

California Current Ecosystem LTER

Coastal upwelling biomes are found along the eastern margins of all major ocean basins, and represent some of the most productive ecosystems in the world ocean. The 193,000 km² California Current Ecosystem (CCE) LTER focuses on the planktonic food web, which is particularly responsive to climate forcing. Over 70 years of records from CCE LTER partner California Cooperative Oceanic Fisheries Investigations (CalCOFI) demonstrate that the California current food web is perturbed on multiple time scales by El Niño, multi-decadal oscillations, and an underlying warming trend.

Scientists at CCE LTER are addressing all of these time scales, focusing in particular on abrupt transitions in pelagic ecosystem state and the mechanisms that lead to such changes. California Current Ecosystem LTER integrates experimental process studies at sea, diverse autonomous and shipboard observational technologies, and coupled models.



Between 2010-2018:

43 investigators

30 institutions represented

57 graduate students



Marine

Principal Investigator:

Mark D. Ohman

Scripps Institution of Oceanography, UC San Diego

Est. 2004

Funding Cycle:

LTER III

NSF Program:

Geosciences /
Division of Ocean Sciences /
Biological Oceanography



Key Findings

Episodic and (sub)mesoscale features alter primary production and carbon export.

Process studies and related time series measurements reveal the under-appreciated importance of episodic events in the oceanic carbon budget. Spatial and temporal perturbations to the carbon cycle can be associated with (sub)mesoscale features (fronts, eddies, and filaments), which CCE LTER researchers have shown tend to be sites with enhanced phytoplankton and zooplankton biomass and production, and vertical carbon flux. [Products 3, 6, 10]

Iron supply broadly influences carbon dynamics. Iron supply in the CCE LTER region not only impacts carbon production and export associated with mesoscale circulation features. It also influences phytoplankton growth and species composition at the subsurface chlorophyll maximum layer (SCML), which is a widespread feature during spring and summer. Consistent with regional climate indices, biogeochemical proxies for iron

limitation revealed increasing frequency of iron

limitation at SCMLs in the California Current system.

These results are relevant to upwelling systems worldwide. [1, 6, 10]

El Niño and Warm Anomalies restructure the ecosystem.

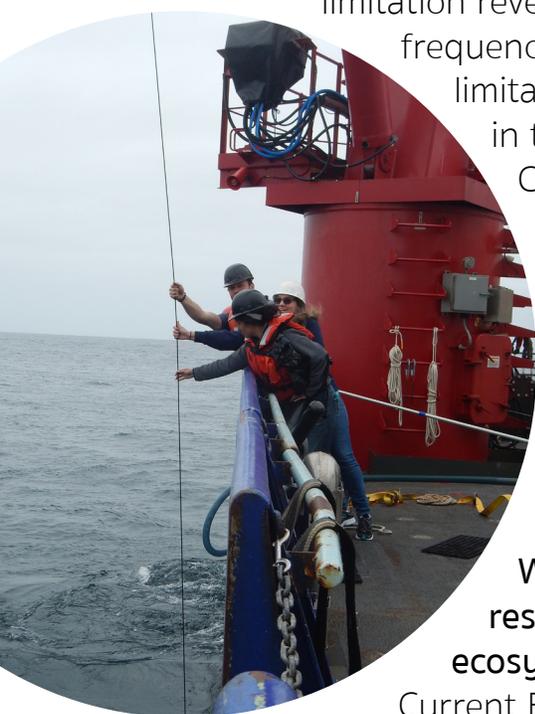
California Current Ecosystem

LTER researchers published

a cluster of 5 papers in *Deep-Sea Research* (vol. 140, Oct. 2018) that analyzed biotic responses to two successive perturbations of the California Current pelagic ecosystem: the Warm Anomaly of 2014-15 followed by El Niño of 2015-16. These studies drew on 12 years of LTER process studies and an analysis of 66-year records from CalCOFI to develop a quantitative basis for forecasting future responses of biotic processes including primary production, zooplankton community composition, and carbon export [2].

Double Integration of climate forcing. More than 60 years of zooplankton census data revealed that some populations respond indirectly to climate changes in two stages: first, ocean circulation responds to wind, then the zooplankton population level responds to ocean circulation. This broadly applicable principle of 'double integration' implies that direct correlations with climate variables should be replaced by metrics that reflect the biological time scale (e.g., life span) of the organisms concerned [9].

Optimized satellite remote sensing products. Several years of effort have led to an important California Current [merged satellite-derived 4 km dataset](#) becoming openly available online. The website provides access to regionally optimized remote sensing products and rigorously integrated time series for chlorophyll-a, net primary production, and export flux of carbon from 1996 to 2019.





Synthesis

LTER EcoTrends project. Lead PI Mark Ohman was a member of the editorial board and co-author of 11 chapters in the LTER EcoTrends report, which summarized extensive climate and ecosystem time series across all U.S. LTER (and other) sites. Peters et al. (eds.) (2013) Long-Term Trends in Ecological Systems: A Basis for Understanding Responses to Global Change.

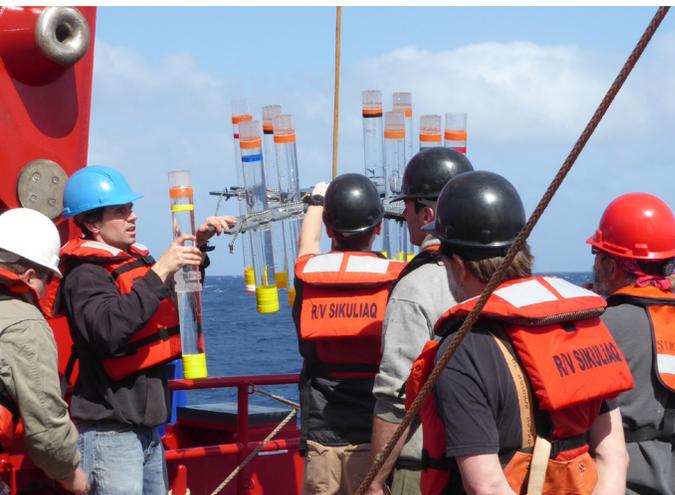
Integration of new pelagic sites into the LTER network. The LTER Network established 3 new marine sites in 2017. Investigators at CCE LTER organized meetings and workshops at scientific society meetings and LTER All-Scientists' Meetings, as well as informal data and methods exchanges.

Researchers from CCE LTER led an **international, pan-Pacific synthesis** of pelagic ecosystem responses to climate forcing: Di Lorenzo et al. 2013. Synthesis of Pacific Ocean Climate and Ecosystem Dynamics. *Oceanography*. 26: 68-81.



Partnerships

California Cooperative Oceanic Fisheries Investigations (CalCOFI) | Birch Aquarium | Scripps Institution of Oceanography (SIO) | SIO Pelagic Invertebrate Collection



Data Accessibility

Project and collaborator data (e.g. CalCOFI) are published through CCE LTER's local data catalog, Datazoo (documented according to LTER best practices). Datazoo archives new and updated datasets with the Environmental Data Initiative (EDI) through a single command. Other data are archived in appropriate repositories, such as NCEI (via R2R) for shipboard data.

Broader Impacts

Engaging the public at Birch Aquarium at Scripps. California Current Ecosystem LTER partners with Birch Aquarium, the public outreach center for the Scripps Institution of Oceanography, to support and deliver sustained outreach programming that incorporates research into exhibits and hands-on activities.

Professional Development for Teachers.

Professional development is delivered to teachers from local urban school districts. Drawing on LTER data and research methods, the program empowers teachers to provide authentic coastal ocean learning experiences.



Partnership with the private, non-profit Ocean Institute. Through a 14-year citizen science partnership with Ocean Institute, student volunteers collect and evaluate data while on educational programs, and share these data with CCE LTER scientists.

Undergraduate Opportunities. Undergraduate students are hosted by CCE LTER each summer via a REU program, which focuses on students from traditionally underrepresented groups and undergraduate-serving institutions.

Top Products

1. Hogle SL, et al. 2018. Pervasive iron limitation at subsurface chlorophyll maxima of the California Current. **PNAS**. doi: 10.1073/pnas.1813192115
2. Ohman MD. 2018. Introduction to collection of papers on the response of the southern California Current Ecosystem to the Warm Anomaly and El Niño, 2014–16. **Deep Sea Research Part I**. doi: 10.1016/j.dsr.2018.08.011 (5 papers).
3. Smith KL et al. 2018. Episodic organic carbon fluxes from surface ocean to abyssal depths during long-term monitoring in NE Pacific. **PNAS**. doi: 10.1073/pnas.1814559115
4. Taylor AG, Landry MR. 2018. Phytoplankton biomass and size structure across trophic gradients in the southern California Current and adjacent ocean ecosystems. **Marine Ecology Progress Series**. doi: 10.3354/meps12526
5. Biard T et al. 2018. The significance of giant phaeodarians (Rhizaria) to biogenic silica export in the California Current Ecosystem. **Global Biogeochemical Cycles**. doi: 10.1029/2018gb005877
6. Stukel MR et al. 2017. Mesoscale ocean fronts enhance carbon export due to gravitational sinking and subduction. **PNAS**. doi: 10.1073/pnas.1609435114
7. Lindegren M et al. 2016. Resilience and stability of a pelagic marine ecosystem. **Proceedings of the Royal Society of London Series B**. doi: 10.1098/rspb.2015.1931
8. Asch RG. 2015. Climate change and decadal shifts in the phenology of larval fishes in the California Current ecosystem. **PNAS**. doi: 10.1073/pnas.1421946112
9. Di Lorenzo E, Ohman MD. 2013. A double-integration hypothesis to explain ocean ecosystem response to climate forcing. **PNAS**. doi: 10.1073/pnas.1218022110
10. Landry MR et al. 2012. Pelagic community responses to a deep-water front in the California Current Ecosystem: overview of the A-Front Study. **Journal of Plankton Research**. doi: 10.1093/plankt/fbs025 (entire issue of 8 articles devoted to CCE-LTER's A-Front study).

Photo credits: CCE LTER