DRAFT 7
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Implementing a Climate and Ecosystem approach to management of hake and sardines in the California Current: a demonstration project

Background. NOAA Fisheries recognizes the need to improve resource surveys, to improve climate and ecosystem observations, and to develop the means to incorporate climate variability and ecosystem observations into the stock assessment process (PaCOOS 2004). Such activities will contribute to the new NOAA mandate to manage fisheries in an ecosystem context. The California Current Large Marine Ecosystem (CCLME) is an excellent choice for implementing an ecosystem-based approach to management because it supports valuable fisheries stocks, it has a long and rich tradition of oceanographic and climate observations resulting from the CalCOFI and GLOBEC programs, and because it features strong climate forcing and ecosystem response. An understanding of the linkages between climate variability, ocean conditions and variability in recruitment and biomass of marine resources is a requisite if NOAA is to successfully implement an ecosystem approach to management.

The goal of implementing an Ecosystem Approach to Management cannot be achieved for all living marine resources in the CCLME without an increase in funding by at least one or two orders of magnitude. Projected costs required to improve resource surveys, to implement a system of oceanographic observations, to establish data base systems and to incorporate all information into models, all of which are needed to nowcast and forecast the consequences of climate variability and climate change, is on the order of $60M (PaCOOS 2004). The cost of implementing only the oceanographic observations network, data management, and modeling system has been estimated to be $30M by the PaCOOS Board of Governors.

Synopsis of this Prospectus. We propose a demonstration project, at a cost that is a fraction of the PaCOOS (2004) estimate, to show how climate information from NOAA and academic observation and modeling systems can be linked with NOAA resource management to produce better models for management of living marine resources. Given limitations on funding, we focus on three species within the living marine resource complex: two of them (hake and sardines) are commercially important fish that utilize the third species group (euphausiids) as a food source. Because these species have a demonstrated sensitivity to climate variability and may indicate climate change sooner than can be detected in other measurements, they have been designated as "sentinel species" (NOAA Climate: PBA 2004).

The goals of this pilot are to expand the collection of relevant climate-ocean data that would, in combination with the existing euphausiid, sardine and hake times series, allow improved understanding of climate-ocean factors affecting distribution, abundance and status of these three sentinel species. Moreover, we propose to build on existing sea-going programs by adding new measurements and sampling protocols, and by modeling the linkages between species observations and climate-driven ocean dynamics**.** We will demonstrate how information on climate variability can be used to describe changes in (a) production, growth, and migration patterns of hake and sardines and (b) euphausiid biomass and production. Thus, **our ecosystem**

approach is to demonstrate ways to link climate information with knowledge of the forage base of important commercial fisheries to produce management models that better explain, and ultimately forecast, recruitment variability.

Climate Connections. While the impact of climate signals like ENSO and PDO on marine communities in the CCLME is well established, developing a reliable ability to predict these impacts will depend on isolating the mechanisms by which classes of physical variability, driven by climate change, impact different ecosystem components. Wind-driven coastal upwelling, advection by large-scale currents, diapycnal mixing as influenced by changing stratification, and vertical motions associated with mesoscale eddies all affect the nutrient supply for primary production. Temperature affects various biological rates and produces behavioral responses such as migration in marine animals. Ocean currents, mesoscale eddies, and surface winds affect the distribution of eggs and larvae. Progress on identifying and predicting climate impacts in the CCLME requires time series of temperature and salinity at least across the EEZ; alongshore advection in the California Current and Undercurrent; persistent and/or recurrent offshore flows induced by topography; stratification over the shelf and in the upper parts of the deep ocean; and at least a general description of mesoscale eddies and fronts. With enough of these basic observations and high-resolution wind and surface flux fields, data-assimilating numerical models could provide a picture, interpolated in time and space, of the dynamics of CCLME.

The project's target species, euphausiids, sardine, and hake, respond to climate variability on time scales ranging from weekly, monthly and seasonal to interannual and multi-decadal. Climate events such as El Niño affect the northern extent of sardine and hake feeding migrations (Figure 1), the location and size of their spawning habitats and feeding grounds, somatic growth, and availability to local fisheries and natural predators. Even short-term climate events affect local fisheries and their management because they change the availability of fish. When such effects are compounded over decades of anomalous ocean conditions, the productivity of the euphausiid and fish stocks is fundamentally altered. This changes the biomass that can be supported by the system, the sensitivity of the population to fishing and predation, alters the role they play in the ecosystem, and shifts population centers. Understanding and predicting these long-term effects of climate is the central goal of this research.

Requirement Drivers. The Climate PBA lists the drivers, and these include the Magnuson-Stevens Fisheries Conservation and Management Act, Marine Mammal Protection Act, and Endangered Species Act. Other drivers are GEOSS and IOOS, the NOAA AGM, the US CCSP, the President's CCRI, the U.S. Commission on Ocean Policy, and the President's U.S. Ocean Action Plan (Dec 2004) in response to the U.S. Commission on Ocean Policy's Final Report.

Approach.

Monitoring will include key physical, ecological, and fishery variables along several transect lines (Figure 2), as well as a reanalysis of existing data sets (e.g., NCEP, CalCOFI, GLOBEC). Monitoring cannot be comprehensive, due to cost factors, but must be selective to climate-sensitive locations and variables. The monitoring will benefit the NOAA Climate and Ecosystem Goals, will provide ocean data for IOOS and will demonstrate technologies to incorporate into the coastal and global observational system. We propose three efforts:

1. To add value to existing monitoring programs by increasing the number of physical and biological measurements made on cruises and surveys. This activity could include processing and analysis of CTD profiles and shipboard ADCP measurements and the addition of new measurements where possible (e.g., flow-through thermo-salinographs, chlorophyll fluorescence; low-cost CTD profiles); collection of zooplankton (net tows, video plankton recorders and optical plankton counters), otoliths, and fish stomachs. We would add these types of measurements where appropriate to annual hake, sardine and marine mammal surveys, and NOS Marine Sanctuary cruises.

2. To begin regular glider and/or AUV surveys of physical and bio-optical properties at a few climate-sensitive locations to better understand variability between quarterly cruises and to assess the ability of these platforms to fill gaps in the ship-based observing system.

3. To begin a pair of well instrumented bio-optical, physical and acoustical mooring time series on the continental slope to supplement the near-shore mooring time series observations now being made. These will be particularly useful in extrapolating remote sensing signals below the surface, assaying mesoscale eddies and fronts, and exploring the ability to monitor temporal variations in euphausiid biomass using acoustic observations.

Modeling will focus on mechanisms linking climate variability to the sentinel species. The project will not develop new models, rather we will apply existing models. Two types of modeling efforts are envisioned:

1. Coupled physical and biological NPZ models, and diagnostic and prognostic models will be developed in collaboration with other modeling initiatives such as the ROMS models supported by the recent GLOBEC synthesis and GODAE efforts. A long-term goal is to have prognostic models of hake and sardine that incorporate climate variability. An early effort at producing coupled biophysical models is needed because the capability of such models is poorly known and the models can help evaluate potential new observations.

2. Ecosystem Modeling. NOAA Fisheries scientists are developing ecosystem models, such as a CCLME version of the ATLANTIS model and ECOPATH- ECOSIM models. We would expand these models to explicitly estimate the ecosystem and population-level consequences of various fisheries management alternatives in the face of varying climate regimes or directional climate change.

Biophysical and *ecosystem* models will be used to model a range of climate scenarios ranging from ENSO to scenarios of climate change generated by the Intergovernmental Panel on Climate Change. Moreover, models used to estimate population parameters for management of sardines and hake would be more accurate because of larger amounts and higher quality input data from surveys, and could explicitly include climate as a factor used to “tune” the models. The historical physical and biological observation will provide the scales of temporal and spatial variability of the CCLME, and allow models to be tested in a hindcast mode.

Ecosystem indicators will be developed in collaboration with the NOAA FATE program on both physical and biological indices that provide a better understanding of linkages between climate and ecosystem processes, and the dynamics of hake, sardine and euphausiid populations.

An Annual-to-biannual assessment of the physical and ecological aspects of the CCLME will be produced that summarizes the status of the climate-ocean system and the three target species. This assessment will be targeted largely for managers, and include information on sentinel species that can be used as an early warning of climate change in the CCLME.

Pacific hake are a key component of the CCLME. They are the most abundant groundfish in the CCLME and support one of the largest fisheries in the region. In 2004, the U.S. portion of the catch was over 216,000 metric tons with a value of nearly 22 million U.S. dollars. This large biomass accordingly affects the populations of their prey (euphausiids, fish and pink shrimp). Furthermore, direct links between hake recruitment and abundance and climate have been shown. The usual migration pattern of hake is northward in spring after spawning and southward from feeding grounds in the fall—this migration appears to be moderated by climate-ocean conditions (e.g. hake migrate further northward in warm years). El Niño events have been shown to affect the summer distribution of hake as well as the proportion of hake in the Canadian zone, and the abundance of hake appeared more closely related to El Niño events than to the regime shift. Transport can have an important role in producing strong year classes, as strong year classes are established during the egg or larval stage of development. Hake is a good choice for future research on climate for several reasons. A clear (but not well-defined) linkage already is established between key events in the hake populations and climate. The large biomass of this species indicates that fluctuations in this species will have cascading effects throughout the CCLME. A large, robust and continuing time-series of data about hake already exists, resulting from acoustic and bottom trawl surveys since at least 1977, pre-recruit surveys, commercial catch and bycatch statistics, growth and food habits information, as well as concurrently-collected oceanographic data.

The **California sardine** is a key species in the CCLME food web as a predator and as food for other fish, marine mammals and birds. The commercial fishery has a long history that has displayed enormous swings in biomass and productivity. John Steinbeck recounted the sardine collapse in the 1940s in "Cannery Row" that was driven in part by a regime shift to cooler conditions and a different ecosystem structure. Since the 1970s, when the CCLME returned to a warmer state, the sardine biomass has grown rapidly. Paleo records indicate sardine biomass has fluctuated for centuries on the time scales associated with regime shifts in the North Pacific. Because of its strong response to the environment, the sardine is managed with an annual quota based on ocean temperature. It is the only marine fishery stock currently managed by NOAA that requires an environmental driver. The historical record of the California sardine will be valuable in understanding climate-ecosystem links.

Euphausiids compose a group of keystone species in the CCLME with two species making up most of the biomass: *Euphausia pacifica* and *Thysanoessa spinifera*. They serve as the major prey item and dietary component of a large number of managed and endangered species. The list is long and includes blue and fin whales, seabirds (Cassins Auklets, and most shearwaters) and commercially important fishes such as hake, sablefish, rockfish, sardines, herring, mackerel, Chinook salmon and coho salmon. Year to year variations in the availability of euphausiids contributes to and may explain the high degree of variability in survival and recruitment of marine mammal, bird and fish species. The Pacific Fisheries Management Council is developing management measures to regulate directed fisheries for krill within the U.S. EEZ, including the possible prohibition of krill harvest within the west coast National Marine Sanctuaries. The proposed action is in recognition of the importance of krill in the natural economy of the CCLME. In order to provide support for the management plan, information regarding their biomass, vital rates, short-term variations of theses properties, and how they respond to climate variations is required.

Performance Measures.

- Increased number of **ecological observations** to detect the impacts of climate variability and global change on the CCLME, at local and regional scales;

- Increased skill of climate-forced biological and coupled physical-biological **models** to forecast ecosystem production and change at seasonal and interannual time scales;

- Increased number of physical and biological **indicators** that track changes in physical forcing and ecosystem response due to climate variability;

- **Assessments** of physical oceanographic and ecosystem response to variations in climate forcing with a focus on the response of zooplankton, euphausiids, sardines and hake;

- Increased number of new cases where **climate** information is integrated into **fisheries management plans**. Our initial focus would be on euphausiids and sardines in the Coastal Pelagics Fisheries Management plans.

Data Management/Communications. The Pacific Coastal Ocean Observing System (PaCOOS), the west coast backbone of marine ecosystem observations for IOOS, is coordinating data management systems for west coast activities. Our demonstration project will rely on the standards developed by IOOS and PaCOOS as well as the infrastructure to archive and disseminate data and products from observations, models, and assessments.

Beneficiaries. Primary beneficiaries are the Pacific Fishery Management Council (PFMC) and stock assessment teams that actively manage sardine (Coastal Pelagic Species FMP) and hake (West Coast Groundfish FMP and the U.S./Canada agreement on the management of hake). In addition, the PFMC is developing management measures to regulate directed fisheries for krill and are now working on a euphausiid amendment within the Coastal Pelagic Species FMP. The hake work would be a direct economic benefit for the industry because if the proportion of hake in the Canadian zone could be predicted, industry could prosecute the fishery more efficiently. We also expect that this demonstration project will create a guide for future climate-ecosystem programs. Moreover, the observations, models, and indicators will benefit NOAA Oceans coastal activities, including the management of west coast NMS and NERRS (e.g., HABs). Monitoring sentinel species will provide NOAA climate scientists with a new way of detecting climate change. Finally, technological improvements can be applied to other regions and projects for monitoring the oceans (e.g., IOOS).

Budget. An excel spreadsheet of this budget is included as a separate attachment to the e-mail**.** See the next page for "Budget Justification".

PERSONNEL COSTS	FTE 75	FTE	FTE	FTE	FTE	Year 1	Year 2	Year 3	Year 4	Year 5
Observations										
Transect Lines	5	5	6	7	7	375	386	477	574	591
Gliders	2.5	2.5	3	3.5	3.5	188	193	239	287	295
Hake analysis	1.5	1.5	2	2.5	2.5	113	116	159	205	211
Sardine analysis	1.5	1.5	2	2.5	2.5	113	116	159	205	211
NOAA Surveys	2.5	2.5	3	3.5	3.5	188	193	239	287	295
Mooring	2	2	2.5	3	3	150	155	199	246	253
Modeling										
Biophysical	2.5	2.5	3	3.5	3.5	188	193	239	287	295
Ecosystem	1	1	1.5	2	2	75	77	119	164	169
Ecosystem indicators & ecosystem status reports	1	2	1	2	2	75	155	80	164	169
Data Management	2	2	2.5	3	3	150	155	199	246	253
Total Salary + Fringe						1613	1738	2109	2664	2743
Travel/Annual Workshops						50	52	53	55	56
Supplies/Expendables						200	206	212	219	225
TOTAL HARDWARE						1000	100	805	200	200
TOTAL DIRECT						2863	2096	3179	3137	3225
OVERHEAD (assumed 50%)						931	998	1187	1468	1512
GRAND TOTAL						3794	3093	4366	4605	4737
TOTAL w/o HARDWARE						2794	2993	3561	4405	4537
HARDWARE COSTS detail										
Gliders (100K each)						600	100	100	200	200
Moorings						300		600		
CTD, Fluorometers						50		50		
Computer						50		55		

Budget Justification.

1. Annual salary are calculated as an average rate of 75K per year with increases calculated at 3%.

2. Salaries will likely be a mix of Research Assistants, Post-Doctoral Research Faculty, and some Principal Investigator time. The FTE reflects a mix of both Federal FTE and Academic FTE-equivalents. Note also that salaries include only wages and benefits. Overhead is calculated in the OVERHEAD section of the budget.

3. Many of the oceanographic cruises discussed in this proposal are funded from existing NOAA sources. Sampling off Newport OR is an exception. The only funding that exists is for the biweekly cruises that sample seven stations from 1 mile from shore, across the shelf, to the edge of the continental slope (water depth at the most offshore station is 300 m). We request funds to support the "long lines" shown in Figure 2 of this proposal, out to 100 miles from shore. We propose to pick up lines in Northern and Central California as the project evolves. Costs are for personnel to participate in these cruises and for data analysis. NOAA shiptime requests for sampling on the Newport line have already been submitted to NOAA HQ for FY 08-FY12. Requests were for cruises in February, May, July, September and November, for a total of 40 Days at Sea.

4. Gliders. Costs are for personnel to launch/retrieve units and process data. Gliders will be deployed on 4 east-west lines to start, expanding to 6+ lines as the program evolves.

5. Other NOAA Surveys. Costs are for personnel to participate in hake and sardine surveys, on bird and mammal surveys, and on NOS Marine Sanctuary survey cruises. These technicians will do all data analysis (CTD, ADCP) and collect and analyze chlorophyll, euphausiid, sardine and hake samples.

6. Mooring. The request is for technical support to design, build and deploy two moorings with physical, bio-optical and bioacoustical instruments in two different regions of the CCS. Support is also requested for data processing and analysis. The number of mooring sites will be increased to cover more of the biogeographical regions of the CCS as the program matures.

7. Modeling. Two separate activities are proposed: biophysical models using circulation and nutrient-phytoplankton-zooplankton-detritus models; ecosystem models, e.g. the CCLME implementation of the ATLANTIS model. In both cases, costs are solely for personnel. Hardware costs for computer clusters to run and analyze the model runs are included.

8. Hardware. Costs are for the purchase of moored instruments, gliders, and equipment to augment the existing NOAA oceanographic cruises (e.g., flow-through thermosalinographs with chlorophyll fluorescence).

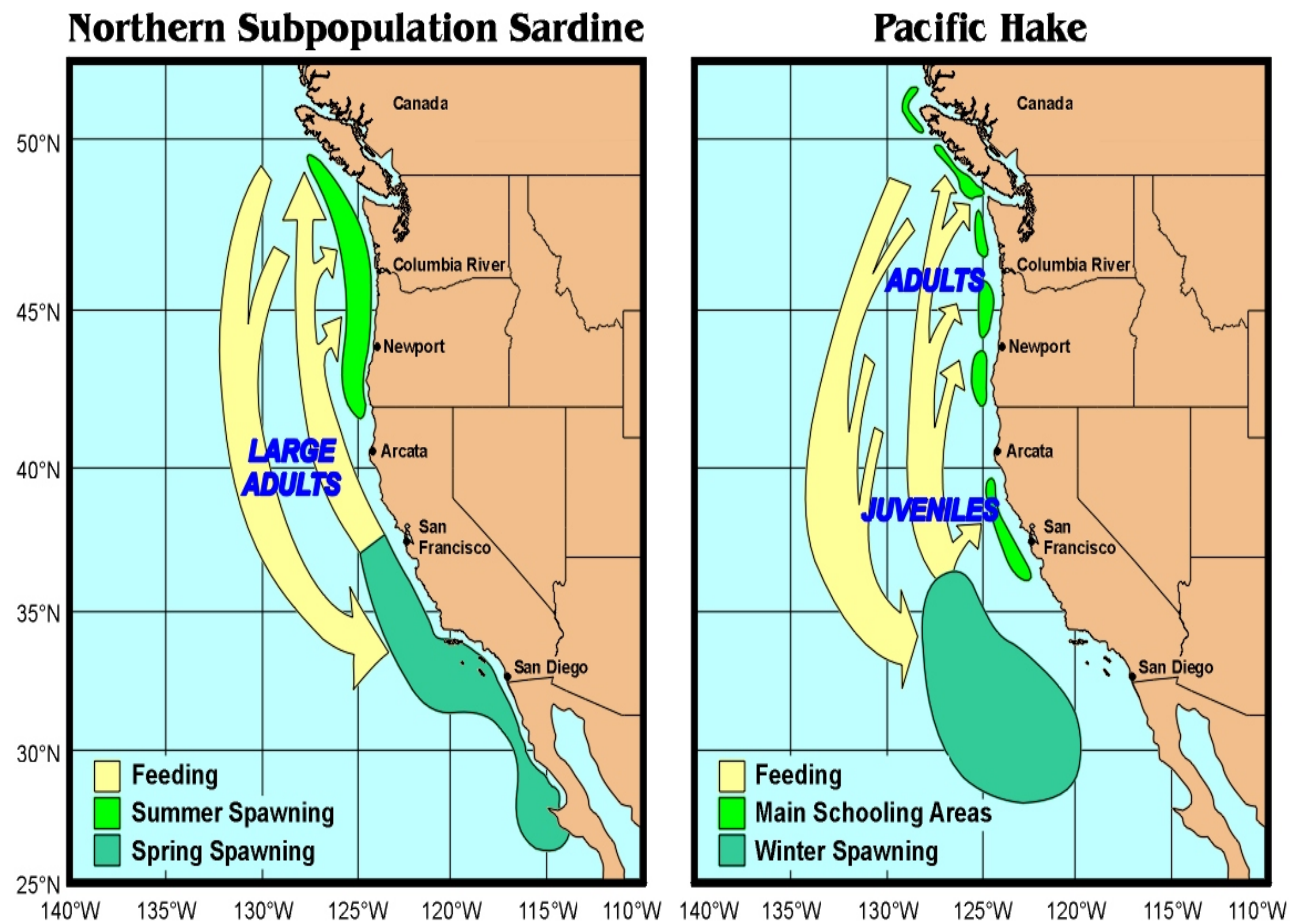

Figure 1. Migration pattern of Pacific hake and Pacific sardines.

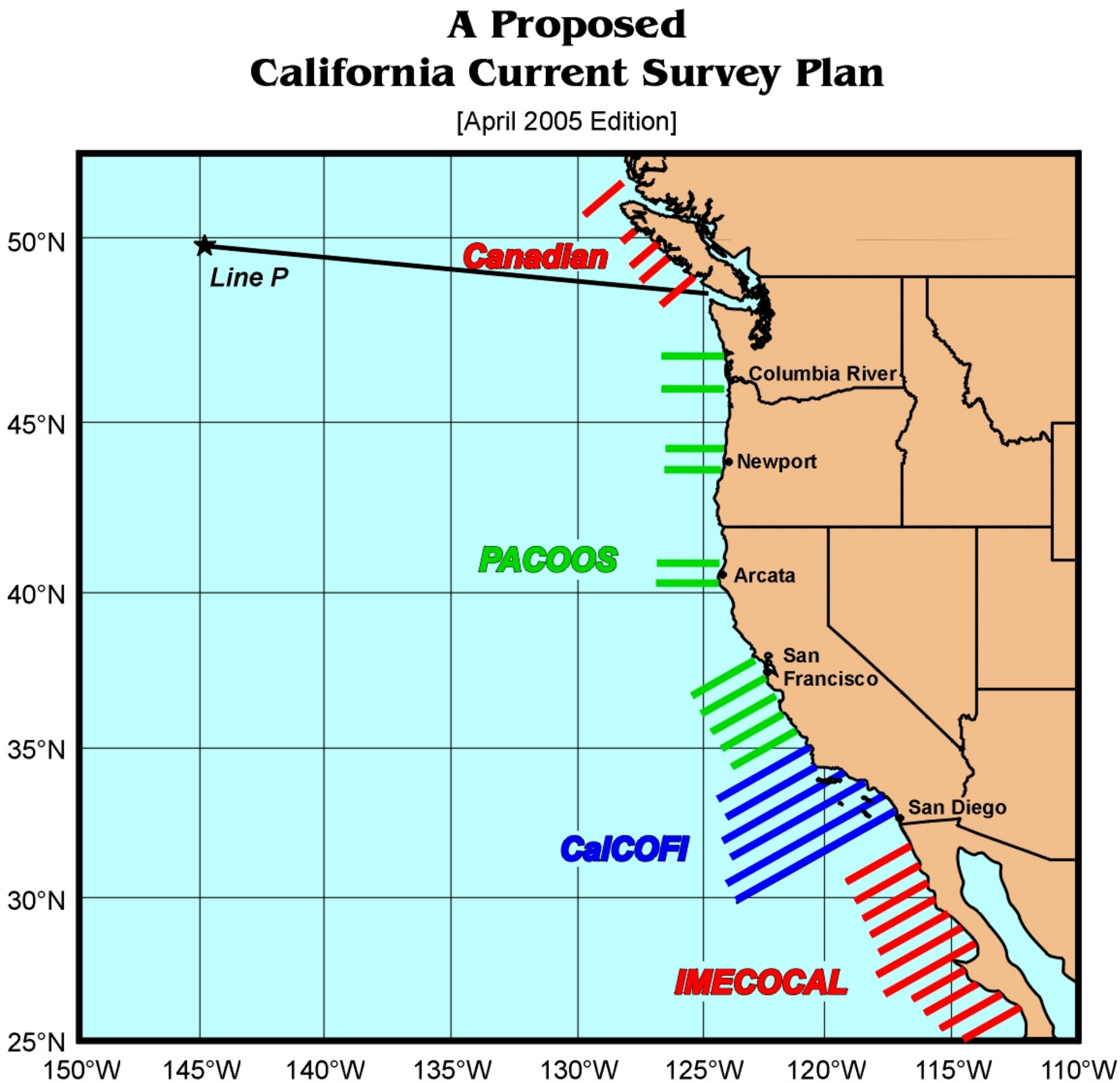

Figure 2. Oceanographic transect lines that are presently being sampled (IMECOCAL, CalCOFI, Canadian and Line P). Some of the green lines off Monterey are sampled on a regular basis. The other green lines are transect lines that have been endorsed by PaCOOS, but are not now sampled regularly. Lines off Newport and Arcata were sampled during the GLOBEC program beginning in 1998 but funding for that program ceased in 2003.