

Beyond the Golden Gate Research Symposium 2011



Host Institutions

*Cordell Bank National Marine Sanctuary
Gulf of the Farallones National Marine Sanctuary
Point Reyes National Seashore
San Francisco Bay National Estuarine Research Reserve
University of California, Bodega Marine Laboratory*

Sponsors

*Cordell Marine Sanctuary Foundation
Farallones Marine Sanctuary Association*



BEYOND THE GOLDEN GATE RESEARCH SYMPOSIUM

A symposium focused on the oceanography, geology, and ecology of the Gulf of the Farallones and adjacent waters between Point Arena and Point Año Nuevo – including Cordell Bank, Point Reyes and outer San Francisco Bay

**San Francisco, CA
1 November 2011**

Preface

Cordell Bank National Marine Sanctuary (CBNMS), Gulf of the Farallones National Marine Sanctuary (GFNMS), Point Reyes National Seashore (PRNS), San Francisco Bay National Estuarine Research Reserve (SFBNERR), and University of California - Bodega Marine Laboratory (BML) are pleased to convene a multidisciplinary symposium on research in the Gulf of the Farallones and adjacent waters between Point Arena and Point Año Nuevo – including Cordell Bank, Point Reyes, and outer San Francisco Bay. After a seven year hiatus since our last regional research symposium, we are excited to provide this forum for researchers to collaborate and exchange information about their current and new projects within the region. Within the symposium you will hear about the need for increased data and information on marine resource management, including climate change impacts and indicators, restoration and mitigation activities, defining and identifying ecological hotspots, oceanographic patterns, the integration of biological and physical observations, habitat characterization, and the importance of long-term monitoring of our marine and estuarine habitats and species. Our goal is to increase our understanding and protection of coastal ocean ecosystems, as well as to increase people's awareness of our marine and estuarine resources, because it is this understanding that will best guide wise management of the environment.

Abstract requests were sent to the community of researchers and marine educators, private organizations, schools, and public agencies known to be investigating or educating the public about the ecosystem within the region. This year we received 69 abstracts from a broad range of disciplines: 2 on geography and mapping, 20 on the ecology of various habitats, 11 pertaining to oceanographic processing and influences on productivity, 4 on geology, sediment and marine debris transport, and coastal erosion, 6 on predator-prey relationships, 5 dealing with planning for climate change impacts, 6 population assessments, and 15 projects pertaining to resource management issues, pressures, status and trends. The symposium is an opportunity for local managers, researchers, and educators to meet people working in other disciplines and to increase communication and collaboration between researchers, managers, policy makers, and the public.

The abstracts in these Proceedings, include projects recently completed, in-progress reports, and projects planned to begin in the near future. We hope that you use this forum to critique and contribute to each other's work, as well as to develop new collaborations. Several investigators were not able to attend the workshop but their abstracts are included in the Proceedings.

This year the Gulf of the Farallones National Marine Sanctuary celebrates 30-years of protecting our ocean wilderness just beyond the Golden Gate, while Cordell Bank National Marine Sanctuary returned its "roots" to re-discover the Bank with divers. Point Reyes National Seashore is celebrating its 50th anniversary in 2012 and has ongoing commitment to marine science, conservation, and education. San Francisco Bay National Estuarine Research Reserve is one of 28 estuarine research reserves in the nation and protects two of the most pristine marshes in the Bay. Bodega Marine Laboratory continues to strengthen research interests in this region, integrating across disciplines and combining discovery with formal education opportunities through degree programs. The protection of our ocean-based natural and cultural resources will be diminished without the research represented in these Proceedings. The data and information produced through these research and monitoring projects are vital to the continued wise management of the bay, coastal and pelagic sanctuaries, parks, and reserves. Sustaining research and monitoring activities is increasingly difficult, with recent funding cuts. However, through collaborations, such as those embodied in this symposium, research and monitoring projects will continue.

We thank our colleagues at CBNMS, GFNMS, PRNS, SFBNERR, and BML, as well as the Farallones Marine Sanctuary Association and Cordell Marine Sanctuary Foundation for funding and in-kind assistance to produce this symposium.

Ben Becker
Point Reyes National Seashore

Dan Howard
Cordell Bank National Marine Sanctuary

John Largier
University of California Davis,
Bodega Marine Laboratory

Marina Psaros
San Francisco Bay National Estuarine
Research Reserve

Jan Roletto
Gulf of the Farallones National Marine Sanctuary

If you did not receive an announcement of the workshop and wish to be added to the GFNMS research mailing list or if you have comments on this our future research symposia, please submit written request and suggestions to Jan Roletto, GFNMS, 991 Marine Dr., The Presidio, San Francisco, CA, 94129.

The Proceedings and PDFs of the presentations are available on the symposium web site at:
<http://www.sfbaynerr.org/ctp/beyondthegoldengate/>

Program

- 0800-0900 Morning Reception and One-on-One Exchange of Introductions and Ideas
- 0900-0910 Welcome and Introductory Remarks – **John Largier**

Session 1. Environmental Change, Moderator – Ben Becker

- 0910-0917 Inter-annual and Decadal Variability of Coastal Upwelling off Bodega Bay, California
Marisol García-Reyes and John L. Largier
- 0918-0925 Copepod Assemblages as Indicators of Ocean Conditions in Central California
Meredith L. Elliott, Jaime Jahncke, Moira Galbraith, and Dave Mackas
- 0926-0933 Spatial Ecology of Marine Nekton: Implications for Defining Important Ecological Areas in the Central California Current
Jarrold A. Santora, John C. Field, William J. Sydeman, Isaac D. Schroeder, and Brian Wells
- 0934-0941 Why Long Term Intertidal Monitoring Matters
Daniel Orr, Christy Bell, Dave Lohse, and Pete Raimondi
- 0942-0949 Population Viability of Cassin's Auklets on the Farallon Islands in Relation to Environmental Variability and Management Actions
Nadav Nur, Derek E. Lee, Russell W. Bradley, Peter M. Warzybok, and Jaime Jahncke
- 0950-0957 The Challenge of Seabird Restoration in a Warming World
Russell W. Bradley, Pete Warzybok, Gerard J. McChesney, and Jaime Jahncke
- 0958-1005 Conservation of Forage Fish in California Current: An Ecosystem Assessment
Julie Thayer, William Sydeman, Anna Weinstein, John Field, and Alec MacCall
- 1006-1013 Climate Change Effects on Species Interactions
Sarah Gravem and Steven Morgan
- 1014-1021 Coralline Algal Turf Communities in Northern California: Community Structure and Potential as a Bioindicator of Local Seawater Carbonate Saturation State
Linden Schneider, Thomas Nguyen, and Karina Nielsen
- 1022-1029 Developing a Set of Linked Environmental and Biological Climate Change Indicators for the North-central California Coast
Benét Duncan, Kelley Higgason, Tom Suchanek, John Stachowicz, and Dan Cayan
- 1030-1050 Break

Session 2. Oceanography & Lower Trophic Levels, Moderator – Marina Psaros

- 1050-1057 Interactions of San Francisco Bay Outflow with Coastal Upwelling
John L. Largier
- 1058-1105 Geomorphic Changes, Anthropogenic Influences, and Coastal Management Challenges Beyond the Golden Gate
Patrick L. Barnard, Li H. Erikson, Jeff E. Hansen, and Kate L. Dallas
- 1106-1113 Benthic Infauna and Sediment Patterns in the Nearshore Gulf of the Farallones
Michael G. Kellogg
- 1114-1121 Coastal Oceanographic Fronts within the Gulf of the Farallones-Cordell Bank Region: Patterns, Predictability, and Biological Importance
Rachel E. Fontana, J. Jahncke, and J. L. Largier
- 1122-1129 Point Reyes Shoreline Plastic Pollution Assessment
Christopher Pincetich
- 1130-1137 Comparison of a Wind-driven Mixed Layer Conveyor Model with Observations of Fluorescence and Nitrate from a Mooring
Louis W. Botsford, Matt Holland, John Largier, Ed Dever, and Alan Hastings
- 11-38-1145 An Abundance of Nearshore Phytoplankton: What Drives Formation and Oscillations of the 'Green Ribbon' Over Short Time Scales?
Adele Paquin, Karina Nielsen, and John Largier
- 1146-1153 Nutrient and Phytoplankton Distributions in the Gulf of the Farallones
Frances Wilkerson, Richard Dugdale, Al Marchi, Alex Parker and Jim Fuller
- 1154-1201 What's Going on "Out There"? Results and Applications of the Applied California Current Ecosystem Studies (ACCESS)
Kaitlin Graiff, Jaime Jahncke, Jan Roletto, Meredith Elliott, and Julie Howar
- 1202-1209 Developing the Applied California Current Ecosystem Studies (ACCESS) into an Ecosystem-Based Management (EBM) Network Project
Jaime Jahncke, Meredith Elliott, Dan Robinette, Kaitlin Graiff, and Jan Roletto
- 1210-1320 Lunch Provided in the Ventana Room and Poster Review in the Hawthorn
1225-1240 Sanctuary Integrated Monitoring Network (SIMoN) Demonstration (*in Ventana Room*)
Steve Lonhart

Session 3. Marine Populations & Upper Trophic Levels, Moderator – Jan Roletto

- 1320-1327 Ocean Diet Cycle of Adult Chinook Salmon in the Gulf of the Farallones
Peter Adams, Wayne Samiere, and Constance Ryan
- 1328-1335 Changes in Breeding Population Sizes of the Brandt's Cormorants in the Gulf of the Farallones, California, 1979-2010
Phillip J. Capitolo, Gerald J. McChesney, Harry R. Carter, Michael W. Parker, Lisa E. Eigner, Sandra J. Rhoades, and Richard T. Golightly
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- 1336-1343 Anthropogenic Disturbance Affecting Common Murre Colonies in Central California
Lisa E. Eigner, Gerald J. McChesney, Richard T. Golightly, Sandra J. Rhoades, and Sage Tezak
- 1344-1351 Recovery of the Common Murre (*Uria aalge*) in Central California
Gerard J. McChesney, Harry R. Carter, Michael W. Parker, Richard T. Golightly, Phillip J. Capitolo, Lisa E. Eigner, Sandra J. Rhoades, and Stephen W. Kress
- 1352-1359 Impacts of House Mice on Breeding Seabirds and Endemic Species of the South Farallon Islands, and a Proposed Invasive Mouse Removal Project
Daniel J. Grout, Russ Bradley, and Gerry McChesney
- 1400-1407 Leptospirosis in California Sea Lions – Challenging the Dogma?
Katherine Prager, Denise Greig, Colleen Duncan, Jennifer Soper, Richard Zuerner, Frances Gulland, and James Lloyd-Smith
- 1408-1415 Assessing Potential Resource Utilization by Gray Whales in the Gulf of the Farallones National Marine Sanctuary Waters
Paul Jones and Allan Ota
- 1416-1423 Harbor Porpoises in San Francisco Bay: A Report on Research in Progress
Jonathan Stern, William Keener, Isidore Szczepaniak and Marc Webber
- 1424-1431 Long-term Individual Identification and Site Fidelity of Great White Sharks, *Carcharodon carcharias*, Off California Using Dorsal Fins
Scot D Anderson, Taylor K Chapple, Salvador J Jorgensen, A. Peter Klimley, and Barbara A Block
- 1432-1439 Where the Whales are: Using Habitat Modeling to Inform Marine Spatial Planning in Cordell Bank and Gulf of the Farallones National Marine Sanctuary.
Andrea Dransfield, Ellen Hines, and Jaime Jahncke
- 1440-1500 Break

Session 4. MPAs, Nearshore & Benthic Environments, Moderator – Maria Brown

- 1500-1507 Baseline Breeding and Foraging Distributions of Three Coastally Breeding Seabirds within the North Coast Study Region of the Marine Life Protection Act Initiative
Dan P. Robinette, Gerry McChesney, Sara Acosta, and Jaime Jahncke
- 1508-1515 Monitoring Human Uses and Values along the North Central Coast of California
Astrid J. Scholz, Chris L. LaFranchi, and Charles Steinbeck
- 1515-1523 What Are They Doing Out There? Baseline Characterization of the North Central California Coast Marine Protected Areas
James Lindholm, Dirk Rosen, and Donna Kline
- 1524-1531 Oceanographic Effects on Yellowtail and Chilipepper Rockfish Condition and Productivity at Cordell Bank
Sabrina Beyer, Susan Sogard, John Field, and Chris Harvey
- 1532-1539 The First *In Situ* Observations of Deep-sea Corals and Sponges on the Continental Slope West of Cordell Bank
Kaitlin Graiff, Dale Roberts, and Dan Howard

- 1540-1547 Larval Advection and Behavioral Control Regulating Population Connectivity in Upwelling Regions: Implications for the Adaptive Management of our Network of Marine Protected Areas.
Steven G. Morgan
- 1548-1555 Baseline Characterization and Monitoring of Sandy Beaches in California's North Central MPAs
Karina J. Nielsen, Steven Morgan, and Jenifer Dugan
- 1556-1603 Do Macrophyte Wrack Species Composition and Input Rates Influence the Distribution and Abundance of Talitrid Amphipod (*Megalorchestia* spp.) Populations on Northern California Beaches?
Preston D. Malm and Karina J. Nielsen
- 1604-1611 Gulf of the Farallones Beach Watch Program: Informing Natural Resource Damage Assessment in the San Francisco Bay Area's Outer Coast
Kirsten Lindquist and Jan Roletto
- 1612-1619 Variation in Blade Morphology Ameliorates Emersion Stress and Photosynthetic Performance of the Intertidal Kelp *Saccharina sessilis*
Jill A. Stokes and Karina J. Nielsen
- 1620-1630 Closing Remarks – **John Largier**
- 1630-1730 ***Poster & Reception in the Hawthorn Room***

Poster Group 1. Environmental Change

Our Coast—Our Future: Planning for Sea Level Rise and Storm Hazards Along the Bay Area's Outer Coast

Patrick L. Barnard, Kelley Higgason, Grant Ballard, Li H. Erikson, and Sam Veloz

OMEGAS: A Large-scale Approach to Studying the Effects of Ocean Acidification on Calcifying Organisms in Intertidal and Nearshore Habitats

R. Williams, C. DaCosta, M. Redfield, E. Sanford, B. Gaylord, T.M. Hill, A.D. Russel, P.T. Raimondi, B. A. Menge

Poster Group 2. Oceanography & Lower Trophic Levels

The Influence of Nutrients from the Gulf of the Farallones on Drakes Estero

Christina Buck, Frances Wilkerson, John Largier, Alex Parker

A Broad Range of Intra-species Diversity in Introduced Copepods in the San Francisco Estuary

Carrie Craig, Wim Kimmerer, and C. Sarah Cohen

Aquatic Microbial Nitrogen Cycling: Planktonic Ammonia Oxidation in San Francisco Bay

Julian Damashek and Christopher A. Francis

Oceanic Near-Coastal Frontal Mapping, Northern California
Matt Gough, Jeffrey Paduan, Chris Halle, and John Largier

Surface Water Pathways From Cape Mendocino to the Golden Gate
Chris Halle and John Largier

Central Bay Sand Resource and the Golden Gate
Barry Keller and Mike Bishop

Poster Group 3. Marine Populations & Upper Trophic Levels

Diet Comparisons of Brandt's Cormorant (*Phalacrocorax penicillatus*) at Alcatraz Island in the San Francisco Bay and Southeast Farallon Islands in the Gulf of the Farallones
Sara Acosta, Meredith L. Elliott, Jason Yakich, Russ Bradley, Pete Warzybok, and Jaime Jahncke

Large-scale movements and high-use areas of western Pacific leatherback turtles, (*Dermochelys coriacea*)
Scott R. Benson, Tomoharu Eguchi, Dave G. Foley, Karin A. Forney, Helen Bailey, Creusa Hitipeuw, Betuel P. Samber, Ricardo F. Tapilatu, Vagi Rei, Peter Ramohia, John Pita, and Peter H. Dutton

Developing a Method to Quantify Jellies, Prey of the Critically Endangered Leatherback Turtle, *Dermochelys coriacea*
Erin E. Frolli, Lisa A. Webb, Scott R. Benson

Spatial Distribution of Blue and Humpback Whales Relative to San Francisco, California Shipping Lanes and Vessel Traffic
C. A. Keiper, J. Calambokidis, G. Ford, J. Casey, C. Miller, and T. Kieckhefer

Seabird Hot Spots in Central California's National Marine Sanctuaries and their Implications for Oil Spill Response Preparedness and Marine Spatial Planning
Jennifer McGowan, Ellen Hines, and Jaime Jahncke

Hair Concentrations of Mercury and Selenium in Pacific harbor seals (*Phoca vitulina richardii*) off Central California
Elizabeth A. McHuron, James T. Harvey, and Todd M. O'Hara

Modeling the Dispersion and Habitat Associations of Black-footed Albatross in Central California National Marine Sanctuaries
Pamela E. Michael, Jaime Jahncke, and K. David Hyrenbach

Pilot Study of Pigeon Guillemot (*Cepphus columba*) Breeding Colony at Point Reyes
Sandra J. Rhoades, Corey Shake, Gerard J. McChesney, Lisa E. Eigner, Ben Becker, Sarah Allen, and Richard T. Golightly

Poster Group 4. MPAs, Nearshore & Benthic Environments

Assessing Suitable Habitat and the Population Size of Black Abalone (*Haliotis cracherodii*) for Critical Habitat Designation

Christy Bell, Karah Ammann, Maya George and Pete Raimondi

Exploring for Deep-Sea Corals in Gulf of Farallones National Marine Sanctuary

Peter J. Etnoyer, Jan Roletto, and Guy Cochrane

Long-term Rocky Intertidal Monitoring Informs Design of Marine Protected Areas for the North Central Coast Study Region

N. C. Fletcher, M. A. Redfield, D. W. Orr, P. T. Raimondi

Protection and Establishment of Tidewater Gobies within Tomales Bay, Marin Co., CA

Darren Fong and Barbara Ann Martin

Re-discovering Cordell Bank: Technical Dive Expedition 30 Years Later

Dan Howard, Kaitlin Graiff, and Bob Vansyoc

Decreased Solar Radiation and Increased Temperature Combine to Facilitate the Spread of Marine Non-indigenous Fouling Species in Elkhorn Slough, California

Taewon Kim and Fiorenza Micheli

Acidified and Lowly Oxygenated Water Driven by Upwelling along the West Coast of California May Affect the Mortality and Growth of the Red Abalone *Haliotis rufescens*

Taewon Kim and Fiorenza Micheli

Habitat Complexity and Biodiversity as Indicators of Endangered Black Abalone (*Haliotis cracherodii*) Presence in Central California

You-Young Clover Lee

Japan Tsunami Current Flows Observed by HF Radars on Two Continents

Belinda Lipa, Donald Barrick, Sei-Ichi Saitoh, Yoichi Ishikawa, Toshiyuki Awaji, John Largier, and Newell Garfield

Response to Changes: Asexual and Sexual Reproductive Patterns of Eelgrass (*Zostera marina*) in San Francisco Bay

Xuman Tang and C. Sarah Cohen

Abstracts Not Presented

Sanctuary Ecosystem Assessment Surveys – Monitoring the Rocky Intertidal Habitat at the South Farallon Islands

Jan Roletto

Urban seabirds: Coping with bottom-up and top-down pressures

Julie Thayer, Jason Hassrick, William Merkle, and Victoria Seher

Abstracts

Listed Alphabetically by First Author's Last Name

Diet comparisons of Brandt's Cormorant (*Phalacrocorax penicillatus*) at Alcatraz Island in the San Francisco Bay and Southeast Farallon Islands in the Gulf of the Farallones

Sara Acosta¹, Meredith L. Elliott¹, Jason Yakich², Russ Bradley¹, Pete Warzybok¹, and Jaime Jahncke¹

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Diet information of Brandt's Cormorants (*Phalacrocorax penicillatus*) has been collected from the offshore Southeast Farallon Islands breeding colony as well as the estuarine breeding colony at Alcatraz Island for over 10 years. The breeding colony at Alcatraz Island is unique in that it is only one of two locations where Brandt's Cormorants breed in an estuarine habitat. It is also a more recently established colony which began with three pairs in 1991 and has grown to a population of over 1700 pairs, a peak that occurred in 2007. The Farallon Islands host a much larger population with over 3000 breeding pairs in 1999 and has grown to over 10,000 breeding pairs, a peak size also reached in 2007. Since then, the populations at both islands have declined and also experienced an unprecedented breeding failure in 2009. Reproductive success has varied through the years with higher success at the estuarine colony at Alcatraz in the early 2000s and an overall switch to higher success at the Farallon Islands in the latter half of the decade. Shallow, benthic habitat of the central San Francisco Bay provides different foraging opportunities when compared to the oceanic waters surrounding the Farallon Islands and likely has an effect on population and breeding success at these colonies.

Our diet findings show that species richness in the diet at both colonies followed some similar trends through the mid- to late-2000s; cormorants ate more species in 2003-04, then species richness decreased as they consumed high proportions of northern anchovy (*Engraulis mordax*) in several years (e.g., 2005-07). In other years, cormorants relied more on benthic species of fish such as English sole (*Parophrys vetulus*), speckled sanddab (*Citharichthys stigmaeus*), plainfin midshipman (*Porichthys notatus*), and Pacific sanddab (*Citharichthys sordidus*). While Alcatraz cormorants consumed some estuarine species (e.g., bay goby), Farallon cormorants ate rockfish species (*Sebastes* sp.) found in offshore environments. Years when Farallon cormorants ate greater numbers of rockfish (2003, 2009-10) correlated with years of low breeding population size and productivity at the Farallones. This diet comparison in combination with studies of prey availability at each colony could help explain differences, discern mechanisms behind breeding failures, and provide information to assist in management and conservation of these seabirds in central California.

Ocean Diet Cycle of Adult Chinook Salmon in the Gulf of the Farallones

Peter Adams¹, Wayne Samiere², and Constance Ryan³

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Adult Chinook salmon (*Oncorhynchus tshawytscha*) is a key predator in the Gulf of the Farallones and is a strong force in structuring the ecosystem. Their spatial occurrence in the Gulf is related to a well-defined seasonal diet cycle. During February and March, the salmon prey mainly on northern anchovy and herring, feeding in the northern nearshore area of the Gulf. In April, salmon switch prey to juvenile rockfish, euphausiids, and in a brief pulse, crab megalopa, feeding in the offshore area. By August, the salmon have return to feeding almost exclusively on Anchovy in both the northern area and the central and nearshore area. The Chinook salmon diet cycle is due to reproductive traits of the different prey complexes.

Long-term Individual Identification and Site Fidelity of Great White Sharks, *Carcharodon carcharias*, Off California Using Dorsal Fins.

Scot D Anderson¹, Taylor K Chapple^{2, 3*}, Salvador J Jorgensen⁴, A. Peter Klimley² and Barbara A Block⁴

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Mark-recapture techniques are one type of method used to estimate great white shark (*Carcharodon carcharias*) populations. These frameworks are based on the assumptions that marks are conserved and animals are present at the sampling location over the entire duration of the study. Though these assumptions have been validated across short time scales for white sharks, long-term studies of population trends are dependent on these assumptions being valid across longer periods. We use 22 years of photographic data from aggregation sites in central California to support the use of dorsal fin morphology as long-term individual identifiers. We identified five individuals over 16-22 years with little change in their dorsal fins. These identifications support the use of dorsal fins as long-time individual identifiers and illustrate strong yearly site-fidelity to coastal aggregation sites even across long time periods. These findings support the use of mark-recapture frameworks for white sharks over longer time-series.

Geomorphic changes, anthropogenic influences, and coastal management challenges beyond the Golden Gate

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Since 2003, the USGS has performed a comprehensive physical process study to investigate the causes of significant coastal change at the mouth of San Francisco Bay. Highly detailed information has been gathered about the processes that shape this high energy coast through historical change analysis, multibeam bathymetry, lidar, sediment sampling, periodic beach and nearshore surveys, wave and current measurements, and numerical modeling. Historical bathymetric changes highlight major anthropogenic influences since the 19th century to the Golden Gate region, the core of the San Francisco Bay Coastal System. Hydraulic mining during the Gold Rush introduced enormous volumes of sand and gravel into the Bay that continued well into the 20th century. During this same period, Bay development significantly reduced the tidal prism, and, from 1900 to the present, channel dredging, borrow pits and aggregate mining removed at least 200 million m³ of mostly sand and gravel from the system. Bathymetric change analysis of North Bay, Central Bay, South Bay and the San Francisco Bar demonstrates that ~250 million m³ of sediment has been lost from the system over the last 50 years, the majority of which is sand-sized material from the Golden Gate region. During this same period, widespread shoreline erosion persisted and accelerated along the adjacent outer coast. The coincident timing of Bay sediment loss/removal, erosion of the San Francisco Bar, and shoreline erosion highlight the importance of taking a regional approach to understanding geomorphic changes beyond the Golden Gate. The changes at the mouth of San Francisco Bay also have a direct influence on adjacent beach behavior. For example, the shape of the San Francisco Bar affects the size and variability of the wave field at Ocean Beach, which, in turn, influences long term coastal evolution and storm impacts. Local high rates of erosion at the southern end of Ocean Beach are linked to the current configuration of the San Francisco Bar, regional reduction in sediment supply, modification to the shoreline, and a submerged sewage outfall pipe. The observed trends of coastal erosion and sediment loss at a range of spatial and temporal scales present major challenges for managers and emergency planners as we move further into the 21st century, with climate change likely to add additional stresses to coastal systems world-wide.

Our Coast—Our Future: Planning for Sea Level Rise and Storm Hazards Along the Bay Area’s Outer Coast

Patrick L. Barnard^{1*}, Kelley Higgason², Grant Ballard³, Li H. Erikson¹ and Sam Veloz³

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With a changing climate, the North-central California coast faces challenges from sea level rise, increased storm frequency and intensity, and coastal erosion. To prepare for these impacts, coastal managers and planners need to understand how these future changes will affect the local landscape, ecosystems, and human infrastructure. The Gulf of the Farallones National Marine Sanctuary, PRBO Conservation Science, U.S. Geological Survey, and the National Park Service have teamed up to help address the affects of sea level rise and storm hazards from Half Moon Bay to Bodega Head. The goal of Our Coast—Our Future (OCOF) is to provide Bay Area natural resource managers, local governments and others with science-based, decision-support tools to plan for and respond to sea level rise and storm hazards along the region's outer coast (<http://prbo.org/ocof>). Input and feedback from stakeholders and potential users of the final product are being considered in the development process through a series of workshops and a preliminary test group. Final products will include an interactive web-based tool and a report summarizing impacts to the natural environment and infrastructure at select open coast sites. Training workshops on the use of the interactive web-based maps and decision support system will be given.

Impacts of sea level rise and future storms are being considered through development of projected climate scenarios, statistics describing frequency of occurrence and co-occurrence of extreme events, numerical model simulations of waves and total water level changes, and GIS layers that reveal inundation extents based on a 2-m seamless digital elevation model and results of the numerically modeled scenarios. In addition to eustatic sea level rise, potential changes in water level due to changes of the wave climate, storm surge, tide, and El Niño events are being considered. Preliminary simulation results indicate for example that, for the IPCC middle to upper emissions climate scenario (A2), the number of local storm events is projected to increase by 26% in 2040-2050 while storm surge levels due to winds and barometric pressure gradients along the open coast in ~50m water depth are projected to increase by 10% for the same decade as compared to 2010-2020. For the 21st Century, both the recurrence frequency and storm surge levels are projected to peak in 2040-2050 under the stated climate scenario.

Assessing suitable habitat and the population size of black abalone (*Haliotis cracherodii*) for critical habitat designation

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Black abalone (*Haliotis cracherodii*) have experienced mass mortalities along the coast of California since the mid-1980s and are now protected under the USA Endangered Species Act. Mortality is due to poaching and a fatal wasting disease called “withering syndrome”. Working with MARINE (Multi-Agency Rocky Intertidal Network) and PISCO (Partnership for Interdisciplinary Studies of Coastal Oceans) monitoring groups we have documented their decline along the California coast. We regularly sample abalone populations at 27 sites from Half Moon Bay to Point Conception. Withering syndrome has decimated populations south of San Simeon and as such the last extant large and healthy populations exist in the Monterey Bay National Marine Sanctuary- *their area of ecological viability*. To assess change in abundance and size structure we initially established sites where abalone occurred in relatively high densities. However, this design may be unsuitable for estimating population size. To rectify this we designed a study to estimate the population size and to determine the amount of suitable habitat available to black abalone along the California mainland from Point Arena to Point Conception. We sampled occupied and unoccupied intertidal areas for black abalone within their current geographic range and also characterized the quality of habitat suitable for abalone occupation as: Good Habitat, Moderate Habitat, and Poor Habitat. Additionally, we used a gradient of sample areas away from an area of known suitable habitat (when possible the center of the gradient was an existing monitoring site) and found that suitable habitat is not spatially clustered. We also found strong correlation between the quality of habitat and the density of abalone. Using GIS layers from the Coastal Impact Assessment Program (MBNMS) we calculated the amount of rocky shoreline within our study area. This information, when combined with our data, allowed us to estimate the amount of suitable abalone habitat available in areas with and without disease. While the number of abalone per linear km is dramatically different in areas with and without disease, the number of abalone in areas free of disease is similar to pre-disease areas in the south. We also found that in areas with disease there is almost no recruitment. Likewise, in areas with disease, the average density of mature abalone is <1 individual per square meter which is not enough for reproductive success. As expected, we also found fewer black abalones at sites near the northern edge of their current geographic range. To date we have surveyed more than 300 areas at 51 sites between Pt. Arena and Pt. Conception. Our data on recruitment and habitat alteration post-disease suggest that without intervention the recovery of black abalone in areas decimated by “withering syndrome” is unlikely. Our data are being used by the National Marine Fisheries Service to designate critical habitat and to aid in the recovery of black abalone.

**Large-scale movements and high-use areas of western Pacific leatherback turtles,
(*Dermochelys coriacea*)**

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The western Pacific leatherback, one of three genetically distinct stocks in the Indo-Pacific region, has declined markedly during past decades. This diverse metapopulation nests year-round at beaches of several western Pacific island nations and seasonally inhabits the California Current. The objective of this study was to synthesize results of 126 satellite telemetry deployments conducted on leatherbacks at western Pacific nesting beaches and neritic central California foraging grounds during 2000-2007 to provide a large-scale picture of movements, high use areas, and habitat associations. There was a clear separation of migratory destinations for boreal summer vs. boreal winter nesters, and leatherbacks used multiple large marine ecosystems (LMEs) as foraging destinations. Foraging habitats included diverse pelagic and coastal regions exhibiting a wide range of mechanisms that are known or expected to aggregate leatherback prey. Use of the most distant, temperate LME (California Current) required a 10-12 month trans-Pacific migration and commonly involved multiple years of migrating between high-latitude summer foraging grounds and low-latitude eastern tropical Pacific wintering areas without returning to western Pacific nesting beaches.

Oceanographic Effects on Yellowtail and Chilipepper Rockfish Condition and Productivity at Cordell Bank

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Climate effects on ecosystem productivity are well established for the California Current, and climate variability is reflected in bottom-up effects on fish growth and productivity. In this study, we explore the consequences of poor feeding conditions during warm oceanographic regimes (i.e., El Niño or positive PDO) on female bioenergetic allocation patterns. A decrease in fish condition or storage of fatty lipids in muscle tissues or organs such as the liver was hypothesized to adversely affect fish growth and production of eggs; however, this relationship is not well understood for many species. Female rockfish were sampled by hook-and-line from Cordell Bank over the period of egg development and larval release in the winters of 2009-10 and 2010-11. Basic demographic data was collected (length, age, weight, maturity), as well as fecundity and liver condition from multiple rockfish species to evaluate this hypothesis. Our results were combined with two historical datasets comparing female fecundity and condition back to 2004 for chilipepper rockfish and back to the mid-1980s for yellowtail rockfish. For both species we found a significant maternal effect on fecundity, with older, larger females producing proportionately more larvae on a weight specific basis (i.e., accounting for the difference in body size) than younger, smaller females. After accounting for the maternal effects, we found significant interannual differences in fecundity for both species and a reduction in the number of eggs produced by females in poorer condition. These interannual differences were correlated with periods of reduced productivity off the Central coast of California within the Cordell Bank National Marine Sanctuary. The results of this study will help us to better understand climate effects on fisheries production and ecosystem dynamics and will be incorporated into existing stock assessment models of West Coast groundfish to provide more precise parameter estimates.

Comparison of a wind-driven Mixed Layer Conveyor model with observations of fluorescence and nitrate from a mooring

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With increasing emphasis on Ecosystem Based Management, policy analysis and the interpretation of the responses will depend increasingly on our perception of primary production. There have been a number of modeling efforts that combine NPZ and physical circulation models to represent production in coastal upwelling systems, but few direct comparisons with data reflecting nutrients, phytoplankton and zooplankton. Here we compare predictions from a very simple physical and NPZ model to fluorometer and nitrate measurements at a mooring during the 2001 field season of WEST (Wind Events and Shelf Transport). The model is the essentially 1-dimensional Mixed Layer Conveyor (MLC) model developed in WEST. It is driven by cross-shelf velocity from Ekman transport based on local winds, and mixed layer depth varying with time lagged wind stress. Both model N and nitrate observations, and model P and fluorescence are highly correlated over periods of tens of days. The intervening errant periods have not all been completely explained, but likely involve circulation conditions during which the transport paths of upwelled parcels become two-, rather than one-dimensional. While this comparison lends credibility to MLC calculations, the ultimate effect on higher trophic level marine resources depends on the ultimate fate of this production, observed here at a very early stage.

The Challenge of Seabird Restoration in a Warming World

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While artificial nesting habitat can be crucial to effective seabird restoration, increased temperatures from climate change can cause serious negative impacts. Cassin's Auklet (CAAU, *Ptychoramphus aleuticus*) is a small cavity nesting alcid which has been studied by PRBO Conservation Science in partnership with the Farallon National Wildlife Refuge (USFWS) on Southeast Farallon Island, California (SEFI) for over 40 years. This population has declined dramatically since the early 1970s. CAAU show high site fidelity to nesting boxes that allow monitoring of individuals without disturbing natural habitat. We assessed increases in air temperature at SEFI over the last 4 decades and recently explored the utility of mitigation measures to reduce temperatures in auklet nesting boxes, compared to uncovered boxes and natural burrow sites. Since 2009 we have used temperature loggers to assess differences between the following 3 treatment groups: natural burrows (occupied), treated boxes covered with a wooden shade (occupied), and untreated boxes (unoccupied). Control loggers captured surface temperatures in all study areas. Wooden shades were ½ inch thick painted plywood, supported by a two inch wood gap to generate a pocket of air between the shade and the nest box. Temperature loggers were attached inside nesting boxes or burrows, away from direct contact with birds. Temperature was recorded once every 30 minutes. We assessed 3 areas with nest boxes and natural burrows, each at least 500m apart. Daytime temperature data (700 – 1900) was summarized weekly by treatment group, and reported with standard errors for both mean and maximum temperatures. SEFI air temperature shows increasing maximum temperature, up 2 degrees celsius over 40 years, and increased frequency of extreme heat events. Mean and maximum control temperatures showed variation between areas but similar seasonal trends. Ground temperatures were greater than those from standard weather box measurements. Untreated boxes had the warmest temperatures, followed by controls, treated boxes, and burrows. Mean and maximum treatment temperatures showed similar trends, with greater variability in maximum temperatures. Mean and Max temperature anomalies to area specific controls showed untreated boxes were always warmer than controls. Treated boxes were cooler than controls. Burrows were always in negative anomaly. No negative temperature impacts on bird behavior or survival in nest boxes was observed during this study. In summary, simple wood shades effectively reduced temperatures of treated nest boxes – sometimes by well over 25% - relative to controls. Treated boxes had higher temperatures than natural burrow habitat, but were generally cooler than ambient temperature. Nest boxes provide essential artificial habitat for restoration and research, and while new long lasting designs should be pursued to manage for climate change effects, simple mitigation efforts can have significant results.

The influence of nutrients from the Gulf of the Farallones on Drakes Estero

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Drakes Estero, located in Point Reyes National Seashore, CA, is a shallow low-inflow estuary where harmful algal bloom (HAB) species including *Alexandrium catenella* have been observed. Nutrient supply to the estero is primarily via tidal fluxes from the adjacent ocean, which is an important wind-driven coastal upwelling region. Additional terrestrial nutrients delivered through land runoff from wilderness areas and cattle grazing lands are likely important in winter. The estero is also the site of an oyster aquaculture facility, which may enhance local sources of regenerated nutrients. The influence these varied nutrient sources on phytoplankton communities and primary production is unknown. . A study was initiated in May 2010 to measure seasonal and spatial variations in nutrient concentrations, chlorophyll, and primary production and nitrogen uptake as well as to enumerate phytoplankton species. During the low-inflow estuarine season (July-October) a gradient in nutrient concentrations and elemental ratios was observed along the land-to-sea axis of the estero with the landward region exhibiting elevated ammonium and low DIN : PO₄, compared to coastal locations that had elevated levels of nitrate and high DIN : PO₄ ratio. Phytoplankton blooms were observed at the coastal and middle estero locations, dominated by diatoms during the upwelling season and dinoflagellates during the fall. This study provides a mechanistic look at the how oceanographic processes in the coastal ocean- estuary transition influence the ecology of Drakes Estero.

Changes in Breeding Population Sizes of the Brandt's Cormorant in the Gulf of the Farallones, California, 1979-2010

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Using primarily aerial photography, we examined Brandt's Cormorant *Phalacrocorax penicillatus* breeding population trends in 1979–2010 in the Gulf of the Farallones (GF), central California, where the species largest known colony (South Farallon Islands [SFI]) and greatest breeding concentration occurs. We conducted regression analyses for different periods in 1985–2006, and have continued to determine counts of nearshore colonies annually through 2010. Analyses in 1985–2006 provide valuable comparisons to those that have been conducted for Common Murres *Uria aalge* in the GF for the same periods. In 1979, Brandt's Cormorant colony sizes were relatively large offshore at SFI and nearshore north of San Francisco Bay. By 1985, all GF colonies were greatly reduced, following impacts from the strong 1982–1983 El Niño event. In 1985–1995, while no trend was detected for SFI, nearshore colonies increased by 19% per annum combined. New colonies at Alcatraz and Año Nuevo islands grew rapidly in 1994–1995. Nearshore growth likely reflected increased protection, movements of birds from SFI, and changes in prey availability in the GF. After the strong 1998 El Niño event, significant increase occurred at all colonies in 1998–2006 (range 13–29% per annum, 18% overall), associated with high reproductive success especially during strong La Niña conditions in 1999–2000. The 1979–2006 period corresponded mostly with a warm phase of the Pacific Decadal Oscillation (PDO), but also a possible shift to a new cold phase beginning in 1999. In 2006, the GF total breeding population peaked (34,876 birds), with SFI having returned to its largest known size (~23,500 birds), last recorded in 1974 during the previous cold phase of the PDO. The GF population increased further in 2007, before declining dramatically beginning in 2008. Annual aerial photographic surveys of all major Brandt's Cormorant breeding colonies are conducted not just in the GF but throughout California, critical for best documentation of population trends.

A broad range of intra-species diversity in introduced copepods in the San Francisco Estuary

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We determined bar-codes for several species of introduced copepod in the San Francisco Estuary. These bar-codes, widely used in phylogenetic analysis, are based on sequences of a 585 base-pair region of the mitochondrial gene cytochrome oxidase I (COI). We found a broad range of intra-species diversity across groups; i.e., some species had many unique haplotypes while others had only a few. Previous work found that one introduced copepod, *Tortanus dextrilobatus*, had unusually high haplotype diversity (38 unique haplotypes out of 41 individuals sequenced, Allegra Briggs, Master's thesis, 2009), and of the copepods we examined, *Tortanus dextrilobatus* was the most diverse. At the opposite end of the spectrum, *Oithona davisae* had low haplotype diversity across multiple sampling sites in the Estuary. We might expect the introduction process to create similar patterns in haplotype diversity, by bottlenecking populations for example, or by bringing in propagules from disparate locations. However, these data suggest that different processes are at work in each species. In this poster, we propose mechanisms that might generate the patterns we observe. Variation in COI haplotype diversity may reflect invasion history (single vs. multiple sources, diversity of source populations, existence and extent of population bottlenecks, time since introduction), life history traits (quality of DNA repair mechanisms, skewed male to female ratios, single vs. multiple mating events per lifetime), post-arrival demographic variation including responses to selection, or idiosyncrasies in COI evolution. The better we understand the significance of COI haplotype diversity in these copepods, the more useful it will be in predicting their ability to persist, adapt, and disperse.

Aquatic Microbial Nitrogen Cycling: Planktonic Ammonia Oxidation in San Francisco Bay

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Nitrogen (N) is an essential nutrient for life and often limits the primary productivity of temperate estuaries. Massive anthropogenic alteration of the N cycle, due to crop fertilization, sewage, and fossil fuel burning, has led to increased N inputs into many estuaries. In the environment, N is cycled through various compounds via the metabolism of microorganisms, affecting the availability of N in the environment and thus biological productivity. N can be removed from ecosystems by the coupling of microbial nitrification (the oxidation of ammonia to nitrate) and denitrification (the conversion of nitrate to N₂ gas). The rate-limiting step of microbial N removal, ammonia oxidation, was long believed to be catalyzed solely by ammonia-oxidizing bacteria (AOB). The recent discovery of the existence and prevalence of ammonia-oxidizing archaea (AOA) has suggested that mesophilic Crenarchaea may play a greater role in global biogeochemistry, but studies of microbial N cycling in estuaries suggests a complex and unresolved dynamic between AOA and AOB. However, the vast majority of research on microbial N cycling has focused on sediments; N cycling in estuarine water columns has been generally unstudied by microbiologists, biogeochemists, and modelers alike. This study examines the diversity and abundance of AOA and AOB within the water column of San Francisco Bay in relation to environmental parameters and nutrient levels.

Water samples from San Francisco Bay were collected monthly aboard the R/V *Polaris*. At each station, 1 L of water was collected from the surface (~2 m depth) with an onboard pump and collected from the bottom via a Niskin sampler. Samples were immediately prefiltered through 10.0 µm and 1.2 µm Isopore polycarbonate filters and collected on a 0.2 µm Isopore filter via a Masterflex peristaltic pump. Nutrient concentrations of filtered bottom water were measured using a WestCo SmartChem 200 discrete analyzer. Surface water nutrient data were downloaded from the USGS Water Quality of San Francisco Bay website. After extracting bulk DNA from collection filters, diversity of AOA and AOB was estimated by amplifying with the polymerase chain reaction (PCR) amplification, cloning, and sequencing of the *amoA* gene, a powerful functional marker of ammonia oxidation. Microbial abundance was estimated by quantitative PCR (qPCR) analysis of both *amoA* and clade-specific 16S rRNA genes. Statistical analyses using the programs MOTHUR and UniFrac will reveal trends in microbial diversity between sites and between months, and canonical correspondence analysis will assess correlations between abundance data and environmental parameters to determine which, if any, are important in determining the abundance of AOA and AOB.

Preliminary data suggest that AOA were present in both surface and deep water throughout San Francisco Bay, in both spring and summer 2011. While *amoA* copy numbers are orders of magnitude below what is typically found in estuarine sediments, the presence of AOA *amoA* and 16S rRNA genes suggests the presence of AOA in the water column, while AOB abundance appears to be far lower. Future work includes measurements of AOA expressional activity (via qPCR analysis of RNA extracts), as well as measurements of potential ammonia oxidation rates, in San Francisco Bay water. The presence of AOA within the water column of San Francisco Bay suggests that this overlooked aspect of estuarine N cycling may play a role in the ecology and nutrient dynamics of San Francisco Bay and other temperate estuaries.

Where the Whales are: Using Habitat Modeling to Inform Marine Spatial Planning in Cordell Bank and Gulf of the Farallones National Marine Sanctuary.

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The extent to which humpback whales (*Megaptera novaeangliae*) select distinct habitats in the North Pacific has not yet been determined and should be considered a top priority in the context of marine spatial planning to ensure minimum conflict between human uses and wildlife conservation. The purpose of this study was to identify predictable locations of humpback whale aggregations within sanctuary waters in central California. We used data collected during Applied California Current Ecosystem Studies (ACCESS) cruises conducted by PRBO Conservation Science, Cordell Bank and Gulf of the Farallones National Marine Sanctuaries from 2004 to 2010. We estimated whale encounter rates at 3-km bin intervals. We overlaid whale distributions on hydrography (CTD) and bathymetry (depth) layers using a Geographic Information System to extract covariate data at appropriate time and spatial scales. We used statistical model techniques to determine habitat associations and to develop predictive models to identify preferred whale habitats. We found that humpback whales select particular locations for use, and that these habitats change depending on ocean conditions. Our results highlight the potential use that spatial analysis on marine wildlife may have to inform marine spatial planning and ensure the conservation of important threatened species.

Developing a Set of Linked Environmental and Biological Climate Change Indicators for the North-central California Coast

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Climate change impacts have been observed in physical and biological elements of the NOAA Gulf of the Farallones National Marine Sanctuary (GFNMS) region, which is located along the north-central California coast from Point Arena to Año Nuevo. A variety of habitats supporting a rich and diverse ecosystem exist in the region, each with specific characteristics that result in unique responses to changing environmental conditions. Ecosystem-based climate change monitoring plans frequently begin with a defined set of environmental and biological climate change indicators. The GFNMS Ocean Climate Center seeks a set of environmental and biological climate change indicators that can be integrated into a collaborative monitoring plan to help track and address the effects of climate variability and change on the region. Climate change indicators are measurable variables that can be used to determine the presence and impacts of climate change in a region. Examples of environmental climate indicators include water and air temperature and sea level, while biological indicators can include the northward range expansion of a species and specific changes in phenology.

A new interdisciplinary research project aims to meet this need by creating a clearly defined set of environmental and biological climate change indicators for the GFNMS region. The two-year project beginning in late September, 2011, will utilize active collaboration with partner scientists and other experts through meetings and surveys, together with numerical computer model experiments and data analysis, to maximize confidence in the chosen climate change indicators. It will also define climate change monitoring goals for the GFNMS region and incorporate these goals and the climate change indicators into a collaborative monitoring plan that tracks the vulnerability of resources in the GFNMS region to climate change.

Initial work is focused on completing an extensive review of existing climate change indicator reports and the most recent published research about the physical and biological systems in the study region. This literature review will inform the creation of a list of candidate environmental and biological climate change indicators. A series of meetings and surveys with partner scientists and regional experts will then assist with reducing the candidate indicators to a list of finalists. Regional climate model experiments will be run to assess the relative importance of each indicator, and together, with input from the surveys and meetings, will help determine the final set of climate change indicators. The final set will include information about the available data for each indicator, any needs for additional indicator measurements, an explanation of each indicator's importance in the ecosystem, projections of expected changes that may occur, and the potential impacts of those changes. Finally, the climate change indicators will be incorporated into a collaborative monitoring plan through a regional working group of scientific experts. This monitoring plan will be used to



track climate-induced changes to the study region over time, and allow for climate impacts to be more quickly and successfully identified and mitigated.

Anthropogenic disturbance affecting Common Murre colonies in central California

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The Common Murre Restoration Project (CMRP) began in 1996 to restore breeding colonies of seabirds, especially Common Murres (*Uria aalge*), harmed by the *Apex Houston, Command*, and *Luckenbach* oil spills. From 1995 to 2005, our primary goal was to restore the previously extirpated Devil's Slide Rock colony using social attraction techniques and to assess restoration needs at other central California colonies. Although some central California murre colonies have increased to levels observed in the early 1980s, others such as Devil's Slide Rock and the Castle-Hurricane Colony Complex have not fully recovered. Disturbances from aircraft and boats have affected these colonies. Since 2005, restoration efforts have focused largely on reducing human disturbance to murre colonies. To assess impacts of disturbance, monitoring was conducted from mid-April to late July at several Common Murre colonies in central California: Point Reyes (2001-2002, 2005-2011); Drakes Bay Colony Complex (2005-2011); Devil's Slide Rock & Mainland (2001-2011); and the Castle-Hurricane Colony Complex (2001-2011). For aircraft, activity rates were measured as the number of fixed-wing planes and helicopters observed per hour that flew ≤ 305 m (1000 ft) above sea level (ASL) over colonies. Boat activity was measured as the number of vessels observed per hour that approached within 457 m (1500 ft) of colonies. Aircraft, boat and other anthropogenic disturbance rates were measured as the number of disturbance events per hour. Both activity and disturbance rates were highest at Devil's Slide Rock & Mainland, which is closest to Bay Area airports and marinas. Point Reyes had the lowest combined aircraft and boat observation and disturbance rates. At the Castle-Hurricane Colony Complex, along the more remote Big Sur coast, observation and disturbance rates were relatively low from 2001 to 2007 but have increased from 2008 to 2010. Helicopters caused the most disturbance events and were more likely to cause birds to flush than planes and boats. Boat disturbance varied among years and colonies and is influenced by factors such as weather and fishing conditions. This information is used to guide outreach and education efforts conducted by the Seabird Protection Network and to assess the success of those efforts. The goal of the Seabird Protection Network (coordinated by the Gulf of the Farallones National Marine Sanctuary) is to restore affected breeding colonies mainly through reduction of human disturbance. Monitoring data from the CMRP was also instrumental in identifying potential areas for establishing Special Closures around sensitive seabird colonies. These Special Closures became effective on 1 May 2010 under the California Marine Life Protection Act and prohibit watercraft from entering six designated areas. The CMRP is monitoring four of these areas to assess the effect on disturbance levels.

Copepod assemblages as indicators of ocean conditions in Central California

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At-sea surveys conducted in the Gulf of the Farallones and Cordell Bank National Marine Sanctuaries in central California have shown drastic changes in the abundance and species compositions of copepods from 2004 to 2008. We characterized copepod species as “transition zone” (i.e., common to the region), boreal (i.e., larger, high-lipid species common to northern latitudes), and equatorial (i.e., smaller, less fatty species with a more equatorial distribution). In 2004, a relatively “normal” year for upwelling, “transition zone” copepods (e.g., *Calanus pacificus* and *Metridia pseudopacifica*) were most numerous. In the poor upwelling years of 2005 and 2006, “transition zone” species dominated samples again. In the strong upwelling conditions of 2007, boreal copepods became copious, particularly coastal and shelf species (e.g., *Pseudocalanus mimus* and *Acartia longiremis*); boreal species continued to be abundant into 2008 (another relatively “good” ocean productivity year). Results show that the depth of the mixed layer, water density, average sea surface temperature, the Pacific Decadal Oscillation (PDO), and the North Pacific Gyre Oscillation (NPGO) are the main factors contributing to the abundances of copepods in the Central California region.

Exploring for Deep-Sea Corals in Gulf of Farallones National Marine Sanctuary

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Coral reefs are often recognized as important marine habitats in warm, shallow, tropical seas, but the value of deep-sea coral (DSC, or cold-water coral) habitats is much less understood. Awareness is growing within the scientific research community that DSC are actually more diverse and probably more abundant than shallow corals, and DSC can provide similar habitat functions to 2500 meters (m) depth and more.

In recognition of the growing awareness of the value of DSC to the United States' fisheries and biodiversity, the US Congress reauthorized the Magnuson-Stevens Fishery Conservation and Management Act (MSA) in the year 2006 (U.S.C. 1801 *et seq.*). MSA grants discretionary authority to regional fisheries management councils to establish 'essential fish habitat' where deep-sea corals are known or suspected to occur. The National Marine Sanctuary Act also provides a mandate for science and management actions related to DSC habitats.

For NOAA, DSC are structure-forming anthozoans and hydrozoans in the Phylum Cnidaria that grow at depths of 50m or more. The depth maxima vary by taxa and region. Globally, constructional scleractinian species (stony corals) are known to occur to 2500m, octocorals (or sea fan) species are reported to 5600m depth. Antipatharian (or black coral) species are known to occur at 8500m depth. Unlike shallow tropical corals with symbiotic algae, DSC are azooxanthellate, heterotrophic suspension-feeders consuming surface exported particulate organic matter. Rocky hard-bottom substrates provide anchor to most DSC, but Pennatulaceans (sea pens) are well adapted to soft and sandy substrates.

DSC are expected to occur in Gulf of Farallones National Marine Sanctuary (GFNMS) because colonies occur to the north and south, GFNMS has highly productive surface waters up to 3000 m deep, and seafloor topography suggests many steep and/or hard-bottom features between 50-1000 m deep. A joint multibeam mapping exercise between NOAA and USGS will seek to identify DSC habitat in GFNMS in October 2011. The project will 1) conduct multibeam mapping of Rittenburg Bank (50-150m) and Farallon Escarpment (150-1000m); 2) produce high-resolution maps of depth, hardness, slope, and rugosity; and, 3) use these maps to identify high-confidence targets for visual surveys of deep-sea coral and sponges with autonomous and remotely operated vehicles in 2012.

Long-term Rocky Intertidal Monitoring Informs Design of Marine Protected Areas for the North Central Coast Study Region

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The 1999 Marine Life Protection Act (MLPA) mandates the establishment of a network of Marine Protected Areas (MPAs) along the California coast. In May 2010, the North Central Coast Study Region (NCCSR), the second of five study regions, was implemented. It includes 25 MPAs from Point Arena to Pigeon Point. In order to meet the goals of the MLPA and ensure the effectiveness of each MPA and the network as a whole, MPAs must represent a variety of marine habitats and bioregions. The MLPA mandates that each key habitat is represented in 3-5 MPAs within each biogeographic region (the NCCSR is within the biogeographic region defined from Oregon to Point Conception) and that replication of State Marine Reserves (SMR) occurs within each recognized bioregion. To accomplish this, it was necessary to know where bioregions exist within the NCCSR and the habitat area needed within each MPA replicate to encompass a sufficient level of biodiversity.

Our research group at UC Santa Cruz, in collaboration with the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) and the Multi-agency Rocky Intertidal Network (MARINe), has established 176 long-term rocky intertidal monitoring sites from Alaska to Baja California. This program includes sites used for baseline characterization and evaluation of MPAs. Key elements of this monitoring program include assessment of biodiversity, community structure, and species of special interest. In addition to being useful for capturing and understanding broad scale temporal and spatial changes, this long-term monitoring also informs policy and management decisions, in this case, MPA design. Here, long-term data from our monitoring group, and that of several others, were used to define bioregions within the NCCSR and determine the area of each habitat needed for ecological representation in an MPA.

While the concept of large biogeographic regions, defined by the range boundaries shared by many species, is widely recognized, smaller subregions called bioregions are also key to the MPA design process. Bioregions are differentiated by dissimilarities in species composition and community structure within a habitat type, such as the rocky intertidal. Defining bioregions is crucial to MPA design to help ensure that the unique species composition and community structure of each bioregion is represented and protected within the MPA network. Long-term rocky intertidal monitoring data, as well as data from other habitats such as sandy seafloor and subtidal rocky reef, were used in defining these specific bioregions. These data found that within the NCCMPA network, there are three main bioregions, Point Arena to Point Reyes, Point Reyes to Pigeon Point, and the Farallon Islands.

It is important to identify the habitat types within the NCCSR that need to be represented by an MPA, as well as the area of habitat needed to obtain ecological representation. Data from rocky intertidal biodiversity surveys were among the data sources used in determining the amount of area needed to ecologically represent each habitat type. A re-sampling procedure and accumulation

functions were used to estimate the area required to include 90% of the biodiversity of each habitat type. These methods estimate that approximately 0.5 linear miles of rocky intertidal habitat must be encompassed by an MPA for ecological representation.

Long-term datasets such as those collected by large-scale monitoring consortiums PISCO and MARINe, prove to be crucial to not only monitoring and assessing effectiveness of MPAs, but also undeniably important planning decisions within MPA design. Rocky intertidal researchers at UCSC plan to continue monitoring within the NCCSR region, as well as be involved in the upcoming baseline monitoring for the South Coast Study Region.

Protection and Establishment of Tidewater Gobies within Tomales Bay, Marin Co., CA

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The Giacomini tidal wetland restoration project, a 560-acre project completed by the Point Reyes National Seashore in October 2008, resulted in the need to translocate the endangered tidewater goby (*Eucyclogobius newberryi*) to various locations within Tomales Bay as a part of a “biological insurance plan” to ensure that tidewater gobies persist within the watershed. Tidewater gobies were translocated in two phases with fish moved to four sites within the wetland project footprint in 2008. In 2009, additional tidewater gobies were moved to a pond within Tomales Bay State Park. Field data and initial problems with a captive rearing program suggest low survivorship associated with sharp changes in water quality parameters. Monitoring data have indicated the continued presence of tidewater gobies at three of the four translocation sites within the project footprint and at the Tomales Bay State Park location. Long-term monitoring will determine whether this population persists over time and even expands into new areas.

Coastal oceanographic fronts within the Gulf of the Farallones-Cordell Bank region: patterns, predictability, and biological importance

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Coastal upwelling regions are among the most productive ocean ecosystems known. Productivity within these areas is spatially and temporally heterogeneous. Studying the distribution and dynamics of productivity patchiness is critical to understanding the variation of coastal pelagic ecosystems (1). Large-scale (>>100km) oceanographic processes shape patterns of production observed in the coastal ocean. However, small-scale (<<100 km) oceanographic features can enhance and accumulate productivity (1 - 3). One such small-scale feature is a front, which forms at the boundary between water types (4,5). Due to the movement of waters near front boundaries, buoyant or upward-swimming particles accumulate rapidly. These particles include both inorganic debris and living organisms, i.e. plankton. Plankton aggregations attract consumers, which in turn attract higher trophic level predators, such as seabirds and marine mammals (6,7). Visible surface manifestations of fronts (foam and debris lines) facilitate the study of these features (6,7), yet despite extensive research, many questions remain about their manifestation and associated biological activity (1,8). More specifically, few studies have addressed fronts within the Farallones-Cordell Bank region.

Our research elucidates the areas of frontal activity and their biological importance over the north-central California shelf from Bodega Bay south to San Francisco Bay. Here, we examine the presence, patterns, and underlying causes of fronts. We have analyzed ten years of underway thermosalinograph data, including data collected by the Applied California Current Ecosystem Studies (ACCESS) and Wind Events and Shelf Transport (WEST) cruises. Front patterns are predictable, both spatially and temporally. Fronts are more common during spring and summer, at which time they exhibit sharp temperature gradients characteristic of strong upwelling. During rainy winters, salinity fronts develop due to freshwater outflow. We have identified five areas with increased probability for front activity. The San Francisco Bay plume front is associated with freshwater outflow meeting coastal waters. The four remaining fronts are defined by sharp thermal gradients and associated with flow structures due to upwelling and its interaction with topography.

To further understand the intricacies of small-scale front dynamics within this region, we are currently conducting an in-depth investigation of the physical and biological oceanography occurring at specific fronts. We conducted a boat-based case study at one specific front off Pt. Reyes, California. Fronts off Pt. Reyes occur during all seasons due to interactions of flow structures with upwelling waters, topography, and San Francisco Bay outflow. This study was conducted during relaxation of upwelling winds, and the front appeared as an extremely strong gradient (>.5 psu surface salinity change in <1km) directly offshore of Pt. Reyes. This front area may have biologically important ramifications for this coastal region. It is expected that understanding fronts within the Farallones-Cordell Bank area will further our appreciation for the foundation of high productivity in this dynamic region.

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Developing a method to quantify jellies, prey of the critically endangered leatherback turtle, *Dermochelys coriacea*

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We tested the efficacy of an automated method to quantify aggregations of moon jellies, *Aurelia* spp., from the sea surface to approximately 1m depth with aerial photographs taken with a 10 megapixel digital still camera. Images were obtained during aerial line-transect surveys conducted at altitudes of 190-210m to assess distribution and abundance of the critically endangered leatherback turtle, *Dermochelys coriacea*, that migrates long distances to forage on jellies. Following existing protocols, jellies observed within the strip-transect under the plane were recorded using a categorical index: none, low (0-30), moderate (31-300), or high (>300). Several photographs of each jelly abundance category were chosen from different aerial surveys to minimize autocorrelation. Jellies in each photograph were manually counted using ArcGIS to obtain a proxy total number of individuals. A second, more automated method used a MATLAB program that: calibrated each photo for water color, assessed the pixel color of jellies contained in the photo, and counted the total number of pixels containing jellies. For each photograph, mean bell surface area in pixels was calculated by first determining bell diameter for 100 randomly selected jellies (assuming horizontal orientation) and then calculating surface area in pixels. The total number of pixels containing jellies was divided by the mean surface area of a jelly in pixels, yielding a second estimate for total number of jellies in each photo. A regression was used to test the relationship between the two count methods and indicated a significant, positive relationship ($y=0.654(\text{ArcGIS count}+22.339, r^2=0.964, p\ll 0.001, n=15)$). The regression slope was significantly different from 1.0 (t-test) and preliminary results indicate this was caused by a downward bias in the automated MATLAB count for moderate to high density jelly aggregations. Additional photos will be analyzed to refine the ArcGIS and MATLAB regression relationship so that future MATLAB jelly counts can be corrected using this equation. A similar relationship is being developed for sea nettles, *Chrysaora fuscescens*, another important prey species for leatherback turtles. This quantification method is efficient and has potential for use in tracking significant changes in the abundance of jellies in sea surface waters, thus allowing the development of a quantitative index of jelly biomass to support leatherback turtle prey studies and critical habitat assessments.

Oceanic Near-Coastal Frontal Mapping, Northern California

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An array of seven high frequency (HF) radar stations has been recording sea surface currents on an hourly basis in the Bodega Bay/Gulf of the Farallones region since May 2006 as part of the State Coastal Conservancy funded Coastal Ocean Currents Monitoring Program (COCMP). In this study, we use HF-radar measured surface currents averaged to a 6-kilometer grid extending from the coast to between 60 and 150 km offshore (across the continental shelf into the deep ocean) to obtain surface current divergence and convergence (“frontal”) maps. HF radar provides uniquely high spatial and temporal resolution that is not provided by satellite measurements. Understanding the evolution of fronts in these regions can provide insight into debris accumulation, oil spill trajectories, seabird feeding strategies and ocean productivity.

Inter-annual and decadal variability of coastal upwelling off Bodega Bay, California

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The California coastal ocean is dominated by coastal upwelling, particularly in the vicinity of Bodega Bay. Seasonally varying upwelling determines not only the amount of nutrients available for primary productivity, but also the phenology of the ecosystem. However, upwelling winds are driven by large-scale pressure systems over the North American continent and the North Pacific, and thus are influenced by variations in the climate over this region. The inter-annual, decadal, and multi-decadal variability of the coastal environment is thus closely related to the state of the Pacific Ocean and to the climate over the continent, and understanding these influences is critical for prediction of future changes.

To better understand the processes that drive inter-annual and decadal variability in coastal upwelling process, we have analyzed 29 years of data from NDBC/NOAA buoys over the continental shelf off central California. We analyzed the upwelling forcing (wind), and also the ocean response to these winds (Sea Surface Temperature). We correlate the variability with well-known basin-scale or global climate indices to better understand large-scale forcing and/or response. Also, we compare the time series of upwelling winds and response to data on biological responses.

We find that during the period of study (1982-2010), upwelling winds off Bodega Bay strengthen from March to September, enhancing coastal upwelling but also extending the upwelling season. Large inter-annual variability is observed, in both the winds and SST due to climate variability in the region, and the capacity of the winds to bring cold deep water to the surface is found to depend on the state of the North Pacific, with a net increase during the study period, but with a sharp change since 1999.

The first *in situ* observations of deep-sea corals and sponges on the continental slope west of Cordell Bank

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Interest in the conservation of deep-sea coral and sponge communities (DSC) has grown over the last decade. Deep-sea corals and sponges are often long-lived, slow growing, fragile animals; characteristics that make them particularly vulnerable to physical disturbance such as bottom trawling, oil and gas development, and the laying of undersea cables. The structurally complex morphology of DSC can provide valuable habitat for fishes and other invertebrates.

An effort to locate and characterize DSC communities using a remotely operated vehicle (ROV) in Cordell Bank and Gulf of the Farallones National Marine Sanctuaries was conducted in June, 2010 under the sponsorship of the NOAA Deep Sea Coral Research and Technology Program. ROV dive locations targeted regions predicted from multibeam sonar data to be hard substrate; the most likely habitat for deep-sea coral assemblages. Adverse weather pre-empted most of the planned ROV operations allowing just a single eleven hour dive on the continental slope west of Cordell Bank. High definition video collected by the ROV was analyzed to characterize habitat type, corals and sponges, other small invertebrates, and fishes.

Results showed that the substrate was primarily (>90% of total area) mixed cobble and sand rather than the predicted rugose rocky bottom. Therefore, observed assemblages of DSC were not as diverse or abundant as predicted. A total of six deep-sea coral species were observed, two of which are structure forming species (*Paragorgia* sp. and *Plumarella longispina*). The sea pen *Virgularia* sp. accounted for over 80% of observed corals and sponges. The abundance of sponges was overall low (<5%) but some large individuals (30-60cm) were observed. The diversity of fishes was higher than invertebrates with 44 taxa observed, including 18 species of rockfishes (*Sebastes*), accounting for 38% of the fishes observed on quantitative transect segments. Fishes and other invertebrates were often observed in close association with DSC. Evidence of human disturbance to the seafloor included a derelict trawl net. Analysis of California bottom trawl logbook data (1997-2001) showed that this region has experienced moderate (40 hours in 5 years) trawl effort.

We believe that the lack of consolidated rugose bedrock is limiting the DSC assemblages in the study region. Another factor which likely influenced DSC size and abundance was historic bottom trawling which may have degraded the habitat and removed many of the sponges and corals. A reduction in trawl effort (a consequence of fishery closures enacted over a decade ago) has allowed the small DSC we observed to become established. The few large sponges we observed likely inhabited a region not impacted by bottom trawls. Further exploration of this continental slope ecosystem needs to be conducted as we cannot confidently deduce from a single ROV dive that the overall low abundance of DSC disqualifies this region as significant habitat.

What's going on "out there"? Results and applications of the Applied California Current Ecosystem Studies (ACCESS)

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The Applied California Current Ecosystem Studies (ACCESS) partnership collects integrated data on oceanographic conditions, zooplankton community (focusing on krill and copepods), seabird and marine mammal distribution and abundance in northern and central California to study the health of the marine ecosystem and provide information to resource managers, policy makers, conservation partners, and the public. ACCESS was formed by PRBO Conservation Science, Cordell Bank and Gulf of the Farallones National Marine Sanctuaries.

Ongoing surveys started in May 2004. Four to five cruises are conducted annually between April and October. Twenty-nine cruises have been completed through 2010. Ocean conditions have varied in the seven-year time period. The Southern Oscillation Index (SOI) and Pacific Decadal Oscillation (PDO) showed warm water conditions in the first three years (2004-2006), followed by cold water conditions in 2007-2009. The 2010 results showed a split, with warm conditions early in the year, followed by cold conditions in the late months. Overall zooplankton abundance was low in the first three years (2004-2006), followed by a significant increase in zooplankton abundance in 2007-2008 (particularly for euphausiids and copepods).

Abundance and distribution of resident breeding and migrant seabirds differed from species to species. Years with poor ocean conditions were linked to late and poor breeding success for Cassin's Auklets (*Ptychoramphus aleuticus*), Common Murres (*Uria aalge*), and Brandt's Cormorants (*Phalacrocorax penicillatus*). Abundance of Black-footed Albatross (*Phoebastria nigripes*) and Sooty Shearwaters (*Puffinus griseus*) also varied with ocean productivity. For marine mammals, the highest number of humpback whales (*Megaptera novaeangliae*) was observed in July 2010; blue whales (*Balaenoptera musculus*) were most abundant in 2004 and 2010.

ACCESS monitoring takes an ecosystem approach and applies the analysis of past and present data to better understand changing ocean conditions for the adaptive management of ocean use and emergency response. Specifically, ACCESS partners have provided whale abundance and distribution information for the United State's Coast Guard San Francisco Port Access Route Study and ACCESS data sets are being integrated into an Environmental Response Management Application (ERMA) for the greater Cordell Bank and the Gulf of the Farallones region.

Climate Change Effects on Species Interactions

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Much of the current climate research is focused on the effects of changing temperature on individual species ranges, called “climate envelope” studies. However, it is increasingly clear that climate change will interfere with species interactions, such as those between predators and prey, pollinators and plants, and competitors. These changes will undoubtedly have ramifications for entire ecosystems.

Intertidal communities may be one of the ecosystems most threatened by global climate change because they face changes in both aquatic and terrestrial stresses, and many species already exist at their thermal tolerance limits. We are using a rocky intertidal ecosystem as a model to understand how climate changes species interactions, especially those between predators and prey. The mussel *Mytilus californianus* is the dominant competitor for space and a foundation species. Its upper limit is set by long-term aerial thermal stress while its lower limit is controlled by the common carnivorous seastar *Pisaster ochraceus*. By eating mussels, *Pisaster* increases the diversity of competitors for space, but reduces the diversity of species living within the mussel bed.

Unlike mussels, the upper limit of mobile *Pisaster* is limited by short-term stresses, so warming climate may not negatively affect seastars as drastically as sessile mussels. Further, warming climate is predicted to increase the feeding rates of the seastars. As temperatures warm, increased pressure at both mussel limits may cause a “squeeze effect” and even local extinctions. These sorts of squeeze effects are not restricted to mussels; any species whose range is controlled by multiple factors could experience squeeze effects or range expansions as the climate changes.

To address the effects of changing climate on *Mytilus*, *Pisaster* and other intertidal community members, we are using an ideal study system of large, stationary intertidal boulders. The different sides of each boulder provide 360° of strong, predictable gradients in stressors, allowing us to investigate the effects of changing climate on species distributions conveniently at one locale. Further, a long-term experiment began in 2004 at a boulder field near Bodega Bay, California, where *Pisaster* have been removed biweekly from 12 of 24 boulders for the past 6 years. This design allows us to parse out the contributions of abiotic and biotic factors determining species distributions, and study climate effects on key species interactions.

Impacts of House Mice on Breeding Seabirds and Endemic Species of the South Farallon Islands, and a Proposed Invasive Mouse Removal Project

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Non-native rodents have adverse impacts on marine bird populations and to seabird communities and island ecosystems. Invasive rodents have been implicated in approximately 40-60% of bird and reptile extinctions globally. Introduced House mice (*Mus musculus*) on the South Farallones have altered the island ecology in ways that are disproportionate to their small size. Mice are endangering the Ashy Storm-petrel (*Oceanodroma homochroa*) as well as the endemic plants, amphibians, and invertebrates of the Farallon ecosystem. The decline of Ashy Storm-petrels and likely Leach's storm-petrels (*Oceanodroma leucorhoa*) on the South Farallones is partially driven by the interaction between wintering burrowing owls and non-native mice in a process known as *hyperpredation*. A non-breeding transient burrowing owl population is being artificially subsidized by a large mouse population in the fall and early winter. With the cyclical decline of mouse numbers in late winter, the wintering owls shift to preying on petrels and other seabirds. PRBO estimates the owls subsidized by the mice kill 225-270 Ashy Storm-petrels each year.

Mark/recapture studies conducted by Island Conservation in the fall of 2010 recently revealed that the invasive house mouse population on Southeast Farallon reaches plague-like densities of over 1200/ha, one of the highest reported mouse densities in the world. Mice at these densities can collectively consume over 150 kg of plant, invertebrates and bird biomass per hectare each month. The omnivorous mouse diet is known to include endemic Farallon Goldfields, and likely endemic Farallon Camel Crickets, endemic Farallon Arboreal Salamanders, as well as eggs and chicks of breeding seabirds. In addition to consuming plants used for nesting material by seabirds, burrowing mice may also be disturbing and competing with cavity-nesting seabirds, and affect the intertidal algal and marine invertebrate environment and thus shorebirds as well. The removal of introduced rodents from islands can be a highly successful and important conservation tool for land managers interested in recovering seabird species that are threatened with extinction or declining populations. Introduced rodents have been successfully removed from more than 330 islands worldwide using techniques that have evolved and adapted and refined over the last three decades. To assist in the protection and restoration of the South Farallon Islands ecosystem, including Ashy Storm-petrels and other native biological resources, the U.S. Fish and Wildlife Service and its partners (PRBO and Island Conservation), are now developing an EIS to assess the alternatives to be used to eradicate all mice from the Farallon National Wildlife Refuge.

Surface Water Pathways From Cape Mendocino to the Golden Gate

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In order to improve the monitoring of near-coastal waters and newly established Marine Protected Areas, the state of California installed a series of high frequency radar (HF Radar) stations along the U.S. West Coast (Coastal Ocean Currents Monitoring Program, <http://www.cocmp.org>). The stations provide hourly estimates of surface current speed and direction from coast into the deeper ocean, with a spatial resolution that varies from 2 to 6 kilometers depending on the location. Complete coverage of the central California coast was achieved by mid-2006, with longer observational records near Bodega and Monterey Bays. The HF Radar stations provide higher spatial and temporal resolution than is available via satellite, although the satellite records allow the “local” HF Radar measurements to be placed in a longer-term context. Together, the systems enable detailed investigation of upper ocean processes, with particular emphasis on connectivity between upwelling “hotspots” and productive marine sanctuaries.

In this presentation, we focus on recent observations of surface water pathways from Cape Mendocino, Point Arena, and Bodega Bay to the productive marine sanctuaries offshore San Francisco. We summarize transport during upwelling conditions, and emphasize the large-scale recirculation patterns offshore Bodega, as well as the occasional seasonal development of the Cape Mendocino Eddy. The canonical picture of the transport of nutrient rich waters to the sanctuaries during upwelling favorable winds needs to be modified by a more nuanced view, with the eddies and recirculations influencing (and occasionally dominating) the surface water pathways. Some of these features appear more likely during specific wind patterns. Apparently, the “delivery system” of surface waters can be significantly locally modified by changes in the currents near the shelf during shifting atmospheric and oceanic regimes. Teasing apart the relative contributions of “typical” and “rare” surface current patterns to the connectivity between the marine sanctuaries and the areas to the north will be aided by continued HF Radar observations, and research into blending HF Radar and satellite measurements.

Re-discovering Cordell Bank: Technical Dive Expedition 30 years later

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For the first time since the designation of the Cordell Bank National Marine Sanctuary (CBNMS) in 1989, and 32 years after the initial exploration of Cordell Bank by SCUBA divers from the non-profit group Cordell Expeditions, technical scientific SCUBA divers revisited the shallowest parts of Cordell Bank's reef crest (123-193ft) on October 7-9th, 2010.

Six technical dives were completed in rigorous conditions at five sites on Cordell Bank. Three of the dive sites had previously been sampled by Cordell Expeditions in the 1980s, while two other sites had been surveyed by a submersible in the 2000s. Divers collected invertebrate specimens, high definition video and still images to be used for site characterization and temporal comparisons of the habitats and species composition of the reef crest environment.

A total of 112 specimen lots collected by the divers have been sorted by taxonomists at the California Academy of Sciences. Of these lots, 22 are Mollusca, 21 Porifera, 21 Arthropoda, 16 Echinodermata, 13 Cnidaria, 8 Bryozoa, 6 Annelida, 2 Brachiopoda, 2 Chordata and 1 Sipincula. Of particular interest are the northern range extensions of the barnacle *Megabalanus californicus* and some decapod shrimp. Four lots of the hydrocoral *Stylaster* having different colony morphology were collected. The *Stylaster* specimens will contribute to our understanding of the unique role played by Cordell Bank as habitat for the northern *S. venustus* and the southern *S. californicus* whose ranges overlap at Cordell Bank. One sediment sample was collected and analyzed for Foraminifera by Mary McGann (USGS). A human-created hole originally described by Robert Schmieder (Cordell Expeditions) was found to still contain a metal pipe left by Cordell Expeditions divers 30 years ago. Today, there is 100% invertebrate coverage in and around the hole verses the virtually bare rock documented by Cordell Expeditions in 1981. A striking observation from the series of dives on the shallower sections of Cordell Bank was the abundance of juvenile rockfish indicating a successful recruitment in 2010.

Images captured by the dive teams illustrated the abundance, diversity, and color palette of life on Cordell Bank. The photos, video, and invertebrate specimens collected during this mission are being used to compare the current community composition to historical conditions and will serve as a baseline upon which to measure future change on Cordell Bank.

Developing the Applied California Current Ecosystem Studies (ACCESS) into an Ecosystem-Based Management (EBM) Network project

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The Applied California Current Ecosystem Studies (ACCESS) is a partnership that was initially founded by PRBO Conservation Science, Cordell Bank National Marine Sanctuary, and Gulf of the Farallones National Marine Sanctuary. The ACCESS partnership currently includes twelve stakeholder groups including government agencies, academia, scientists, and NGOs. Currently, no commercial business, recreational users or public participate actively on ACCESS; however, a initial approach to involve local fishers has been made.

The ecosystem goal of ACCESS is to support marine wildlife conservation and healthy marine ecosystems in northern and central California by conducting ocean research to inform resource managers, policy makers and conservation partners. The Plan of Action is broad and includes 1) improving conservation of marine wildlife and their food webs, 2) improving ocean zoning by guiding human uses of the marine ecosystem, 3) documenting the effects of climate change on the marine ecosystem, 4) contribute to ecosystem-based management approaches of local fisheries, 5) contribute to assess the ecosystem effects of freshwater outflow from San Francisco Bay.

Data and expertise from ACCESS are being used proactively to inform sanctuary management, for example, ACCESS data on whale abundance and distribution was provided to the United State's Coast Guard San Francisco Port Access Route Study and ACCESS data sets are currently being integrated into an Environmental Response Management Application (ERMA) for the greater Cordell Bank and the Gulf of the Farallones region. Data will become available as part of the California Avian Data Center (<http://data.prbo.org/accessoceans>).

The ACCESS partnership effort's in the greater Cordell Bank and the Gulf of the Farallones region resembles similar efforts of the six community-based Initiatives focused on the successful implementation of ecosystem-based management (EBM) along the coasts of Washington, Oregon and California. These Initiatives form the West Coast EBM Management Network and have begun implementing EBM approaches for the unique and specific needs of their community and associated ecosystem. In this presentation we assess what the ACCESS Partnership can offer to and learn from the EMB Network to advance marine conservation in central California.

Assessing Potential Resource Utilization by Gray Whales in the Gulf of the Farallones National Marine Sanctuary Waters

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Gray whales have been called “sentinels of climate change” and little is known about the organisms upon which they are feeding within the Gulf of the Farallones National Marine Sanctuary (GNMS) waters or within other coastal segments. In late April to May 2009, gray whales began to forage regularly between Mori Point and Point San Pedro in relatively shallow waters (3-6 fathoms). This feeding activity had not been previously documented, and while gray whales have been sighted frequently over the past 20 years foraging in summer months near SE Farallon Island (SEFI), the prey organisms were unknown. While there is a legacy of waste dumping in the GNMS from the 1940s through the 1960s, as well as sunken vessels containing petroleum products and other contaminants, it appears that any legacy contamination may reside in deeper depths (in finer grain sediments) off the continental shelf. Sediment samples were collected in two relatively shallow shelf sites (maximum of 15 fathoms depth) with a modified Van Veen sediment grab (upper 10 centimeter strata), off Pacifica and in the vicinity of the SEFI, in August and September 2009. The sediments were analyzed for chemical composition and benthic community. Sediment chemistry analysis showed low to non-detect levels of standard list of chemical constituents (metals and organics), which was expected for coarse-grain sediments subject to wave and current energy typical of shelf environment. A total of 5,758 organisms were collected and preserved for benthic community analysis. Taxonomic analysis revealed an abundant species list of prey organisms typically targeted by benthic feeding fishes. While polychaetes and crustaceans dominated in both sites, there were distinct differences in the species assemblages between the Pacifica and SEFI sites. Gray whales may be utilizing these benthic resources in these areas, as well as swarms of krill in the water column at SEFI. Further studies are warranted to confirm this resource utilization.

Spatial distribution of blue and humpback whales relative to San Francisco, California shipping lanes and vessel traffic

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The identification of cetacean habitat use associated with major feeding areas for endangered blue (*Balaenoptera musculus*) and humpback whales (*Megaptera novaeangliae*) within areas of high ship densities has become of greater conservation importance in the San Francisco Bay area due to the three endangered whales that died from ship strike injuries during July, September and October 2010. The objective of this study was to examine ship use in shipping lanes approaching San Francisco Bay in relation to temporal and spatial high use areas of blue and humpback whales to identify primary areas of overlap and assess potential risks. The study area extended from 35.5-38.5 °N. latitude and from 121-124°W. longitude and included Cordell Bank, Gulf of the Farallones, and Monterey Bay National Marine Sanctuaries. To quantify the risk imposed by vessels on whales, GIS analyses were conducted using Automatic Identification System (AIS) ship data and historical whale sighting data during selected time periods to identify primary habitats for seasonal foraging whales. Results indicated 1) increases in ship use of the western approach lanes that cross the shelf edges due to the air pollution-related fuel requirements and 2) a clear overlap of vessel traffic densities and whale distributions and densities during seasonal high use feeding locations associated with shelf edges. The identification of high risk areas associated with the shelf edges will contribute important information about redesigning shipping lanes to minimize vessel traffic time along these critical habitats. Results of cetacean habitat use within areas of high ship densities are being shared with the US Coast Guard and participation in a National Marine Sanctuary Advisory Council Joint Working Group to assess issues and problems related to impacts of vessel traffic on large whales and provide recommendations to develop future action plans to implement important marine conservation goals.

Central Bay Sand Resource and the Golden Gate

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The construction sand resource of Central San Francisco, in unconsolidated Quaternary sediment deposits, is important for the local economy. The resource belongs to the State of California and is leased by the State Lands Commission to sand mining companies. The sand miners have supported scientific research to better understand the geologic aspects of the deposits. Activities supported include: bathymetric studies by USGS/CSUMB; sediment transport modeling by CEQA process consultants; and other consultant studies including lithologic descriptions and particle size evaluation. Important results to date are: 1) Lithologic and particle size analyses indicate that an important source of the material is the Golden Gate itself, particularly serpentine deposits on the south side; 2) Bathymetric changes in the interval 1997 - 2008 associated with sand mining are largely restricted to the immediate vicinity of mining activity and are not affecting more distant areas, including beaches; 3) The bathymetric changes are approximately the same volume as the mined sand, so, at most, limited deposition is currently occurring; 4) Evaluation of fine scale bathymetric features associated with sand waves indicates that some transport is presently occurring along the bottom.

Benthic Infauna and Sediment Patterns in the Nearshore Gulf of the Farallones

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The City and County of San Francisco has monitored sediment quality and benthic infauna communities in the nearshore Gulf of the Farallones since 1982. The primary purpose of the monitoring program is to determine the effects of a wastewater discharge on the receiving water environment. The program has documented temporal changes in infauna communities that correspond to major oceanographic events. Regional monitoring since 1997 has identified consistent patterns of sediment grain size distribution that correspond to three distinct infauna communities. One community characterized by suspension feeders and interstitial forms occurs in coarse and medium sands in the interior of the ebb tide delta that surrounds the mouth of San Francisco Bay. A shallow-water, high energy community with a high proportion of Crustacea occurs in the fine sands that compose the sandbars of the delta, while the most diverse community occurs in very fine sands seaward of the sandbars. 2007 saw an as yet unexplained and substantial increase in the percentage of silt and clay in the surface sediments of the study area, which have since declined annually although not yet back to “background” percentages established from 1997 – 2006.

Decreased solar radiation and increased temperature combine to facilitate the spread of marine non-indigenous fouling species in Elkhorn Slough, California

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Studies of the effects of climate changes on biological invasions have focused on the effects of temperature increase. However, decreased level of solar radiation could also influence the spread of non-indigenous species (NIS). Here we tested if combination of decrease in solar radiation and/or increased temperature influences the establishment and persistence of marine invasive fouling species in estuaries. We manipulated solar radiation by deploying different shading devices (black, white, or transparent screens) over recruitment tiles placed in the intertidal zone of a central California estuary containing over 50 marine NIS. To decouple the effects of temperature and light on colonization, we also compared recruitment between undersides of black and white plates used as screens in the previous study. Non-indigenous fouling species had greater recruitment and growth under the shading treatments (black and white screens) than under transparent plates, indicating that low radiation facilitates establishment and persistence of NIS in the intertidal region. The abundance of NIS was greater on recruitment substrates placed under white screens, where solar radiation and temperature are both higher than under black screens. In contrast, the coverage of NIS on the underneath of warmer black plates was higher than that of white plates, indicating that increased temperature accelerates recruitment and growth of NIS. Additionally, spatial comparisons of recruitment showed that NIS had a tendency to recruit and grow better in the warmer region of the estuary whereas native species showed the opposing trend. Taken together, results suggest that both lower radiation and higher temperature facilitate the spread of marine NIS.

Acidified and lowly oxygenated water driven by upwelling along the west coast of California may affect the mortality and growth of the red abalone *Haliotis rufescens*

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Exposure of nearshore animals to hypoxic, low pH waters upwelled from below the continental shelf and advected to near the coast may be stressful and lead to impaired physiological performance. Along the west coast of California, episodes of upwelled, low O₂, low pH waters are observed frequently in nearshore areas. We mimicked these conditions in the laboratory and tested the effect of short-term exposure to water with low oxygen (40% saturation, 5mg/L) and/or acidification (pH 7.5) on the mortality and growth rate of juvenile red abalone (*Haliotis rufescens*, carapace size 5-10mm). When exposure time was 3 to 6 hours at the interval of 3-5 days, the mortality rates of juvenile abalones did not differ between low O₂, low pH treatments and control conditions (surface: high O₂, pH). When they were exposed for 24 hrs two times per 15 days at 7 day interval, abalone experienced higher mortality under low oxygen treatments than high oxygen treatments (100% saturation, 12mg/L) regardless of pH levels (pH 7.5 vs. pH 8.0). In contrast, growth was significantly lower when they were exposed to acidified water than when they were exposed to any other treatments. These results indicate that whereas oxygen concentration is detrimental for survival of red abalones, pH (or related factors) is a crucial factor for their growth. Further, our results imply that even short-term exposure to upwelled waters can significantly influence the mortality and growth rate of abalones.

Interactions of San Francisco Bay Outflow with Coastal Upwelling

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San Francisco Bay waters are jetted seaward from Golden Gate each tidal cycle. Beyond the immediate tidal effect, this bay effluent is subject to direct wind forcing, wind-driven ambient currents, ambient pressure gradients, and buoyancy forcing. The general transport pattern alternates between a southbound offshore route during upwelling periods and a northbound onshore route during strong freshwater flow, during southerly winds, and during times of relaxation from upwelling winds. While these larger scale patterns show intriguing interactions with coastal upwelling, it is local small-scale patterns that control contact with the shoreline and that may be most important for a variety of ecological issues, including fate and transport of contaminants, dispersal of plankton, coastal ocean productivity, and harmful algal blooms. An emerging understanding of Bay outflow and its importance to the Gulf of Farallones ecosystem can be expected to guide improved management of the Bay-ocean system and also represents an important step toward anticipating the impacts of climate-change on the coastal ocean, including the effects of stronger upwelling winds and the changing seasonal runoff.

Habitat Complexity and Biodiversity as Indicators of Endangered Black Abalone (*Haliotis cracherodii*) Presence in Central California

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Assessing the strength of species-habitat relationships is critical to the understanding of marine ecological systems for efficient and effective management decisions, reserve implementation, and design. In this study, terrestrial landscape modeling techniques were adapted for analysis of local biodiversity and habitat complexity, as primary factors indicative of endangered black abalone (*Haliotis cracherodii*) presence within intertidal landscapes in Monterey Bay, CA. The combination of (1) over-harvesting from black abalone fisheries in the mid 1900's; (2) the bacterial disease 'Withering Food Syndrome (WS)'; (3) environmental stressors; and (4) their fickle reproductive requirements have been suggested as contributing factors to massive population declines that resulted in the placement of black abalone on the federal endangered species list in 2008. High-resolution digital photographs were taken from rocky crevices where black abalone are observed within Monterey Bay at 3 sites; (1) Garrapata State Beach, (2) Point Lobos State Natural Reserve, and (3) Hopkins Marine Station. Subsequent images were analyzed for biodiversity. Black abalone movement within the confines of my study sites were monitored for a full year and assigned coordinate information using ArcGIS 9.0 software. Generalized linear models (GLMs) were used to quantitatively estimate the relationship between black abalone presence and landscape derived habitat and biodiversity variables. The results of my analysis will suggest the habitat suitability between landscape derived habitat and biodiversity variables and black abalone presence.

What Are They Doing Out There? Baseline Characterization of the North Central California Coast

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Overview: The ultimate success of any management measure, spatial or otherwise, in the marine environment is predicated on a clear understanding of the baseline conditions present at the time of implementation. In locations where comparatively little is known about the biological community and the environment in which it occurs, a baseline characterization can provide the reference points needed to evaluate the success of a management regime at some future date.

In 2010 the Marine Life Protection Act (MLPA) process resulted in the implementation of 22 marine protected areas (MPAs) throughout the North Central Coast Study Area (Pt. Arena to Pillar Point, including the Gulf of the Farallones) as part of a state-wide network of MPAs. The MLPA process requires a 5-year review of the status of resources inside and out of the MPAs in each study region. This presentation will describe the efforts to characterize the deep subtidal areas across the study region to lay the groundwork for future monitoring efforts.

Project goals and objectives: The objective of this project is to collect data on the structural and biological attributes of communities in the deep (20 – 116 m) benthic rock and soft-bottom ecosystems across the full extent of the North Central Coast Study Area. Specifically, we collect information on the microtopographic attributes of seafloor habitats (including biogenic and physical structure), epifaunal macroinvertebrates, and demersal fishes. Where possible, five treatment sites were selected at each location – inside and outside the SMR, inside and outside the SMCA, and a site relatively distant from both but of similar depth distribution and bottom habitat composition to be considered a reference site.

Summary of project activities completed to date: In 2010 we sampled inside and out of eight MPAs, including State Marine Reserves (SMRs) and State Marine Conservation Areas (SMCAs) at four locations (listed from north to south) 1): Pt. Arena SMCA and SMR, 2) Bodega Head SMCA and SMR, 3) South Farallone Island SMCA and SMR, and 4) Montara SMR and Pillar Point SMCA. In 2011 we re-sampled each of those four locations and added the Point Reyes SMR and SMCA.

The remotely operated vehicle (ROV) *Beagle* was used to collect photographic and continuous videographic imagery along transects. All operations were conducted from the F/V *Donna Kathleen*. Multiple ROV transects at each location encompassed hard bottom habitats, soft sediment habitats, and the transitional areas between the two. The analysis of more than 20,000 still photographs and more than 300 hours of video is on-going. In advance of the completed analyses, we implemented a rapid assessment protocol for data collection and developed a new graphical approach to visualize those data to provide data summaries to managers in the near term.

Gulf of the Farallones Beach Watch program: informing Natural Resource Damage Assessment in the San Francisco Bay Area's Outer Coast.

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The Gulf of the Farallones National Marine Sanctuary's first priority following an oil spill is to ensure future restoration of impacted sanctuary resources. GFNMS's Beach Watch Program is in a unique position to provide both historic and near real time data to Natural Resource Damage Assessment for spills impacting the San Francisco Bay Region. NRDA, a joint federal and state board of experts appointed to determine the impacts imparted by a specific oil spill event, which directs restoration efforts. Beach Watch surveys are designed to understand shoreline sanctuary resources and establish baseline, status and trend data for live and dead birds and marine mammals, oil/tarball deposition, and human-use activities. Since 1983 bimonthly surveys have been completed for on 42 beaches from Bodega Bay to Año Nuevo State Park. During a spill, Beach Watch is additionally able to deploy a trained cadre of staff and volunteers on beached bird and mammal surveys and collection of oil as evidence for Natural Resource Damage Assessment. Beach Watch can provide NRDA pre-spill monitoring as well as near real-time status of species or habitats at risk, and historic trends of impacted species or rates of occurrence. All of these resources contribute to the direction and lead or assist in the development, extent, location, and duration of restoration projects. New ways of documenting beached animals and oil such as geotagged photo documentation expand our capacity to collect evidence that can be used in NRDA. Beach Watch has collected data through six major spill events in the San Francisco Bay Area, and continues to collaborate and refine our efforts for the future.

Japan Tsunami Current Flows Observed by HF Radars on Two Continents

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Quantitative real-time observations of a tsunami have been limited to deep-water, pressure-sensor observations of changes in the sea surface elevation and observations of sea level fluctuations at the coast, which are essentially point measurements. Constrained by these data, models have been used for predictions and warning of the arrival of a tsunami, but to date no detailed verification of flow patterns nor area measurements have been possible. Here we present unique HF-radar area observations of the tsunami signal seen in current velocities as the wave train approaches the coast. Networks of coastal HF-radars are now routinely observing surface currents in many countries and we report clear results from five HF radar sites spanning a distance of 8200 km on two continents following the magnitude 9.0 earthquake off Sendai, Japan, on 11 March 2011. We confirm the tsunami signal with three different methodologies and compare the currents observed with coastal sea level fluctuations at tide gauges. The distance offshore at which the tsunami can be detected, and hence the warning time provided, depends on the bathymetry: the wider the shallow continental shelf, the greater this time. Data from these and other radars around the Pacific rim can be used to further develop radar as an important tool to aid in tsunami observation and warning as well as post-processing comparisons between observation and model predictions.

Published: 2 August 2011: *Remote Sens.* 2011, 3, 1-x manuscripts; doi:10.3390/rs30x000x; Open Access; Remote Sensing, ISSN 2072-4292; www.mdpi.com/journal/remotesensing

Sanctuary Integrated Monitoring Network (SIMoN)

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The Sanctuary Integrated Monitoring Network (SIMoN) is an integrated, long-term program that takes an ecosystem approach to identify and understand changes within sanctuaries managed by the Office of National Marine Sanctuaries. SIMoN provides information to resource managers for effective decision-making and provides an introductory understanding of the complex and unique marine processes within the California Current ecosystem. By gathering summary metadata from on-going, recently completed and historic monitoring and research projects within sanctuaries, SIMoN facilitates the critical but often overlooked communication between researchers, resource managers, educators and the public.

SIMoN, and in particular the SIMoN web site, was designed as a powerful tool for sanctuary staff to quickly access summary information on hundreds of monitoring and research programs. Sanctuary staff also seeks to increase the effective use of scientific research by integrating existing programs and identifying gaps in information. To avoid duplicating programs and leverage available resources, managers and their staff must first know what has been done in the past and which programs continue to collect data. With this knowledge, managers can more effectively target their limited resources on surveying and characterizing under-studied habitats, assessing the impact of natural processes or human activities on specific resources, and implement relevant, long-term monitoring programs.

The SIMoN web site also offers a variety of tools to access basic and advanced data characterizing the west coast sanctuaries and the natural resources and processes protected by sanctuaries. Among the more popular tools are the Photo Library, with nearly 4000 digital images of marine organisms, habitats, and activities; the Species Database, with natural history information on 130 species commonly occurring within the west coast sanctuaries; and Interactive Maps that allow users to manipulate a Google map interface to better visualize where research and monitoring projects are taking place in sanctuaries.

Finally, SIMoN not only provides information to managers, decision makers, the research community, but also to the general public. SIMoN serves as a hub for initiating and integrating data collecting efforts and disseminating information.

Do Macrophyte Wrack Species Composition and Input Rates Influence the Distribution and Abundance of Talitrid Amphipod (*Megalorchestia* spp.) Populations on Northern California Beaches?

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Sandy beaches are characterized by low levels of in situ primary productivity but high inputs of subsidies from adjacent marine habitats. Sandy beach consumers in temperate regions rely on inputs of carbon and other organic nutrients from adjacent marine habitats primarily in the form of deposited marine macrophytes. Surprisingly little ecological study has been done on these communities in northern California, despite extensive research in other parts of the world. Here we report results of our research at four beaches (Miwok, Salmon Creek and Doran beaches in Sonoma Co. and Dillon Beach in Marin Co.) aimed at increasing our understanding of the factors that affect the distribution and abundance of talitrid amphipod populations in northern California.

The composition of allochthonous macrophyte inputs varies seasonally as well as among beaches probably due at least in part to their proximity to different habitat types (e.g., rocky intertidal and subtidal reefs vs. estuaries and bays). Some macrophyte wrack types are more palatable to talitrid amphipods than others, yet they may all have similar value as habitat. Prior work has shown that kelp wrack is typically preferred by talitrid amphipods over other seaweeds and in southern California these amphipods are more abundant where standing crop of wrack is highest. Another common component of wrack, eelgrasses (e.g., *Zostera* spp.), are thought to be unpalatable due to the presence of zosteric acid. However, most descriptions of the distribution and abundance of amphipod species found in reference texts focus on physical characteristics of beaches, despite the fact that these have not been well supported by empirical field studies. To tease apart the relative influence of these factors on amphipod abundance patterns, we are combining field surveys of: 1) wrack composition and input rates, 2) population sizes of talitrid amphipods and 3) physical characteristics of the beaches (i.e., beach slope, significant wave height, sand grain size) over time with field and laboratory experiments to assess amphipod feeding preferences and wrack consumption rates.

Our weekly surveys show that inputs to Dillon Beach and Doran Beach are dominated by *Zostera* while inputs to Salmon Creek Beach and Miwok Beach are predominately brown algal wrack (kelp and fucoid algae). Surprisingly, the two *Zostera* dominated beaches have the highest abundance of amphipods (>30,000 m⁻¹ vs. < 500 m⁻¹ of shoreline), although the relative abundance of amphipod species varies among the beaches. Feeding preference trials, interactions between feeding rate and sand grain size and field consumption rates of the dominant macrophyte types are in process and will allow us to test specific mechanistic hypotheses about the factors that influence the abundance of these species among beaches.

Recovery of the Common Murre (*Uria aalge*) in Central California

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The central California breeding population of Common Murres (*Uria aalge*) extends from the Point Reyes Headlands to Point Sur, although most birds occur within the Gulf of the Farallones. This population experienced severe declines in the mid-19th to mid-20th centuries due to commercial eggging and oil spill mortality. Following partial recovery in the mid-20th century, the central California murre population again declined rapidly (about 50%) in the mid-1980s mainly because of large-scale set gill-net fishery and oil spill mortality as well as impacts of the strong 1982-83 El Niño event. These declines also resulted in the extirpation of one murre colony at Devil's Slide Rock (DSR). Efforts by California and U.S. agencies led to a series of restrictions to the gill-net fishery beginning in the mid-1980s that substantially reduced murre mortality. In the early 1990s, most colonies began to reverse the declining trend. Beginning in 1996, funds from the 1986 *Apex Houston* oil spill settlement were used to restore the DSR colony using social attraction techniques and to assess other colonies. In the late 1990s, the discovery of continued gill-net mortality in the Monterey Bay area led to broader-scale restrictions that essentially eliminated this fishery. Reduced anthropogenic mortality combined with favorable ocean and prey conditions in the 1999-2007 period resulted in rapid increases at most colonies. By 2007, most colonies had recovered to or exceeded the early 1980s levels although some colonies, such as at DSR, are still below pre-decline sizes. Since 2007, reduced prey availability in certain years led to lower than average murre productivity and may be slowing population growth. A recently established program to reduce human disturbance at colonies will assist further recovery. Other, sometimes severe impacts to certain murre colonies include disturbance from Brown Pelicans (*Pelecanus occidentalis*) and Common Ravens (*Corvus corax*).

Seabird hot spots in Central California's National Marine Sanctuaries and their implications for oil spill response preparedness and marine spatial planning

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Oil-related incidents from industrial shipping are one of the most significant threats to marine wildlife in the Cordell Bank and Gulf of Farallones National Marine Sanctuaries. The goal of this study is to identify predictable foraging habitats used by resident species of marine bird to inform oil spill response preparedness and improve ocean zoning thus contributing to new marine spatial planning efforts in central California. We used data collected during the Applied California Current Ecosystem Studies (ACCESS, www.accessoceans.org) cruises conducted by PRBO Conservation Science, Cordell Bank and Gulf of the Farallones National Marine Sanctuaries from 2004 to 2010. Marine bird data was collected using standardized strip transect survey methods and binned at 3-km intervals. Hydrographic data was collected continuously using a thermosalinograph equipped with a fluorometer and averaged to single values that matched the 3-km bins used for birds. Bathymetric data was extracted using a Geographic Information System for each 3-km bin. We modeled the distribution and abundance of resident marine birds relative to bathymetry and hydrography using negative binomial regression. We used models to predict preferred foraging habitat within the study area. Preferred foraging habitat raster surfaces were combined using MARXAN to identify hotspots for each species and across species. We present preliminary results that show the value of these analytical approaches to improve marine conservation in central California.

Hair concentrations of mercury and selenium in Pacific harbor seals (*Phoca vitulina richardii*) off central California

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Pacific harbor seals (*Phoca vitulina richardii*) inhabit nearshore areas along the central California coast, including Monterey Bay, San Francisco Bay (SFB), and Tomales Bay, and their associated coastlines. Because of their year-round presence, relatively long life-span, and ability to accumulate contaminants, harbor seals are considered good indicators of ecosystem health. Harbor seals have the potential for increased exposure to toxicants as they often inhabit areas that are heavily urbanized, therefore, understanding exposure levels and potential health problems associated with toxicants is important. It has been suggested that a proportion of harbor seals that use SFB may suffer from chronic selenium toxicity, and the study objective was to evaluate this hypothesis. We measured total mercury (THg) and selenium (Se) concentrations in hair, and Se:Hg (molar ratio interaction) of harbor seals caught off central California from 2009-2011 (n=145). THg concentrations ranged from 2.96 to 144 µg/g, and differed significantly with location (P<0.01; SFB=Tomales Bay>Elkhorn Slough) and sex (P<0.01; males>females). Seals in SFB had greater variability in THg concentrations when compared with the other two sites, and greater concentrations than previously reported. Se concentrations in hair ranged from 0.21 to 4.93 µg/g, and differed significantly among sites (P<0.01; Elkhorn Slough>SFB=Tomales Bay). Differences in THg concentrations among sites were likely due to contamination from historic mining activities in SFB and Tomales Bay. Greater THg concentrations in males might be explained by the ability of females to offload mercury to their developing fetuses. Variability in THg may reflect differences in foraging ecology (e.g. location, prey type, prey size), and is currently being evaluated using carbon, nitrogen, and sulfur stable isotopes. The lack of differences in THg and Se concentrations between SFB and Tomales Bay may be the result of similar concentrations of THg and Se at each site, and/or movement of seals between sites. Results do not support the hypothesis that harbor seals from SFB may be suffering from chronic Se toxicity, however, the lesser concentrations of Se in hair from seals captured in SFB and Tomales Bay is an important nutritional consideration in the context of Hg and observed hair coat changes. Se: Hg molar ratios varied by location, indicating further investigation is warranted. Results support previous suggestions that hair may serve as an important excretory route for some toxicants.

Modeling the dispersion and habitat associations of Black-footed Albatross in Central California National Marine Sanctuaries

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We characterized the seasonal (chick-rearing, post-breeding) and inter-annual (2004 – 2008) distribution and abundance of black-footed albatross (*Phoebastria nigripes*; BFAL) in Cordell Bank and Gulf of the Farallones National Marine Sanctuary (NMS) waters using standardized vessel-based survey data from the Applied California Current Ecosystem Studies (ACCESS) partnership. Using a hypothesis-based approach, we quantified the relative relationship of (1) seasonal and inter-annual variability, (2) static habitat features, (3) local / regional dynamic oceanographic habitats, and (4) basin-wide fluctuations with BFAL occurrence (presence/absence) and abundance (number). BFAL occurrence was greatest near the shelf break in months with strong northern and southern upwelling. Abundance increased over the study period, with high abundance associated with large-scale productive conditions, strong regional upwelling, and the rearing season. Although occurrence onshore of the shelf break was rare, occasional large groups of BFAL were observed sitting on the water, often near Rittenburg Bank. Our findings indicate that BFAL dispersion is a complicated balance of static and dynamic features with unique patterns for occurrence and abundance. The shelf break, particularly during months of strong upwelling may provide BFAL important foraging habitat. Occasional large groups of albatross sitting onshore of the shelf break could be related to past feeding events, where BFAL remain within the area while digesting or awaiting favorable wind conditions. Continued monitoring of BFAL is essential for managers to accurately assess of patterns and trends in BFAL habitat use within NMS waters.

Larval advection and behavioral control regulating population connectivity in upwelling regions: Implications for the adaptive management of our network of marine protected areas.

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Connectivity among marine populations is poorly known, because we have little idea of where planktonic larvae go. Spatial variation in currents can cause populations in some areas to receive or export more larvae than other populations, even though habitat quality may be similar among locations. The goal of this arm of my research program is to improve estimates of population connectivity for the management of fisheries stocks and evaluation of the newly implemented network of marine protective areas along the coast of California and other upwelling regions. We have used a multifaceted approach to address this challenging problem. We conducted cross-shelf surveys of the larval assemblage of nearshore benthic crustaceans (43 species) while monitoring larval recruitment across the upwelling cell that extends from Point Reyes to Point Arena, which includes a major upwelling center and coastal jet that are believed to transport larvae from adult populations. We demonstrated that sweeping generalizations regarding the role of oceanographic processes affecting larval transport and settlement in productive upwelling regions along the western margins of continents require much closer scrutiny to provide reliable information on larval connectivity between source and sink populations. Contrary to the prevailing view, larvae of most invertebrates appear to exert considerable control over their movements, remain very close to shore and recruit onshore in strong upwelling conditions. Fewer species reliably migrate different distances across the shelf. We are now testing our conceptual model regarding the behavioral and physical mechanisms regulating cross-shelf transport, supply and connectivity across the upwelling cell using three approaches. First, we estimated connectivity of a representative species that retains larvae nearshore (porcelain crab *Petrolisthes cinctipes*) across 29 populations from Big Sur to the Oregon border (~700 km). We used a Bayesian inverse modeling approach in which prior estimates of larval transport and connectivity (a dispersal kernel) were combined with field estimates of larval production and larval settlement to obtain updated estimates of connectivity patterns. Estimated connectivity patterns reveal considerable spatial heterogeneity in the strength of larval sources, as a consequence of variation in habitat quality, population density and estimated oceanographic dispersal distances. In contrast to widespread expectations, larvae were estimated to disperse very short distances strongly coupling larval production and settlement. We anticipate that our approach will be broadly applicable worldwide in situations where information on dispersal from larval tracers or circulation models is unavailable. Second, we are developing a natural elemental marking technique for determining population connectivity of species that do not retain calcified structures during larval development. This approach is being used to establish larval connectivity of up to 21 populations for five years from northern California to southern Oregon. Third, we are planning to incorporate the innermost shelf and identified suites of larval behaviors into ocean circulation (ROMS) models to provide more realistic estimates of larval transport and connectivity for the wide diversity of species that inhabit nearshore communities along our coast. Thus, our results indicate that larvae of many species may settle closer to natal habitats than is commonly believed, even in highly advective upwelling regimes, which has important implications for designing and evaluating networks of marine protected areas.

Population Viability of Cassin's Auklets on the Farallon Islands in Relation to Environmental Variability and Management Actions

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The Cassin's Auklet, a small krill-eating seabird, is a California Species of Special Concern. Since 1970, PRBO Conservation Science (PRBO) has continuously monitored the population of breeding Cassin's Auklets on Southeast Farallon Island (SEFI), the largest colony in California. This population has shown declines of over 70% since the 1970's and has demonstrated strong sensitivity to climate variability. To examine the long term viability of this population we conducted state-of-the-art statistical analyses to estimate demographic parameters for this population. We then developed a stochastic population-dynamic model to project future population trends in the face of anticipated climate change and potential management action.

Results of the Population Viability Analysis demonstrated that over the next 20 years:

- The Cassin's Auklet population on the Farallon Island is expected to be able to maintain its current population levels assuming future El Niño events continue at the same frequency as has been observed over the past 100 years.
- However, the population is expected to decline on average by 27% over the next 20 years if El Niño events continue at an increased frequency, as has been observed in the last 30 years. Furthermore, in such a scenario there is a 25% probability that the population will decline by over 60% and a 5% probability the population will decline to fewer than 3700 individuals (i.e., an 85% decline).
- The population is expected to decline by >62% over 20 years if the oceanographic anomaly of 2005 and 2006 were to re-occur and El Niño events continue at the same frequency as has been observed in the last 30 years.
- Partial reduction of adult mortality due to predation has the potential to counteract expected population declines, turning substantial declines into stable populations. Western Gulls are the principal predator of Cassin's Auklets, responsible for over 80% of depredated Cassin Auklet sub-adults and adults observed in the field.

There is thus great benefit to management action that reduces predation, even partially, given anticipated future climate variation. Without reduction in predation mortality, the prospects for future population growth are very unlikely.

Baseline Characterization and Monitoring of Sandy Beaches in California's North Central MPAs

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Sandy beaches and adjacent surf zones are important foraging areas for shore birds and fishes that feed on intertidal invertebrates. The amount of wrack and plankton cast onto beaches is dynamically linked to adjacent ecosystem features, ocean climate and the growth rates and reproductive output of invertebrates. These links are the critical pathways through which direct and indirect effects of marine protected area (MPA) implementation and variation in ocean climate will cascade, making sandy beaches an important target for long-term monitoring to assess ecosystem condition and functioning of California's North Central Coast (NCC) MPAs. We are conducting surveys of biodiversity, evaluating prospective long-term ecosystem indicators (e.g., sand crabs, shorebirds, wrack, surf zone fish abundances, recreational use, etc.) and working with existing citizen-scientist monitoring efforts (and piloting new models) to establish baseline metrics of ecosystem condition and functioning. We have sampled 17 different sandy beaches [with emphasis on 6 MPA and 6 reference sites] to characterize the large and pocket beaches (< 1 km of shoreline) of the NCC region. Quantitative measurements include: 1) species richness and abundance of intertidal macroinvertebrates; 2) biomass and population size structure of focal species/taxa; 3) abundance and species composition of shorebirds and macrophyte wrack; and 4) characterization of human activities and physical attributes of the study beaches. We are also working with the existing citizen-scientist monitoring efforts in the region to compare, cross-calibrate and optimize sampling methods to help maximize the potential value of their data in informing management efforts. In addition we are currently in the process of developing a pilot citizen-scientist surf zone fishing monitoring program to quantify the abundance, diversity and size structure of surfzone fishes. Our approach consists of recruiting volunteer recreational fishers from local fishing clubs to catch and release fishes using standardized gear and a rigorous sampling design (designed in consultation with experienced, local surf zone fishers).

As sample processing and development of pilot programs are still underway, we focus here on reporting initial results from: 1) surveys of wrack and shorebird abundances and recreational uses of beaches in the region and 2) results of a paired sand crab (*Emerita analoga*) sampling effort done in collaboration with Gulf of the Farallones National Marine Sanctuary LiMPETS (Long-term Monitoring Program and Experiential Training for Students) program. Preliminary analyses from wrack surveys show strong seasonal variation as anticipated. Furthermore, beach-cast *Nereocystis* wrack in the fall (when deposition of wrack biomass is highest) is positively correlated with the extent of offshore kelp canopy at length scales corresponding to average MPA size. Results of our paired sampling effort, using different methods, indicate that sand crab abundance estimates varied strongly and negatively with beach slope regardless of method, but estimates for a given site varied substantially depending on the method used. Getting accurate estimates of sand crab abundance can be challenging due to the high mobility of the target organism, dynamic nature of their habitat and the risks inherent in surf zone sampling, especially on steep, wave exposed beaches. Our analyses are yielding critical information for optimizing existing citizen-science methods and cross



calibrating historic citizen-scientist data sets with current best practices in scientific sampling of sandy beach macroinvertebrate infauna.

Why Long Term Rocky Intertidal Monitoring Matters

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The Multi-Agency Rocky Intertidal Network (or MARINE program) conducts outer coast rocky intertidal ecological surveys and has established long-term datasets along the west coast and parts of the east coast of North America. Many of these sites now have 10 to 30 years of data. This program has expanded to include more than 176 west coast sites, 27 of which fall between Point Arena and Año Nuevo. MARINE conducts two main types of surveys, biodiversity and core monitoring. Biodiversity surveys focus primarily on the biodiversity of a given site or region. Core monitoring targets specific algal and sessile invertebrate assemblages that represent the different intertidal zones. Core monitoring also targets species of special interest or concern such as *Postelsia palmaeformis* (sea palm kelp), *Lottia gigantea* (owl limpet) and the endangered *Haliotis cracherodii* (black abalone). Both survey types utilize permanent transects and quadrats so that the same areas can be repeatedly sampled (for more detailed methodology see: cbsurveys.ucsc.edu and marine.gov).

Together these studies help us understand how rocky intertidal communities and assemblages change spatially and temporally. They also establish baseline data which allows for flexible approaches to analysis that is useful in a variety of ways. Our data have documented the presence and spread of invasive species as well as disease. Our data have also been used to address natural temporal and spatial variation in measured parameters, which has been essential in Natural Resource Damage Assessments (such as the Cosco Busan and Dubai Star oil spills) as well as assessing impacts of urban runoff. This monitoring program also has the potential to address questions regarding global climate change, its effects on sensitive species and shifts in species ranges. We conclude that such programs are essential not only to further our understanding of the biology and ecology of marine systems but also to responsibly inform the protection and preservation of coastal ecosystems in an inherently impacted world.

An Abundance of Nearshore Phytoplankton: What Drives Formation and Oscillations of the 'Green Ribbon' Over Short Time Scales?

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Several recent studies demonstrate decoupling between chlorophyll *a* (chl *a*) concentration in nearshore (<1 km) and offshore zones (>1 km), calling into question the assumption that estimating phytoplankton abundance from buoys, vessels, and satellite ocean color images gives an accurate picture of phytoplankton dynamics in nearshore regions. Recent work suggests that the taxonomic composition and physiological state of phytoplankton may combine with physical transport processes such as Stokes drift to promote accumulation of phytoplankton against the shore on short time scales (days to weeks). We are combining measurements from the shore and from nearby moorings and buoys to assess the physical and biological correlates of these nearshore phytoplankton blooms. Our objective is to describe nearshore phytoplankton community composition and explore relevant oceanographic time series to determine whether biological processes, physical processes, or both are responsible for the observed patterns in nearshore chl *a*. Nearshore food webs and mariculture operations are both dependent upon (as food) and vulnerable to (e.g., harmful algal blooms) the accumulation of phytoplankton against the shoreline. However, our understanding of what promotes nearshore blooms on short time scales (< seasonal) is limited; this work will increase our understanding of these important dynamics.

In spring and summer 2010 we performed high frequency (daily to weekly) shore-based phytoplankton sampling at Bodega Head. Samples were preserved with Lugol's acid solution and settled out using the Utermohl method to identify phytoplankton to the lowest taxon possible and quantify abundances. Intertidal and mooring fluorometers recorded chl *a* fluorescence and were calibrated to *in situ* extracted chl *a* from bottle samples to create time series of chl *a*. We combined these with concurrent physical time series of winds, waves, seawater temperature, salinity, light levels and an upwelling index (from the Bodega Ocean Observing Node, the National Data Buoy Center, the Coastal Data Information Program, the Central and Northern California Ocean Observing System, and the Pacific Fisheries Environmental Laboratory) to explore alternate mechanistic hypotheses about nearshore phytoplankton accumulation.

Spring and summer peaks in chl *a* are dominated by diatoms in the genera *Chaetoceros*, *Skeletonema*, and a yet to be determined (via SEM) solitary centric diatom. Dinoflagellates and flagellates were rare during spring and summer. Another diatom, *Leptocylindrus danicus*, which has not previously been reported to be an important component of the phytoplankton community in this area, made up fifty percent of the community during at least one late summer, high chl *a* event (~20 mL⁻¹). Peaks in wave energy appear to be correlated with peaks of nearshore chlorophyll *a*, as shown in prior years in this region, lending further support for the hypothesis that wave-driven Stokes drift might drive cells in the surface layer toward the shore. Ongoing evaluation of time series of the taxonomic composition of the phytoplankton and other physical oceanographic variables will be used to assess alternate hypothesized mechanisms for nearshore phytoplankton accumulation. We hope to draw conclusions about whether diatom physiology might interact with environmental forcing to determine which genera and species appear in nearshore accumulations.

Point Reyes Shoreline Plastic Pollution Assessment

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California's marine ecosystem is contaminated with pelagic plastic pollution that accumulates on shorelines. Marine plastic pollution is prevalent, persistent, and when ingested by marine life causes nutrient dilution, may transfer toxic chemicals, and can be lethal. The purpose of the study is to characterize seasonal trends, types, recruitment rates, and areas of high-density plastic pollution accumulation along shorelines in the Point Reyes National Seashore as an indicator of offshore habitat quality for the endangered leatherback sea turtle. A secondary goal of the project is to educate coastal communities about the effects of plastic pollution on endangered sea turtles and engage them to take action to rethink, reduce, and remove plastics from their lives and public beaches. Study locations within the National Seashore include Kehoe, South, Drakes, Limantour, Coast Camp, Wildcat, and Palomarin Beaches. Shoreline debris and plastic pollution density assessments were performed using a modified draft protocol developed by NOAA and consisted of four transects perpendicular from water's edge of 5 meters width sampled within a 100 meter shoreline section in which all anthropogenic debris greater than 1.0 cm was identified as either fresh or weathered and quantified. Micro-plastic debris density was determined by screening sand within a random quadrat along each transect. After all data was recorded, shoreline plastic pollution and other litter were sorted for disposal, recycling, and repurposing. Preliminary results indicate the majority of anthropogenic debris is plastic, the relative abundance of weathered debris is negatively correlated with distance from public beach access, and high densities of fragmented polystyrene accumulate in grasses on the upper slope of north facing sand dunes (up to 60 pieces per square meter). Derelict fishing gear found ranged from beached crab pot buoys to a bundle of monofilament netting that had entangled and killed an unidentified seabird. Data from Bodega Marine Laboratory's offshore ocean currents monitoring (BOON) will be used to evaluate oceanographic influences on results.

Leptospirosis in California sea lions – challenging the dogma?

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The California sea lion (CSL: *Zalophus californianus*) population has recovered from a low of 1500 animals in the 1920s to an estimated 300,000 today. Although the population appears to be healthy and stable and may still be increasing, its numbers fluctuate from year to year. These fluctuations result from the interactions of a number of factors including an infectious disease called leptospirosis. Leptospirosis is a bacterial disease, caused by numerous pathogenic species and serovars within the spirochete genus *Leptospira*, which is common in wildlife, domestic animals and humans worldwide. Since 1970, periodic outbreaks of leptospirosis (*L. interrogans* serovar Pomona) have caused morbidity and mortality of California sea lions along the California coast. Most cases occur during yearly outbreaks between the months of July and December, and epizootics affecting hundreds of animals have occurred every 3-5 years. We hypothesized that circulation of the pathogen between yearly outbreaks is a consequence of ‘chronic carrier’ CSL that continue shedding infectious leptospire post infection. We used a combination of molecular, biochemical and histopathological techniques to determine whether *Leptospira* may be shed chronically by some CSL that have no clinical signs or serum chemistry results suggestive of an active *Leptospira* infection. We identified 1 of 9 asymptomatic CSL with leptospire in its kidneys, supporting our hypothesis that some individuals may become carrier animals, but further work is needed. Therefore, we are currently performing a prospective study to identify additional potential chronic carriers and to characterize any differences in kidney pathology and *Leptospira* strains that may exist between chronic carriers and acutely ill CSL. Our findings may challenge the prevailing dogma that mammalian host species are divided into maintenance hosts which become mildly ill and are capable of chronic shedding and accidental hosts which become acutely ill and shed for a brief time post infection. CSL exhibit traits of both maintenance and accidental hosts: leptospirosis appears to be enzootic in CSL, but also causes periodic epizootics of acute disease and mortality.

Pilot Study of Pigeon Guillemot (*Cepphus columba*) Breeding Colony at Point Reyes

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The Pigeon Guillemot (*Cepphus columba*) is a colonial seabird of the family Alcidae. Although they are widespread in mostly small colonies along the California coast, they are little studied outside the offshore Farallon Islands because they breed in largely inaccessible rock crevice habitats. Point Reyes Headlands (PRH), within Point Reyes National Seashore, has one of the largest Pigeon Guillemot colonies in central California, where two State Marine Protected Areas (MPAs) were established in 2010. To learn more about their breeding ecology in this region and to collect baseline data on the potential benefits of MPAs to this species, we began a study in 2010 at PRH. To allow easy access to nest sites, 20 wooden nest boxes were installed in April 2010 underneath the Drakes Bay Fish Dock, where a small colony of guillemots already existed. In 2010-11, our focus was on establishing breeding in the boxes and monitoring breeding success and chick growth rates. In 2010 only one box was used, one egg was laid, and it never hatched. In 2011, concrete & gravel were added to ten randomly selected boxes to test if this addition increased box use. In 2011, eight clutches were laid in five boxes. Four of the five boxes used had concrete and gravel. Of the seven clutches laid in boxes with concrete and gravel, three clutches were laid in the concrete depression, and four were laid off the concrete. Productivity for 2011 was 0.4 chicks fledged per box. Fledging success of the two chicks that hatched was 100%, and chick weight gain appeared normal. In the future, our goal is to further examine box preference, increase box occupancy, and expand studies so that we can better understand the breeding ecology of this species in central California.

Baseline Breeding and Foraging Distributions of Three Coastally Breeding Seabirds within the North Coast Study Region of the Marine Life Protection Act Initiative

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In April 2010, PRBO Conservation Science and the U.S. Fish and Wildlife Service began a collaborative project to document baseline use of coastal habitats by seabirds within the North Central Coast Study Region of the Marine Life Protection Act (MLPA) Initiative. The MLPA established a network of marine protected areas (MPAs) within the NCCSR (Point Arena to Pigeon Point). Seabird monitoring was conducted at coastal sites between Duncan Point and Pescadero State Beach. Three types of MPAs were established within the focal area. State Marine Reserves (SMRs) prohibit all take of any marine resource. State Marine Conservation Areas (SMCAs) prohibit most take, but each has specific fishing activities that are allowed. Special Closures (SCs) were established to protect important seabird breeding sites and prohibit all boating activities. Establishing MPAs can have both direct and indirect benefits to seabird populations. Direct benefits include reduced interaction with humans such as fisheries bycatch and decreased disturbance to breeding and roosting sites. Indirect benefits include reduced competition for prey resources and increased reproductive success due to decreased human interaction. Our baseline surveys had four main components: 1) breeding population sizes and distribution, 2) foraging rates, 3) annual breeding productivity, and 4) human disturbance rates at breeding and roosting sites. We collected baseline data at sites inside the SMRs and SMCAs and at control sites several kilometers away from the MPAs. Here we present two years (2010-2011) of baseline population and foraging distributions relative to MPA placement. We present data for three nearshore foraging species that will potentially benefit from coastal MPAs: 1) Brandt's Cormorant, 2) Pelagic Cormorant, and 3) Pigeon Guillemot.

Brandt's Cormorants were most abundant at Point Reyes and Bodega sites, while Pelagic Cormorants and Pigeon Guillemots were most abundant at Bodega. The Pigeon Guillemot was the only species found breeding at Pescadero. Breeding densities for all three species were highest within or immediately adjacent to MPAs. However, areas with high breeding densities were not always aligned with areas of high foraging rates, indicating that preferred breeding habitat is not necessarily located adjacent to preferred foraging habitat. While foraging distributions overall aligned well with MPA placement, there were definite cases where control sites were used more than MPA sites. Given that most breeding activity is already occurring within MPAs, it is not likely that population distributions will change in response to MPA establishment. However, if MPA establishment leads to localized increases in prey availability, it is likely that foraging distributions will change over time. Finally, if MPA establishment leads to increased reproductive success of these species, there is potential for the abundance of breeding individuals to change over time.

Sanctuary Ecosystem Assessment Surveys – Monitoring the Rocky Intertidal Habitat at the South Farallon Islands.

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Gulf of the Farallones National Marine Sanctuary (GFNMS) has conducted long-term monitoring of the rocky intertidal habitats of the Farallon Islands since 1992. GFNMS is contiguous with the Farallon National Wildlife Refuge at the mean-high tide and we work collaboratively with the Refuge to characterize the island shoreline. Data collected include percent cover, density counts, and species inventories. Surveys are conducted annually during the late summer (August); fall (November) and winter (February) months to avoid wildlife disturbance. Weather, tides and decreased funding have caused data gaps in recent years. Over the next two years, GFNMS will be working with National Marine Fisheries Service to explore and map locations of the endangered black abalone (*Haliotis cracherodii*) on the South Farallon Islands.

The rocky intertidal areas on the Farallon Islands are predominated with red-turf and coralline algae. The most common genera at the Farallon Islands include *Corallina*, crustose corallines, *Cryptopleura*, *Egregia*, *Endocladia*, *Gastroclonium*, *Gelidium*, *Mastocarpus*, *Mazzaella*, *Neorhodomela*, petrocelis, *Prionitis*, *Ulva*, and invertebrates *Anthopleura*, and *Mytilus*. The intertidal areas of the islands are highly productive and diverse. We have found over 200 taxa; 5 are rare and 7 were extended ranges. The mean annual percent cover for algae and sessile macroinvertebrates at the South Farallon Islands ranges from 148-255%.

Rocky intertidal monitoring data provides assistance to management when deciding the level and timing of restoration activities and marine zoning. For example rocky intertidal monitoring data from the Farallon Islands aid management authorities in the detection of collateral impacts from the use of rodenticides and herbicides to control non-native species on the Farallon National Wildlife Refuge. Species composition and seasonal trends help management gauge the impacts from vessel groundings and diesel spills into the sanctuary, and provide information for placement and sizing of new marine zones. The long-term data are “banked” into information “savings accounts.” This savings account of information can later be “withdrawn” and used to determine the extent of damages from future events such as oil spills and boat groundings. The progression of climate change can be tracked through intertidal monitoring by detecting and tracking shifts in sea level rise, impacts from increase storm events, freshwater inundation, and shifts in species ranges, distribution and abundance. The pristine, rocky intertidal areas at the Farallon Islands are far-removed from the coastal pressures and impacts found the intertidal areas along the mainland – such as trampling and the collection of organisms, chronic oil pollution, contaminated water from streams and culverts, and other pressures from urbanization. Thus, the pristine rocky intertidal communities at the Farallon Islands are used to compare and to scale the level of human-impacts and pressures on similar rocky intertidal communities along the mainland.

Spatial Ecology of Marine Nekton: Implications for Defining Important Ecological Areas in the Central California Current

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Informing marine spatial management and conservation of living resources requires long-term data to characterize patterns of baseline distribution. We investigate the spatial ecology of marine nekton (krill and forage fishes) off central California because some of these species are of direct commercial value and all are ecologically important as forage assemblage for populations of locally-breeding and migrant seabirds, endangered marine mammals, and predatory fish such as hake. For the past 30 years, the NMFS Juvenile Rockfish Assessment has collected information on the distribution and abundance of marine nekton as well as concurrent environmental data and information on seabirds and marine mammals during the peak upwelling period (May-June) off central California (Pt. Arena to Pt. Sur). We analyzed long-term “spatial climatologies” for a variety of species including krill, juvenile rockfish, juvenile salmon, myctophids, juvenile hake, anchovy, sardine, and market squid relative to the distribution of top predators. Using this extensive data set, we quantify habitat associations and spatial relationships among marine nekton and their environment (e.g. winds, Ekman transport, stratification, pycnocline depth, chlorophyll-a) in doing so identify important ecological areas, and potential “hotspots” of trophic interactions. We discuss how quantifying spatial distribution of marine nekton provides valuable reference points for ecosystem-based management of central California.

Coralline Algal Turf Communities in Northern California: Community Structure and Potential as a Bioindicator of Local Seawater Carbonate Saturation State.

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Ocean acidification (OA) is likely to have significant effects on the physiology, ecology, and biogeography of marine organisms. Marine calcifying organisms are directly influenced by changes in seawater saturation state of calcium carbonate compounds. Coralline algae form calcium carbonates that contain a high proportion of magnesium ions increasing their solubility in seawater (relative to aragonite and calcite) and making them especially vulnerable to OA. Coralline algal turfs are common and sometimes dominate the lower rocky intertidal and are known to facilitate recruitment of two dominant habitat forming macrophytes: the kelp *Saccharina sessilis* and the surfgrass *Phyllospadix scouleri*. However, little is known about the structure of coralline algal turf communities per se. In addition, although ocean conditions influenced by upwelling (including pH) are known to vary among sites and influence community structure, little is known about the variability in calcium carbonate content of coralline algae among sites in northern California (or elsewhere). Such information is critically important to understanding the potential effects of OA on coralline algal turf communities and their role as key facilitators of low intertidal zone community structure.

We investigated the community structure, species richness, and calcium carbonate content of coralline algal turf communities at four sites in northern California. To quantify community structure and species richness we destructively sampled 5 100 cm² plots of coralline algal turf zone (dominated by *Corallina vancouveriensis*) from the middle of the low intertidal at each site, and identified, counted and weighed all invertebrates and macrophytes present. We subsampled *C. vancouveriensis* fronds from each replicate to estimate average calcium carbonate content among sites. In addition, we sampled fronds of *C. vancouveriensis* from low, mid and high intertidal locations within the low zone to assess within site variation. We estimated the average percentage of calcium carbonate in *C. vancouveriensis* fronds as a proportion of dry mass by first drying the fronds and then acidifying the fronds in a dilute HCl solution to remove the calcium carbonate and drying the fronds again.

Coralline turf community structure varied among sites with pronounced differences in the abundance of several invertebrates as well as associated fleshy algae. As expected, we found germlings of kelps: *S. sessile*, *Egregia menziesii*, and *Alaria marginata* and seedlings of *P. scouleri*, as well as the remnants of attached seeds. We found high numbers of juvenile mussels (mostly *Mytilus spp.* but also *Modiolus spp.*) and substantial variation in their abundance among sites that appears consistent with rates of recruitment measured using standardized collectors at these same sites, suggesting coralline turfs may be an important recruitment or juvenile habitat for intertidal mussels. High diversity red algal sporelings were also observed suggesting coralline turfs provide important habitat for many juvenile stages of low zone species. Many smaller (adult) invertebrates are abundant in these coralline turfs too, including *Barleeia haliotiphila*, *Lacuna spp.*, *Hiatella arctica*, *Paracerceis sculpta* and gammarid amphipods. Determination of calcium carbonate content of *C. vancouveriensis* is still in progress, but preliminary findings suggest calcium carbonate content varies among these 4 sites.

Monitoring Human Uses and Values along the North Central Coast of California

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In this presentation we share interim results from a three-year project conducted by Ecotrust and NaturalEquity to establish a spatially-explicit baseline dataset of human uses along California's North Central Coast to better understand the influence of marine protected areas (MPAs) recently established under the mandate of the Marine Life Protection Act (MLPA). The study examines both consumptive (e.g., commercial fishing and charter fishing) and non-consumptive (e.g., diving, kayaking, whale watching, beach walking) uses of the region, extending from Alder Creek near Point Arena in Mendocino County to Pigeon Point near Half Moon Bay in San Mateo County. This project is one of 11 projects that comprise the North Central Coast MPA Baseline Program that was developed by the MPA Monitoring Enterprise.

The objectives of this research are to:

1. Provide spatial and demographic baseline estimates of economic activity in the study region;
2. Describe the initial responses of ocean/coastal user communities to the MPAs; and
3. Inform the planning and implementation of long-term monitoring, in order to understand the causal links between ecosystem features, socioeconomic changes, and the implementation of MPAs.

We are surveying various sectors of human use using a range of methods. This includes an online survey designed to provide a representative sample of NCC residents in which we will collect information on the location, frequency of use, and economic contribution of non-consumptive coastal recreational activities. In addition, in order to collect a sample that accurately represents the recreational consumptive dive community—in particular those targeting abalone, one of the “species of concern” during the MPA designation process—we are also conducting in person surveys of this specific user group. For the commercial and charter fishing sectors, Ecotrust conducted interviews in 2007–08 as part of the North Central Coast MLPA planning process and the data collected established a baseline on fisheries uses and values across the region. In order to build upon this previous effort, we will be conducting follow-up interviews with fishermen who participated in the initial baseline study as well as other fishermen who are representative of the economic value of various fisheries in each port community.

Harbor porpoises in San Francisco Bay: A report on research in progress.

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Harbor porpoises (*Phocoena phocoena*) have returned to daily, year-round use of San Francisco Bay after a near absence of approximately 65 years. We have begun a multi-year assessment to document this population's size, distribution, and behavior. While the basic biology of this species is well known, relatively little work has been done on free-ranging animals. Harbor porpoises are upper level trophic predators, and their re-occupation of historical habitat in the Central Bay may be an indicator of the health of the ecosystem. Our efforts are focused on the photo-identification of individuals, behavioral observations, and reproductive timing.

Photo-identification has not been successful with harbor porpoises in other locations because of their small size, timidity and lack of prominent markings. However, using a combination of platforms – the Golden Gate Bridge, shore, and boat – we have been able to photograph and catalog 225 animals, recognizable from scars and pigmentation patterns. Of these, 35 have been resighted: 20 seen twice, 9 seen three times, 5 seen four times, and 1 was seen six times. The shortest interval between first and last sighting is 1 day, and the longest interval is 525 days. The cumulative discovery curve continues to rise, and mark-recapture methods will provide abundance estimates. By tracking known females over time we will be able to determine their birth rate, previously possible only from the study of carcasses. On 26 August 2011, an adult lactating female stranded on Ocean Beach, San Francisco and was identified from our catalog, providing a rare opportunity to correlate behavioral observations with life history.

Mating is difficult to observe in wild cetaceans, but we have used the Golden Gate Bridge as a platform to observe sexual behavior, including intromission, heretofore unseen in harbor porpoises. Since April 2010 we have photographed 28 events that appear to be mating (copulations or attempted copulations). In 12 events the male's penis is visible. The other 16 events are presumed mating events based on similarity of behavior. All 28 events shared the following features: the presumed male rapidly approached the presumed female from below and behind, contact was made on the female's left flank, and all or part of the male's body emerged from the water, likely due to the momentum of his charge at the female. In 8 of the events, the females were mothers accompanied by young calves.

Variation in Blade Morphology Ameliorates Emersion Stress and Photosynthetic Performance of the Intertidal Kelp *Saccharina sessilis*

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Saccharina sessilis (hereafter *Saccharina*) is an ecologically important and dominant kelp of the low intertidal zone on rocky shores of the northeastern Pacific. *Saccharina* exhibits two distinct blade morphologies: bullate and strap-like. Organisms with bullate morphology have upright, rugous blades that grow in a compact, cabbage-like habit. In contrast, thalli with strap-like growth habit have blades that are smooth and long, and upon emersion are laid flat against the rock often in layers on top of each other. Based in part on observations that bullate *Saccharina* thalli are more common on wave protected than wave exposed shores, previous researchers have argued that the bullate morphology is an adaptive response to growing in habitats with reduced water flow or wave exposure where nutrient or carbon dioxide supply to smooth, overlapping submerged thalli can be limited by boundary layer formation. Bullate or ruffled kelp thalli have been shown to create small scale turbulence that disrupts boundary layers at the surface of the thalli under low, laminar flow conditions, augmenting delivery of nutrients or carbon dioxide. However we observed that the two morphologies also vary systematically with tidal height, and furthermore that bullate thalli often retain small pools of water during low tide. Thus we hypothesized that the bullate morphology in intertidal kelps might be critically important in ameliorating emersion stress during low tide, and allows *Saccharina* to persist in higher intertidal habitats than it would if it only exhibited strap-like morphology. Here we report initial results of a project testing this hypothesis.

We measured the *in situ* photosynthetic performance and hydration state of strap-like and bullate *Saccharina* thalli during low tides together with ambient environmental conditions likely to influence photosynthetic performance [air temperature, relative humidity, wind speed and photosynthetically active radiation (PAR)]. We used a pulse-amplitude-modulation (PAM) fluorometer to measure two metrics of photosynthetic performance: maximum quantum yield (F_v/F_m) and electron transport rate (ETR). During a sunny morning low tide, we found that high zone bullate thalli remained hydrated longer than low zone strap-like thalli despite longer emersion times. More importantly, these high zone, bullate thalli also had greater (F_v/F_m) and greater ETR than the low zone, strap-like thalli. These differences were less pronounced during the more environmentally benign conditions of a morning low tide coinciding with foggy conditions.

Intertidal kelps, including *Saccharina*, exhibit extraordinarily high rates of production, yet our understanding of the factors that control their productivity and vulnerability to climatic change is still extremely limited. The canopy created by a bed *Saccharina* creates important understory habitat for a diverse suite of intertidal invertebrates and seaweeds that do not persist in the absence of the canopy. The results reported here and additional experiments in progress will contribute important information on the physiological ecology of *Saccharina* needed to assess the vulnerability of intertidal kelps, and the understory species they support, to climatic change.

Response to changes: Asexual and sexual reproductive patterns of eelgrass (*Zostera marina*) in San Francisco Bay

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Eelgrass (*Zostera marina*), a highly clonal flowering marine angiosperm, has high productivity in estuarine ecosystems. However, worldwide declines in eelgrass populations, mostly related to anthropogenic activities, mandate a greater understanding of reproductive patterns and demographic variation. Sexual reproduction is important to maintain genetically diverse populations that are resistant or resilient to environmental stress, however, little is known about the effects of dramatic population declines on reproductive patterns. Here, we have estimated aspects of the significance of sexual reproduction in annual and perennial populations in San Francisco Bay. Annual populations, with higher genetic diversity, are expected to show enhanced reproductive and growth traits in comparison to perennial populations. However, our greenhouse mesocosm comparison of germination success and early growth among three populations (one annual and two perennials) showed no significant differences in these important early life history traits. To examine genetic diversity in a perennial bed recovering from an extreme population constriction in 2006, we produced a fine-scale clone map at Point Molate, San Francisco Bay. We expected this perennial population to show reduced genetic diversity, and high numbers of eelgrass plants produced by asexual reproduction. However, our clone map by genotyping with nine microsatellite loci revealed a high clonal diversity. This recovering perennial population had significantly higher clonal diversity (0.97) in comparison to five other local perennial populations (0.79) but slightly lower observed heterozygosity (0.22), in comparison with previously reported populations based on 7 shared loci (observed heterozygosity: 0.26 to 0.38) (Ort, Cohen, et al., in review). Thus, recruitment of sexually produced offspring appears significant to the recovery of this demographically bottlenecked population. Together, the mesocosm and field population clone map experiments suggest different ways that sexual reproduction is significant to sustaining healthy eelgrass beds.

Urban seabirds: Coping with bottom-up and top-down pressures

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Alcatraz Island in San Francisco Bay is the site of large colonies of Brandt's Cormorant (*Phalacrocorax penicillatus*) and Western Gull (*Larus occidentalis*), which are endemic to the California Current ecosystem. This is one of very few estuarine colonies of pelagic seabirds; it is one of only two such sites that exist for Brandt's Cormorant. Alcatraz is a part of the Golden Gate National Recreation Area (GGNRA), a unit of the National Park Service (NPS). This colony, although protected by the Migratory Bird Treaty Act, NPS management policies and GGNRA site plans for island management, exists in a delicate balance with the considerable human presence both on and around Alcatraz. Seabird populations on Alcatraz experience substantial disturbance from a number of different sources. Encroachment near the island shoreline by large numbers of commercial and/or recreational boaters (e.g. tour boats, fishermen, kayakers), and uncontrolled aircraft overflights (e.g. air tour operators) may disrupt the breeding efforts of Alcatraz seabirds. Fireworks displays in the bay are also an annual and sometimes more frequent occurrence. On the island itself, there are about 1.4 million visitors annually, and associated historic preservation and safety construction projects, a historic garden restoration program, special events, and public access to breeding areas may also cause disturbance. The educational opportunity of public access should not be underestimated, as Alcatraz offers a unique opportunity for public viewing of seabird breeding activities up close. However, cumulative effects of disturbance may cause increased behavioral sensitivity in Brandt's Cormorants, which may be compounded by unfavorable environmental conditions as observed in 2011. Oceanographic conditions often affect seabirds through bottom-up processes influencing prey resources. Demersal fish populations in the bay, including some main seabird prey species, have been shown to vary with large-scale climate forcing, and we show that prey availability (as indexed by fisheries-independent trawl surveys) influences seabird reproductive success on Alcatraz. Recently, productivity of cormorants and gulls on Alcatraz in 2008-2011 was the lowest documented in 12 to 16-year time series, respectively. Breeding populations of both species have also declined. Specifically, the population size of cormorants decreased in 2008 by 15%, and no cormorants bred on the island at all in 2009. The population rebounded to only about 10% of peak numbers in 2010, but recovered further to nearly 45% of peak numbers in 2011. Reducing disturbance to breeding seabirds may provide them greater resilience to cope with adverse environmental conditions, especially as climate change is predicted to increase environmental variability.

Conservation of Forage Fish in California Current: An Ecosystem Assessment

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Mid-trophic level forage species are an important component of marine food webs which directly support marine birds, mammals and fish of societal concern, but are generally under-studied in most marine ecosystems. In the California Current system (CCS), primary forage species include a variety of coastal pelagic fish (e.g. sardine, anchovy), juveniles of predatory fishes (e.g. age 0-1 rockfish, hake), and invertebrates (e.g. squid, krill). Forage species management within the CCS falls under various jurisdictions including federal and state agencies, and tribes. The California Marine Life Management Act (MLMA) and the federal Magnuson-Stevens Fisheries Conservation and Management and Sustainable Fisheries Acts require that ecological interactions and dependencies be incorporated into fishery management plans (FMPs) and regulatory decisions, but this has been infrequently implemented. U. S. management agencies are now grappling with development of ecosystem fisheries management plans (EFMP). Our objectives here are to provide an overview of forage fish status, importance and management in the CCS, including forage in relation to predator needs (e.g., recent salmon and seabird failures), environmental/oceanographic effects, climate change and human non-fisheries threats, problems with biomass estimation, fisheries-induced age-structure truncation, challenges of conservation in the face of natural population fluctuations of pelagic schooling species, difficulties in managing for juvenile fishes as forage, intersection of science and policy, and potential approaches for strategically improving forage species management. For example, the importance of krill as the base of the food web in the CCS has been recognized by management agencies, and as a result krill harvest was recently banned in Pacific U.S. federal and state waters. However, in California the two most lucrative commercial fisheries are for forage species – squid and sardine. The increased importance of forage species to commercial fisheries revenue and aquaculture increases the urgency of improving management and understanding the implications of removing forage species from the ecosystem.

Nutrient and phytoplankton distributions in the Gulf of the Farallones

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The Gulf of the Farallones is known as a productivity “hot spot” with an abundance of marine mammals, sharks, recreational fish and sea birds and can go through sporadic declines in populations of many of these groups. It is hypothesized that these animals rely on a rich food chain supported by phytoplankton supplied from two major nutrient sources: wind driven coastal upwelling along the northern California coast and outflow from the San Francisco Estuary. At present, relatively few measurements of nutrients or phytoplankton productivity are available for the Gulf as most studies there focus on higher trophic groups. The objectives of our study were to measure the spatial and temporal distributions of $p\text{CO}_2$, dissolved inorganic carbon and aragonite saturation, inorganic nutrient concentrations and phytoplankton functional groups and relate this to the pelagic primary productivity, using cruises of opportunity aboard the RV Fulmar and various NOAA vessels. Preliminary findings describe a predictable productivity sequence where periodic relaxation of the upwelling favorable winds results in rapid uptake of nutrients by a diatom-dominated community. Diatoms tend to be good quality food and typically fuel short, efficient marine food chains. However, this sequence may be disrupted by anthropogenic ammonium supply in the San Francisco Estuary outflow that inhibits diatom nutrient uptake and growth, and favors slow-growing non-diatom species. The result is a less productive ecosystem. More data of this kind is needed to evaluate how anthropogenic or climate driven changes at the base of the Gulf of the Farallones food web may impact the near shore marine protected areas and oceanic upper trophic levels.

OMEGAS: A Large-scale Approach to Studying the Effects of Ocean Acidification on Calcifying Organisms in Intertidal and Nearshore Habitats

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Due to increases in the release of anthropogenic CO₂, the acidity of the ocean is rapidly increasing. The implications of this phenomenon, called ocean acidification (OA), are widespread with some organisms being more heavily affected than others. For example, growth rates of many calcifying organisms are inhibited by decreases in both pH and the saturation state of calcium carbonate, a critical building block for many shells and skeletons. However, changes in ocean chemistry, and the effects of those changes on marine species, may vary among oceanographic regions.

The California Current Large Marine Ecosystem (CCLME) is of particular interest in the field of OA studies due to large variations in CO₂ resulting from differences in upwelling patterns along the western coast of the U.S. The Ocean Margin Ecosystems Group for Acidification Studies (OMEGAS) consortium is comprised of research groups from Oregon State University (OSU), University of California, Davis (UCD-Bodega Marine Laboratory (BML)), University of California, Santa Cruz (UCSC), Monterey Bay Aquarium Research Institute (MBARI), Stanford University (Hopkins Marine Station), and University of California, Santa Barbara (UCSB). This collaboration is investigating the effects of OA on two ecologically important intertidal biomineralizing species, the purple urchin (*Strongylocentrotus purpuratus*), and the California mussel (*Mytilus californianus*). The study will be conducted over at least two field seasons and is close to completing the first season. Based upon previous studies, pH is expected to be generally lower along the coasts of Oregon and Northern California, increasing into Central and Southern California. On a smaller geographic scale, strong upwelling areas are expected to have a lower pH than low upwelling zones. These differences in pH are expected to affect growth rates of the two focal species and might also underlie differences in the ability of organisms from these regions to acclimate or adapt to OA.

An OA monitoring network was established in four regions ranging from south of Point Conception in California up to Central Oregon. Each region contains one stronger and one weaker upwelling site, with both sites per region containing both intertidal and subtidal components. Our focus here is the Northern California region, including the sites Bodega Bay (weaker upwelling) and Van Damme State Park (stronger upwelling). The intertidal and near-shore oceanic environment is highly dynamic, and a wide array of data is being taken to investigate changes in growth rates of the urchins and mussels in relation to oceanic acidification and other factors. On both offshore moorings and in the rocky intertidal zone, growth rates of *Mytilus californianus* are being measured, pH is being measured using newly designed sensors, variability in temperature and dissolved oxygen is being assessed, and water samples are taken regularly to record salinity, alkalinity, dissolved inorganic carbon (DIC), nutrients and chlorophyll a. In addition, to determine whether populations along the coast vary in their sensitivity to OA, the early life stages (larvae) of urchins and mussels are being cultured under controlled CO₂ conditions at Bodega Marine Laboratory. Assays are also being conducted to examine whether different levels of OA have selected for genetic difference among urchin larvae from different populations.

Information gathered by the OMEGAS consortium will aid in 1) providing a more complete picture of the oceanic environment, 2) predicting how biomineralizing species like urchins and mussels will respond to changing pH levels, and 3) providing data for regulating agencies regarding which areas are most vulnerable to the increasing acidification of the oceans, ultimately aiding in decision making associated with marine conservation policy.
