend of the time series regardless without respect to the overall variability. This information is important especially for those time series that have shown consistent, long-term declines or increases. In these cases, the s.d. is often high, and evaluating the trend over the last five years relative to the s.d. will fail to identify cases where the time series is still declining.

APPENDIX E. NON-FISHERIES THREATS – LITERATURE REVIEW

In the sections below labeled “Threat data layer description, from Halpern et al. (2009)”, we have copied information from Halpern et al. (2009) supporting materials; thus, any use of “we” or “our” refers to analyses or work performed by the authors of the original paper.

Threat data layer description, from Halpern et al. (2009): Currently no data exist for the location of aquaculture facilities. Google Earth imagery was used to search the coastlines in the California Current for evidence of fish pens. This effort was focused on Puget Sound, Southern California, and Baja, Mexico where aquaculture is known to exist. Data on shellfish aquaculture facilities are not included because they do not exist at this time.

Effects: The impact of aquaculture facilities varies according to the species cultured, the type and size of the operation, and the environmental characteristics of the site (Johnson et al. 2008). Intensive cage and floating netpen systems typically have a greater impact because aquaculture effluent is released directly into the environment. The relative impact of finfish and shellfish aquaculture differs depending on the foraging behavior of the species. Finfish require the addition of a large amount of feed into the ecosystem, which can result in environmental impacts from the introduction of the feed, but also from the depletion of species harvested to provide the feed. Bivalves are filter feeders and typically do not require food additives; however, fecal deposition can result in benthic and pelagic habitat impacts, changes in trophic structure and nutrient and phytoplankton depletion. Aquaculture activities can effect fisheries at both a habitat and species-level. Typical environmental impacts resulting from aquaculture production include: (1) impacts to the water quality from the discharge of organic wastes and contaminants; (2) seafloor impacts; (3) introductions of exotic invasive species; (4) food web impacts; (5) gene pool alterations; (6) changes in species diversity; (7) sediment deposition; (8) introduction of diseases; (9) habitat replacement or exclusion; and (10) habitat conversion (Johnson et al. 2008).

Sensitivity scores–

Mortality: 1 (juvenile and adult forms of all species). Mortality effects are not likely from the range of current aquaculture activities in the region.

Behavior/Physiology: 1 (juvenile and adult forms of all species). Direct behavioral effects are not likely from the range of current aquaculture activities in the region, although indirect effects are likely via water quality, light, seafloor and related habitat impact, etc.

Trends: Growing U.S. and worldwide demand for seafood is likely to continue as a result of increases in population and consumer awareness of seafood's health benefits. The most recent federal *Dietary Guidelines for Americans* (2010) recommend Americans more than double their current seafood consumption. Because wild stocks are not projected to meet increased demand even with rebuilding efforts, future increases in supply are likely to come either from foreign aquaculture or increased domestic aquaculture production, or some combination of both (NOAA Aquaculture Draft Policy).

In order to estimate the trend in aquaculture in the California Current, we used the Estimated U.S. Aquaculture production from the 2003-2008: Fisheries of the United States 2009, NMFS Office of Science and Technology. Current Fishery Statistics No. 2009. US Dept Comm. We limited this data to categories that did not include catfish or trout. However, the data was not limited to West Coast aquaculture operations. We detected no trend over the last five years in the amount of aquaculture production (Fig. 44), but the five year mean is near the upper standard deviation of the long-term mean.

ATMOSPHERIC DEPOSITION

Threat data layer description, from Halpern et al. (2009) : We used the atmospheric deposition of sulfates derived from the National Atmospheric Deposition Program (http://nadp.sws.uiuc.edu/), processed in the same manner as for nitrogen as described above in 'Nutrient Input'. We used sulfate deposition as a proxy measure for the distribution and deposition of all atmospheric pollutants.

Effects: Substances such as sulfur dioxide, nitrogen oxide, carbon monoxide, lead, volatile organic compounds, particulate matter, and other pollutants are returned to the earth through either wet or dry atmospheric deposition (Johnson et al. 2008). Atmospheric pollution is a major source of many nutrient, chemical, and heavy metal pollutants whose sources can be far away from the marine ecosystems being impacted. See pollutants, above.

Sensitivity scores–

Mortality: 3 (juvenile forms of all species); 2 (adult forms of all species). Scored as if inorganic/organic pollution; Sensitivity scores reflect that most fish species are particularly sensitive to contaminants/pollution during early life history.

Behavior/Physiology: 3 (juvenile forms of all species); 2 (adult forms of all species). Scored as if inorganic/organic pollution; reflect that most fish species are particularly sensitive to contaminants/pollution during early life history.

Trends: Increasing; atmospheric N input is rapidly approaching global oceanic estimates for N_2 fixation and is predicted to increase further due to emissions from combustion of fossil fuels and production and use of fertilizers (Paerl et al. 2002; Duce et al. 2008). Atmospheric deposition is one of the most rapidly increasing means of nutrient loading to both freshwater systems and the coastal zone, as well as one of the most important anthropogenic sources of mercury pollution in aquatic systems (Johnson et al. 2008). Industrial activities have increased atmospheric mercury levels, with modern deposition flux estimated to be 3-24 times higher than preindustrial flux.

In order to estimate the trend of atmospheric deposition in the California Current, we used data from the National Atmospheric Deposition Program (http://nadp.sws.uiuc.edu/data/ntndata.aspx) using sulfate as a proxy - based on Halpern et al. 2009 as described above. We found no short-term trend, but the short-term mean was greater than 1 SD below the long-term mean, suggesting that current levels of atmospheric deposition are better than historic levels (Fig. 45).

COASTAL ENGINEERING:

Coastal engineering Threat data layer description, from Halpern et al. (2009) : Coastal engineering represents shore hardening of various kinds, including riprap walls, cement walls (for harbors, sediment containment, etc.), and jetties and piers. For coastlines within the United States, we extracted data from NOAA's Environmental Sensitivity Index (ESI) for California, Puget Sound and Columbia River regions (http://response.restoration.noaa.gov) and from The Nature Conservancy's (TNC) Pacific Northwest coast ecoregional assessment geodatabase (Ferdaña et al. 2006) for Oregon and Washington. These databases classify linear segments of coast into ecosystem types and also report location of hardened shorelines. For Baja, Google Earth images were generally at high enough resolution to be able to identify human-modified shorelines, but where they were not we assumed no coastal engineering exists.

Effects: Coastal engineering structures destroy the habitat directly under them and can significantly modify surrounding ecosystems through changes in circulation patterns and sediment transport (National Research Council 2007; Halpern et al. 2009b; Shipman et al. 2010). Any structural modification of the shoreline will alter several important physical processes, and can therefore be considered an impact (Williams and Thom 2001). For the most part, impact potential can be related to the size and location of the structure and the types of physical processes it alters. Impacts may be considered direct or indirect. Direct impacts are generally associated with construction activities, including excavation, burial, and various types of pollution. Indirect impacts occur following physical disturbance, and are chronic in nature due to permanent alteration of physical processes such as sediment transport and wave energy. "Cumulative impacts" are associated with increasing number or size of indirect or direct impacts, which can have either linear or non-linear cumulative responses. Many shoreline "hardening" structures, such as seawalls and jetties, tend to reduce the complexity of habitats and the amount of intertidal habitats (Williams and Thom 2001). Differences in fish behavior and usage between modified and unmodified shorelines are caused by physical and biological effects of the modifications, such as changes in water depth, slope, substrate, and shoreline vegetation (Toft et al. 2007).

Sensitivity scores –

Mortality: 1 (juvenile and adult forms of all species). We assume most of the chronic effects of coastal engineering structures on fishes will be behavioral in nature.

Behavior/Physiology: 3 (juvenile and adult forms of bocaccio and canary rockfish); 2 (adult and juvenile forms of hake and sablefish). We assume most coastal engineering impacts will affect behavior of species highly dependent on or associated with complex benthic habitat structure (i.e., rockfish).

Trends: The rate of shoreline armoring has been shown to correspond with the rate of population growth in coastal areas (Douglass and Pickel 1999), and in the absence of good time series of geospatial data for hardened shorelines (TNC), we assumed coastal population data for the west coast of the United States provided a good proxy for this stressor.

Coastal population density data was obtained from Crossette et al. (2005). Briefly, they found that in 2003 the coastal population density (not including Alaska) of the Pacific Region was 303 persons per square mile, up from 207 in 1980, and expected to increase to 320 in 2008. From 2003 to 2008, the Pacific region is expected to increase by 2.2 million people or 6 percent in coastal population (Crossett et al. 2005). From this data, we detected a significantly positive increase in the short-term trend (Fig. 46; over the last 40 years in this dataset). Other threats that correlate with population growth (e.g. light pollution, and direct human impacts) however, show much greater variation than what would be expected if measured by population growth. Thus, we plan to search for data more closely tied to coastal engineering along the West Coast of the U.S.

DIRECT HUMAN IMPACTS

Threat data layer description, from Halpern et al. (2009) : To estimate the impact of this source of stress, we employed a 3 step process. First, we collected annual beach attendance data that are available for 98 beaches in Central and Southern California (Kildow and Colgan 2005; Dwight et al. 2007)(http://www.parks.ca.gov/?page_id=23308). Of these, only 59 have additional information on fees, facilities, and parking availability. U.S. beach access points in the California Current are reported in the MLPA database for California (http://marinemap.org/mlpa), the Oregon Geospatial Enterprise Office (http://gis.oregon.gov/DAS/EISPD/GEO/alphalist.shtml), and Washington State Department of Ecology BEACH (Beach Environmental Assessment, Communication and Health) Program (http://www.doh.wa.gov/ehp/TS/WaterRec/beach/default.htm). Second, we used these actual beach attendance data to develop a predictive model of beach visitation for all access points without recorded data. Predictor variables included number of parking spaces (park), entrance fee (fee), available facilities (facils: a yes/no variable) and number of people with 50 miles of the access point (pop). Fifty miles was chosen because studies of beach attendance (in southern California) suggest most visitors are local and travel 50-80 miles from home to get to the beach (Dwight et al. 2007; Nelsen et al. 2007). Population density data come from the LandScan project (http://www.ornl.gov/sci/landscan/index.html) and are reported at $1km^2$ resolution. We implemented a backwards selection procedure of a multivariate linear model on these variables, and used AIC to select the best model. The final model for predicting annual beach access (BA) was BA = 0.1706(pop) – 16840 ($F = 9.743$, $df = 2,94$, $p < 0.001$, adjusted $R^2 = 0.15$). We then applied this model to all beach access points without real attendance data. These annual beach access values were then used as estimates of the relative intensity of direct human impact on that pixel of coastline. Beach access point data were not available for Baja, so this impact was not estimated along the Mexican coastline.

Effects: People visiting beaches and coastal areas can impact intertidal and nearshore ecosystems through direct trampling or by disturbing or displacing species that would normally use those locations. None of these species are sessile intertidal inhabitants and therefore they would not be subject to this type of disturbance.

Sensitivity scores –

Mortality: 1 (juvenile and adult forms of all species). Trampling and disturbance is not likely to affect these species.

Behavior/Physiology: 1 (juvenile and adult forms of all species). Trampling and disturbance is not likely to affect these species.

Trends: In order to estimate the trend of direct human impacts, we also used beach attendance at Central and southern California State Parks identified as "State Beaches" (California State Park System Annual Statistical Reports: 2001 -2010: http://www.parks.ca.gov/?page_id=23308). We limited the data to 48 State Beaches that had total attendance data for each year from 2002 – 2010. We detected a non-significant decline in beach attendance over the last five years (Fig. 47).

INORGANIC POLLUTION:

Inorganic pollution Threat data layer description, from Halpern et al. (2009) : Inorganic pollution into coastal marine waters was estimated from two sources, point source pollution from factories and mines and non-point source pollution that scales with the amount of impervious (hardened) surface area. Point source data are reported in the EPA Toxics Release Inventory (http://www.epa.gov/tri/). We multiplied the amount of each chemical released on-site to the ground or water (excluding aerial releases, off-site transfers, treated and recycled chemicals) by its toxicity (reported by the Indiana Clean Manufacturing Technology and Safe Materials Institute (ICMTSM) in its Indiana Relative Chemical Hazard Score (IRCHS): https://engineering.purdue.edu/CMTI/IRCHS/) to produce a weighted amount of inorganic pollution release from each source, and summed all values within each watershed. For those chemical compounds not listed in the IRCHS database, we applied the average score from the class of chemicals to which the missing chemical. Impervious surface area (ISA) data were processed as in the global project (Halpern et al. 2008), using the global impervious surface area data layer developed by the U.S. National Geophysical Data Center for the years 2000-2001 (http://www.ngdc.noaa.gov/dmsp/download_global_isa.html) as a proxy measure for the use and input of inorganic pollutants. The %-coverage of impervious area in each $1km^2$ pixel was identified, and the average %-coverage for all $1km^2$ pixels within a watershed is multiplied by the number of pixels to produce a total area (km^2) of impervious surface within each watershed. Point source and ISA estimates of inorganic pollution in each watershed were then log-transformed and normalized (described below) separately, and then the two layers were summed and re-normalized to create a single inorganic pollution value for each watershed. These values were then assigned to the pour-point for each watershed.

Effects: While all pollutants can become toxic at high enough levels, there are a number of compounds that are toxic even at relatively low levels (Johnson et al. 2008). The US Environmental Protection Agency (US EPA) has identified and designated more than 126 analytes as “priority pollutants.” According to the US EPA, “priority pollutants” of particular concern for aquatic systems include: (1) dichlorodiphenyl trichloroethane (DDT) and its metabolites; (2) chlorinated pesticides other than DDT (e.g., chlordane and dieldrin); (3) polychlorinated biphenyl (PCB) congeners; (4) metals (e.g., cadmium, copper, chromium, lead, mercury); (5) polycyclic aromatic hydrocarbons (PAHs); (6) dissolved gases (e.g., chlorine and ammonium); (7) anions (e.g., cyanides, fluorides, and sulfides); and (8) acids and alkalis. While acute exposure to these substances produce adverse effects of aquatic biota and habitats, chronic exposure to low concentrations probably is a more significant issue for fish population structure and may result in multiple substances acting in “an additive, synergistic or antagonistic manner” that may render impacts relatively difficult to discern (Johnson et al. 2008).

Coastal/estuarine pollution can affect any life stage of fish, but fish can be particularly sensitive to toxic contaminants during the first year of life. Effects of pollutants on reproduction, recruitment, behavior, and survival may be particularly critical; e.g., survival may be reduced by inherited and dietary contaminants such as PCBs; reproductive rate may be a more sensitive parameter than survival.

The negative impacts of pollution on commercial fish stocks have generally not been demonstrated, largely due to the fact that only drastic changes in marine ecosystems are detectable and the difficulty in distinguishing pollution induced changes from those due to other causes (Sinderman 1994). Normally chronic and sublethal changes take place very slowly and it is impossible to separate natural fluctuations from anthropogenically caused ones. Furthermore, fish populations themselves are estimated only imprecisely, so the ability to detect and partition contaminant effects is made even more difficult.

Sensitivity scores –

Mortality: 3 (juvenile forms of all species); 2 (adult forms of all species); Scoring based on assumption that most fishes are particularly sensitive to contaminants/pollution during their early life history.

Behavior/Physiology: 3 (juvenile forms of all species); 2 (adult forms of all species); Scoring based on assumption that most fishes are particularly sensitive to contaminants/pollution during their early life history.

Trends: Temporal trends in benthic pollutants within three large coastal areas of the West Coast (Puget Sound, San Francisco Bay, and southern California Bight) demonstrate a number of significant reductions over periods of monitoring, ranging from one to three decades (EPA 2008). No consistent temporal trends were detected in concentrations of the persistent chlorinated hydrocarbons, such as PCBs and DDTs, in Pacific coast sediments and fish for the 7-year period from 1984-1990 (Brown et al. 1998).

Halpern et al. (2008) estimated via point source pollution from factories and mines (USEPA) and non-point source pollution that scales with the amount of impervious (hardened) surface area. Our analysis of temporal trends in inorganic pollution was limited to queries of the EPA Toxics Release Inventory (http://www.epa.gov/tri/) for inorganic pollutants [1988 Core Chemicals list] disposed of or otherwise released (in pounds) from all industries on-site to the ground or water (excluding aerial releases, off-site transfers, treated and recycled chemicals) in the states of WA, OR, and CA. We detected a non-significant decline in the amount of inorganic pollutants over the last five years (Fig. 48)

LIGHT POLLUTION:

Threat data layer description, from Halpern et al. (2009): Species that use coastal habitats can be impacted by noise and light pollution that emerges from coastal human populations. To estimate the distribution of this stressor, we used the stable lights at night database (http://www.ngdc.noaa.gov/dmsp/global_composites_v2.html) and isolated the light coming from coastal land area (that can be seen in ocean pixels) and offshore oil rigs (both sources of light do not move from night to night and so can be isolated, which NGDC has already processed). The files are cloud-free composites made using all the available archived DMSP-OLS smooth resolution data for 2003.

Effects: Ecological light pollution has demonstrable effects on the behavioral and population ecology of organisms in natural settings. As a whole, these effects derive from changes in orientation, disorientation, or misorientation, and attraction or repulsion from the altered light environment, which in turn may affect foraging, reproduction, migration, and communication. (Longcore and Rich 2004). Juvenile sablefish exposed to a horizontal light gradient exhibited an avoidance of bright light (Sogard and Olla 1998). While juvenile sablefish were primarily surface-oriented, they nonetheless displayed clear day/night differences in vertical distribution. Proximity to the surface and low activity at night contrasted with higher activity and the greater range of vertical movement that typified daytime behavior. Movement throughout the water column during the day and the negative phototaxis observed in a horizontal gradient suggests that juveniles in nature, at least during the day, may not be restricted to the neuston.

Sensitivity scores –

Mortality: 1 (juvenile and adult forms of all species); Light pollution is generally not considered a stressor leading to the indirect/direct mortality of any of these species.

Behavior/Physiology: 2 (juvenile forms of all species); 1 (adult forms of all species); Light pollution may cause some behavioral changes, such as avoidance or vertical migration; we assume these would disproportionately affect juveniles foraging in the water column.

Trends: In the past century, the extent and intensity of artificial night lighting has increased such that it has substantial effects on the biology and ecology of species in the wild (Longcore and Rich

2004). To estimate the temporal trend of light pollution in the California Current, we used NOAA's National Geophysical Data Center's Version 4 DMSP-OLS Nighttime Lights Time Series Average Lights X Pct from 1992 – 2009 (http://www.ngdc.noaa.gov/dmsp/downloadV4composites.html). This data is derived from the average visible band digital number (DN) of cloud-free light detections multiplied by the percent frequency of light detection. The inclusion of the percent frequency of detection term normalizes the resulting digital values for variations in the persistence of lighting. For instance, the value for a light only detected half the time is discounted by 50%. Note that this product contains detections from fires and a variable amount of background noise.

We detected a significant increase in the amount of light pollution in waters of the California Current over the last five years (Fig. 49). However, prior to this most recent trend, light pollution was decreasing, such that current levels are well within 1 SD of the long-term mean. Technological advances in street lighting may decrease the amount of light that is reflected to the atmosphere for satellite detection; thus, changing the relationship between population growth and light pollution at local or regional scales.

NUTRIENT INPUT:

Nutrient Threat data layer description, from Halpern et al. (2009) : Nutrient input (considering nitrogen only here) comes primarily from three sources: farming (fertilizer application and animal farm runoff), sewage, and atmospheric deposition. Because sewage input is generally very difficult to document across larger scales, only nitrogen input from farming and atmospheric deposition was quantified. County-level fertilizer application data come from the USGS (source: "Vulnerability of Shallow Groundwater and Drinking-water Wells to Nitrate in the United States" by Bernard T. Nolan and Kerie J. Hitt) and report average annual nitrogen input from 1992-2001 in kgs/hectare. Confined manure (primarily from dairy farms) is from the same source and reported in the same units, but for the years 1992-1997. Atmospheric wet deposition of pollutants is recorded at over 100 stations within the U.S. as part of the National Atmospheric Deposition Program (http://nadp.sws.uiuc.edu/); data from the 19 stations along the west coast and in the Aleutian Islands was used along with spatially kriged values between the stations over the landscape and onto the waters of the California Current (including Baja), measured in $kgs/yr/km^2$.

Effects: While much of the excess nutrients within coastal waters originates from sewage treatment plants, nonpoint sources of nutrients from municipal and agricultural run-off, contaminated groundwater and sediments, septic systems, wildlife feces, and atmospheric deposition from industry and automobile emissions contribute significantly (Johnson et al. 2008). Failing septic systems contribute to non-point source pollution and are a negative consequence of urban development. The US EPA estimates that 10- 25% of all individual septic systems are failing at any one time, introducing feces, detergents, endocrine disruptors, and chlorine into the environment. Sewage waste contains significant amounts of organic matter that cause a biochemical oxygen demand, leading to eutrophication of coastal waters.

Severely eutrophic conditions may adversely affect aquatic systems in a number of ways, including: reductions in submerged aquatic vegetation (SAV) through reduced light transmittance, epiphytic growth, and increased disease susceptibility; mass mortality of fish and invertebrates through poor water quality; and alterations in long-term natural community dynamics.

Sensitivity scores –

Mortality: 2 (juvenile forms of all species); 1 (adult forms of all species). Scoring is based on assumption that fish are particularly sensitive (mortality) from eutrophic conditions / hypoxia early in their life history.

Behavior/Physiology: 3 (juvenile forms of all species); 2 (adult forms of all species). Scoring is based on assumption that fish are particularly sensitive (behavioral/physiological response) to eutrophic conditions / hypoxia early in their life history.

Trends: Halpern used time series data from Nolan and Hitt (2006) on county-level fertilizer application data from 1992-2001 (kgs/hectare) and confined manure (primarily from dairy farms) from 1992-1997. We did not extract and apply these files (http://water.usgs.gov/GIS/dsdl/gwava-s/index.html) (Nolan and Hitt 2006), in part because the data only extend through 2001. Rather, we queried the USGS surface water database http://infotrek.er.usgs.gov/apex/f?p=NAWQA:HOME:5572182579967972, for nutrient levels [nitrite+nitrate] from all Pacific coastal basins 1991-2011, limited to surface water samples from the following land use classes: Ag, Crop, Forest, Orchard, Range, Reference, Mixed (n=4577). Annual samples were averaged across all dates. We detected a significant decline in nutrient input over the last five years, where the last data point is below the lower standard deviation of the long-term mean (Fig. 50).

Question / Comment re: Annual means: Seasonal effects of sampling can skew these results considerably based on runoff timing; we plan to work with USGS to refine this data set in a way that would reduce this effect.

OCEAN-BASED POLLUTION

Threat data layer description, from Halpern et al. (2009) : Ocean-based pollution is assumed to derive from two primary sources, commercial shipping and ports, as was done in the global project (Halpern et al. 2008). We used the shipping data described above in combination with port volume data derived largely de novo for the California Current. In all cases we used data for, or projected to, the year 2003 as this was when the largest amount of data was available. Commercial port tonnage and location data for US ports came from the US Army Corps of Engineers Navigation Data Center: http://www.iwr.usace.army.mil/ndc/wcsc/portname03.htm. Commercial port location data for ports in Mexico or Canada came from the Princeton University Library Digital Map and Geospatial Information Center: http://www.princeton.edu/~geolib/gis/index.html, with tonnage for Canadian ports from Transport Canada (http://www.tc.gc.ca/pol/en/report/anre2005/8F_e.htm) and tonnage for Mexican ports from the global project (Halpern et al. 2008). Non-commercial ports and their modeled ship traffic (measured in tonnage, but related to port facilities; see (Halpern et al. 2008)) were included from the global project. All port layers were then combined into a single layer, and this layer (log-transformed and normalized) and the shipping layer were combined and then renormalized to create a single pollution layer.

Effects: Marine trash may be ingested by some fish species, resulting in mortality, although this is most prominently reflected in the bird and sea turtle literature (Derraik 2002). The behavioral effects of marine trash or debris may be t concentrate fish both at the water's surface (FAD – floating aggregation devices) and on the bottom (artificial reefs).

Sensitivity scores –

Mortality: 3 (juvenile forms of all species); 2 (adult forms of all species). Scored as if inorganic/organic pollution; Sensitivity scores reflect that most fish species are particularly sensitive to contaminants/pollution during early life history. Most likely mortality effects of solid trash would be from ingestion, but there are few good examples of this in the fish literature.

Behavior/Physiology: 3 (juvenile forms of all species); 2 (adult forms of all species); Scored as if inorganic/organic pollution; Sensitivity scores reflect that most fish species are particularly sensitive to contaminants/pollution during early life history. Most likely effects of solid trash may be positive for some species using reefs or floating debris as cover….

Trends: While in some areas of the world the quantities of marine debris apparently show a decreasing trend during the past two decades (Ribic et al., 1997. C.A. Ribic, S.W. Johnson and C.A. Cole , Distribution, type, accumulation, and source of marine debris in the United States, 1989–1993. In: J.M. Coe and D.B. Rogers, Editors, *Marine debris: Sources, impacts, and solution*, Springer, New York (1997), pp. 35–47.Ribic et al., 1997), other authors reported increases. (Coe and Rogers 1997).

In order to estimate ocean-based pollution in the California Current, we also used shipping activity as a proxy (Halpern et al. 2008, 2009). The U.S. Department of Transportation projects that, compared to 2001, total freight moved through U.S. ports will increase by more than 50 percent by 2020 and the volume of international container traffic will more than double (American Association of Port Authorities Fact Sheet 2011: http://www.aapa-ports.org/files/PDFs/facts.pdf). We used data on the total amount of shipping cargo (tonnage) that moved through each port in the Unites States. This data was available from the US Army Corps of Engineers Navigation Data Center (http://www.ndc.iwr.usace.army.mil/data/datawcus.htm). CSV files were available for years 1993 – 2009. We limited and summed the tonnage from each port for each year for waterways in CA, OR, and WA. Among ports along the West Coast of the United States, we detected a non-significant negative trend over the last five years in the amount of shipping activity (Fig. 51).

OFFSHORE OIL ACTIVITIES

Threat data layer description, from Halpern et al. (2009): Offshore oil rigs in the California Current are exclusively found in southern California. We obtained location information for these rigs using the same methods as described in the global project (Halpern et al. 2008), producing a total of 27 oil rigs. These locations were confirmed with the data from the California MLPA (http://marinemap.org/mlpa).

Effects: The environmental risks posed by offshore exploration and production are well known. They include the loss of hydrocarbons to the environment, smothering of benthos, sediment anoxia, destruction of benthic habitat, and the use of explosives (Macdonald et al. 2002). Petroleum exploration involves seismic testing, drilling sediment cores, and test wells in order to locate potential oil and gas deposits (Johnson et al. 2008). Petroleum production includes the drilling and extraction of oil and gas from known reserves. Oil and gas rigs are placed on the seabed and as oil is extracted from the reservoirs, it is transported directly into pipelines. While rare, in cases where the distance to shore is too great for transport via pipelines, oil is transferred to underwater storage tanks. From these storage tanks, oil is transported to shore via tanker. According to the MMS, there are 21,000 miles of pipeline on the United States OCS. According to the National Research Council (NRC), pipeline spills account for approximately 1,900 tonnes per year of petroleum into US OCS waters, primarily in the central and western Gulf of Mexico. Other potential negative impacts include: physical damage to existing benthic habitats within the "drop zone", undesired changes in marine food webs, facilitation of the spread of invasive species, and release of contaminants as rigs corrode (Macreadie et al. 2011).

However, the effects of oil rigs on fish stocks is less conclusive, with these risks balanced out by the possible enhanced productivity brought about by colonization of novel habitats by structure-associated fishes and invertebrates (e.g., rockfish, encrusting organisms, etc.) (Love et al. 2006). Decommissioned rigs could enhance biological productivity, improve ecological connectivity, and facilitate conservation/restoration of deep-sea benthos (e.g. cold-water corals) by restricting access to fishing trawlers. Preliminary evidence indicates that decommissioned rigs in shallower waters can also help rebuild declining fish stocks. Petroleum extraction and transportation can lead to a conversion and loss of habitat in a number of other ways. Activities such as vessel anchoring, platform or artificial island construction, pipeline laying, dredging, and pipeline burial can alter bottom habitat by altering substrates used for feeding or shelter. Disturbances to the associated epifaunal communities, which may provide feeding or shelter habitat, can also result. The installation of pipelines associated with petroleum transportation can have direct and indirect impacts on offshore, nearshore, estuarine, wetland, beach, and rocky shore coastal zone habitats. The destruction of benthic organisms and habitat can occur through the installation of pipelines on the sea floor (Gowen 1978). Benthic organisms, especially prey species, may recolonize disturbed areas, but this may not occur if the composition of the substrate is drastically changed or if facilities are left in place after production ends. (Johnson et al. 2008).

Sensitivity scores –

Mortality: 2 (juvenile and adult forms of bocaccio and canary rockfish); 1 (juvenile and adult forms of hake and sablefish). Mixed effects, depending on species and location, but more likely behavioral than mortality-based effects on structure associated species like rockfish.

Behavior/Physiology: 2 (juvenile and adult forms of bocaccio and canary rockfish); 1 (juvenile and adult forms of hake and sablefish). Mixed effects, depending on species and location, but more likely behavioral than mortality-based effects on structure-associated species like rockfish.

Trends: Increasing pressure to find oil on continental shelves will probably increase the risk of hydrocarbon pollution to the North Pacific: Canada (British Columbia), the U.S.A. (California), Republic of Korea and Japan have all indicated that they intend either to begin or to expand exploration on the continental shelves of the Pacific, and drilling already occurs off Alaska and California and in the East China Sea (Macdonald et al. 2002).

To estimate the temporal trend in activities related to oil rigs, we consulted annual reports of the California State Department of Conservation's Division of oil, gas, and geothermal resources (ftp://ftp.consrv.ca.gov/../pub/oil/annual_reports/). The total number of offshore oil and gas wells in production and the number of barrels of oil produced was tallied on an annual basis from 1981 to 2009. We chose to use number of wells in production as a proxy for oil rig activity, to offset technological efficiencies that may have influenced oil production. We detected no short-term trend in offshore oil activities in the California Current (Fig. 52).

ORGANIC POLLUTION:

Organic pollution Threat data layer description, from Halpern et al. (2009) (Halpern et al. 2009a): Dasymetric mapping techniques (Halpern et al. 2008) were used to estimate input rates based on national level statistics and land-use categories. Land cover data came from the U.S. Geologic Survey (http://edcsns17.cr.usgs.gov/glcc/) for the US and Baja and from the National Atlas of Canada (http://atlas.nrcan.gc.ca/site/english/index.html) for those watersheds. Pesticide use statistics were reported for the US by the National Center for Food and Agricultural Policy 1997 Summary Report and by Environment Canada's Survey of Pesticide Sales and Use in British Columbia for the year 1999. These values were then distributed onto the landscape using dasymetric mapping techniques to get annual pesticide use per km^2. Values for Baja, Mexico were taken from the global project (Halpern et al. 2008). Data were also available at the county level within the State of California, and so we reran the dasymetric mapping for California using these county data and then compared the output to that from the national level data to test the accuracy of the broader model.

Effects: [in addition to the general pollution effects described under inorganic pollution, above. Much of the following is taken from Johnson et al. (2008)].

Pesticides - There are three basic ways that pesticides can adversely affect the health and productivity of fisheries: (1) direct toxicological impact on the health or performance of exposed fish; (2) indirect impairment of the productivity of aquatic ecosystems; and (3) loss or degradation of habitat (e.g., aquatic vegetation) that provides physical shelter for fish and invertebrates (Johnson et al. 2008). For many marine organisms, the majority of effects from pesticide exposures are sublethal, meaning that the exposure does not directly lead to the mortality of individuals. Sublethal effects can be of concern, as they impair the physiological or behavioral performance of individual animals in ways that decrease their growth or survival, alter migratory behavior, or reduce reproductive success. Early development and growth of organisms involve important physiological processes and include the endocrine, immune, nervous, and reproductive systems. Many pesticides have been shown to impair one or more of these physiological processes in fish. For example, evidence has shown that DDT and its chief metabolic by-product, dichlorodiphenyl dichloroethylene (DDE), can act as estrogenic compounds, either by mimicking estrogen or by inhibiting androgen effectiveness. DDT has been shown to cause deformities in winter flounder eggs and Atlantic cod embryos and larvae. Generally, however, the sublethal impacts of pesticides on fish health are poorly understood. The direct and indirect effects that pesticides have on fish and other aquatic organisms can be a key factor in determining the impacts on the structure and function of ecosystems. This factor includes impacts on primary producers and aquatic microorganisms, as well as macroinvertebrates that are prey species for fish. Because pesticides are specifically designed to kill insects, it is not surprising that these chemicals are relatively toxic to insects and crustaceans that inhabit river systems and estuaries.

PAH - Petroleum products, including polycyclic aromatic hydrocarbons (PAH), consist of thousands of chemical compounds which can be particularly damaging to marine biota because of their extreme toxicity, rapid uptake, and persistence in the environment (Johnson et al. 2008). PAH have been found to be significantly higher in urbanized watersheds when compared to nonurbanized watersheds. Low-level chronic exposure to petroleum components and byproducts (i.e., polycyclic aromatic hydrocarbons [PAH]) have been shown in Atlantic salmon (*Salmo salar*) to increase embryo mortality, reduce growth, and lower the return rates of adults returning to natal streams. As spilled petroleum products become weathered, the aromatic fraction of oil is dominated by PAH as the lighter aromatic components evaporate into the atmosphere or are degraded. Because of its low solubility in water, PAH concentrations probably contribute little to acute toxicity; however, lipophilic PAH (those likely to be bonded to fat compounds) may cause physiological injury if they accumulate in tissues after exposure. Even concentrations of oil that are diluted sufficiently to not cause acute impacts in marine organisms may alter certain behavior or physiological patterns.

Sublethal effects that may occur with exposure to PAH include impairment of feeding mechanisms for benthic fish and shellfish, growth and development rates, energetics, reproductive output, juvenile recruitment rates, increased susceptibility to disease and other histopathic disorders, and physical abnormalities in fish larvae. Effects of exposure to PAH in benthic species of fish include liver lesions, inhibited gonadal growth, inhibited spawning, reduced egg viability and reduced growth. Toxicity responses to winter flounder (*Pseudopleuronectes americanus*) exposed to PAH and other petroleum-derived contaminants, include: liver and spleen diseases, immunosuppression responses, tissue necrosis, altered blood chemistry, gill tissue clubbing, mucus hypersecretion, altered sex hormone levels, and altered reproductive impairments. For Atlantic cod (*Gadus morhua*) exposed to various petroleum products, responses included reduced growth rates, gill hyperplasia, increased skin pigmentation, hypertrophy of gall bladder, liver disease, delayed spermatogenesis, retarded gonadal development and other reproductive impairments, skin lesions, and higher parasitic infections. Effects from exposure of aquatic organisms to PAH include: carcinogenesis, phototoxicity, immunotoxicity, and disturbance of hormone regulation. Fuel, oil, and some hydraulic fluids contain PAH which can cause acute and chronic toxicity in marine organisms, and toxic effects of exposure to PAH have been identified in adult finfish at concentrations of 5-50 ppm and the larvae of aquatic species at concentrations of 0.1-1.0 ppm (Logan 2007). Observed effects of fish exposed to PAH include decrease in growth, cardiac disfunction, lesions and tumors of the skin and liver, cataracts, damage to immune systems, estrogenic effects, bioaccumulation, bioconcentration, trophic transfer, and biochemical changes. PAHs can be toxic to meroplankton, ichthyoplankton, and other pelagic life stages exposed to them in the water column. Short-term impacts include interference with the reproduction, development, growth, and behavior (e.g., spawning, feeding) of fishes, especially early life-history stages. Although oil is toxic to all marine organisms at high concentrations, certain species are more sensitive than others. In general, the early life stages (eggs and larvae) are most sensitive, juveniles are less sensitive, and adults least so.

There are no rockfish-specific PCB threshold data available to determine whether observed concentrations are likely to adversely affect rockfish health (West et al. 2001).

Sensitivity scores –

Mortality: 3 (juvenile forms of all species); 2 (adult forms of all species); Sensitivity scores reflect that most fish species are particularly sensitive to contaminants/pollution during their early life history.

Behavior/Physiology: 3 (juvenile forms of all species); 2 (adult forms of all species); Sensitivity scores reflect that most fish species are particularly sensitive to contaminants/pollution during their early life history.

Trends: Levels of PAHs, which are nonpoint source contaminants, have shown consistent increases from 1984-1990 at both nonurban and urban near-coastal sites along the Pacific coast of North America (Brown et al. 1998). The increasing trend for PAH concentration with time in Puget Sound is potentially a result of the large increases in human population in the region. In western North America, untreated and secondarily-treated sewage is still discharged to coastal waters by some cities (*e.g*., Victoria and Vancouver) (Thomson *et al.* 1995), but upgrades are proceeding in many areas, and it seems likely that the impact of municipal outfalls on shallow coastal waters has been declining despite population increases. Widely-distributed poorly-maintained septic systems continue to contaminate shorelines in many places, however (Macdonald et al. 2002).

Halpern et al. (2008) estimated organic contamination from pesticide use statistics, reported for the US by the National Center for Food and Agricultural Policy 1997 Summary Report (Gianessi and

Marcelli 2000) and by Environment Canada's Survey of Pesticide Sales and Use in British Columbia for the year 1999.

We consulted the US summary report for trends, but this source provides only two annual estimates for 1994 and 1997. Therefore, we drew upon a recently published USGS report (Ryberg et al. 2010) which estimated the trends in pesticide concentrations from urban streams in the United States from 1992-2008. We downloaded the data and summarized organic pesticide contamination levels from western index streams (n=5) as follows: 1. Calculated the mean annual recovery-adjusted concentration (micrograms/l) of each (n=16) pesticide and degradate; 2. Calculated the normalized mean across years for each compound; 3. Summed the normalized means for all compounds which were represented in all years (n=13); 4. Calculated the normalized annual mean of the summed normalized means. We found no trend in the short-term and all data from the last five years were within 1 sd of the long-term mean (Fig. 53). Another potential source for trend information can be found in Johnson et al. (2011), who found a mix of increasing and decreasing trends, often reflecting shifts to alternative pesticides due to use restrictions.

POWER PLANTS

Threat data layer description, from Halpern et al. (2009) : We mapped the location of all coastal power plants that lie on the coastline from the Platts database (http://www.platts.com/Analytic%20Solutions/Custom/gis/index.xml), and applied a 3km buffer around these power plants as an estimate of the scale of their impact. We found 5 plants in Puget Sound, 1 in Oregon, and 17 in central and Southern California.

Effects: Coastal power plants draw in huge amounts of marine water for cooling purposes, creating an area around the intake pipes where larvae and small plants are entrained. These entrainment 'plumes' will vary in size and shape depending on ocean currents and the size of the power plant. The construction and operation of water intake and discharge facilities can have a wide range of physical effects on the aquatic environment including changes in the substrate and sediments, water quality and quantity, habitat quality, and hydrology. Most facilities that use water depend upon freshwater or water with very low salinity for their needs (Johnson et al. 2008).

The entrainment and impingement of fish and invertebrates in power plant and other water intake structures have immediate as well as future impacts to estuarine and marine ecosystems (Johnson et al. 2008). Not only is fish and invertebrate biomass removed from the aquatic system, but the biomass that would have been produced in the future would not become available to the ecosystem. Water intake structures, such as power plants and industrial facilities, are a source of mortality for managed-fishery species and play a role as one of the factors driving changes in species abundance over time. Organisms that are too large to pass through in-plant screening devices become stuck or impinged against the screening device or remain in the forebay sections of the system until they are removed by other means.

Sensitivity scores –

Mortality: 3 (juvenile forms of all species); 1 (adult forms of all species); Mortality effects would be most significant for larval or juvenile life history stages.

Behavior/Physiology: 2 (juvenile and adult forms of all species. Behavioral effects would primarily be reflected in discharge plumes that affect local ocean temperatures.

Trends: Thermoelectric power has been the category with the largest water withdrawals since 1965, and for 2000 comprised 48 percent of total withdrawals (Hutson et al. 2005). The largest total and fresh and saline surface-water withdrawals were during 1980. Withdrawals by thermoelectric-power plants increased from 40 Bgal/d during 1950 to 210 Bgal/d during 1980. Withdrawals for thermoelectric power declined and then stabilized since 1980; the total withdrawal of 195 Bgal/d for 2000 is the same as the total withdrawal for 1990. Thermoelectric-power water withdrawals primarily have been affected by Federal legislation that required stricter water-quality standards for return flow and by limited water supplies in some areas of the United States. Consequently, since the 1970s, power plants increasingly were built with or converted to closed-loop cooling systems or air-cooled systems instead of using once-through cooling systems. By 2000, an alternative to once-through cooling was used in about 60 percent of the installed steam-generation capacity in the power plants (Hutson et al. 2005).

To estimate the potential entrainment impact of coastal power plants, we extracted the average daily withdrawal volumes (millions of gallons per day) of saline water over time from all thermoelectric power plants on the west coast of North America, using Table 14, from Hutson et al. (2005) http://pubs.usgs.gov/circ/2004/circ1268/. We found no short-term trends (over the last twenty years in this dataset), but the short-term mean is near the upper standard deviation of the long-term mean (Fig. 54).

SEDIMENT DECREASE

Threat data layer description, from Halpern et al. (2009) : See Sediment increase, above.

Effects: Changes in sediment regimes can affect marine ecosystems due to decreases in sediment input (largely resulting from river damming). Dams affect the physical integrity of watersheds by fragmenting the lengths of rivers, changing their hydrologic characteristics, and altering their sediment regimes by trapping most of the sediment entering the reservoirs and disrupting the sediment budget of the downstream landscape (Heinz Center 2002) (Johnson et al. 2008). Because water released from dams is relatively free of sediment, downstream reaches of rivers may be altered by increased particle size, erosion, channel shrinkage, and deactivation of floodplains (Heinz Center 2000). The consequence of reduced sediment also extends to long stretches of coastline where the erosive effect of waves is no longer sustained by sediment inputs from rivers (World Commission on Dams, 2000).

The effects to fishes of a reduced sediment regime would be indirect and primarily experienced through the long-term loss of soft-bottom habitat features and coastal landforms and/or changes to benthic habitat composition.

Sensitivity scores –

Mortality: 1 (juvenile and adult forms of all species). Sediment decreases are unlikely to result in any mortality to these marine species; if there is any response, it would likely be behavioral in nature.

Behavior/Physiology: 1 (juvenile and adult forms of all species). We assume that behavioral effects of sediment decrease would be on marine species associated with soft-bottom areas or on water column species that rely on low water clarity for predation refuge.

Trends: Construction of large dams peaked in the1970s in Europe and North America (World Commission on Dams 2000). Today most activity in these regions is focused on the management of existing dams, including rehabilitation, renovation, and optimizing the operation of dams for multiple functions.

To estimate the temporal change in sediment decrease, we focused on dams as the key feature affecting this change, per Halpern et al. 2008. The history of total reservoir storage area by water resource region was summarized from the early 1900's to the early 1990's by Graf (1999), based on data from the US Army Corps of Engineers (1996). Since this data is no longer available electronically by the USACE, we extracted data from Figure 4 in Graf (1999), which presents total reservoir storage in 10^9 cubic m over time for the California and PNW water resource regions. We found no change in the short-term trend, but the short-term mean is above the upper standard deviation of the long-term mean, suggesting that levels of sediment retained behind dams is still high compared to the entire time series (Fig 55).

SEDIMENT INCREASE

Threat data layer description, from Halpern et al. (2009) : We modeled changes in sediment regimes for all watersheds feeding in to the California Current using a 5-step process. First, we created a new, very high resolution watershed layer (see above). Second, we used the sediment release model developed by Syvitsky and colleagues (Syvitski et al. 2003) to model natural levels of sediment runoff from these watersheds without dams in place. This model is based on 4 parameters: maximum relief, latitude, basin area, and temperature, which serves as a proxy for rainfall. Third, to calculate changes in sediment input we placed onto the landscape all moderate-sized or larger dams included in the National Inventory of Dams produced by the Army Corps of Engineers for the year 2005 (http://www.nationalatlas.gov/index.html). We focused on dams >50ft high and/or with a capacity >5000 acre-feet (N=809). Fourth, we reran the sediment model on the sub-watersheds to determine how much sediment reached each dam from its own sub-watershed (i.e., excluding upstream sub-watersheds), using average current temperature data from the years 1996-2006 (http://www.prism.oregonstate.edu) and the other parameters listed above. Finally, we applied each dam's sediment trapping efficiency rate to its sub-watershed, releasing the appropriate amount of sediment below that dam into the downstream sub-watershed, and continued this process until the sediment reached the coastal pourpoint. This analysis therefore also accounted for changes in sediment runoff from these watersheds due to changing climate (i.e. increases in precipitation correlated with rising temperature). For those watersheds without dams, this process produced a new 'natural' value of sediment input that in almost all cases was higher than the pre-industrial estimates due to climate change increasing local temperatures. Consequently, this process produced two stressor layers, increases in sediment (exclusively those watersheds without dams) and decreases in sediment (mostly watersheds with dams). Where temperature changes increased sediment but dams decreased it, the increase (always the smaller of the two) was subtracted from the decrease to produce a single value for the sub-watersheds and the final watershed pourpoint.

Effects: Changes in sediment regimes can affect marine ecosystems due to increases in sediment input (due to land use practices and climate change that can increase precipitation and runoff). Much of the available data come from bioassays that measure acute responses and required high concentrations of suspended sediments to induce the measured response, usually mortality (Wilber and Clarke 2001). Although anadromous salmonids have received much attention, little is known of behavioral responses of many estuarine fishes to suspended sediment plumes. There is a high degree of species variability in response to sedimentation; reports of "no effect" were made at concentrations as great as 14,000 mg/L for durations of 3 d and more (oyster toadfish and spot) and mortality was observed at a concentration/duration combination of 580 mg/L for 1 d (Atlantic silversides). For both salmonid and estuarine fishes, the egg and larval stages are more sensitive to suspended sediment impacts than are the older life history stages.

Sensitivity scores –

Mortality: 1 (juvenile and adult forms of all species). For these species, we assume that mortality effects are not likely from the range of current activities increasing sedimentation in the region.

Behavior/Physiology: 3 (juvenile and adult forms of bocaccio and canary rockfish); 2 (adult and juvenile forms of hake and sablefish). For these species, we assume that activities increasing sedimentation in the region will primarily affect species which have associations with unique benthic habitat features.

Trends: Humans are simultaneously increasing the river transport of sediment through soil erosion activities and decreasing this flux to the coastal zone through sediment retention in reservoirs (Syvitski et al. 2005). The net result is a global reduction in sediment flux by about 1.4 BT/year over prehuman loads. The seasonal delivery of sediment to the coast should be a valuable aid to those investigating the dynamics of nutrient fluxes to the coast and to those monitoring coastal fisheries, coral reefs, and seagrass communities.

In order to estimate increases in sediment runoff in the California Current, we queried the USGS surface water database (http://infotrek.er.usgs.gov/apex/f?p=NAWQA:HOME:5572182579967972), for suspended sediment levels [mg/L] from Pacific coastal basins from 1991-2010 from all land use classes (n=6625). Annual samples were averaged across all dates. We found no significant trend in short-term data (Fig. 55).

Discussion Point: Question / Comment re: Annual means - Seasonal effects of sampling can skew these results considerably based on runoff timing; we plan work with USGS to refine this data set in a way that would reduce this effect.

SHIPPING ACTIVITY

Threat data layer description, from Halpern et al. (2009) : Data was combined from the global mapping effort (Halpern et al. 2008), clipped to the California Current region, with data on ferry traffic within the region. Ferry routes were digitized, and the ferry schedule data were converted into annual ship traffic data by multiplying the number of daily ferry trips by 260 for weekdays (5 days x 52 weeks) and 104 for weekends, summed for total annual trips, and then applied to the appropriate ferry route.

Effects: Commercial shipping activity can lead to ship strikes of large animals, noise pollution, and a risk of ship groundings or sinkings. Data on effects of commercial shipping on fish suggests most responses are behavioral in nature, and mortality is not a major concern. Recent studies suggest fish are actually attracted vessels, rather than being repelled by them; fish even appeared to be attracted to noisy commercial vessels, and recorded swimming velocities of fish schools suggest that fish do not become scared by noisy, passing ships (Rostad et al. 2006). Vessel activity in coastal waters is generally proportional to the degree of urbanization and port and harbor development within a particular area (Johnson et al. 2008). Benthic, shoreline, and pelagic habitats may be disturbed or altered by vessel use, resulting in a cascade of cumulative impacts in heavy traffic areas. The severity of boating-induced impacts on coastal habitats may depend on the geomorphology of the impacted area (e.g., water depth, width of channel or tidal creek), the current velocity, the sediment composition, the vegetation type and extent of vegetative cover, as well as the type, intensity, and timing of boat traffic. Recreational boating activity mainly occurs during the warmer months which coincide with increased biological activity in east coast estuaries. Similarly, frequently traveled routes such as those traveled by ferries and other transportation vessels can impact fish spawning, migration, and recruitment behaviors through noise and direct disturbance of the water column. Other common impacts of vessel activities include vessel wake generation, anchor chain and propeller scour, vessel groundings, the introduction of invasive or nonnative species, and the discharge of contaminants and debris.

Sensitivity scores –

Mortality: 1 (juvenile and adult forms of all species). Shipping strikes, groundings, and noise pollution not likely to affect these species

Behavior/Physiology: 1 (juvenile and adult forms of all species). Shipping strikes, groundings, and noise pollution not likely to affect these species

Trends: Increases in the traffic noise of about 8–10 dB from the mid- 1960s to the present. Contemporary traffic noise levels appear to be either holding steady or slightly increasing at the southern sites, depending on frequency, but decreasing at the northern sites (Andrew et al. 2011).

In order to estimate shipping activity, we used the same dataset as we did for "ocean-based pollution" above. We detected a non-significant negative trend over the last five years in the amount of shipping activity (Fig. 56).

SPECIES INVASION:

Threat data layer description, from Halpern et al. (2009) : The potential impact of invasive species was modeled in the same manner as in the global project (Halpern et al. 2008). Briefly, for each port, the annual tonnage of goods passed through the port (i.e., port volume) was used as a proxy measure for ship traffic and therefore probability of invasive species introduction. Past research has shown this to be a reasonable approach to estimating numbers of invasive species at a location (Carlton and Geller 1993; Drake and Lodge 2004). Port volume data were obtained from the global database (Halpern et al. 2008). These port volume values were then plumed away from each port using a diffusive model and a maximum distance of spread set at 27km for the largest port in the region, Long Beach, California.

Effects: Introductions of nonnative invasive species into marine and estuarine waters are considered a significant threat to the structure and function of natural communities and to living marine resources in the United States (Carlton 2001; Johnson et al. 2008). The mechanisms behind biological invasions are numerous, but generally include the rapid transport of invaders across natural barriers (e.g. plankton entrained in ship ballast water, organisms contained in packing material (Japanese eelgrass *Zostera japonica*) or fouling on aquaculture shipments, aquarium trade with subsequent release to natural environments). Nonnative species can be released intentionally (i.e., fish stocking and pest control programs) or unintentionally during industrial shipping activities (e.g., ballast water releases), aquaculture operations, recreational boating, biotechnology, or from aquarium discharge.

Sensitivity scores –

Mortality: 1 (juvenile and adult forms of all species); Direct mortality from exotic species is generally not considered an issue at this time for these marine species.

Behavior/Physiology: 1 (juvenile and adult forms of all species); Behavioral interactions with exotic competitors or habitat forming species is generally not considered an issue at this time for these marine species.

Trends: The rate of biological species introductions has increased exponentially over the past 200 years, and it does not appear that this rate will level off in the near future (Carlton 2001). The U.S. Department of Transportation projects that, compared to 2001, total freight moved through U.S. ports will increase by more than 50 percent by 2020 and the volume of international container traffic will more than double (American Association of Port Authorities Fact Sheet 2011: http://www.aapa-ports.org/files/PDFs/facts.pdf). In order to estimate the potential for species invasions, we used data on the total amount of shipping cargo (tonnage) that moved through each port in the Unites States as a proxy. This data was available from the US Army Corps of Engineers Navigation Data Center (http://www.ndc.iwr.usace.army.mil/data/datawcus.htm). CSV files were available for years 1993 – 2009. We limited and summed the tonnage from each port for each year for waterways in CA, OR, and WA.

Among ports along the West Coast of the United States, we detected a negative trend over the last five years in the amount of shipping activity (Fig. 58). If these trends continue and enforcement of ballast water transfer regulations are enforced, then the probability of biological invasions affecting native marine fishes in the next five years may decrease as well. However, this short-term trend is likely influenced by current economic conditions and the trend in the future may very likely increase as USDOT projects.

COASTAL TRASH

Threat data layer description, from Halpern et al. (2009) : Good spatial data do not exist for marine debris at sea, but beach clean up efforts provide data for the amount of trash that ends up on (and impacts) intertidal ecosystems. The State of California collects county-level statistics on the amount of trash collected from coastal areas each year as part of the California Coastal Commission Public Education Program (http://www.coastal.ca.gov/publiced/pendx.html). We extracted data for the years 2003-2007 and calculated the average amount of trash collected, and then divided this county-level average by the number of coastal pixels per county to obtain the average pounds of trash collected per 1 km^2 of coastline. Similar data do not exist for Washington, Oregon, or Baja, but we chose to include this layer given its importance and length of the California coastline relative to the region. Intertidal ecosystems in California will have marginally higher cumulative impact scores due to this inclusion.

Effects: Marine debris causes stress to organisms that ingest it mistaking it for food, most notably sea birds, sea turtles, and some sea mammals. Ingestion by some species, resulting in mortality (Derraik 2002). Behavioral effects – may concentrate fish (FAD, Artificial reefs).

Sensitivity scores –

Mortality: 1 (juvenile and adult forms of all species). Marine trash is not likely to affect these species; the most likely effects would be from ingestion, but there are few good examples in the fish literature.

Behavior/Physiology: 1 (juvenile and adult forms of all species). Marine trash is not likely to affect the behavior of these species; however, effects may be positive for some reef species….?

Trends: While in some areas of the world, the quantities of marine debris apparently show a decreasing trend during the past two decades (Ribic et al. 1997), other authors have reported increases. (Coe and Rogers 1997).

In order to estimate trends in coastal trash, we used the same data source as Halpern et al. 2009: California Coastal Commission's Public Education Program (www.coastal.ca.gov/publiced/ccd/data.xls). This data provided counts of trash picked up off of California beaches from 1989 – 2010. We did not detect any short-term trend, but the short-term mean is above the upper standard deviation of the long-term mean, suggesting that there has been an increased amount of trash over the last five years compared to the entire time series (Fig. 59).:

CLIMATE CHANGE THREATS

We did not include time series data for these climate change threats, because they are dealt with in more precise detail elsewhere in the IEA process. They were included to provide perspective to the magnitude of other non-fisheries related threats. However, the details of the data for each threat layer are included below as well as the scoring rationale for the Sensitivity scores for each threat.

OCEAN ACIDIFICATION

Data layer description: Data for all three measures of climate change stressors (sea surface temperature anomalies, UV radiance anomalies, and ocean acidification) were taken from global data described elsewhere (Halpern et al. 2008), clipped to the California Current region. Briefly, SST anomalies measure the number of times SST was higher in the most recent five years (2000-2005) relative to the longer term (1985-2005) variance (measured as standard deviation). UV radiation anomalies were calculated in the same manner, but with a shorter range of data comparison (2000-2004 vs. the long term variance 1996-2004). Ocean acidification was modeled as the change in aragonite saturation state from pre-industrial times (1870) to modern times (2000-2009). All data layers were represented at 1km^2 resolution.

Effects: Increased acidity in oceans is expected to effect calcium carbonate availability in seawater, which would lower the calcification rates in marine organisms (e.g., mollusks and crustaceans, some plankton, hard corals) (IPCC 2007). Alteration of water alkalinity could have severe impacts on primary and secondary production, which have implications at the ecosystem level (Fabry et al. 2008). Increasing atmospheric carbon dioxide concentrations and altered seawater carbonate chemistry could have a range of effects, including physiological changes to marine plankton on the organismal level, changes in ecosystem structure and regulation, and large scale shifts in biogeochemical cycling (Fabry et al. 2008). For example, increased carbon dioxide concentrations are predicted to decrease the carbonate saturation state and cause a reduction in biogenic calcification of corals and some plankton, including coccolithophorids and foraminifera; however, increasing carbon dioxide concentrations could increase the rates of photosynthetic carbon fixation of some calcifying phytoplankton.

Juvenile salmon in weakly acidic freshwater streams do not respond to alarm cues (Leduc et al. 2006). The hatchling stages of some fish species appear fairly sensitive to pH decreases on the order of 0.5 or greater, but high CO_2 tolerance developed within a few days of hatching (Fabry et al. 2008).

Sensitivity scores –

Mortality: 3 (juvenile forms of all species); 2 (adult forms of all species); Theoretically lethal (3) for all life history stages based on effects of ocean acidification on primary and secondary production being manifested at ecosystem level, but scored sublethal (2) for adults based on no specific literature documenting mortality in these species.

Behavior/Physiology: 3 (juvenile forms of all species); 2 (adult forms of all species). Theoretically, juveniles would be more susceptible to the behavioral effects of low pH; adults scored moderate (2) based on no specific literature documenting behavioral change in these species.

Trends: Increasing atmospheric carbon dioxide concentrations may acidify the oceans, reducing pH levels by 0.14 and 0.35 units by 2100 (IPCC 2007). The uptake of anthropogenic carbon since 1750 has led to an average decrease in pH of 0.1 units; however, the effects of observed ocean acidification on marine ecosystems are unclear at this time.

SEA SURFACE TEMPERATURE

Data layer description: Data for all three measures of climate change stressors (sea surface temperature anomalies, UV radiance anomalies, and ocean acidification) were taken from global data described elsewhere (Halpern et al. 2008), clipped to the California Current region. Briefly, SST anomalies measure the number of times SST was higher in the most recent five years (2000-2005) relative to the longer term (1985-2005) variance (measured as standard deviation). UV radiation anomalies were calculated in the same manner, but with a shorter range of data comparison (2000-2004 vs. the long term variance 1996-2004). Ocean acidification was modeled as the change in aragonite saturation state from pre-industrial times (1870) to modern times (2000-2009). All data layers were represented at $1km^2$ resolution.

Effects: Temperature affects nearly every aspect of marine environments, from cellular processes to ecosystem function (Johnson et al. 2008). The distribution, abundance, metabolism, survival, growth, reproduction, productivity, and diversity of marine organisms will all be affected by temperature changes. Most marine organisms are able tolerate a specific temperature range and will become physiologically stressed or die after exposure to temperatures above or below the normal range. At sublethal levels, temperature extremes can effect the growth and metabolism of organisms, as well as behavior and distribution patterns. Reproduction timing and the rates of egg and larval development are dependent upon water temperatures. The reproductive success of some cold water fish species may be reduced if water temperatures rise above the optimum for larval growth (Johnson et al. 2008). Stratification could affect primary and secondary productivity by altering the composition of phytoplankton and zooplankton, thus affecting the growth and survival of fish larvae. However, in warmer ocean areas phytoplankton became less abundant as sea surface temperatures increased further, possibly because warm water blocks nutrient-rich deep water from rising to the upper strata where phytoplankton exist; effects have been implicated as a factor in the decline in North Sea cod stocks. Impacts to the base of the food chain would not only affect fisheries but will impact entire ecosystems. Mountain (2002) predicted a northward shift in the distributional patterns of many species of fish because of increasing water temperatures in the Mid-Atlantic region as a result of climate change.

Sensitivity scores –

Mortality: 2 (juvenile and adult forms of all species). Theoretically lethal (3) based on effects of primary and secondary production being manifested at ecosystem level, but scored sublethal (2) based on lack of specific literature documenting mortality in these species

Behavior/Physiology: 3 (juvenile and adult forms of all species). Theoretically severe response (3) based on effects of temperature change being manifested as behavioral change such as habitat avoidance or range shifts that effect local ecosystem.

Trends: The Intergovernmental Panel on Climate Change (IPCC) concludes that recent human-induced increases in atmospheric concentrations of greenhouse gases are expected to cause much more rapid changes in the earth's climate than have previously been experienced (IPCC 2007). By 2100 average global surface air temperatures will increase by 1.8°C (lower-emissions scenario) to 4.0°C (higher-emissions scenario) above 2000 levels. The most drastic warming will occur in northern latitudes in the winter.

ULTRAVIOLET LIGHT

Data layer description: Data for all three measures of climate change stressors (sea surface temperature anomalies, UV radiance anomalies, and ocean acidification) were taken from global data described elsewhere (Halpern et al. 2008), clipped to the California Current region. Briefly, SST anomalies measure the number of times SST was higher in the most recent five years (2000-2005) relative to the longer term (1985-2005) variance (measured as standard deviation). UV radiation anomalies were calculated in the same manner, but with a shorter range of data comparison (2000-2004 vs. the long term variance 1996-2004). Ocean acidification was modeled as the change in aragonite saturation state from pre-industrial times (1870) to modern times (2000-2009). All data layers were represented at $1 km^2$ resolution.

Effects: The eggs and larvae of many fish are sensitive to UV-B exposure. However, imprecisely defined habitat characteristics and the unknown effect of small increases in UV-B exposure on the naturally high mortality rates of fish larvae are major barriers to a more accurate assessment of effects of ozone depletion on marine fish populations (Hader et al. 2003). Visual predators, including most fish, are necessarily exposed to damaging levels of solar UV radiation. Skin and ocular components can be damaged by UV, but large differences are found between different species. Coral reef fishes can adapt to the UV stress by incorporating UV-absorbing substances, which they acquire through their diet, into their eyes and epidermal slime.

In addition to direct effects, including damage to biological molecules such as DNA and proteins and the generation of reactive oxygen species, photoactivation of organic pollutants and photosensitization may be detrimental (Hader et al. 2003). The damaging effects on eggs and larval stages may be enhanced by polycyclic aromatic hydrocarbons (PAHs) such as retene, which is a pollutant from pulp and paper mills. Solar UV radiation has been shown to induce DNA damage in the eggs and larvae of the Atlantic cod, where larvae were more sensitive than eggs. Artificial UV causes massive apoptosis in larval embryos of Japanese flounders. Use of video taping and measurement of oxygen consumption showed sublethal effects of UV radiation in juvenile rainbow trout. Under worst-case scenarios (60% ozone loss, sunny weather and low water turbulence), solar UV-B eliminated buoyancy and caused mortality within 1 or 2 days. Fish spawning depth strongly correlates with UV exposure. It is not known whether the fish are able to detect and avoid the high UV at shallower depths in the highUV lake or whether this spawning pattern is due simply to differential survival. A similar phenomenon has been observed in bluegill larvae (*Lepomis macrochirus*) in a UV-transparent lake where in 19% of nests the estimated UV-induced mortality of larvae exceeds 25%.Most nests are exposed to relatively low UV levels because they are either located at deeper depths or under overhanging branches (Hader et al. 2003).

Sensitivity scores –

Mortality: 3 (juvenile forms of all species); 1 (adult forms of all species); Evidence of mortality in juveniles and eggs, especially when exposed to PAH or other photo-activated chemicals.

Behavior/Physiology: 2 (juvenile and adult forms of all hake and sablefish; juvenile forms of bocaccio and canary rockfish); 1 (adult forms bocaccio and canary rockfish). Theoretically the effects of increased ultraviolet radiation on fishes is moderate (2), resulting in higher melanin production and potential alteration of spawning behavior (freshwater literature); however, large benthic species would not be susceptible to these effects.

Trends: Levels of biologically active ultraviolet radiation reaching the earth's surface appear to be gradually increasing, based on several locations where monitoring has been conducted since the late 1970's (McKenzie et al. 2003).

OTHER POTENTIAL THREATS

HYPOXIA (NOT USED IN THE CURRENT ANALYSIS – WAITING ON SPATIALLY-EXPLICIT DATA):

Data layer description: Oxygen data from 2009-2010 Pacific groundfish survey (Keller et al. in prep)

Effects: Demersal fish and benthic invertebrate communities in shallow shelf waters of the California Current were acutely affected by seasonally persistent anoxia and severe hypoxia. In August 2006, surveys along previously monitored (2000 to 2004) transect lines revealed the complete absence of all fish from rocky reefs that normally serve as habitats for diverse rockfish (*Sebastes* species) communities that are of current fishery management concern (Chan et al. 2008). Change in activity such as swimming speed and growth and avoidance of low oxygen conditions by changing the habitat have been observed in the marine environment quite frequently (Ekau et al. 2010). Sablefish, as well as a number of other fish species (e.g., Dover sole) exploit oxygen minimum zones; oxygen interfaces may be important to these species as aggregation sites or predation refugia (Levin 2003).

Sensitivity scores –

Mortality: 2 (juvenile and adult forms of all species). Assumes most species effects will be manifested behaviorally.

Behavior/Physiology: 3 (juvenile and adult forms of all species, except adult sablefish); 2 (adult form of sablefish, which may be physiologically adapted to exploit oxygen minimum zones).

Trends: There are no records of anoxia over the continental shelf prior to Chan et al. (2008). Spatial and temporal variability of dissolved oxygen (DO) in the southern California Current System (CCS) analyzed over the period 1984–2006 showed large declines in DO (up to 2.1 mmol/kg/y) throughout the domain, with the largest relative DO declines occurring below the thermocline (mean decrease of 21% at 300 m) (Bograd et al. 2008). Linear trends were significant ($p < 0.05$) at the majority of stations down to 500 m.

HARMFUL ALGAL BLOOMS (NOT USED IN THE CURRENT ANALYSIS – WAITING ON SPATIALLY-EXPLICIT DATA):

Data layer description: none?

Effects: Mortality via direct or indirect exposure; species effect varies based on location in water column, species, mechanism, etc. (Landsberg 2002). There are few specific examples in literature that address effects on these four species, however.

Sensitivity scores –

Mortality: 2 (juvenile and adult forms of all species). Theoretically lethal (3), but scored sublethal (2) based on no specific literature documenting mortality in these species.

Behavior/Physiology: 2 (juvenile and adult forms of all species). Theoretically severe response (3), but scored moderate (2) based on no specific literature documenting behavior/physiology change in these species.

Trends: The recent increase in harmful algal blooms (HABs) in aquatic systems has begun to demonstrate the far-reaching effects of these blooms on species interactions, aquatic animal health and population growth, ecology, human health, and ecosystem integrity, as well as on major industries and economies (Landsberg 2002). Anthropogenic influences interacting with natural processes have helped to increase the frequency of blooms, and the frequency with which toxic species are transferred globally.

LITERATURE CITED*

* Please note that all literature cited in the text above is not listed here in the bibliography yet.

Bograd SJ, Castro CG, Lorenzo ED, Palacios DM, Bailey H, Gilly W, Chavez FP (2008) Oxygen declines and the shoaling of the hypoxic boundary in the California Current. Geophysical Research Letters 35: 1-6

Bottrill MC, Joseph LN, Carwardine J, Bode M, Cook CN, Game ET, Grantham H, Kark S, Linke S, McDonald-Madden E, Pressey RL, Walker S, Wilson KA, Possingham HP (2008) Is conservation triage just smart decision making? Trends in Ecology & Evolution 23: 649-654

Brown DW, McCain BB, Horness BH, Sloan CA, Tilbury KL, Pierce SM, Burrows DG, Chan S, Landahl JT, Krahn MM (1998) Status, correlations, and temporal trends of chemical contaminants in fish and sediment from selected sites on the Pacific Coast of the USA. Marine Pollution Bulletin 37: 67-85

Carlton JT (2001) Introduced species in U.S. coastal waters: Environmental impacts and management priorities. Pew Oceans Commission, Arlington, VA

Carlton JT, Geller JB (1993) Ecological Roulette - The Global Transport Of Nonindigenous Marine Organisms. Science 261: 78-82

Chan F, Barth JA, Lubchenco J, Kirincich A, Weeks H, Peterson WT, Menge BA (2008) Emergence of anoxia in the California Current large marine ecosystem. Science 319: 920

Coe JM, Rogers DB (1997) Marine debris: sources, impacts, and solutions. Springer, New York

Crossett KM, Culliton TJ, Wiley PC, Goodspeed TR (2005) Population trends along the coastal United States: 1980-2008. National Oceanic and Atmospheric Administration, Coastal Trends Reports Series

Derraik JGB (2002) The pollution of the marine environment by plastic debris: a review. Marine Pollution Bulletin 44: 842-852

Douglass SL, Pickel BH (1999) The tide doesn't go out anymore - the effects of bulkheads on urban bay shorelines. Shore and Beach 67: 19-25

Drake JM, Lodge DM (2004) Global hot spots of biological invasions: evaluating options for ballast-water management. Proceedings Of The Royal Society Of London Series B-Biological Sciences 271: 575-580

Duce RA, LaRoche J, Alteri K, Arrigo KR, Baker AR (2008) Impacts of atmospheric Nitrogen on the open ocean. Science 320: 893-897

Dwight RH, Brinks MV, SharavanaKumar G, Semenza JC (2007) Beach attendance and bathing rates for Southern California beaches. Ocean & Coastal Management 50: 847-858

Ekau W, Auel H, Portner HO, Gilbert D (2010) Impacts of hypoxia on the structure and processes in pelagic communities (zooplankton, macroinvertebrates and fish). Biogeosciences 7: 1669-1699

EPA (2008) National Coastal Condition Report III. EPA/842-R-08-002, Washington, DC

Fabry VJ, Seibel BA, Feely RA, Orr JC (2008) Impacts of ocean acidification on marine fauna and ecosystem processes. ICES J. Mar. Sci. 65: 414-432

Ferdaña Z, Beck MW, Dorfmann D (2006) Improving Methods for Marine Regional Assessments: Examples from the Pacific Northwest., Arlington, VA

Gianessi LP, Marcelli MB (2000) Pesticide use in U.S. crop production: 1997. National Center for Food and Agricultural Policy, Washington, DC

Hader DP, Kumar HD, Smith RC, Worrest RC (2003) Aquatic ecosystems: effects of solar ultraviolet radiation and interactions with other climatic change factors. Photochemical & Photobiological Sciences 2: 39-50

Halpern BS, Kappel CV, Selkoe KA, Micheli F, Ebert CM, Kontgis C, Crain CM, Martone RG, Shearer C, Teck SJ (2009a) Mapping cumulative human impacts to California Curent marine ecosystems. Conservation Letters 2: 138-148

Halpern BS, Kappell CV, Selkoe KA, Micheli F, Ebert CM, Kontgis C, Crain CM, Martone RG, Shearer C, Teck SJ (2009b) Mapping cumulative human impacts to California Current marine ecosystems. Conservation Letters 2: 138-148

Halpern BS, Walbridge S, Selkoe KA, Kappel CV, Micheli F, D'Agrosa C, Bruno J, Casey KS, Ebert C, Fox HE, Fujita R, Heinemann D, Lenihan HS, Madin EMP, Myers R, Perry M, Selig E, Spalding M, Steneck R, Watson R (2008) A global map of human impact on marine ecosystems. Science 319: 948-952

Hutson SS, Barber NL, Kenny JF, Linsey KS, Lumia DS, Maupin MA (2005) Estimated Use of Water in the United States in 2000. USGS Circular 1268

IPCC (2007) Climate change 2007: the physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [IPCC], New York, NY

Johnson HM, Domagalski JL, Saleh DK (2011) Trends in pesticide concentrations in streams of the western United States, 1993-2005. Journal of the American Water Resources Association 47: 265-286

Johnson MR, Boelke C, Chiarella LA, Colosi PD, Greene K, Lellis K, Ludemann H, Ludwig M, McDermott S, Ortiz J, Rusanowsky D, Scott M, Smith J (2008) Impacts to marine fisheries habitat from nonfishing activities in the Northeastern United States. NOAA Tech. Memo. NMFS-NE-209, Gloucester, MA

Kildow J, Colgan CS (2005) California's ocean economy: report to the resources agency State of California

Landsberg JH (2002) The Effects of Harmful Algal Blooms on Aquatic Organisms. Reviews in Fisheries Science 10: 113-390

Leduc AOHC, Roh E, Harvey MC, Brown GE (2006) Impaired detection of chemical alarm cues by juvenile wild Atlantic salmon (Salmo salar) in a weakly acidic environment. Canadian Journal of Fisheries and Aquatic Science 63: 2356-2363

Levin LA (2003) Oxygen minimum zone benthos: Adaptation and community response to hypoxia. Oceanogr. Mar. Biol. Annu. Rev. 41: 1-45

Logan DT (2007) Perspective on ecotoxicology of PAHs to fish. Human and Ecological Risk Assessment: An International Journal 13: 302-316

Longcore T, Rich C (2004) Ecological light pollution. Frontiers in Ecology and the Environment 2: 191-198

Love MS, Schroeder DM, Lenarz W, MacCall A, Bull AS, Thorsteinson L (2006) Potential use of offshore marine structures in rebuilding an overfished rockfish species, bocaccio (Sebastes paucispinis). Fish. Bull. 104: 383-390

Love MS, Yoklavich M, Thorsteinson L (2002) The rockfishes of the northeast Pacific. University of California Press, Berkeley

Macdonald RW, Morton B, Addison RF, Johannessen SC (2002) Marine environmental contaminant issues in the North Pacific: What are the dangers and how do we identify them? North Pacific Marine Science Organization (PICES), Sidney, B.C., Canada

Macreadie PI, Fowler AM, Booth DJ (2011) Rigs-to-reefs: will the deep sea benefit from artificial habitat? Frontiers in Ecology and the Environment

McKenzie RL, Bjorn LO, Bais A, Ilyasd M (2003) Changes in biologically active ultraviolet radiation reaching the Earth's surface. Photochemical & Photobiological Sciences 2: 5-15

National Research Council (2007) Mitigating shore erosion along sheltered coasts. National Academies Press, Washington, D.C.

Nelsen C, Pendleton L, Vaughn R (2007) A socioeconomic study of surfers at Trestles Beach. M.S. Thesis. M.S. Thesis, Los Angeles

Nolan BT, Hitt KJ (2006) Vulnerability of shallow ground water and drinking-water wells to nitrate in the United States. Environmental Science & Technology 40: 7834-7840

Paerl HW, Dennis RL, Whitall DR (2002) Atmospheric deposition of nitrogen: Implications for nutrient over-enrichment of coastal waters. Estuaries 25: 677-693

Ribic CA, Johnson SW, Cole CA (1997) Distribution, type, accumulation, and source of marine debris in the United States, 1989–1993. In: Coe JM, Rogers DB (eds) Marine debris: Sources, impacts, and solution. Springer, New York, pp 35-47

Rostad A, Kaartvedt S, Klevjer TA, Melle W (2006) Fish are attracted to vessels. ICES J. Mar. Sci. 63: 1431-1437

Ryberg KR, Vecchia AV, Martin JD, Gilliom RJ (2010) Trends in pesticide concentrations in urban streams in the United States, 1992–2008. U.S. Geological Survey Scientific Investigations Report 2010–5139

Samhouri JS, Levin PS (In review) Linking land- and sea-based activities to risk in coastal ecosystems. Biological Conservation

Shipman H, Dethier MN, Gelfenbaum G, Fresh KL, Dinicola RS (2010) Puget Sound shorelines and the impacts of armoring - Proceedings of a state of the science workship, May 2009. U.S. Geological Survey Scientific Investigations Report 2010-5254

Sinderman CJ (1994) Quantitative effects of pollution on marine and anadromous fish populations. NOAA Technical Memo. NMFS-F/NEC-104, U.S. Dept. Commerce, Woods Hole, MA

Sogard SM, Olla BL (1998) Behavior of juvenile sablefish, *Anoplopoma fimbria* (Pallas), in a thermal gradient: Balancing food and temperature requirements. Journal of Experimental Marine Biology and Ecology 222: 43-58

Syvitski JPM, Peckham SD, Hilberman R, Mulder T (2003) Predicting the terrestrial flux of sediment to the global ocean: a planetary perspective. Sedimentary Geology 162: 5-24

Syvitski JPM, Vorosmarty CJ, Kettner AJ, Green P (2005) Impact of humans on the flux of terrestrial sediment to the global coastal ocean. Science 308: 376-380

Teck SJ, Halpern BS, Kappell CV, Micheli F, Selkoe KA, Crain CM, Martone R, Shearer C, Arvai J, Fischhoff B, Murray G, Neslo R, Cooke R (2010) Using expert judgment to estimate marine ecosystem vulnerability in the California Current. Ecological Applications 20: 1402-1416

Toft JD, Cordell JR, Simenstad CA, Stamatiou LA (2007) Fish distribution, abundance, and behavior along city shoreline types in Puget Sound. North American Journal of Fisheries Management 27: 465-480

West J, O'Neill S, Lomax D, Johnson L (2001) Implications for reproductvie health in rockfish (Sebastes spp.) from Puget Sound exposed to polychlorinated biphenyls Puget Sound Research 2001

Wilber DH, Clarke DG (2001) Biological effects of suspended sediments: A review of suspended sediment impacts on fish and shellfish with relation to dredging activities in estuaries. North American Journal of Fisheries Management 21: 855-875

Williams GD, Thom RM (2001) Development of guidelines for aquatic habitat protection and restoration: marine and estuarine shoreline modification issues. Prepared for the WA State Department of Transportation, WA Department of Fish and Wildlife, and the WA Department of Ecology

World Commission on Dams (2000) Dams and development: a new framework for decision-making. Earthscan Publications, Ltd, London, UK

CHAPTER 4: QUANTIFYING THE ABUNDANCE AND CONDITION DYNAMICS OF CHINOOK SALMON (*ONCORHYNCHUS TSHAWYTSCHA*) AND PREY IN THE CENTRAL CALIFORNIA COASTAL REGION.

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THE QUESTION: IS THERE A SUITE OF QUANTIFIABLE FACTORS AFFECTING CALIFORNIA SALMON IN THE OCEAN?

INTRODUCTION

Population productivity of fish is largely derived from survival during a critical period in their early life history whereby it is essential that there be match temporally and spatially between juvenile fish and their prey resources (Hjort 1914, Lasker 1978, Cushing 1990). Specific to salmon populations, it is accepted that growth and mortality during the first period at sea is a primary determinant of later adult salmon abundance from that cohort (Pearcy 1992, Beamish & Mahnken 2001, Beamish et al. 2004, Quinn 2005). The first few months following emigration to the Gulf of the Farallones has been identified as a critical location and period of time during which central California Chinook salmon (*Oncorhynchus tshawytscha*) recruitment is set (MacFarlane 2010). However, only inferential statistics on survival to the point after the first ocean winter (OW) from tagging studies and *in situ* measures of juvenile condition have been used to evaluate early mortality effects on later spawning abundance (Lindley et al 2009, MacFarlane 2010). Quantifying environmental and biological mechanisms that drive early condition and likely juvenile salmon survival is essential for predicting salmon populations (Beamish et al 2004). Specifically, an ecosystem perspective may better elucidate the mechanisms acting on salmon dynamics (Wells et al. 2008a). We do, however, in this first report, restrict our discussion to Central California salmon. In the complete report we will include information on additional populations.

In any discussion of the mechanisms forcing early condition of salmon, the environmental effects should be considered as they likely act, ultimately, as predictors of future abundance. A dramatic example of environment on salmon dynamics is the collapse of adults from the 2004 and 2005 brood years (2005 and 2006 emigration years) of California's Sacramento River fall-run Chinook salmon resulting from weak late initiation of the upwelling season as the juveniles entered the Gulf of the Farallones. Lindley et al

(2009) examined a suite of environmental variables but, other than the clear effects of upwelling dynamics generally, there has been no mechanistic understanding developed for quantifying the relationships between salmon dynamics and environmental factors. The examination of environmental drivers of salmon dynamics has been by no means complete, but numerous studies have successfully developed correlative models whereby inferential relationships between wind, upwelling, and secondary production leads or tracks survival and growth dynamics (e.g. Beamish & Bouillon 1993, Koslow et al. 2002, Logerwell et al. 2003, Wells et al. 2006, 2007, 2008b). Quantifying the links between ocean variables and the salmon recruitment is critical for improving forecast models. Our objectives relate to connectivity between trophic levels and environmental conditions and the functional relationships between them. Specifically, we determine if linking oceanographic parameters (e.g. wind) and aspects of the juvenile salmon's prey provide more predictive power for understanding future changes in salmon populations.

The phenology of the California current ecosystem has been implicated as the critical force acting on salmon survival. Specifically, the spring transition date (the day on which cumulative upwelling is greater than zero), and the winter conditions preceding transition have been shown to have an indirect role on ecosystem productivity in central California (Bograd et al. 2009, Schroeder et al. 2009, Wells et al 2008). The anomalously late arrival of the spring transition in 2005 and 2006 has been considered a likely candidate for the recent salmon collapse. Beyond intra-annual phenological considerations, studies have demonstrated that population dynamics can actually relate more significantly to conditions experienced in the previous year, including Chinook salmon growth and maturation (Wells et al. 2007). If the mechanisms behind such annual lags can be quantified, the otherwise tangled ecosystem functional relationships can be described.

The region that juvenile central California Chinook salmon inhabit when they enter the ocean system at the Gulf of the Farallones is immediately south of a predominate geographic point, Point Reyes (38˚N Fig. 78). The dominant wind direction (northerly) and strength occurring locally are correlated to the large-scale factors (eg. El Niño, Pacific Decadal Oscillation phase shifts). Once the upwelling system is fully developed in early spring, five reasonably stable meso-scale features exist between Point Arena (38.3N) and Monterey Bay (Graham & Largier 1997, Wing et al 1998). These include an upwelling jet occurring at the prominence of Point Reyes, a back eddy forming in the Gulf of the Farallones, an oceanic ocean plume or freshwater outflow plume, a second upwelling plume forming just north of Monterey Bay, and an upwelling shadow forming in Monterey Bay (Graham & Largier 1997, Wing et al 1998). These local features have the potential to work in concert to promote or disrupt overall productivity of the region. Specifically, the region south of Point Reyes and east of the Farallon Islands, the Gulf of the Farallones, provides a relaxed area wherein nutrients from upwelling are retained, and krill and juvenile fishes can converge (Wing et al 1998, Santora et al. 2011a, b). The development of this feature and continual enrichment of nutrients from the upwelling jet may relate directly to the dynamics of juvenile Chinook salmon and ultimately the final number of adults.

We determine if there is evidence that the first period at sea is the critical period defining the overall central California Chinook salmon adult abundance. Secondly, we examine the spatio-temporal scale at which the environment and resulting production and spatial distribution of krill (*Euphausiacea*) affects the early survival and condition of Chinook salmon. We hypothesize that multiple cohorts of krill occurring concomitantly increases prey availability to salmon affecting their condition and survival.

METHODS

Study area and collection techniques

The study area is located off central California spanning Point Reyes (38°N) to Monterey Bay (36.5°N). We combine data series from trawl surveys and data sets with overlapping temporal coverage. Importantly, for each data series we use the complete series covering all years for which data existed (Table 10). Data from a midwater trawl survey (Sakuma et al. 2006) and a surface trawl survey (MacFarlane 2010) are used to develop environmental indices and estimates of krill, salmon diet and physiological condition. The midwater trawl survey operates annually during May-June; the same period that juvenile salmon emigrate to the ocean. The surface trawl survey focused in the same region but occurred during June-August and was designed specifically to collect juvenile salmon (MacFarlane 2010). By July, juvenile salmon tend to be distributed outside of the Gulf of the Farallones and north of Point Reyes. Therefore, the midwater trawl survey represented conditions for salmon entering the ocean while the surface trawl survey represented the cumulative condition of juvenile salmon having begun passing through the Gulf of the Farallones.

Krill data

We use time series of species-consolidated krill (mostly *Euphausia pacifica* and *Thysanoessa spinifera*) from 39 stations between Point Reyes and Monterey Bay during 1990-2009 (Fig. 78). Samples were collected from a modified Cobb midwater trawl, with a head rope depth of 30 m (the average depth of the thermocline in the region) at a speed of ~2 knots for 15 minutes at depth (Sakuma et al. 2006). As all trawls were conducted similarly, these values represent catch per unit effort. Midwater trawl catches at each station were averaged and then we calculated the mean krill abundance per station each year. We also calculated the average abundance of krill at two stations within the Gulf of the Farallones (Fig. 78). To quantify the effects of krill distribution on juvenile Chinook salmon diet and condition, we calculated the mean of station latitudes weighted by the mean abundance of krill captured at each station (this provided a centroid of latitudinal distribution). A northerly mean latitude of krill indicates greater overlap between krill and juvenile salmon in the Gulf of the Farallones and around Point Reyes. While annual mean latitude is not a measure of abundance it can be considered a standardized measure of distribution between years (not dependent on absolute abundance differences between years).

Beginning in 2002, analysis of the midwater trawl krill catch was expanded to include species identification. Length frequency measurement of krill was made using traditional zooplankton nets in 2008-2009. In 2008, 0.7 diameter Bongo nets equipped with 505 micron nets and codends were used, while in 2009 a $1m^2$ Tucker trawl equipped with 333 micron net and codend was utilized. For both years tows were conducted immediately prior to the first midwater trawl of the evening in an identical manner (15 minute duration at 30 meters depth).

<ins>Environmental data</ins>

Environmental data includes CTD casts collected at the three closest westwards stations to the Farallon Islands (1990-2008; Fig. 78). We calculated the thermocline depth as indicated by the greatest change in temperature occurring between successive 2m depth bins. The greatest difference in temperatures used to define the thermocline was used as an estimate of stratification. These stations allowed for at least an 80m cast depth while the depth within the Gulf of the Farallones (~55m) was too shallow to get reasonable thermocline depth estimates. Wind speed data (wind speed cubed; turbulence) was collected from a buoy located within the Gulf of the Farallones (National Data Buoy Center #46026; 1990-2008 minus 1991 and 1998 which were unavailable; Fig. 78). Wind speed was used to determine the environmental force determining thermocline depth and stratification. The dominant wind direction in the region during May - August is northerly so wind speed represents not only the wind strength in the region but also correlates with the amount of upwelling and transport (Wells et al. 2008a); important drivers of ecosystem dynamics in this region (Checkley & Barth, 2009). While upwelling winds are critical for nutrient introduction and development of mesoscale structure (e.g., upwelling plumes, eddies, fronts), too strong a northerly wind can lead to advection and more diffuse aggregations of krill (Cury & Roy 1989, Santora et al. 2011b) . To represent the climatological mesoscale structuring and degree of advection we used QuikSCAT remote data on meridinal Ekman transport for the region .

<ins>Chinook salmon data</ins>

There were incidental catches of juvenile salmon in the midwater trawl across the 39 stations during 1990-2009. We use these incidental catches as a representation of the distribution of juvenile salmon during May-June. During June-August 1995-2005, juvenile salmon were collected from the surface trawl in the California central coastal ocean following methods and sample locations in MacFarlane (2010). For each of these fish (N = 1541) a Fulton's K index of condition (Fulton 1904; $K = (W/L^3 \times 10^5)$) was determined and averaged for each year. Fish stomach contents collected from the surface trawl were quantified during 1995 and 1997-2003 (N=321, yearly averages were used in analyses), using the methods described in MacFarlane & Norton (2002). We restricted our diet samples to fish < 200 mm to better target the fall-run population which is typically smaller than fish from other runs at sea. The four greatest contributors to the average percent volume of diet were juvenile fish (27%), crab (including megalopa and zoea; 20 %), *E. pacifica* (11%), and *T. spinifera* (7%). Annual averages of these volume percents were compared to Fulton's K condition values. During 1995 and 1997-2003 the average lengths of complete *T. spinifera* in the juvenile salmon diets were quantified.

Returning Chinook salmon that spent only a single winter in the ocean (1OW) and then matured a year sooner than average (commonly referred to as "jack" salmon), and 2OW abundances of Chinook salmon were obtained from Pacific Fisheries Management Council 1990-2010 (PFMC 2010). The juvenile salmon used in this study were overwhelmingly Sacramento River fall run Chinook salmon as determined by emigration timing and size. 1OW fish represent those fish that emigrated the year before. The abundance of the 1OW fish returning to spawn represent an estimate of the number of emigrants from the cohort, first year survival, and maturation rate. However, they relate to 2OW abundance a year later. In fact, as much as ~70% of the variability in adult abundance can be accounted for by the number of early maturing fish returning the year before (PFMC 2010). We used values for the Sacramento Index as a measure of adult abundance of Sacramento River fall run Chinook salmon (O'Farrell et al. 2008). While the Sacramento Index represents largely the number of 2OW fish, it is not age specific and includes a smaller fraction of 3OW and 4OW fish (O'Farrell et al. 2008).

RESULTS

Krill distribution

Ekman transport in the lee of Point Reyes is weak relative to that in the upwelling plume (Fig. 79a). Associated with this more relaxed area is a dense population of krill on the shelf within the Gulf of the Farallones (Fig. 79b). During May and June juvenile Chinook salmon emigrate into the region and overlap this dense krill population (Fig. 79c).

Krill abundance exhibited interannual temporal and spatial variability in the central California region. Specifically, the location within the Gulf of the Farallones typically has the greatest krill abundance at the depth which the trawl surveys (Fig. 80a). Examination of the species composition data from the 2003-2009 indicated that the shelf waters from the Gulf of the Farallones to immediately north of Monterey Bay had significantly greater abundance of *T. spinifera* than in Monterey Bay, westward of the Farallon Islands and northward of Point Reyes ($P < 0.05$). By contrast, *E pacifica* was least abundant in the Gulf of the Farallones ($P < 0.05$). This indicates *T. spinifera* is associated with shallower shelf waters while *E. pacifica* distribute to deeper waters along the shelf break. In addition, between 2003 and 2007, *T. spinifera* abundances from the midwater trawls taken are ~10% of the value observed in 2008. In 2009, the abundance dropped to nearly the levels observed in 2003-2007.

The relationship between turbulence and thermocline depth, which correlates well with mixing depth, was significant (linear, $P = 0.0026$, $R^2 = 0.46$, $N = 16$; Fig. 80b). Also, the relationship between turbulence and stratification was negative and significant ($P= 0.016$, $R^2 = 0.33$, $N= 17$). The average latitude of krill abundance was positively related (log-linearly) to thermocline depth ($P = 0.043$, $R^2 = 0.23$, $N = 19$; Fig. 80c). When the thermocline in the Gulf of the Farallones region was approximately 25m or less, krill was less abundant in the Gulf of the Farallones and Point Reyes region.

Importantly, comparison of bongo net, tucker trawl, and midwater trawl data from 2008 (N = 6) and 2009 (N = 11) indicated that the midwater trawl was not capturing *T. spinifera* less than 17 mm (Fig. 81a,b). Further, an examination of 2008 (Fig. 81a) indicated that there were no small *T. spinifera*, yet in 2009 the smaller cohort appeared (Fig. 81b).

<u>Chinook salmon diet and condition</u>

The spatial distribution of krill during May-June did not relate to the volume percent of krill in the diet of juvenile Chinook salmon collected June-August. In fact, the proportion of krill in salmon diet, specifically *T. spinifera,* was less likely in the diet when overall krill were distributed more northerly (linear, $P = 0.0304$, $R^2 = 0.57$, $N = 8$; Fig. 82a). When krill was northerly distributed crab accounted for a larger percentage of salmon diet although the relationship was statistically insignificant (linear, $P = 0.053$, $R^2 = 0.49$, $N = 8$; Fig. 82a). The percent volume of fish in the diet was not related to the distribution of the krill (Fig. 82b).

There was a one year lag in the amount of *T. spinifera* in the diet and the latitudinal distribution of krill (Fig. 82c). This relationship was represented dramatically between the years 1998 and1999. In 1998 no krill was apparent in the midwater trawl survey within the Gulf of the Farallones (Fig. 80a) yet krill were observed in the diets of the juvenile salmon. In contrast, 1999 represented greater krill abundance within the Gulf of the Farallones (Fig. 80a) yet none was found in the juvenile salmon diets, which were dominated by juvenile fishes that year. In addition, the amount of *T. spinifera* in the diet of juvenile Chinook salmon was nominal when the estimate of latitudinal distribution of krill was centered below 37.5°N, but when distributed northward to that it seemed to cross a threshold becoming substantially more present in the diet (Fig. 82c). *E. pacifica* (Fig. 82c), fish, and crab proportional contribution to the diet of juvenile salmon did not show a pattern with lags nor distribution of krill.

The frequency plots for all fish for which *T. spinifera* in the diets were measured, indicated juvenile salmon feed on nearly the entire length frequency distribution (Fig. 82d) however the midwater trawl samples tend to catch larger *T. spinifera* relative to those found in the diet (Fig. 81 a,b).

The condition of juvenile Chinook salmon was related to the latitudinal distribution of the larger krill cohort the previous year ($P = 0.00102$, $R^2 = 0.72$, $N = 11$; Fig. 83a). When krill in the midwater trawl survey was distributed farther north, condition of juvenile salmon emigrating to sea the next year was greater. When krill was distributed northward the year before juvenile salmon ocean entry, salmon diet had proportionally more *T. spinifera.* The condition of the fish is log-linearly related to the amount of *T. spinifera* in salmon diet when present ($P = 0.025$, $R^2 = 0.67$, $N = 7$, with 1999 removed as the fraction of *T. spinifera* in the diet was 0%; Fig. 83b). The percent volume of *E. pacifica,* crab and fish in the diet were not related to fish condition (Fig. 83b, c).

<u>Projecting salmon abundance</u>

The number of 1OW salmon returning to spawn tracked the condition of the juvenile salmon the year before when they first entered the ocean system, yet the relationship was insignificant (Power, $P = 0.057$, $R^2 = 0.345$, $N = 11$; Fig. 84a). These 1OW numbers were significantly related to cumulative number of adults (Sacramento Index) caught and spawned the next year ($P = 0.0001$, $R^2 = 0.71$, $N = 19$; Fig. 84b). The relationship between the latitudinal distribution of mean krill abundance in a given year was significantly related to the abundance of salmon three years later ($P = 0.0015$, $R^2 = 0.53$, $N = 16$, minus 1992 with Cook's $D = 3.702$; Fig. 84c).

DISCUSSION

Gulf of the Farallones ecosystem and early condition of Chinook salmon
The Gulf of the Farallones is a shallow region in the lee of the Point Reyes upwelling plume and receives nutrients from the plume water by means of eddies (Wing et al. 1998). These eddies in the slow relaxed region of the Gulf of Farallones provide proper conditions for primary productivity and retention of krill (Santora et al 2011a, b) and pelagic larval fish (Wing et al 1998). If there are optimal winds (Cury & Roy 1978) and hence increased upwelling, nutrient influx, mesoscale structuring, and limited advection, krill biomass is accumulated across at least two years. This accumulated krill is then spatially coherent with juvenile salmon. The relationships between the consumption of three prey items to salmon condition and productivity shows that only *T spinifera* was significantly related. Therefore, salmon dynamics are related to the abundance and distribution of krill in the Gulf of the Farallones whereby increased availability to *T spinifera* relate to better condition and productivity. Specifically, in this study it is important to focus on, the climatological match between environment, prey, and juvenile salmon (Fig. 79), the positive effect of a northern distribution of krill on juvenile condition (Fig. 83a) and the ultimate positive effect on the later abundance of salmon as adults (Fig. 84c): an indication of the effect of early survival and condition on population dynamics.

<u>The critical period</u>
The accepted tenant is that the first period at sea for salmon accounts for the greatest amount of mortality across the life history and is, therefore, the period of time at which the abundance of spawners and fish available to the fishery is established (Beamish et al. 2004). There has been limited direct evidence of this relationship. For instance, given the size selectivity of the fishery and limited mark recovery, the youngest age for which a reliable estimate of mortality can be obtained is 1OW: a full year after ocean emigration. Here we show that the condition of salmon captured during the summer of ocean entry is reasonably correlated to the number of 1OW fish to return a year later (although at a $P = 0.057$). That the 1OW return rate is dependent on the confounded variables maturation and mortality suggests that the relationship we demonstrate is a powerful representation of the effects of condition on survival to age 1OW. That 1OW return numbers correlate very well with the number of fish from the cohort returning a year later indicates that the covariability between juvenile condition and 1OW fish returns was simply not a representation of condition early in life mediating 1OW maturation. Notably, that 1OW fish

correlate to early condition and then the number of fish returning yet a year later indicates that recruitment is indeed set at the period of ocean entry. This result was the primary suggestion offered by Lindley et al (2009) for why the condition of the average juvenile salmon can, during some years, be improved on average as the remaining population of the healthiest remaining individuals moves from summer season to the fall.

Salmon are migratory fish living in a dynamic environment related to the climate at different spatial and temporal scales. Large-scale events and conditions such as El Niño or Pacific Decadal Oscillation phase shifts can affect the entirety of the California Current ecosystem. However, as salmon first enter the ocean they may be most strongly affected by mesoscale features, with greater sensitivity to larger-scale features and conditions as they age and migrate. Wells et al. (2006, 2007, 2008b) demonstrated that the size at maturity, growth rate, and maturation rates can be affected by conditions at the large- (1000s km) and regional-scales (100s km). Here, we show the relationship of juvenile salmon condition to mesoscale structures (10s km). We demonstrate that minor shifts in krill distribution can dramatically affect the likelihood that fish will survive to maturation. This relationship likely represents a shift not only in the distribution, but in the species composition of the krill community, such that the larger, and more energetically rich species (*T. spinifera*) is more available for juvenile salmon. Specifically, juvenile salmon condition was dependent on the habitat quality and availability of forage in the region just eastward of the Farallon Islands. As juvenile salmon first enter the ocean they remain in the Gulf the Farallones and are rarely ever found south (MacFarlane 2010). Their residence here however is reasonably short as by late summer the fish begin their migration northward (MacFarlane 2010).

<u>Krill as an ecosystem indicator of Chinook salmon condition and survival</u>

Krill, specifically *T. spinifera* , make up, on average, only 7% of the volume of the diet but clearly have a positive log-linear relationship on the condition of juvenile Chinook salmon especially once the diet was 5% or more *T. spinifera* (Fig. 83b). The same was not true for other prey items. This suggests that while *T. spinifera* is a subdominant prey item, it is critical. Fig. 80a shows that the region of the Gulf of the Farralones typically has much higher abundance of krill than the other locations sampled in this study. *E. pacifica* is usually found in waters at or beyond the shelf-break (200-1000m) and over submarine canyons, whereas *T. spinifera* populates coastal habitats extending to the outer-shelf (Brinton 1962, Tanasichuk 1998 a,b, Feinberg & Peterson 2003, Marinovic et al. 2002, Gómez-Guitiérrez et al. 2005, Dorman et al. 2005). The reproductive ecology of *E. pacifica* and *T. spinifera* involves multiple spawning attempts throughout the year, the timing of which appears to be synchronized to increased wind events (Brinton 1962, 1976, Tanasichuk 1998 a,b, Feinberg & Peterson 2003, Shaw et al., 2010). *T. spinifera* are larger than *E. pacifica* and are nearly as nutrition rich as larval fish prey (Daly et al 2010). In total, the presence of multiple cohorts of *T. spinifera* on the shelf offers the potential for a nutrient rich and abundant prey resource for juvenile salmon that use that environment.

Our data suggests a positive relationship between crab volume in the diet and northerly distribution on krill in the same year. It is likely crab become entrained in the Gulf of the

Farallones like krill. Unlike krill, which appear to remain regionally for at least two years, crab would not be expected to show a lag in pattern between diet and trawl survey results. Interestingly, the increased crab in the diet did not translate to better condition. This suggest the fish may not be selecting crab to obtain better condition but rather because it was within the size range of interest (Mean = 3.5mm, Min = 1mm, Max = 6mm) while the smaller cohort of *T. spinifera* was not present. As such, we demonstrate that during years with increased abundance of only the larger cohort of *T. spinifera*, the fish select crabs.

There was a log-linear relationship between water column characteristics and the distribution of krill yet when krill were distributed farther north they did not show up the diets of juvenile salmon until the next year. This is curious and, at first, counter intuitive. However, the explanation may be in the biology of the *T. spinifera*. Interestingly, *T. spinifera* had multiple cohorts in a given year (Fig. 81a,b). Data from the bongo net and tucker trawl samples collected between 2008-2009 suggest that the large spawning stock of *T. spinifera* in 2008 produced strong juvenile recruitment in 2009 as a consequence of winter/early spring spawning. In contrast, during 2008, following lower *T. spinifera* abundance detected in 2007 (Fig. 80a), showed no such recruitment. We also demonstrated that the smaller cohort of *T. spinifera* was represented in the diets of juvenile salmon. Specifically, juvenile salmon diet was made up of the juveniles resulting from the previous year's spawning stock. Yet, the midwater trawl, the data for which we have longest and most reliable series, fails to capture the smaller cohort of the *T. spinifera*.

We have not captured all the mechanisms forcing salmon dynamics and the system is more complex than that presented here. For instance, we removed the 1999 diet data from our analysis of the effect of *T. spinifera* in the diet on condition of juvenile salmon because during a year when there was no krill present in the juvenile salmon diets (following 1998 during which there was none in the environment) they maintained reasonably good condition (Fig. 83b). In fact, the responses that foragers have to a dynamic prey field are not linear and, therefore, their resultant condition may not be as well. It is also possible that we sampled a select group of survivors from 1999 which, if we believe condition relates to survival, would inherently have above average condition. In addition to 1999, 1992 presented an interesting scenario. Specifically, in a relationship between condition and adult abundance three years later (Fig. 84), 1992 was an extreme outlier. In fact, 1992 was an anomalous year in many regards across both the freshwater and marine environment: high fishing pressures followed by drought conditions in 1992 led to the lowest adult abundance on record prior 2007 (Lindley et al 2009), krill in the Gulf of the Farallones region was estimated to be absent (Fig. 80a), yet, when we apply our three year lag, the 1995 adult abundance resulting from the recruitment of juveniles during these conditions was the second greatest on record (Lindley et al 2009).

Environmental conditions in the ocean have been implicated as a factor in forcing salmon dynamics. However, few studies have drawn the direct link between atmospheric conditions and prey and the recruitment of salmon to the spawning population (Peterson & Schwing 2003). Here, we have demonstrated a likely path between wind and early salmon survival. If wind slows during the upwelling season or the upwelling season begins late, the thermocline near the Farallon Islands is shallow and more stratified. This, in turn, alters the latitudinal distribution of krill. We cannot yet determine the cause of a change in distribution. However, a plausible hypothesis would be that the stratified and shallow mixed layer leads to reduced primary productivity and/or productivity derived from dinoflagelates as opposed to diatoms (Rykaczewski & Checkley 2008). While a switch in primary producers to dinoflagellates has been demonstrated immediately south of the Farallon Islands there are no studies in the immediate location.

<u>Application to management</u>
We demonstrate significant relationships between salmon diet, condition, and later recruitment by simply including a one year lag in the data between midwater trawl samples and the juvenile salmon that enter the ocean system a year later. While this lag is derived from sampling biases, there remains value in the data. Firstly, we have an understanding of the mechanism and, therefore, remove the primary concerns of the bias from our analysis. Secondly, we have the opportunity to use the midwater trawl survey to inform our estimates of the condition and survival of juvenile salmon a year before they even reside in the ocean. In fact, the relationships seem to dominate the system dramatically with the ultimate number of spawners and harvestable fish being highly significantly related to the distribution of krill the year their previous cohort returned to spawn (Fig. 84c). Future efforts will allow us to confirm (or refute) this hypothesis, as krill are now routinely identified to the species level in the surveys described here, and ongoing efforts are being undertaken to compare catch rates and size selectivity among multiple gear.

As part of the study we inherently included a forecasting model for the number of fish available to fishery and spawning 2OW (Fig. 84b). Specifically, the Sacramento Index was forecasted using a regression on the number of 1OW fish to return the year prior. This model assumes that the majority of variability in mortality occurs by age 1OW. We show here this is likely the case. In addition, we show there is potential to improve the forecast model by including information from the earliest period at sea or even the year before the cohort emigrates to sea: that year that the previous cohort returned to spawn. We show this dramatically in Fig. 84c wherein the Sacramento Index is regressed against the latitudinal distribution of krill occurring the year the previous cohort returned to spawn.

A goal of salmon management is to make certain that a given number of spawners is allowed to enter the river to spawn and assure the viability of the stock. Currently, managers make no adjustments to the escapement goals they set forward; a static escapement goal is used between years. Yet, there may be interest in adjusting this value if, in a given year when spawners are returning, the midwater trawl indicates there are very few adult *T. spinifera*. Following, there would be fewer of the next cohort of *T. spinifera* available to juveniles entering the ocean the next year. If managers act cautiously by allowing more spawners to enter the river during years when the adult *T. spinifera* abundance is reduced they may mitigate the increased mortality that is to follow on the juveniles the next year.

In this chapter we do not address the issue of predation on salmon however, in final documents we will include information on top predators: sea lions and striped bass. As of 2005, the year for which there was the last published pup counts, the California sea lion population has been at carrying capacity (Figure 85)(data source, Marine Mammal Stock Assessment Report, prepared in 2007 by Office of Protected Resources, NOAA, http://swfsc.noaa.gov/prd-sars/,). For reading on the impact of a primary predator, sea lions, see Weise and Harvey (2005 and 2008) wherein it is demonstrated that California sea lions can depredate hooked salmon at rates as great as ~30%. Additionally, the depredation rate is greatest during poor ocean production years. Therefore, as resources for salmon are limited the impact of sea lion predation is greatest, possibly creating a negative synergistic effect. Importantly, no estimates of the actual relationships between depredation and vital rates of salmon has been made, however, depredation can effectively increase harvest as the fishery mitigates the losses to sea lions.

We also do not address the impact of hatchery contribution in salmon population health but have included this information in the summary report of Chapter 1. The timing of certain behavioral characteristics, such as emigration to sea, migration along the coast, and return timing, may vary within each run type and across years. For instance, fall-run Chinook salmon express a degree of behavioral variability within and between years. However, hatchery production of fall-run Chinook salmon,, as currently managed, is relatively homogenized. Therefore, if hatchery production overwhelms natural production, we run the risk of stock collapse much like that observed for the Sacramento River fall-run Chinook salmon. The proportion of Sacramento River fall-run Chinook salmon spawning in hatcheries has increased to its greatest values during the last six years and natural production has been reduced (Figure 86). Note, that while the estimates are substantially greater than previous years there is no specific trend within the recent five year period (data source, Hatchery contribution data was obtained from Table II-1 of PFMC March 2011 Preseason Report I: Stock abundance analysis and environmental assessment part 1 for 2011 ocean salmon fishery regulations; http://www.pcouncil.org/salmon/stock-assessment-and-fishery-evaluation-safe-documents/preseason-reports/).

Conclusion

We have tested the hypothesis that survival during the first period at sea for Chinook salmon represents the greatest amount of survival variability in the population during ocean residence. We demonstrated a supported mechanism between the environment, prey resources, and Chinook salmon survival. Specifically, the degree of collocation between *T. spinifera* and juvenile Chinook salmon determines the success of a cohort; if *T spinfera* is on the shelf in the Gulf of the Farallones more is consumed, the condition of the salmon improves, and the later adult abundance is greater. Interestingly, we show that the krill abundance and distribution in one year is partly the result of an accumulated biomass from the previous year. This relationship was reliable enough that the dynamics of Chinook juveniles could be confidently modeled by krill abundance the year before juveniles had even emigrated to sea. Finally, we offer an ecosystem-informed population model that can be directly used to advise management of Chinook salmon years before current models, therefore, allowing for more adaptive management.

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References

Beamish RJ, Bouillon DR (1993) Pacific salmon production trends in relation to climate. Canadian Journal of Fisheries and Aquatic Science. 50:1002–1016.

Beamish RJ, Mahnken C (2001) A critical size and period hypothesis to explain natural regulation of salmon abundance and the linkage to climate and climate change. Progress in Oceanography. 49:423–437.

Beamish RJ, Mahnken C, Neville CM (2004) Evidence that reduced early marine growth is associated with lower survival of coho salmon. Transactions of the American Fisheries Society. 133: 26–33.

Bograd SJ, Schroeder ID, Sarkar N, Qiu X, Sydeman WJ, Schwing FB (2009) The phenology of coastal upwelling in the California Current, Geophysical Research Letters, 36, L01602, doi:10.1029:/2008GL035933

Brinton E (1962) The distribution of Pacific euphausiids. Bulletin of Scripps Institute of Oceanography 8: 51-270.

Brinton E (1976) Population biology of *Euphausia pacifica* off southern California. Fisheries Bulletin 74: 733-762.

Checkley DM, Barth JA (2009) Patterns and processes in the California Current System. Progress in Oceanography 83:49-64.

Cury P, Roy R (1989) optimal environmental window and pelagic fish recruitment success in upwelling areas. Canadian journal of Fisheries and Aquatic Sciences 46:670-680.

Cushing DH (1990) Plankton production and year-class strength in fish populations: an update of the match/mismatch hypothesis. Advances in Marine biology 26:250-293.

Daly EA, Benkwitt CE, Brodeur RD, Litz M, Copeman LA (2010) Fatty acid profiles of juvenile salmon indicate prey selection strategies in coastal marine waters. Marine Biology 157 (9): 1975-1987.

Dorman J, Bollens G, Slaughter AM (2005) Population biology of euphausiids off northern California and effects of short time-scale wind events on *Euphausia pacifica*. Marine Ecology Progress Series 288: 183-198.

Feinberg LR, Peterson WT (2003) Variability in duration and intensity of euphausiid spawning off central Oregon, 1996-2001. Progress in Oceanography 57: 262-379.

Fulton TW (1904) The rate of growth of fishes. Fisheries Board of Scotland, Annual Report 22 part 3, pp. 141–241.

Graham WM, Largier JL (1997) Upwelling shadows as nearshore rentention sites: the example of northern Monterey Bay. Continental Shelf Research 17:509-532.

Gómez-Gutiérrez J, Peterson WT, Miller CB (2005) Cross-shelf life-stage segregation and community structure of the euphausiids off central Oregon (1970–1972). Deep Sea Research Part II: Topical Studies in Oceanography 52:289-315.

Hjort J (1914) Fluctuations in the great fisheries of northern Europe viewed in the light of biological research. Rapports et Proces-verbaux des Reunions, Conseil International pour l'Exploration de la Mer 20: 1-228

Koslow JA, Hobday A, Boehlert GW (2002) Climate variability and marine survival of coho salmon (*Oncorhynchus kisutch*) off the coast of California, Oregon and Washington. Fisheries Oceanography. 11:65–77.

Lasker R (1978) The relationship between oceanographic conditions and larval anchovy food in the California Current: identification of factors contributing to recruitment failure. Rapports et Proces-verbaux des Reunions, Conseil International pour l'Exploration de la Mer 173:212-230

Lindley ST, Grimes CB, Mohr MS, Peterson W, Stein J, Anderson JT, Botsford LW, Bottom DL, Busack CA, Collier TK, Ferguson J, Garza JC, Grover AM, Hankin DG, Kope RG, Lawson PW, Low A, MacFarlane RB, Moore K, Palmer-Zwahlen M, Schwing FB, Smith J, Tracy C, Webb R, Wells BK, Williams TH (2009) What caused the Sacramento River fall Chinook stock collapse? NOAA, Technical Memorandum, NMFS/SWFSC.

Logerwell EA, Mantua NJ, Lawson PW, Francis RC, Agostini VN (2003) Tracking environmental processes inthe coastal zone for understanding and predicting Oregon coho (*Oncorhynchus kisutch*) marine survival. Fisheries Oceanography.12:554–568.

MacFarlane RB (2010) Energy dynamics and growth of Chinook salmon (*Oncorhynchus tshawytscha*) from the Central Valley California during the estuarine phase and first ocean year. Canadian Journal of Fisheries and Aquatic Sciences. 67:1549-1565.

MacFarlane RB, Norton EC (2002) Physiological ecology of juvenile chinook salmon (*Oncorhynchus tshawytscha*) at the southern end of their distribution, the San Francisco Estuary and Gulf of the Farallones, California. Fishery Bulletin 100:244–257.

Marinovic BB, Croll DA, Gong N, Benson SR, Chavez FP (2002) Effects of the 1997–1999 El Niño and La Niña events on the zooplankton abundance and euphausiid community composition within the Monterey Bay coastal upwelling system. Progress in Oceanography 54:265–277.

O'Farrell MR, Mohr MS, Palmer-Zwahlen ML, Grover AM (2008) The Sacramento Index. NMFS Technical Report, September 2008.

Pacific Fishery Management Council. (2010) Preseason Report I: Stock Abundance Analysis for 2009 Ocean Salmon Fisheries.(Document prepared for the Council and its advisory entities.) Pacific Fishery Management Council, 7700 Ambassador Place, Suite 101, Portland, Oregon 9722-1384.

Pearcy DW (1992) Ocean ecology of north Pacific salmonids. University of Washington Sea Grant, Seattle, WA.

Peterson W T, Schwing F (2003) A new climate regime in the northeast Pacific ecosystems. Geophysical Research Letters 30:1896, doi:10.1029/ 2003GL017528.

Quinn TP (2005) The behavior and ecology of pacific salmon and trout. American Fisheries Society Press, Bethesda, MD

Rykaczewski RR, Checkley DM, Jr. (2008) Influence of ocean winds on the pelagic ecosystem in upwelling regions. Proceeding of the National Academy of Sciences 105:1965-1970.

Sakuma KM, Ralston S, Wespestad VG (2006) Interannual and spatial variation in the distribution of young-of-the-year rockfish (Sebastes spp.): expanding and coordinating a survey sampling frame. California Cooperative of Oceanographic Fisheries Investigations, Reports 47, 127-139.

Santora JA, Ralston S, Sydeman WJ (2011a) Spatial organization of krill and seabirds in the central California Current. ICES Journal of Marine Science: 68: 1391-1402

Santora JA, Sydeman WJ, Schroeder ID, Wells BK, Field JC (2011b) Mesoscale structure and oceanographic determinants of krill hotspots in the California Current: Implications for trophic transfer and conservation. Progress in Oceanography.

Schroeder ID, Sydeman WJ, Sarkar N, Bograd SJ, Schwing FB (2009) Effects of winter pre-conditioning on seabird phenology in the California Current, Marine Ecology Progress Series 393:211-223.

Shaw CT, Peterson WT, Feinberg LR (2010) Growth of *Euphausia pacifica* in the upwelling zone off the Oregon coast. Deep-Sea Research II 57, 584-593.

Tanasichuk RW (1998a) Interannual variations in the population biology and productivity of Euphausia pacifica in Barkley Sound, Canada with special reference to the 1992 and 1993 warm ocean years. Marine Ecology Progress Series 173, 163-180.

Tanasichuk RW (1998b) Interannual variations in the population biology and productivity of Thysanoessa spinifera in Barkley Sound, Canada with special reference to the 1992 and 1993 warm ocean years. Marine Ecology Progress Series 173, 181-195.

Wells, BK, Field J, Thayer J, Grimes C, Bograd S, Sydeman W, Schwing F, Hewitt R (2008a) Untangling the relationships among climate, prey, and top predators in an ocean ecosystem. Marine Ecology Progress Series. 364:15-29

Wells BK, Grimes CB, Sneva JG, McPherson S, Waldvogel JB (2008b) Relationships between oceanic conditions and growth of Chinook salmon (*Oncorhynchus tshawytscha*) from Alaska, Washington, and California, USA. Fisheries Oceanography, 17:101-125

Wells BK, Grimes CB, Waldvogel JB (2007) Quantifying the effects of wind, upwelling, curl, turbulence, and sea surface temperature on growth and maturation of a California Chinook salmon (*Oncorhynchus tshawytscha*) population. Fisheries Oceanography 16:363-382

Wells BK, Grimes CB, Field JC, Reiss CS (2006) Covariation between the average lengths of mature coho (*Oncorhynchus kisutch*) and Chinook salmon (*Oncorhynchus tshawytscha*) and the ocean environment. Fisheries Oceanography. 15:67-79.

Wing SR, Botsford L W, Ralston S, Largier JL (1998) Meroplankton distribution and circulation in a coastal retention zones of the Northern California upwelling system. Limnology and Oceanography 43, 1710-1721.

Table 10. Shown are the data series used in this study. CTD represent a conductivity, temperature, and depth instrument, K represents condition ($W/L^3 \times 10^5$), 1OW and 2OW represent one and two winters at sea, and PFMC represents the Pacific Fisheries Management Council.

												Year											
Data	Source	Mo.	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09
Krill	Mid-water trawl	May-Jun		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Bongo	May-Jun																				■	
	Tucker	May-Jun																					■
Wind	Buoy 42026	May		■		■	■	■	■	■	■		■	■	■	■	■	■	■	■	■	■	
Thermocline	CTD	May-Jun		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	
Salmon diet	Surface trawl	Jun-Aug							■		■	■	■	■	■	■	■						
Salmon K	Surface trawl	Jun-Aug							■	■	■	■	■	■	■	■	■	■	■				
Salmon 1OW	PFMC	N/A	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	
Salmon 2OW	PFMC	N/A		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

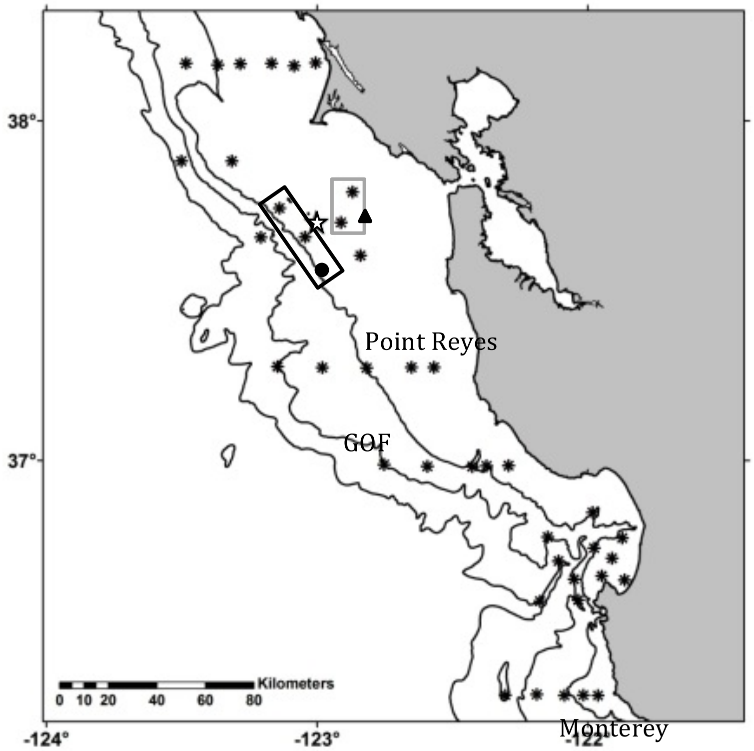


Figure 78. Map of the central California region sampled during the midwater trawl survey (Sakuma et al 2006). Asterisks (*) represents stations sampled 1990-2008. The black border represents the stations used for which thermocline was estimated including an additional station at which CTD was performed regularly 1990-2009 (black circle). The grey border represents the locations used to estimate abundance of krill in the Gulf of the Farallones (GOF). The triangle represents the location of buoy National Buoy Data Center 46026

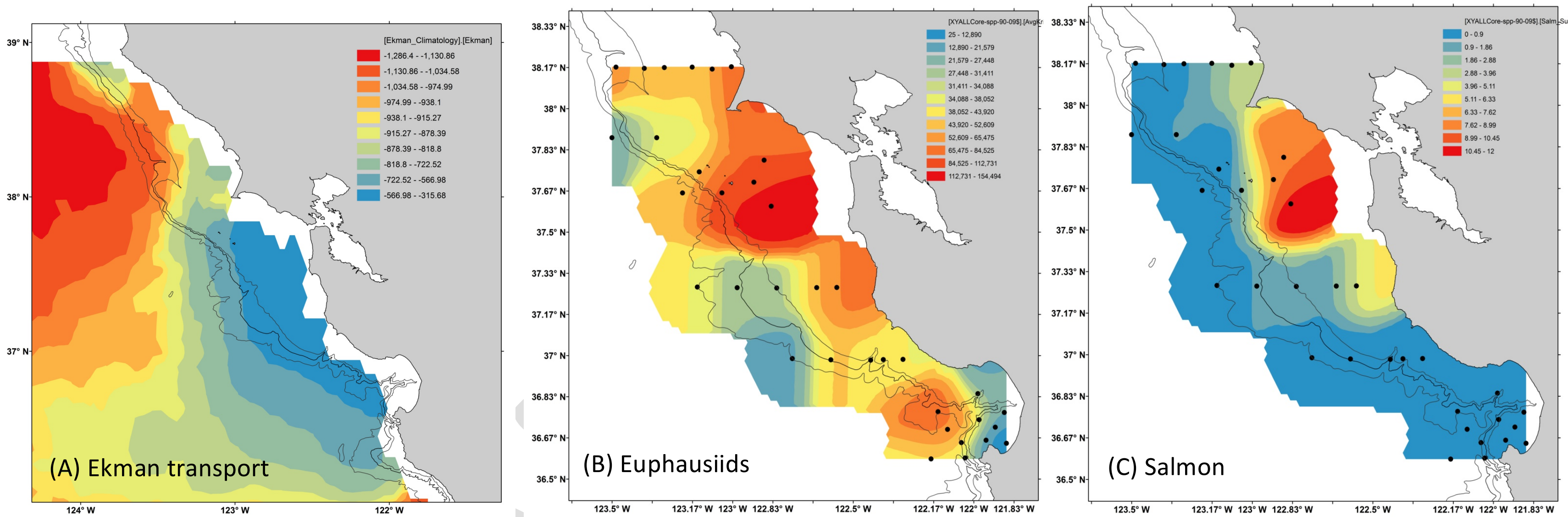


Figure 79. Spatial patterns of (A) Ekman offshore transport (metrics), (B) euphausiids, (C) juvenile Chinook salmon in coastal central California during May-June. Abundance of euphausiids is the long-term mean number of individuals collected per net haul (black dots) 1990-2009. Abundance of salmon is total number of individuals collected during 1990-2009. The Ekman Transport climatology is estimated from the QuikSCAT satellite.

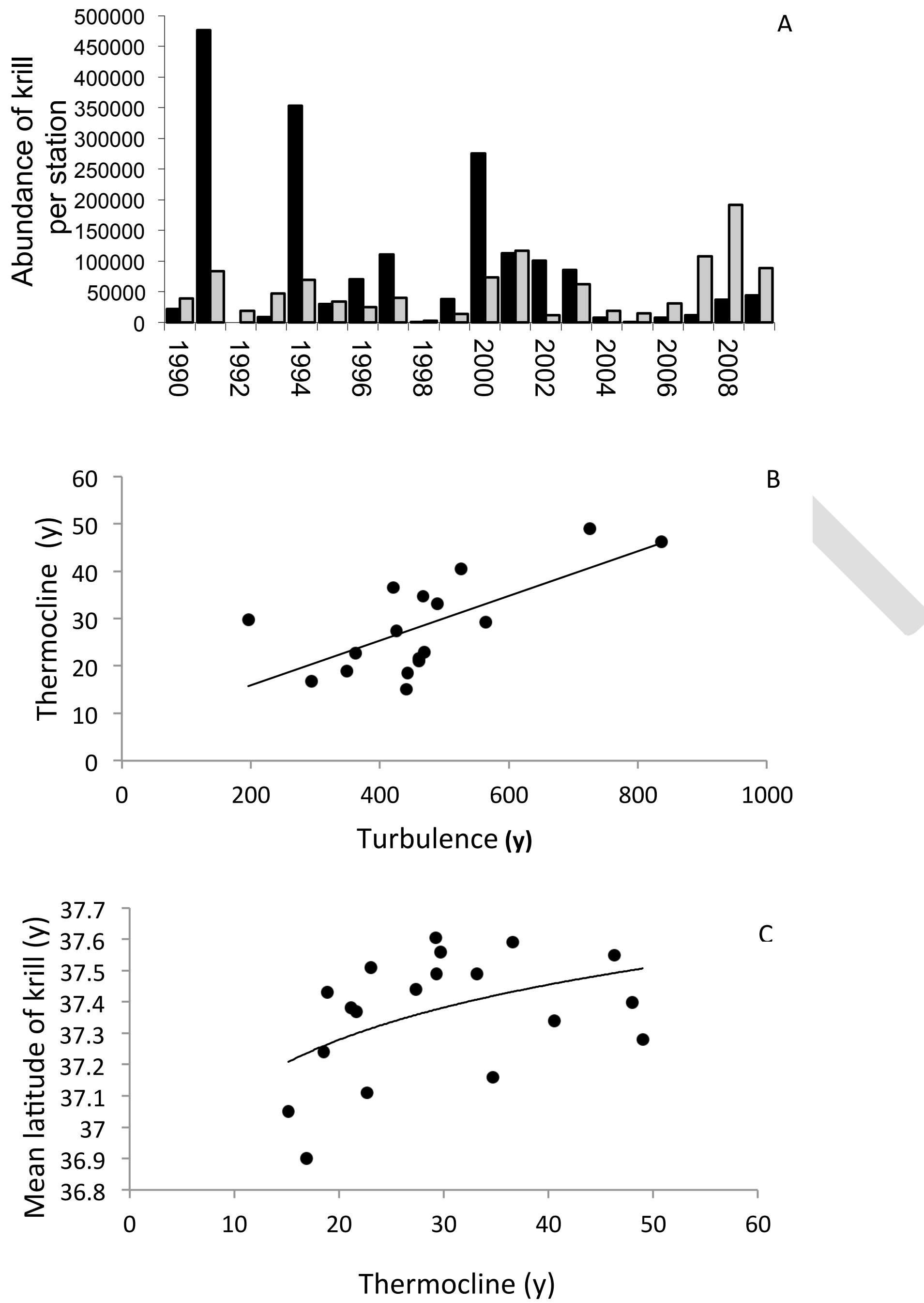


Figure 80. A) represents the average abundance of krill from all midwater trawl sample sites in central California (gray) and from two locations in the Gulf of the Farallones (black), B) shows the relationship between turbulence and thermocline depth just westward of the Farallon Islands, and C) demonstrates the relationship between thermocline depth and the average latitude at which krill is distributed across all sample locations.

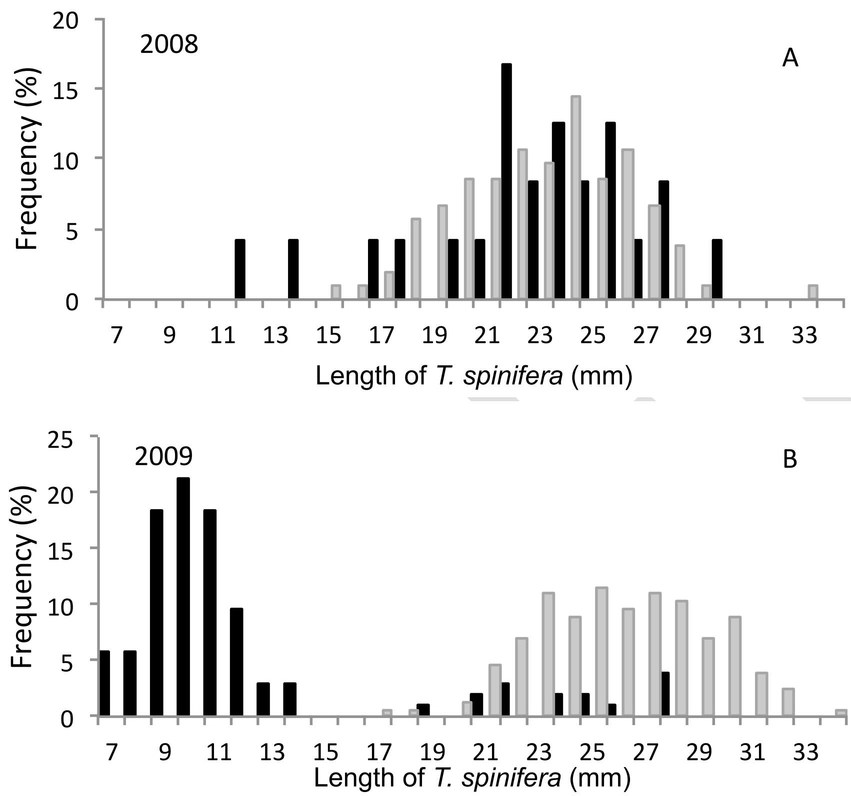


Figure 81. A) shows the size distributions of *T. spinifera* captured in bongo nets (black) and midwater trawls (grey) in 2008, and B) shows the size distributions of *T. spinifera* captured in tucker trawls (black) and midwater trawls (gray) in 2009.

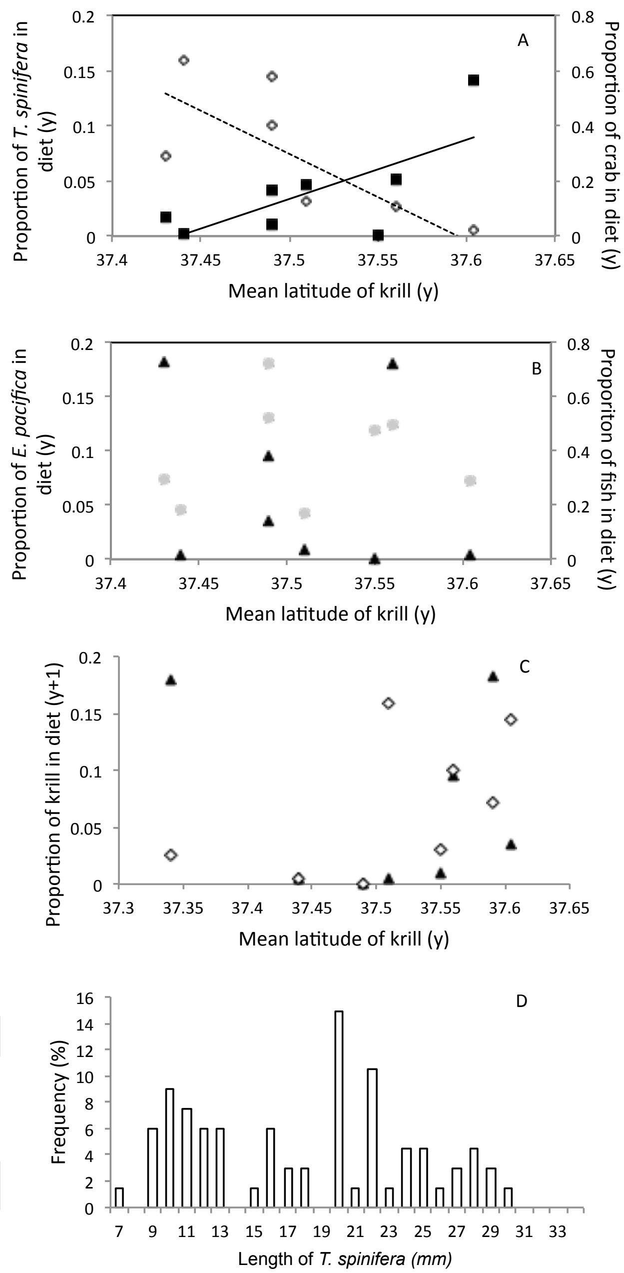


Figure 82. A) shows the relationships between *T. spinifera* (open) and crab (closed) distributions in central California to their proportional contribution to the diet of juvenile salmon, B) shows the lack of correlations between fish (gray) and *E. pacifica* (black) distributions in central California to their proportional contribution to the diet of juvenile salmon , C) shows that the relationship between *T. spinifera* distribution and its proportional contribution to the diet of juvenile salmon the next year (open) is significant but that for *E. pacifica* (black) is not, and D) demonstrates the size distribution of *T. spinifera* measured in the juvenile salmon diets.

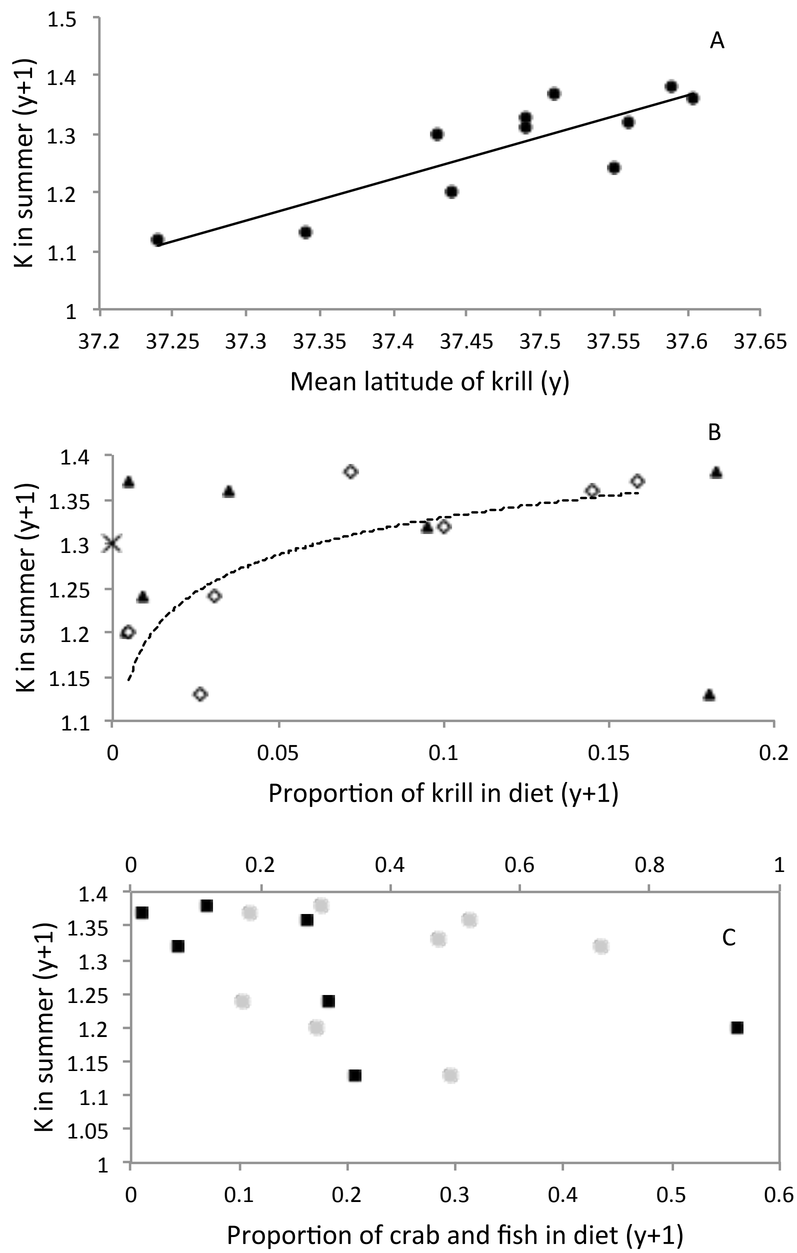


Figure 83. A) demonstrates that the distribution of krill from midwater trawl samples relates to the condition of juvenile salmon the next year, B) demonstrates that *T. spinifera* in the diet is positively related to the condition of juvenile salmon (open) but *E. pacifica* is not (black), while 'x' presents 1999 during which no krill was present in the juvenile salmon diets, and C) demonstrates that the proportion of crab in the diet (black, primary x-axis) nor fish (grey, secondary x-axis) were related to the condition of the fish.

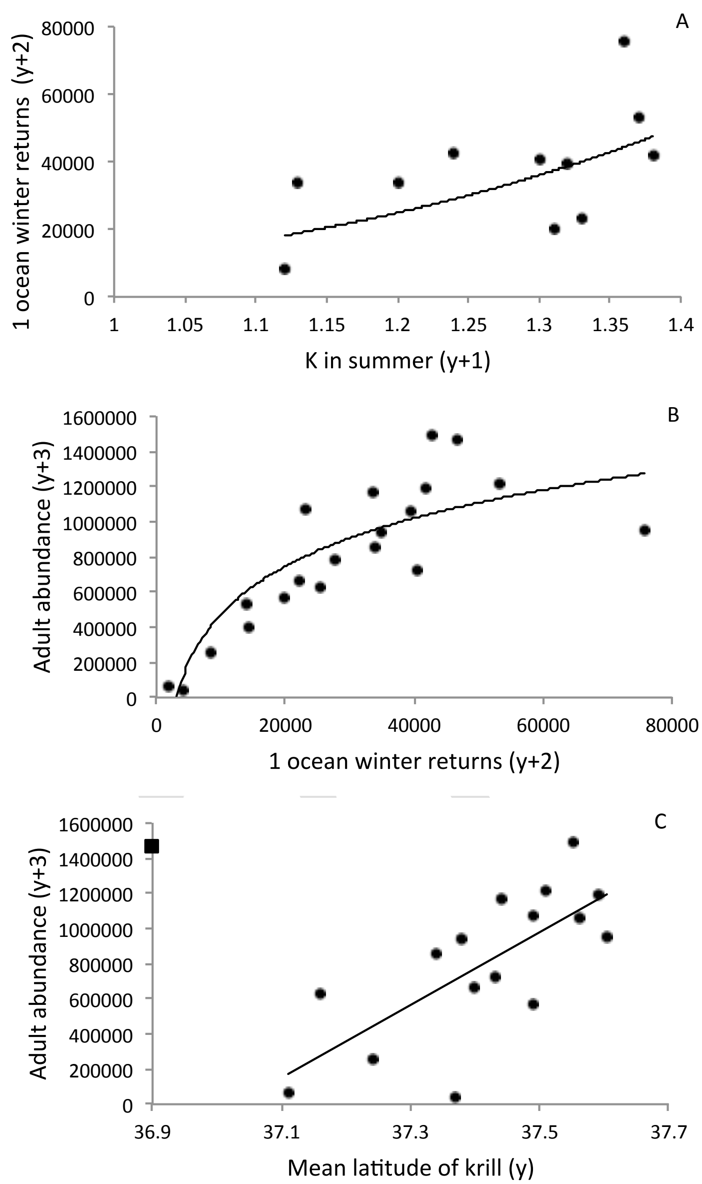


Figure 84. A) demonstrates that the condition of juvenile salmon in the summer is positively related to the number of 1 ocean winter fish (1OW) returning the next year, B) demonstrates that the number of 1OW fish relates positively to the abundance of adult fish (Sacramento Index), returning the following year, and C) represents the relationship between adult abundance and the distribution of krill the year before they migrated to sea (minus 1992, 'x').

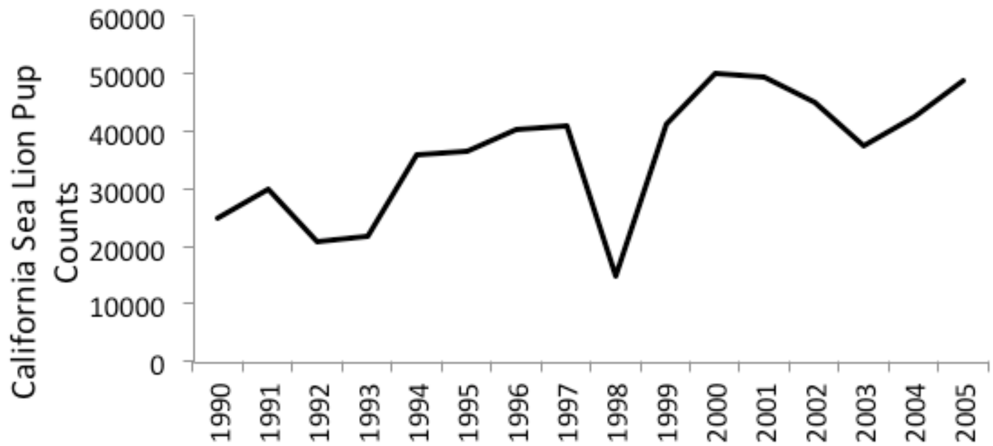


Figure 85. Counts of California sea lion pups along the California coast.

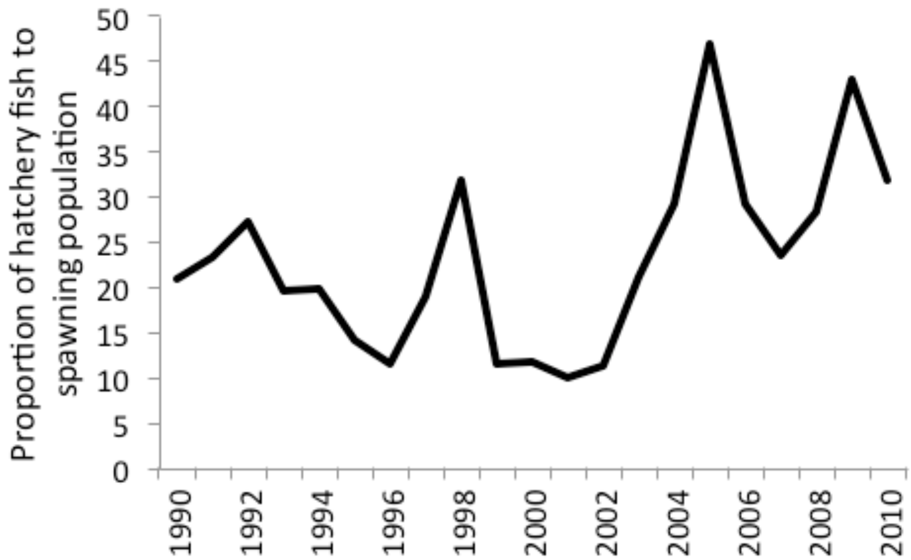


Figure 86. Proportion of Sacramento River Fall run Chinook salmon returning to hatcheries.

Science, Service, Stewardship

Agenda Item H.1.b
Supplemental IEA PowerPoint
November 2011

California Current INTEGRATED ECOSYSTEM ASSESSMENT

PFMC Meeting, Costa Mesa

November 6, 2011

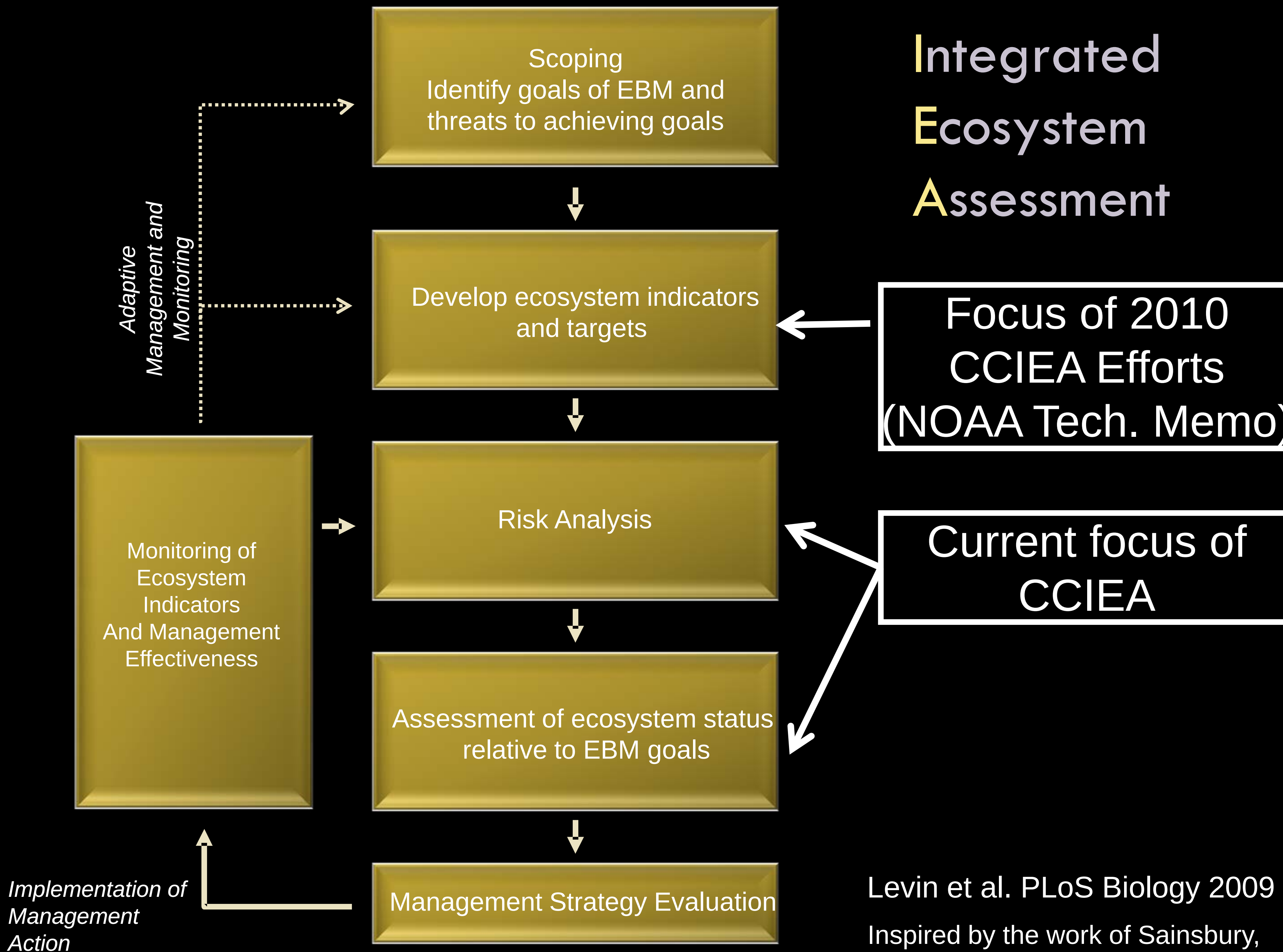
NOAA FISHERIES SERVICE

Integrated Ecosystem Assessment

A process for implementation of EBM

An IEA is a synthesis and quantitative analysis of information on relevant physical, chemical, ecological and human processes in relation to specified ecosystem management objectives.


WE NEED TO ENHANCE OUR SECTOR—RELEVANT SUPPORT FOR A SUITE OF INTEGRATED RISK ASSESSMENT TOOLS.
Dilbert.com
DilbertCartoonist@gmail.com
DO YOU UNDER-STAND?
MAYBE. IS YOUR POINT THAT YOU DON'T KNOW HOW TO COMMUNI-CATE?
9-8-11 © 2011 Scott Adams, Inc./Dist. by Universal Uclick
NO.
OH. THEN I DIDN'T GET IT.



Integrated Ecosystem Assessment

Levin et al. PLoS Biology 2009

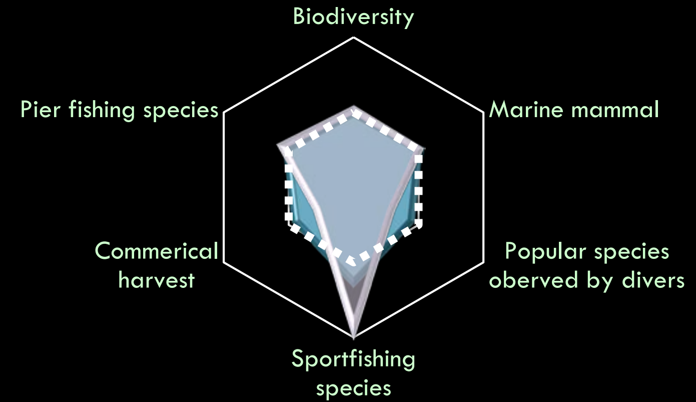
Inspired by the work of Sainsbury, Smith and probably others

CCIEA -- Ecosystem Considerations in FMPs

Overarching IEA: The ecosystem from the ecosystem perspective

"How do fishery practices affect the ecosystem?"

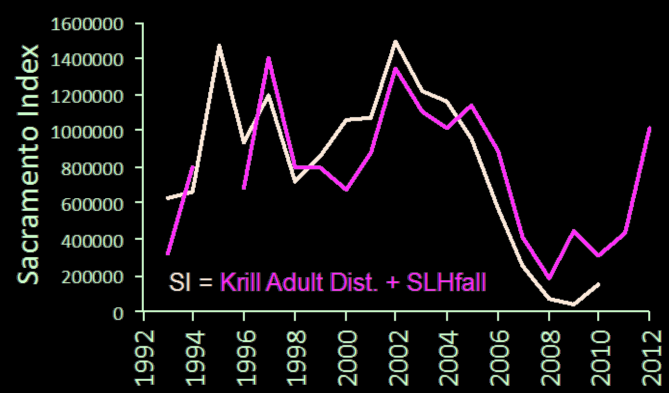
1. Indicator/Target
2. Status
3. Risk
4. MSE



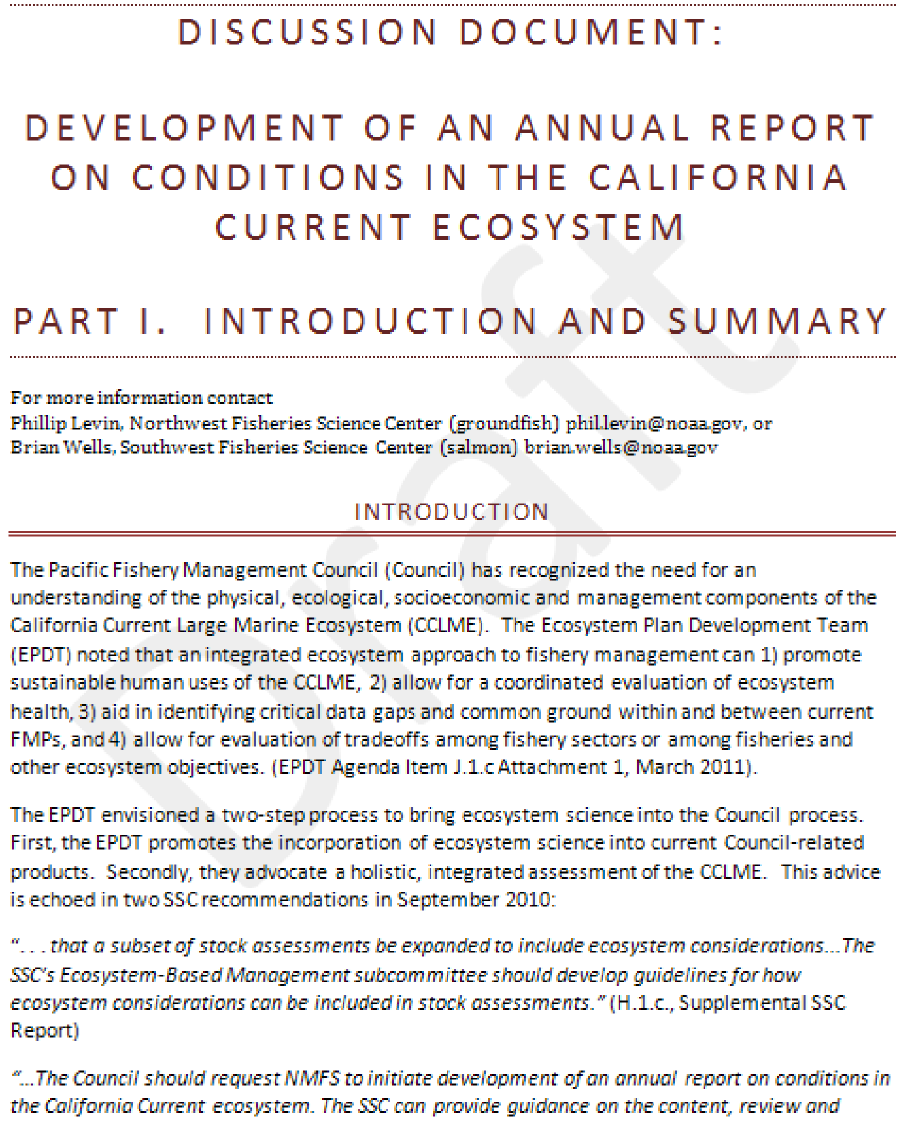
PFMC Focus: The ecosystem from the fish's perspective

" How can information on the ecosystem be used to improve fishery practices?"

1. Climate
2. Ecological interactions
3. Non-fisheries threats
4. Other factors as needed



Presentation to Council SSC – Nov 2nd



DISCUSSION DOCUMENT:

DEVELOPMENT OF AN ANNUAL REPORT ON CONDITIONS IN THE CALIFORNIA CURRENT ECOSYSTEM

PART I. INTRODUCTION AND SUMMARY

For more information contact
Phillip Levin, Northwest Fisheries Science Center (groundfish) phil.levin@noaa.gov, or
Brian Wells, Southwest Fisheries Science Center (salmon) brian.wells@noaa.gov

INTRODUCTION

The Pacific Fishery Management Council (Council) has recognized the need for an understanding of the physical, ecological, socioeconomic and management components of the California Current Large Marine Ecosystem (CCLME). The Ecosystem Plan Development Team (EPDT) noted that an integrated ecosystem approach to fishery management can 1) promote sustainable human uses of the CCLME, 2) allow for a coordinated evaluation of ecosystem health, 3) aid in identifying critical data gaps and common ground within and between current FMPs, and 4) allow for evaluation of tradeoffs among fishery sectors or among fisheries and other ecosystem objectives. (EPDT Agenda Item J.1.c Attachment 1, March 2011).

The EPDT envisioned a two-step process to bring ecosystem science into the Council process. First, the EPDT promotes the incorporation of ecosystem science into current Council-related products. Secondly, they advocate a holistic, integrated assessment of the CCLME. This advice is echoed in two SSC recommendations in September 2010:

". . . that a subset of stock assessments be expanded to include ecosystem considerations…The SSC's Ecosystem-Based Management subcommittee should develop guidelines for how ecosystem considerations can be included in stock assessments." (H.1.c., Supplemental SSC Report)

"…The Council should request NMFS to initiate development of an annual report on conditions in the California Current ecosystem. The SSC can provide guidance on the content, review and

In this document, we focus on the first part of this process – providing ecosystem information that could inform stock assessments and single-species management. In their March 2011 report (Agenda Item J.1.c Attachment 1), the EPDT proposed that NMFS invest time to develop a format for and contents of a Council-focused ecosystem considerations report. They then suggested that the NMFS team work iteratively with the Council and its advisory bodies to refine the format and contents of the document. This document represents the outputs of NMFS' initial investment in this process.

Based on discussion with the EPDT, NMFS opted to focus on a limited number of stocks across three FMPs. These are: hake, sablefish, canary rockfish, bocaccio, Chinook salmon, and sardine. This document focuses on the four groundfish (hake, sablefish, canary rockfish, bocaccio) suggested by the EPDT as pilot species.

HOW THIS DOCUMENT IS ORGANIZED

This document is organized around three basic questions:

1) What are the status and trends of key climate/ocean drivers that influence hake, sablefish, canary rockfish, bocaccio, and Sacramento River Chinook salmon?
2) What are the status and trends of important predators and prey that may influence hake, sablefish, canary rockfish, bocaccio, and Sacramento River Chinook salmon?
3) What are the status and trends of non-fisheries pressures that may influence productivity of hake, sablefish, canary rockfish, bocaccio, and Sacramento River Chinook salmon?

Answering these questions required NMFS staff to answer a number of basic questions about the ecology of the focal species. For example, in order to report the status and trends of key climate drivers, it is necessary to understand the relationship between climate and productivity of focal species. Similarly, documenting status and trends of the forage base c
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3) What are the status and trends of non-fisheries pressures that may influence productivity of hake, sablefish, canary rockfish, bocaccio, and Sacramento River Chinook salmon?

Discussion Document:
Focus on hake, sablefish, canary rockfish, bocaccio, and Sacramento River Chinook salmon

Status and trends of:

- Key **climate/ocean drivers** that influence these stocks
- Important **predators and prey** that influence these stocks
- **Non-fisheries pressures**

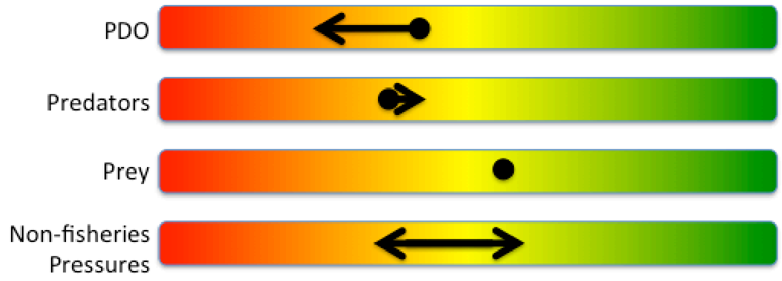
Costa Mesa Discussions

- Presented to SSC, CPS Panels, EAS, Habitat Committee

- Previously presented to EPDT

Examples of Analyses

SABLEFISH



PHYSICAL FORCING

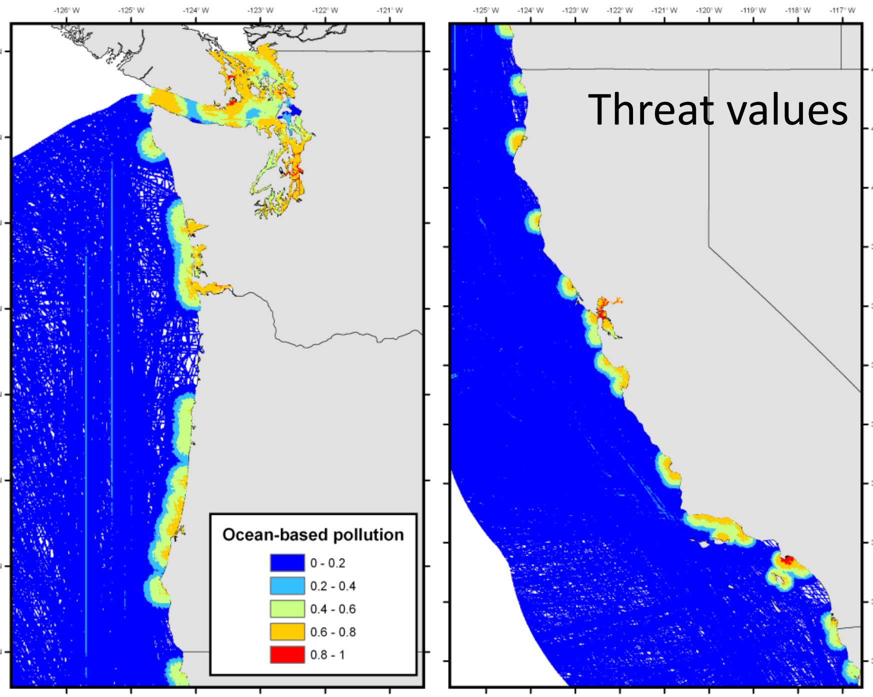
Strong sablefish year classes occur during periods of more intensive Aleutian Low Pressure and after extended periods of below average SST switched to periods of above average temperatures. ENSO effects on sablefish biomass and abundance are weak. Biomass and occurrence of adult sablefish is positively correlated with PDO. Thus, the recent shift to a cool PDO period (past five years) may yield poorer ocean conditions for sablefish. Long-term warming is hypothesized to yield declines in sablefish populations in the southern CC due to reduced spring productivity and copepod production.

TROPHIC INTERACTIONS

Recent densities of sablefish prey are greater than long term mean but may be declining in recent years. Predators on sablefish include pinnipeds, pelagic sharks, large skates, and bocaccio rockfish. Predator abundance is high, but predator biomass appears to be declining in recent years. However, the trends were within historic norms (but the recent decline of predators is just under one s.d. of the long term mean). The sablefish prey index has shown substantial variation through time with a peak in the mid-2000's. (Note that deposit feeders and cephalopods are not included in the prey index and pelagic sharks and bocaccio are absent from the predator index due to lack of data)..

NON-FISHERIES PRESSURES

The status of most of the 19 non-fisheries pressures on sablefish is average with no evidence of improving or declining trends. Some non-fisheries pressures are improving (e.g. nutrient inputs), while others (e.g. coastal engineering) are declining. However, in general the highest risk threats, (e.g., atmospheric deposition of pollutants and increases in sediment runoff) show no trend. When placed in context with climate change pressures (e.g. sea surface temperature), most other non-fisheries pressures pose limited risk to the focal species.



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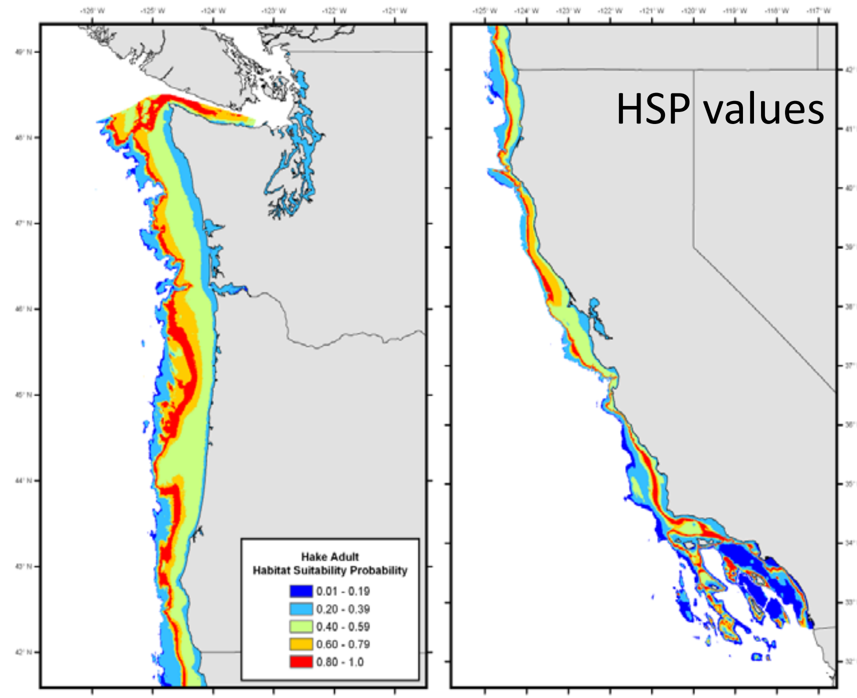

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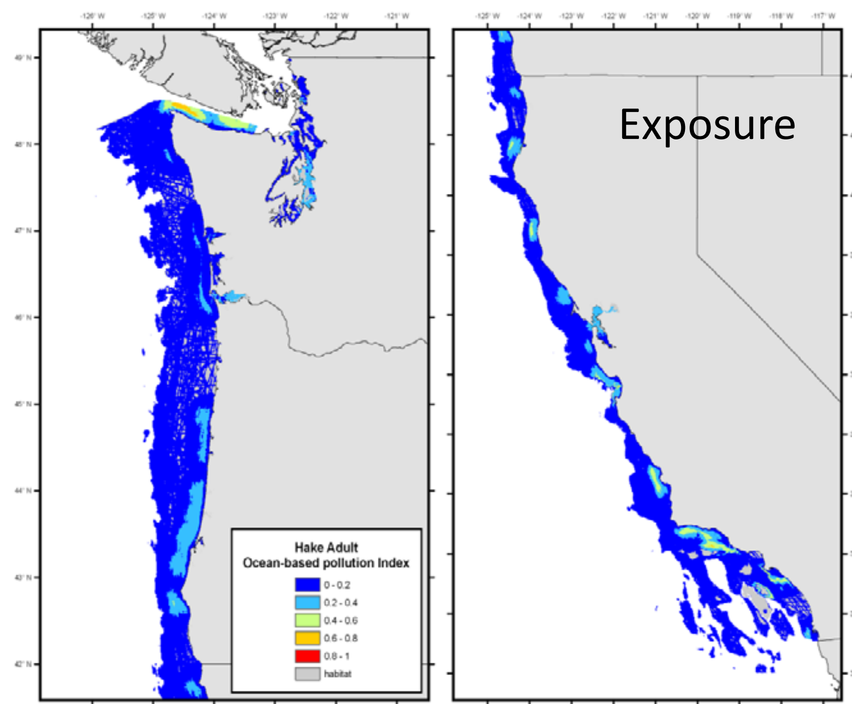
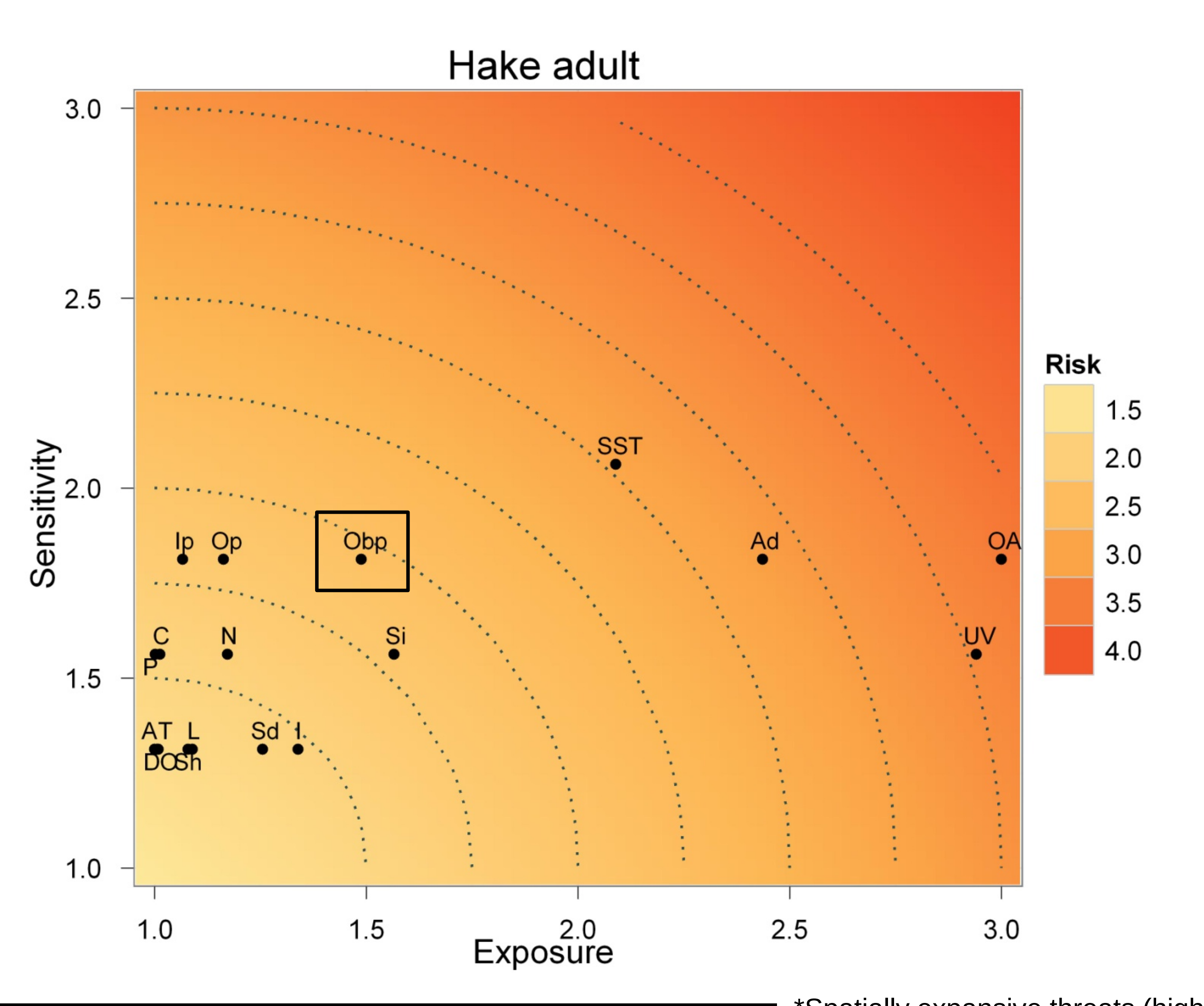


Calculating Risk

Exposure = Threat * HSP

Sensitivity = Life history + R&R factors

Risk from non-fisheries threats: Hake

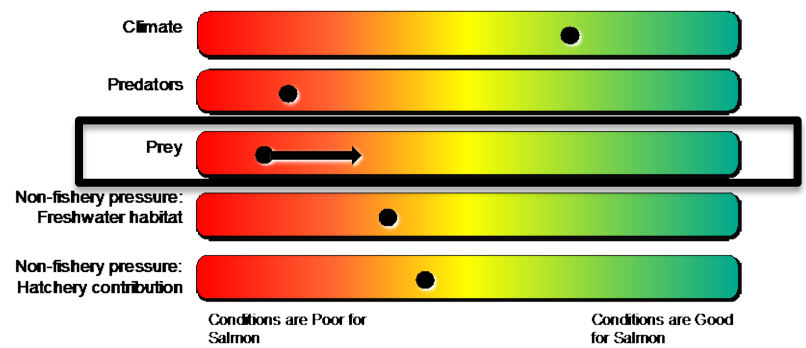


Non-fisheries threats
A – Aquaculture
Ad – Atmospheric deposition
C – Coastal engineering
D – Direct human impacts
Ip – Inorganic pollution
L – Light pollution
N – Nutrient input
Obp – Ocean based pollution
Op – Organic pollution
O – Oil rigs
P – Power plants
Sd – Sediment decrease
Si – Sediment increase
Sh – Shipping activity
I – Species invasions
T – Trash
OA – Ocean Acidification
SST – Sea Surface Temp
UV – UV Radiation

*Spatially expansive threats (high exposure) overshadow point source threats as sensitivity scores among groundfish are similar.

The salmon ecosystem

SACRAMENTO RIVER CHINOOK SALMON



PHYSICAL FORCING

The ocean condition has been generally in a good state for promoting ecosystem and salmon production. Wells et al 2008 (*Marine Ecology Progress Series* 364:15-29) developed an index of ecosystem productivity based on environmental variables (e.g. wind, temperature) and biological productivity. This index tracked, without modification, the abundance of Chinook salmon 1990-2008. This index can be used as an approximation of the ocean conditions in central California; the region wherein recruitment of salmon juveniles to the adult population is determined.

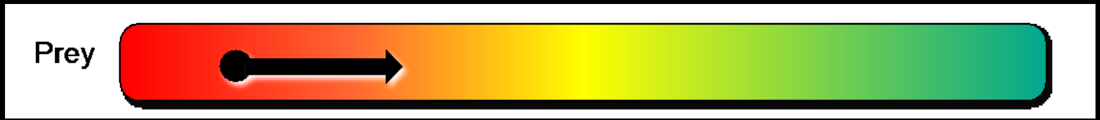
TROPHIC INTERACTIONS

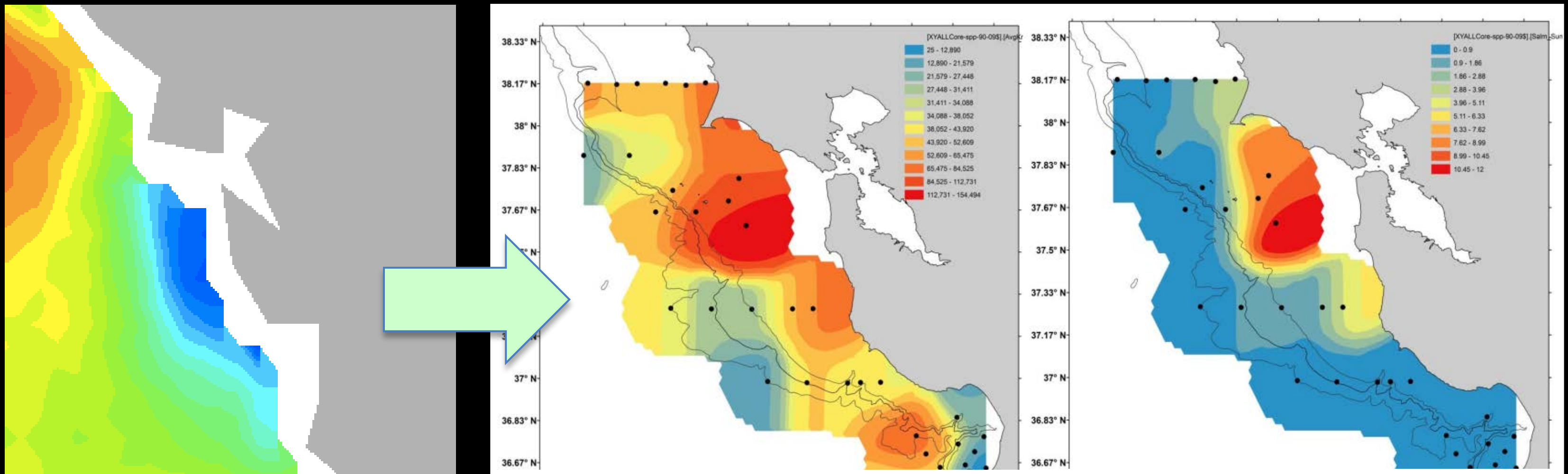
The forage base for Sacramento River salmon has been restricted in recent years with an increasing trend apparent. We represent forage as the the abundance of krill in the Gulf of the Farallones. As of 2005, the population of California sea lion, a primary predator, was at carrying capacity. Research has shown that California sea lions remove salmon from fishing gear at a rate as great as 30%; the greater the loss to depredation the greater is the true harvest as fish are replaced in the fishery.

NON-FISHERIES PRESSURES

Freshwater habitat: River discharge has been less than optimal for salmon health and productivity. Freshwater flow has been shown to relate to the survival and condition of salmon living in the freshwater environment and moving into the ocean. Hatchery contribution: In the last five years hatchery contribution to the Sacramento River Fall Run Chinook salmon has been approximately 31% with no recent trend. Hatchery contribution represents the proportion of the spawning populations that returns to hatcheries

The salmon ecosystem



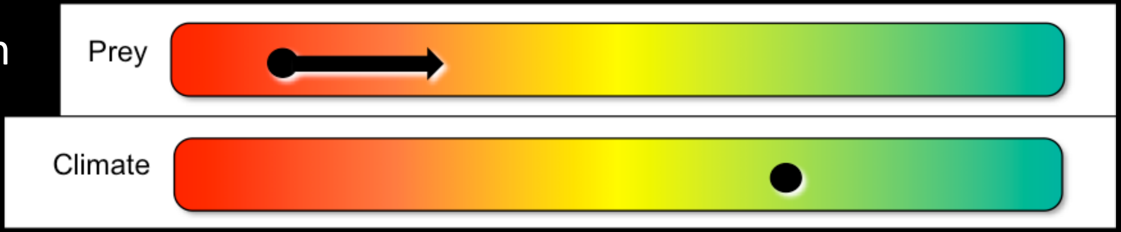


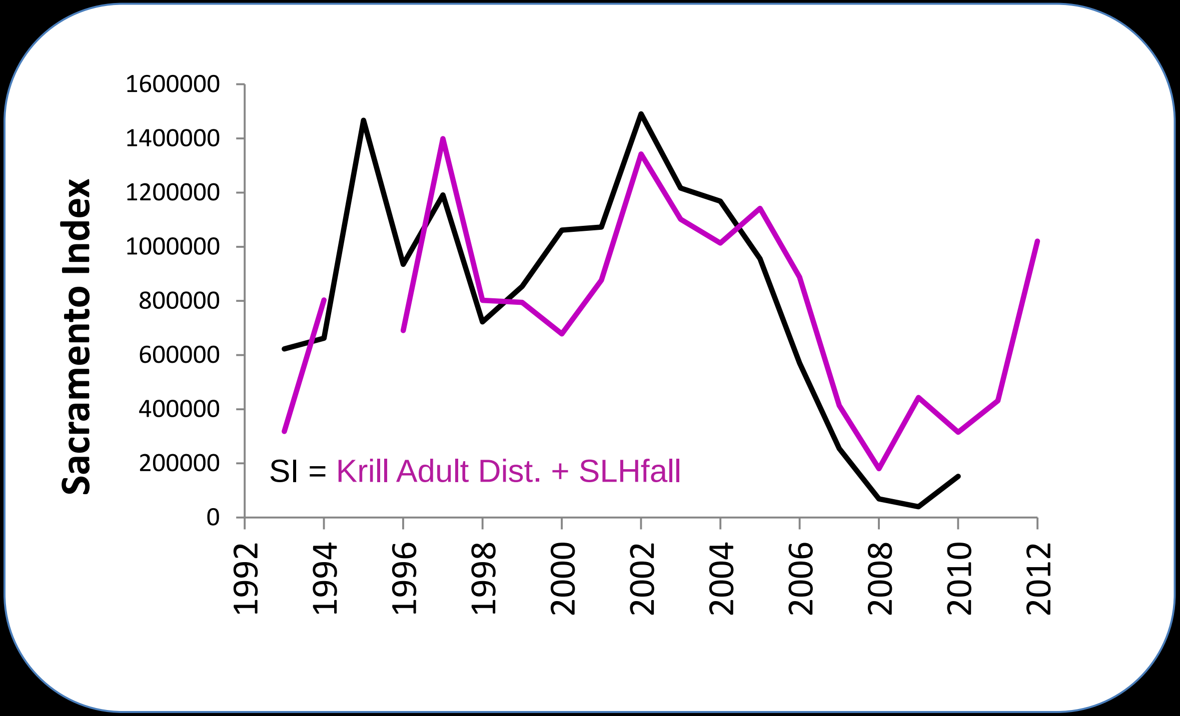
Offshore transport

Krill abundance

Juvenile salmon abundance

The salmon ecosystem





Next Steps

Discussion Document: Questions

- Chapter 1: Physical forcing
  1. Are there other important sources of ocean-climate variability?
  2. What literature is missing from this review?
- Chapter 2: Predators and prey
  1. Which time series should be included?
  2. Do we need a more complex analysis for time series data?
  3. What are the correct weights (predators/prey)?
- Chapter 3: Non-fisheries threats
  1. Calculation of risk score: euclidean distance or something else
  2. Exposure intensity score: 1) sum then standardize or 2) standardize then average
  3. Sensitivity criteria: Average of 4 life-history traits or use each independently
  4. Behavior/physiological response scoring (*Sensitivity*)
  5. Threat time series data: a) use all data? b) different proxies?
- Chapter 4: Central California Chinook Salmon
  1. What time series lengths should we use?
  2. Which stocks should we include?
  3. How should we include the whole life cycle?

Future Directions

- Additional FMP species: Sardine, albacore, additional salmon stocks

- Develop organized working relationships with PFMC

- IEA focused analyses: Cruise data, forage dynamics and environmental drivers, MSEs

- Proposing to hold an IEA sponsored workshop with Council participation

IEA Workshop Proposed Goals

- Assess where ecosystem considerations could be included in current management models
- Review current IEA analytical approaches and products, including data used
- Examine potential of new models that include ecosystem considerations for use by PFMC
- Discuss additional IEA products that would be useful to PFMC

Agenda Item H.1.c
Supplemental CPSAS Report
November 2011

COASTAL PELAGIC SPECIES ADVISORY SUBPANEL REPORT ON INTEGRATED ECOSYSTEM ASSESSMENT (IEA) REPORT

The Coastal Pelagic Species Advisory Subpanel (CPSAS) heard a presentation by Brian Wells, from the Southwest Fisheries Science Center, reviewing progress on the cooperative effort by the Northwest and Southwest Fisheries Science Centers to develop an annual Integrated Ecosystem Assessment Report.

The CPSAS appreciates the work done to date, and agrees that the report should remain advisory for the foreseeable future, particularly in light of the acknowledgement that current ecosystem models don't accurately forecast CPS due to their boom / bust cycles.

CPSAS members expressed concern with various aspects of the report:

- Currently the IEA does not adequately assess the nearshore component of CPS stocks, particularly in the Southern California Bight. This is problematic because the IEA Team recommended including Pacific sardine in its next steps.
- The CPSAS recommends that future research include the nearshore area in the Southern California Bight, as it represents a significant portion of CPS resources.
- Past research surveys have not occurred during peak summer feeding seasons in the Pacific Northwest and Canada, when sardines are aggregated. The IEA Team should include consideration of this data gap in future work.
- The CPSAS expresses appreciation of the IEA Team's goals to assess the forage community as a whole.

The conservation representative commented that the IEA may be a helpful tool to advance ecosystem-based fishery management, including the Fishery Ecosystem Plan. The needs statement of the PFMC Fishery Ecosystem Plan includes the need for understanding the effects of fishery management measures on the California Current ecosystem. As currently drafted, the IEA does not evaluate the effects of fishery management on the ecosystem. Therefore, the conservation representative requests that future iterations of the IEA evaluate the effects of the fisheries on the ecosystem to better inform the Council management process and future management decisions.

PFMC
11/4/11

COASTAL PELAGIC SPECIES MANAGEMENT TEAM REPORT ON INTEGRATED ECOSYSTEM ASSESSMENT (IEA) REPORT

The Coastal Pelagic Species Management Team (CPSMT) heard a presentation by Dr. Brian Wells on the current capabilities of the IEA. The CPSMT supports continued efforts of the IEA Team. The CPSMT encourages the IEA Team to include low trophic level (LTL) species in their work. In particular, examination of the ecosystem influences on LTL species population dynamics is of interest to the CPSMT. The CPSMT also encourages the IEA Team to investigate and quantify the LTL species biomass and composition consumed annually by predators in the California Current Ecosystem and how that changes in varying oceanographic regimes. The CPSMT looks forward to working with the IEA Team as they incorporate coastal pelagic species into the IEA.

PFMC
11/4/11

ECOSYSTEM ADVISORY SUBPANEL REPORT ON THE INTEGRATED ECOSYSTEM ASSESSMENT (IEA) REPORT

The Ecosystem Advisory Subpanel (EAS) heard a report from Dr. Brain Wells on the developing Integrated Ecosystem Assessment (IEA). The draft product for the Pacific Fishery Management Council looks at the ecosystem from the perspective of managed fish populations. This includes the effects of climate, ecological interactions and non-fisheries impacts. The continued development of the IEA will be an important and valuable tool for the developing Fishery Ecosystem Plan. There appears to be much potential for the use of this type of analysis to inform ecosystem-based fishery management decisions. That said, there needs to be more of a nexus between this work and the purpose and need of the developing Fishery Ecosystem Plan. For example, we recommend that the IEA analyses be part of the annual ecosystem reports.

In the further development of the IEA and its application to fisheries management, the following would be helpful:

1. Identify how ecosystem information could be helpful in reducing uncertainty in ways that could both enhance or restrict fishing opportunities.
2. Utilize the planned IEA treatment of Pacific sardine as an opportunity to analyze the ecosystem services of forage species including their ecological role in the food chain as well as their potential benefits to humans.
3. Consider the effects of fishery management on the California Current ecosystem, species and habitats.
4. Incorporate IEA information as a component of Management Strategy Evaluations to assess the full ecological and economic tradeoffs of different fishery management approaches.

PFMC
11/06/11

ECOSYSTEM PLAN DEVELOPMENT TEAM REPORT ON THE INTEGRATED ECOSYSTEM ASSESSMENT (IEA) REPORT

The Ecosystem Plan Development Team (EPDT) did not receive Agenda Item H.1.b., the *Discussion Document: Development of an Annual Report on Conditions in the California Current Ecosystem,* in time to provide for an adequate review. The EPDT did review draft IEA materials during a September 21-22 meeting via teleconference. The EPDT supports an annual reporting process on the state of the California Current Ecosystem (CCE), and has recommended an annual schedule for that process in Section 1.4 of its report at H.2.a. The EPDT looks forward to collaborating with the authors of this agenda item's *Discussion Document*, other Council advisory bodies, stock assessment scientists, the Council itself, and the public on the desirable format and contents of CCE conditions reports. We note that the Scientific and Statistical Committee's (SSC's) Ecosystem Subcommittee provided some initial guidance on this subject in June 2011:

> *The purpose of [an] annual update is to provide information about the physical and biological conditions of the system in the previous year that have the potential to affect recruitment, distribution, or vital rates of managed stocks. Possible information to include would be El Niño/La Niña conditions, environmental indices such as the Pacific Decadal Oscillation, upwelling start and end time, extent of the hypoxic zone off the central coast, krill, copepod or crab larvae abundance, and marine mammal and seabird trends. Information in the report should be put in the context of Council management. This report should be developed specifically for fisheries management applications; as such, it would need to be distilled and summarized to provide an update on the available science and ways it should be considered by the Council. The NPFMC has produced an annual Ecosystem Report, but the document is over 200 pages; any comparable report for the California Current would need to be summarized according to implications for each FMP to be useful for consideration in setting optimum yields (OYs) or prioritizing research needs.* (Subcommittee Report at H.1.b, June 2011)

Under this agenda item, the EPDT would appreciate guidance from the Council on:

- Whether the structure of the *Discussion Document* addresses ecosystem information the Council would like to see in support of its management priorities, and
- Initiating a collaborative process to outline the contents of an annual CCE conditions report, based on the SSC Ecosystem Subcommittee, or other guidance.

PFMC
11/03/11

HABITAT COMMITTEE REPORT ON INTEGRATED ECOSYSTEM ASSESSMENT (IEA) REPORT

The Habitat Committee (HC) heard a briefing on the integrated ecosystem assessment (IEA) by Brian Wells of NOAA's Southwest Fisheries Science Center. The HC believes the IEA will improve management with new information based on the status of the ecosystem, interactions between ecosystem components, and fishing and non-fishing effects on selected species (hake, sablefish, canary rockfish, bocaccio, and Sacramento River Chinook).

The HC suggests that the IEA Team expand its focus to Klamath River Fall Chinook and other salmon stocks limiting Council salmon fisheries.

It is important that the IEA remain flexible in order to incorporate new information, such as new groundfish habitat information, seabird distribution modeling efforts, kelp surveys, etc. In addition, it would be helpful to model the effects of habitat protection on recruitment and dispersal.

PFMC
11/06/11

SCIENTIFIC AND STATISTICAL COMMITTEE REPORT ON INTEGRATED ECOSYSTEM ASSESSMENT (IEA) REPORT

Drs Brian Wells (SWFSC), Nick Tolimieri (NWFSC), and Kelly Andrews (NWFSC) provided the SSC with an overview of the Integrated Ecosystem Assessment (IEA) discussion document (Agenda Item H.1.b, Attachment 1). This substantial document provides information on climate, predator-prey and non-fisheries impacts on hake, sablefish, canary rockfish, bocaccio and Sacramento River Chinook salmon, and moves forward the inclusion of ecosystem considerations in assessments and Council decision-making. The document is one outcome of the IEA process, and is focused on providing information for a limited number of species. It is not a broad overview of the status and trends of the California Current Ecosystem.

The information provided in the report could potentially be used in a variety of contexts, including improving salmon forecast models and identifying information and hypotheses that could be included in stock assessments, and in principle harvest control rules. It may also provide information that would assist the Council when selecting P*, and assist the Scientific and Statistical Committee (SSC) when it assesses sigma, the uncertainty associated with the Overfishing Level.

It will be necessary to develop appropriate processes for reviewing the use of this information. Due to time constraints, the SSC was unable to review the technical aspects of the document, nor was the SSC able to comment on any of questions raised in the document. Rather, review of the document would best be conducted in the context of a focused workshop, which would likely require several days to a full week. Such a workshop would evaluate the detailed analyses underlying the conclusions presented. Once the basic methodology and hypotheses are reviewed, there would be little need to prepare a lengthy document each year; rather an annual update of the basic indices could be provided.

The SSC is concerned that the overall summary plots could be easily mis-interpreted and recommends that these plots be modified to better reflect the uncertainty associated with the indices and their likely impact on stocks. In addition, information should be provided on how the various factors should be weighted when used for decision making.

The SSC notes that the document provides trends in indicators over five years. The appropriate length of time for assessing both time-trends and current indicator status is likely species-specific. The time length for each species should be evaluated separately for each species. The SSC also notes that some of the conclusions such as climate impacts on recruitment and abundance are more definitive than appears to be case from the data. In general, the information provided in the report should be considered hypotheses, which would be examined further before being used for decision making.

Finally, the SSC reiterates the benefit of having scientists with an ecosystem considerations background directly involved in stock assessment teams as this will provide the best way for ecosystem information to be integrated into stock assessments. However, even as currently structured the document is sufficient to identify factors which might be explored in stock assessments.

PFMC
11/03/11

DEVELOPMENT OF A COUNCIL FISHERY ECOSYSTEM PLAN

The Pacific Fishery Management Council (Council) is considering ecosystem-based approaches to fishery management and is in the process of developing a Fishery Ecosystem Plan (FEP) as a vehicle for bringing ecosystem-based principles into the Council decision-making process under its existing Fishery Management Plans (FMPs). The Council has also been exploring the plan's potential to broaden its current authority to species and issues not currently addressed in existing FMPs.

In June, the Council moved to develop an FEP with the adopted purpose of *"[enhancing] the Council's species-specific management programs with more ecosystem science, broader ecosystem considerations and management policies that coordinate Council management across its FMPs and the California Current Ecosystem (CCE). An FEP should provide a framework for considering policy choices and trade-offs as they affect FMP species and the broader CCE."*

In addition to adopting a Purpose and Need statement for its FEP, the Council also moved:

- Developing an FEP that would be primarily advisory in nature, with the potential to expand the plan to include regulatory authority in the future, should the Council so desire;
- Continuing to manage stocks and fisheries through existing FMPs, including developing potential new management measures for forage fish species through those FMPs, as the Council deems appropriate;
- Developing a list of West Coast species that are currently not included in any FMP, not managed under state authority, and not listed under the Endangered Species Act to, in part, define "forage species" and to assess their potential vulnerability to developing fisheries, and;
- Tasking the Ecosystem Plant Development Team (EPDT) with recommending a preliminary draft process and schedule for the development of an FEP.

In response to the Council's tasks, the EPDT has provided a draft outline for an FEP (Agenda Item H.1.a, Attachment 1) which includes the plan's adopted purpose and need, a proposed schedule and process for developing and revising the FEP, and a proposed reporting schedule under which the Council will receive a comprehensive annual ecosystem conditions report, as well as periodic reports throughout the year that focus on specific management issues before the Council. Appendix A of the draft FEP outline also includes an analysis of CCE low trophic level species and their potential vulnerability to future fisheries exploitation.

Given the broad interest in ecosystem-based management in the Council process, it is anticipated that the Council will receive reports from a variety of its advisory groups including the EPDT, the Ecosystem Advisory Subpanel, the Scientific and Statistical Committee, and the Habitat Committee. Management teams and advisory subpanels in attendance in November may also report under this agenda item as their schedules allow. At the meeting the Council is being asked to provide feedback on the draft FEP outline and the initial list of forage species and to provide guidance on the process, schedule, and tasks for further development of the FEP.

Council Action:

1. **Provide feedback on the Draft FEP Outline.**
2. **Review and comment on the list of species and accompanying analysis.**
3. **Provide guidance on the process, schedule, and tasks for future work on FEP development.**

Reference Materials:

1. Agenda Item H.2.a, Attachment 1, Draft Pacific Coast Fishery Ecosystem Plan.
2. Agenda Item H.2.c, Public Comment.

Agenda Order:

a. Agenda Item Overview — Mike Burner
b. Reports and Comments of Advisory Bodies and Management Entities
c. Public Comment
d. **Council Action:** Provide guidance for Further Development

PFMC
10/14/11

Agenda Item H.2.a
Attachment 1
November 2011

PACIFIC COAST
FISHERY ECOSYSTEM PLAN

FOR THE U.S. PORTION OF THE
CALIFORNIA CURRENT LARGE MARINE ECOSYSTEM

DRAFT

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OCTOBER 2011

OCTOBER 13, 2011: NOTE TO REVIEWERS

This Fishery Ecosystem Plan (FEP) outline is intended as a discussion document to help the Pacific Council, its advisory bodies, and the public think about and comment upon the structure and content of an advisory FEP for the California Current Ecosystem (CCE). This document has been developed in response to Council direction from its June 2011 meeting and includes work developed by the EPDT and commented upon by the Council's other advisory bodies for the Council's September 2010, March 2011, and June 2011 meetings.

LIST OF ACRONYMS AND ABBREVIATIONS

CalCOFI	California Cooperative Oceanic Fisheries Investigations
CCE	California Current Ecosystem, or California Current Large Marine Ecosystem
Council	Pacific Fishery Management Council
CPS	Coastal Pelagic Species
EEZ	Exclusive Economic Zone
EFH	Essential Fish Habitat
EPDT	Ecosystem Plan Development Team
ESA	Endangered Species Act
FEP	Fishery Ecosystem Plan
FMP	Fishery Management Plan
HMS	Highly Migratory Species
MMPA	Marine Mammal Protection Act
MSA	Magnuson-Stevens Fishery Conservation and Management Act

1.0 Introduction

1.1 Purpose and Need

At its June 2011 meeting, the Pacific Fishery Management Council (Council or Pacific Council) adopted the following Purpose and Need Statement for a Fishery Ecosystem Plan (FEP):

The purpose of the FEP is to enhance the Council's species-specific management programs with more ecosystem science, broader ecosystem considerations and management policies that coordinate Council management across its Fishery Management Plans (FMPs) and the California Current Ecosystem (CCE). An FEP should provide a framework for considering policy choices and trade-offs as they affect FMP species and the broader CCE.

The needs for ecosystem-based fishery management within the Council process are:

1. *Improve management decisions and the administrative process by providing biophysical and socio-economic information on CCE climate conditions, climate change, habitat conditions and ecosystem interactions.*
2. *Provide adequate buffers against the uncertainties of environmental and human-induced impacts to the marine environment by developing safeguards in fisheries management measures.*
3. *Develop new and inform existing fishery management measures that take into account the ecosystem effects of those measures on CCE species and habitat, and that take into account the effects of the CCE on fishery management.*
4. *Coordinate information across FMPs for decision-making within the Council process and for consultations with other regional, national, or international entities on actions affecting the CCE or FMP species.*
5. *Identify and prioritize research needs and provide recommendations to address gaps in ecosystem knowledge and FMP policies, particularly with respect to the cumulative effects of fisheries management on marine ecosystems and fishing communities.*

1.2 How this Document is Organized

This FEP takes its organization from the Council's Purpose and Need statement (Section 1.1). Chapter 2 provides the FEP's Goals and Objectives, a more detailed exploration of what the FEP would do to meet its Purpose and Need. Chapter 3 provides biophysical and socio-economic information on the CCE, including its climate conditions, climate change and shift conditions, habitat conditions, and ecosystem interactions. Chapter 3 also includes information on the cumulative effects of fisheries management on marine ecosystem and fishing communities. Chapter 4 discusses the uncertainties of environmental and human-induced impacts to the marine environment and potential cross-FMP fishery management measures that could be used to buffer against those uncertainties. Chapter 5 discusses Council CCE policy priorities across its FMPs, so that ocean resource management and policy processes external to the Council (e.g. West Coast Governors' Agreement on Ocean Health, National Ocean Council, international fishery and ocean resource management bodies) may be made aware of and may better take into account those priorities. Chapter 6 identifies and prioritizes research needs and provides recommendations to address gaps in ecosystem knowledge and FMP policies.

1.3 Schedule and Process for Developing the FEP

At its June 2011 meeting, the Council tasked its EPDT with drafting a schedule and process for developing the FEP. This FEP is a living document, which means that the Council anticipates regularly amending and updating the FEP. The following proposed process and schedule is intended to allow the Council to swiftly finalize an initial FEP, with the understanding that the Council will annually assess and update the FEP.

June 2011: Council decides to develop an advisory FEP, adopts Purpose and Need Statement. Advisory FEP is to be structured so that, if the Council wishes, it could be later converted to an Ecosystem FMP with regulatory authority.

November 2011: Council reviews EPDT's draft FEP outline, makes recommendations on additions to or subtractions from proposed FEP contents, makes recommendations on prioritizing issues to be considered within the FEP. [Prioritized issues to be listed here.]

June 2012: Council reviews and initially comments on draft FEP containing chapters on highest-priority issues; Council sends FEP out for public comments.

November 2012: Council receives comments on draft FEP from its advisory bodies and the public, directs EPDT to revise FEP as appropriate, and adopts 2013 FEP workload priorities. [Prioritized issues and chapters to be listed here.]

March 2013: EPDT provides draft initial FEP, as modified in response to Council direction from November 2012; Council adopts final initial FEP.

June 2013: Council reviews and initially comments on 2013 FEP priority issues and chapters.

November 2013: Council receives comments on 2013 draft FEP sections from its advisory bodies and the public, directs EPDT to revise as appropriate, adopts 2014 FEP workload priorities. [Prioritized issues and chapters to be listed here.]

2014 and beyond: Council continues to add issues and chapters to FEP in priority order, with draft additions available each June and Council final decisions each November.

1.4 Schedule and Process for Annual State-of-the-Ecosystem Reporting

In addition to an FEP, the Council and its advisory bodies have discussed an annual process for bringing state-of-the-ecosystem information into the Council process. In its June 2011 report to the Council, the SSC's Ecosystem Subcommittee noted that much of the available information on ecosystem dynamics is highly technical and "not developed specifically for fisheries management applications." The Subcommittee also noted that NMFS's annual Ecosystem Considerations Report to the North Pacific Fishery Management Council is over 200 pages long, although its authors also provide summary information for that report. Bearing these and other comments in mind, the EPDT proposes that the Council consider both an annual ecosystem report and brief species-group ecosystem hotsheets. Ecosystem hotsheets would distill relevant annual report information for Council use during meetings when harvest-setting decisions are needed for particular species or species groups.

November 2011: Council receives sample discussion document on developing an annual report on conditions in the CCE, highlighting processes and results from the California Current Integrated Ecosystem Assessment.

June 2012: Draft list of potential indicators and information to be included in an annual ecosystem considerations report provided for Council and public review and comment.

November2012 (and each subsequent November): First annual ecosystem considerations report and ecosystem hotsheet for sardines and other coastal pelagic species (CPS) under Council management consideration at that meeting.

March 2013 (and each subsequent March): Ecosystem hotsheets for salmon and Pacific whiting.

June 2013 (and each subsequent June): Ecosystem hotsheet for mackerel.

September 2013 (and September in other odd-numbered years): Ecosystem hotsheet for groundfish. ***The EPDT is aware that the Council is considering revising its groundfish harvest specifications and management measures process. September odd-year hotsheet reporting is proposed as a placeholder until and unless groundfish process revisions occur.***

September 2014 (and September in other even-numbered years): Ecosystem hotsheet for highly migratory species.

2.0 Goals and Objectives

[Unlike the Purpose and Need Statement in Chapter 1.0, the Council has not yet adopted FEP Goals and Objectives. The EPDT first provided the draft Goals and Objectives in its September 2010 report to the Council (Agendas Item H.1.b., Attachment 1). For this draft FEP, the EPDT has modified its September 2010 draft Goals and Objectives, taking into account comments received from the Council and its advisory bodies].

The overarching goal of this FEP is to bring a greater understanding of the CCE to the Council participants and the public, so as to provide broad consideration and analysis of social, economic, and ecological policy options across the Council's areas of responsibility. The FEP and its associated scientific products are intended to support Council decision-making by more fully addressing the goals and objectives shared by all FMPs for a healthy ecosystem with productive and sustainable fisheries.

The Council's four existing FMPs each have suites of goals and objectives that differ in their precise language, but have four common themes that are consistent with an ecosystem approach to fishery management: avoid overfishing, maintain stability in landings, minimize impacts to habitat, and accommodate existing fisheries sectors. The CPS FMP also explicitly recognizes the role of the target species in the food web; this is the only FMP that specifies a need to "provide adequate forage for dependent species." These FEP objectives are intended to help integrate management across all the FMPs:

- Provide a vehicle to better inform Council decision-making by improving and integrating information that may affect species from multiple FMPs, such as trends in climate conditions or indicator species.

- Identify and address gaps in ecosystem knowledge, particularly with respect to the cumulative effects of fishing on marine ecosystems, and provide recommendations to address such gaps.

- Provide an ecosystem context for Council decisions that may involve common management concerns or trade-offs among species-specific FMPs.

- Provide administrative structure and procedures for coordinating conservation and management measures that address inter-species relationships across FMPs and with species external to the FMPs.

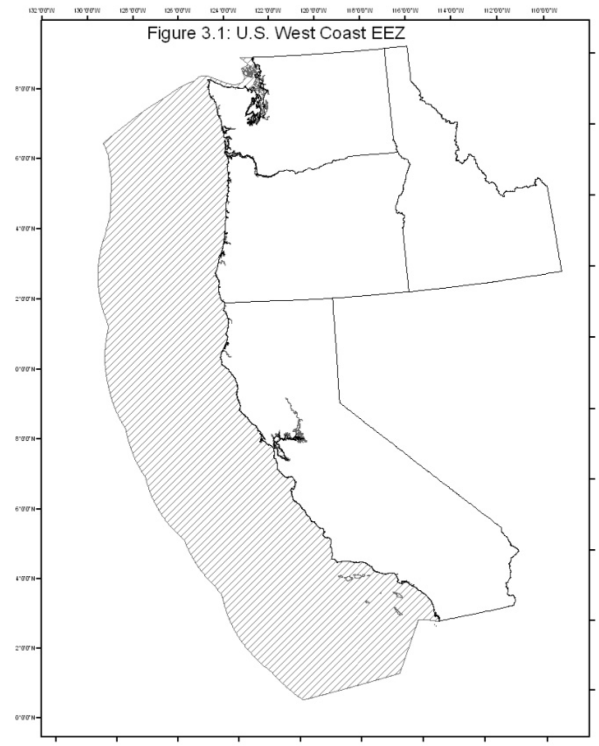
- Provide a nexus to regional and national ecosystem-related endeavors, particularly with respect to the consequences of non-fishing activities.

- Provide a framework for the consideration of cooperative management strategies that might facilitate management actions at appropriate spatial scales.

3.0 The FEP's Geographic Area and the California Current Ecosystem

[The Council adopted an initial geographic area for this FEP at its September 2010 meeting. Descriptions of the CCE are excerpted from the EPDT's March 2011.]

3.1 Geographic Area



The geographic range for this FEP is the entire U.S. West Coast Exclusive Economic Zone (EEZ.) The Council recognizes that the EEZ does not encompass all of the CCE, nor does it include all of the waters and habitat used by many of the Council's more far-ranging species. However, the Council also does not believe that designating the EEZ as the FEP's geographic range in any way prevents it from receiving or considering information on areas of the CCE or other ecosystems beyond the EEZ.

3.2 Oceanographic Features of the CCE

The California Current is an "Eastern Boundary Current," an upwelling-dominated ecosystem characterized by fluctuations in physical conditions and productivity over multiple time scales (Parrish et al. 1981, Mann and Lazier 1996). Food webs in these types of ecosystems tend to be structured around coastal pelagic species that exhibit boom-bust cycles over decadal time scales (Bakun 1996, Checkley et al. 2009). By contrast, the top trophic levels of such ecosystems are often dominated by highly migratory species such as salmon, tuna, billfish and marine mammals, whose dynamics may be partially or wholly driven by processes in entirely different ecosystems, even different hemispheres.

The CCE essentially begins where the west wind drift (or the North Pacific Current) reaches the North American continent. The North Pacific Current typically encounters land along the northern end of Vancouver Island, although this location varies latitudinally from year to year. This current then splits into the southward-flowing California Current heading south and the northward-flowing Alaska Current. The "current" part of the California Current is a massive southward flow of water ranging from 50 to 500 kilometers offshore (Mann and Lazier, 1996). Beneath this surface current, lies the California Undercurrent in the summer, which surfaces and is known as the Davidson current in winter. This current moves water poleward from the south in a deep yet more narrow band of water typically close to (but offshore of) the continental shelf break (Hickey 1998, Checkley and Barth 2009). The southward-flowing California Current is typically considered distinct from the wind-driven coastal upwelling jet that develops over the continental shelf during the spring and summer, which tends to be driven by localized forcing and to vary on smaller spatial and temporal scales than offshore processes (Hickey, 1998). Jets result from intensive wind-driven coastal upwelling, and lead to higher nutrient input and productivity; they in turn are influenced by the coastal topography (capes, canyons and offshore banks), particularly the large capes such as Cape Blanco, Cape Mendocino and Point Conception. The flow from the coastal upwelling jets can be diverted offshore, creating eddies, fronts and other mesoscale changes in physical and biological conditions, and even often linking up to the offshore California Current (Hickey, 1998). One example is south of Point Conception, where part of the California Current swirls eastward and then northward to form the Southern California Eddy.

Superimposed on the effects of these shifting water masses that drive much of the interannual variability of the California Current, are substantive changes in productivity that often take place at slower rates, during multi-year and decadal periods of altering ocean condition and productivity regimes. Climatologists and oceanographers have identified and quantified both the high and low frequency variability in numerous ways. The El Niño/Southern Oscillation (ENSO) is the dominant mode of interannual variability in the equatorial Pacific, with impacts throughout the rest of the Pacific basin (including the California Current) and the globe (Mann and Lazier 1996). During the negative (El Niño) phase of the ENSO cycle, jet stream winds are typically diverted northward, often resulting in increased exposure of the West Coast of the U.S. to subtropical weather systems (Cayan and Peterson 1989). Concurrently in the coastal ocean, the effects of these events include reduced upwelling winds, a deepening of the thermocline, intrusion of offshore (subtropical) waters, dramatic declines in primary and secondary production, poor recruitment, growth and survival of many resident species (particularly salmon and groundfish), and northward extensions in the range of many tropical species.

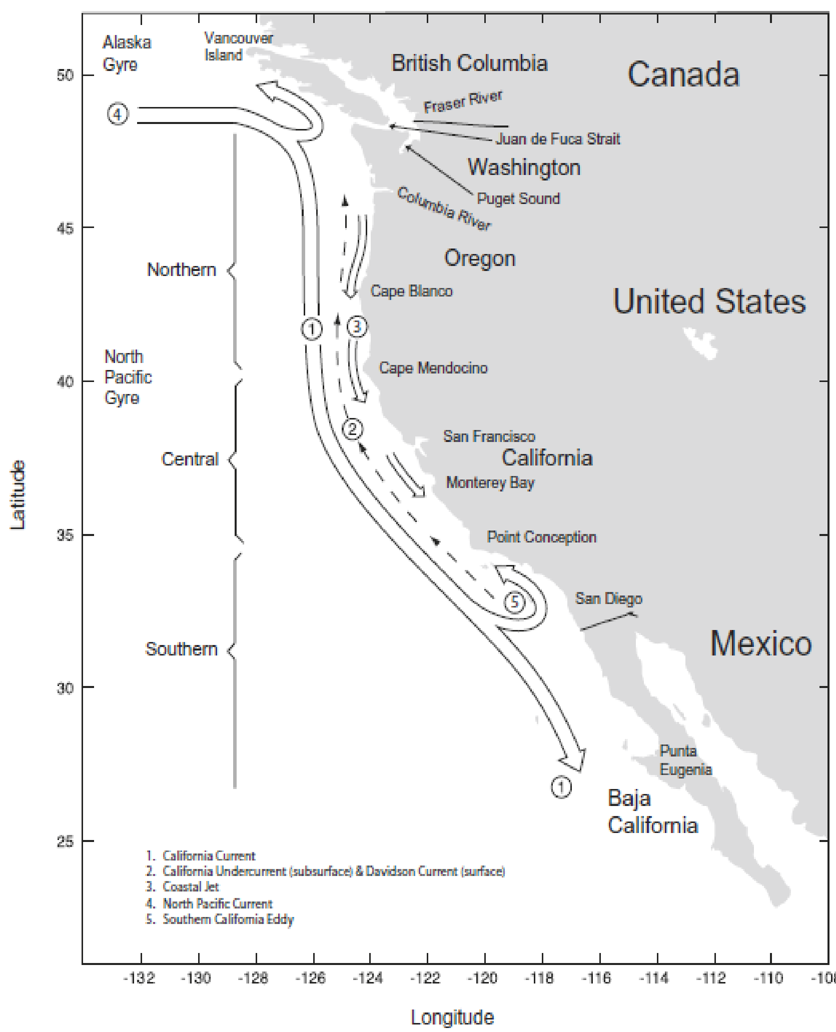


Figure 3.2: Dominant current systems off the U.S. West Coast

While the ENSO cycle is generally a high-frequency event (taking on the order of three to seven years to complete a cycle), lower frequency variability has been associated with what is now commonly referred to as the Pacific (inter)Decadal Oscillation, or PDO (Mantua et al. 1997). The PDO is the leading principal component of North Pacific sea surface temperatures (above 20° N. lat.), and superficially resembles ENSO over a decadal time scale. During positive regimes, coastal sea surface temperatures in both the Gulf of Alaska and the California Current tend to be higher, while those in the North Pacific Gyre tend to be lower; the converse is true in negative regimes. The effects of the PDO have been associated with low frequency variability in over 100 physical and biological time series throughout the Northeast Pacific, including time series of recruitment and abundance for commercially important coastal pelagics, groundfish and invertebrates (Mantua and Hare 2002).

Three major aspects of climate change that will have direct effects on the CCE are: ocean temperature, pH (acidity versus alkalinity) of ocean surface waters, and deep-water oxygen. Globally by 2050, ocean temperatures *on average* are expected to rise at least 1°C (by the most conservative estimates, ref: climate IPCC report), while at the same time, ocean pH in the upper 500m has steadily been decreasing (becoming more acidic, aka “ocean acidification”) at a rate of approximately -0.0017 pH per year (Byrne et al., 2010). On a more regional basis within the CCE, deep-water oxygen levels have shown a steady and relatively rapid decrease since the mid 1980’s (Bograd et al., 2008, McClatchie et al., 2010). There is linkage between these three factors: ocean temperature affects ocean pH, ocean temperature and deep water oxygen levels both can be controlled by large scale circulation patterns, primary production can affect both oxygen and pH, all three factors show long term trends and decadal scale variance similar to changes in the PDO (Mantua et al., 1997) and North Pacific Gyre Oscillation (DiLorenzo et al., 2008) climate signals.

Temperature

Increasing temperature will have both direct and indirect effects on all managed species within the CCE. For cold-blooded species, vital rates will change as a function of temperature, specifically growth and development rates, which could lead to changes in size-at-age relationships, and/or changes in egg production rates (Houde, 1989; Blaxter, 1992). Certain species with upper thermal limit tolerances, may become locally extirpated in some areas, or conversely expand into new territories that were once too cold. Other, more mobile species, may change their depth/and or spatial range in response to increasing temperature, typically through a northward shifting of population boundaries. Indirect effects on managed species include changes in both basic primary and secondary production rates, and/or community composition of the lower trophic levels which provide the food base for managed species. It is also likely that along with increased warming, there has been an increase in thermal stratification within the CCE (Palacios et al., 2004), which may lead to a decrease in overall primary production, through a reduction in the effectiveness of upwelling bringing nutrients to the surface layers. Thus we may expect system-wide changes in productivity or changes in the centers of productivity over the next 50 years. Related to changes in temperature, there may also be associated changes in the timing of the onset of spring’s seasonal upwelling, which could have widespread effects on total production, the match-mismatch of certain trophic interactions, and possible community shifts (Loggerwell et al., 2003; Holt and Mantua, 2009).

Ocean pH

Decreasing ocean pH ("ocean acidification") will have direct effects on certain species within the CCE. Primarily, decreasing pH makes it more difficult for shell-bearing species (such as corals, bivalves, gastropods, and crustaceans) to make their shells (Kleypas et al., 1999; Riebesell et al., 2000; Fabry et al., 2008). Decreased pH may possibly impact the larvae and young stages of fish, although studies documenting such effects on fish are sparse (see Fabry et al. 2008, and references therein). The most significant impact likely for the managed species within the CCE would be if decreasing pH caused changes in plankton productivity or community composition. Currently, the likeliness and extent of such effects are poorly known, but could be considerable. As changes in ocean pH roughly track changes in atmospheric pCO2 levels, it is expected that as pCO2 continues to rise, ocean pH will continue to steadily decrease, making changes in ocean plankton production and community structure more likely in the future. It is important to note that there is considerable daily, seasonal, and decadal scale variability in ocean pH, overlain on the overall long-term trend (reviewed in Fabry et al., 2008). Thus many oceanic species are already exposed to considerable variability in ocean pH compared to the rate of long-term change, and thus have some natural resilience to such changes.

Oxygen

Within the CCE, there has been a notable decrease in deep-water oxygen levels since the mid 1980's (Bograd et al., 2008, Chan et al., 2008). Effects of low oxygen levels on marine organisms are fairly well known: death in most cases if the organisms cannot avoid the area, or reduced growth for those species with some tolerance. Overlaid on this steady decrease, occasional periods of heightened primary production without concomitant surface grazing, have sometimes led to large hypoxic or even anoxic zones in deeper waters, resulting in mass fish kills (e.g. recent events off Oregon coast; Chan et al., 2008). The decrease in deep water oxygen levels is most likely a result of changes in oxygen content of the source waters of deeper parts of the CCE, more of a basin-wide phenomenon affecting large regions of the CCE (Bograd et al., 2008). On top of the long term, system-wide changes in deeper water oxygen are regional-scale events that may further decrease oxygen levels. Particularly, strong surface primary production may sink out before being remineralized in surface layers, leading to a higher respiratory demand in deeper waters. Coupling such events with the already depleted deeper waters, may thus lead to fish kills, the likelihood of which will probably increase as the deep water oxygen continues to decrease under the current trend.

3.3 Biological Components and Relationships of the CCE

This section would describe the living components of the CCE, not individually, but by trophic level and ecological guild, as they interact with each other at the ecosystem scale. Sub-ecosystem, or regional, ecological interactions may also be described, as deemed necessary or useful by the Council and its advisory bodies. This section would also assess the cumulative effects of Council-managed fisheries on ecological interactions within the CCE. See Appendix A for a sample discussion of CCE lower trophic level species.

3.4 Socio-Economic Components and Relationships of the CCE

This section would describe the U.S. West Coast fisheries managed under the Council's authority, without duplicating descriptions from the Council's FMPs. This section assesses West Coast fisheries capacity and the cumulative socio-economic effects of Council-generated fishery management measures on fishing communities and summarizes safety-of-human-life-at-sea issues for West Coast fisheries.

3.5 Sources for Chapter 3

Bakun, A. 1996. Patterns in the Ocean: Ocean Processes and Marine Population Dynamics. California Sea Grant.

Blaxter JHS (1992) The effect of temperature on larval fishes. Neth J Zool 42:336–357.

Bograd, S. J., C. G. Castro, E. Di Lorenzo, D. M. Palacios, H. Bailey, W. Gilly, and F. P. Chavez (2008), Oxygen declines and the shoaling of the hypoxic boundary in the California Current, Geophys. Res. Lett., 35, L12607, doi:10.1029/2008GL034185.

Cayan, D.R. and D.H. Peterson. 1989. The influence of North Pacific atmospheric circulation on streamflow in the west. Geophysical Monograph 55: 375-397.

Chan, F., J. Barth, J. Lubchenko, A. Kirincich, H. Weeks, W. Peterson, and B. Menge (2008), Emergence of anoxia in the California Current large marine ecosystem, Science, 319, 920.

Checkley, D.M. and J.A. Barth. 2009. Patterns and processes in the California Current System. Progress in Oceanography 83: 49–64.

Checkley, D.B., J. Alheit, Y. Oozeki and C. Roy. 2009. Climate change and small pelagic fish. Cambridge University Press: Cambridge.

Di Lorenzo E., Schneider N., Cobb K. M., Chhak, K, Franks P. J. S., Miller A. J., McWilliams J. C., Bograd S. J., Arango H., Curchister E., Powell T. M. and P. Rivere, 2008: North Pacific Gyre Oscillation links ocean climate and ecosystem change. Geophys. Res. Lett., 35, L08607, doi:10.1029/2007GL032838.

Fabry, V.J., Seibel, B.A., Feely, R.A., and Orr, J.C. 2008. Impacts of ocean acidification on marine fauna and ecosystem processes. ICES JMS, 65:414-432.

Hickey, B.M. 1998. Coastal oceanography of Western North America from the tip of Baja California to Vancouver Island. In A.R. Robinson and K.H. Brink (editors) The Sea, Volume 11. John Wiley and Sons: New York.

Holt, C.A., Mantua, N. 2009. Defining the spring transition: regional indices for the California Current System. Mar.Eco.Prog.Sers. 393:285-299.

Houde ED. 1989. Comparative growth, mortality, and energetics of marine fish larvae: temperature and implied latitudinal effects. Fishery Bulletin U.S. 87:471-495.

Kleypas, J.A., Buddemeier, R.W., Archer, D., Gattuso, J.-P., Langdon, C., and Opdyke, B.N. 1999. Geochemical consequences of increased atmospheric cardon dioxide on coral reefs. Science, 284:118-120.

Loggerwell, E. A., N. J. Mantua, P. W. Lawson, R. C. Francis, and V. N. Agostini. 2003. Tracking environmental processes in the coastal zone for understanding and predicting Oregon coho (Oncorhynchus kisutch) marine survival. Fish. Oceanogr. 126:554-568.

Mann, K.H. and J.R.N. Lazier. 1996. Dynamics of Marine Ecosystems. Blackwell: Cambridge.

Mantua, N.J., S.R. Hare, Y. Zhang, J.M. Wallace and R.C. Francis. 1997. A Pacific interdecadal climate oscillation with impacts on salmon production. Bull. Am. Met. Soc. 78:6:1069-1079.

Mantua, N.J. and S.R. Hare. 2002. The Pacific Decadal Oscillation. Journal of Oceanography 58:1: 35-44.

McClatchie, S., R. Goericke, G. Auad and K. Hill. 2010. Re-assessment of the stock-recruit and temperature-recruit relationships for Pacific sardine (Sardinops sagax). Ca. J. Fish. Aquat. Sci. 67: 1782-1790.

Palacios, D.M., S.J. Bograd, R. Mendelssohn, F.B. Schwing. 2004. Long-term and seasonal trends in stratification in the California Current, 1950-1993. Journal of Geophysical Research, 109: 12 pp.

Parrish, R.H., F.B. Schwing, and R. Mendelssohn. 2000. Midlatitude wind stress: The energy source for climate regimes in the North Pacific Ocean. Fisheries Oceanography 9: 224-238.

Riebesell, U., Zondervan, I., Rost, B., Tortell, P.D., Zeebe, R.E., and Morel, F.M.M. 2000. Reduced calcification of marine plankton in response to increased atmospheric CO2. Nature, 407:364-367.

4.0 Uncertainties of Environmental and Human-Induced Impacts to the Marine Environment

Chapter 4 would consider the potential effects to the CCE from environmental processes and human activities, and could inform risk choices and recommend safeguards in fisheries management measures to buffer against uncertainties induced by those effects.

5.0 PFMC Policy Priorities for Ocean Resource Management

Chapter 5 would discuss Council CCE policy priorities across its FMPs, as they may apply to ocean resource management and policy processes external to the Council (e.g. West Coast Governors' Agreement on Ocean Health, National Ocean Council, international fishery and ocean resource management bodies). Unlike Chapter 2, Goals and Objectives, the purpose of Chapter 5 would not be to guide future Council work, but to better ensure that external entities are better aware of, and may better take into account, Council priorities for the CCE's health and function.

6.0 Bringing Cross-FMP and Ecosystem Science into the Council Process

[This Chapter is based on Chapter 4 of the EPDT's March 2011 report to the Council, Agenda Item J.1.c., Attachment 1, updated and modified by comments received from the Council and its advisory bodies through June 2011.]

6.1 Bringing Ecosystem Science into the Council Process

Based in part on advice received from the SSC in September 2010, the EPDT views the incorporation of ecosystem science into the Council process as a two-part process. The first part is to identify and act on opportunities to improve the quantity and quality of ecosystem information used in the science that supports Council decision-making, particularly stock assessments. The second part is to bring a new whole-picture assessment of the CCE into the Council process.

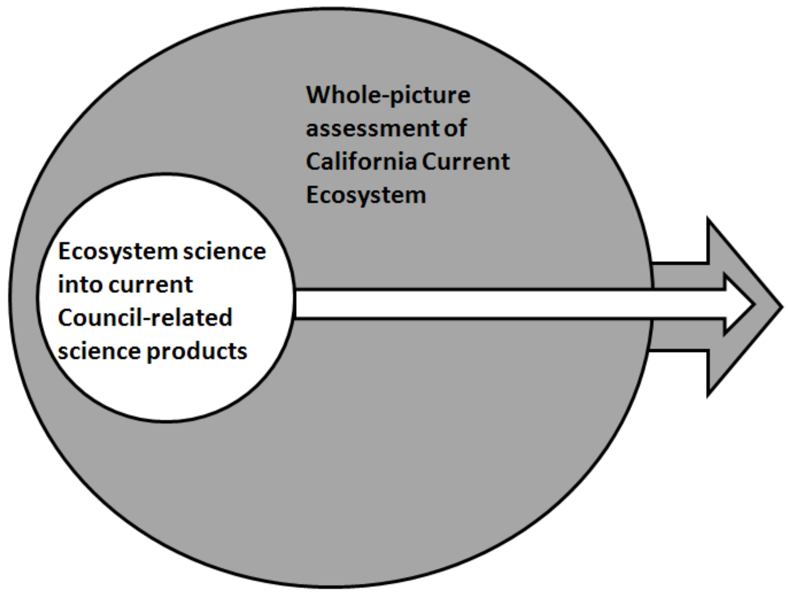


Figure 6.1: Two-part process to bring ecosystem science to the Council

6.1.1 Bringing More Ecosystem Information into Stock Assessments

While Council management decisions address a host of issues requiring wide-ranging science support and analysis, stock assessments and other harvest-level support science are the largest category of science products directly used in the Council process. Simultaneous to the FEP development process, the Council's SSC has been considering a process to bring ecosystem considerations into stock assessments. Recognizing the status of stock assessments as both frequently conducted and heavily used Council-related science, the SSC recommended in September 2010:

> "*. . . that a subset of stock assessments be expanded to include ecosystem considerations. This would likely require the addition of an ecologist or ecosystem scientist to the Stock Assessment Teams (STATs) developing those assessments. The SSC's Ecosystem-Based Management subcommittee should develop guidelines for how ecosystem considerations can be included in stock assessments.*" (H.1.c., Supplemental SSC Report)

In its June 2011 statement, the SSC further outlined the process it had discussed in prior statements:

> *"A section on ecosystem considerations should be added to all stock assessments, starting with the 2013 assessment cycle. The detail and length of the section will*

vary and evolve over time. Stock assessment teams should include expertise in ecosystem processes to assist with this section development and stock assessment review.

The SSC will need to modify Terms of Reference for stock assessment reviews to include reviews of ecosystem consideration sections of assessments and application of ecosystem processes in assessments and harvest control rules. Consideration of resources needed will be important to insure that STATs are not overcommitted." (H.1.b., Supplemental SSC Report)

6.1.2 Bringing Ecosystem Information and Science into the Larger Council Process

In June 2011, the SSC and its Ecosystem SubCommittee also commented on an annual state of the CCE reporting process. The SSC wrote:

> *"A report on the state of California Current Ecosystem is available now to provide information on physical processes, habitat, and food web dynamics that are affecting Council-managed stocks. However, this information needs to be distilled into a useful product for Council review and discussion."* (H.1.b., Supplemental SSC Report)

And from the June 2011 SSC Ecosystem SubCommittee report at H.1.b:

> *The purpose of [an] annual update is to provide information about the physical and biological conditions of the system in the previous year that have the potential to affect recruitment, distribution, or vital rates of managed stocks. Possible information to include would be El Niño/La Niña conditions, environmental indices such as the Pacific Decadal Oscillation, upwelling start and end time, extent of the hypoxic zone off the central coast, krill, copepod or crab larvae abundance, and marine mammal and seabird trends. Information in the report should be put in the context of Council management. This report should be developed specifically for fisheries management applications; as such, it would need to be distilled and summarized to provide an update on the available science and ways it should be considered by the Council. The NPFMC has produced an annual Ecosystem Report (http://www.afsc.noaa.gov/refm/docs/2009/ecosystem.pdf) but the document is over 200 pages; any comparable report for the California Current would need to be summarized according to implications for each FMP to be useful for consideration in setting optimum yields (OYs) or prioritizing research needs.*

This draft FEP outline provides a proposed process for annual state of the ecosystem reporting in Section 1.4, above. The contents and format of an annual ecosystem considerations report would need to be developed through collaborative discussions between report contributors and Council advisory bodies.

6.2 Science Questions for Future Consideration

Ecosystem science can be useful both in its application to FMP species-group management, and to aid in long-term Council planning on ecosystem-wide concerns. In this section, we review the science questions common across all four FMPs, follow with FMP-specific research issues, and conclude with a discussion of some broad-scale and long-term issues that could affect fisheries management, such as climate shifts and ocean acidification. Francis et al. (2007) recommend making scientific progress towards ecosystem based fisheries management with these principles: 1. Keep a perspective that is holistic, risk-averse, and adaptive. 2. Question key assumptions, no matter how basic. 3. Maintain old-growth age structure in fish populations. 4. Characterize and maintain the natural spatial structure of fish stocks. 5. Characterize and maintain viable fish habitats. 6. Characterize and maintain ecosystem resilience. 7. Identify and maintain critical food web connections. 8. Account for ecosystem change through time. 9. Account for evolutionary change caused by fishing. 10. Implement an approach that is integrated, interdisciplinary, and inclusive (Francis et al. 2007). Given those recommendations, here are areas where ecosystem science might better inform Council decisions:

6.2.1 Cross-FMP – Needed Future Ecosystem Considerations

1. Evaluate the influence of climatic/oceanographic conditions on the population dynamics of FMP species. Develop IEA indicators to track that influence, such as for upwelling, sea surface temperatures, Pacific Decadal Oscillation, chl-a, and zooplankton index. Evaluate the efficacy of incorporating environmental factors within the current stock assessment modeling framework (Stock Synthesis 3). Model effects of climate forcing on productivity and assess utility of simulated estimates of the unexploited biomass over time (a “dynamic B0”) rather than the static estimate of long-term, mean, unfished abundance (Sibert et al. 2006). This is now done for many assessments in order to represent relative depletion from both a static and dynamic perspective (Maunder and Aires-da-Silva 2010).
2. Assess high and low frequency changes in the availability of target stocks, and the vulnerability of bycatch species, in response to dynamic changes in climate and oceanographic conditions (such as seasonal changes in water masses, changes in temperature fronts or other boundary conditions, and changes in prey abundance). Link with socio-economic data and modeling to assess effects of changes in availability on West Coast fisheries. For example, during periods of low HMS availability, recreational fishermen who might prefer to harvest HMS species may increase harvest rates and activity for alternative species, such as rockfish and other groundfish.
3. Examine ecological interactions for influence on managed and non-managed species, including predator-prey relationships, competition, and disease. Investigate the role of FMP species in the food web, including analysis of behavioral interactions (e.g. functional response) between predators and prey.
4. Evaluate effectiveness of standardized bycatch reporting methodologies in all FMP fisheries and develop quantitative information on the extent of the cumulative bycatch of all FMP fisheries.
5. Spatially-explicit management: What is the effect of marine spatial planning on FMP species and fisheries? To address this question, a review of marine spatial planning would include both fisheries and non-fisheries closures, traditional fishing grounds, the effects of potential future non-fishing ocean areas uses, and asking about the types of activities tend to generate EFH/ESA consultations.

6. Investigate how viability and resilience of coastal communities are affected by changes in ecosystem structure and function, including short- and long-term climate shifts.
7. Investigate how fishing activity affects ecosystem structure and function, particularly spatial and temporal fishing patterns and their relation to changing patterns in the ecosystem (cumulative impacts of all FMP fisheries).
8. Identify key indicators for recruitment, growth, spatial availability, and overall CCE productivity.
9. Review management reference points, including rebuilding reference points, in light of ecosystem interactions. For example, do reference points like Bzero account for ecosystem interactions of a given species, or do they just reference the life history information about that particular stock? (Brand et al, 2007)
10. Investigate how different habitat types contribute to species productivity rates (habitat-specific demographic rates). Determine whether Habitat Assessment Improvement Plan (NMFS 2010) can be used to incorporate habitat data into stock assessment models.
11. Better understand spatial structure and geographic range (meta-population structure) of managed stocks and investigate what are the most appropriate spatial scales for management.
12. Assess the effects of different types of fishing gear on ecosystem structure and function, and investigate the effects of the ecosystem structure and function on gear performance.
13. Assess near-shore distribution of FMP species for habitat needs and fishery vulnerability during nursery and pre-reproductive life stages. Characterize the influence of nearshore marine, estuarine and freshwater water quality on survival, growth, and productivity.
14. Assess the evolutionary impacts of fishery management measures and fishing practices, and investigate whether those impacts affect yield or sustainability.
15. Develop an analytical framework to compile the information and evaluate the tradeoffs society is willing to make across the alternative ecological benefits fishery resources provide.

6.2.2 CPS FMP – Needed Future Ecosystem Considerations

1. Climate or ecosystem indicators are not included in the annual stock assessments for Pacific sardine and Pacific mackerel, the FMP's actively managed species. If significant climate-productivity relationships could be developed for Pacific sardine and Pacific mackerel, as well as for other CPS, assessments would benefit since CPS are known to be quite sensitive to long and short-term climate change in the CCLME.
2. Review and revise the climate-based factor in the harvest control rule for Pacific sardine. While not included directly in the assessment process, a climate-based factor is included in the process for determining the annual harvest level for Pacific sardine. For sardine, the FRACTION term in the harvest control rule formula is a function of a three-year average of sea surface temperatures (SST) taken at the Scripps Institute of Oceanography pier located in La Jolla, California. Including this term reflects the positive relationship between sardine reproductive success and water temperature; at higher SSTs a greater fraction of the available biomass can be harvested. Recent work by McClatchie et al. (2010) finds that the Scripps Institute of Oceanography SST is no longer valid in terms of predicting sardine reproductive success. The Council has long identified the review of harvest control rules as a high priority research need and has tasked the CPSMT and the SSC with reviewing these findings. It is anticipated that the Council, the SWFSC, and the States will work toward the development of improved environmental indicators.

3. A management concern of the Council under EBFM will be the evaluating trade-offs between increasing/decreasing the yield of CPS and the potential yield loss/gain of a predator that may be in another Council FMP or be of concern in terms of its ecological importance. In order to come up with a comprehensive optimum yield in this situation, ecological and economic considerations come to the fore, since its resolution depends crucially on the relative net benefits provided society through these interactions (Hannesson et al. 2009; Hannesson and Herrick 2010).
4. NMFS's Southwest Region initiated a pilot observer program for California-based coastal purse seine fishing vessels targeting CPS in 2004 to augment and confirm bycatch rates derived from CDFG dockside sampling. The pilot observer program's primary intent was to gather data on total catch and bycatch, and on interactions between their fishing gear and protected species such as salmon, marine mammals, sea turtles, and sea birds. This program needs to be reviewed to determine whether it should be revived and fully implemented to include standardization of data fields, development of a fishery-specific Observer Field Manual, construction of a relational database for the observer data, and creation of a statistically reliable sampling plan.

6.2.3 Groundfish FMP – Needed Future Ecosystem Considerations

1. Many species show low frequency variability in recruitment due to lower biomass and/or a low productivity environmental regime. For example, the biomass of widow rockfish has decreased steadily since the early 1980s, and recruitment during the early 1990s is estimated to have been considerably smaller than before the mid 1970s (He et al. 2007). However, there is evidence that recruitment of many rockfish species since 1999 has been higher than the average of the 1990s (He et al. 2007). Additionally, several data sources in the cabezon assessment indicate that there was potentially good recruitment after 1999 and before 1977, whereas these same sources indicate that recruitment was poor prior to 1999 in the Southern California Stock (Cope and Punt, 2006). The cabezon recruitment patterns of the California sub-stocks suggest a possible link between environmental forcing and population dynamics (Cope and Key 2009). Specifically, strong ENSO conditions (especially in southern California) may be a pre-cursor to significant recruitment events and should be explored further to help increase the understanding of spatially-explicit recruitment responses and inform future recruitment events (Cope and Key 2009). For example, declines in kelp habitat caused by increasing ocean temperatures in southern California since the 1990s led assessors to suspect that the decline of blue rockfish in this area was in part due to environmental factors affecting habitat, rather than entirely a function of fishing (Key et al. 2008). Finally, correlations between spring sea surface height (Schirripa 2005), zooplankton indices (Schirripa 2007) and sablefish age-0 survival suggest environmental forcing of recruitment. Hamel et al. (2009) recommend investigating effects of PDO, ENSO and other climatic variables on recruitment. A better understanding of the relationship between the population dynamics and climate for such species could reduce the uncertainty of future assessments (Cope and Punt, 2006; He et al. 2007).
2. Provide research on relative density of rockfish in trawlable and untrawlable areas and differences in age and length compositions between these areas (e.g. shortspine thornyhead (Hamel 2005); darkblocked rockfish (Hamel 2008)).
3. Investigate predation impacts likely to affect abundance of assessed species (e.g. lingcod on gopher rockfish (Key et al. 2005); sablefish and shortspine thornyhead on longspine

thornyhead (Fay 2005, Field et al. 2006); Humboldt squid on Pacific hake (Field et al. 2007, Homes et al. 2008).

4. Investigate hake spatial distributions across all years and between bottom trawl and acoustic surveys to estimate changes in catchability/availability across years (Helser et al. 2006; Helser et al. 2008). Two primary issues are related to the changing spatial distribution of the survey as well as the environmental factors that may be responsible for changes in the spatial distribution of hake and their influences on survey catchability and selectivity (Agostini et al. 2006, Helser et al. 2006; Helser et al. 2008). Hamel et al (2009) also recommend investigating time-varying availability inshore for lingcod.
5. Review acoustic hake data to assess whether there are spatial trends in the acoustic survey indices that are not being captured by the model (Helser et al. 2006; Helser et al. 2008). Analysis should include investigation of stock migration (expansion/contraction) in relation to variation in environmental factors (Helser et al. 2006; Helser et al. 2008).
6. Investigate time-varying growth rates and maturity schedules as influenced by environmental factors because of apparent low frequency variability (e.g. Pacific hake (Hamel and Stewart 2009), bocaccio (MacCall 2008); chillipepper rockfish (Field 2007); english sole (Stewart 2008); lingcod (Hamel et al. 2009); splitnose rockfish (Gertseva et al. 2009), chilipepper (Harvey et al., 2011).
7. Research consequences of poor environmental conditions on bioenergetic allocation patterns (bocaccio (Field et al. 2009)).

6.2.4 HMS FMP – Needed Future Ecosystem Considerations

1. Assess nearshore distribution of juvenile sharks for habitat needs and fishery vulnerability during nursery and pre-reproductive life stages (Hanan 1993, Cartamil 2010).
2. Research and modeling needed on the links between climate and the migration patterns of protected bycatch species to allow us to refine our closed area management programs, such as for leatherback and loggerhead sea turtles.
3. Evaluate utility of Pacific pelagic ecosystem models (e.g., Kitchell et al. 1999, Kitchell et al. 2002, Cox et al. 2002, Olson and Watters 2003, Watters et al. 2003, Hinke et al. 2004, Lehodey et al. 2008) for informing Council decisions. Polovina et al. (2009) recently found that with increasing fishing pressure, the catch rates of top predators such as marlin, spearfish, sharks, and large tunas (bigeye and yellowfin) declined, while the catch rates of mid-trophic level species such as mahimahi, pomfret and escolar increased – consistent with earlier models for this same area (Kitchell et al. 1999, Kitchell et al. 2002). Conversely, some later models did not predict as strong effects of fishing through the food web (e.g., Cox et al. 2002) or did not predict long term changes (e.g., Watters et al. 2003), the resulting release of predation mortality from mid-trophic level populations from declines in top trophic-level predators is consistent with the empirical results described in Sibert et al. (2006) and Polovina (2009).

6.2.5 Salmon FMP – Needed Future Ecosystem Considerations

1. Develop tools that describe the environmental state and potential habitat utilization for near-shore anadromous fish, including coastwide sampling of juvenile distributions, monitoring and characterization of the forage based for juvenile and adult salmon, and fine-scale mapping of stock-specific ocean catch distributions.

2. Characterize and map the ocean habitats for anadromous species using data from satellites and electronic tags.
3. Characterize trends in hatchery salmon production and assess the potential for density-dependent effects in freshwater streams, estuaries, and coastal ocean environments. Assess the potential for increasing hatchery production throughout the Pacific Rim to impact body size, age-at-maturity and productivity of salmon in offshore ocean environments.
4. Examine temporal trends in regional salmon harvest rates and measure their covariation with temporal and spatial patterns of environmental variability. Characterize temporal changes in size, age and migration timing of heavily exploited salmon stocks to evaluate correlations with harvest and environmental patterns.
5. Research is needed on the effects of ecological interactions such as disease, predation and competition on the population dynamics of adult and juvenile salmon. In particular, research is needed on the unique impact of cultured salmon, both hatchery smolts and marine net pen reared fish, on disease and competition.
6. Characterize the influence of nearshore marine, estuarine and freshwater water quality on survival, growth, and reproduction of salmon.
7. Evaluate potential impact to wild salmon populations of interbreeding with genetically-modified hatchery salmon.
8. Determine influence of sea surface temperature anomalies to smolt-to-adult return predictions.
9. Evaluate apparent increasing percentage of one-ocean jacks in salmon returns to fresh water.

6.2.6 Oceanographic Conditions, Broad-Scale and Long-Term Ecosystem Conditions

Temperature within the CCE is monitored reliably via several methods. Surface temperatures are sampled via satellite on relatively high temporal (daily) and spatial (several km) scales. In situ and some sub-surface temperatures are less frequently monitored by buoys and ship-based measurements. Gliders and shore-stations provide additional measurements at lower spatial coverage. CCE water temperature measurements have been taken for a longer span of time than any other measurements, providing excellent background data to evaluate current and historic trends (e.g. the CALCOFI program).

Measurement of ocean pH requires in situ water sampling, and cannot currently be conducted via remote means. However, because of the relatively tight coupling of ocean pH with atmospheric forcing, biogeochemical models may be used in some cases to determine ocean pH at higher temporal and spatial frequency than in situ sampling would allow. In fact, historic ocean pH levels used for calculating long term trends have mostly been calculated used biogeochemical-atmospheric models (Fabry et al., 2008). There is much less data available, both temporally and spatially concerning ocean pH than nearly all other physical-chemical measurements, partly because up until recently, it was believed that the ocean was relatively “self-buffering” and would not undergo significant changes in pH. With the recent recognition that pH is indeed decreasing, and that this may be detrimental to many marine organisms, monitoring of pH has increased, particularly in coastal regions.

Oxygen levels have been measured for many decades throughout the CCE (e.g.CALCOFI), traditionally via in situ sampling, followed by ship-board analysis. Oxygen cannot be measured remotely via satellites or other means. However, recent technological advances have enabled the development of in situ oxygen sensors that can provide fairly rapid subsurface measurements of oxygen (Tengberg et al., 2006). Modeling in situ oxygen levels is problematic in most cases, since it requires complex atmospheric-physical-biological coupled models with accurate mixing schemes, although such models do exist and can be applied in some areas with decent success (Najjar and Keeling, 2000). Thus, modeling may provide a limited ability to fill in data gaps, and make limited predictions of water oxygen content.

Future research considerations that would improve the Council's ability to incorporate temperature, pH, and Oxygen research and information into ecosystem-based fishery management are:

1. Direct physiological effects of temperature, pH, and O changes on managed and non-FMP forage species, including, but not limited to: tolerance limits, growth rate, reproductive rate
2. Current spatial and depth boundaries of all FMP, and non-FMP forage species in regards to Temperature, pH, and O.
3. Spatially-specific trend analysis of temperature, pH, and O changes specific to the EFH of all FMP and non-FMP forage species
4. Spatially-specific forecasts of temperature, pH, and O changes specific to the EFH of all FMP and non-FMP forage species
5. Spatially-specific trend and forecast of temperature, pH, and O effects on food chain base (1° and 2° production) for all FMP and non-FMP forage species

6.3 Sources for Chapter 6

Cartamil, D., N.C. Wegner, D. Kacev, N. Ben-aderet, S. Kohin and J. B. Graham. 2010. Movement patterns and nursery habitat of juvenile thresher sharks Alopias vulpinus in the Southern California Bight. Marine Ecology Progress Series 404: 249-258.

Cayan, D.R. and D.H. Peterson. 1989. The influence of North Pacific atmospheric circulation on streamflow in the west. Geophysical Monograph 55: 375-397.

Cope, J.M., and A.E. Punt. 2006. Status of Cabezon (Scorpaenichthys marmoratus) in California Waters as Assessed in 2005. Pacific Fishery Management Council [PFMC], Portland, OR.

Cope, J.M., and M. Key. 2009. Status of Cabezon (Scorpaenichthys marmoratus) in California and Oregon Waters as Assessed in 2009. Pacific Fishery Management Council [PFMC], Portland, OR.

Cox, S.P., T.E. Essington, J.F. Kitchell, S.J.D. Martell, C.J. Walters, C. Boggs and I. Kaplan. 2002. Reconstructing ecosystem dynamics in the central Pacific Ocean, 1952-1998. II. A preliminary assessment of the trophic impacts of fishing and effects on tuna dynamics. Canadian Journal of Fisheries and Aquatic Sciences 59: 1736-1747.

Fabry, V.J., Seibel, B.A., Feely, R.A., and Orr, J.C. 2008. Impacts of ocean acidification on marine fauna and ecosystem processes. ICES JMS, 65:414-432.

Fay, G. 2005. Stock Assessment and Status of Longspine Thornyhead (Sebastolobus altivelis) off California, Oregon and Washington in 2005. Pacific Fishery Management Council [PFMC], Portland, OR.

Field, J.C., K. Baltz, A.J. Phillips, and W.A. Walker. 2007. Range expansion and trophic interactions of the jumbo squid, Dosidicus gigas, in the California Current. California Cooperative Oceanic and Fisheries Investigations Reports 48: 131-146.

Field, J.C., R.C. Francis, and K. Aydin. 2006. Top-down modeling and bottom-up dynamics: linking a fisheries-based ecosystem model with climate hypotheses in the Northern California Current. Progress in Oceanography 68: 238-270.

Field, J.C., 2008. Status of the Chilipepper rockfish, Sebastes goodei, in 2007. Pacific Fishery Management Council [PFMC], Portland, OR.

Field, J.C., Dick, E.J., Pearson, D., and A.D. MacCall. 2009. Status of bocaccio, Sebastes paucispinis, in the Conception, Monterey and Eureka INPFC areas for 2009. Pacific Fishery Management Council [PFMC], Portland, OR.

Francis, R.C., M.A. Hixon, M.E. Clarke, S.A. Murawski and S. Ralston. 2007. Ten Commandments for Ecosystem-Based Fisheries Scientists. Fisheries 32:5: 217-233.

Gertseva, V.V., Cope, J.M., and D.E. Pearson. 2009. Status of the U.S. splitnose rockfish (Sebastes diploproa) resource in 2009. Pacific Fishery Management Council [PFMC], Portland, OR.

Hamel, O.S. 2005. Status and Future Prospects for the Shortspine Thornyhead Resource in Waters off Washington, Oregon, and California as Assessed in 2005. Pacific Fishery Management Council [PFMC], Portland, OR.

Hamel, O.S., 2008. Status and Future Prospects for the Darkblotched Rockfish Resource in Waters off Washington, Oregon, and California as Assessed in 2007. Pacific Fishery Management Council [PFMC], Portland, OR.

Hamel, O.S. and I.J. Stewart. 2009. Stock Assessment of Pacific Hake, Merluccius productus, (a.k.a. Whiting) in U.S. and Canadian Waters in 2009. Pacific Fishery Management Council Stock Assessment and Fishery Evaluation. Portland, OR.

Hamel, O.S., Sethi, S.A., and T.F. Wadsworth. 2009. Status and Future Prospects for Lingcod in Waters off Washington, Oregon, and California as Assessed in 2009. Pacific Fishery Management Council [PFMC], Portland, OR.

Hannesson, R., S. Herrick and J. Field. 2009. Ecological and economic considerations in the conservation and management of the Pacific sardine (Sardinops sagax). Canadian Journal of Fisheries and Aquatic Sciences 66: 859-868.

Hannesson, R. and S.F. Herrick Jr. 2010. The value of Pacific sardine as forage fish. Marine Policy 34: 935–942

Harvey, C.J., J.C. Field, S.G. Beyer, and S.M. Sogard. 2011. Modelling growth and reproduction of chilipepper rockfish under variable environmental conditions. Fisheries Research, 109: 187-200.

He, X., Pearson, D.E., Dick, E.J., Field, J.C., Ralston, S., and A.D. MacCall. 2007. Status of the widow rockfish resource in 2007 An Update. Pacific Fishery Management Council [PFMC], Portland, OR.

Helser, T.E., Stewart, I.J., Fleischer, G.W., and S. Martell. 2006. Stock Assessment of Pacific Hake (Whiting) in U.S. and Canadian Waters in 2006. Pacific Fishery Management Council [PFMC], Portland, OR.

Helser, T.E., Stewart, I.J., and O.S. Hamel. 2008. Stock Assessment of Pacific Hake, Merluccius productus, (a.k.a Whiting) in U.S. and Canadian Waters in 2008. Pacific Fishery Management Council [PFMC], Portland, OR.

Hickey, B.M. 1998. Coastal oceanography of Western North America from the tip of Baja California to Vancouver Island. In A.R. Robinson and K.H. Brink (editors) The Sea, Volume 11. John Wiley and Sons: New York.

Hinke, J.T., I.C. Kaplan, K. Aydin, G.M. Watters, R.J. Olson and J.F. Kitchell. 2004. Visualizing the food-web effects of fishing for tunas in the Pacific Ocean. Ecology and Society 9. http://www.ecologyandsociety.org/vol9/iss1/art10/inline.html

Key, M., MacCall, A.D., Bishop, T. and B. Leos. 2005. Stock assessment of the gopher rockfish (Sebastes carnatus). Pacific Fishery Management Council [PFMC], Portland, OR.

Key, M., MacCall, A.D., Field, J., Aseltine-Neilson, D., and K. Lynn. 2008. The 2007 Assessment of Blue Rockfish (Sebastes mystinus) in California. Pacific Fishery Management Council [PFMC], Portland, OR.

Kitchell, J. F., T. E. Essington, C. H. Boggs, D. E. Schindler, and C. J. Walters. 2002. The role of sharks and longline fisheries in a pelagic ecosystem of the central Pacific. Ecosystems 5:202–216.

Kitchell, J. F., C. Boggs, X. He, and C. J. Walters. 1999. Keystone predators in the Central Pacific. In Ecosystem approaches to fisheries management, p. 665 – 683. Univ. Alaska Sea Grant Rep. AL -SG-99-01, Anchorage, Alaska.

Lehodey, P., I. Senina and R. Murtugudde. 2008. A spatial ecosystem and populations dynamics model (SEAPODYM) – Modeling of tuna and tuna-like populations. Progress in Oceanography 78: 304:318.

MacCall, A.D. 2008. Status of bocaccio of California in 2007. Pacific Fishery Management Council [PFMC], Portland, OR.

Maunder, M.N. and A. Aires-da-Silva. 2010. Status of the yellowfin tuna in the Eastern Pacific Ocean in 2008 and outlook for the future. Inter-American Tropical Tuna Commission (IATTC) Report.

McClatchie, S., R. Goericke, G. Auad and K. Hill. 2010. Re-assessment of the stock-recruit and temperature-recruit relationships for Pacific sardine (Sardinops sagax). Ca. J. Fish. Aquat. Sci. 67: 1782-1790.

Najjar, R.G., Keeling, R.E. 2000. Mean annual cycle of the air-sea oxygen flux: A global view. Glob. Biog. Chem. Cyc. 14:573-584.

NMFS. 2010. Marine fisheries habitat assessment improvement plan. Report of the National Marine Fisheries Service Habitat Assessment Improvement Plan Team. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-F/SPO-108, 115 p. available online at http://www.st.nmfs.noaa.gov/st4/HabitatScience.html

Olson, R.J. and G.M. Watters. 2003. A model of the pelagic ecosystem in the Eastern Tropical Pacific Ocean. Inter-Amer. Trop. Tuna Com. Bull. 22:3:135-218.

Parrish, R.H., F.B. Schwing, and R. Mendelssohn. 2000. Midlatitude wind stress: The energy source for climate regimes in the North Pacific Ocean. Fisheries Oceanography 9: 224-238.

Polovina, J.J., M. Abecassis, E.A. Howell and P. Woodworth. 2009. Increases in the relative abundance of mid-trophic level fishes concurrent with declines in apex predators in the subtropical North Pacific, 1996-2006. Fishery Bulletin 107: 523-531.

Schirripa, M.J. 2005. Status of the Sablefish Resource off the Continental U.S. Pacific Coast in 2005. Pacific Fishery Management Council [PFMC], Portland, OR.

Schirripa, M.J. 2007. Status of the Sablefish Resource off the Continental U.S. Pacific Coast in 2007. Pacific Fishery Management Council [PFMC], Portland, OR.

Sibert J, J. Hampton, P. Kleiber, and M. Maunder. 2006. Biomass, size, and trophic status of top predators in the Pacific Ocean. Science 314:1773–1776.

Stewart, I.J. 2008. Updated U.S. English sole stock assessment: Status of the resource in 2007. Pacific Fishery Management Council [PFMC], Portland, OR.

Tengberg, A., Hovdenes, J., Andersson, H. J., Brocandel, O., Diaz, R., Hebert, D., Arnerich, T., Huber, C., Kortzinger, A., Khripounoff, A., Rey, F., R¨onning, C., Schimanski, J., Sommer, S.,and Stangelmayer, A. 2006. Evaluation of a lifetime-based optode to measure oxygen in aquatic systems, Limnol. Oceanog. Methods., 4:7–17

Watters, G.M., R.J. Olson, R.C. Francis, P.C. Fielder, J.J. Polovina, S.B. Reilly, K.Y. Aydin, C.H. Boggs, T.E. Essington, C.J. Walters and J.F. Kitchell. 2003. Physcial forcing and the dynamics of the pelagic ecosystem in the eastern tropical Pacific: simulations with ENSO-scale and global-warming climate drivers. Canadian Journal of Fisheries and Aquatic Sciences 60: 1161-1175.

Appendix A – List of Species

At its June 2011 meeting, the Council directed the EPDT to develop "a list of species that are not currently included in any FMP, not the subject of state management, and not managed under ESA regulations. Also, identify the subset of this species list that could be subject to future target fishing."

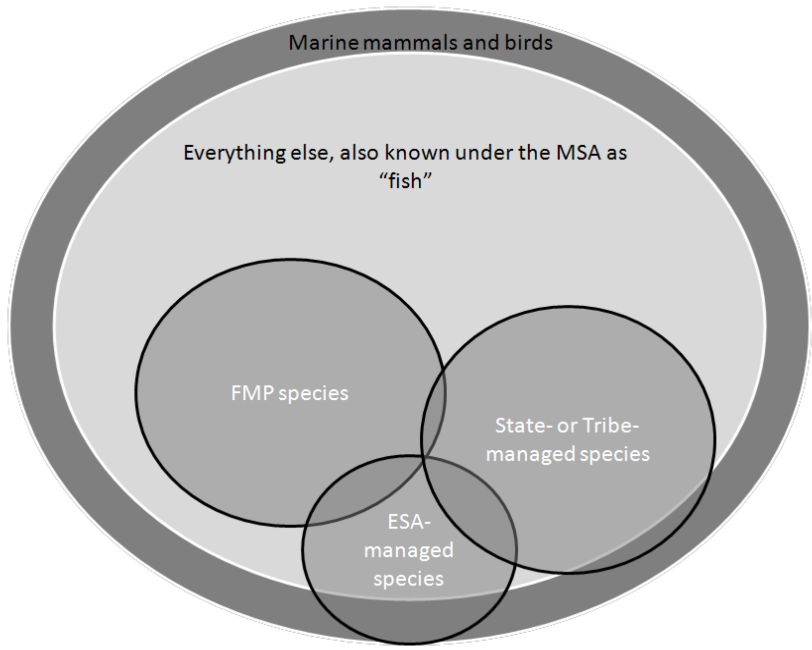


Figure A1: Separating Organisms of the West Coast Exclusive Economic Zone by Jurisdiction

Figure 1 represents the separate management jurisdictions for the organisms of the U.S. West Coast EEZ, as envisioned by the Magnuson-Stevens Fishery Conservation and Management Act (MSA.) Federal management of marine mammals is shared between NOAA and the US Fish and Wildlife Service (USFWS,) under the Marine Mammal Protection Act (MMPA) and, where applicable, the Endangered Species Act (ESA). Federal management of seabirds is primarily the responsibility of the USFWS, under the Migratory Bird Treaty Act. Of the organisms of the West Coast EEZ, the Council has potential jurisdiction over "fish," which the MSA defines as: "finfish, mollusks, crustaceans, and all other forms of marine animal and plant life other than marine mammals and birds." Within the subset of organisms the MSA calls "fish" lie FMP species, state- or tribe-managed species (which may also be FMP species,) and species managed under the Endangered Species Act (which may also be FMP or state- or tribe-managed species.)

In thinking about how best to address the Council's list-of-species assignment, the EPDT tried to develop an ecosystem-based approach to the assignment that was guided by the FEP's Purpose and Need statement. The Council's direction came out of a discussion about the desire of some stakeholders to protect "forage species," and counter-concern by other stakeholders that the term "forage species" is overly broad, and can refer to any animals that are preyed upon by other animals. The EPDT reviewed the scientific literature for a more definitive term for these organisms that are themselves generally plankton-eating and eaten by higher-order predators and suggests initially tackling the Council's assignment by:

1. Providing a draft definition to bound the term "low trophic level (LTL) species," which would include those species commonly thought of as "forage fish," accompanied by a list

of those CCE species that currently meet that definition, with information on those species' relative abundance, fisheries potential, and role in the ecosystem;

2. Assessing worldwide fisheries landings (marketability) for low trophic level (LTL) species that are unfished or little-fished within the CCE, yet are similar to species that are moderately- or heavily-fished elsewhere in the world;
3. Reviewing the range of fisheries permissible within the West Coast EEZ under the MSA and current Federal regulations.

If the Council finds this approach to its list-of-species assignment acceptable for LTL species, the EPDT would be interested in reporting back to the Council at a future meeting, using this same approach for mid- and higher trophic level species. Many of the lowest trophic order organisms, such as phyto- and zooplankton smaller than krill, are likely to be too small to be of interest as fisheries targets. The Council may, however, be interested in the status of those species, either as potential predictors of available harvest levels of FMP species, or as indicators of health and status of the ecosystem at large. The EPDT does not yet have suggestions for how best to review the lowest trophic order organisms within the CCE, but can work at that level, should the Council so desire. Depending on Council guidance on FEP contents, some or most of the information from these discussions could be used in Chapter 3, above.

Defining Low Trophic Level (LTL) Species

The EPDT found a helpful working definition for LTL species developed by Smith et al. (2011,) which they defined as species that are often present in high abundance, forming dense schools or aggregations, and which are generally plankton feeders for a large part of their life cycle. They characterize such species as including small pelagic "forage" fish such as anchovy, sardine, herring, mackerel and capelin, as well as invertebrate species such as krill. Such species are often the principal means of transferring production from primary and secondary tropic levels (typically phytoplankton and zooplankton) to larger predator fish, marine mammals and seabirds.

Many researchers have noted that in coastal upwelling ecosystems, like the CCE, the vast majority of trophic transfer often takes place through a small number of key LTL species. Coastal upwelling systems have been described as 'wasp-waist' ecosystems , where the abundance of a few key low-to-mid-trophic level species (such as sardines, anchovies or krill) exerts both top-down control on a much more species rich assemblage of zooplankton prey, as well as bottom-up control on a diversity of higher trophic level predators. Consequently, we focus this preliminary analysis on LTL species that may be very abundant in a given habitat (e.g., nearshore, shelf, pelagic, mesopelagic) in any of the major biogeographical regions of the CCE, rather than on providing a comprehensive list of each and every species within the CCE. Table A-1, below, focuses on a handful of select or key species or taxonomic groups: providing: some approximations of their known typical habitat and relative abundance,

The term "wasp-waist"and the species assemblages it refers to have been described by Bakun (1996), Cury (2000) and Freon et al. (2009). These authors suggest that ecosystems for which this seem to be especially true are Eastern Boundary Current upwelling systems, which are subject to dynamic interannual and interdecadal changes in physical conditions. Ecosystems analogous to the CCE include other shelf and coastal systems, such as the confluence of the Kuroshio and Oyashia currents off of the east coast of Japan.

briefly noting their fisheries history or potential, current level of management, and, qualitatively evaluating their role in the ecosystem. For this report, the EPDT focused most strongly on pelagic zone LTL species. The EPDT believes that, should the Council find it of interest, further analysis focused on benthic zone LTL species could provide additional information on LTL species that primarily feed on small benthic invertebrates.

For the purpose of Table A-1, the term "managed" refers to whether there is active management under state, tribal or federal actions (including both FMP species and ESA listed species,) noting that some species for which management is listed as "none" may have some gear restrictions or other regulatory actions. The EPDT considered that if the ultimate objective is truly an ecosystem-wide perspective, information on state-managed species is or will be relevant for evaluating trade-offs and making decisions. For simplification, the EPDT also did not include juveniles of species that would otherwise be considered higher trophic level predators, although we recognize that the role of younger life history stages of all species as forage is critical and that the vast majority of predation mortality typically takes place in the larval or juvenile life history stages of most marine species. While the list in Table A-1 is incomplete, it captures a majority of the significant species and assemblages that could be considered LTL species under the suggested Smith et al (2011) definition, based on a documented review of existing literature.

In the diet of Pacific whiting, Euphausiids (krill), herring and anchovy represented over half of the prey, with predation on younger groundfish and other species (including cannibalism) representing the bulk of the remainder (Osmerids accounted for approximately 2% of all prey). Similarly, in a combined study and literature review of food habits of North Pacific albacore, Glaser (2010) found that northern anchovy consistently represented the most important prey species across multiple decades and regions. Finally, in a study of sea lion food habits in the southern California Bight, Lowry (1999) found that the CPS FMP species (market squid, northern anchovy, Pacific sardine, Pacific mackerel and jack mackerel), as well as Pacific hake, shortbelly rockfish and pelagic red crabs, were the most important prey species over a two decade period. Smelts (Osmerids) and to a lesser extent silversides (Atherinospsidae,) among others, are present in some food habits studies, but rarely to the magnitude of managed species.

Ichthyoplankton, which includes planktonic eggs and larvae, typically reflect relative spawning biomass for their species. A summary of over nearly 50 years of the ichthyoplankton community gives some sense of the relative abundance of various ecologically important species in the CCE (Moser et al. 2001). Six of the top 10 most abundant species throughout this long time period are northern anchovy, Pacific hake, Pacific sardine, jack mackerel, and rockfish (shortbelly rockfish and unidentified *Sebastes*, as most species are not identifiable to the species level). This indicates that the relative abundance and importance, at least in the southern part of the CCE, of these key species is far greater than most other LTL species. Notably, the remaining four species in the top 10 are mesopelagic species that further account for 12 of the top 20 most abundant species. There is considerably less comparable ichthyoplankton data for central and northern California, although survey data suggest that anchovy, herring, sardine and whitebait smelt have been the most abundant and important forage species in this region over the past 13 years (Orsi et al. 2007, Bjorkstedt et al. 2010). Ichthyoplankton data are more limited for the CCE north of Cape Mendocino, but existing studies suggest that off Washington and Oregon, *Osmeridae* (smelts, typically not identified to the species level) are often very abundant in the nearshore shelf waters, and tomcod and sandlance are often fairly abundant (see Richardson and Pearcy 1977, Kendall and Clark 1982 and Brodeur et al. 2008).

Although a comprehensive review of every food habits study and result was also beyond the scope of this exercise, and despite the observation that virtually all of the species listed in Table A-1 are encountered in predator food habits studies at times, the literature suggests that the greatest proportion of energy flow in the CCE appears to be through krill, market squid, northern anchovy, Pacific sardine and Pacific herring. There are few other species (excluding juveniles of non LTL species) that occur with high frequency and with a comparable significance to the above core group of species, suggesting that the conceptual wasp-waist model described earlier is reasonable for the CCE. Thus, despite real or potential historical or future conservation problems for some of these species, there is not a high level of unmanaged standing biomass for LTL species that could become subject to fisheries targeting over the short term and which are critical to large scale CCE functioning, energy flow, or integrity.

Table A-1: Preliminary summary of select LTL species in the CCE

Common and species name	Relative abundance	Fisheries potential	Role in ecosystem	Managed
Vertebrates				
Northern anchovy (*Engraulis mordax*)	Low frequency (regime scale) variability over time and space, but typically abundant from nearshore to offshore habitats throughout the CCE	Formerly a major fisheries target (100,000s tons), currently a small scale (largely bait) and incidental catch	Key forage species for wide range of HMS, salmon, groundfish, seabird and marine mammals	CPS FMP
Pacific sardine (*Sardinops sagax*)	Low frequency (regime scale) variability over time and space, but often abundant from nearshore to offshore habitats throughout the CCE	Historically, largest fishery in California Current (100,000s tons), currently a major fisheries target	When abundant, a key forage species for wide range of HMS, salmon, groundfish, seabird and marine mammals	CPS FMP
Pacific mackerel (*Scomber japonicus*)	Low frequency (regime scale) variability over time and space, but often abundant from nearshore to offshore habitats throughout the CCE	Historically and currently an important fisheries target (10,000s tons)	When abundant, a moderately important forage species for many HMS and some marine mammals	CPS FMP
Jack mackerel (*Trachurus symetricus*)	Low frequency (regime scale) variability over time and space, but often abundant in offshore habitats (rarely close to shore) throughout the CCE	Occasionally important fisheries target (10,000s tons)	When abundant, a moderately important forage species for many HMS and some marine mammals	CPS FMP
Pacific herring (*Clupea pallasi*)	Abundant to very abundant in nearshore and many estuaries	Fairly high commercial importance (up to 10,000s tons)	Among the more frequently encountered prey in predators such as salmon, hake, rockfish, marine mammals, seabirds	States
Round and thread herrings (*Etrumeus teres* and *Opisthonema libertate*)	Subtropical species that are "reasonably abundant" in the southern part of the CCS. Range likely to expand with global climate change	Unknown in CCS, but in 100,000s tons throughout Eastern Tropical Pacific	Currently key LTL species in core range, could potentially be in CCS with global change	none
American shad (*Alosa sapidissima*)	Anadromous, moderately abundant in rivers, estuaries	CCS landings in 100s tons, com./rec. important elsewhere	An introduced species (Bzero=0!), moderately important prey for some predators	none
Mesopelagic fishes (Myctophidae, Bathylagidae, Paralepididae, Gonosomatidae; 100s of species in CCS)	Likely the most abundant fish assemblage on the planet. Uncommon inshore but tremendously abundant in mesopelagic (offshore, midwater) waters	Currently limited fisheries potential; despite tremendous abundance, technology is historically infeasible	Important prey for entire mesopelagic food web, many large squids, many tunas and HMS, some rockfish (esp. blackgill, bank), rare in mammal or seabird diets	none
Pacific sandlance (*Ammodytes hexapterus*)	Common, but not abundant, in coastal waters of Pacific Northwest	Important fishery target in other regions (particularly North Atlantic)	Moderately important prey for some fishes, seabirds and marine mammals in the Pacific Northwest	none
Pacific saury (*Cololabis saira*)	Low frequency (regime scale) variability over time and space, primarily an offshore (pelagic) species, often very abundant in offshore waters during cool regimes/periods	Very important fishery off of Japan, elsewhere in North Pacific; presumably a potential large-scale target	Relatively important prey to albacore, sablefish, sharks, other HMS species (rarely found in predators shoreward of shelf break)	none

Common and species name	Relative abundance	Fisheries potential	Role in ecosystem	Managed
Silversides (Atherinospsidae; includes grunion, jacksmelt, topsmelt, perhaps 3-5 other rare spp.)	Moderately abundant in nearshore (but considerably less so than osmerids based on larval abundance data)	Historically commercial and recreational targets (up to ~ 1000 tons in 1940s), recent catches relatively modest. Fisheries typically nearshore	Very abundant in some nearshore areas, presumably important forage species in such areas, but rarely encountered in food habits data for key commercial species	none
Eulachon (*Thaleichthys pacificus*)	Anadromous, coastal, formerly fairly abundant, currently rare	Formerly of fairly high commercial/recreational importance (CCS landings in 1000s tons)	Common but not abundant prey item for wide range of predators	ESA
Other Osmerid smelts (Osmeridae; includes capelin, surf smelt, whitebait smelt, perhaps 3-5 other spp)	After the clupeids (and exclusive of mesopelagics), among the most abundant family of forage fish species in nearshore; typically less abundant offshore	Some species are of minor to modest commercial significance (surf smelt), or have been the target of major fisheries elsewhere (e.g., Atlantic capelin)	Preyed on by wide range of piscivores (seabirds, marine mammals, Pacific hake, sablefish, rockfish, salmon), but rarely comprise a large fraction of total prey.	none
Shortbelly rockfish (*Sebastes jordani*)	Likely the most abundant Sebastes spp. in Central and Southern California, exhibits low frequency (regime like) variability	Minor incidental landings, potential future fisheries target	Juvenile and adult life history stages are very important to salmon, many groundfish, seabirds and marine mammals.	Groundfish FMP
Sanddabs (*Citharichthys* spp), particularly Pacific (*C. sordidus*) and speckled (*C. stigmaeus*)	One of the more abundant soft-bottom groundfish, also found in water column, typically over shelf.	Substantial commercial and recreational catches (100s to 1000s tons)	Juvenile and adult life history stages are very important to many groundfish, particularly piscivorous flatfish; some seabirds and marine mammals.	Groundfish FMP
Pacific tomcod (*Microgadus proximus*)	Locally abundant in some nearshore habitats	Trace historical landings, little current fishery interest or potential	Relatively minor importance in most food habits studies.	none
Small croakers (*Sciaenidae*) e.g. white croaker and queenfish **	Fairly abundant, particularly in nearshore waters of the southern CCE	Some commercial and recreational landings (perhaps to 1000s tons)	Somewhat important for some nearshore species; larvae are very abundant in ichthyoplankton, suggesting relatively high abundance in some areas.	none
Invertebrates				
Euphausiids (krill), primarily *Euphausia pacifica* and *Thysanoessa spinifera*	Tremendously abundant throughout coastal and offshore waters, a hugely important component of the food web	Commercial targets in Antarctica, Japan, small fisheries off British Columbia and other locations; increasing commercial potential.	Key forage species for wide range of both juvenile and adult salmon, groundfish, squid, seabird and marine mammals	Fishing prohibited in CPS FMP
Market squid (*Doryteuthis opalescens*)	Nearshore and shelf distribution (adults relatively rare offshore)	Very important commercial target in CCS (up to, rarely over, 100,000 tons)	Key forage species for wide range of HMS, salmon, groundfish, seabird and marine mammals	CPS FMP (CA state)
Pelagic squids (such as boreal clubhook squid, neon flying squid and Humboldt squid)	Offshore distribution (most spp. rare inshore)	Important commercial target elsewhere in range	These and other squid are key prey for HMS species and marine mammals.	none

** Sciaenidae, excluding white sea bass (*Atractoscion nobilis*) and corbina (*Menticurrhus undulates*) but including small, schooling species such as queenfish (*Seriphus politus*), spotfin croaker (*Roncador stearnsii*), white croaker and potentially others (the latter three are probably the most abundant; note that white seabass is clearly a higher trophic level predator).

Potential for Developing LTL Fisheries in the CCE

In addition to assigning the EPDT to review unmanaged species, the Council requested that we identify species that could be subject to future target fishing within the CCE. Under this criterion, several of the select LTL species in the CCE could potentially be the subject of future fisheries targeting, based on their importance in global commodity markets. Although these species are not presently targeted by large-scale U.S. commercial fisheries, they are an incidental catch in a number of fisheries and occasionally show up in the West Coast commercial fisheries landings (Figure A2). Globally, some of these species constitute significant landings outside of the CCE (Figure A3).

Figure A2. West Coast landings (mt) of select California Current Ecosystem LTL species, 1981-2010.

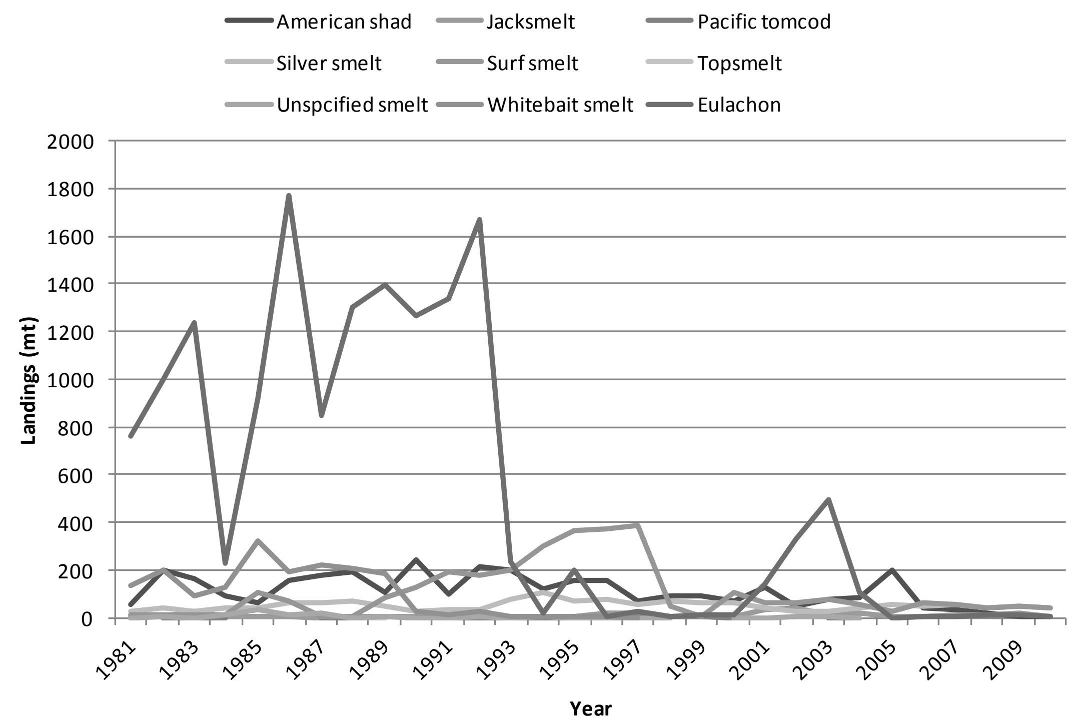
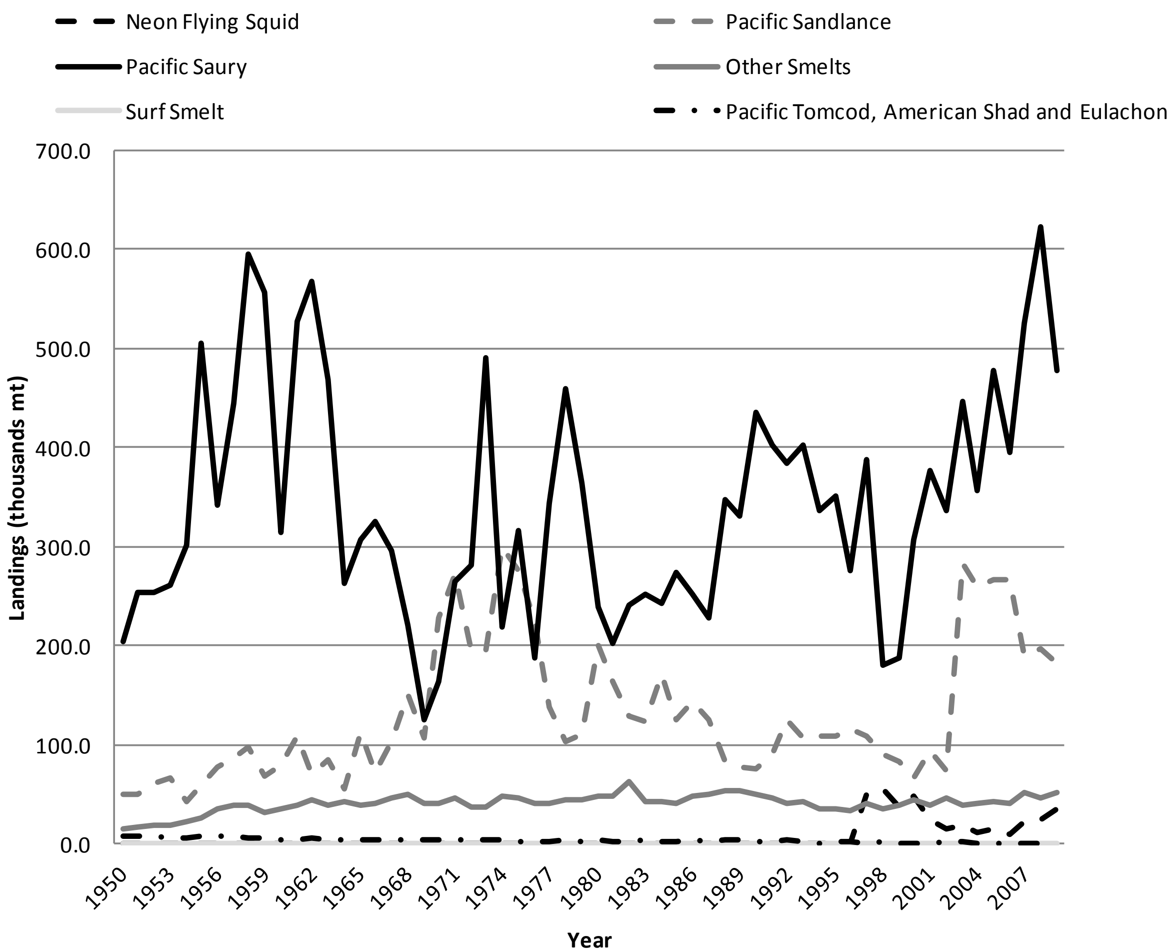


Figure A3. Global landings of select California Current Ecosystem LTL species, 1950-2009.



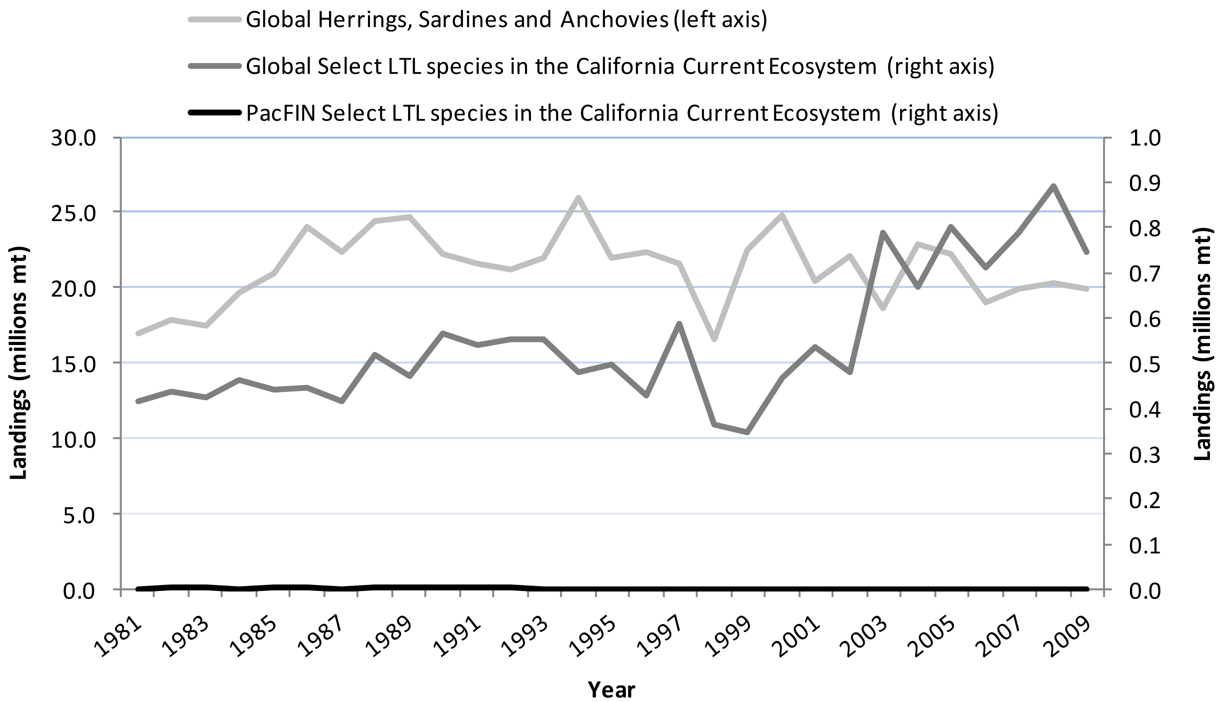
Sources: FAO Statistics and Information Service of the Fisheries and Aquaculture Department. 2011. Capture production 1950-2009. FISHSTAT Plus - Universal software for fishery statistical time series [online or CD-ROM]. Food and Agriculture Organization of the United Nations. Available at: http://www.fao.org/fishery/statistics/software/fishstat/en; PacFIN Management Database.

Harvests of LTL species are converted into various commodities through value added production processes (Herrick et al. 2009). Based on Food and Agriculture Organization (FAO) fisheries commodities, production and trade data from1976-2009, most of the reported LTL species commodities production was in the fishmeal and fish oil category. During that period, commodities in the fishmeal and fish oil category increased to well over 50% of total annual LTL species commodities production. With the fisheries for traditionally popular LTL species appearing to be at or exceeding MSY levels, the growing importance of these minor LTL species in the global landings largely reflects their increasing use as ready substitutes in the production of fishmeal and fish oils (Figure A3).

Demand for LTL species in the production of fishmeal has mainly been driven by the spectacular growth of global aquaculture, which is expected to continue into the foreseeable future (Tacon and Metian 2008, Shamshak and Anderson 2008, Herrick et al. 2009). The production of many aquaculture species depends on LTL species fisheries to supply the raw ingredients in today's aquafeeds. In the recent boom in capture-based aquaculture, demand has increased for whole live/fresh/frozen LTL species for pen fattening aquaculture operations (Zertuche-Gonzales et al. 2008). All these feed requirements pose a potential sustainability problem for the aquaculture industry, because at present, unlike fishmeal use in livestock production, there are limited opportunities to replace LTL species, either in fresh or in fishmeal form, with cost effective protein substitutes. Given limited potential for increased fishmeal production from traditional LTL species prices for fishmeal and fish oil will continue to rise (Figure A5). This makes the prospect for fisheries developing on the minor LTL species all that more attractive, as higher fishmeal prices are sure to translate into higher exvessel prices for the raw ingredients.

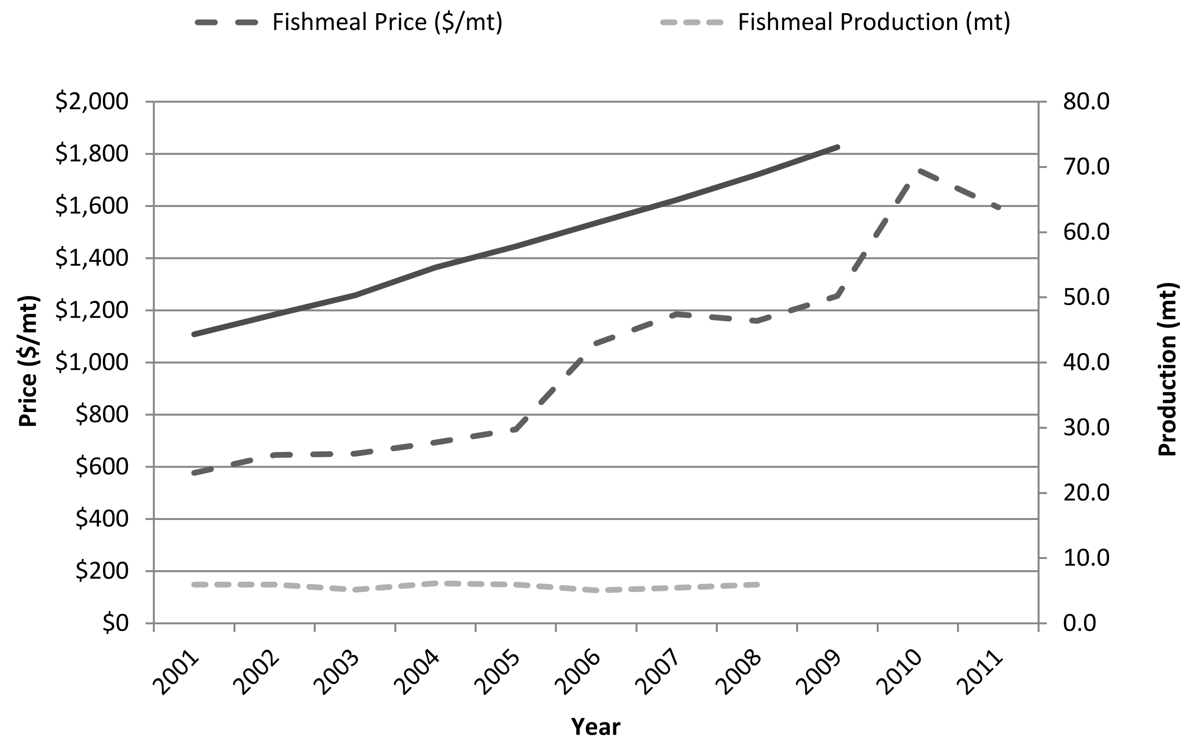
From an ecosystem prospective, the benefits resulting from commercial exploitation of LTL species will have to be balanced against the full range of benefits these resources provide when considering their total economic value (Hannesson et al. 2009). In terms of ecosystem impacts, more intense use of LTL species for fishmeal and fish oil will incur economic costs associated with the role LTL species play as prey for numerous finfish species targeted by higher trophic level fisheries, as well as economically valuable seabirds and marine mammals.

Figure A4. Landings of herrings, sardines, anchovies and selected California Current Ecosystem low trophic level (LTL) species, 1981-2009.



Sources: FAO Statistics and Information Service of the Fisheries and Aquaculture Department. 2011. Capture production 1950-2009. FISHSTAT Plus - Universal software for fishery statistical time series [online or CD-ROM]. Food and Agriculture Organization of the United Nations. Available at: http://www.fao.org/fishery/statistics/software/fishstat/en; PacFIN Management Database.

Figure A5. Global aquaculture production, fishmeal production and fishmeal price, 2001-2011.



Sources: FAO Statistics and Information Service of the Fisheries and Aquaculture Department. 2011. Aquaculture production 1950-2009 and fisheries commodities production 1976-2008. FISHSTAT Plus - Universal software for fishery statistical time series [online or CD-ROM]. Food and Agriculture Organization of the United Nations. Available at: http://www.fao.org/fishery/statistics/software/fishstat/en. Mundi commodity price index at: http://www.indexmundi.com/commodities/?commodity=fish-meal&months=120

Allowable CCE Fisheries

At its June 2011 meeting, the Council had requested a list of those species outside of FMP, state- or ESA-management that "could be subject to future target fishing." In addition to the question of which species might be subject to future targeting by virtue of their marketability is the question of what fisheries are currently allowed within the West Coast EEZ. Under the MSA at §305(a), the Secretary of Commerce (via NMFS) is required to maintain a list of all fisheries and fishing gear under the authority of each Council. No person or vessel is permitted to "employ fishing gear or engage in a fishery not included on such list without giving 90 days advance written notice to the appropriate Council…" With these provisions, the list of fisheries essentially prohibits new fisheries from developing without some sort of alert to the appropriate Council. Fisheries not on the list are not prohibited altogether, but Councils may use the 90-day period to comment on, develop a regulatory plan for, or prohibit the proposed fishery as appropriate.

The MSA requirement for a federal list of allowable fisheries is found in Federal regulations at 50 CFR 600.725(v). This list was implemented in 1999 and, at least for the West Coast EEZ, has not been amended since. The list of fisheries within the Pacific Council's jurisdiction is fairly liberal, naming not only those fisheries that were in place at the list's creation, but also providing generally for unspecified recreational fisheries (spear, trap, handline, pot, hook and line, rod and reel, hand harvest gears) and unspecified commercial fisheries (trawl, gillnet, hook and line, longline, handline, rod and reel, bandit gear, cast net, spear). The list does not supersede any other federal, state, or tribal regulations that otherwise prohibit or constrain participation in any of the fisheries on the list.

The list of authorized fisheries and gears for the West Coast EEZ is clearly in need of updating, since it does not reflect the changes from the Northern Anchovy FMP to the CPS FMP, nor the development of the HMS FMP. If the Council ultimately seeks to protect unfished species from becoming the subject of as-yet-unformed fisheries, it could do so by more actively managing its federal list of allowable fisheries, requesting that the Secretary update the list so that it is less open-ended in the types of fisheries permitted.

For this report, the EPDT focused on the federal list of fisheries. For future iterations of this report, if the Council so desires, the EPDT could also provide information on laws and processes for emerging fisheries within the state waters of Washington, Oregon, and California. These fisheries and gear are currently authorized under 50 CFR 600.725(v) for the U.S. West Coast EEZ (3-200 nm off the coasts of Washington, Oregon, and California).

Table A2: Authorized West Coast EEZ Fisheries and Gear	
Fishery	**Authorized gear types**
1. Washington, Oregon, and California Salmon Fisheries (FMP):	
A. Salmon set gillnet fishery	A. Gillnet
B. Salmon hook and line fishery	B. Hook and line
C. Trawl fishery	C. Trawl
D. Recreational fishery	D. Rod and reel
2. West Coast Groundfish Fisheries (FMP):	
A. Pacific coast groundfish trawl fishery	A. Trawl
B. Set gillnet fishery	B. Gillnet
C. Groundfish longline and setline fishery	C. Longline
D. Groundfish handline and hook-and-line fishery	D. Handline, hook-and-line
E. Groundfish pot and trap fishery	E. Pot, trap
F. Recreational fishery	F. Rod and reel, handline, spear, hook-and-line
3. Northern Anchovy Fishery (FMP)	**Purse seine, lampara net**
4. Angel Shark, White Croaker, California Halibut, White Sea Bass, Pacific Mackerel Large-Mesh Set Net Fishery (Non-FMP)	**Gillnet**
5. Thresher Shark and Swordfish Drift Gillnet Fishery (Non-FMP)	**Gillnet**
6. Pacific Shrimp and Prawn Fishery (Non-FMP):	
A. Pot and trap fishery	A. Pot, trap
B. Trawl fishery	B. Trawl
7. Lobster and Rock Crab Pot and Trap Fishery (Non-FMP)	**Pot, trap**
8. Pacific Halibut Fishery (Non-FMP):	
A. Longline and setline fishery	Longline
B. Hook-and-line fishery	Hook-and-line
9. California Halibut Trawl and Trammel Net Fishery	**Trawl, trammel net**
10. Shark and Bonito Longline and Setline Fishery (Non-FMP)	**Longline**
11. Dungeness Crab Pot and Trap Fishery (Non-FMP)	**Pot, trap**
12. Hagfish Pot and Trap Fishery (Non-FMP)	**Pot, trap**
13. Pacific Albacore and Other Tuna Hook-and-line Fishery (Non-FMP)	**Hook and line**
14. Pacific Swordfish Harpoon Fishery (Non-FMP)	**Harpoon**
15. Pacific Scallop Dredge Fishery (Non-FMP)	**Dredge**
16. Pacific Yellowfin, Skipjack Tuna, Purse	**Purse seine**

Table A2: Authorized West Coast EEZ Fisheries and Gear	
Fishery	**Authorized gear types**
Seine Fishery (Non-FMP)	
17. Market Squid Fishery (Non-FMP)	**Purse seine, dip net**
18. Pacific Sardine, Pacific Mackerel, Pacific Saury, Pacific Bonito, and Jack Mackerel Purse Seine Fishery (Non-FMP)	**Purse seine**
19. Finfish and Shellfish Live Trap, Hook-and-line, and Handline Fishery (Non-FMP)	**Trap, handline, hook and line**
20. Recreational Fishery (Non-FMP)	**Spear, trap, handline, pot, hook and line, rod and reel, hand harvest**
21. Commercial Fishery (Non-FMP)	**Trawl, gillnet, hook and line, longline, handline, rod and reel, bandit gear, cast net, spear**

Sources for Appendix A

Bakun, A. 1996. Patterns in the Ocean: Ocean Processes and Marine Population Dynamics. California Sea Grant.

Bjorkstedt, E.P., G. Gaxiola-Castro, Y. Xue, R. Goericke, F. Chavez, J.T. Pennington, W.J. Sydeman, S.A. Thompson, J.A. Santora, S. McClatchie, E. Weber, W. Watson, N. Lo, J. Field, S. Ralston, K. Sakuma, J. Largier, C. Halle, S. Morgan, B. Peterson, B. Emmett, S.J. Bograd, F.B. Schwing, K.P.B. Merkens, J.A. Hildebrand, J. Peterson, R. Durazo, L. Munger. 2010. State of the California Current 2009–2010: Regional variation persists through transition from La Niña to El Niño (and back?). CalCOFI Reports 51: 39-69. available online at http://calcofi.org/publications/calcofireports/v51/Vol51_CACurrent_pg39-69.pdf

Brodeur, R.D., W.T. Peterson, T.D. Auth, H.L. Soulen, M.M. Parnel and A.A. Emerson. 2008. Abundance and diversity of coastal fish larvae as indicators of recent changes in ocean and climate conditions in the Oregon upwelling zone. Marine Ecology Progress Series 366: 187-202.

Cury, P. A. Bakun, R.J.M. Crawford, A. Jarre, R.A. Quinones, L.J. Shannon and H.M. Verheye. 2000. Small pelagics in upwelling systems: patterns of interaction and structural changes in “wasp-waist” ecosystems. ICES Journal of Marine Science 57: 603-618.

Cury, P.M., L.J. Shannon and Y.J. Shin. 2003. The functioning of marine ecosystems: a fisheries perspective. Pages 103-123 in Responsible Fisheries in the Marine Ecosystem, edited by M. Sinclair and G. Valdimarsson. FAO and CABI Publishing.

Fréon, P., J. Arístegui, A. Bertrand, R.J. Crawford, J.C. Field, M.J. Gibbons, L. Hutchings, H. Masski, C. Mullon, M. Ramdani, B. Seret, M. Simier and J. Tam. 2009. Functional group biodiversity in Eastern Boundary Upwelling Ecosystems questions the wasp-waist trophic structure. Progress in Oceanography 83: 97-106.

Glaser, S. 2010. Interdecadal variability in predator–prey interactions of juvenile North Pacific albacore in the California Current System. Marine Ecology Progress Series 414: 209-221.

Hannesson, R., S. Herrick and J. Field. 2009. Ecological and economic considerations in the conservation and management of the Pacific sardine (*Sardinops sagax*). Ca. J. Fish. Aquat. Sci. 66: 859-868.

Herrick, Jr, S.F., J.G. Norton, R. Hannesson, U.R. Sumaila, M. Ahmed and J.Pena-Torres. 2009. Global production and economics of small pelagic fish. In Checkley, D.M., C. Roy, J. Alheit, and Y. Oozeki (eds.), Climate Change and Small Pelagic Fish. Cambridge University Press, UK.

Kendall, A.W. and J. Clark. 1982. Ichthyoplankton off Washington, Oregon and Northern California April-May 1980. NWAFC Processed Report 82-11.

Lowry, M.S., and J.V. Carretta. 1999. Market squid (*Loligo opalescens*) in the diet of California sea lions (Zalophus californianus) in southern California (1981-1995). CalCOFI Reports 40:196-207.

Moser, H.G, R.L. charter, P.E. Smith, D.A. Ambrose, W.Watson, S.R. Charter and E.M. Sandknop. 2001. Distributional atlas of fish larvae and eggs in the southern California Bight region: 1951-1998.

Orsi, J.A., J.A. Harding, S.S. Pool, R.D. Brodeur, L.J. Haldorson, J.M. Murphy, J.H. Moss, E.V. Farley, R.M. Sweeting, J.F.T. Morris, M. Trudel, R. Beamish, R.L. Emmett and E.A. Fergusson. 2007. Epipelagic fish assemblages associated with juvenile Pacific salmon in neritic waters of the California Current and Alaska Current. Pages 105-155 in Grimes, C.B., R.D. Brodeur, L.J. Haldorson and S.M. McKinnel (editors) The ecology of juvenile salmon in the northeast Pacific Ocean. American Fisheries Society Symposium 57.

Richardson, S.L. and W.G. Pearchy. 1977. Coastal and oceanic fish larvae in an area of upwelling off Yaquina Bay, Oregon. Fishery Bulletin 75: 125-145.

Shamshak, G.L. and J. L. Anderson. 2008. Future aquaculture feeds and feed costs: the role of fish meal and fish oil. In: Offshore Aquaculture in the United States: Economic Considerations, Implications & Opportunities (ed. By M. Rubino), pp 73-96. U.S. Department of Commerce; Silver Spring, MD; USA. NOAA Technical Memorandum NMFS F/SPO-103.

Smith, A.D.M., C.J. Brown, C.M. Bulman, E.A. Fulton, P. Johnson, I.C. Kaplan, H. Lozano-Montes, S. Mackinson, M. Marzloff, L.J. Shannon, Y. Shin and J. Tam. 2011. Impacts of Fishing Low–Trophic Level Species on Marine Ecosystems. Science 333: 1147-1150.

Weise, M.J. and J.T. Harvey. 2008. Temporal variability in ocean climate and California sea lion diet and biomass consumption: implications for fisheries management. Marine Ecology Progress Series 373: 157–172.

Tacon, A.G.J. and M. Metian. 2008. Global overview on the use of fish meal and fish oil in industrially compounded aquafeeds: Trends and future prospects. Aquaculture 285, 146–158.

Zertuche-Gonzales, J.A., O. Sosa-Nishizaki, J.G.V. Rodriguez, R.M. Simanek and C. Yarish. 2008. Marine science assessment of capture-based tuna (*Thunnus orientalis*) aquaculture in the Ensenada region of northern Baja California, Mexico. Publications. Paper 1. http://digitalcommons.uconn.edu/ecostam_pubs/1

COASTAL PELAGIC SPECIES ADVISORY SUBPANEL REPORT ON DEVELOPMENT OF A COUNCIL FISHERY ECOSYSTEM PLAN

The Coastal Pelagic Species Advisory Subpanel (CPSAS) heard a presentation by Council staff, Mr. Mike Burner, reviewing progress on the development of the Fishery Ecosystem Plan (FEP) for the California Current.

The CPSAS appreciates the work of the Ecosystem Plan Development Team (EPDT), and concurs with the EPDT and Council that the FEP should remain advisory text in nature (with the potential to expand to include regulatory authority in the future if the Council so desires), particularly in light of the acknowledgement that current ecosystem models don't accurately forecast CPS due to their boom / bust cycles.

CPSAS members agree with the basic format of the FEP, but recommend that the EPDT address a data gap that the CPSAS identified as a high priority research need. Currently the Atlantis model does not adequately assess several components of CPS stocks, in particular, the nearshore component of the Southern California Bight and the peak summer feeding cycle in the Pacific Northwest and Canada. The CPSAS recommends that future research include these areas as they represent a significant portion of CPS resources.

The CPSAS concurs with the Coastal Pelagic Species Management Team's (CPSMT) statement that if a clear need for immediate resource management is established for any particular species, then it should be included in the appropriate regulatory plan.

The conservation representative noted that forage species play an important ecological role in the California Current ecosystem as prey for other marine life. Given the global demand for aquaculture and aquaculture feeds, currently unfished forage species may become the target of future fisheries. A minority of the CPSAS supports being proactive and precautionary by initiating an amendment process to include the non-managed lower trophic level (forage) species identified in Table A-1 of the draft Pacific Coast Fishery Ecosystem Plan into the CPS Fishery Management Plan (pages 28-29). Similar to the forward thinking approach the Council and National Marine Fisheries Service took to protect krill; the amendment process should include consideration of prohibiting the development of new commercial fisheries for these species.

PFMC
11/04/11

Agenda Item H.2.b
Supplemental CPSMT Report
November 2011

COASTAL PELAGIC SPECIES MANAGEMENT TEAM REPORT ON THE DEVELOPMENT OF A COUNCIL FISHERY ECOSYSTEM PLAN

The Coastal Pelagic Species Management Team (CPSMT) reviewed the Ecosystem Plan Development Team's (EPDT) draft Pacific Fishery Ecosystem Plan (FEP) (Agenda Item H.2.a, Attachment 1). The CPSMT also reviewed the Council decisions from the June 2011 in which the Council directed the EPDT to develop a list of species not currently included in a Fishery Management Plan, not managed under State authority, and not listed under the Endangered Species Act (ESA).

The CPSMT commends the EPDT on developing a draft FEP. The CPSMT endorses the structure of the document if the FEP will indeed be non-regulatory. In regards to the draft FEP, the schedule outlined in section 1.3 appears to be adequate. The goals and objectives outlined in section 2.0 need to be further developed and should be a high priority for completion. The 'hotsheets' will be beneficial for providing information on the state of the ecosystem and management decisions.

The CPSMT reviewed the 'Preliminary summary of select Lower Trophic Level species' (Agenda Item H.2.a, Attachment 1, Table A-1). The CPSMT appreciates the work done by the EPDT on the list of species, and the CPSMT is willing to work with the EDPT to finalize the list. As stated in the June 2011 CPSMT report, the CPSMT would not exclude the possibility of having the advisory FEP evolve into a regulatory fishery management plan (FMP) that would include management unit species. If a need for resource management is established, then these species should be included in a regulatory plan. In this case, the CPSMT recommends that the species be managed under the appropriate fishery management plan. If no existing FMP is appropriate, then the FEP could transition to a regulatory plan to encompass these species. The CPSMT would appreciate closer coordination with the EPDT and would like to be consulted before any discussions occur in regards to changing the species in the CPS FMP.

PFMC
11/04/11

ECOSYSTEM ADVISORY SUBPANEL REPORT ON DEVELOPMENT OF A FISHERY ECOSYSTEM PLAN

The Ecosystem Advisory Subpanel (EAS) met November 4th and 5th and reviewed Pacific Fishery Management Council's (Council) June 2011 action and the draft Fishery Ecosystem Plan (FEP) outline (Agenda Item H.2.a, Attachment 1) provided by the Ecosystem Plan Development Team (EPDT). The EAS appreciates the efforts of the EPDT in developing the initial outline and looks forward to working with the EPDT on the next steps. The EAS remains supportive of the FEP approach and offers the following comments and recommendations on its future development.

Draft Fishery Ecosystem Plan

Section 1.3 - Schedule and Process for Developing the FEP: The EAS is generally supportive of the proposed process, but notes that the schedule for development of the FEP and process for implementation are lengthy. The EAS recommends an accelerated schedule involving three Council meetings per year rather than two to expedite the plan's development.

Section 1.4 Schedule and Process for Annual State-of-the-Ecosystem Reporting: The EAS encourages the development of early concrete examples or case studies of how the ecosystem information could be applied. For example, a mock-up of a "hotsheet" would be useful to illustrate the form and utility of the information. A clearer label than "hotsheet" such as "Summary Ecosystem Consideration Report," would be more descriptive. The EAS also suggests that the Scientific and Statistical Committee (SSC), the EPDT, and stock assessment authors collaborate in providing early examples of the use of ecosystem principles to improve stock assessments and better inform fishery management decisions. These examples should demonstrate how ecosystem science and/or indicators could give the Council better information for making decisions about appropriate catch levels.

Section 2.0 - Goals and Objectives: The EAS notes and continues to support the goals and objectives presented, which reflect previous discussions between the EPDT and the EAS on this topic. The EAS recommends that the FEP explicitly incorporate ecosystem principles and the four commonly held goals (avoid overfishing, maintain stability in landings, minimize impacts to habitat, and accommodate existing fisheries sectors) of the existing FMPs as well as the goal of providing adequate forage from the Coastal Pelagic Species Fishery Management Plan (FMP). The EAS recommends that this section be identified as a high priority for early completion and Council consideration.

Section 3.4 - Socio-Economic Components: Socio-economic considerations are an important element of ecosystem management. The EAS recommends, for example, that the "Summary Ecosystem Consideration Report" include a summary of relevant socio-economic issues and information.

Section 4.0 - Uncertainties of Environmental and Human-Induced Impacts to the Marine Environment: The desired benefit of an FEP is to enhance information and reduce uncertainty. This information may inform either increases or decreases in harvest opportunities. The EAS recommends that this section also describe the scientific uncertainty and precautionary approaches currently in place.

Section 5.0 – Council Policy Priorities for Ocean Resource Management: The EAS recommends that the impacts and interactions of aquaculture on the ecosystem be included in this section of the FEP.

Section 6.2 – Science Questions for Future Consideration: The EAS recommends prioritization of the scientific questions presented to determine which species or issues should be the focus of initial research and management consideration. While the listed research is valuable, a prioritization exercise could streamline the implementation of the most critical research issues.

<u>List of Species</u>

Appendix A in Agenda Item H.2.a, Attachment 1 provides useful information about the status of forage fish. This first-cut analysis of global demand for forage fish indicates the possibility of future harvest pressures. The EAS acknowledges controversy in this preliminary finding. If the economics and future prospects of aquaculture is a key factor in the future exploitation of unmanaged fish, then the EAS recommends that the EPDT expand the review of the economics of developing fisheries, processing operations, and existing utilization of fish resources.

If the Council ultimately seeks to protect unmanaged species from as-yet-unformed fisheries or to ensure that exploitation on currently unmanaged species does not occur until such time as it can be demonstrated that this exploitation is sustainable and does not have substantial adverse impacts to the ecosystem or their dependent predators, the EAS recommends that:

a) First, determine the effectiveness and support for using the Authorized West Coast Exclusive Economic Zone Fisheries and Gear (Table A2, Agenda Item H.2.a, Attachment 1) as an adequate mechanism.
b) Second, if "a)" proves inadequate, assess the methods and merits of regulating currently unmanaged species within an existing FMP.

Finally, the EAS recommends that any future protective measures for currently unmanaged forage fish not impact the allowable catch of currently managed species.

PFMC
11/06/11

ECOSYSTEM PLAN DEVELOPMENT TEAM REPORT ON DEVELOPMENT OF A COUNCIL FISHERY ECOSYSTEM PLAN

At its June 2011 meeting, the Pacific Fishery Management Council (Council) directed the Ecosystem Plan Development Team (EPDT) to suggest a draft process and schedule for developing the Fishery Ecosystem Plan (FEP). The Council also directed the EPDT to develop a list of species that are: not currently included any fishery management plan (FMP), not the subject of state management, and not listed under the Endangered Species Act (ESA). Our main report, Agenda Item H.2.a, Attachment 1, takes the form of a draft FEP outline, and is intended to illustrate how an FEP might look if its design were based on the Purpose and Need statement the Council adopted in June 2011.

Section 1.3 of the draft FEP responds to the Council's direction to provide a preliminary draft process and schedule for developing an FEP by proposing a schedule for handling the FEP over the next 12-18 months. Section 1.4 proposes a schedule and process for annual state-of-the-ecosystem reporting.

Appendix A to the draft FEP outline is provided in response to the Council's list-of-species assignment. The EPDT has initially focused on pelagic low trophic level (LTL) species with the following approach to reviewing those species:

- Providing a draft definition for the term "low trophic level (LTL) species," which would include those species commonly thought of as "forage fish," accompanied by a list of the most common of the California Current Ecosystem (CCE) species meeting that definition, with information on those species' relative abundance, fisheries potential, and role in the ecosystem;
- Assessing worldwide fisheries landings (marketability) for LTL species with no or low harvest from the CCE, yet which are similar to species that are moderately- or heavily-fished elsewhere in the world; and
- Reviewing the range of fisheries permissible within the West Coast Exclusive Economic Zone (EEZ) under the Magnuson-Stevens Act (MSA) and current Federal regulations.

Based on the EPDT's work developing our reports over the past several months, we are recommending that the Council consider the following actions at this November 2011 meeting.

- Adopt an annual review schedule for developing the FEP, with the first iteration of the plan to be finalized in early 2013. The EPDT anticipates that the FEP will go through multiple iterations over time, and therefore requests guidance on prioritizing the sections of the FEP that should first be developed for review by the Council, its advisory bodies, and the public. The EPDT recommends that highest priority be given to developing the desired contents of an annual state-of-the-ecosystem report, so that the Council can build its future policy priorities from a science-informed position.

- Provide comment on the EPDT's approach to the list-of-species assignment, particularly on the question of whether benthic LTL species and mid-to-upper trophic level species should be added to the analysis.
- Assign the EPDT to draft suggested updates for the Federal list of fisheries allowable within the West Coast EEZ, based on the EPDT's list-of-species analysis and current West Coast Fishery Management Plan parameters.

PFMC
11/03/11

Agenda Item H.2.b
Supplemental EPDT PowerPoint
November 2011

Ecosystem Plan Development Team Draft Fishery Ecosystem Plan

Process and Schedule for Moving Forward with an FEP; Developing a List of Unmanaged Species

1.1

The purpose of the FEP is to enhance the Council's species-specific management programs with more ecosystem science, broader ecosystem considerations and management policies that coordinate Council management across its FMPs and the California Current Ecosystem (CCE). An FEP should provide a framework for considering policy choices and trade-offs as they affect FMP species and the broader CCE.

Agenda Item A.4
Proposed Detailed Council Meeting Agenda
June 2012

214th Session of the Pacific Fishery Management Council

June 20-26, 2012

San Mateo Marriott
1770 South Amphlett Boulevard
San Mateo, CA 94402
Phone: 650-653-6000

1.3

Wednesday June 20	Thursday June 21	Frida[illegible] Jun[illegible]	Saturday [illegible] 23	[illegible]day [illegible] 24	Monday June 25	Tuesday June 26
Advisory Body Meetings – schedule begins on page 7	9:00 am Closed Executive Session	Highly Migratory Species Management	Groundfish Management	[illegible]oastal Pelagic Species Management	Groundfish Management	Groundfish Management
	10:00 am General Session			Ecosystem Based Management		
	Open Comment Period	Groundfish Management		Habitat Matters		
	Salmon Management		Administrative Matters	Groundfish Management		Administrative Matters


1.4

September

2013, 2015, 2017, 2019…

2014, 2016, 2018, 2020…

2.0

3.0

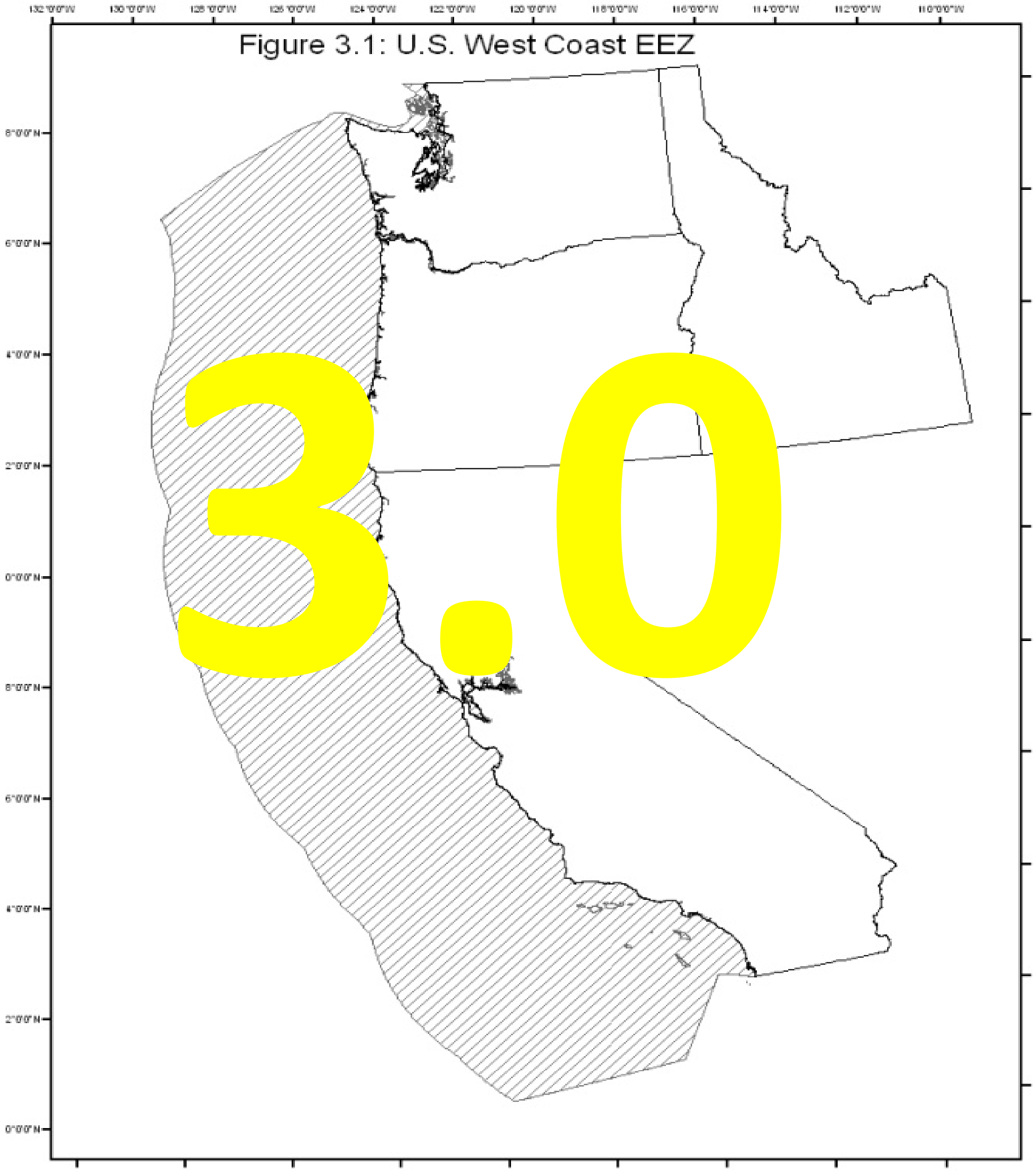
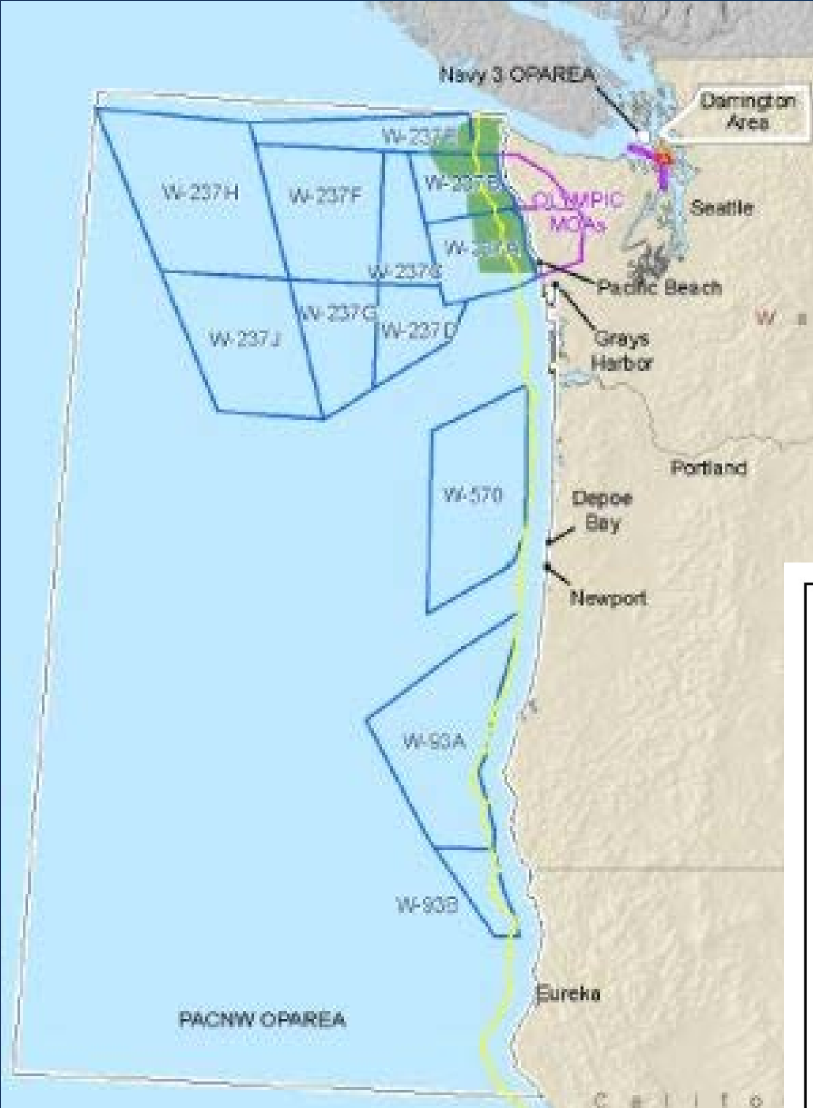


Figure 3.1: U.S. West Coast EEZ

4.0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Pacific Beach
Grays Harbor
Portland
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Newport
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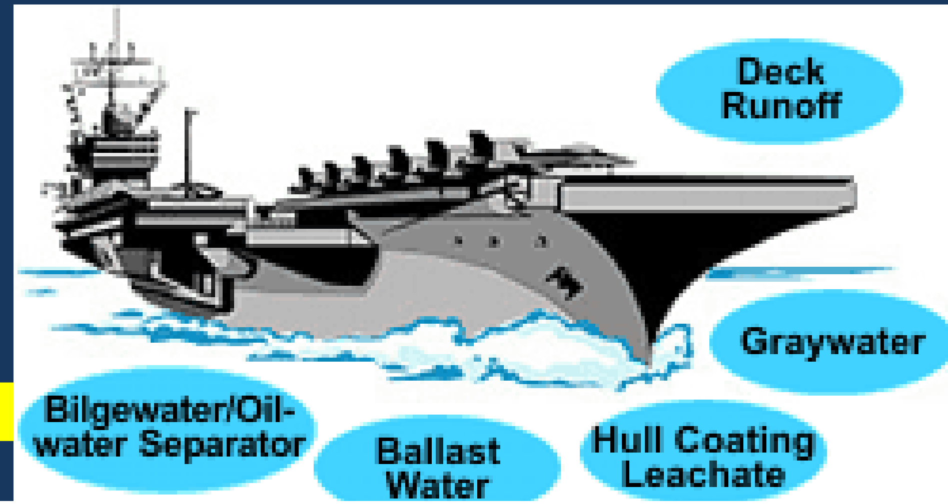
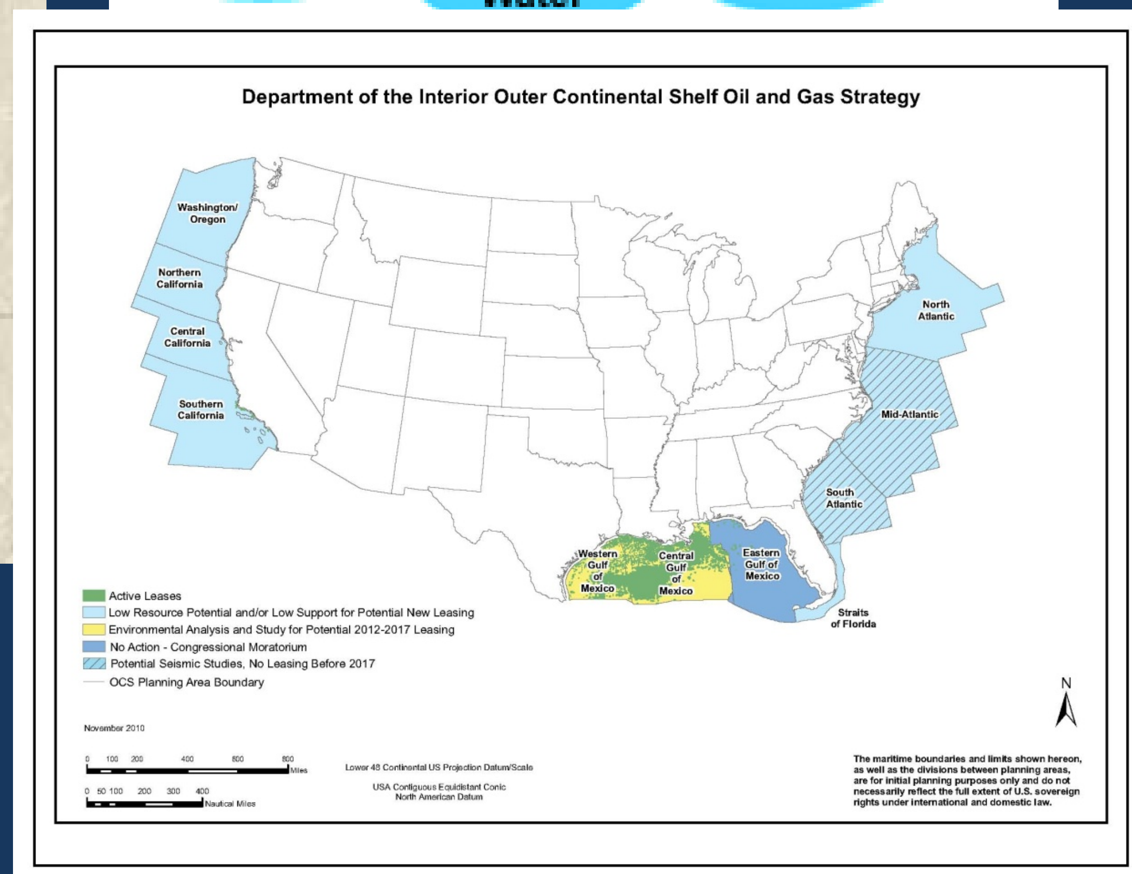
Eureka
PACNW OPAREA


Deck Runoff
Graywater
Bilgewater/Oil-water Separator
Ballast Water
Hull Coating Leachate


Department of the Interior Outer Continental Shelf Oil and Gas Strategy
Washington/ Oregon
Northern California
Central California
Southern California
North Atlantic
Mid-Atlantic
South Atlantic
Western Gulf of Mexico
Central Gulf of Mexico
Eastern Gulf of Mexico
Straits of Florida
Active Leases
Low Resource Potential and/or Low Support for Potential New Leasing
Environmental Analysis and Study for Potential 2012-2017 Leasing
No Action - Congressional Moratorium
Potential Seismic Studies, No Leasing Before 2017
OCS Planning Area Boundary
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November 2010
0 100 200 400 600 800 Miles
0 50 100 200 300 400 Nautical Miles
Lower 48 Continental US Projection Datum/Scale
USA Contiguous Equidistant Conic
North American Datum
The maritime boundaries and limits shown hereon, as well as the divisions between planning areas, are for initial planning purposes only and do not necessarily reflect the full extent of U.S. sovereign rights under international and domestic law.

Table 1. 2012 OFLs (mt) and recommended 2013 and 2014 OFLs (mt) for west coast groundfish stocks (overfished stocks in CAPS; stocks with new assessments in **bold**; component stocks in status quo stock complexes in *italics*).

Stock	2012 OFL	2013 OFL	2014 OFL	Comments
OVERFISHED STOCKS				
BOCACCIO S. of 40°10' N latitude	732	**884**	**881**	**Projected using a 50% SPR from the 2011 rebuilding analysis with a 6% reduction to subtract the portion of the assessed stock north of 40°10' N. lat.**
CANARY	622	**752**	**741**	**Projected using a 50% SPR from the 2011 rebuilding analysis.**
COWCOD S. of 40°10' N latitude	13	11	12	Sum of Conception and Monterey OFLs.
COWCOD (Conception)	*6*	7	7	Projected using a 50% SPR from the 2009 rebuilding analysis.
COWCOD (Monterey)	*7*	5	5	Revised DB-SRA estimate.
DARKBLOTCHED	497	**541**	**553**	**Projected using a 50% SPR from the 2011 rebuilding analysis.**
PACIFIC OCEAN PERCH	1,007	**844**	**838**	**Projected using a 50% SPR from the 2011 rebuilding analysis.**
PETRALE SOLE	1,279	**2,711**	**2,774**	**Projected using a 30% SPR from the 2011 rebuilding analysis.**
YELLOWEYE	48	**51**	**51**	**Projected using a 50% SPR from the 2011 rebuilding analysis.**
NON-OVERFISHED STOCKS				
Arrowtooth Flounder	14,460	7,391	6,912	Projected using a 30% SPR from the 2007 full assessment.
Black Rockfish (OR-CA)	1,169	1,159	1,166	Projected using a 50% SPR from the 2007 full assessment with the addition of the northern OFL 3% reduction to account for the portion of the stock estimated between Cape Falcon and the Columbia River.
Black Rockfish (WA)	435	430	428	Projected using a 50% SPR from the 2007 full assessment with a 3% reduction to account for the portion of the stock estimated between Cape Falcon and the Columbia River.
Pacific Whiting (U.S. + Canada)	TBD in 2012	TBD in 2013	TBD in 2014	
Cabezon (OR)	50	49	49	Projected using a 45% SPR from the 2009 full assessment.
California scorpionfish	132	126	122	Projected using a 45% SPR from the 2005 full assessment.
Chilipepper S. of 40°10' N latitude	1,872	1,768	1,722	Projected using a 50% SPR from the 2007 full assessment. The portion of the coastwide stock south of 40°10' N. lat. (93%) is based on average historical landings.
Dover Sole	44,826	**92,955**	**77,774**	**Projected using a 30% SPR from the 2011 full assessment.**
English Sole	10,620	7,129	5,906	Projected using a 30% SPR from the 2009 update assessment.
Lingcod N. of 42° N latitude (OR & WA)	2,251	2,102	1,984	Projected using a 45% SPR from the 2009 full assessment.
Lingcod S. of 42° N latitude (CA)	2,597	2,566	2,454	Projected using a 45% SPR from the 2009 full assessment.

"A section on ecosystem considerations should be added to all stock assessments, starting with the 2013 assessment cycle. . . The SSC will need to modify Terms of Reference for stock assessment reviews to include reviews of ecosystem consideration sections of assessments and application of ecosystem processes in assessments and harvest control rules. . .

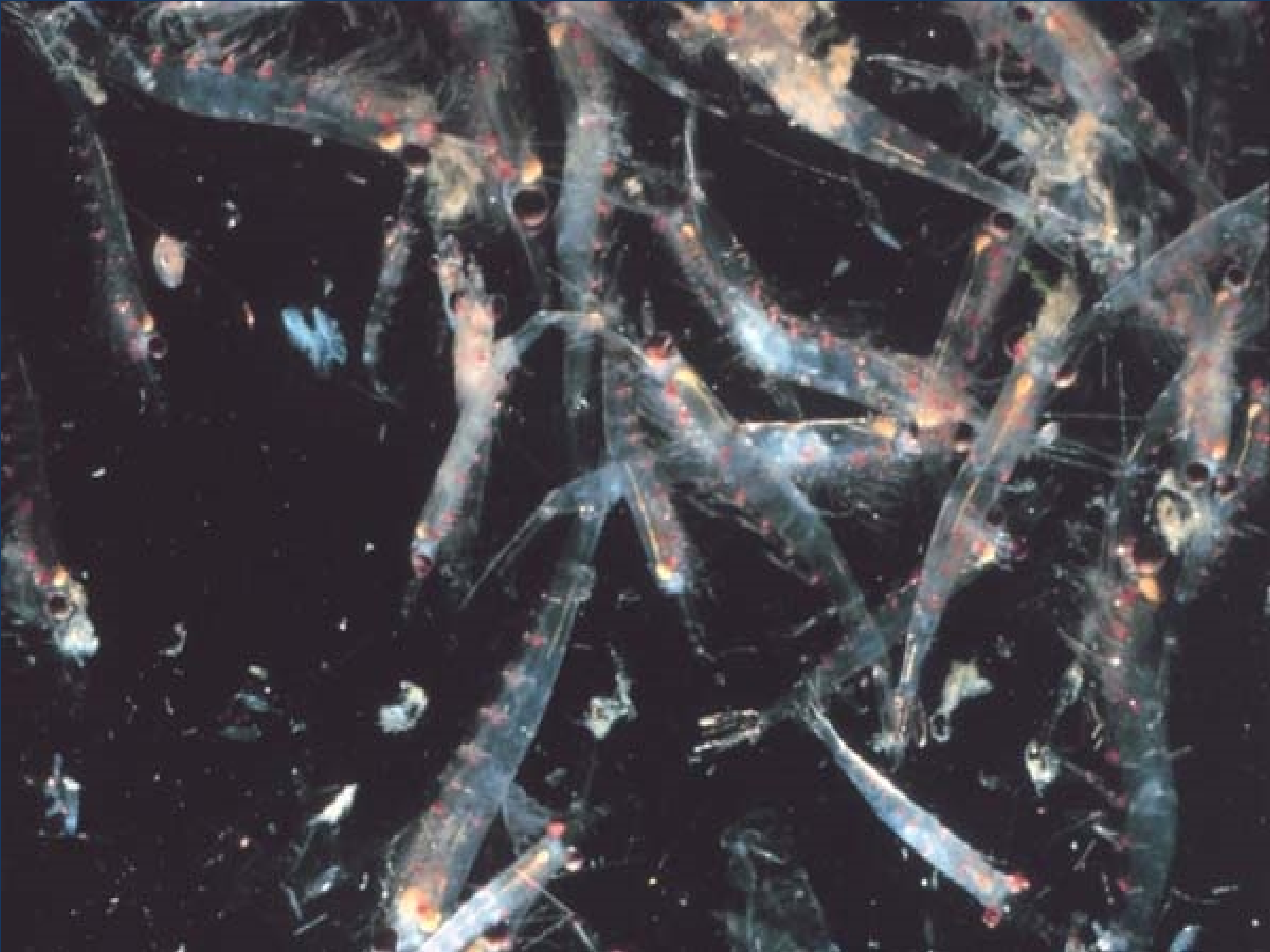
(June 2011 H.1.b., Supplemental SSC Report)

6.0

App. A

"The term 'fish' means finfish, mollusks, crustaceans, and all other forms of marine animal and plant life other than marine mammals and birds."

MSA at §3, definitions



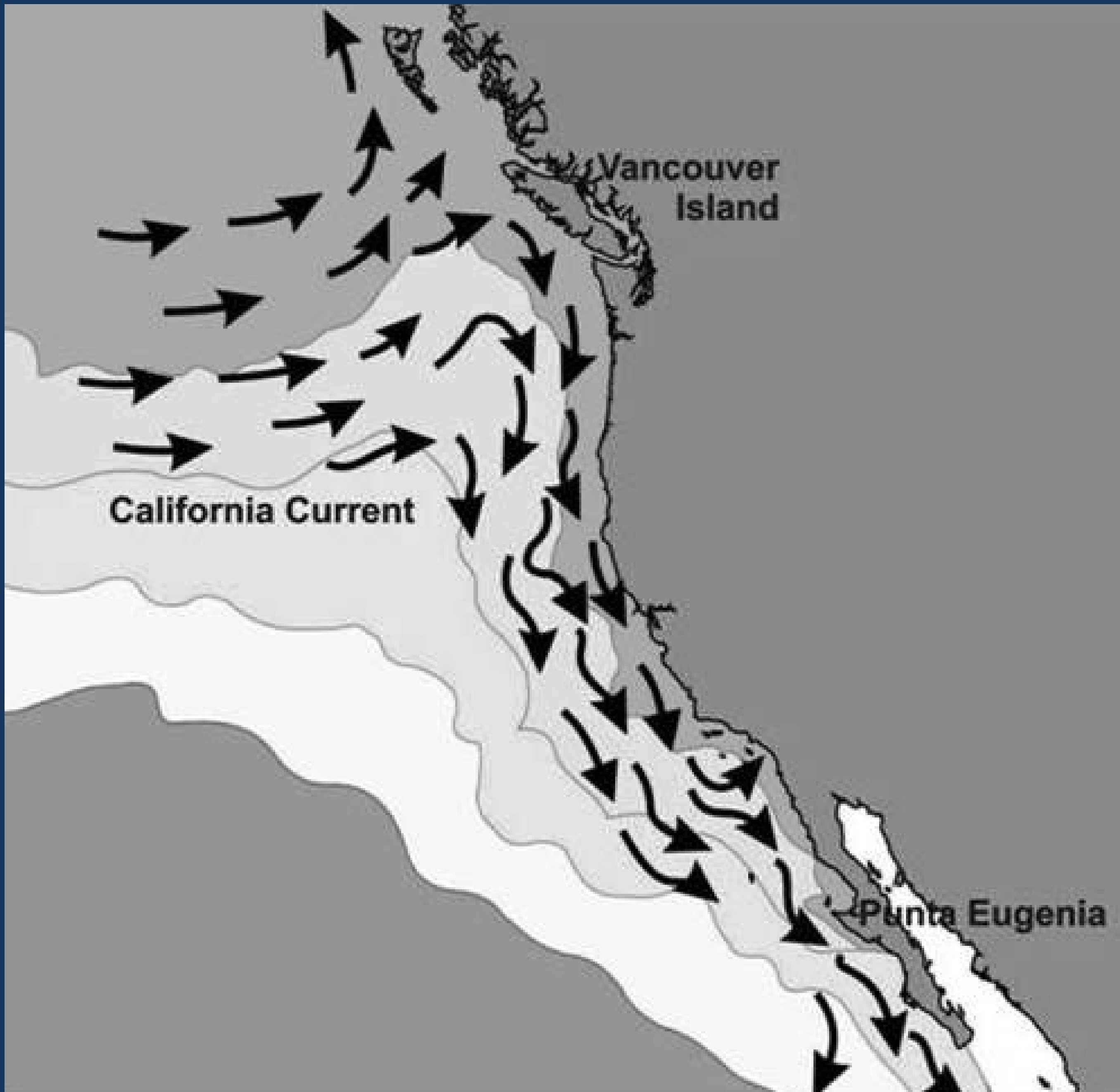


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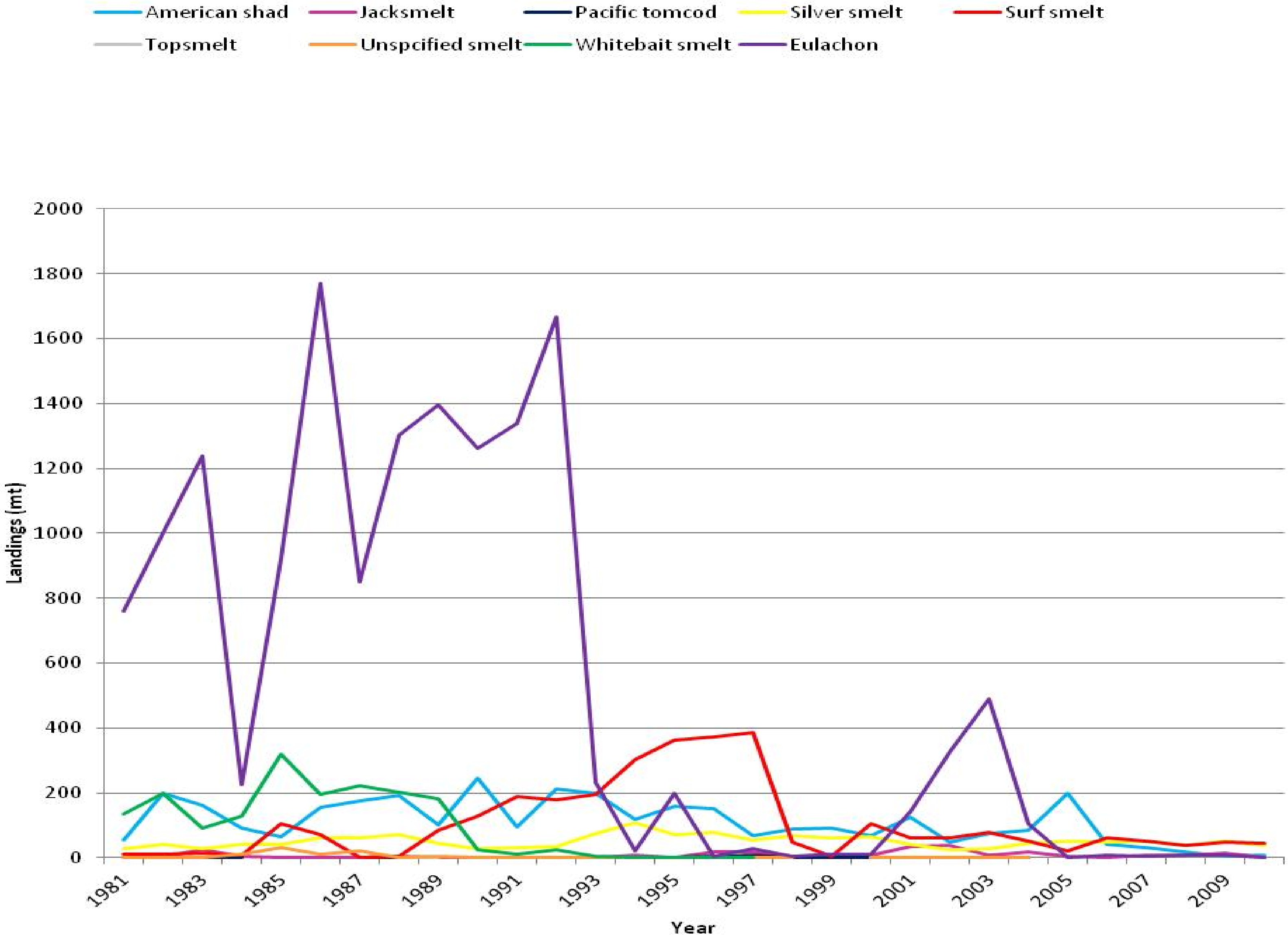
Figure A2. West Coast landings (mt) of select California Current Ecosystem LTL species, 1981-2010.



From 50 CFR 600.725(v), Authorized Fisheries for the West Coast EEZ

. . .

20. Recreational Fishery (Non-FMP)

Spear, trap, handline, pot, hook and line, rod and reel, hand harvest

21. Commercial Fishery (Non-FMP)

Trawl, gillnet, hook and line, longline, handline, rod and reel, bandit gear, cast net, spear

EPDT Supplemental Report H.2.b

- Adopt an annual review schedule for developing the FEP, with the first iteration of the plan to be finalized in early 2013.

- Provide comment on the EPDT’s approach to the list-of-species assignment.

- Assign the EPDT to draft suggested updates for the Federal list of fisheries allowable within the West Coast EEZ.

All images courtesy of the U.S. National Oceanic and Atmospheric Administration, except:

Slide 2: Spokane River stream monitoring station location, United States Geological Survey
Slide 4: Martin, David, artist, “Benjamin Franklin.” 1767; Library of Congress. Pumpkin; Microsoft stock. Army NCO of the Year 2007, Jason Seifert, demonstrates proper push-up technique in presence of drill instructor; photo, U.S. Air Force Tech. Sgt. Larry. A. Simmons. President Barak Obama’s handwritten 2009 NCAA bracket; White House photo, Pete Souza.
Slide 5: Kelp and sardines; California Department of Fish and Game.
Slide 6: Schooling fish and kelp; California Department of Fish and Game.
Slide 9: Council members; Pacific Fishery Management Council.
Slide 11: Northwest Training Ground Complex map; U.S. Navy. Ship discharge diagram; U.S. Environmental Protection Agency. Outer Continental Oil and Gas Strategy map; U.S. Department of Interior.
Slide 13: snuggling lingcod; Alaska Department of Fish and Game.
Slide 16: Lillie Langtry, 1899 image; copyright expired.
Slide 21: Douglas fir canopy; National Park Service. Northeast Pacific Ocean; NASA/Goddard Space Flight Center.

Agenda Item H.2.b
Supplemental GMT Report
November 2011

GROUNDFISH MANAGEMENT TEAM (GMT) REPORT ON DEVELOPMENT OF A COUNCIL FISHERY ECOSYSTEM PLAN

The Groundfish Management Team (GMT) reviewed the Ecosystem plan Development Team (EPDT) Report (Agenda Item H.1.a, Attachment 1) and has the following comments and suggestions.

Schedule

As the Council contemplates adopting a reporting schedule for the fishery ecosystem plan (FEP), the GMT recommends aligning that report with development of biennial specifications and management measures alternatives. Right now there is a placeholder of September in odd years in the EPDT report. Given that the Council is considering a fishery management plan (FMP) amendment to revise the biennial specifications and management measures process, and that FMP amendment could include alterations to the schedule for developing those, the GMT recommends that the ecosystem hotsheet for groundfish schedule retain a placeholder until that FMP amendment is finalized.

Content

As we pointed out in our June report (Agenda Item H.1.b, Supplemental GMT Report, June 2011) and repeat here, the groundfish management process and development of National Environment Policy Act (NEPA) analyses would benefit from ecosystem considerations for a number of issues of such as: spatial management; species designated as Ecosystem Component (EC) species under National Standard 1 (NS1); protected species; and better characterization of the human environment and cumulative impacts. We would like to see these included in both the annual reports and the considerations reported in the groundfish hotsheet and appreciate the EPDT including those in the draft report.

As mentioned above, the Council is considering an FMP amendment to revise the biennial specification and management process. NEPA analyses are a central component of that biennial process. Given that impacts to the human environment and cumulative impacts are the focus of NEPA and are a major point of focus of the FEP, the GMT recommends that the development and use of the reports under the FEP is coordinated with the development of the FMP amendment and the subsequent biennial process.

Also, in Chapter 3, the draft report states, “the Council also does not believe that designating the Exclusive Economic Zone (EEZ) as the FEP’s geographic range in any way prevents it from receiving or considering information on areas of the California Current Ecosystem or other ecosystems beyond the EEZ.” The GMT would like to see more explicit reference to including international trans-boundary stock information wherever possible. The majority of groundfish FMP management unit stocks are part of larger biological stocks with ranges and fisheries interactions that cross international boundaries. This issue is frequently reference in the research and data needs for groundfish stock assessments and should be included in ecosystem considerations for those species.

The GMT would also point out that spatial management includes smaller scales as well. Many rockfishes are sedentary as adults and may exhibit considerable stock structure that should be included in ecosystem considerations that could be used in management decisions.

PFMC
11/06/11

HABITAT COMMITTEE COMMENTS ON DEVELOPMENT OF A COUNCIL FISHERY ECOSYSTEM PLAN

The HC reviewed the Pacific Coast Fishery Ecosystem Plan (FEP), and commends the Council and Ecosystem Plan Development Team (EPDT) on progress with creating this plan. We offer the following comments:

Chapter 1

The HC noted that the schedule in Section 1.3 appeared ambitious but reasonable.

Regarding the schedule and process for annual state-of-the–ecosystem reporting in Section 1.4, the HC supported the idea of providing both an annual ecosystem report and brief species-group ecosystem "hotsheets." We believe the condensed, timely information included in the hotsheets would be more useful to the Council than the full report for making management decisions. The PaCOOS quarterly reports could be used as a template for developing these reports.

Chapter 2

The HC recommends the Council condense the goal of the FEP as follows:

"*The goal of this FEP is to incorporate ecosystem science into the Council's FMPs so as to ensure a sustainable and productive ecosystem for long-term support of Pacific coast fisheries.*"

Chapter 3

Chapter 3 does not cover the geological aspect of habitat, and the HC recommends this information be included.

The intent of Section 3.3 (Biological Components and Relationships of the CCE) is unclear, and the HC is concerned that it may be overwhelming to consider all these types of complex trophic interactions. The HC recommends that the EPDT clarify the scope of this section.

Chapter 5

This chapter is designed to inform external entities about Council ecosystem priorities, but the process should also work in reverse. External state and regional processes can inform and assist the Council's ecosystem policies and priorities, and the Council should seek out this information.

Appendix A

This section includes a list of selected lower trophic level species in the California Current Ecosystem. The EPDT noted that the lowest tropic order organisms (e.g., phytoplankton and zooplankton) are likely too small to be of interest as fisheries targets, but that the Council may be interested in the status of these species as indicators of ecosystem health or potential predictors of available harvest levels of FMP species. In this context, the HC believes that crab larval abundance collected in nearshore waters and estuaries is a valuable indicator, and should be considered.

The HC suggests expanding the list of species to include benthic invertebrates that would be considered forage species. In addition, the HC recommends adding the abalone, razor clam, and sea urchin fisheries to Table A-2.

General Comments

Unlike other FMPs, there is no annual status report planned for the FEP, and therefore, there is no mechanism for tracking FEP performance. The HC recommends a regular status report on how the Council's ecosystem management approach affects Council managed fisheries. This report could be similar to other SAFE reports or the North Pacific Fishery Management Council's Aleutian Islands Plan.

Finally, the HC notes that because the plan will likely be iterative, the EPDT could continue to serve an important role after the plan is completed.

PFMC
11/06/11

SALMON ADVISORY SUBPANEL REPORT ON DEVELOPMENT OF A COUNCIL FISHERY ECOSYSTEM PLAN

The Salmon Advisory Subpanel (SAS) has the following comments on the draft Pacific Coast Fishery Ecosystem Plan (Agenda Item H.2.a, Attachment 1):

1. The SAS requests clarification of what would be included in an ecosystem hotsheet for salmon, and how it might be used in the context of annual salmon management. We are concerned that recommendations for management actions may be based on presumed relationships between salmon stock status and environmental variables that have not been adequately established or are highly uncertain.

2. The SAS has not had adequate time to review the list of needed future ecosystem considerations for the Salmon FISHERY MANAGEMENT PLAN, but several topics in the list have raised some concerns. The SAS would like to reserve the right to provide comments on these at a later date.

PFMC
11/2/11

SCIENTIFIC AND STATISTICAL COMMITTEE REPORT ON DEVELOPMENT OF A COUNCIL FISHERY ECOSYSTEM PLAN

The Scientific and Statistical Committee (SSC) reviewed a draft of a Pacific Coast Fishery Ecosystem Plan being developed by the Ecosystem Plan Development Team (EPDT). The EPDT proposes development of an annual ecosystem report and species-group reports that would summarize information from the annual ecosystem report for the Council's use in its harvest-setting deliberations.

The SSC notes that the National Marine Fisheries Service Science Centers and the Integrated Ecosystem Assessment (IEA) Team (Agenda Item H.1) have also begun drafting an IEA Report that describes conditions in the California Current Ecosystem as they relate to FMP species. The IEA Report and the annual ecosystem report proposed by the EPDT appear to be similar in terms of objectives and content. The SSC recommends that the EPDT and IEA Team coordinate to ensure that they are working from the same base data, avoid duplication of effort, and perhaps even consider producing a single joint report. Such coordination would be facilitated by the fact that some EPDT members are also members of the IEA Team.

The SSC appreciates the desire of the EPDT to provide relevant species-group summaries that would facilitate the Council's harvest deliberations. The SSC notes that these informational documents (referred to by the EPDT as 'hotsheets') should provide sufficient detail to allow stock assessment scientists and Stock Assessment Review Panels to consider species-relevant ecosystem information in a nuanced manner. The SSC is willing to review future drafts of the annual report and the species-group information documents as they become available.

Appendix A of the draft Fishery Ecosystem Plan includes a preliminary list of lower trophic-level species in the California Current Ecosystem that are currently harvested or could potentially be subject to fishery development. In terms of ecosystem management, the SSC considers it premature to consider lists of species for management action without first considering what species groupings would best serve to promote ecosystem diversity and function. The SSC recommends that the EPDT develop species groupings based on criteria related to diversity and function. The SSC also notes that maintaining ecosystem diversity may or may not require bans on harvest.

PFMC
11/3/11

RECEIVED
SEP 28 2011
PFMC

PFMC Council,

I am writing out of a concern that the increasingly huge demand the aqua culture industry has for forage fish. If left unchecked it would literally take the fish out of the mouths of salmon, tuna, & all the marine wildlife that is totally dependent on forage fish, Commerial fisheries would fail & all the marine life would be depleted.

Did we not learn our lesson when Weyerhauser's salmon farms in Chile gobbled up most of the forage fish off S. America. Local fisheries collapsed & most fisherman were out of work, That in turn caused a envirnemental disaster & Weyerhauser just bailed out on the whole mess.

It is not sustainable to take 7-12 lbs of forage fish out of the ocean ~~to~~ ship it halfway around the world to grow 1 lb. of bluefin tuna. We're cutting our own throats & it is just plain stupid.

I support a strong fishery ecosystem plan that accounts for the value of forage fish as prey for ocean wildlife.

Thank You,
Al [signature]
F/V Mickey

comm. fisherman
for 38 yrs.

Subject: Protect forage fish
Date: Thu, 13 Oct 2011 20:07:45 -0400 (EDT)
From: BobUnreel@aol.com
To: pfmc.comments@noaa.gov
CC: JGERSON@beitler.COM, dpickford@roadrunner.com, LPortnuff@deweysquare.com

As a fishing club with a 30 year record of supporting marine fishery conservation we strongly urge support for the Pacific Fishery Management Council effort to develop a fishery echosystem plan for forage fish. Our Club has been working with the Dept of fish and Game and Hubb's Research Institute for the last 14 years raising and releasing white seabass. For most of the those 14 years there have been very few white seabass in SM Bay. This year and last we have had an abundance of krill and squid in the Bay. Predictably, we have seen an increase in seabass and all marine animals including blue whales. On the other hand we have seen fleets of squid boats from all over the Pacific Coast descend on the Channel Islands and take incredible hauls to be turned into fish meal. There needs to be a management plan to protect our forage fish and ensure enough stay in the ocean as a food source to sustain other valuable fish and marine life that are vital to our coastal fishing and tourism economy. I am reminded about what happened to the economy of Monterrey after the sardines were wiped out.

Robert Godfrey, Secretary
MARINA DEL REY ANGLERS, Inc.
4230 del Rey Ave
Marina del Rey, CA 90292

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October 13, 2011

Mr. Dan Wolford, Chair
Pacific Fishery Management Council
7700 NE Ambassador Place, Suite 101
Portland, OR 97220

RE: Agenda Item H.2. Ecosystem Based Management/ Request to initiate CPS FMP amendment to protect forage species

Dear Chairman Wolford and members of the Council:

We are pleased that in June 2011 the Pacific Fishery Management Council (PFMC) tasked the Ecosystem Plan Development Team (EPDT) with developing a list of important West Coast forage species which might potentially be the targets of fisheries in the future. Given the importance of forage species to the overall health of the ocean ecosystem, the intent of developing this list is to determine precautionary management measures to ensure that any new fisheries for forage species be conducted without harming the health of the ocean ecosystem. Based on this discussion and our work on this topic over the last several years, we submitted comments to the EPDT and attended the September 21-22 EPDT meeting addressing this issue. We are writing now to provide the Council with a list of important forage species which we believe the Council should consider. We've also included the current management status of each species, and known population status. Oceana respectfully requests that the PFMC move this issue forward by initiating an amendment process to the Coastal Pelagic Species (CPS) Fishery Management Plan (FMP) to incorporate those forage species not already in another Federal FMP into the CPS FMP. Further we request that directed commercial fisheries be prohibited from developing on these species unless and until an ecosystem plan and appropriate management benchmarks are in place that would allow a sustainable fishery to commence without adversely impacting the functional role these species provide as prey to other marine life.

As you know, the Council took unanimous action in 2006 to prohibit directed fishing for krill off the U.S. West Coast through an amendment to the CPS FMP. This action followed state prohibitions on fishing and landing krill in California, Oregon and Washington. The Council and NMFS took this action with interest in, "preserving key trophic relationships between fished and unfished elements of the food web in order to maintain the integrity of the ecosystem and to minimize the risk of irreversible adverse impacts on managed fish stocks and other living marine resources from adverse impacts."[1] At the time, some Council members wondered why the focus was only on krill, as there are many other important and unmanaged forage species that should also be protected in a similar fashion. This fact was not lost on many people and hence, for the same reasons the krill prohibition was put in place, there has been a growing call over the past few years to identify and protect all of the unmanaged forage species in the California Current ecosystem.

We are aware of several previous and ongoing attempts to compile lists of important forage species of the California Current ecosystem, including: the list identified in the partial Draft Environmental Assessment for Amendment 13 to the CPS FMP,[2] forage species already protected by the North Pacific Fishery Management Council,[3] the below list we provided to the EPDT at its September meeting, and the list submitted by the Pew Environment Group to the Council at the September 2011 meeting. Also relevant are several key data sources including: a NOAA Tech Memo elucidating diet guilds,[4] California Current ecosystem models,[5] and specific diet studies on seabirds, marine mammals, and key fish species.

As you may be aware, global finfish and shrimp aquaculture are increasing faster than any other food sector, and this industry is dependent on feeds derived from wild-caught fish. As pointed out by a member of the EPDT at the September meeting, it is inevitable that the ever-increasing demand for fish meal and fish oil from the rapidly growing global aquaculture industry will at some point make any species from which these products can be extracted economically viable, even if they do not appear viable today. We can only postulate whether this will be next year or decades from now. Prohibiting fisheries from developing for forage species before they start is much easier politically and economically than closing fisheries after capital investments are made. Therefore, no species should be excluded from a list of species for which fisheries could potentially develop.

In the discussion of the June 2011 motion on Ecosystem-Based Management, the PFMC indicated that the appropriate pathway toward establishing precautionary protections for this important group of forage species that are not currently included in federal FMPs or subject to commercial fishing pressure would be to add them to the CPS FMP. This is in part because the PFMC decided that the Fishery Ecosystem Plan would not have regulatory authority. Given the increasing scientific recognition of the ecological importance of forage species,[6] the precautionary actions already taken by the Council to prohibit a commercial krill fishery, action by the Council to set the 2011-2012 shortbelly rockfish catch at less than 1% of the ABC, and the work done by the EPDT in response to the Council's direction, we request that the Council now initiate an amendment to the CPS FMP that would:

1. Add to the CPS FMP all forage species for which no major commercial fishery exists, and which are not currently included in a federal FMP; and
2. Promulgate regulations that prohibit directed commercial fishing for all such species (similar to what was done for krill or as ecosystem component species with management measures, including a prohibition on catch).

In considering which species would meet the definition of forage species, we recommend the Council include those species which:

- Are major components of the diets of one or more upper trophic level species;
- Are frequently found in the diets of numerous upper trophic level species;
- Comprise a major part of the overall forage base; and/or
- Provide prey for key life history stages or are important during certain seasons.

To aid the Council in this process, we have attached at the end of this letter a list of forage species meeting these criteria, and describe the current management status and the extent to which major commercial fisheries are currently being prosecuted on each species. We submitted this previously to the EPDT and we respectfully request your adoption of this list.

Regarding the question of whether these unfished forage species would be management unit species or ecosystem component species (as defined in the NS1 guidelines), we would be open to either approach, but we suggest that establishing them as ecosystem component species with management measures including a prohibition on directed commercial catch would allow the Council to achieve the desired objectives while minimizing the staff burden associated with adding new species to the Council's jurisdiction. We suggest that the EPDT continue to assist with this approach moving forward. In addition, we would hope that any such regulations would not conflict with or supersede management currently in place by state fishery managers.

Ultimately, this action would be a tangible transition to an ecosystem approach to fisheries. Similar action was taken by the North Pacific Fishery Management Council in the 1998 forage species prohibition and in the 2009 Arctic FMP. This action would not adversely affect any existing stakeholder and much of the background work has already been completed. We hope you will move this issue forward on the path indicated by the June 2011 Council discussion by initiating this proposed CPS FMP amendment at the November 2011 Council meeting.

Sincerely,

Ben Enticknap
Pacific Project Manager, Oceana

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[1] PFMC 2008. Management of Krill as an Essential Component of the California Current Ecosystem. Amendment 12 to the Coastal Pelagic Species Fishery Management Plan. Environmental Assessment. February 2008, at page 1.

[2] PFMC 2010. Amendment 13 to the CPS FMP, Partial Draft EA. Agenda Item F.2.a, Attachment 1. June 2010, at 17.

[3] NMFS 1998. Final Environmental Assessment and Regulatory Impact Review for Amendment 36 to the Fishery Management Plan for the Groundfish Fishery of the Bering Sea and Aleutian Islands Area and Amendment 39 to the Fishery Management Plan for Groundfish of the Gulf of Alaska to Create and Manage a Forage Fish Species Category. National Marine Fisheries Service, Juneau, Alaska. 1998.

[4] Dufault, A.M., K. Marshall, and I.C. Kaplan. 2009. A synthesis of diets and trophic overlap of marine species in the California Current. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-103, 81 p.

[5] Field, J.C., Francis, R.C., and Aydin, K. 2006. Top-down modeling and bottom-up dynamics: Linking a fisheries-based ecosystem model with climate hypotheses in the Northern California Current. Progress in Oceanography 68:238-270. AND, for example: Samhouri, J.F., Levin, P.S., and Harvey, C.J. 2009. Quantitative Evaluation of Marine Ecosystem Indicator Performance Using Food Web Models. Ecosystems 12:1283-1298. AND Horne, P.J., I.C. Kaplan, K.N. Marshall, P.S. Levin, C.J. Harvey, A.J. Hermann, and E.A. Fulton. 2010. Design and parameterization of a spatially explicit ecosystem model of the central California Current. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-104, 140 p.

[6] E.g., Smith et al. 2011. *Science*. Impacts of fishing low-trophic level species on marine ecosystems. 10.1126/science.1209395. 21 July 2011.

Oceana's Proposed List of Key Forage Species in the California Current (as of October 13, 2011)

Common Name	Scientific Name	Management	Major fishery?*	Population status
California market squid	*Doryteuthis opalescens*	California Market Squid FMP and NMFS CPS FMP	yes	unknown
Northern anchovy	*Engraulis mordax*	NMFS: CPS FMP/ Washington Forage FMP	yes	unknown
Pacific herring	*Clupea pallasi*	Various levels of state management (CA, OR, WA). Washington Forage Fish Management Plan	yes	Stocks range from moderately healthy to critically low.
Pacific sardine	*Sardinops sagax*	NMFS: CPS FMP/ Washington Forage FMP	yes	Coastwide overfishing in 2009, Stock below sustainable biomass levels (Bmsy)
Pacific mackerel	*Scomber japonicus*	NMFS: CPS FMP	yes	low
Jack mackerel	*Trachurus symmetricus*	NMFS: CPS FMP	yes	unknown
Pacific hake YOY	*Merluccius productus*	NMFS: Groundfish FMP	yes	healthy/ large uncertainty
Rockfishes YOY	*Sebastes spp.*	NMFS Groundfish FMP and states (e.g. CA Nearshore FMP)	yes	some rockfishes overfished, some healthy, some unknown
Krill	*Euphausiidae*	NMFS: CPS FMP, OR/WA/CA fishery prohibitions	no	unknown
Neon flying squid	*Ommastrephes bartramii*	No active management	no	unknown
Boreal clubhook squid	*Onychoteuthis borealijaponica*	No active management	no	unknown
American shad	*Alosa sapidissima*	No active management	no	unknown, assumed healthy
Surf smelt	*Hypomesus pretiosus*	No active management/ WA Forage Fish Management Plan	no	unknown
Night smelt	*Spirinchus starksi*	No active management/ WA Forage Fish Management Plan	no	unknown
Longfin smelt	*Spirinchus thaleichthys*	No active management/ WA Forage Fish Management Plan	no	active petition to list CA population as threatened species under federal ESA. CA listed as threatened
Eulachon	*Thaleichthys pacificus*	NMFS: ESA Threatened as of 2010/ WA Forage Fish Management Plan and OR/ WA joint Columbia River Eulachon Management Plan	no	threatened
Whitebait smelt	*Allosmerus elongatus*	No active management/ WA Forage Fish Management Plan	no	unknown
Delta Smelt	*Hypomesus transpacificus*	California endangered species/ U.S. Fish and Wildlife Service threatened species	no	threatened - endangered
Capelin	*Mallotus villosus*	No active management/ WA Forage Fish Management Plan	no	unknown (southern extent of range is WA)
Topsmelt	*Atherinops affinis*	No active management	no	unknown
Jacksmelt	*Atherinops californiensis*	NMFS: proposed EC species in CPS FMP	no	unknown
Lanternfish	*Myctophidae*	No active management	no	unknown
Pacific saury	*Cololabis saira*	No active management	no	unknown
Pacific sandlance	*Ammodytes hexapterus*	No active management/ Washington Forage Fish Management Plan	no	unknown
Shortbelly rockfish	*Sebastes jordani*	NMFS: Fishery prevented through 2012 in Groundfish FMP	no	depressed
Californian grunion	*Leuresthes tenuis*	CDFG: recreational fishery only	no	unknown
Codfishes YOY	Gadidae	NMFS: Groundfish FMP	no	unknown
Pacific tomcod	*Microgadus proximus*	No active management	no	unknown
Greenlings YOY	*Hexagrammos spp.*	NMFS: Groundfish FMP	no	unknown
Pacific Sanddab	*Citharichthys spp.*	NMFS: Groundfish FMP	no	unknown
Surfperches	Embiotocidae	No active management	no	unknown
Sculpins	Cottidae	No active management	no	unknown
Midshipman	*Porichthys* spp.	No active management	no	unknown
White croaker juvenile	*Genyonemus lineatus*	No active management	no	unknown
Kelpfish	Clinidae	No active management	no	unknown
Gunnels	Pholididae	No active management	no	unknown
Pricklebacks	Stichaeidae	No active management	no	unknown
Deep-sea smelts	Bathylagidae	No active management	no	unknown
Bristlemouths	Gonosomatidae	No active management	no	unknown

* Major Fishery = greater than 1,000 metric tons landed on average, 1996-2010. Pacific Fisheries Information Network (PacFIN) Report #307, 1996-2010. Pacific States Marine Fisheries Commission, Portland, OR.

AGENDA ITEM H.2.

NATIONAL COALITION FOR MARINE CONSERVATION
4 Royal Street, S.E., Leesburg, VA 20175

October 13, 2011

Dr. Donald McIsaac
Executive Director
Pacific Fishery Management Council
7700 NE Ambassador Place, Suite 101
Portland, OR 97220

RE: Development of a Council Fishery Ecosystem Plan

Dear Dr. McIsaac,

At the June 2011 Pacific Fishery Management Council meeting, the National Coalition for Marine Conservation (NCMC) supported development of a Fishery Ecosystem Plan and adoption of the purpose and needs statement drafted by the Ecosystem Plan Development Team. We are pleased that the council has taken this important step and that you are now engaged in preparing a process and a schedule for moving forward.

In written and oral statements to the Council in June and at previous meetings, we've testified in favor of developing indicators of ecosystem status as a key element of the FEP, with an emphasis on an index of California Current forage fish abundance and benchmarks for assessing "healthy" states to be maintained and "unhealthy" states to be avoided. I am writing now to re-state the importance of this issue and to urge the Council to establish development of such an ecosystem status indicator as a priority FEP goal.

The NMFS Ecosystem Principles Advisory Panel, on which I served, recommended that a Fishery Ecosystem Plan "provide a metric against which all fishery-specific FMPs are measured in order to determine whether or not management effectively incorporates and achieves the Council's ecosystem goals." I believe this objective is captured in the Purpose and Needs Statement, viz., "…to enhance the Council's species-specific management programs with more ecosystem science, broader ecosystem considerations and management policies that coordinate Council management across its FMPs and the California

Current Ecosystem (CCE)." The metric, in this context, is where information and policy intersect, resulting in improved decisions.

At the June EPDT meeting, members of the team agreed that we need benchmarks for ecosystem status and/or integrity. There was also agreement within the team that "forage is a reasonable place to start" and that we have the science to begin developing an index of forage abundance now.

There can and should be other indicators under development, but assessing the status of the CCE forage base, qualitatively as well as quantitatively, should be identified as a priority, near-term action under the FEP. The literature and emerging practice demonstrate that these kinds of ecosystem status indicators are necessary to an effective ecosystems approach to fishery management and, most importantly, that they are viable.

For instance, Aydin (2008) points out that the low level of overall available forage in the Bering Sea and Aleutian Islands ecosystem (sandlance, eulachon, capelin, herring, shrimp, jellyfish and other forage fish) was viewed by the North Pacific Council's Plan Team as a *qualitative* reason for being cautious in setting allowable harvests of pollock.[1] In short, low numbers of forage fish are considered a negative indicator, while high numbers are an indication of favorable conditions for predators.[2]

Livingston et al (2005) discuss the need to a) develop indicators to assess the ecosystem-level impacts of fishing and b) predict possible future trends in these indicators. Noting the ecosystem goals of maintaining predator-prey relationships, energy flow and balance within the system and species diversity, the authors recommend (among other things) a *quantitative* index of forage biomass, with a threshold for action, as an indicator for maintaining pelagic forage availability.[3]

Earlier this month, the 4th National SSC Workshop (October 4-6 in Williamsburg, Virginia) was convened to consider approaches to implementing ecosystem-based fishery management through the Councils, and a special session was devoted to conserving forage fish. Recognizing the importance of maintaining productivity and stability at the ecosystem level, the group recommended Councils consider exploring ways to estimate forage biomass for a system as well as estimating demands for forage in that same system. Information on system level productivity, it was noted, could be used strategically to guide and coordinate management under individual FMPs.

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[1] Aydin, K. 2008. *The evolution of ecosystem approaches: notes from the front lines.* Alaska Fisheries Science Center. NOAA Fisheries Service.

[2] Northwest Fisheries Science Center. 2011. *Indicators Under Development: Forage Fish and Pacific Hake Abundance.* NOAA Fisheries Service.

[3] Livingston, P.A., Aydin, K., Boldt, J., Ianelli, J., and Jurado-Molina, J. 2005. *A framework for ecosystem impacts assessment using an indicator approach.* ICES Journal of Marine Science, 62: 592-597.

We urge the Council to task the EPDT with identifying and developing ecosystem indicators that could be used to inform existing and future management decisions, especially those affecting key forage species in the California Current, consistent with the Council's ecosystem-based fishery management goals as set out in the FEP's Purpose and Needs Statement and entered into the record during deliberations at the June Council meeting.

Thank you for considering our views.

Sincerely,

Ken Hinman

Ken Hinman
President

PACIFIC COAST FEDERATION of FISHERMEN'S ASSOCIATIONS

Please Respond to:

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02 November 2011

Mr. Dan Wolford, Chair
Pacific Fishery Management Council
7700 NE Ambassador Place, Suite 101
Portland, OR 97220-1384

RE: Protection of Forage Fish – Suspend Development of New Fisheries on Prey Species

Dear Chairman Wolford and Council Members,

The Pacific Coast Federation of Fishermen's Association's (PCFFA) represents working men and women in the West Coast commercial fishing fleet. PCFFA has long been concerned for the protection of forage, or prey, species in the marine ecosystem. These are the species that are prey for economically valuable food fish fisheries, including salmon, tuna, billfish, white bass, sablefish and halibut. Our members voiced such concern over three decades ago, urging conservatism in the setting of quotas for the herring roe fishery – which many of our members were engaged in – since herring are an important prey species of salmon. PCFFA also initiated and sponsored successful California legislation over 15 years ago to prohibit fishing on krill – another important forage species, and PCFFA has consistently opposed development of a shortbelly rockfish fishery for the same reason.

Because of our concern for the protection of important prey species, we respectfully request the Pacific Council suspend development of new fisheries on species that play an important forage role in the marine ecosystem.

We believe such a suspension is necessary until the council has a fully developed ecosystem management plan, to enable it to determine the impact the take of forage stocks on other fish and the marine environment. Moreover, we appreciate the fact the council has been conservative to date in its setting of quota for a number of important forage fish that have had a long fishery history, including sardine and anchovy.

PCFFA fully supports historic fishing on some common forage species such as herring, anchovy, sardine and squid and encourages efforts to increase their use for human food, along with their traditional use for bait. The best use clearly for these stocks that are being fished is for human consumption, with some for bait, to achieve the highest economic value for each pound delivered. The Council should discourage the use of these fish stocks for such uses as animal feeds (e.g., feed for tuna "ranches" and salmon farms) and industrial products – that fail to achieve the highest economic value or human nutritional use of these fish.

Thank you for this opportunity to comment and share our concerns regarding the importance of a healthy forage base. We look forward to working with the Council and all stakeholders to maintain healthy oceans and sustainable fisheries.

Sincerely,

W.F. "Zeke" Grader, Jr.
Executive Director

Agenda Item H.2.C

From: BobUnreel@aol.com [mailto:BobUnreel@aol.com] **Sent:** Thursday, October 13, 2011 5:08 PM **To:** pfmc.comments@noaa.gov **Cc:** JGERSON@beitler.COM; dpickford@roadrunner.com; Lindsay Portnuff **Subject:** Protect forage fish

As a fishing club with a 30 year record of supporting marine fishery conservation we strongly urge support for the Pacific Fishery Management Council effort to develop a fishery echosystem plan for forage fish. Our Club has been working with the Dept of fish and Game and Hubb's Research Institute for the last 14 years raising and releasing white seabass. For most of the those 14 years there have been very few white seabass in SM Bay. This year and last we have had an abundance of krill and squid in the Bay. Predictably, we have seen an increase in seabass and all marine animals including blue whales. On the other hand we have seen fleets of squid boats from all over the Pacific Coast descend on the Channel Islands and take incredible hauls to be turned into fish meal. There needs to be a management plan to protect our forage fish and ensure enough stay in the ocean as a food source to sustain other valuable fish and marine life that are vital to our coastal fishing and tourism economy. I am reminded about what happened to the economy of Monterrey after the sardines were wiped out.

Robert Godfrey, Secretary
MARINA DEL REY ANGLERS, Inc.
4230 del Rey Ave
Marina del Rey, CA 90292

Agenda Item H.2.C

From: **Garth Murphy** <garthmy@gmail.com>
Date: Tue, Nov 1, 2011 at 10:30 AM
Subject: PFMC decision to adopt an Ecosystem-based management plan for forage species
To: pfmc.comments@noaa.gov

TO: DAN WOLFORD, CHAIR
PACIFIC FISHERIES MANAGEMENT COUNCIL
FROM: GARTH MURPHY, CO-FOUNDER, THE SURFERS PARTY

RE: ECOSYSTEM PLAN DEVELOPMENT TEAM

I am a second generation ecologist, son of Garth I Murphy, founding coordinator of CALCOFI, who cut his scientific teeth on the decline of the California Sardine in the 50's and received the first PhD in marine ecology from Scripps Intitute/UCSD.

I am an avid surfer and founder of an organization of surfers dedicated to a clean ocean full of fish.

We believe that an ecosystem function and interactivity based plan is critical for the successful management of all ocean species, and especially the so-called forage species in discussion at this week's meeting of the Council. We urge you to adopt an Ecosystem Based Plan, and a comprehensive list of potential 'forage' species to protect.

The current state of collective knowledge of marine ecosystems leaves no doubt that there is interaction within the entire ecosystem. But forage species are of critical importance in food webs because many of them are pelagic, swimming and drifting between micro-ecosystems, contributing their biomass to all of them, connecting and affecting the entire California Current - at all age classes from spawn to maturity. Thus they embody the concept of ecosystem function connectivity.

Research shows that the number of inter-species interactions in Marine ecosystems seems to be much larger than in terrestrial counterparts, which should make marine food webs more stable, taken as a whole, but this knowledge also indicates that, over variable environmental conditions, any one of the many marine prey species could rise to dominate the regular back up meals that guarantee ecosystem stability, sustainability and overall abundance, the stated goal of fisheries management.

One species gone will not bring down the whole system, but every species that declines or disappears weakens the stability and sustainability of the entire system, over time and changes in seasonal environmental dynamics, as well as larger events like El Nino or global warming, events that will have different effects on different species.

In the most basic terms, the greatest diversity of forage species, the greatest variability within those species and the largest possible range of species age classes will provide the

highest overall productivity, abundance and sustainable biomass of a particular marine ecosystem - because there are correspondingly more regularly available meals for everyone to eat, including us.

Basic understanding of how marine ecosystems function leaves no choice for fisheries management today but to adopt and adhere to an Ecosystem Based Plan that protects the maximum possible number of species. No other plan will do the job required.

Thank you for all the good work of the PFMC in the past and future...working together to maximize marine ecosystem productivity.

Garth Murphy
The Surfers Party

LITTLE FISH BIG DEAL!

Dear Pac'' Fishery Management Council,

Fishermen know the importance of baitfish to a productive ocean. That's why I am asking you t suspend developing any new fisheries that target forage species along the West Coast. Abund populations of forage species feed the rest of the food web – including wild-caught tuna, salm and groundfish. Plenty of forage keeps the public's favorite seafood robust and healthy.

By acting now, the council can protect our important fisheries and the ecosystem that supports them. Suspending development of new fisheries on non-managed forage species will protect t prey base without creating winners or losers. The council did just that when it put krill off-limits in 2006. Similarly, the North Pacific Fishery Management Council prohibited directed fishing fo many key forage species with the strong support of commercial fishermen.

There is no reason to wait. Before allowing the lifeblood of a healthy ocean to seep away as low-grade feed overseas, let's make sure we've left enough bait in the water for the fishermen and coastal communities that depend on it.

Sincerely, Paul D. Madsen F.V. Full Boot 0123785
Signature
Paul D. Madsen
Print name

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Sincerely, Dan Manny-Young
Signature
[redacted]

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Sincerely, Dan D
Signature
Danny Davis Anacortes, (
Print name

!!! Farmed Fish is BAD!!!

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KICK THEIR BUTTS we need our FISH

Sincerely, Ken Wolsiffer
Signature
Ken WOLSIFFER
Print name

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Sincerely, Richard Laurence Pettersen

RICHARD LAURENCE PETTERSEN

F/V FRANCIS WAKE, N…ORT, O

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Sincerely, Edward J. Chevalier

EDWARD J. CHEVALIER

"SALMON TROLLER"

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Sincerely, [signature]

VARDON TREMAIN

owner F/V HEIDI

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Sincerely, F. D. Greenidge

FREDERICK DAVID GREENIDGE

WA. STATE SALMON TROLLER

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Sincerely, Nick Mavar
Signature

NICK MAVAR
Print Name

[illegible] Croatia Way Anacortes-WA 982[illegible]

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Sincerely, Richard G. Ward
Signature

Richard G. Ward – F/V MANATEE II
Print Name

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Sincerely, Mark Chase
Signature

MARK CHASE
Print Name 4426 S. COAST HWY,
SOUTH BEACH, ORE 97366

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Sincerely, Daniel J Swain F.V. Bev Lee
Signature

Daniel L Swain
Print Name

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Sincerely, [signature]

Signature

Henry James Critzfeld

Print name

F/V Rose Lynn - Salmon Co.

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Sincerely, [signature]

Signature

Martin V. Rise

Print name

Astoria Or. 97103

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Sincerely, Jim Moser F/V Tradewind

Signature

Jim Moser

Print name

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Sincerely, C. D. Wise & Loretta Wise

Signature

Chuck Wise & Loretta Wise

Print name

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Sincerely, Gary Hayes

Signature

GARY HAYES

Print name

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Sincerely, [illegible]

Signature

[illegible]

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Sincerely, Albert A. Jackson

Signature

ALBERT A. JACKSON

Print name

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Sincerely, Dan L. Glissendorf

Signature

DAN L. GLISSENDORF

Print name

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Sincerely, Wayne Edgar

Wayne Edgar

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Sincerely, Douglas Cornman

Cornman Douglas

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Sincerely, Dean Mosley

Dean Mosley

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Sincerely, Delbert Cole

DelberT Cole

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Sincerely, [signature]
Signature

MARK M. O'Connor
Print name

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Sincerely, [signature]
Signature

RANDY D. Dobyns
Print name

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Sincerely, [signature]
Signature

ANDREW W. O'Connor
Print name

LITTLE FISH **BIG DEAL**

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Sincerely, Dean Frost
Signature

Dean Frost
Print name

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Sincerely, Kate Scannell

Signature

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Sincerely, Ellen Haley

Signature

ELLEN HALEY

Print name

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Sincerely, Harold D. Crocker

Signature

HAROLD D. CROCKER

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Sincerely, DJWise

Signature

D.J. WISE

Print name

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Signature

Donald Kelly
Print name

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Sincerely, (signature)
Signature

Steve Davis
Print name

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Signature

Tom Lomnicky
Print name

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Sincerely, Wayne R. Hildebrand (signature)
Signature

Wayne R. Hildebrand
Print name

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Sincerely, [signature]

Signature

JIM LAWES

Print name

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Signature

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Signature

LEONARD G. TROTTER

Print name

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Signature

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Sincerely, David Blood

Signature

DAVID BLOOD

Print name

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Signature

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Print name

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Sincerely, [signature]

Signature

Alicia M. Ritter

Print name

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Signature

Walter Lewis

Print name

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Sincerely, Barbara Frost
Signature

Barbara Frost
Print name

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Print name

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Sincerely, Wm L. Taylor
Signature

Wm L. Taylor
Print name

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Signature

Michael Wood
Print name

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Sincerely, Carla Hedgepeth
Signature

CARLA HEDGEPETH
Print name

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Signature

Stephen GRAY
Print name

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Sincerely, Craig Hedgpeth
Signature

Craig Hedgpeth
Print name

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Signature

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Print name

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Sincerely, Carl Sheats
Signature

CARL SHEATS
Print name

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Sincerely, [signature]
Signature

David McCutcheon
Print name

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Signature

Robert L. JACKSON
Print name

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Sincerely, Gerald L. Ashley
Signature

GERALD L. ASHLEY
Print name

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PAT ROOKHUYZEN
Print name

LITTLE FISH BIG DEAL

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Fishermen know the importance of baitfish to a productive ocean. That's why I am asking you to suspend developing any new fisheries that target forage species along the West Coast. Abundant populations of forage species feed the rest of the food web – including wild-caught tuna, salmon, and groundfish. Plenty of forage keeps the public's favorite seafood robust and healthy.

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Sincerely, Darby R Dickerson
Signature

Darby R. Dickerson
Print name

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Sincerely, Michael E.C. Fly
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Michael L.C. Flynn
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Sincerely, [illegible]
Signature

Eric [illegible]
Print name

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Sincerely, Ken W. Ander

Signature

Ken W. Anderson

Print name

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Signature

JAMES L. FARRAR

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Signature

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Sincerely, [signature]

Theodore K West

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Sincerely, Norman & Karen Thompson

Norman Thompson, Karen

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Sincerely, [signature]

JOHN [illegible]

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Sincerely, [signature]

Dan WEBB

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Sincerely, Bryan Benkman

Signature

Bryan Benkman

Print name

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Signature

George Fisher

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Sincerely, Tonia M. Crookshanks

TONIA M. CROOKSHANKS

Print name

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Sincerely, Chris L. Johnson

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Signature

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Print name

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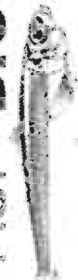

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Signature

ROBERT H. WEBER
Print name

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Sincerely, James B [illegible]
Signature

James B Fries
Print name

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Signature

MICHAEL TAMALONIS

Print name

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Signature

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Signature

Richard I. [illegible]

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Signature

Charlie L Mayfield JR.

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[signature]
Signature

Brendan Flynn
Print Name

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[signature]
Signature

Dennis W [illegible]
Print Name

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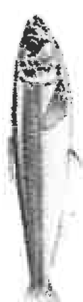

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[signature]
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JOE M Pollich
Print Name

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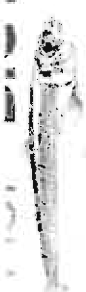

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Paul R Johnson

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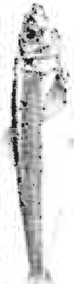

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EDWARD C ISAACSON

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There is no reason to wait. Before allowing the lifeblood of a healthy ocean to seep away as low-grade feed overseas, let's make sure we've left enough bait in the water for the fishermen and coastal communities that depend on it.

Sincerely, [signature]

Signature

Norris A. Petit

Print name

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Sven Stroosma

Print name

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LITTLE FISH BIG DEAL

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Sincerely, Michael H Galligan Commercial Fisherman

Michael H Galligan

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Sincerely, Don A Barnes

DON A BARNES

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Sincerely, Calvin W Bradshaw
Signature
Calvin W Bradshaw
Print name

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Sincerely, Abraham "Joe" Verdoes
Signature
Abraham "Joe" Verdoes
Print name

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Sincerely, Ardelle Perkins
Signature
ARDELLE PERKINS
Print name

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Sincerely, Charlotte Heyer
Signature
Charlotte Heyer
Print name

Agenda Item H.2.c
Supplemental Public Comment PowerPoint
November 2011

Ecosystem Based Management

Ben Enticknap
Pacific Fishery Management Council
Agenda Item H.2
November 6, 2011

OCEANA | Protecting the World's Oceans

Ecosystem Principles Advisory Panel 1999 Report to Congress

Goals: Maintain ecosystem health and sustainability

Policies:

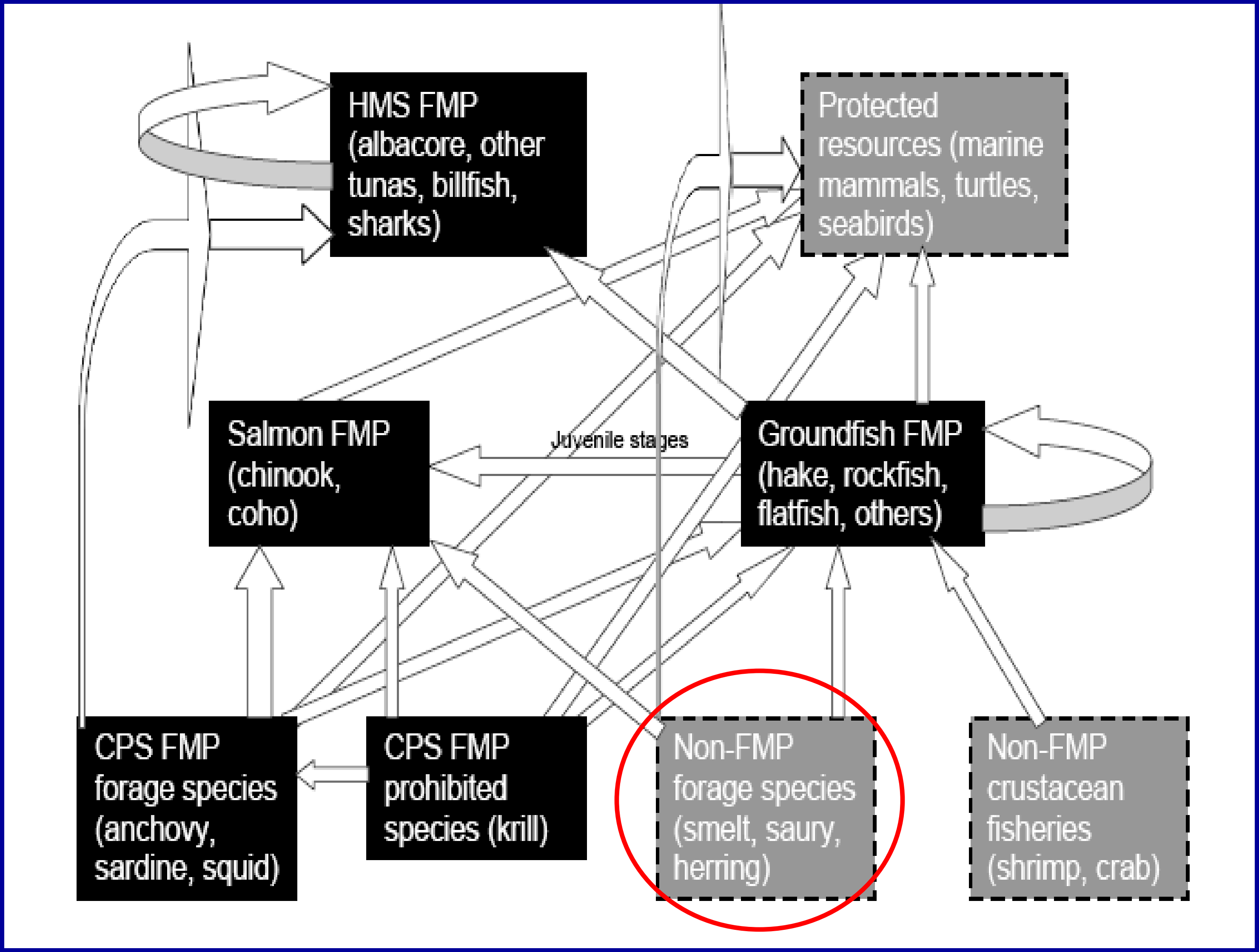
- **Change the burden of proof**
- **Apply the precautionary approach**
- Purchase "insurance" against unforeseen, adverse ecosystem impacts
- Learn from management experiences
- Make local incentives compatible with global goals
- Promote participation, fairness and equity in policy and management

"The overall objective of ecosystem based fishery management is to sustain healthy marine ecosystems and the fisheries they support"

Pikitch et al. 2004. Ecosystem-Based Fishery Management. Science. 305: 346-347.

“Provide Adequate Forage for Dependent Species”

PFMC CPS FMP Goal



Ecosystem Plan Development Team February 2011

Threats and Pressures

"Demand for LTL [lower trophic level] species in the production of fishmeal has mainly been driven by the spectacular growth of global aquaculture, which is expected to continue in the foreseeable future. … This makes the prospect for fisheries developing on the minor LTL species all that more attractive…" pg 32 Draft Fishery Ecosystem Plan

North Pacific Fishery Management Council Forage Protections

"This action creates a forage fish species category in both FMPs and implements associated management measures. The intended effect of this action is to prevent the development of a commercial directed fishery for forage fish, which are a critical food source for many marine mammal, seabird, and fish species. This action is necessary to conserve and manage the forage fish resource off Alaska and to further the goals and objectives of the FMPs."

Fed Reg 63. No 51. March 17, 1998

“Forage fish means all species of the following families:

1. *Osmeridae* (eulachon, capelin and other smelts),
2. *Myctophidae* (lanternfishes),
3. *Bathylagidae* (deep-sea smelts),
4. *Ammodytidae* (Pacific sand lance),
5. *Trichodontidae* (Pacific sandfish),
6. *Pholidae* (gunnels),
7. *Stichaeidae* (pricklebacks, warbonnets, eelblennys, cockscombs and shannys),
8. *Gonostomatidae* (bristlemouths, lightfishes, and anglemouths), and
9. the Order *Euphausiacea* (krill).”

Protection of Krill

Purpose: ***"Preserving key trophic relationships between fished and unfished elements of the food web in order to maintain the integrity of the ecosystem and to minimize the risk from adverse impacts."***

- PFMC 2008. Amendment 12 to the CPS FMP

List of Allowable Fisheries

"An individual fisherman may notify the appropriate Council…of the intent to use a gear or participate in a fishery not already on the list. Ninety days after such notification the individual may use the gear or participate in that fishery unless regulatory action is taken to prohibit…through emergency rulemaking or interim regulations."

Recommendations

1. Establish a clear goal in the FEP to:

   Protect the integrity of the food web through conservation of forage species.

2. Initiate an amendment process to prohibit the harvest of forage species not currently managed in a PFMC Federal FMP (include those in Table A-1, Draft FEP).