CIMT

Center for Integrated Marine Technologies

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With increasing human populations, demands on coastal resources are increasing, leading to dramatic changes in coastal ecosystems.

Because we rely on the ocean for food, commerce, mineral, and energy resources, as well as for recreation, it is critical that we develop conservation and management strategies that facilitate the sustainable use of marine resources while minimizing impacts on natural systems. A major impediment to achieving this has been a lack of an integrated understanding of the basic processes governing coastal ocean ecosystems.

The Center for Integrated Marine Technologies (CIMT), a project within the Central and Northern California Ocean Observing System (CeNCOOS), was organized to understand the relationship between the physical dynamics and productivity, **from wind to whales,** of California's coastal ocean.

CIMT's mission is to create a coastal ocean monitoring program that links new technologies and data across multiple disciplines of marine science to address key questions for the management and conservation of California coastal marine resources. These technologies are being used to investigate the critical linkages among:

- Physical processes such as wind and ocean currents.
- The availability of critical nutrients or fertilizers.
- The distribution, abundance and species composition of phytoplankton and zooplankton.
- The distribution, abundance and species composition of top-level consumers including fish, seabirds, marine mammals and sea turtles.

This effort has been simultaneously collecting data via moorings, shipboard surveys, apex predator tagging and tracking, and satellite, aircraft, and land-based remote sensing since 2002 and is built on a foundation of data collection initiated in 1997.

CIMT focuses on three critical areas for coastal resource management:

- Marine populations
- Water quality
- Marine operations/disaster resilience

CIMT core variables

Physical	Chemical	Biological
Salinity	Dissolved nutrients	Fish abundance/biomass
Water temperature	Dissolved oxygen	Zooplankton species
Bathymetry	Carbon: total organic	Pathogens
Currents	Carbon: total inorganic	Phytoplankton species
Chlorophyll	Suspended sediments	Mammals: mortality
Bioacoustics	pCO_2	Mammals: abundance
Optical properties	Total nitrogen: water	Chlorophyll
Ocean color		Phytoplankton abundance
		Phytoplankton productivity
		Bioacoustics

In its final report, the U.S. Commission on Ocean Policy proposed a list of core elements to be measured by the National Integrated Ocean Observing System (IOOS). CIMT currently measures 23 of 36 relevant variables (excluding variables concerning ice).

A few Important CIMT Accomplishments & Findings

Marine Populations

- Coastal currents are closely linked to wind patterns and variability in wind and currents have significant repercussions for commercially important and protected species.
- Krill is critically important to transferring energy from phytoplankton to commercially important and endangered species such as squid, schooling fishes, seabirds, and marine mammals and can vary dramatically due to variability in ocean climate (e.g. El Niño, La Niña).
- California sea lions are an abundant top predator. They utilize specific foraging hotspots in the region, and strongly influence the coastal ecosystem - including commercially important fishes. Analyses show that their impacts are important to consider for ecosystem-based fisheries management of rockfish and salmon.

Water Quality

- Iron dynamics in central California are important for understanding the seasonal development of harmful algal blooms (HABs).
- River discharges into central California waters influence both bacteria levels and nutrient concentrations in the coastal region.
- Research observations indicate that there is reason for concern for rising contaminant levels in the California Current.

Marine Operations

- Reliable models have been developed that predict coastal winds and currents.
- The wind model is now available for commercial and recreational users on the CIMT website – improving the quality and safety of commercial and recreational activities.
- The current model is an important tool now available for predicting the fate of oil spills, harmful algal blooms, and other contaminants in the region.

Following are a few research projects that are currently underway…

Research: Macro- and Micro-Nutrient Chemistry, Connecting Physics & Biology

Coastal upwelling delivers nutrients such as nitrate, phosphate, and silicic acid that lead to the high productivity of phytoplankton in the Monterey Bay National Marine Sanctuary (MBNMS). Upwelling is also a source of iron, and the delivery of this micro-nutrient can vary markedly in space and time. **In regions with a high input of iron, the upwelled waters support extensive phytoplankton blooms that eventually become nitrate limited.** In regions with a low input of iron, the growth rates of key primary producers–larger coastal diatoms– is limited. As part of the CIMT long-term ocean observation program, we measure coastal concentrations of nitrate (+ nitrite), phosphate, silicic acid and dissolved and particulate iron on the ship surveys that occur in the Monterey Bay.

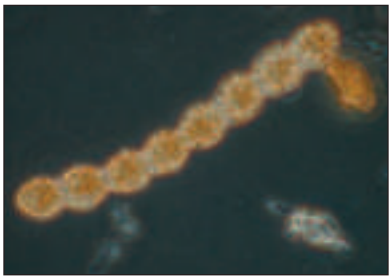
WHY RESEARCH IS IMPORTANT:

- Nutrient data is essential for modeling efforts that connect the physics with the biology and provide a critical linkage from wind to whales.
- Potentially harmful algal species can also respond to nutrient stress by producing toxins.
- Data complements research on harmful algal blooms (HABs).

WHAT RESEARCH IS CURRENTLY SHOWING:

- Early spring upwelling is delivering high concentrations of dissolved and particulate iron and nitrate, phosphate and silicic acid.
- High nutrient concentrations cause extensive blooms of large coastal diatoms.
- Upwelling later in the season delivers far less dissolved and particulate iron and other nutrients. During this period there is a potential for iron limitation to occur within Monterey Bay.
- Macro- and micro-nutrient data sets help in the interpretation of phytoplankton and HAB dynamics in this region.

Research: Toxic Phytoplankton in the Monterey Bay region



In Monterey bay, various species of toxic diatoms and dinoflagellates are common (as they presumably are, all along the US west coast), but in Monterey **Bay, researchers are assessing the abundance of the toxin-producing species** more intensively as part of the CIMT long-term monitoring program. The movement of the toxins into local pelagic food webs is being studied in the region, and the associations of these intoxication events is being linked with local blooms of the toxin-producing algae.

WHY RESEARCH IS IMPORTANT:

- **Toxic microalgae appear to be a universal phenomenon of coastal oceans.**
- **Bloom events represent dangers not only to human health, but also to apex predators such as seabirds and sea lions that feed on herbivores carrying high levels of the algal toxins during bloom events.**
- Shows where high cell densities of toxin producers occur, where cells with the most toxins are found, and the distribution of these toxic blooms in relation to important endangered whale foraging areas.

WHAT RESEARCH IS CURRENTLY SHOWING:

- Toxic diatom events (those of cells responsible for domoic acid poisoning) show similar long-term average abundance over the study period, though at any one time high cell numbers may be focused more in one area than another.
- Toxic diatom blooms have been declining since mid-2004, but since then there has been a rise in blooms of the more dangerous *Alexandrium catanella*, the dinoflagellate responsible for paralytic shellfish (saxitoxin) poisoning in humans.
- Changes in the types of toxic phytoplankton in the area suggest longer term changes, possibly those related to oceanographic regime shifts.

Research: Krill Population Dynamics within the Monterey Bay National Marine Sanctuary

For the last ten years, we have been monitoring seasonal cycles in krill populations for the dominant species of krill found within the waters of the MBNMS. This has involved extensive shipboard hydroacoustic and trawl sampling along a series of transects and hydrographic stations stretching from Cypress Point off Monterey north to Davenport. Data on the distribution and abundance of total zooplankton as well as krill are collected in concert with a suite of physical oceanographic and phytoplankton parameters. In addition, detailed demographic information such as population size and sex structure are determined for the dominant species of krill.

WHY RESEARCH IS IMPORTANT:

- Provides key baseline information on the abundance and distribution of krill species within the MBNMS.
- Helps understand how variability in marine climate affects patterns of krill reproduction and growth
- Provide insights into how changes in marine climate, whether natural or anthropogenic in nature, are likely to affect krill stocks within this ecosystem.

WHAT RESEARCH IS CURRENTLY SHOWING:

- Krill population dynamics are highly correlated to seasonal cycles of ocean productivity with peak reproduction and growth corresponding to periods of persistent upwelling in the spring and early summer.
- Interannual perturbations in marine climate such as El Niño/ La Niña have significant impacts on krill abundance and species composition.
- Krill recruitment appears to be highly dependent on strong, sustained upwelling, particularly during the late spring/early

summer, but is also capable of responding quickly upwelling favorable changes in the marine ecosystem throughout the year.

Research: Apex Predator Foraging Behavior

In the short-term, apex predator foraging behavior research will provide us with an understanding of the location and dynamics of apex predator foraging habitat; ultimately, it will provide the basis from which to predict the effects of climate variability on them–a key goal of resource managers. A key component of ecosystem based management is the consideration of trophic interactions that may influence fisheries harvest or management strategies. By developing quantitative tools, such as foraging models and consumption estimates, managers can evaluate predator impacts on marine resources, and thereby more effectively manage marine fisheries.

Why research is important:

- California sea lions are the most abundant apex predator in the California Current and exert strong influences on coastal food webs.
- This study demonstrates how physical oceanography determines the movements and behavior of sea lions and can be used to incorporate their impacts as part of ecosystem-based fisheries management.
- Animal-collected oceanographic data provides data that is impossible to replicate using standard oceanographic sampling methods.

What research is currently showing:

- In collaboration with the Tagging of Pacific Pelagics we have **identified foraging hotspots** for California sea lions along coastal California that will be used by the National Marine Fisheries Service (NMFS) in spatial analysis of predator **impacts on commercially important fish species through ecosystem-based fisheries management.**
- In collaboration with Moss Landing Marine Labs, the food habits of California sea lions have been used to model the impacts of pinnipeds on listed salmon and rockfish stocks for federal management agencies.

Research: Sources & Effects of Contaminant Exposure in North Pacific Albatrosses

Recent concern about the negative effects on human health from elevated organochlorine and mercury concentrations in marine foods has highlighted the need to understand temporal and spatial patterns of marine pollution. In addition, understanding the sources and effects of marine contamination is important for our ability to mitigate pollution effects in wildlife and humans. The goal of this research is to investigate contaminant exposure in wild seabirds. These studies focus on assessing contaminant exposure sources and effects in black-footed and Laysan albatrosses, large predatory North Pacific seabirds that forage over vast oceanographic areas.

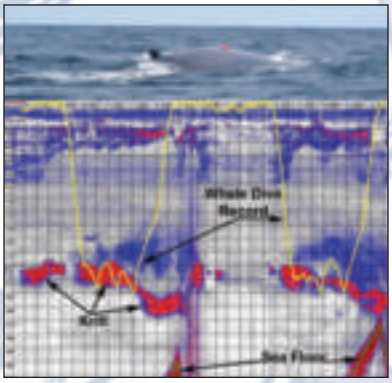
Why research is important:

- Helping to determine the temporal and spatial trends of marine global pollutants (e.g., PCBs, DDTs, mercury)
- Elucidating global pollution's effect on the health and survivorship of albatrosses, long-lived pelagic predators

What research is currently showing:

- Global pollution (e.g., PCBs, DDE) concentrations have increased in black-footed and Laysan albatrosses over the past 10 years.
- Black-footed albatrosses have 3 to 4 x higher organochlorine (PCBs, DDTs) and mercury body burdens than a closely related species, Laysan albatrosses, primarily due to regional segregation of their North Pacific foraging areas.

Research: Seabird and Marine Mammal Dynamics and Foraging in the Monterey Bay National Marine Sanctuary



Seasonally, large aggregations of seabirds and marine mammals arrive in Central California to take advantage of the upwelling-driven productivity. While wide-ranging, these apex predators spend parts of their life history in specific regions–often associated with distinct oceanographic processes such as upwelling regions. In the long term this monitoring program combines the use of shipboard surveys and subsurface hydrophones to track the distribution and abundance of seabirds and marine mammals–particularly protected species – in relation to spatial and temporal patterns of primary producers, zooplankton, and schooling fish. In the short term we are seeking to measure the foraging behavior of key marine mammal predators (blue and humpback whales) to their prey resources.

Why research is important:

- Current scientists only have a rudimentary understanding of the linkages between upwelling dynamics, primary producers, zooplankton, schooling fish, and top predators such as seabirds and marine mammals.
- Few studies simultaneously measure the trophic links between areas of strong oceanographic forcing (upwelling) and the pelagic predators that indirectly exploit them.
- The key to effectively managing, protecting, and potentially designing protected areas for protected species is understanding the trophic linkages that drive their movements.

What research is currently showing:

- Seabirds and marine mammals can respond rapidly to variability in productivity and there are important mis-matches between upwelling, primary production, and the abundance and distribution of seabirds and marine mammals.
- Krill are a key trophic link for seabirds and marine mammals in the Central California upwelling ecosystem.
- Endangered blue and humpback whales exhibit differences in foraging behavior and large scale movement patterns along the California coast.
- Temporal differences in the arrival and departure of humpback and blue whales in the Monterey Bay National Marine Sanctuary.

Research: Analysis of Monterey Bay River Impacts on the Coastal Ocean

Monterey Bay is generally considered to be a "pristine" environment. However, we know that local rivers can contribute to total nitrogen loading in the near shore environment, and many local beaches are regularly subject to regulatory closures for elevated bacteria. In collaboration with the Central Coast Long-term Environmental Assessment Network (CCLEAN), we measure pathogenic bacteria and urea-nitrogen levels (indicative of anthropogenic inputs) to monthly measurements, and are conducting a statistical analysis to determine concentrations and extent harmful bacteria blooms during river discharge events.

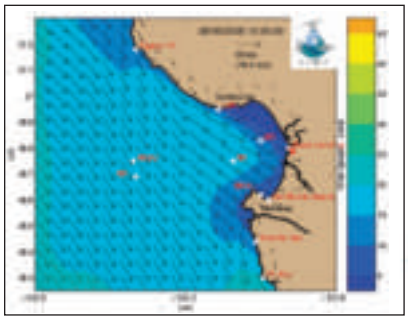
WHY RESEARCH IS IMPORTANT:

- Elevated bacterial counts lead to closed beaches. This research determines how far these events extend.
- To understand the influence of coastal agriculture and other human activities in coastal waters, it is critical to understand the origin and concentration of anthropogenic nitrogen.
- To understand if the rivers influence the ecology of Monterey Bay.

WHAT RESEARCH IS CURRENTLY SHOWING:

- Urea concentrations vary considerably, but are a significant source of nitrogen in the Bay.
- River discharge is most important in the winter; the impact dissipates after about 1 day.

Research: Measuring and Predicting Wind and Currents



The key to understanding the California upwelling system is a knowledge of the relationship between winds and upwelling. The direction, intensity, and duration of winds along the California coast largely determine nearshore climate, ocean productivity, and the movement and fate of human contaminants such as oil and pesticides. The goal of this research is to measure coastal climate, wind, and currents and combine these measurements with large-scale predictive models to generate regional scale predictions of winds and currents in the central California region.

WHY RESEARCH IS IMPORTANT:

- Coastal winds and currents are the major drivers of coastal California climate and its variability.
- Coastal productivity including phytoplankton, zooplankton, schooling fishes, commercially important fisheries; protected seabirds and marine mammals are linked to coastal winds and currents.
- The movement and fate of human contaminants is determined by coastal winds and currents.
- The safety and efficiency of recreational and commercial use of coastal waters is deeply affected by coastal winds and currents.

WHAT RESEARCH IS CURRENTLY SHOWING:

- Coastal currents respond rapidly to changes in wind patterns.
- Nutrient availability in nearshore waters is closely linked to coastal wind and current patterns; variability in these patterns has significant repercussions for commercially important and protected species.
- Reliable predictions of coastal currents can be generated by coupling large scale models with local observations.

This long term monitoring program allows us to improve our understanding of ocean and coastal ecosystems and develop predictive models of how marine populations respond to variations in coastal processes and climate. The distribution and abundance of phytoplankton, zooplankton, schooling fishes and their predators can significantly improve the creation of marine protected areas, monitoring water quality, restoring and maintaining ocean and coastal habitats and resources, and helping to create sustainable fisheries. CIMT data is being integrated in multiple formats from raw data to models to GIS and is being shared with stakeholders to develop products that meet user needs, such as, wind prediction products, ocean climate models to help predict coastal oceanographic conditions, and an observing system capable of helping to predict ocean currents to respond to oil spills.

A long-term coastal monitoring program is key to helping identify human vs. natural changes to the coastal ocean and its resources. **The nearshore marine environment has a profound effect on our lives, and in California, is responsible for a $43 billion economic impact through recreation, fishing, ports and shipping and other coastal ocean uses.** We need to understand this environment and how both natural patterns and human activities affect these coastal ecosystems, and how they in turn affect our lives and well being.

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Trophic Illustrations Page 1-4: Camas Designs – Erika Beyer

Image Descriptions:

Page 1
- Kelly Newton and volunteer recovering a bioacoustic buoy that has been collecting low frequency sounds–whales and humans–over a three-month time period. Buoys helps to identify the numbers and species of whales using the area (Rondi Robison)

Page 2
- Matt Hurst collecting iron samples (Rondi Robison)
- *Cochodinium catenatum* algae (Susan Coale)
- Baldo Marinovic collecting krill samples (Rondi Robison)

Page 3
- Tagged California sea lion (Mike Weise)
- Black-footed and Laysan Albatrosses (Tonya Haff)
- Tagged blue whale & whale dive record (John Calimbokitis, Graphic: Kelly Newton)

Page 4
- Plumes of discharge immediately after a rain event (Raphe Kudela)
- Wind Patterns in the Monterey Bay Region (CIMT)