Introduction: An Incremental Approach to the California Current Integrated Ecosystem Assessment

The California Current Ecosystem

The California Current Large Marine Ecosystem (CCLME) is a large, dynamic, and spatially heterogeneous marine environment in the eastern North Pacific Ocean off the west coast of North America (Duda and Sherman 2002). It spans nearly 3,000 km of latitude from Vancouver Island, British Columbia, Canada, to Baja California, Mexico (Figure 1). Several major physical oceanographic processes, linked to variability in the atmospheric pressure cells that force winds and circulation, determine ecosystem structure, function, and services. From an oceanographic perspective, the CCLME is under influence from the northern and western Pacific and tropical eastern North Pacific. These processes result in local effects of coastal upwelling and basin-scale subarctic and subtropical water mass intrusions.

The California Current is the primary driver of oceanographic variability in the system and is a year-round equatorward flow extending from the continental shelf break to approximately 1,000 km offshore, with strongest speeds at the surface and extending to at least 500 m depth (Hickey 1989). It carries cooler, fresher, and nutrient-rich water equatorward. A narrow, weaker surface poleward flow along the coast is known as the California Countercurrent south of Point Conception and the Davidson Current north of Point Conception. Another narrow but deeper poleward flow, the California Undercurrent, extends the length of the coast along the continental slope. Maximum current speed is usually from summer to early fall for the California Current and California Undercurrent, and in winter for the California Countercurrent and Davidson Current. The CCLME is largely a wind-driven system, with little freshwater input except from the Columbia River.

Three major estuaries—San Francisco Bay, Columbia River, and Puget Sound—contribute significantly to local economies. Coastal upwelling, El Niño, and decadal-scale climate forcing result in highly variable productivity in the region and consequently increased variability in many fisheries (Bakun 1993, Aquarone and Adams 2008). In the northern and middle ecoregions of the CCLME, fishery resources include invertebrate populations, especially in nearshore waters, groundfish populations along the continental shelf, and migratory pelagic species such as salmon (*Oncorhynchus* spp.), Pacific sardine (*Sardinops sagax*), Pacific hake (*Merluccius productus*), and Pacific herring (*Clupea pallasii*). At the southern end, northern anchovy (*Engraulis mordax*) and market squid (*Loligo opalescens*) are important. The CCLME also supports large and diverse seabird and marine mammal populations.

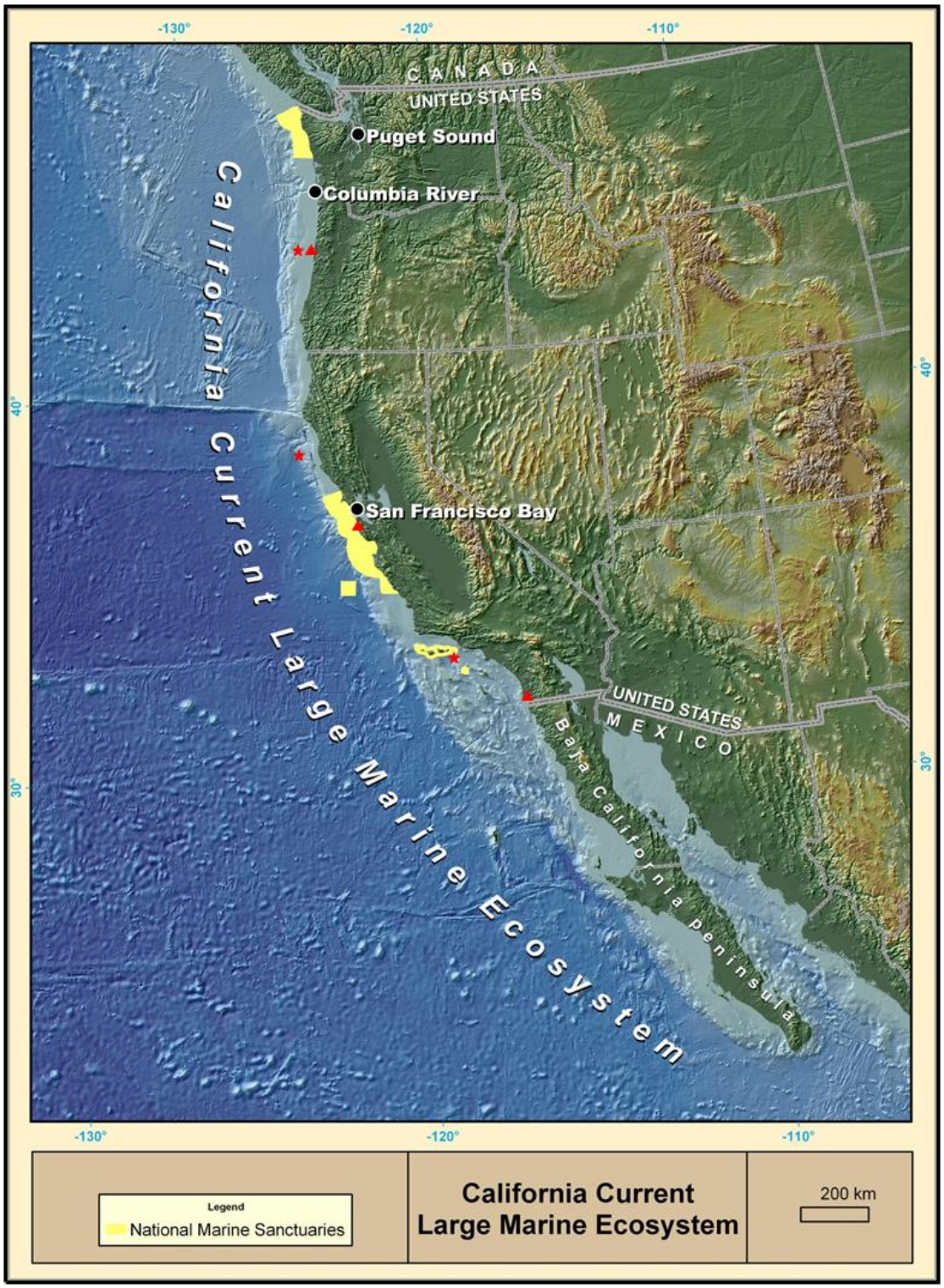

Figure 1. Map of the CCLME. National marine sanctuaries (NMSs) for the U.S. West Coast include (from north to south) Olympic Coast, Gulf of the Farallones, Cordell Bank, Monterey Bay, and the Channel Islands. Sea level measurement locations chosen for this report are represented by red triangles. NDBC buoys collecting sea surface temperatures and meridional wind time series are indicated by red stars. (Map by Blake Feist, NWFSC.)

The California Current is formed as the eastern leg of the North Pacific Gyre. The intensity of transport in the California Current is not well-known, but probably varies by season, year, and decade. It fluctuates in part relative to the position and strength of the North Pacific Current/West Wind Drift, which traverses the subarctic North Pacific Ocean and bifurcates from British Columbia to northern Oregon into the Alaska and California currents. While Washington and southern British Columbia may be considered a transition zone, we define the northern boundary of the CCLME as the northern tip of Vancouver Island, British Columbia, due to frequent upwelling along this section of the coastline in spring and summer (Allen et al. 2001, Yen et al. 2005). Based on physical and biological attributes, Parrish et al. (1981) subdivided the CCLME into three distinct subecosystems:

- Southern British Columbia, Washington, and Oregon to Cape Blanco;
- Cape Blanco, southern Oregon, to Point Conception, California; and
- Southern California (below Point Conception) and Baja California.

What is an Integrated Ecosystem Assessment?

NOAA defines an ecosystem as a "geographically specified system of organisms (including humans), the environment, and the processes that control its dynamics" NOAA further defines the environment as "the biological, chemical, physical, and social conditions that surround organisms" (Murawski and Matlock 2006).

An ecosystem management approach is one that provides a comprehensive framework for marine, coastal, and Great Lakes resource decision making. Integrated ecosystem assessments (IEAs) are a critical science support element enabling ecosystem-based management (EBM) strategies. An IEA is a formal synthesis and quantitative analysis of information on relevant natural and socioeconomic factors in relation to specified ecosystem management goals. It involves and informs citizens, industry representatives, scientists, resource managers, and policy makers through formal processes to contribute to attaining the goals of EBM.

An IEA uses approaches that determine the probability that ecological or socioeconomic properties of systems will move beyond or return to within acceptable limits as defined by management objectives. An IEA must provide an efficient, transparent means of summarizing the status of ecosystem components, screening and prioritizing potential risks, and evaluating alternative management strategies against a backdrop of environmental conditions. To this end, IEAs follow four steps:

- Scoping: Identify management objectives, articulate the ecosystem to be assessed, identify ecosystem attributes of concerns, and identify stressors relevant to the ecosystem being examined.
- Indicator development: Researchers must develop and test indicators that reflect the ecosystem attributes and stressors specified in the scoping process. Specific indicators are dictated by the problem at hand and must be linked objectively to decision criteria.
- Risk Analysis: The goal of risk analysis is to fully explore the susceptibility of an indicator to natural or human threats, as well as the ability of the indicator to return to its previous state after being perturbed.

- Evaluation: Evaluate the potential different management strategies to influence the status of ecosystem components of management concern or the drivers and pressures that affect these ecosystem components.

Further description of IEAs can be found in Levin et al. (2008, 2009).

Scope of this Report

The primary goal of the California Current IEA is to inform the implementation of EBM by melding diverse ecosystem components into a single, dynamic fabric that allows for coordinated evaluations of the status of the California Current ecosystem. We also aim to involve and inform a wide variety of stakeholders and agencies that rely on science support for EBM, and to integrate information collected by NOAA and other federal agencies, states, nongovernmental organizations, and academic institutions. The essence of IEAs is to inform the management of diverse, potentially conflicting ocean-use sectors. As such, a successful California Current IEA must encompass a variety of management objectives, consider a wide range of natural drivers and human activities, and forecast the delivery of ecosystem goods and services under a multiplicity of scenarios.

A full IEA of the California Current is thus a massive undertaking. Our approach to the task of completing this IEA was to systematically decompose the California Current into a series of ecosystem pressures and components that are of keen interest to resource managers, policy makers, and the public. Working with regional managers, we then selected a limited set of pressures and components that we could address in the initial phase of the IEA.

Participants in this exercise—members of the NOAA California Current IEA Team—were John Stein (program manager) and Phillip Levin (science lead), Northwest Fisheries Science Center (NWFSC); Frank Schwing and Brian Wells (science leads), Southwest Fisheries Science Center (SWFSC); Kathi Lefebvre, NWFSC; Yvonne deReynier, National Marine Fisheries Service (NMFS) Northwest Regional Office; Rikki Dunsmore, Monterey Bay National Marine Sanctuary; Churchill Grimes, SWFSC; Joshua Lindsay, Shelby Mendez, and Elizabeth Petras, NMFS Southwest Regional Office; Rondi Robison, NOAA MPA (marine protected area) Center; and Lisa Wooninck, National Marine Sanctuary West Coast Regional Office. Below we present the outcome of this dialogue.

EBM Drivers, Pressures, and Components in the California Current Ecosystem

A lengthy list of drivers and pressures was created. Here we define drivers as factors that result in pressures that in turn cause changes in the ecosystem. For the purposes of an IEA, natural and anthropogenic forcing factors are considered. An example of the former is climate variability and the latter include factors such as human population size in the coastal zone and associated coastal development, and demand for seafood. In principle, human driving forces can be assessed and controlled. Natural environmental changes cannot be controlled but must be accounted for in management. Pressures include factors such as coastal pollution, habitat loss and degradation, and fishing effort that can be mapped to specific drivers. For example, coastal development results in increased coastal armoring and the loss of associated intertidal habitat.

We binned drivers and pressures into 11 broad categories (Figure 2). We define EBM components as the biological, physical, or human dimension entities that policy makers, managers, or citizens are trying to manage or conserve. Expressed this way, the list of management concern targets is quite long; however, the IEA team grouped these into seven bins (Figure 2) defined as follows:

- Wild fisheries, an EBM component centered on the condition of fishery stocks included in the coastal pelagic species, highly migratory species, groundfish, and salmon fishery management plans.
- Seafood, distinct from fisheries, an EBM component focused on the consistent delivery of plentiful, safe seafood. This overlaps with the wild fisheries EBM, but includes aquaculture and production hatcheries and focuses less on the health of the wild stocks and more on the provisioning of food for human consumption.
- Protected resources, species legally designated as protected (e.g., Marine Mammal Protection Act, Migratory Bird Treaty Act, Endangered Species Act).
- Habitat, including biogenic and abiotic habitats on the seafloor and in the water column.
- Ecosystem health, referring to the structure and function of marine and coastal ecosystems and ecological communities.
- Vibrant coastal communities, including social, economic, and cultural well-being and human health as it is tied to the marine environment.
- Scientific knowledge and education, a distinct EBM goal of many agencies to provide unique opportunities for scientific research and education.

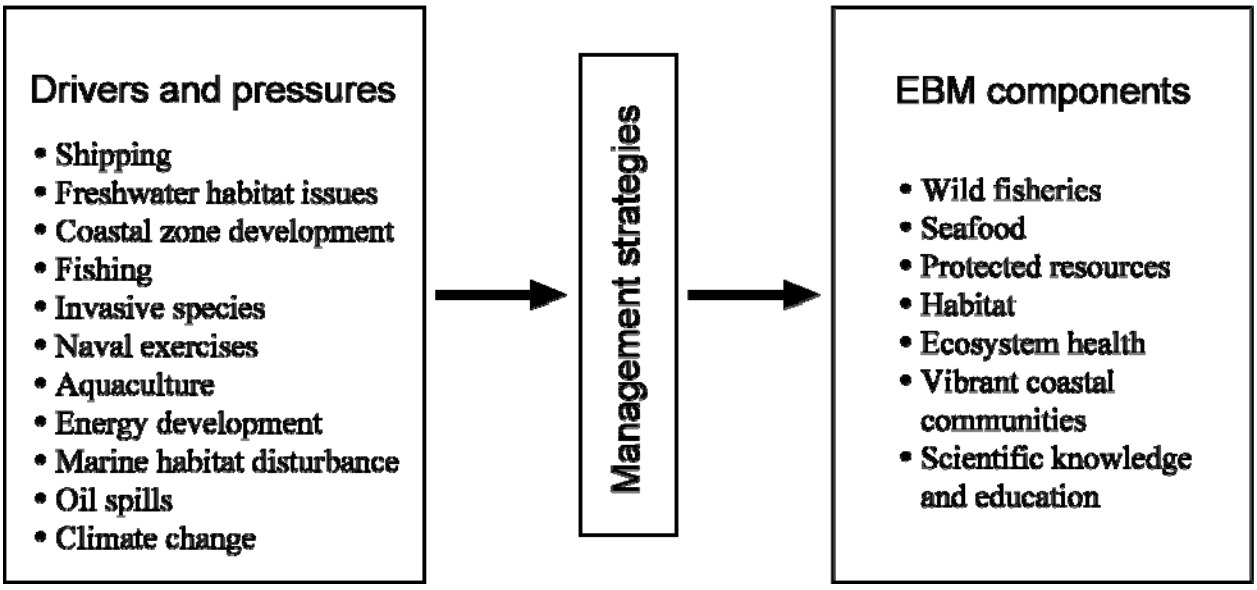

Figure 2. Conceptual diagram of the primary pressures and drivers affecting change in the primary EBM components of the CCLME as defined by the IEA team.

EBM Drivers, Pressures, and Components Addressed in the California Current IEA

The ultimate aim of the California Current IEA is to fully understand the web of interactions that links drivers and pressures to EBM components and to forecast how changing environmental conditions and management actions affect the status of EBM components. The IEA team decided to focus on climate as an important ecosystem driver. In the first year, the IEA team also focused on four aspects of the EBM components:

- Groundfish as an example of the wild fishery EBM component;
- Salmon as a group of species that is of interest as a protected resource, fisheries target, and an aspect of ecosystem health;
- Green sturgeon (*Acipenser medirostris*) as an example of a protected resource; and
- Ecosystem health.

The IEA team believed that given existing scientific tools and management needs, addressing these EBM components would have the greatest benefit to ongoing policy and management processes.

Next Steps for the California Current IEA

This report is the first in a series of efforts to complete a full IEA of the California Current. In addition to improving analytical techniques and models and filling data gaps, the next iteration of the IEA will expand to include more ecosystem pressures and components. Specifically, in fiscal year 2011 the California Current IEA will add two EBM components: vibrant coastal communities and forage fish. In addition, the IEA will explicitly add wave energy power generation as an ecosystem pressure. In this document, we develop an approach to conduct an ecosystem risk assessment and apply this approach to a limited set of human activities and ecosystem components in the California Current. In subsequent years, this approach will be extended to include regions beyond the California Current. Finally, only a limited set of management strategy evaluations are presented here (see The Evaluation of Management Strategies section). In fiscal year 2011 thorough scoping will be conducted, which will allow scientists to analyze specific suites of well-vetted management strategies.

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Technical background for an Integrated Ecosystem Assessment of the California Current

Groundfish, Salmon, Green Sturgeon, and Ecosystem Health

Edited by Phillip S. Levin and Franklin B. Schwing[1]

From contributions by the editors and Cameron H. Ainsworth, Kelly S. Andrews, Steven J. Bograd,[1] Merrick Burden,[2] Shallin Busch, William Cheung,[3] John Dunne,[4] Tessa B. Francis, Elizabeth A. Fulton,[5] Churchill B. Grimes,[6] Elliott L. Hazen,[1] Peter J. Horne, David Huff,[7] Isaac C. Kaplan, Steve T. Lindley,[6] Thomas Okey,[8] Jameal F. Samhouri, Isaac D. Schroeder,[1] William J. Sydeman,[9] Sarah A. Thompson,[9] Nick Tolimieri, Brian K. Wells,[6] and Gregory D. Williams

Northwest Fisheries Science Center
2725 Montlake Boulevard East
Seattle, Washington 98112

[1]Southwest Fisheries Science Center
1352 Lighthouse Avenue
Pacific Grove, California 93950

[2]Pacific Fishery Management Council
7700 Northeast Ambassador Place, Suite 101
Portland, Oregon 97220

[3]University of East Anglia
School of Environmental Sciences
Norwich, United Kingdom NR4 7TJ

[4]Geophysical Fluid Dynamics Laboratory
Princeton University Forrestal Campus
201 Forrestal Road
Princeton, New Jersey 08540

[5]CSIRO
Castray Esplanade
Hobart, Tasmania 7000, Australia

[6]Southwest Fisheries Science Center
110 Shaffer Road
Santa Cruz, California 95060

[7]University of California Santa Cruz
100 Shaffer Road
Santa Cruz, California 95060

[8]University of British Columbia
2329 West Mall
Vancouver, British Columbia V6T 1Z4

[9]Farallon Institute
P.O. Box 750756
Petaluma, California 94952

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Levin, P.S., and F.B. Schwing (eds.) 2011. Technical background for an integrated ecosystem assessment of the California Current: Groundfish, salmon, green sturgeon, and ecosystem health. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-109, 330 p.

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