MARINe

Multi-Agency Rocky Intertidal Network

pacificrockyintertidal.org

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Photo credit: Dave Lohse

Distinct vertical zones along the shoreline are formed by "foundation" species, such as rockweeds and mussels, which shape communities by creating habitat for many other species. As seen from low tide looking onshore in this panoramic photo of Coquille Point, Oregon where a MARINe biodiversity survey was being carried out (July 2019).

OVERVIEW

Rocky intertidal shores, commonly called "tidepools", occur at the interface between the terrestrial and marine environments. The unique physical complexity of this system lends itself to high biological diversity, including many species found only within this narrow band of coastal habitat. The accessibility of rocky shores provides people with an important connection to the marine environment, but also makes them vulnerable to degradation from human activities. Natural variation in environmental conditions and community structure in rocky intertidal systems can occur on the scale of months, years, and even decades. Therefore long-term, well-designed monitoring programs are essential for distinguishing between natural and human-induced changes.

At the core of the Multi-Agency Rocky Intertidal Network (MARINe) program is a simple and inexpensive, yet statistically sound approach to collecting long-term monitoring data. This approach has enabled the program to grow into a multi-organization consortium that monitors sites along the entire Pacific Coast of North America, from Alaska to Mexico (see map, opposite).

The MARINe monitoring approach provides a wealth of information about the structure and dynamics of rocky intertidal communities along the Pacific Coast of North America. It is the largest and longest running program of its kind: sites in many regions have been sampled for 20-30 years. Here we provide an overview of the MARINe program and highlight how our data have been used to inform resource managers at the local, state, and federal levels about the impacts of both natural and human-induced disturbances.

- **MARINe's "core" monitoring approach focuses on foundation and keystone species, with the idea that changes in these species will have broad-reaching community impact. This targeted approach allows us to detect community change at effort levels that can be sustained for the long-term.**
- **Layered upon this "core" approach are the goals of documenting species richness and changes in the distribution of species within and among sites over time. Our biodiversity surveys are designed to capture information about the rocky intertidal community as a whole (rather than targeted species).**

Biodiversity surveys require a high-level of expertise for species identification and are done on a less frequent schedule, typically every 5-7 years.

Species composition of rocky intertidal communities is influenced by many factors including geography (which includes physical features such as rock type and climate) and oceanographic currents (important for key drivers such as larval recruitment, water temperature and nutrient availability).

The abundance and composition of species within neighboring sites tend to be more similar to one another than to those occurring farther away, largely because key drivers of community structure tend to be similar at a regional level. Patterns of community similarity at MARINe sites are indicated here by site marker color.

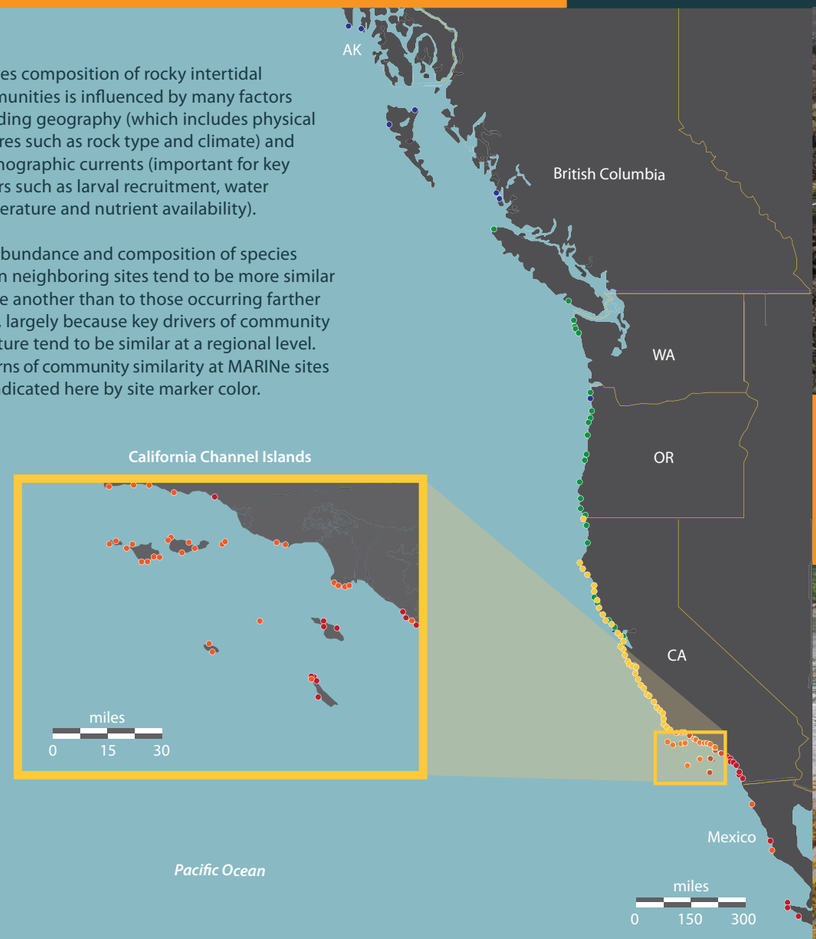

Photo credit: Melissa Miner

Targeted species are monitored annually or semi-annually within fixed plots (above). Surveying equipment is used to collect topographic information along biodiversity sampling transects (below).

Photo credit: Dave Lohse

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Assessing and Monitoring Marine Disease

Designing protocols that adequately capture the effects of disease on key aspects of focal species' populations (i.e., long-term trends, size structure, outlook for recovery) has been integral to MARINe's monitoring approach. Two important examples that illustrate the impact of our work can be found in the dramatic stories of population decline in the black abalone, *Haliotis cracherodii*, and the ochre star, *Pisaster ochraceus*.

Photo credit: Kari Eckdahl

Photo credit: Nate Fletcher

Above, a healthy black abalone specimen (top) clings tightly to the rocks, while a sick abalone withers away inside its shell. Below, a vibrant population of ochre stars whose numbers dropped dramatically due to SSWS, a disease causing their tissues to waste away (bottom).

Photo credit: MARINe/UCSC

Photo credit: Ben Miner

Patterns of Decline and Recovery in Endangered Black Abalone

MARINe surveys documented the spread and impact of withering syndrome (WS) in black abalone populations in California as far north as the San Luis Obispo/Monterey County line. These long-term data (Figure 1), provided strong support for the placement of black abalone on the endangered species list in 2009. Our surveys were integral to the development of a recovery plan for this species and will provide the data necessary for agencies to determine when de-listing criteria have been met.

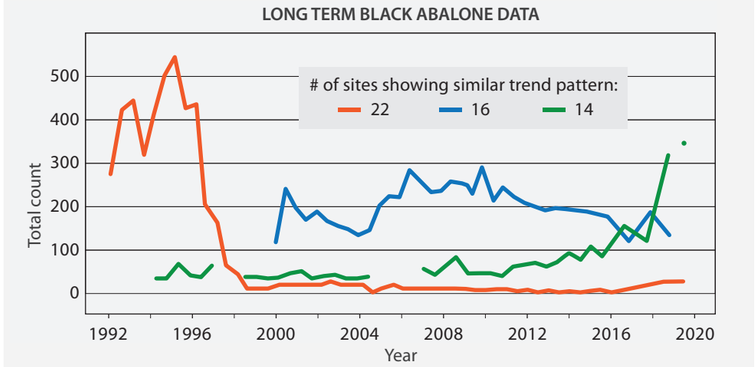

Figure 1: Long-term black abalone data at 3 sites that represent regional patterns. Mainland populations south of Monterey Co. (red line) and on some Channel Islands experienced massive declines and have not recovered. Mainland populations to the north (blue) have been largely unaffected by WS. Recovery has been documented at some Channel Island sites (green line), but populations are not yet approaching pre-WS levels.

Sea Stars Impacted by Coast-Wide Wasting Syndrome

In 2013-2015 sea stars along the entire North American Pacific coast experienced a massive die-off due to a mysterious disease called "sea star wasting syndrome" (SSWS). One heavily impacted species was the keystone intertidal predator, *Pisaster ochraceus* (ochre star).

MARINe surveys revealed unprecedented declines of ochre stars across nearly the entire geographic range of the species. The severity of decline was higher in southern vs. northern regions, and this disproportionate impact has intensified since the initial decline due to substantial differences in ochre star recruitment in the north vs. south. Low levels of symptomatic sea stars are still present throughout the impacted range; thus, the outlook for population recovery is uncertain.

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Informing Impact Assessment of Coastal Oil Spills

A primary driving force behind the creation of MARINe was the desire to establish a baseline dataset that describes the natural condition (i.e., structure and composition) of intertidal communities. After many years of consistent data collected, MARINe has compiled a vast, comprehensive dataset that has enabled researchers to assess injuries to these ecosystems when oil spills occur. Indeed, MARINe data have been used to assess impact in all major oil spills that have occurred in California since 1997.

Rocky intertidal communities are dynamic systems; thus, a common challenge in impact assessment is distinguishing natural fluctuations in species' abundances from changes due to human -induced injuries. The power of the MARINe approach comes from the long-term collection of comparable data across sites spanning broad geographic scales. This allows for comparison of species trends between sites inside and outside of an impact zone, to determine whether the post-spill trajectories of trends at sites within the impact zone fall outside of the "normal" range.

Photo credit: Avrey Parsons-Field

Photo credit: Christy Bell

- **MARINe data were used to assess the impact of four oil spills that have occurred since 1997 – two on the outer coast of Santa Barbara County, CA (Torch-Platform Irene and Plains), and two in San Francisco Bay (Cosco Busan and Dubai Star).**
- **Consistency in protocols and personnel, and active incident command and response training means that MARINe mobilizes quickly when spills occur.**

Above, a trained team of intertidal experts carry out MARINe surveys to assess potential impacts from the Refugio Oil Spill at Tajiguas Beach (left) and El Capitan State Beach in California (right). Below, rocks containing *Fucus* are collected from the intertidal near Golden Gate Fields to be transplanted to Point Isabel.

Photo credits: Rachael Williams

Impacts of Oiling on the Seaweed, *Fucus distichus*

Oil spills within San Francisco Bay, CA resulted in a loss of the rockweed *Fucus distichus,* an important "foundation" species that provides food and shelter to a suite of other species (Figure 2). This rockweed is highly sensitive to both oiling and the processes used to clean-up oil spills. Because juvenile rockweeds do not disperse far from the parent plant, natural recovery is slow. To help mitigate *Fucus* loss, a restoration effort supported by post-spill settlement funds was implemented at three sites within San Francisco Bay. Adult plants were transplanted to areas heavily impacted by oiling, with the hope that these adults would then "seed" the restoration areas. *Fucus* proved to be a challenging species to outplant, and the contribution of this mitigation effort to its overall recovery had mixed results. However, our findings underscore the sensitivity of particular species to oiling and the challenges associated with post-impact recovery efforts.

Photo credit: Dave Lohse

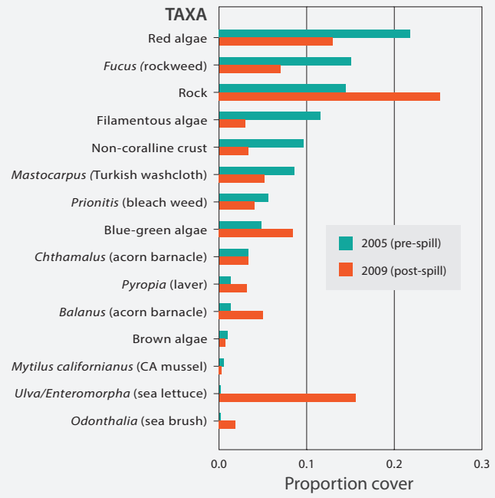


Figure 2: Changes in species composition at Alcatraz, a long-term monitoring site within San Francisco Bay that was impacted by the Cosco-Busan spill. Note the decline in abundance of the rockweed, *Fucus*, accompanied by a corresponding increase in bare rock and the opportunistic species complex, *Ulva/Enteromorpha*.

Climate Change Impacts and Community Resilience

Resilience, as defined by scientists, is a system's ability to resist change or recover quickly following a disturbance. MARINe data are well-designed for detecting shifts in species distributions that might result from impacts due to a changing climate, such as sea level rise or elevated water temperatures. Our data have also been used to assess community-level resilience to climate change impacts.

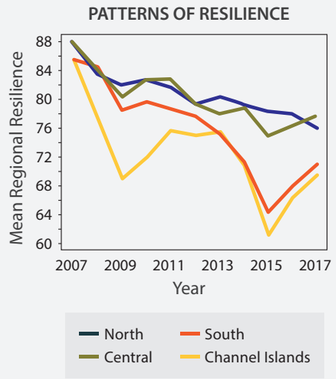


Figure 3. Patterns of resilience over time, as represented by annual mean similarity (annual regional resilience) values across sites within each region. Sites were grouped into regions based on previously described biogeographic provinces as follows: "North" (Washington, Oregon, northern California: 19 sites), "Central" (San Francisco to Point Conception, CA: 20 sites), "South" (Point Conception to San Diego, CA: 16 sites), and the northern "Channel Islands" off the coast of Santa Barbara, CA (19 sites).

Long-term data were used to explore how rocky intertidal communities responded to perturbation in the form of periodic warm water events. The ability to distinguish resilient from non-resilient sites and the factors likely responsible for such patterns have significant implications for resource management and conservation. Our findings suggest that:

- There are substantial regional differences in the ability of rocky intertidal communities to resist or recover from change. Change in response to warm water disturbance events tended to be less extreme at sites in northern (central California to Washington) vs. southern regions (southern California and Channel Islands) as seen in Figure 3.

- Resilience was linked to presence of the mussel, *Mytilus californianus*, an important foundation species in this system. Mussel beds in southern regions experienced greater decline than those in northern regions during the period examined.

A preliminary analysis based on our biodiversity surveys suggests that intertidal community composition has shifted poleward —the direction expected due to impacts of climate change—over the past 15 years.

Long-term trends for "indicator species" that are sensitive to warming water temperatures, such as the sea palm, *Postelsia palmeformis* (above), might provide an early warning of changing conditions. Photo credits: Dave Lohse

Establishment and Effectiveness of Marine Protected Areas in California

MARINe Biodiversity Surveys were a primary data source used in the Marine Protected Area (MPA) Network design and planning process in California to estimate the area required to include 90% of the available biodiversity for intertidal habitats. These methods estimated that approximately 0.5 linear miles of rocky intertidal habitat must be encompassed by an MPA to ensure ecological representation.

MARINe monitors 161 sites, both inside and outside MPAs across the entire MPA network in California. Many were established long before MPA protections were put in place, resulting in a crucial data set for: 1) assessing the effectiveness of MPAs, 2) prioritizing strategies for adaptive management of the MPA Network, and 3) informing California Department of Fish and Wildlife's long-term monitoring plan.

MPA's are important for providing protection to harvested species such as the owl limpet, *Lottia gigantea.*

MARINe and Citizen Science

Citizen science programs offer community members the opportunity to contribute to research and conservation efforts. MARINe has formed partnerships with many west coast programs to better document the extent and impact of sea star wasting.

The heavily publicized 2014 Sea Star Wasting Syndrome (SSWS) event generated increased interest from the general public in the MARINe program. During the event, users accessed our website to view coast-wide trends in long-term sea star abundance, report incidents of disease, and find resources for symptom identification and categorization. We in turn, formed new partnerships with citizen science groups, generating new opportunities for long-term sea star data collection in areas previously not covered by MARINe. These collaborations have refined our ability to track the emergence (and re-emergence) and impact of SSWS along the entire west coast of North America.

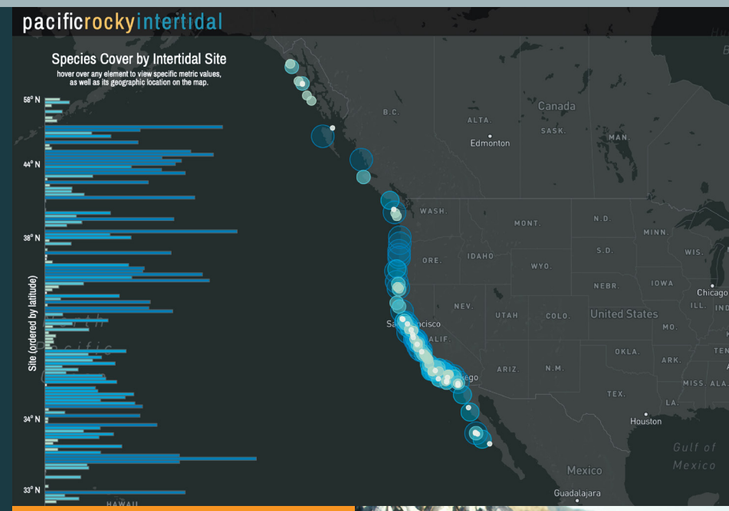
Photo credits: Melissa Miner

A group of citizen scientists (left) collecting sea star size and count data near Point Whitehorn, Washington. The sunflower star, *Pycnopodia helianthoides* (right), once a common sight in the low intertidal, was severely impacted by SSWS.

MARINe's Sustainability

Since its inception in 1997, MARINe has grown from a partnership among a handful of federal agencies and universities monitoring sites in southern California to a collaboration among a diverse group of organizations monitoring over 200 sites from Alaska to Mexico. Successful growth has been based on these key foundational components:

- **Membership requirements are simple—partners can contribute through data collection, field support, and/or funding.**
- **Data compatibility among sites is accomplished through vetted core protocols.**
- **A centralized database assures data accessibility and compatibility across sites and over time.**
- **Data are accessible from the website (see example of GIS mapping tool on right), enabling extensive use by students (grade school-grad school), researchers, citizen stakeholders, and resource managers.**
- **Over 30 member organizations contribute to a geographically broad network, which allows for greater context when assessing local trends.**
- **Network structure allows for rapid mobilization of teams to respond to oil spills and other disturbance events.**



GIS data display tool showing distribution and abundance of the mussel, *Mytilus californianus* (above). Larger, darker blue bubbles indicate more mussels. A healthy population of *Mytilus* at a site on Catalina island (right). Photo credit: Jay Smith

A MARINe field crew headed for breakfast after an early morning of sampling at Ecola State Park on the Oregon coast.

Photo credit: Christy Bell

Acknowledgements

MARINe is a true collaborative effort, with funding and other support coming from over 30 different federal, state, university and private organizations, including these primary funders:

The Bureau of Ocean Energy Management (BOEM) assists with data collection and provides funding to 4 universities to monitor 24 sites in California and 8 in Oregon. BOEM also contributes roughly one third of the database development and maintenance costs.

Survey methods from the **National Park Service (NPS)**, one of the original MARINe partners, provided the foundation for the development of MARINe core protocols. NPS supports monitoring efforts at 6 sites in WA, 1 in OR, and 39 in CA.

US Navy (Navy Marine Ecology Consortium) has funded sampling and data management support for 8 sites on San Clemente and San Nicholas Islands and 2 mainland sites in San Diego.

The Ocean Protection Council (OPC) has funded sampling and data management support for numerous sites in CA to help inform CDFW's management of the state's 124 MPA's and support policy decisions.

The Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) funded in large part by the David and Lucile Packard Foundation, has been a long-time MARINe partner, supporting numerous sites in CA and providing database funding.

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Many other regional groups partner with MARINe to collect compatible data at a coast-wide scale.

Please see **pacificrockyintertidal.org** for a complete list.