NOAA's Integrated Ecosystem Assessment program:
California Current Region 3-Year Work Plan (FY2016-FY2018)

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Regional IEA Goal/Vision: The California Current Integrated Ecosystem Assessment (CCIEA) team proposes six goals to guide development of the CCIEA over the next three years. These goals are drawn from work completed to date and expand the reach of the CCIEA in terms of both integrated science and connecting with new partners who will benefit from CCIEA products. These goals directly address IEA goals of integrated science in support of ecosystem-based management (EBM), particularly in areas of human dimensions, climate change, and development of ecosystem reference points.

Goal	Target audience
1. Provide EBM-focused products related to California Current variability	PFMC, WCRO, ONMS
2. Contribute to sanctuary Condition Reports	ONMS
3. Develop metrics of human dimensions for EBM	PFMC, WCRO, ONMS, states, coastal communities
4. Provide products related to climate change	PFMC, WCRO, ONMS, industry, states
5. Ecosystem reference points and regime shift early warning index	PFMC, WCRO, ONMS
6. Improved communication and outreach	PFMC, WCRO, ONMS, states, IEA program, other agencies

The objectives associated with these six goals are articulated to reflect progress to date as well as advances anticipated over this strategic three-year period.

Introduction: The CCIEA region covers the marine, estuarine, freshwater and terrestrial domains associated with the California Current Large Marine Ecosystem (CCLME). Stretching along the North American west coast from British Columbia to Baja California, the CCLME is an eastern boundary current ecosystem flowing over a narrow continental shelf and steep continental slope. It can be divided into a northern subregion (north of ~Cape Blanco), a central subregion (south from Cape Blanco to Point Conception), and a southern subregion (south of Point Conception). The CCLME is a highly productive system with rich resident and migratory faunas, from microbes to whales, and habitats from coastal estuaries to open pelagic zones. It supports valuable commercial and recreational fisheries, along with numerous other activities that shape the economies and social structure of coastal communities. Five National Marine Sanctuaries (NMS) encompass areas with exceptional biodiversity, unique habitats, and cultural heritage. Dozens of protected species, including marine mammals, seabirds, sea turtles, and ESA-listed fishes such as salmon and green sturgeon, inhabit the CCLME.

Variability is a defining feature of the CCLME. Primary and secondary productivity are driven by local and basin-scale processes that vary at temporal scales from seasons to decades. The major seasonal driver is the spring/summer wind-driven upwelling cycle, which contributes cold, nutrient-rich waters to the surface, particularly in the northern and central portions of the CCLME. Upwelling intensity is influenced by large-scale climate signals at intervals of years (e.g., the El Niño Southern Oscillation (ENSO)) to decades (e.g., the Pacific Decadal Oscillation (PDO)). These processes also affect temperature, stratification, rainfall, and the amount of snowfall that feeds rivers supporting anadromous species like salmon. The temporal variation is superimposed upon a spatially variable system influenced by features both dynamic (currents, eddies, jets and fronts, river discharges, biogenic habitats, and human activities) and static (bathymetry, sediment type, and coastal features). Thus, although productivity is high, it is patchy in time and space, which contributes to complex community ecology.

The extent to which climate change is affecting the system is difficult to detect through the very strong interannual variation and longer-term regime shifts, although stressors such as droughts, declining snowpack, and increasing ocean acidification and hypoxia may be indicative of long-term climate change. Moreover, even if interannual and decadal variability continues to dominate production and other processes in the CCLME in the coming decades, climate change may increase the frequency of extreme ENSO events, cause destructive sea level rise, or cause changes in human population distributions or demand for ecosystem services such as fresh water and energy. Any one of these climate-driven outcomes could have lasting impacts on the CCLME.

Coupled with the ecological system is a human system that is deeply connected to marine resources, ecosystem services, and natural attributes. Coastal residents derive food, revenue, employment, energy, environmental regulation, recreation, shipping, and other uses and benefits from the marine environment. Human cultures, identities, and quality of life are tied to the species, habitats, seasonality, aesthetics, and intangible qualities of the CCLME. Interacting and sometimes conflicting human activities take place virtually in all areas and at all depths. Human activities and behaviors respond in complex ways to environmental, management, societal and global changes. These dynamic human dimensions are fundamental components of the CCLME.

Beginning in 2010, the CCIEA team, made up of scientists from West Coast NOAA line offices and led by the Northwest and Southwest Fisheries Science Centers (NWFSC and SWFSC), began developing IEA tools and products for the CCLME, supported by funding from the national IEA program and leveraging other NOAA and external funds. Much of the effort in the first three capacity-building "phases" of the CCIEA focused on building relationships with our primary management partner, the Pacific Fishery Management Council (PFMC), and developing the research tools needed to complete the IEA loop, namely:

- screening ecosystem indicators of key processes and biota (Phase I)
- quantitative risk assessment methodology and case studies (Phases II and III)
- building ecosystem models to support management strategy evaluation (Phases I-III)

These efforts focused on the broad range of ecosystem components and processes:

- physical and climate drivers (Phases I-III)
- biomass and population condition of species (Phases I-III)
- community structure and functioning (Phases I-III)
- habitat availability and quality (Phase III)
- human activities (fisheries and non-fisheries) (Phases I-III)
- human wellbeing (Phases II-III)

These tools and efforts have helped support PFMC mandates of sustainable fisheries, healthy coastal communities, and low bycatch, as directed by the Magnuson-Stevens Act. However, uptake of CCIEA products has been a slow process, as the PFMC gradually embraces ecosystem management principles while also contending with an extremely heavy workload. Thus, effective communication and relationship building with the PFMC have been a central part of our efforts, in the form of regular interactions and reports, reviews of CCIEA products by the Scientific and Statistical Committee (SSC), and formation of an ecosystem work group to assist in scoping and indicator selection. Interest in CCIEA products has been further encouraged by unprecedented, largely negative ecosystem-scale changes in the past two years, such as historically high temperatures, low snow packs, hypoxic and acidification events, harmful algal blooms, shifts in fish species, and die-offs of marine mammals and seabirds.

As reinforced in the 2015 IEA-SC review of the CCIEA, we have an obligation to work with other management bodies and entities as well, such as states, the ONMS, and the West Coast Regional Office (WCRO). Moreover, we recognize that the funding and effort invested in IEA tool development must lead to integrated products that directly serve the explicit goals and objectives of these partners. This work plan is designed to develop such products to serve those users. It is an ambitious plan; however, we are a large and experienced team leveraged by considerable in-kind support from our line offices. Moreover, the past investments in the CCIEA leverage the future of our work and poise us to generate the cutting-edge, integrated tools and products we outline in our goals and activities below.

REGIONAL GOALS, OBJECTIVES, ACTIVITIES, AND DELIVERABLES:

PRIORITY GOAL #1: **Provide key end-users with management-relevant, fully integrated science products regarding the nature and importance of ecosystem variability in the California Current, at multiple spatiotemporal scales and social-ecological domains.**

Objective #1: *Continue working with the Pacific Fishery Management Council (PFMC) to develop and integrate science products that support EBFM and initiatives in the Fishery Ecosystem Plan (FEP).*

Strategies/Activities/Deliverables:

- Provide annual reports on the status and trends of physical, ecological, habitat, and socioeconomic indicators in the CCLME
- Work with the PFMC's Ecosystem Working Group and advisory bodies to scope key questions and issues, and tailor indicator reporting to PFMC needs
- Complete quantitative risk assessments of:
    - Groundfish to non-fisheries human activities
    - Essential fish habitat of multiple life history stages of 5 species (4 groundfish, 1 salmon) to a range of stressors
- Develop short-term forecasts of spatiotemporal distributions of finfish and shellfish stocks as driven by environmental conditions
    - Species: sardines, Dungeness crabs, Pacific hake
    - Conditions: circulation, temperature, chl-*a*, oxygen, etc.
- Incorporate key ecosystem indicators into the sablefish stock assessment
    - Examine correlations between physical drivers (CCIEA indicators) and sablefish recruitment, based on mechanistic hypotheses
    - Test sablefish assessment with environmental driver(s) included

Objective #2: *Provide the West Coast Regional Office (WCRO) Protected Resources Division (PRD) with integrated science products in support of ecosystem-based management of protected resources*

Strategies/Activities/Deliverables:

- Support dynamic ocean management (DOM) strategies to reduce bycatch of sea turtles, marine mammals and blue sharks in swordfish drift gillnet fishery while minimizing lost fishing opportunities and revenues
    - Develop spatial models that use physical indicators to predict highly migratory species (HMS) fishery catches and the likelihood of protected species presence in the Southern California Bight
    - Deliver daily bycatch risk maps to fishermen via web protocols and smart devices
- Complete DOM work on blue whale habitat projections, based on physical indicators and blue whale tagging data, for use in developing near real-time ship strike risk estimates

- Scope project development to assist WCRO with sea lion-endangered salmonid management issues in the Columbia River.
    - Identify data availability and data gaps related to developing spatiotemporal assessment of Lower Columbia system, including predator/prey distributions, abundances, and population dynamics
    - Develop scenarios for later modeling efforts, focusing on pinniped-prey interactions, pinniped-human interactions, and climate-driven changes to the system
- Developing Central Valley Salmon indicators
    - Collaborate with SWFSC staff to define the indices that best represent the management issues associated with California Central Valley listed salmon and water allocation issues

Objective #3: *Conduct a full IEA loop, with closed-loop management strategy evaluation (MSE), to develop estimates of baleen whale ship strike likelihoods under future climate conditions and shipping scenarios*

- Conduct scoping workshop to define management objectives and decision rules, scope of question (spatial domain, focal species), data availability, model capabilities, and future scenarios
- Conduct simulations of future baleen whale distributions based on climate, environmental conditions, prey distributions
- Update future scenarios of shipping based on expert elicitation of future regional and global shipping trends
- Conduct follow-up "gaming" workshop to evaluate future likelihood of ship strikes and other tradeoffs under different management strategy alternatives

Objective #4: *Provide the PFMC, WCRO, and other end users with ecosystem model outputs to evaluate management strategy alternatives and tradeoffs*

Strategies/Activities/Deliverables:

- Provide Atlantis ecosystem model output as part of a collaborative, multi-model inference effort to determine ecosystem role of forage fish and the management implications of declining sardine and anchovy populations
- Conduct Bayesian loop analysis simulations of the CCIEA conceptual models to qualitatively estimate how environmental and management changes affect species, human activities, and human wellbeing

PRIORITY GOAL #2: **Develop informed status assessments, risk analysis, and management strategies for West Coast National Marine Sanctuaries, and incorporate them into Sanctuary Condition Reports and management plans.**

Objective #1: *Identify and screen ecosystem indicators for inclusion in the Monterey Bay NMS Condition Report*

Strategies/Activities/Deliverables:

- *Indicator screening:* Complete quantitative, habitat-specific indicator selection and screening for population size and condition of biota, using CCIEA indicator screening methods. Indicators will be proxies for priority attributes identified in prior MBNMS plans and Condition Reports.
- *Implementation:* Incorporate indicators and related findings into updated MBNMS Condition Report

Objective #2: *Complete a cycle of the IEA loop in the Channel Islands NMS, with a focus on biodiversity and habitat questions outlined in prior Condition Reports*

Strategies/Activities/Deliverables:

- *Define goals and targets:* Based on prior CINMS management plans and Condition Report guidance documents.
- *Indicator selection:* Identify and assess indicators used in the development of other West Coast ecosystem status reports; screen candidate indicators using process developed in MBNMS (Objective #1); vet selected indicators through sanctuary Research Activities Panel and other experts
- *Data analysis:* Evaluate indicator status/trends with existing, accessible datasets; assess key data gaps
- *Reporting:* summarize status (good, fair, poor) and trends (increasing, neutral, declining); review by expert panel; finalize condition report
- *Risk Assessment/MSE:* assess biodiversity/habitat components with the weakest scores; assess associated stressors; develop management alternatives; assess impacts of "no action" vs management strategies to improve condition
- *Implementing:* incorporate recommendations into sanctuary management plan
- *Framework development:* engage other sanctuaries (regionally, nationally); identify and evaluate additional indicators that are relevant at multiple scales; update the ONMS Condition Report guidance document based on our findings

Objective #3: *Facilitate other integrated ecosystem research collaborations between Fisheries Science Centers and West Coast National Marine Sanctuaries to support Condition Reports, develop indicator time series and close data gaps*

Strategies/Activities/Deliverables:

- SWFSC scientists will contribute to Marine Biodiversity Observation Network (MBON) work in the MBNMS, including juvenile rockfish biodiversity and risk related to anomalous conditions and climate change
- NWFSC scientists will continue partnering with the OCNMS to do subtidal kelp forest survey work
- NWFSC and SWFSC scientists will provide analytical support for Condition Reports, including spatiotemporal analysis of indicator data inside and outside sanctuary boundaries, and risk assessments in Objective #2. NWFSC and SWFSC CCIEA scientists will also provide NMS with relevant research outputs and outreach tools outlined in Priority Goals #1, #3, #4, #5 and #6.

PRIORITY GOAL #3: **Develop robust metrics of human wellbeing, activities, risk, and vulnerability to changes in marine resource status, condition and management along the CCLME coast.**

Objective #1: *Continue development and application of indicators for human wellbeing (HWB)*

Strategies/Activities/Deliverables:

- Complete initial analyses of HWB indicators from the CCIEA Social Wellbeing Indicators for Marine Management (SWIMM) project; publish papers and reports on:
    - a conceptual framework for HWB indicator development and use in EBM
    - HWB indicator selection and evaluation in the CCIEA
    - the role of human behavior in the success and sustainability of marine resource management
    - the best available *social* science for resource management decision-making
- Assess the suite of highest-ranking indicators from the HWB indicator categories ("domains") screened thus far by SWIMM: resource access, self-determination, and job quality
- Relate SWIMM indicators to ecosystem drivers and management actions

Objective #2: *Develop and assess community social vulnerability indicators (CSVI) for coastal communities of the CCLME*

Strategies/Activities/Deliverables:

- Complete and publish initial analyses on CSVI development in the CCLME
- Conduct community-oriented fieldwork to ground-truth CSVI results
- Update CSVI database with 2010-2014 American Community Survey (ACS) data and with new sociodemographic data identified each year
- Compile results at scales of geographically appropriate polygons of data, including non-CDP (Census Dependent Place) fishing areas of socioeconomic and management importance
- Use CSVI results to assess if communities are vulnerable or resilient to climate-driven changes in federally managed target species, as projected by the NMFS climate change vulnerability assessments

Objective 3: *Develop frameworks to determine how fishery effort, participation and revenues respond to changes in environmental changes and fisheries management actions*

Strategies/Activities/Deliverables:

- Assess economic impacts of salmon troll fishery closure (2006-2008; federal disaster declaration) and decline in Dungeness crab fishery (2007-2008), and

develop a predictive analysis of the impacts of a possible closure of salmon troll fisheries and major decline of Dungeness crab fisheries in 2017-2018

- Develop assessment model to estimate drivers of Dungeness crab biomass and recruitment. (This will support subsequent modeling of physical drivers of Dungeness crab recruitment and fishery participation, in the next work plan.)
- Conduct a mail survey of West Coast fishermen to:
    - determine motivation for participation in state and federal fisheries
    - determine role of fisheries in overall household income
    - measure social capital
    - gather information on catch kept for personal use

Objective 4: *Assess economic impacts of drought and freshwater allocation on multiple sectors of water users in Central California*

Strategies/Activities/Deliverables:

- Estimate economic impacts of water supply policy in the San Joaquin Valley
- Develop error correction model of drought impacts on agricultural income, employment, and the local economy
- Evaluate policies of groundwater management in a multi-use system with managed flows for protected fish species

Objective 5: *Conduct spatial analysis of human activities indicators for use in place-based marine EBM*

Strategies/Activities/Deliverables:

- Generate spatiotemporal database and mapping tool of key human activity indicator time series (fishing effort, nutrient loading, inorganic pollution and commercial shipping) in the CCLME
- Analyze relationships between ecosystem indicators and human activity indicators at different spatial scales to determine proper spatiotemporal resolution for risk assessments and management actions

PRIORITY GOAL #4: **Provide key end-users with management-relevant, fully integrated science products regarding the nature and importance of long-term climate change in the California Current.**

Objective #1: *Develop quantitative risk assessments of both forage fish species and forage fish fisheries to climate change*

Strategies/Activities/Deliverables:

- Complete manuscript that evaluates the sensitivity and exposure of forage fish species to climate change, and the dependence of forage fish fleets on climate-sensitive species

Objective #2: *Assess climate change risk to CCLME fauna as a function of life history*

Strategies/Activities/Deliverables:

- Rank species risk to climate change based on outcomes from CCLME Climate Vulnerability Assessment (CVA)
- Examine how including life history characteristics improves our ability to assess species adaptability to climate change
- Compare outcomes from the CVA to outcomes from end-to-end ecosystem modeling to determine the benefits and tradeoffs of a rapid assessment vs. a more detailed approach in applications such as a Regional Action Plan

Objective #3: *Estimate impacts of ocean acidification (OA) on the CCLME through ecosystem modeling, management strategy evaluation and economic modeling*

Strategies/Activities/Deliverables:

- Generate fine-scale ROMS oceanographic model outputs that estimate future conditions of temperature, pH, nutrients, and circulation
- Using new ROMS output and literature reviews and risk assessments of OA impacts to key species and functional groups, use California Current Atlantis ecosystem model to estimate direct and indirect effects of OA on the CCLME food web, fisheries and management effectiveness
- Use Atlantis model, risk assessment outcomes, and input/output economic models to estimate OA impacts at the level of ports and fleets
- Revisit other climate MSE efforts in previous CCIEA reports to determine if new ROMS outputs (with OA included) change results

Objective #4: *Estimate socio-cultural risks posed by OA to coastal communities*

Strategies/Activities/Deliverables:

- Examine multiple case studies of OA-impacted fishery resources and impacted communities to build generalizable analyses and syntheses
- Prepare manuscript on OA and vulnerability of community wellbeing to OA-driven losses in affected species
- Integrate community wellbeing vulnerability assessment to other CCIEA components and risk assessments related to OA (e.g., commercial fisheries, coastal community vulnerability)

Objective #5: *Estimate the potential changes in CCLME habitats caused by climate change.*

Strategies/Activities/Deliverables:

- Using GIS data, determine maximum extent of CCLME estuaries and integrate with sea level rise estimates
- Integrate large spatial datasets on groundfish habitat types, life-stage specific habitat use, and climate-habitat stressors and calculate exposure parameters for multiple species, life stages, and stressors

- Process vertical profiles of temperature and DO from groundfish surveys to generate hotspot maps of high temperatures, hypoxia, and potential for OA

Objective #6: *Determine extent to which LMR distributions in the CCLME are changing spatiotemporally, and if those changes may be connected to climate change*

Strategies/Activities/Deliverables:

- Assess CCLME time series datasets that are amenable to analysis of spatiotemporal shifts
- Use analytical methods (developed previously for CCLME groundfish data) to determine if "centers of gravity" of populations or community compositions are shifting in space and time
- Examine correlations between spatiotemporal shifts and physical drivers to assess potential role of climate change vs. other drivers

PRIORITY GOAL #5: **Identify ecosystem reference points and early warning indicators in the CCLME using advanced statistical methods**

Objective #1: *Develop framework for quantifying ecosystem reference points and apply this framework to indicator time series for the CCLME*

Strategies/Activities/Deliverables:

- Complete the analytical framework (decision tree, statistical methods, etc.) for identifying threshold-type nonlinear relationships between natural and/or anthropogenic drivers and indicators of ecological integrity
    - Framework development begun in FY15, funded by CCIEA
- Apply findings to coastwide CCLME time series to determine the existence of reference points in the form of threshold-type nonlinear relationships
- Determine if reference points exist at particular spatial scales
- Present findings to PFMC, PRD, Sanctuaries, and other end users

Objective #2: *Develop a State Index and Early Warning Index, based on summaries of a large set of biological time series from the CCLME, that can be used as management tools to detect future ecological regime shifts*

Strategies/Activities/Deliverables:

- Convene two workshops, with NOAA, academic and NGO experts, to develop a State Index and an Early Warning Index
- Develop State Index to evaluate large changes in CCLME community state, as measured through ordination of collected time series (e.g. Dynamic Factor Analysis and Multivariate Autoregressive State-Space Models (MARSS)

- Develop Early Warning Index, using MARSS models, to track variability and autocorrelation in CCLME time series, as these indicators have a strong theoretical basis as leading indicators of regime shifts
- Present outcomes to PFMC SSC, PRD, Sanctuaries, and other end users.

PRIORITY GOAL #6: **Enhance CCIEA communication, coordination, data sharing, outreach, and transferability of products.**

Objective #1: *Improve CCIEA website and accessibility of web-based data and deliverables.*

Strategies/Activities/Deliverables:
- Revise flow, navigability and content of the CCIEA website
- Add interactive data interface so that users can view customized indicator plots and download data
- Develop custom indicator webpages for key end users (PFMC, etc.)

Objective #2: *Develop and improve visualization tools that illustrate California Current ecosystem status, trends, processes, relationships and responses*

Strategies/Activities/Deliverables:
- Post conceptual models on website, with links to related data and reports
- Generate fly-through visualizations of Atlantis model simulations using Jason Link et al.'s VES-V software
- Link CCIEA data to IOOS database to take advantage of IOOS spatial data presentations and visualizations

Objective #3: *Provide templates of products and tools to other IEA regions*

Strategies/Activities/Deliverables:
- Make presentations and provide files and code at National IEA face-to-face meetings, with focal areas to include:
    - Website
    - Conceptual models
    - Indicator screening framework
    - Ecosystem reference points analysis framework and code
    - Early Warning Index framework and code

Objective #4: *Build CCIEA contacts with other agencies, institutions, and regional/global science organizations and networks*

Strategies/Activities/Deliverables:
- Initiate interactions with other NOAA partners and state and federal agencies involved in issues relating to Central Valley (CA) salmon and water allocation

- Integrate CCIEA with ICES/PICES Climate Change Working Group (SICCME) to establish the CCIEA as a "modeling node" for simulating climate change effects on commercial fisheries and conducting climate change-based management strategy evaluations

Additional Methodological Information:

- *How will outcomes complete iteration of the IEA loop and/or advance IEA activities?*

Several of the projects represent complete IEA loops, e.g., Goal #2 Objective #2 for the Channel Islands NMS, and the final activity of Goal #1 Objective #2 for the baleen whale/ship strike/climate question. Many of the other projects are focused on the latter portions of the IEA loop (risk assessments and management strategy evaluation), or on advanced statistical methods to determine the need to develop goals and targets relative to ecosystem thresholds, and thus provide the basis for beginning new IEA loops with management partners. The work related to the PFMC is more focused on advancing IEA activities because the PFMC has many firmly established practices, and the process of incorporating our work into their decision-making is going to be gradual and likely mediated through initiatives introduced through the PFMC Fishery Ecosystem Plan. The outreach and communication component is intended to advance IEA activities by making CCIEA work more accessible and interactive, and thus increase the probability that they are used by managers, stakeholders or other researchers.

- *What scientific advancements are anticipated from this work plan that are likely transferrable to other regions?*

    - Human dimensions indicators and screening process
    - Sanctuary framework for supporting Condition Reports
    - Framework and code for ecosystem reference points and Early Warning Index
    - Risk assessment approaches to extend from LMRs to humans
    - Framework and code for tracking spatiotemporal shifts in population centers
    - Conceptual models and conceptual model loop analysis
    - Participation in ICES PICES climate change work group (SICCME)
    - Website update templates

- *How will human dimensions and climate change be incorporated into the work?*

Human dimensions and climate change are each the focus of targeted Priority Goals (#3 and #4, respectively) and are also explicitly addressed in most other Priority Goals.

- *Will this research transition into or inform actionable management decisions?*

Yes, most projects are intended to support actionable management decisions or to advance the science for future application to management decisions.

- *What management entities are engaged or will be engaged by this effort? How do you envision the work informing management decisions in your region? Are there specific*

pending management decisions that you aim to inform with this work?

The main management entities are the PFMC, the WCRO, and the ONMS.

We envision informing PFMC management through refining our indicators to better suit their needs, providing information on climate anomalies and variability that affect fish production, providing threat-based risk assessments of target species and habitats, developing short-term spatiotemporal forecasts of target species, adding ecosystem variables to the sablefish stock assessment, providing management strategy evaluation results and tradeoff assessments for major fisheries, providing initial assessments of ecosystem reference points, and providing indicators of the state and condition of fishery-dependent coastal communities as is relevant to Magnuson-Stevens National Standard 8.

We envision informing WCRO management by engaging in scoping exercises, providing indicators and analytical tools, and risk assessment or MSE analyses and tools to help estimate protected species risk (of bycatch, ship strike, etc.) under different conditions, and by helping to identify and quantify interactions between pairs of protected species (pinnipeds and salmon).

We envision informing ONMS management by refining Sanctuary Condition Reports using the IEA framework, and incorporating outcomes into Sanctuary management plans.

- *What steps will be taken to increase the probability that relevant management agencies make decisions informed by IEA products?*

We will continue to engage the PFMC, its advisory bodies and committees, and ad hoc groups in order to refine our products to meet PFMC needs and also to more effectively define key PFMC goals and objectives. We will work to have new CCIEA tools and products reviewed by the SSC to ensure they are technically sound. We will introduce a PFMC-specific indicators webpage and data portal. We will make use of conceptual models to better convey CCIEA outcomes.

We will engage the WCRO-PRD from the outset on protected species projects and seek their guidance for scoping workshop content, product implementation, and decision rules in management strategy evaluations, so that our work remains relevant to their key objectives.

The Sanctuaries goal includes specific vetting and engagement steps that involve the entire ONMS, and ultimately leads to updating ONMS guidance documents.

- *Identify and describe external drivers related to EBM and IEA in your region. How are you proposing to work with these external drivers to benefit the IEA?*

External drivers related to EBM and IEA in our region are primarily the extensive human use sectors outside of traditional NOAA focal activities (shipping, agriculture, water use, pollution, coastal development, energy development, recreation, etc.). More fully embracing broad suites of human activities and individual and community level wellbeing metrics enables us to consider a more holistic set of influences on behavior and complexities that influence the effectiveness of management and patterns of resource use. We are beginning to explore those other sectors and partner with external agencies and industries related to shipping, water use, and energy.

End-Users (e.g. recipients/ beneficiaries of regional IEA work and impact): The major end-users identified in this work plan are the Pacific Fishery Management Council (PFMC), the West Coast Regional Office (WCRO; in particular, the Protected Resources Division), and the west coast Sanctuaries. Documents of support from these entities are included in the appendix. We also anticipate other partnership opportunities with state agencies, universities, tribes, industry and stakeholder groups, NGOs and regional resource consortiums as well. Finally, many of the tools and products here will, we hope, be transferrable to other IEA regions or similar efforts.

Long-term Outcome(s): The focus of this workplan is integrated, synthesis projects toward the end of the IEA loop, which build on the tools and products that the CCIEA team has developed to date. This is consistent with our goal of making Phase IV of the CCIEA focused on integrative products. The plan represents evolution by the CCIEA in that it explicitly embraces scoping of goals and objectives than the prior phases, and does so with more partners (ONMS, WCRO). It also increases the communication and data accessibility to further strengthen partnerships.

Success: We will judge this effort to have been successful when we see tools we have developed in collaboration with management partners being applied to their decision-making, forecasting, weighing of tradeoffs. Anticipated benefits and impacts of our work include: better tools to understand and anticipate spatiotemporal patterns of environmental variability and change; a quicker and less uncertain path to EBFM by the PFMC; effective data synthesis tools and maps to facilitate analyses and place-based management; regular use of IEA tools and frameworks to anticipate tradeoffs and unforeseen consequences of actions; and a better understanding of how human dimensions are essential components to include in resource decision-making.

Leveraging: Our plan assumes that the regional partners will continue to receive $600K in base funds per year, along with the strategic funding requests. To be successful, the proposed plan will have to be heavily leveraged from other funding sources, just as the work to date has been leveraged. Our funds provide partial support for 2 FTEs and several associates, so the vast majority of research in this plan is leveraged by base NOAA funding (i.e., CCIEA research is built into FTE performance plans and supported by permanent funds) or external funds such as FATE grants, ecosystem modeling grant money from the NOAA Ocean Acidification Program, Social Indicators grants from the NMFS S&T Socioeconomics Program, NASA funds that support remote oceanographic work private foundation funds (e.g., Packard Foundation funds that support the Ocean Modeling Forum work on multi-model inference for forage fish).

COMMUNICATION AND OUTREACH

• *How does the program disseminate information to various partners and stakeholders?*
The communication and outreach plan is generally outlined in Priority Goal #6.

• *Explain how the program uses feedback from partners and stakeholders.*
We meet twice per year with PFMC advisory bodies and the SSC, and those meetings typically involve presentations, discussion, and technical review of CCIEA products. We are also producing 5 webinars on CCIEA indicators and risk assessment for PFMC advisory bodies in FY16 to further open channels of dialog and feedback.

Sanctuaries are well-equipped to communicate results to managers and stakeholders. Both CINMS and MBNMS have full-time education staff to help develop outreach products and share

findings. Staff have access to a number of public outreach forums and media elements including education centers, brochures, banners, public signage, social media, and digital kiosks to reach different stakeholder groups. These can be used to succinctly and intuitively share results with stakeholders so they understand the motives behind management decisions. Sanctuaries also have an effective and routine bridge to stakeholders through their sanctuary advisory councils, which can provide input on the IEA process and decision making from a broad range of sectors.

Finally, we will be holding regular meetings and workshops with WCRO staff and stakeholders to ensure we are constantly updated on their needs and objectives.

APPENDIX A: PRIORITY GOAL WORKPLAN TABLES

Priority Goal #1 Workplan

Activity (from above)	Key Tasks/Input/ Deliverable	Expected Completion Date	Responsible LO/ Partner (or Person)	Progress Reporting
Objective 1: Continue providing PFMC with science products that support EBFM				
Annual status and trends reports	▪ *Written & oral reports on indicator status and trends to PFMC and advisory bodies*	*FY16 Q2* *FY17 Q2* *FY18 Q2*	*SWFSC, NWFSC*	
Scoping and tailoring of indicators to PFMC needs	▪ *Custom list of PFMC-approved indicators for annual reports*	*FY17 Q2*	*SWFSC, NWFSC*	
Quantitative risk assessments	▪ *Groundfish risk to non-fisheries human activities* ▪ *Essential fish habitat risks for 5 species (all life history stages)*	*FY17 Q2* *FY16 Q3*	*NWFSC (Andrews)* *NWFSC (Greene)*	
Short-term forecasts of fish distributions	▪ *Sardine distribution forecasts* ▪ *Dungeness crab forecasts* ▪ *Pacific hake forecasts*	*FY16 Q3* *FY17 Q1* *FY18 Q4*	*NWFSC (Kaplan, Hunsicker)*	
Incorporate key ecosystem indicators into one or more stock assessments	▪ *Effects of physical drivers on sablefish recruitment* ▪ *Sablefish assessment with physical driver(s)*	*FY16 Q4* *FY17 Q2*	*NWFSC (Haltuch, Tolimieri)*	
Objective 2: Provide West Coast Region's Protected Resources Division with science products that support EBM				
Dynamic ocean mgmt to reduce protected species bycatch in drift gillnet fishery	▪ *Predictive model of loggerhead turtles* ▪ *Multispecies predictive model (turtles, mammals, sharks)* ▪ *Bycatch risk maps*	*FY16 Q4* *FY18 Q2* *FY18 Q2*	*SWFSC (Hazen, Bograd)*	
Dynamic ocean mgmt to reduce blue whale ship strikes	▪ *Predictive model of blue whale habitat and near-real time projections of ship strike risk*	*FY16 Q4*	*SWFSC (Hazen, Bograd)*	
Integrated science on Lower Columbia sea lions	▪ *Initial scoping meeting* ▪ *Data/gap analysis and scenario development*	*FY17 Q4* *FY18 Q4*	*NMML (Melin)*	
Central Valley Salmon indicators	▪ *Define relevant indices for Central Valley salmon and water management*	*FY17 Q4*	*SWFSC (Wells)*	
Objective 3: IEA loop on baleen whale ship strike probabilities under future conditions				
Complete IEA loop	▪ *Scoping workshop* ▪ *Future whale/prey distributions* ▪ *Future shipping scenarios* ▪ *Gaming MSE workshop* ▪ *Report/manuscript on outcomes*	*FY17 Q2* *FY18 Q1* *FY18 Q1* *FY18 Q2* *FY18 Q4*	*SWFSC, NWFSC, NMML, ONMS*	
Objective 4: Provide ecosystem model outputs to evaluate management strategies and tradeoffs				
Multi-model inference of ecosystem roles of forage fish	▪ *Atlantis simulations of the role of forage fish* ▪ *Multi-model comparisons*	*FY16 Q3* *FY16 Q3*	*NWFSC (Kaplan)*	
Loop analysis of conceptual models	▪ *Methodology and case study of CCLME pelagic food web* ▪ *Analysis of all conceptual models, decoupled and coupled*	*FY16 Q2* *FY17 Q3*	*NWFSC (Harvey)* *NWFSC, SWFSC*	

Priority Goal #2 Workplan

Activity (from above)	Key Tasks/Input/ Deliverable	Expected Completion Date	Responsible LO/ Partner (or Person)	Progress Reporting
Objective #1: Identify and screen ecosystem indicators for MBNMS Condition Report				
Indicator screening	▪ *IEA report on detailed methods, results, interpretation* ▪ *Publication in peer reviewed journal*	*FY16 Q3* *FY17 Q1*	*MBNMS, NWFSC (Brown, Williams)*	
Implementation	▪ *Incorporate into updated MBNMS Condition Report*	*FY16 Q2*	*MBNMS (Brown)*	
Objective #2: Complete a cycle of the IEA loop in West Coast Sanctuaries				
Define goals	▪ *List of goals*	*FY16 Q3*	*CINMS*	
Indicator selection	▪ *List of potential indicators* ▪ *List of vetted indicators*	*FY16 Q3* *FY16 Q4*	*CINMS, SWFSC, NWFSC*	
Data analysis	▪ *Status and trend plots, stats* ▪ *List of data gaps*	*FY16 Q4* *FY16 Q4*	*CINMS, SWFSC, NWFSC*	
Reporting	▪ *Scoring* ▪ *Condition Report update*	*FY17 Q1* *FY17 Q3*	*CINMS, SWFSC, NWFSC*	
Risk Assessment and MSE	▪ *Risk assessment* ▪ *Identify mgmt alternatives* ▪ *Scenario analysis*	*FY17 Q2* *FY17 Q3* *FY18 Q2*	*CINMS, SWFSC, NWFSC*	
Implementing	▪ *Incorporate into sanctuary mgmt plans*	*FY18 Q4*	*CINMS, SWFSC, NWFSC*	
Framework development	▪ *Engagement* ▪ *ONMS CR guidance doc*	*FY18 Q3* *FY19 Q2*	*CINMS, SWFSC, NWFSC*	
Objective #3: Facilitate research collaborations between Sanctuaries and Science Centers				
Research support	▪ *MBON collaboration* ▪ *Kelp forest surveys*	*ongoing* *ongoing*	*SWFSC* *NWFSC*	
Support on Objective #2	▪ *Risk assessments* ▪ *Indicator analyses* ▪ *Other Work Plan products*	*FY17 Q2* *FY18 Q4* *(see other tables)*	*SWFSC, NWFSC*	

Priority Goal #3 Workplan

Activity (from above)	Key Tasks/Input/ Deliverable	Expected Completion Date	Responsible LO/ Partner (or Person)	Progress Reporting
Objective #1: Develop and apply human wellbeing (HWB) indicators				
Complete initial phase of SWIMM project	▪ *framework for HWB indicators in EBM* ▪ *HWB indicator selection and evaluation in CCLME* ▪ *the role of human behavior in resource management* ▪ *best available social science*	*FY16 Q3* *FY17 Q1* *FY16 Q4* *FY17 Q3*	*NWFSC (Levin)*	

Activity (from above)	Key Tasks/Input/ Deliverable	Expected Completion Date	Responsible LO/ Partner (or Person)	Progress Reporting
SWIMM indicator assessment and application	▪ *Assess highest-ranking SWIMM indicators* ▪ *Relate assessed SWIMM indicators to indicators of ecosystem drivers and management*	*FY17 Q3* *FY18 Q3*	*Sea Grant/NWFSC (Poe)*	
Objective #2: Community social vulnerability indices (CSVI) in the CCLME				
Complete and publish initial CCLME CSVI analyses	▪ *NOAA tech memo on CSVI methods and results* ▪ *Paper on role of CSVI in interdisciplinary research* ▪ *Paper on the CCLME CSVI case study*	*FY17 Q2* *FY16 Q4* *FY17 Q4*	*NWFSC (Norman)*	
Ground-truth	▪ *Field surveys to ground-truth prior mail-based results*	*FY16 Q3*	*NWFSC (Norman, Poe)*	
Update with new data and compile at appropriate spatial scales	▪ *Revise indicators* ▪ *Compare results from CDP and non-CDP scaling* ▪ *Develop and refine time series to assess CSVI trends*	*FY16-FY18* *FY16-FY18* *FY16-FY18*	*NWFSC (Norman)*	
CSVI-Climate analysis	▪ *Estimate community resilience or vulnerability to climate change effects on target spp.*	*FY18 Q4*	*NWFSC (Samhouri, Fuller, Norman, Holland)*	
Objective #3: Fishery effort, participation, economics as functions of ecosystem dynamics				
Assess impacts of salmon and crab fishery declines	▪ *Analysis of recent closure of salmon and decline in crab* ▪ *Predictive analysis of future closure in salmon and decline in crab*	*FY17 Q3* *FY17 Q3*	*NWFSC (Holland, Richerson)*	
Assessment modeling of Dungeness crab	▪ *Crab biomass and recruitment assessment*	*FY17 Q3*	*NWFSC (Holland, Richerson)*	
Survey of fishery participation	▪ *Mail survey of fishermen*	*FY18 Q3*	*NWFSC (Holland, Norman, Poe)*	
Objective #4: Assess economic impacts of drought and water allocation in Central California				
Policy analyses	▪ *Economic impacts of water supply policy, San Joaquin Valley* ▪ *Evaluate groundwater mgmt policies in multi-use system*	*FY17 Q3* *FY16 Q4*	*SWFSC (Speir, Mamula)*	
Modeling	▪ *Model of drought impacts on agriculture income, jobs, economies*	*FY18 Q4*	*SWFSC (Speir, Mamula)*	
Objective #5: Spatial analysis of human activities indicators				
Data management	▪ *Build spatiotemporal database and mapping interface for key activity indicators*	*FY17 Q4*	*NWFSC (Andrews)*	
Analysis	▪ *Analyze relationships between activities and other indicators at different spatial scales* ▪ *Estimate effects of energy extraction on protected salmon habitat*	*FY18 Q2* *FY17 Q3*	*NWFSC (Andrews)* *SWFSC (Mamula)*	

Priority Goal #4 Workplan

Activity (from above)	Key Tasks/Input/ Deliverable	Expected Completion Date	Responsible LO/ Partner (or Person)	Progress Reporting
Risk assessment of forage fish and fisheries	▪ *Paper on climate change risk of forage fish and dependent fisheries*	*FY16 Q3*	*NWFSC (Samhouri)*	
Assess climate change risk as a function of life history	▪ *Rank species risk based on CVA* ▪ *Incorporate life histories into CVA analysis* ▪ *Compare CVA outcomes to end-to-end model outcomes*	*FY16 Q4* *FY17 Q3* *FY18 Q1*	*SWFSC, NWFSC (Hazen, Bograd, Haltuch)*	
Ecosystem modeling of ocean acidification impacts	▪ *New ROMS outputs* ▪ *Atlantis simulations of direct and indirect OA effects* ▪ *Analysis of port- and fleet-level OA impacts* ▪ *Revisit past CCIEA MSEs using new ROMS projections*	*FY16 Q2* *FY17 Q3* *FY17 Q3* *FY17 Q3*	*NWFSC (Kaplan, Marshall)*	
Socio-cultural risks of OA	▪ *Examine case studies and synthesize data* ▪ *Publish case studies manuscript* ▪ *Integrate with related CCIEA risk assessments (fisheries, community vulnerability)*	*FY16 Q4* *FY17 Q4* *FY18 Q4*	*NWFSC (Levin, Poe, Norman)*	
Potential changes in CCLME habitats caused by climate change	▪ *Estimate loss of estuarine habitat to sea level rise* ▪ *Calculate habitat-specific exposure to climate stress for groundfish life history stages* ▪ *Generate maps of temperature, DO and OA stress*	*FY16 Q3* *FY16 Q3* *FY16 Q3*	*NWFSC (Greene)*	
Examine spatiotemporal shifts in species distributions and communities	▪ *Assess CCLME time series* ▪ *Conduct workshop to analyze data and examine correlations*	*FY17 Q3* *FY18 Q2*	*NWFSC, SWFSC* *NWFSC (Thorson)*	

Priority Goal #5 Workplan

Activity (from above)	Key Tasks/Input/ Deliverable	Expected Completion Date	Responsible LO/ Partner (or Person)	Progress Reporting
Objective 1: Develop framework for quantifying ecosystem reference points and apply to CCLME				
Complete the analytical framework	▪ *Monthly working group meetings and write-ups*	*FY16 Q4*	*NWFSC, SWFSC (Samhouri, Andrews, Hazen)*	
Apply framework to CCLME time series	▪ *Paper on reference points at the scale of the CCLME* ▪ *Paper on reference points for rockfish recruitment* ▪ *Paper on reference points at regional spatial scales*	*FY16 Q4* *FY17 Q2* *FY18 Q1*	*NWFSC, SWFSC (Samhouri, Andrews, Hazen, Thompson)*	
Present findings to end-users	▪ *Include findings in PFMC reports* ▪ *Report relevant findings to WCRO, ONMS* ▪ *Post findings on CCIEA website*	*FY16-18* *FY16-18* *FY16-18*	*NWFSC, SWFSC*	
Objective 2: Develop framework for quantifying leading "early warning" indicators of regime change				
Convene expert workshops to develop indices and conduct analyses	▪ *Hold workshops* ▪ *Produce R scripts for analyses and plotting* ▪ *White paper and peer reviewed paper on indices* ▪ *Presentations to key end users*	*FY18 Q2* *FY18 Q2* *FY18 Q4* *FY18 Q4*	*NWFSC (Hunsicker)*	

Priority Goal #6 Workplan

Activity (from above)	Key Tasks/Input/ Deliverable	Expected Completion Date	Responsible LO/ Partner (or Person)	Progress Reporting
Improve website, access to products	▪ *Revise content, flow* ▪ *Add data interface* ▪ *Custom indicator webpages*	*FY16 Q2* *FY16 Q2* *FY17 Q3*	*SWFSC, NWFSC*	
Visualization tools	▪ *Online conceptual models* ▪ *Visualizations of Atlantis model simulations in VES-V* ▪ *CCIEA data to IOOS*	*FY16 Q3* *FY18 Q1* *FY17 Q4*	*SWFSC, NWFSC* *NWFSC (Kaplan)* *SWFSC (DeWitt)*	
CCIEA product sharing with other IEA regions	▪ *Provide templates, frameworks and code to other regions*	*Future IEA F2F meetings*	*SWFSC, NWFSC*	
Build contacts with other agencies, organizations	▪ *Initiate interactions with agencies involved in Central Valley salmon and water use* ▪ *Integrate with SICCME*	*FY17* *FY16-FY18*	*SWFSC, NWFSC* *NWFSC (Kaplan)*	

APPENDIX B: PAST ACCOMPLISHMENTS/ PROGRESS

What are the biggest prior IEA accomplishments in your region? How do these accomplishments position you to be able to complete the proposed IEA objectives and activities?

Our major organizational and research accomplishments include:

- Maintain a team of ~50 multidisciplinary scientists that meet regularly
- Excellent partnership between the two Fishery Science Centers and the Regional Office, and growing partnership with the Sanctuaries
- Significant leveraging of NOAA and external funds to expand the reach of the CCIEA
- Phase I-III reports online and available through the IEA web page: http://www.noaa.gov/iea/pdf/CCIEA-Report/index
- Human Dimensions added as a new section
- We are developing a live, web-based presentation of indices
- Over 100 citations credited to CCIEA scientists
- Screening of hundreds of metrics to identify most robust ecosystem indicators
- Led regional workshop on ecosystem reference points
- Developed a highly regarded series of conceptual models for communication, organization and simulation testing
- The CCIEA underwent the first national IEA regional review

Our major management successes include:

- CCIEA findings on oceanographic variability, climate change effects, and anthropogenic pressures were incorporated into 2013 PFMC Fishery Ecosystem Plan (FEP)
- Provide annual "state of the ecosystem" report to the PFMC (2012-present)
- CCIEA results used to characterize California Current Ecosystem in the PFMC's 2014 Groundfish fishery Draft Environmental Impact Statement
- CCIEA products used in ESA Section 7 consultation on the risk of ESA-listed species to suffer incidental mortality in the West Coast groundfish fishery
- California Current Atlantis model and "state of the ecosystem" reports reviewed by PFMC SSC (2014-2015)
- March 2015: PFMC approves initiative to form ad hoc Ecosystem Work Group to work with the CCIEA team to develop PFMC-specific list of indicators
- September 2015: PFMC requests that CCIEA team work with stock assessment scientists to incorporate environmental variables into sablefish stock assessment
- State of Washington enlists CCIEA scientists to develop conceptual models and indicators for marine spatial planning in Washington coastal waters (2013-2015)
- European Union: Management Strategy Framework Directive (MSFD) is passed to protect biodiversity in European waters; indicator evaluation method adopted to support MSFD is the CCIEA indicator screening method

- Continued support of Puget Sound Partnership (the original "pilot IEA") in Washington State, including writing a chapter on indicator-attribute relationships in the 2011 *Science Update* and plans to develop Atlantis ecosystem model based on CCIEA Atlantis model

These achievements have given us the basic tools, research frameworks, disciplinary expertise, and communication networks needed to complete and apply the research described here.

Has the IEA been successful in informing management decisions by NOAA or external management agencies? Please explain.

As implied by the management successes above, we have been successful in informing managers and "the management process," but we remain at a place where it is difficult to identify specific management decisions that stem from our work. The work plan described here continues to evolve our relationship with managers so that we engage with them from the outset and can provide more effective tools and products to suit their needs. It also demonstrates the continued evolution of our approaches so that our products and tools will be more desirable for broad management purposes.

What impact or benefit has been achieved (qualitative and/ or quantitative)?

The request by the PFMC for the formal arrangement of an Ecosystem Work Group to partner with the CCIEA team to refine the indicators presented in the state of the ecosystem report, the twice-annual meetings we have with the PFMC SSC, and the formal request to assist on the development of an ecosystem-based sablefish stock assessment reflect a growing level of trust and interaction between the PFMC and the CCIEA.

The outreach by the West Coast Sanctuaries to work closely with the CCIEA in the improvement of Condition Reports reflects increased support and coordination across NOAA line offices.

The adoption of CCIEA indicator screening methods and conceptual modeling methods by the State of Washington and the European Union reflect the reach that CCIEA research has achieved.