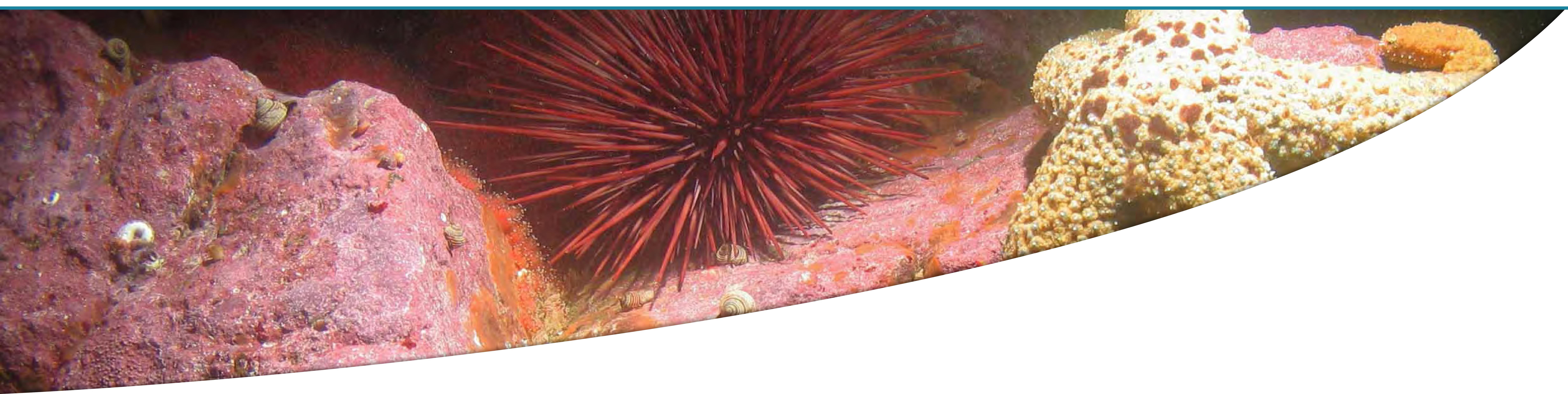
California North Central Coast

A Regional Snapshot

Summaries of Baseline Marine Protected Area Monitoring Projects, 2010–2013



Introduction

With the passage of the Marine Life Protection Act (MLPA) in 1999, California became the first state in the nation to require a statewide network of marine protected areas (MPAs) to protect the integrity of marine ecosystems, rebuild depleted populations of marine life, including those of economic value, and improve ocean health. To implement the MLPA, the state's 1,100 miles of coastline were divided into five regions, four coastal regions and San Francisco Bay. A regional MPA network was designed and implemented in each coastal region.

In 2010, following a broad, stakeholder–driven public policy process, 22 MPAs were adopted by the California Fish and Game Commission in the North Central Coast region, including ten State Marine Reserves (SMRs), 12 State Marine Conservation Areas (SMCAs), and six Special Closures (see page iii).

North Central Coast Region

The North Central Coast region stretches along 584 kilometers (363 miles) of coastline from Alder Creek, near Point Arena, south to Pigeon Point. Waters extend from mean high tide to a maximum depth of 116 meters (382 feet) (see map next page). The region also encompasses state waters around the Farallon Islands, a biological hotspot 45 kilometers (28 miles) offshore of San Francisco. In total, the region covers 1,978 square kilometers (764 square miles) of state waters, including a wide variety of habitats from deep rocky reefs and kelp forests to rocky headlands and seagrass beds.

Altogether, the region is among the most biologically productive marine areas in the world, with a tremendous abundance and diversity of fish, seabirds, marine mammals and other ocean life. In part, this is due to the region lying within the California Current Large Marine Ecosystem (CCLME). CCLME is well-known for persistent upwelling that brings nutrient-rich waters to the surface, which support blooms of phytoplankton that form the foundation of a diverse and complex food web. Collectively, the varied habitats in the region are home to thousands of species, including 36 marine mammal species, 54 breeding seabirds, 4 sea turtles, 345 fishes, thousands of invertebrate species, and more than 450 marine algae. Of these, 25 species are threatened or endangered, including black abalone, Steelhead, Chinook and Coho salmon, and Marbled Murrelets.

Coastal communities depend on the region's rich waters, as they sustain productive commercial and recreational fisheries and support a variety of recreational activities and tourism. Knowing where, how, and why people interact with our coast and ocean is critical to our understanding of ocean conditions and to managing our coastal resources. The major commercial fisheries in the region include Dungeness crab, California halibut, nearshore finfish (rockfish), salmon, and sea urchins. The region also supports vibrant recreational fisheries, such as red abalone, rockfish and salmon, and a variety of coastal recreation activities, from SCUBA diving to bird watching.

About this report

This report shares summaries from the North Central Coast MPA Baseline Program in California's North Central Coast, based on peer-reviewed technical reports.

This is the first of a series of reports that will share highlights, results and next steps for the monitoring, evaluation and management of this regional network of MPAs. We are exploring opportunities to integrate and synthesize data across projects, among regions, and with other sources of data outside of the program. This data integration and synthesis will culminate in the production and release of a State of the Region Report in 2015.

Visit www.oceanspaces.org to view and download data and technical reports that informed this report, and to stay updated on the latest results from this region

This report has interactive elements that are best viewed using Adobe Acrobat.

Acknowledgments

This report was produced by California Ocean Science Trust working in partnership with the California Department of Fish and Wildlife, California Ocean Protection Council, and California Sea Grant, and in collaboration with the North Central Coast MPA Baseline Program Principal Investigators (PIs). Over the past several months, the PIs and their research teams have worked with us to develop their project summaries, provided results and reviewed sections of the report. We thank everyone for sharing their expertise and contributing their time and energy to working with us on this project.

A Benchmark of Ecological and Socioeconomic Conditions

The North Central Coast MPA Baseline Program encompasses 11 projects, selected through a competitive peer-review process and funded by the California Ocean Protection Council. The program is overseen by a partnership among California Ocean Science Trust, California Department of Fish and Wildlife, California Ocean Protection Council, and California Sea Grant.

This program monitored a broad range of habitats, from sandy beaches, rocky reefs and kelp forests to the 380-foot deep waters around the Farallon Islands. Data were also collected on human activities including commercial and recreational fishing, beach use and boating activities.

The baseline program's detailed picture of ocean conditions along California's North Central Coast is an important time stamp, providing a foundation for citizens, managers and scientists to keep a finger on the pulse of marine systems and to make rigorous science-based decisions for our oceans.

A Partnerships-Based Approach to Monitoring

Collectively, the MPA baseline program forged strong partnerships among academic and citizen scientists, state and federal agencies, and nonprofit organizations. In addition to fostering new collaborations, the program brought in new volunteers and stakeholders, such as recreational fishermen. This broad community involvement laid the groundwork for increased stewardship and compliance in support of effective MPA management. Some program partners, such as PISCO and Reef Check California, have been monitoring the region for over a decade, allowing the baseline program to incorporate and build on their long-term datasets.

A Foundation for Science-Informed Decisions

Taken together, the 11 projects in the MPA baseline program give us the fullest picture so far of ocean conditions along California's North Central Coast. This picture serves as a reference point for tracking future changes in ecological and socioeconomic conditions in the region. Data and results from this program not only inform long-term MPA monitoring and management, but also other management initiatives such as fisheries, water quality, and climate change adaptation.

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North Central Coast MPA Network

MPA Classifications in the North Central Coast	Number of MPAs	Area* (km²)	Percent of North Central Coast State Waters*
State Marine Reserve (SMR) An area where all commercial and recreational take of living or geologic resources is prohibited. Scientific research and non-consumptive uses may be allowed.**	10	218	11%
State Marine Conservation Area (SMCA) An area where select recreational and/or commercial take activities are allowed to continue. Scientific research and non-consumptive uses may be allowed.**	12	176	9%
State Marine Recreational Management Area (SMRMA) A non-terrestrial marine or estuarine area designated to provide for recreational hunting opportunities to continue while providing MPA-like protections subtidally. Scientific research and non-consumptive uses may be allowed.**	3	2	<1%
Special Closure An area adjacent to seabird rookeries or marine mammal haul-out sites, where access or boating activities are restricted.†	6	3	N/A
Total for North Central Coast Region*	31	399	20%

Visit the California Department of Fish and Wildlife website for additional information, including official regulations, MPA boundaries, and additional statistics.
* Numbers for area and percent represent rounded values.
** Research within MPAs is allowed pursuant to obtaining a California Department of Fish and Wildlife issued Scientific Collecting Permit.
† These small closures (300' and 1000') often overlap with other MPAs and provide additional protection in sensitive areas.

Oceanographic Conditions

Farallon Institute

If you want to understand what's going to happen biologically, you have to understand the patterns of upwelling.
—Bill Sydeman

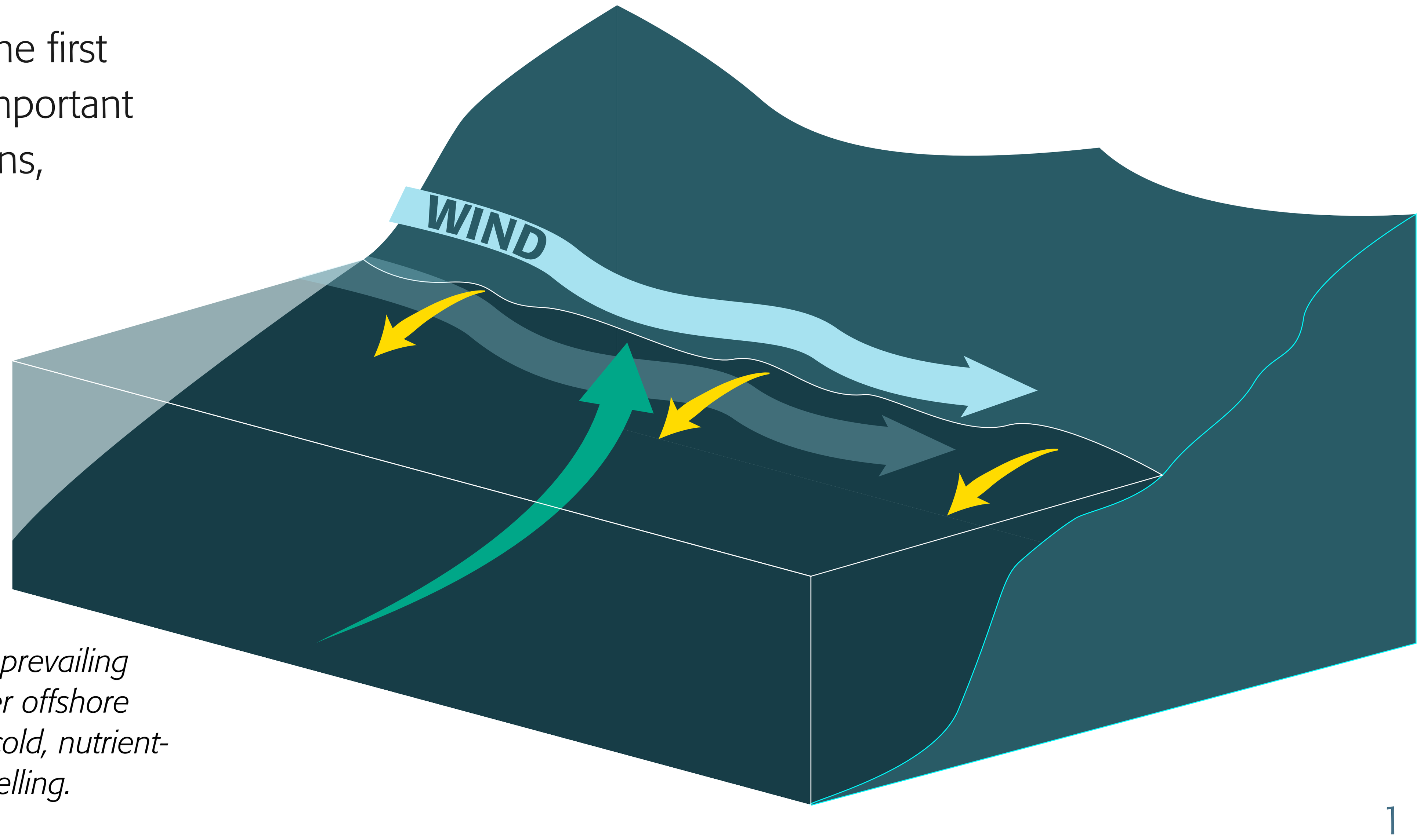
ENVIRONMENTAL VARIABLES
1. Southern Oscillation Index
2. Multivariate ENSO Index
3. Oceanic Nino Index
4. North Pacific Index
5. Pacific Decadal Oscillation
6. North Pacific Gyre Oscillation
7. Northern Oscillation Index
8. California Current flow from Argo
9. California Current flow from HF Radar
10. Upwelling index
11. Wind stress
12. Sea level
13. Sea surface temperature
14. Salinity
15. Air temperature
16. Precipitation

Oceanographic conditions vary widely from season to season and from year to year, driving temperatures, currents, and upwelling patterns that in turn affect marine life. Accounting for this environmental backdrop is essential for understanding the drivers of ecological changes observed inside and outside MPAs. In the North Central Coast region, the primary driver of marine life—from the phytoplankton at the base of the food web to the predators at the top—is upwelling that delivers nutrient-rich water from the ocean depths to the surface. Occurring in a narrow band along the coast, this upwelling is in turn driven by a combination of large- and small-scale factors, from the basin-wide Pacific Decadal Oscillation to local winds (see diagram).

To understand the variability and patterns of environmental and oceanographic conditions within this region, researchers, led by Dr. William Sydeman (Farallon Institute), selected, compiled and analyzed 16 well-known atmospheric and oceanographic measurements that represent key large-scale drivers and regional attributes of the coastal physical environment (see indicators list at right). These were then distilled into seasonal indicators of overall environmental and oceanographic conditions, called MOCI (Multivariate Ocean Climate Indicators). At its simplest, increases in the spring MOCI index represent strong upwelling, cool surface water temperatures, strong winds, and low precipitation. These seasonal indices are based on data that have long been collected routinely by, for example, the National Weather Service and University of California, Davis. While MOCI are based on large- to regional-scale measurements, they have consequences for marine life at local scales inside and outside MPAs.

To assess ocean trends leading up to MPA establishment in the region, researchers derived MOCI from two decades' worth of data for each of the 16 underlying factors, 1990–2010. The data show that environmental conditions varied widely over this time period, with two strong upwelling events in recent years, winter-spring 2008 and summer 2010. Combined with cooler air and ocean surface temperatures, these events were also characterized by increases in phytoplankton productivity, which in turn support healthy populations of other marine species.

This baseline project developed and tested MOCI for the first time in California. These multivariate indices provide important insight into environmental and oceanographic conditions, and thus an important foundation for understanding and interpreting biological patterns in the region over time. Understanding how changes in oceanographic conditions affect populations of marine species will help us not only evaluate changes due to MPA implementation, but also manage our ocean within the context of change.



A diagram illustrating upwelling along the California coast, where the prevailing wind direction is from north to south. The wind displaces surface water offshore due to the earth's rotation (yellow arrows). This displacement draws cold, nutrient-rich water to the surface (green arrow) through a process called upwelling.

Mapping Coastal Habitat

Ocean Imaging, Inc.

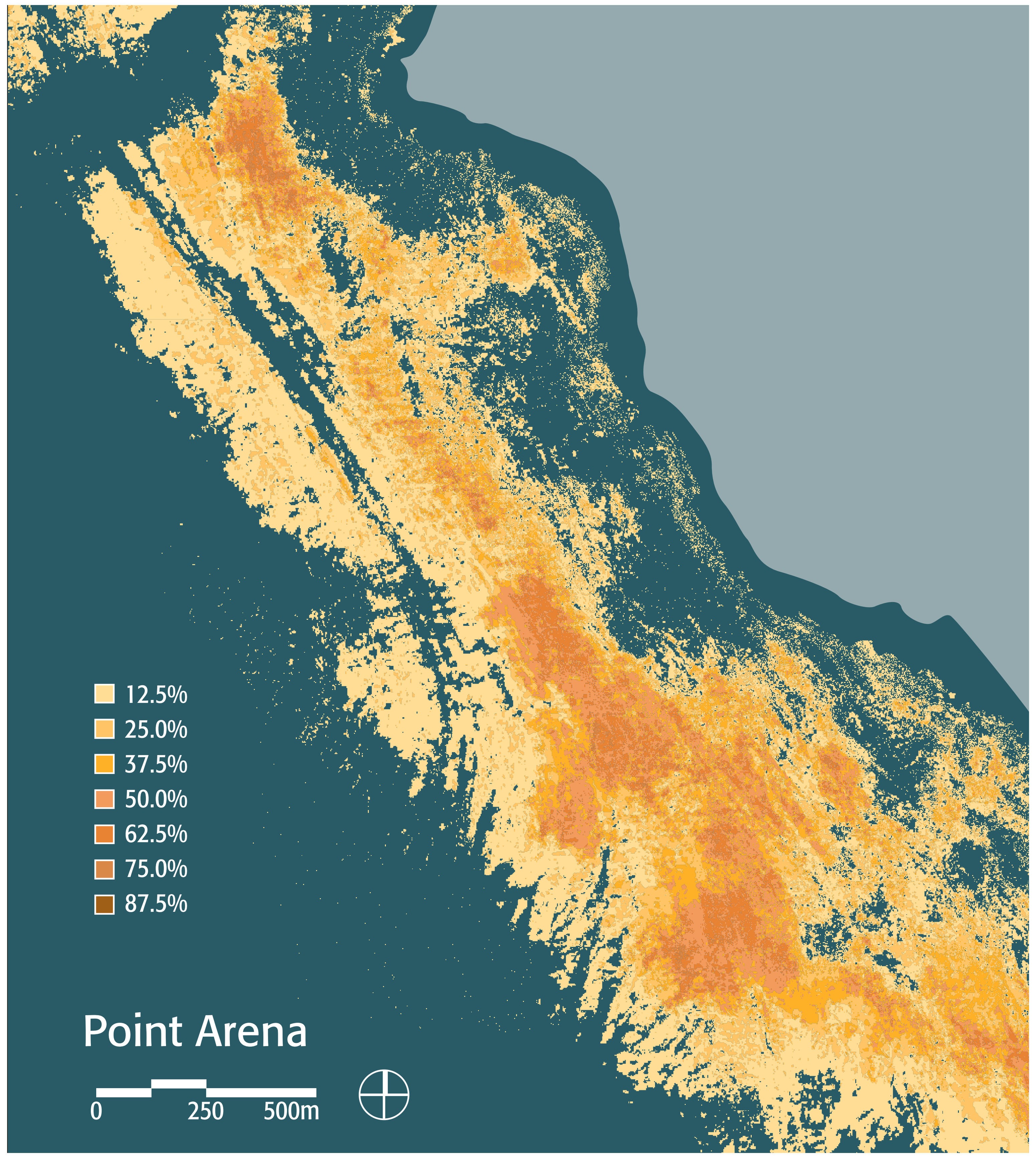
The North Central Coast region spans 290 kilometers (180 miles) of coastline, encompassing a wide range of habitats, including kelp forests, rocky shores, estuaries, and beaches. This project produced the first set of detailed, comprehensive maps of intertidal and kelp forest habitats for this region. These maps serve as a reference point for monitoring future changes in indicators like kelp coverage, and give insights into the likely abundances and distributions of species that depend on habitats such as rocky intertidal, estuaries, and kelp forests.

While previous aerial imagery has a resolution of 30 meters (98 feet), Jan Svejkovsky (Ocean Imaging, Inc.) and his team generated imagery at a resolution of one to two meters. These images were then classified to produce maps that chart the distribution of 20 habitats including mudflats, tidepools, eelgrass beds, sandy beaches, and salt marshes (see example map, of Bodega Bay habitats). In addition to providing an important baseline of coastal habitat distribution, these high-resolution maps support site selection for future monitoring in the region.

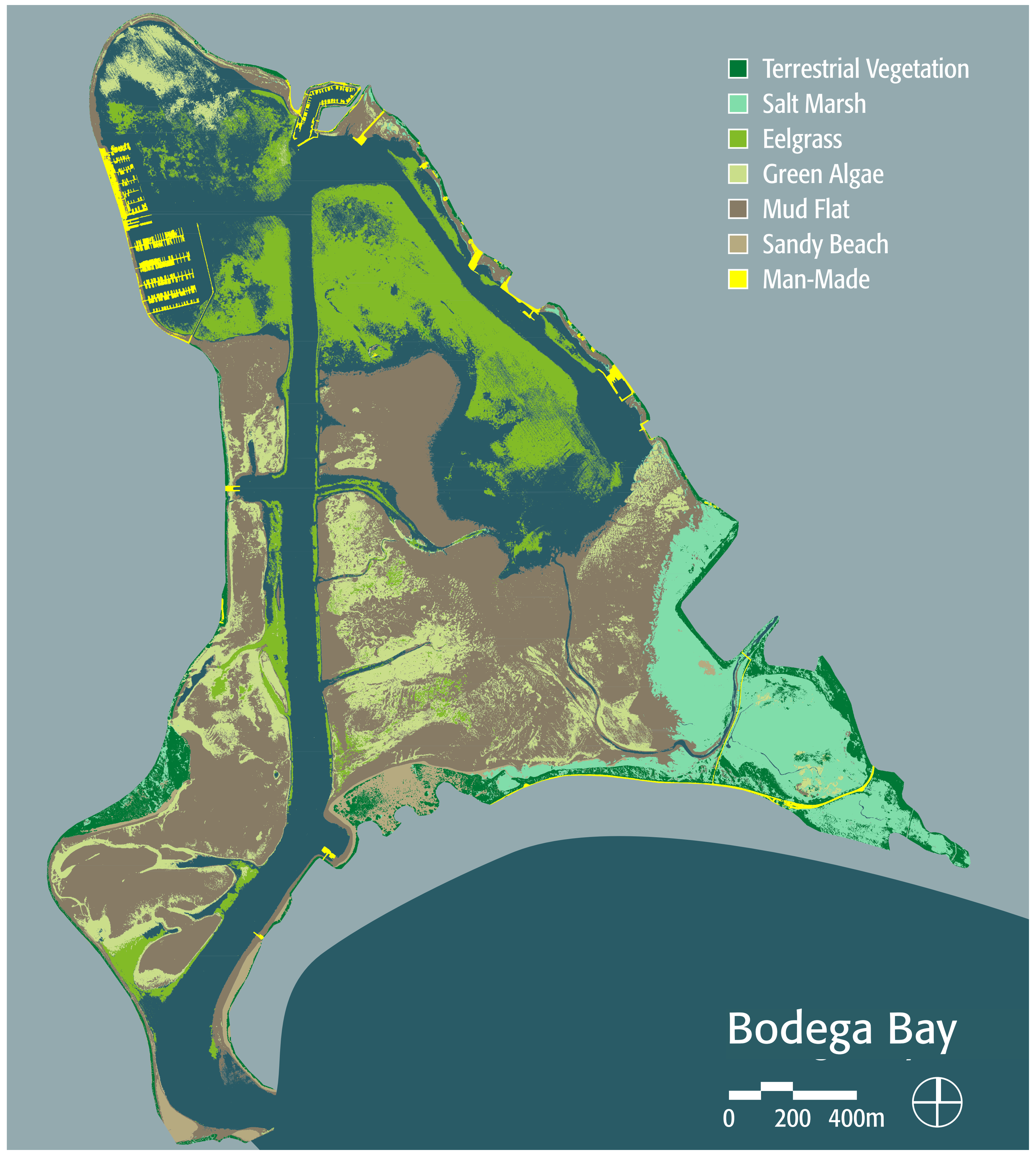
The aerial maps are based on two types of imagery, multispectral and LiDAR. Multispectral imagery records red, green, blue and near infrared wavelengths. These wavelengths can be translated into habitats because each type of habitat has a characteristic reflectance. Surfgrass, for example, strongly reflects both near infrared and green.

LiDAR*, which involves bouncing lasers off surfaces, revealed the 3-dimensional topography of the intertidal and thus helped researchers distinguish among intertidal habitats such as rocky shores and eelgrass beds. Besides fine-tuning the maps, this detailed topography will help researchers understand how small-scale changes in substrate (e.g., sand to rock) or habitat characteristics (e.g., red/brown algae to green algae) affect the species composition, distribution and abundance within coastal ecosystems.

* LiDAR data used in this project was collected through a partnership led by the Ocean Protection Council and NOAA's Coastal Services Center.



Kelp persistence map for Point Arena generated by processing Digital Multispectral Camera (DMSC) images take on March 2010, Fugro EarthData ADS40 multispectral images acquired in September 2010, and Light Detection and Ranging (LiDAR) topographic data. The number of years kelp was observed in a pixel from 1999-2010 increases from yellow to orange. Kelp persistence maps like this one were created for the entire North Central Coast region by USGS orthoquad. Source: Ocean Imaging, Inc.



Estuarine habitat classification map for Bodega Bay generated by processing Digital Multispectral Camera (DMSC) images take on March 2010 and Light Detection and Ranging (LiDAR) topographic data. Habitat classification maps were generated by processing DMSC and LiDAR images only. Habitat classification maps were created for the entire North Central Coast region by USGS orthoquad. Source: Ocean Imaging, Inc.

Analyses of habitat distribution data revealed that mixed red/brown algae covers more than 40% of the area mapped inside MPA boundaries, compared to less than 25% outside MPAs. Conversely, sandy beach and bare rock are nearly twice as common outside MPAs as inside them (see example map of Bodega Bay habitats). In addition, maps of kelp persistence from Point Arena to Bolinas show that coverage varied widely over the past decade (see example map of Point Arena kelp persistence).

The habitat classifications—which were verified and refined against field data and photographs—were 86% accurate, reflecting a significant advance in mapping technology. This exceptional accuracy will help researchers target representative monitoring sites and ensure that future mapping will be able to track region-wide habitat changes over time.

Human Uses of Nearshore Ecosystems

Point 97 Ecotrust

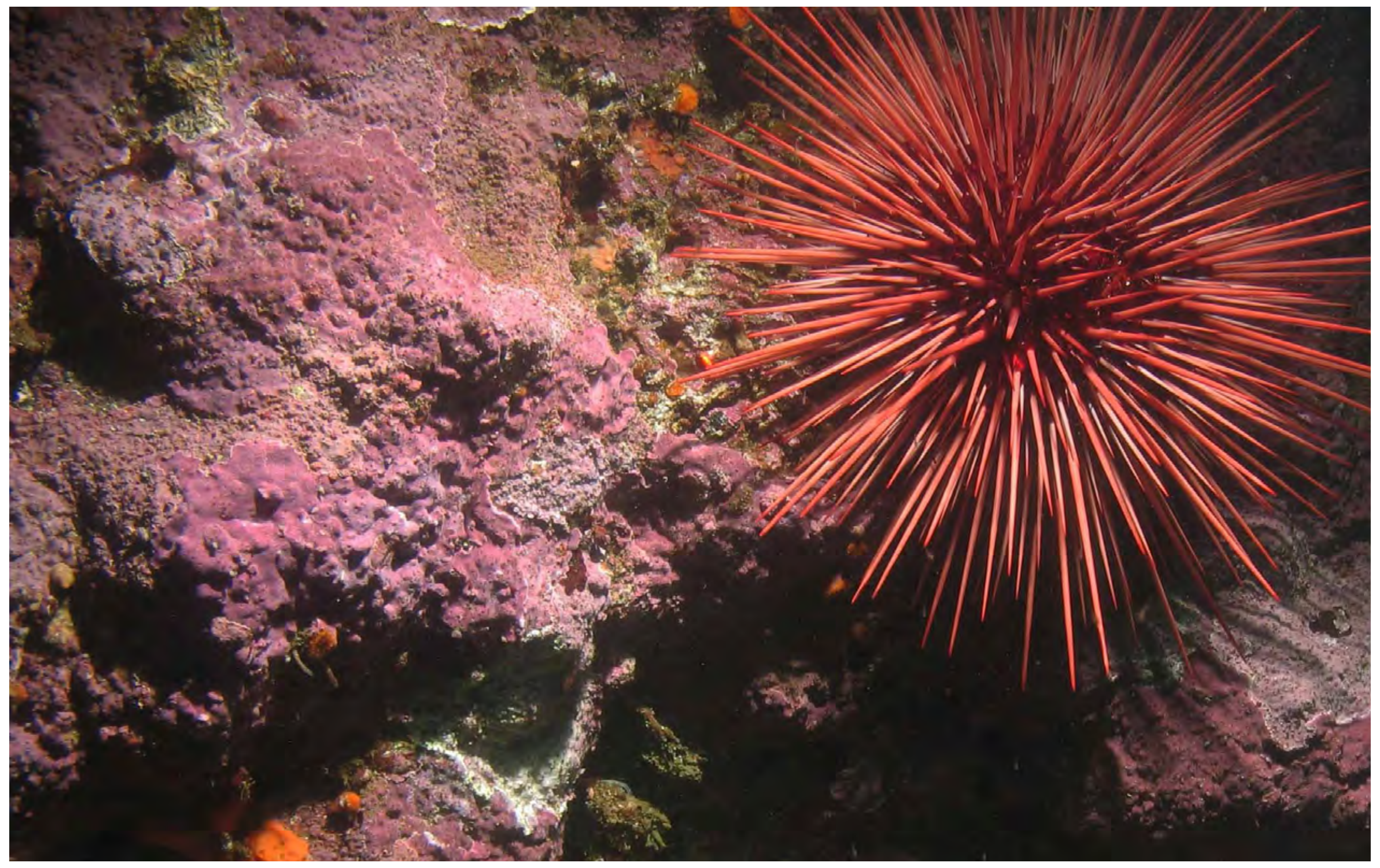
Commercial and recreational fisheries have long been an important part of the local economy in the North Central Coast region. In addition, other coastal activities draw visitors who contribute to the economy, for example, by shopping, dining and staying in hotels. To help establish a benchmark of human uses and socioeconomics for the region, Cheryl Chen (Point 97/Ecotrust), Charles Steinback (Point 97/Ecotrust), and Kristen Sheeran (Ecotrust), led a team of researchers who assessed the status and trends in commercial and recreational fisheries, as well as how many people visit the coast and how they use it.

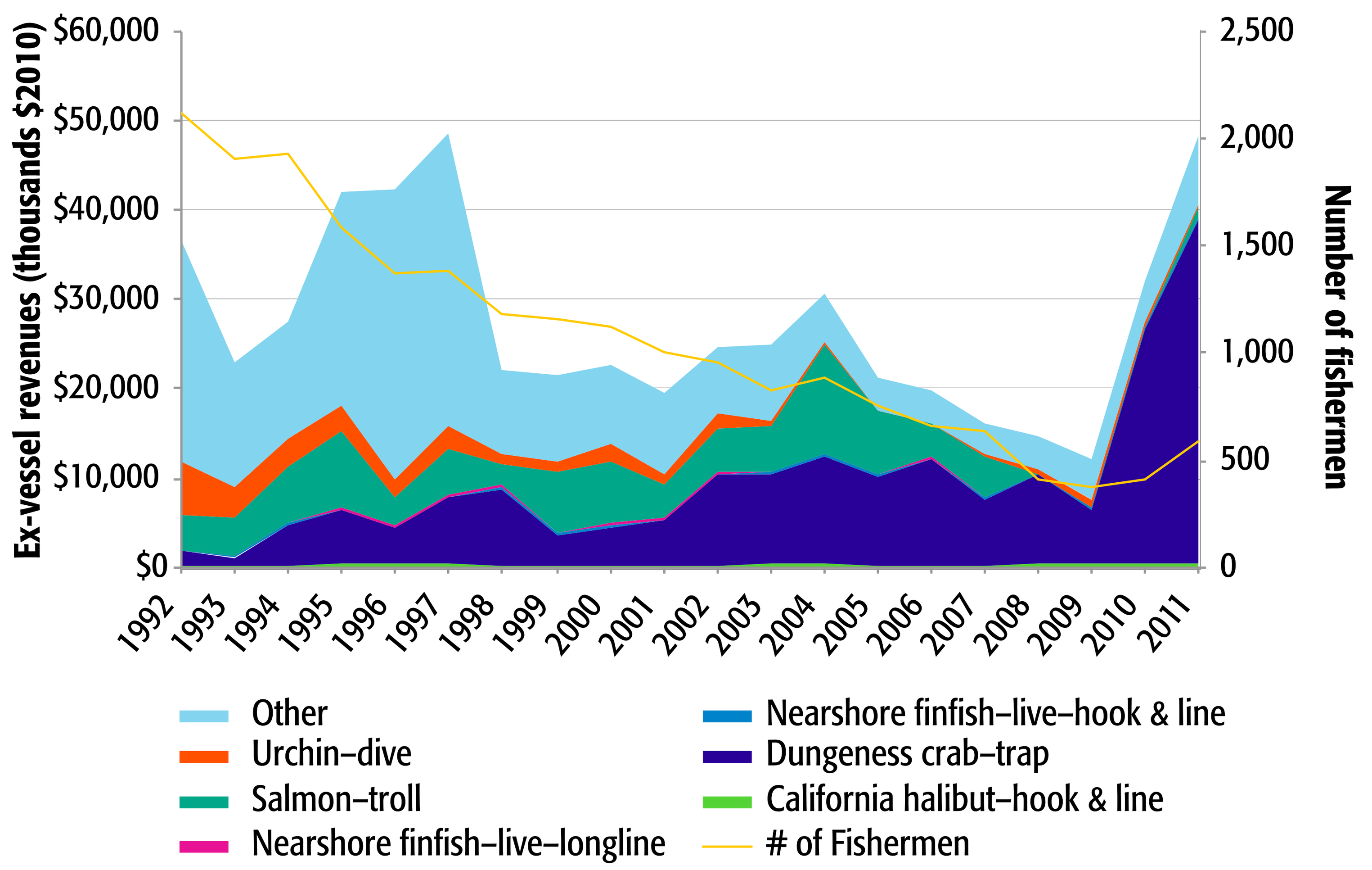
Data on commercial and recreational fishing contribute to the benchmark of socioeconomic conditions in the region. To provide a deeper understanding of the region's fisheries, researchers incorporated long-term data from sources such as vessel landings reports, logbooks from 1992–2012, and interviews with fishermen. These long-term data provide a complete picture of the region's socioeconomic condition before and after MPA implementation.

In addition, researchers mapped fishing patterns for individual commercial fisheries, commercial passenger fishing vessels (CPFV), and recreational abalone fishing, providing a baseline for tracking changes in the location and value of fishing grounds over time. When combined with other long-term monitoring data, such maps could help document shifts in both fishing grounds and the species fished over time.

Commercial Fishing

The researchers used landings data from the California Department of Fish and Wildlife (CDFW) to characterize the status of commercial fishing, focusing on Dungeness crab, nearshore finfish, California halibut, salmon and urchins from 1992 through 2011. Annual landings averaged 7.8 million pounds and $16 million in ex-vessel revenue from 1992–2011. Landings varied considerably from year to year due to natural cycles driven by ocean conditions as well as fishery closures and restrictions. In addition, the contribution of fish caught within state waters to the region's ex-vessel revenue increased from 32% in 1992 to 84% in 2011. This increase is largely due to a reduction in the trawl fleet size in federal waters off the coast of California and to dramatic increases in Dungeness crab fishery revenue. The average ex-vessel revenue per fisherman before and after MPA implementation varied, with notable increases in the Dungeness crab fishery and decreases in the salmon fishery due to its limited season. [NB: Ocean salmon fishing was closed in 2008–2009 for most of the state.]

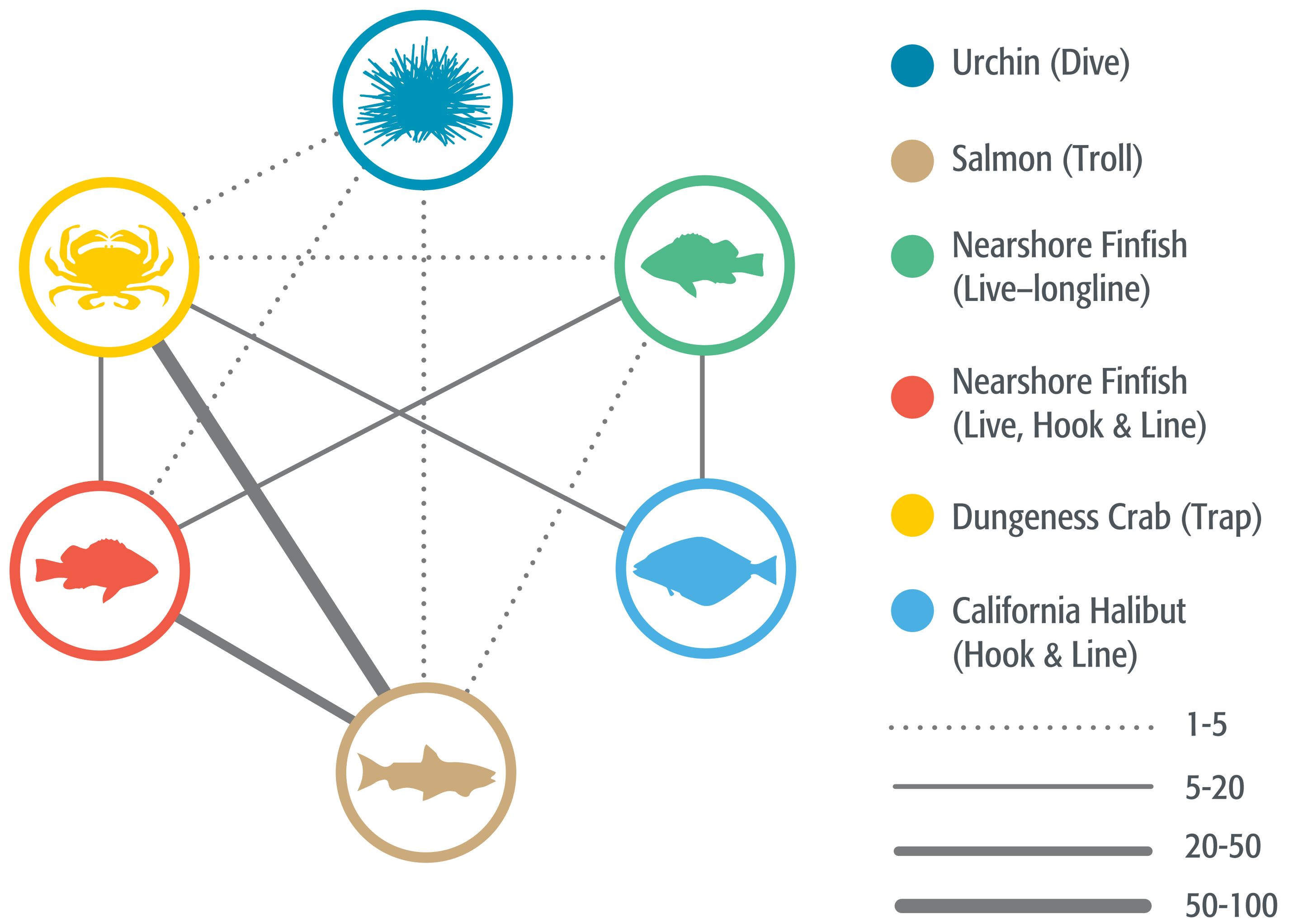




Fishery-specific commercial ex-vessel revenue and total number of fishermen, North Central Coast Region, 1992–2011. Data are averaged across all ports. Source: Point 97/Ecotrust, CDFW

In addition, the number of fishermen in the region dropped about 70% to 584 from 1992–2011, while the annual revenue per fisherman generally rose after 2010 (see graph). The exceptions were the salmon (troll) and urchin (dive) fisheries, which dipped $5,545 and $4,693 a year per fisherman, respectively. In contrast, the annual revenue per fisherman rose $678 for California halibut (hook & line), $1,523 for nearshore finfish (hook & line), and $7,586 for nearshore finfish (live-longline). Moreover, the annual revenue per fishermen for Dungeness crab more than tripled, rising to $131,577 after 2010. This fishery's growth was influenced by many factors, including a peak in the crab's natural reproduction cycle and increased fishing effort by both California and out-of-state fishermen.

In addition to analyzing
CDFW landings data, the Point 97/Ecotrust team also conducted in-person interviews with 101 commercial fishermen who made landings in 2010 for select state fisheries, including California halibut (hook & line), Dungeness crab (trap), nearshore finfish (live, fixed gear), salmon (troll), and urchin (dive). More than three-quarters of those interviewed reported being directly affected by MPAs. For example, they travelled farther, fished in more dangerous waters, and experienced more crowding in the remaining fishing areas.



A diagram depicting how many fishermen participated in multiple fisheries in 2010. Source: Point 97/Ecotrust, CDFW

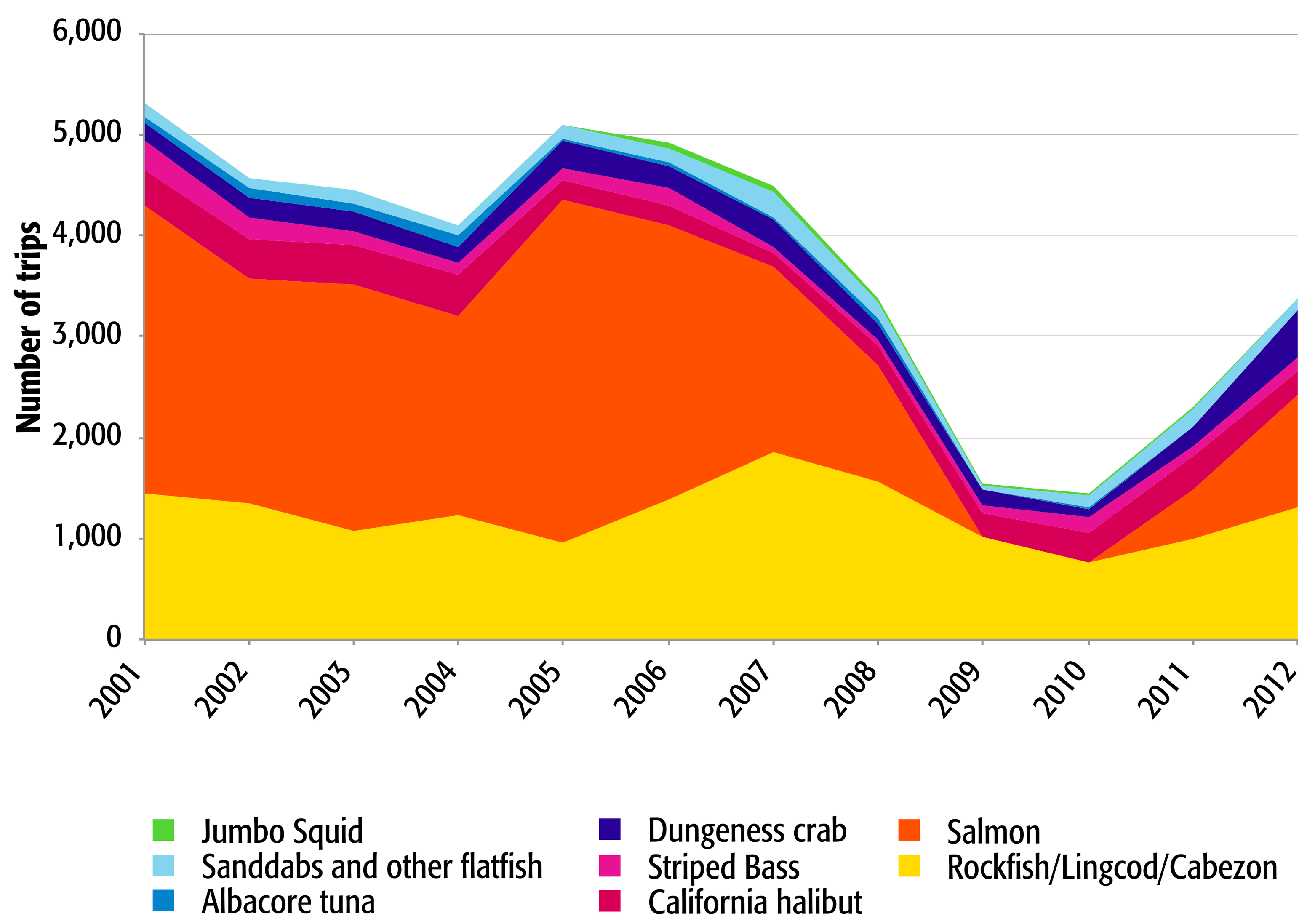
Our research shows how significant coastal recreation is for the region and its visitor-based businesses. As demands on coastal areas grow, increasing our understanding of existing uses will lead to smarter management of our coastline.

—Cheryl Chen

Charter Fishing

The researchers characterized Commercial Passenger Fishing Vessels (CPFV), or charter fishing, by examining CDFW logbook data from 2000–2011. Nearly half of CPFV trips target salmon, but rockfish account for most of the catch (about 70%). The number of CPFV anglers dropped by nearly half, due largely to the recent general economic decline as well as the emergency closure of the salmon fishery from 2008–2009. This closure decreased the number of anglers, trips and fish caught during those years. After the salmon season reopened in 2009, the number of anglers, trips and fish caught increased but generally have not reached pre-closure levels. Possible reasons include the recent economic recession and shorter salmon seasons.

Results from in-person interviews with 30 CPFV operators suggest that most operators were directly affected by the implementation of MPAs. Impacts included loss of traditional fishing grounds, travelling farther to fish, fishing in areas where weather is worse or less predictable, and increased fishing pressure in remaining fishing grounds.



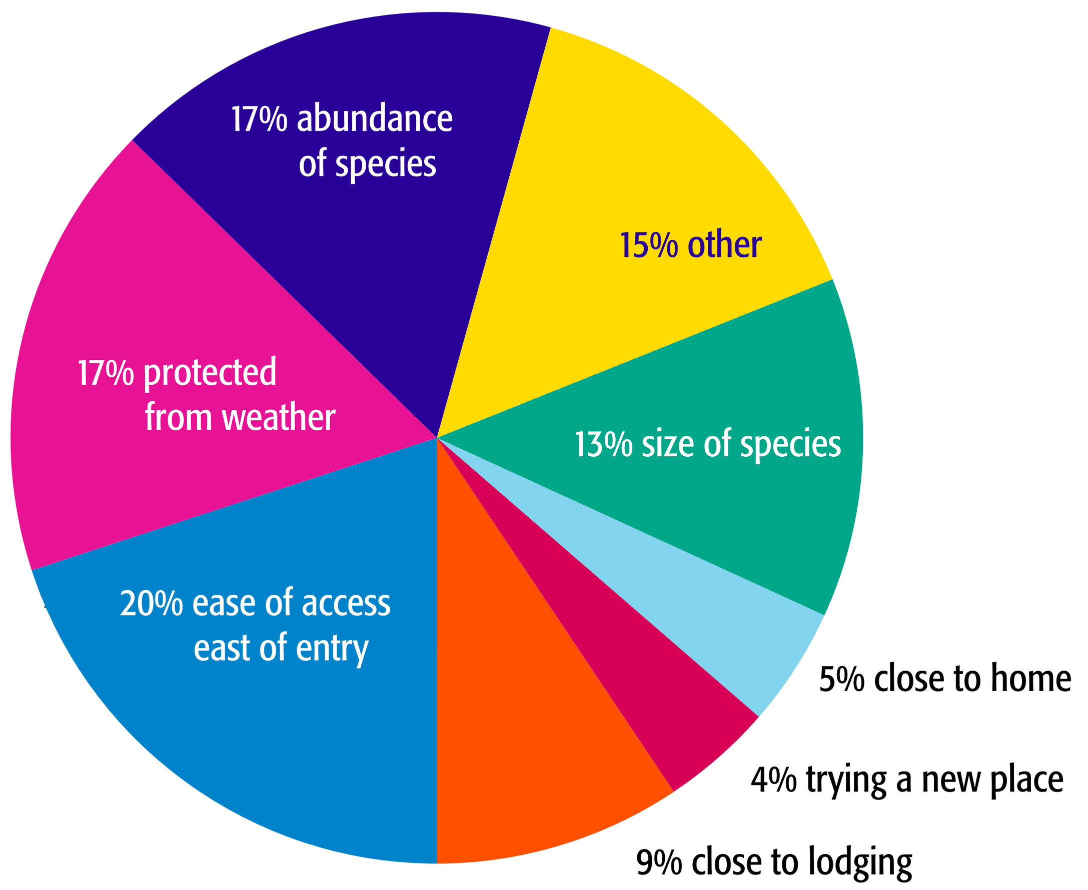
Number of CPFV trips by target fishery from 2000–2011 in the North Central Coast Region. Source: Point 97/Ecotrust, CDFW

Recreational abalone harvesting

To characterize the recreational red abalone fishery, Ecotrust collaborated with key leaders in the community to design and conduct interviews of almost 100 recreational abalone harvesters.

Recreational abalone harvesters contribute significantly to the coastal economy, spending an average of $1,000 on their sport each year. According to punch card data collected by CDFW, the most popular sites were Fort Ross/Reef Campground and Timber Cove, both of which are outside of MPAs. Nearly 90% of the abalone harvesters surveyed knew about the MPAs, mostly from CDFW (i.e., website, outreach documents) or from word of mouth.

Harvesters chose sites primarily for ease of access, protection from weather, and abundance of abalone (see chart). Approximately 30% of those interviewed said MPA establishment was the main reason that they did not return to sites harvested prior to 2010. Shifts in harvesting also reflected the 2011 emergency closures of the fishery along the Sonoma coast. The closure followed abalone dieoff due to a harmful algal bloom event that caused withering disease (see page 14).



Primary reason for harvesting abalone at a specific site. Data are from interviews conducted of 96 people who actively harvested abalone in 2010. Note that the "close to lodging" category includes campgrounds, hotels, and vacation rentals. Ease of access/entry was the primary reason respondents chose to harvest at a site followed by protection from weather and abundance of abalone. Source: Point 97/ Ecotrust, CDFW

Map depicting the relative intensity of coastal recreation use in the North Central Coast region in 2010. Source: Point 97/Ecotrust

Coastal recreation

Recreation is a major part of the coastal economy, and altogether people from North Central Coast counties make more than 22 million trips per year to the local coast, where they spend a total of $1.2 billion per year. To get a baseline of activities and patterns, researchers surveyed over 5,000 people in select counties about where they go on the coast, what they do and how much they spend. The top five activities were scenic enjoyment, going to the beach, photography, biking or hiking, and watching seabirds and other marine life from shore. Researchers mapped the distribution of coastal activities to provide a baseline for tracking future changes. Over time, this could help answer questions such as whether the region's MPAs attract more SCUBA divers and other visitors.

Sandy Beaches and Surf Zones

Sonoma State University
UC Davis UC Santa Barbara

With our new understanding of the striking differences between long and pocket beaches, California is poised to track the condition of this important ecosystem.
—Karina Nielsen

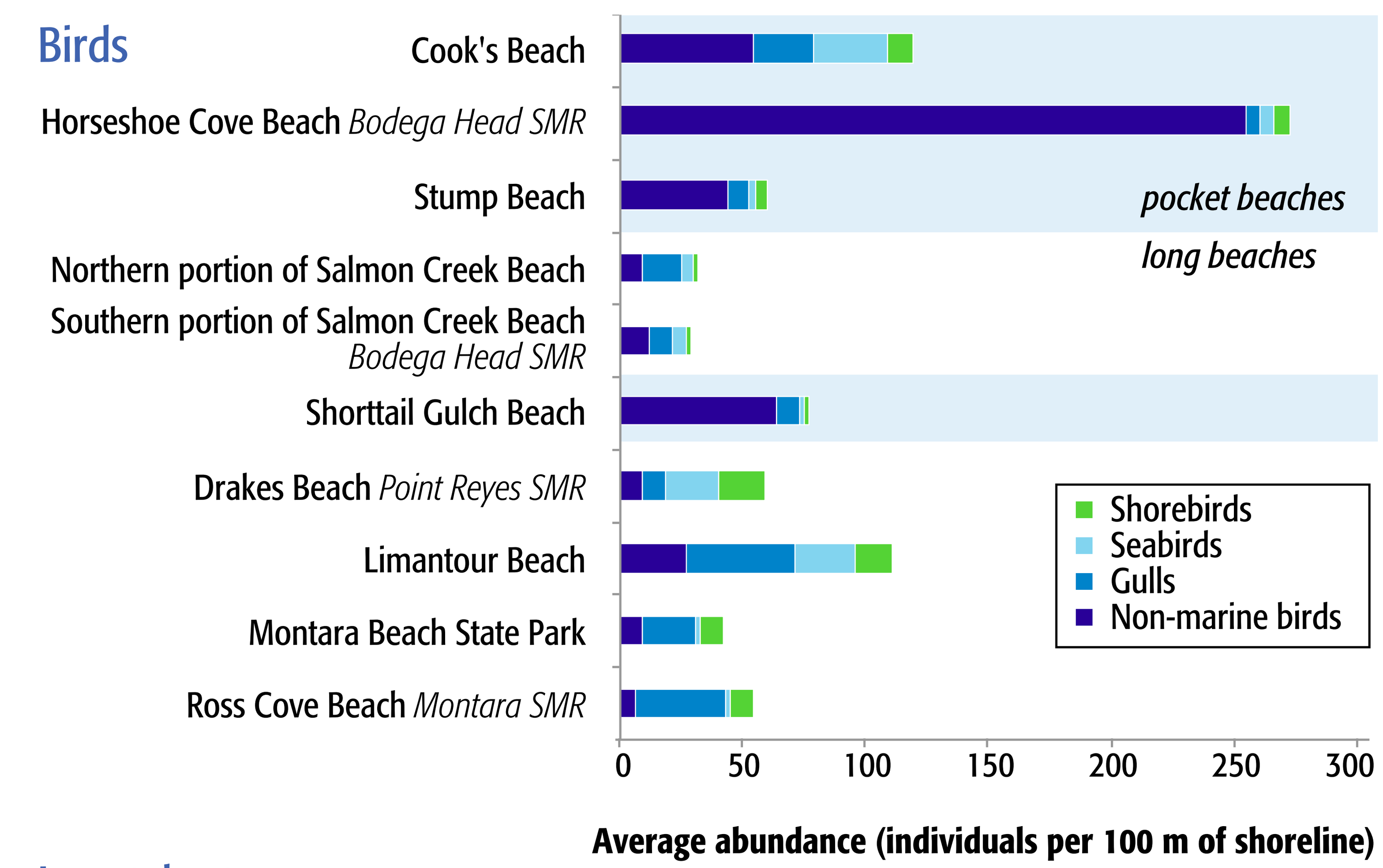
An often overlooked ecosystem, sandy beaches encompass half of the shoreline in the North Central Coast region and provide vital foraging habitat for shorebirds and surfzone fishes. Sandy beaches are also often the first point of interaction between MPAs and people who visit to socialize, exercise or relax. About a tenth of this ecologically and economically important coastal habitat occurs within MPAs in the region. Baseline monitoring characterized sandy beach and surf zone ecosystems in the region for the first time, yielding an entirely new view of this key habitat.

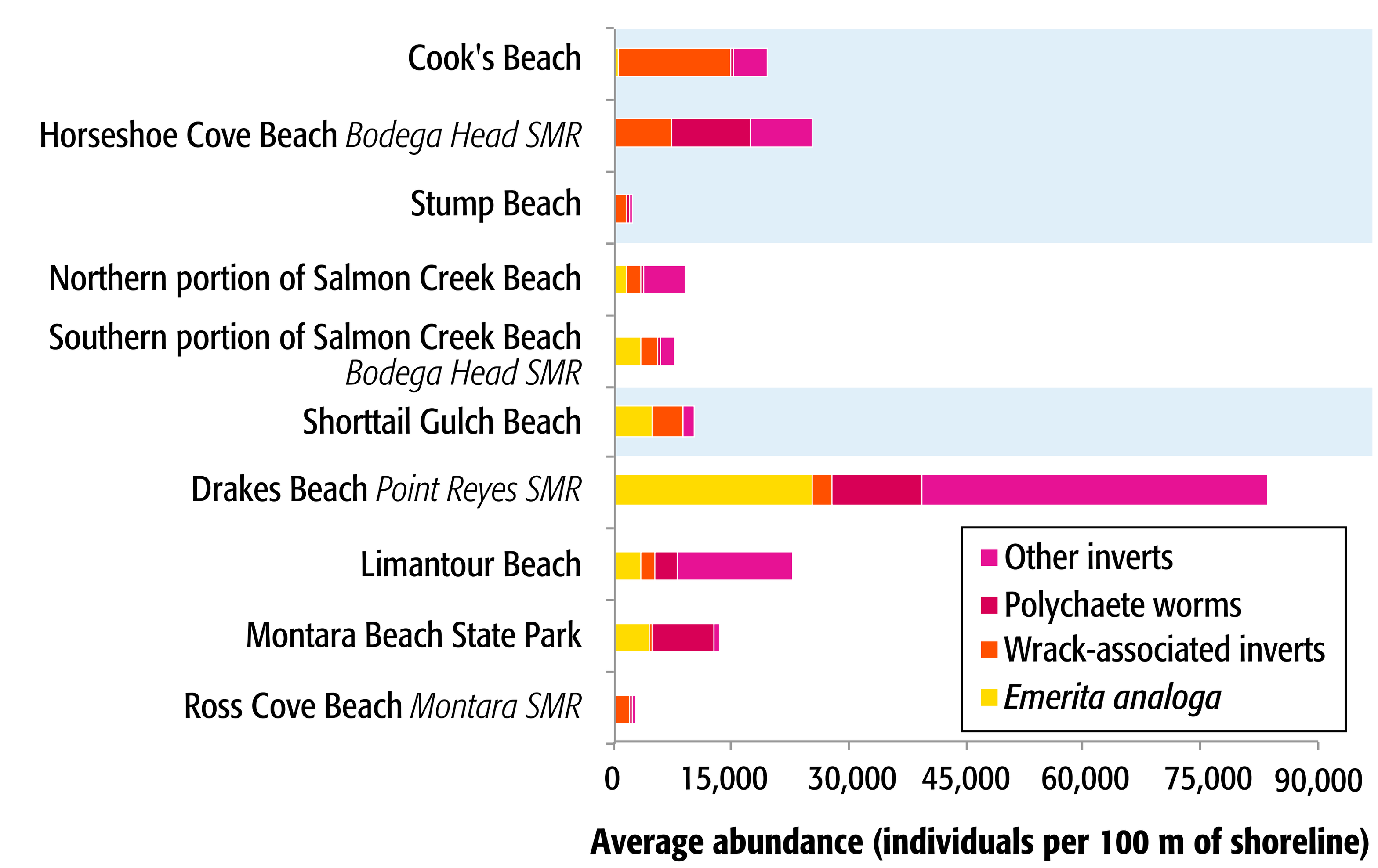
The project, led by Dr. Karina Nielsen (Sonoma State University), Dr. Steven Morgan (University of California Davis), and Dr. Jenny Dugan (University of California Santa Barbara), studied 17 beaches: six pocket beaches and 11 long beaches. Pocket beaches have less than one kilometer of contiguous sandy shoreline bounded by rocky shoreline (see pocket beach, next page), whereas long beaches have more than one kilometer of contiguous sandy shoreline (see long beach, top of next page). Six of the study beaches were inside MPAs, while 11 were outside MPAs. Researchers monitored beach wrack (seaweeds, seagrasses and surfgrasses deposited on the beach), key coastal life (birds, surfperch, and invertebrates) and human activities.

Beach wrack is full of beach hoppers and other invertebrates, which in turn are critical food sources for many birds and fish. Wrack abundance and composition varied widely but was similar on beaches inside and outside MPAs. Kelp deposition peaked in November at more than 2,000 plants per kilometer of shoreline on pocket beaches versus less than 500 plants per kilometer on long beaches. Thus, at its peak abundance, kelp wrack was four times greater on pocket than long beaches. Analyses revealed that standardized counts of freshly stranded kelp plants were an excellent predictor of total kelp wrack across the beach.

While beaches inside and outside of MPAs were similar overall, there are striking differences between how species use long and pocket beaches. While long beaches are rich in gulls, seabirds and shorebirds, pocket beaches were dominated by terrestrial birds including Brewer's blackbirds (*Euphagus cyanocephalus*), American crows (*Corvus brachyrhynchos*), flycatchers and ravens (*Corvus corax*). This is a new observation of how birds are distributed between beach types. In addition, pocket beaches have greater average wrack cover than long beaches. Finally, researchers observed more visitors on long beaches, using them mostly for recreational activities such as nature walks, resting, socializing, beach sports, water sports and play. Importantly, researchers observed that people and off-leash dogs often disturb nesting shorebirds, but this disturbance was less common on MPA beaches. These distinguishing characteristics emphasize the importance of including both long and pocket beaches in long-term monitoring efforts of this ecosystem.

Suspension-feeding sand crabs (Emerita analoga)





Average abundance of birds (top) and macroinvertebrates (bottom) observed at ten beaches, including six long beaches and four pocket beaches, during monthly surveys in 2010–2011. Beaches are arranged from north to south; bars for pocket beaches are shaded. All bird observations were made along a standard 1 km transect except on pocket beaches where transect lengths were truncated to the length of the shoreline. Macroinvertebrate abundances were sampled across the entire width of the beach from 450 core samples (1,571 cm³ per sample) Abundances were normalized to 0.1 km for all beaches. Source: SSU, UCD, UCSB

Baseline findings suggest that future monitoring could be narrowed to monthly or seasonal observations (targeting fall and spring bird migration seasons) of a few indicators that can easily be surveyed by citizen scientists. For example, volunteers could walk transects to survey birds, people, dogs, and fresh kelp, which predicts total beach wrack. Likewise, collaborative teams of citizen and professional scientists could survey sand crabs – a good predictor of total invertebrates – and surfperch. This suite of indicators would provide a reliable, cost effective approach to monitor the condition of sandy beaches in the region over time.

Pocket beach along the headlands of the Point Reyes Peninsula

Refining and developing new citizen monitoring protocols

Researchers on this project refined the citizen monitoring protocol for sand crabs and developed a new protocol for surfperch surveys, both of which are key indicators of sandy beach health.

Sand crab surveys

On some beaches, sand crabs are monitored by a citizen science program for high school students called LiMPETS (see page 8). To assess the utility of LiMPETS surveys for MPA monitoring, academic researchers compared their protocol and data with those of LiMPETS. This revealed that LiMPETS data underestimate adult sand crabs, likely because their surveys avoid the surf zone for safety reasons, which is where most adults reside. However, the relative abundance* of juvenile sand crabs (<1 year old), which live inland of the surf zone, are comparable between LiMPETS and academic researchers. To generate a complete picture of sand crab populations, the research team suggested extending surveys into the surf zone, perhaps by recruiting adult volunteers.

Surfperch surveys

The research team also developed a new citizen monitoring protocol for surfperch, which forage close to shore and are fished recreationally. Local fishermen teamed with scientists in 38 catch-and-release surveys: the former caught surfperch while the latter identified, weighed, measured and sexed each fish. Altogether, the teams logged 353 hours of fishing effort and caught six species of surfperch. The most commonly caught species were silver (*Hyperprosopon ellipticum*) and redtail (*Amphistichus rhodoterus*) surfperch. Data reveal that diversity and abundance are similar inside and outside MPAs throughout the region, but surfperch abundance is higher north of Bodega Head.

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* Relative abundance is a measure of how common sand crabs are at one site in comparison to another.

Monitoring by Citizen Scientists

LiMPETS
Beach Watch:
- Farallones Marine Sanctuary Association
- Gulf of the Farallones National Marine Sanctuary

The MPA Baseline Program aims not only to establish a benchmark of ecological and socioeconomic conditions within the North Central Coast region, but also to begin exploring best practices to inform and develop approaches to scientifically rigorous, efficient, and cost-effective MPA monitoring. With this in mind, the program provided an opportunity to explore the role of citizen science in MPA monitoring by leveraging existing capacity of long-term citizen science programs. By drawing on the expertise and experience of such programs, the utility of historical data for informing benchmark conditions was examined, which led to a deeper understanding of the role citizen science can play in long-term MPA monitoring.

Researchers with LiMPETS and Beach Watch were funded to examine historical data sets from 2001–2012 and 1993–2012, respectively. These organizations began collecting data prior to the establishment of the MPA network, and therefore the data collection approaches were not designed for MPA monitoring (e.g., the types of data that were collected and monitoring inside and outside of MPAs). Nonetheless, analyses of these data are useful in helping us to understand the opportunities and challenges of citizen science. Citizen science programs have a wealth of capacity and thus can extend the geographic and temporal coverage of MPA monitoring. Moving forward, we are exploring ways to develop protocols that will align with MPA monitoring and management needs, while still being designed for broad public participation.

Beyond the science

These and other citizen science groups (e.g., Reef Check California, California Collaborative Fisheries, Point Blue Conservation Science) have the potential to contribute to MPA monitoring in ways beyond the science. These groups engage a diverse segment of the community, including high school students, fishermen, recreational and professional divers, and nature enthusiasts of all ages. Through this broad participation, they contribute to MPA education efforts and informed discussions with the public.

LiMPETS students conduct baseline monitoring at Pillar Point, May 2010.

Beach Watch

Beach Watch is a long-term shoreline monitoring program that was founded in 1993. This program is conducted by the Farallones Marine Sanctuary Association in partnership with the Gulf of the Farallones National Marine Sanctuary. Beach Watch surveyors are trained volunteers, who monitor live and dead birds and marine mammals, and human activities. This program has monitored sandy beaches in the North Central Coast region for 20 years. From 1993 through 2012, Beach Watch conducted 14,443 surveys on 39 beaches in the region. Citizen scientists collected data on 256 bird species, 25 marine mammal species, and 25 human activities. Five of the most commonly observed species include Black Oystercatchers, Willets, Double-crested Cormorants, Western Gulls, and harbor seals. The long-term dataset produced through the Beach Watch program provides a foundational understanding of the dynamic context of bird and mammal populations over the past 20 years.

Through in-class workshops, fieldwork, and continuing education, Beach Watch has trained more than 300 people over the past two decades. In addition to contributing to our understanding of California's coast, Beach Watch volunteers gain a deeper connection with and sense of stewardship for marine ecosystems and provide outreach to beach visitors.

LiMPETS

LiMPETS trains students in grades 6–12 to monitor sand crabs in beach habitats and 33 species in rocky intertidal habitats, including a fucoid alga, California mussels, ochre sea stars, purple sea urchins, and owl limpets. This program monitors 16 beaches and four rocky intertidal sites from Bodega Bay to Pigeon Point. Scientists, educators and park officials developed the protocols that LiMPETS students use to monitor these habitats. To explore the utility of the data produced, LiMPETS sand crab surveys were conducted alongside academic surveys at two beaches (see Sandy Beach Summary, pages 9–10). By doing this, researchers developed practical guidance on engaging citizens in monitoring, while considering broader education and outreach goals.

Their findings show that densities of sand crabs, sea urchins, owl limpets, and fucoid algae varied widely from 2006 to 2012. For example, sand crab recruitment spiked during two years (2003 and 2010) but was quite low during others, and owl limpet density increased for the first three years, followed by a three-year decline.

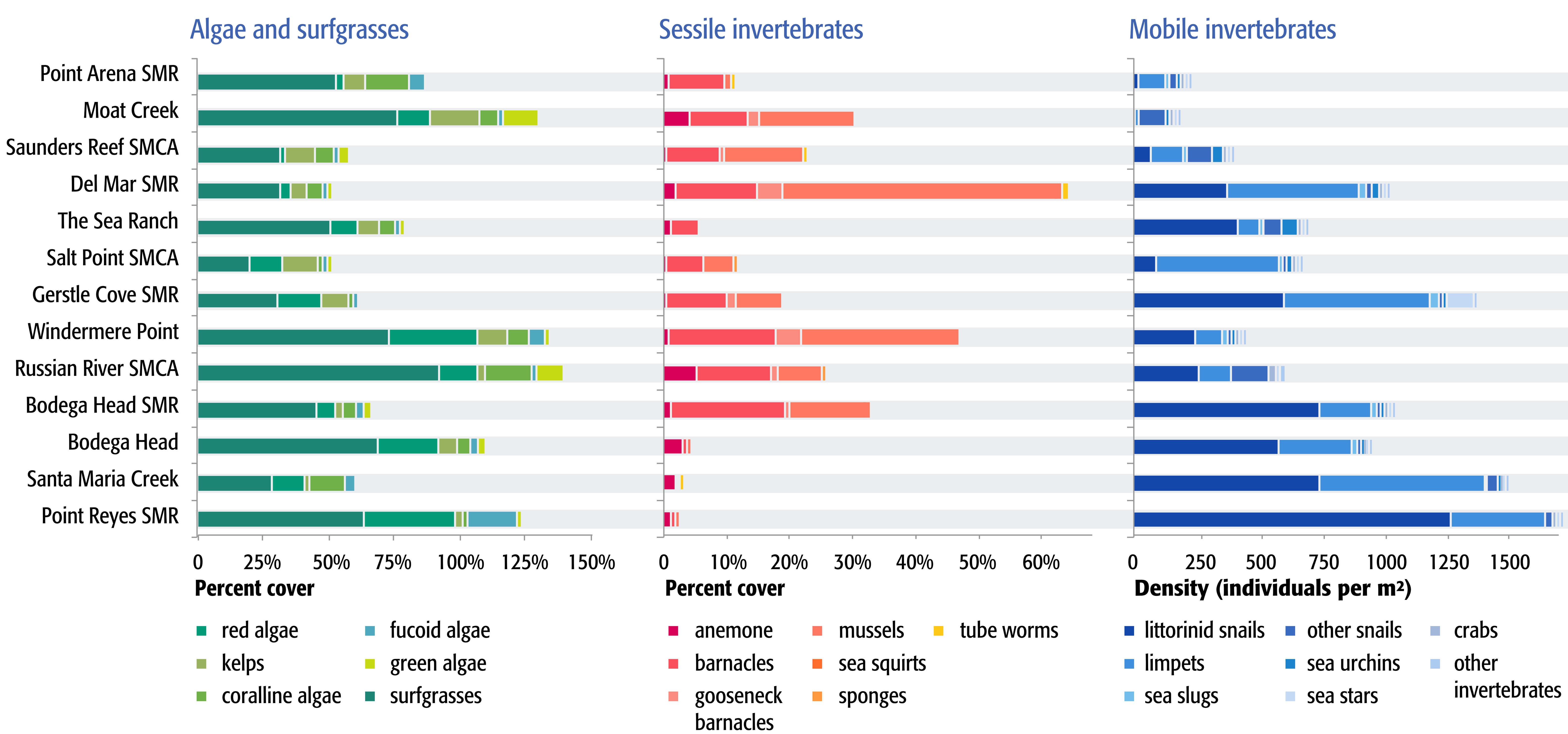
The value of LiMPETS extends far beyond the data students collect. During the baseline monitoring period, LiMPETS engaged 3,300 students from 60 schools representing geographically and socioeconomically diverse communities. By participating in this program, students gain a stronger connection to and deeper understanding of the ocean, sparking an interest in marine science and stewardship and inspiring the next generation of scientists, decision makers and policy makers.

Rocky Intertidal

UC Santa Cruz PISCO

The North Central Coast region's rocky intertidal habitat is home to an exceptional diversity of algae and invertebrates. Baseline monitoring focused on rocky intertidal reefs—the most stable rocky intertidal habitat—to facilitate comparisons among sites and regions over time. Long and broad, rocky intertidal reefs typically range from 50 to 500 meters in length along the shore (164 to 1,640 feet) and from 30 to 50 meters in width across the shore (100 to 165 feet).

Led by Dr. Pete Raimondi (University of California, Santa Cruz), researchers deployed their long-standing and rigorous field survey methods at 22 sites in this region. Teams surveyed intertidal rocky reefs at 14 sites inside MPAs and eight sites outside MPAs, assessing diversity and abundance of algae and invertebrates. In addition to biodiversity surveys, researchers conducted fixed plot surveys to document changes in the cover or abundance of selected species over time, including abalone and sea stars, as well as those that occupy a lot of space on the rocks such as barnacles and rockweeds.

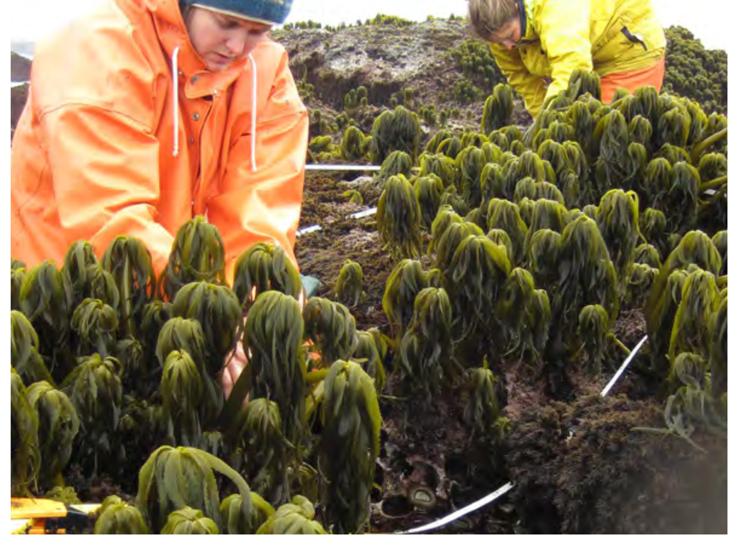


Percent cover of algae and surfgrasses (left) and sessile invertebrates (center). Density of mobile invertebrates (right) observations from 13 rocky intertidal sites in the North Central Coast region in 2010. Sites are arranged from North to South. Source: PISCO, UCSC

Biodiversity surveys tallied 256 rocky intertidal species across the 19 monitoring sites. Initial results reveal that these rocky reefs are inhabited mostly by red algae, mussels, and barnacles (see graphs). At the vast majority of sites, the most common mobile species include littorinid snails and limpets. Importantly, paired sites inside and outside of MPAs did not show statistically significant differences in diversity or composition. This is an important foundation for long-term MPA monitoring; tracking these sites over time will reveal whether protections offered by MPAs are leading to shifts in species diversity or abundance with different trajectories of change inside and outside the protected areas.

To help identify indicators for long-term monitoring, researchers tested how well various species combinations characterize and distinguish the region's distinct rocky intertidal communities. These analyses identified nine taxa (species or groups of species): three algae species, two species of surfgrass (*Phyllospadix* spp.), California mussel (*Mytilus californianus*), black turban snail (*Chlorostoma funebralis*), littorinid snails (Littorinidae) and small limpets. These taxa, together with other ecologically important species such as sea stars, could serve as indicators of changes in ecosystem condition, providing scientific guidance to focus long-term monitoring efforts.

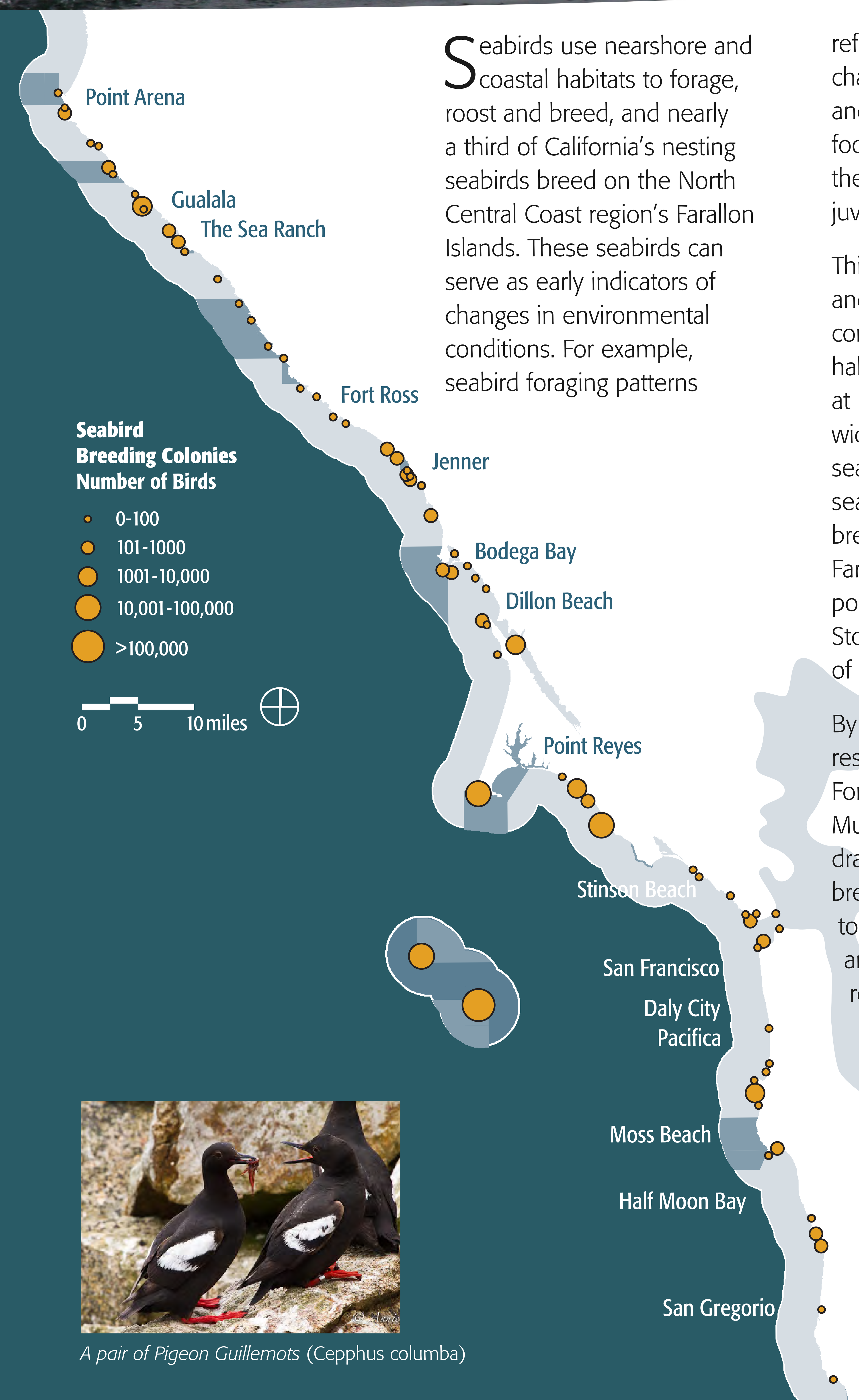
Littorinid snails and limpets



Researchers sampling sea palm (Postelsia sp.) *at Saunders Reef SMCA*

Seabirds

Point Blue Conservation Science
US Fish & Wildlife Service



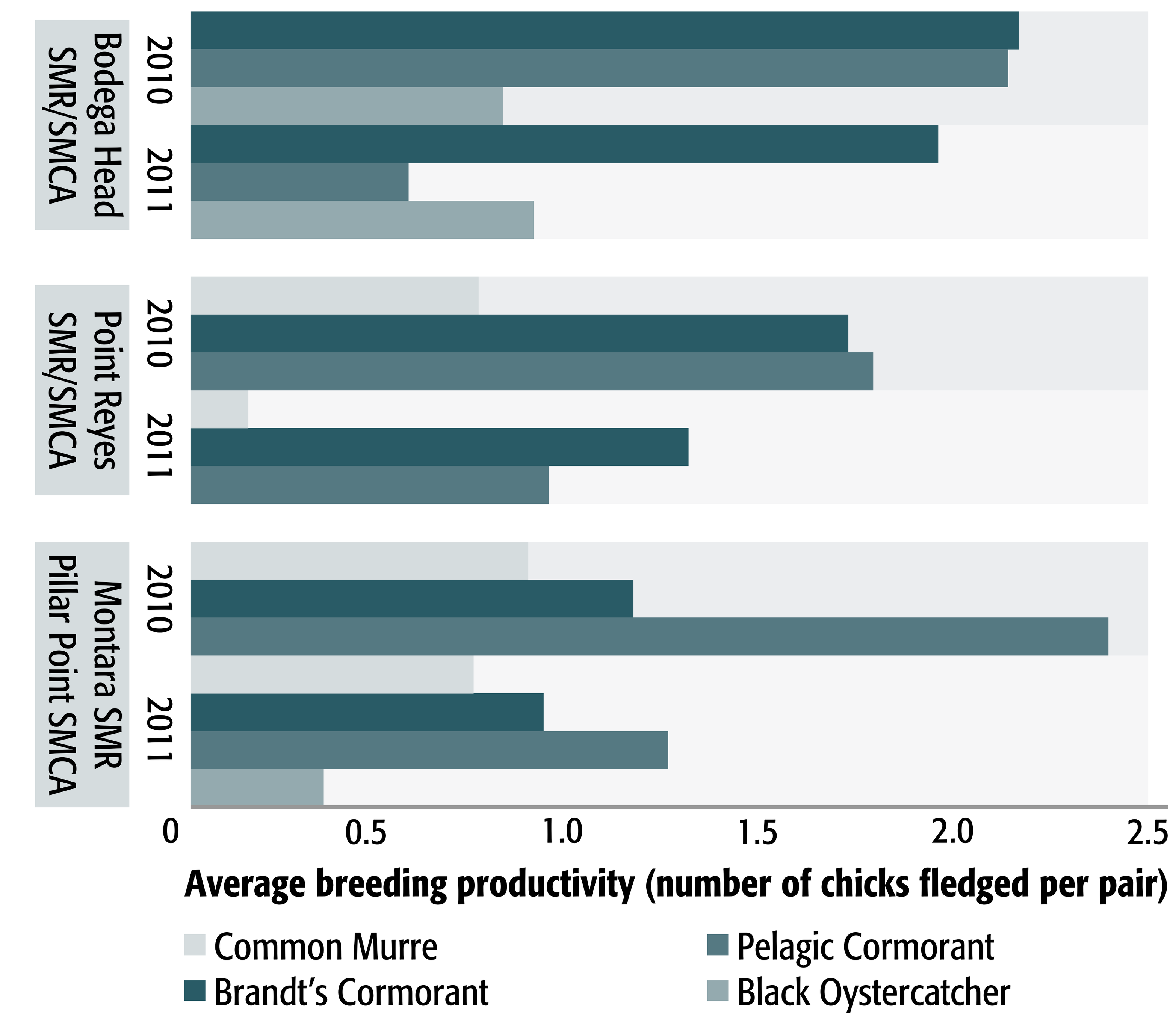
A pair of Pigeon Guillemots (Cepphus columba)

Seabirds use nearshore and coastal habitats to forage, roost and breed, and nearly a third of California's nesting seabirds breed on the North Central Coast region's Farallon Islands. These seabirds can serve as early indicators of changes in environmental conditions. For example, seabird foraging patterns reflect changes in fish populations, which in turn can reflect changes in water temperature and ocean productivity. MPAs and Special Closures in the region may protect seabirds from foot and boat traffic, which can disturb them to the point that they abandon their colonies, and may boost populations of the juvenile fish and invertebrates they eat.

This collaborative project, led by Gerald McChesney (USFWS) and Dan Robinette (Point Blue Conservation Science), conducted baseline monitoring to assess how seabirds used habitats in the region as well as rates of human disturbance at major breeding colonies. Their work also included a region-wide census that found more than half a million breeding seabirds of 13 species at 68 colonies. The vast majority of these seabirds breed inside Special Closures and MPAs. Notably, 83% breed at the Farallon Islands, with 65% breeding on the South Farallon Islands alone. Other areas with large breeding seabird populations include Point Reyes Headlands and Double Point/Stormy Stack at 11% and 3% of the total, respectively. Just 1.7% of seabirds breed outside protected areas in the region.

By evaluating long-term data collected by USFWS (1996–2011), researchers monitored trends in seabird populations over time. For example, when compared to 1989 estimates, Common Murres were 379% more abundant in 2010–2012, reflecting dramatic increases in all populations and an expansion of their breeding distribution in the region. This trend is likely due to a combination of reduced mortality from gill-net fishing and productive ocean conditions leading to abundant prey resources.

To provide a point of comparison for future monitoring, the populations of five bird species likely to benefit from MPAs were assessed inside and outside of three MPA clusters. Common Murres (*Uria aalge*), Pigeon Guillemots (*Cepphus columba*), Brandt's Cormorants (*Phalacrocorax penicillatus*), Pelagic Cormorants (*P. pelagicus*), and Black Oystercatchers (*Haematopus bachmani*) population data were assessed at Bodega Head, Point Reyes, and Montara/Pillar Point MPA clusters. Researchers



Average breeding productivity for four species of birds for three areas in 2010 and 2011. Common Murres did not breed at Bodega Head in either year. Pigeon Guillemot use of new artificial nesting boxes at Drakes Bay was limited during the survey years, but is expected to increase in the future. Source: Point Blue, USFWS

documented breeding population size and productivity through land-based, boat, and aerial photographic surveys. Breeding productivity was highest in 2010 for all species but Black Oystercatchers, with Common Murres and Pelagic Cormorants showing the largest differences among years (see graph). The research team also monitored foraging rates for the same species across MPA clusters. While foraging rates varied by species, they were highest overall inside MPAs in the northern parts of the region, particularly Bodega Head and Point Reyes.

By providing a link between ecological and oceanographic conditions, seabirds can serve as an "alert" for major environmental shifts. Because seabirds use a broad range of habitat, foraging offshore and breeding on land, monitoring these species can provide important insights into offshore, underwater ecosystems that are challenging and costly to monitor. For example, changes in seabird populations often track closely with changes in forage fish populations.

Kelp Forests & Shallow Rocky Reefs

UC Santa Cruz PISCO

We have created a new snapshot of kelp forests in the region, and a network of researchers, students, and citizens who are mobilized to track this ecosystem into the future.

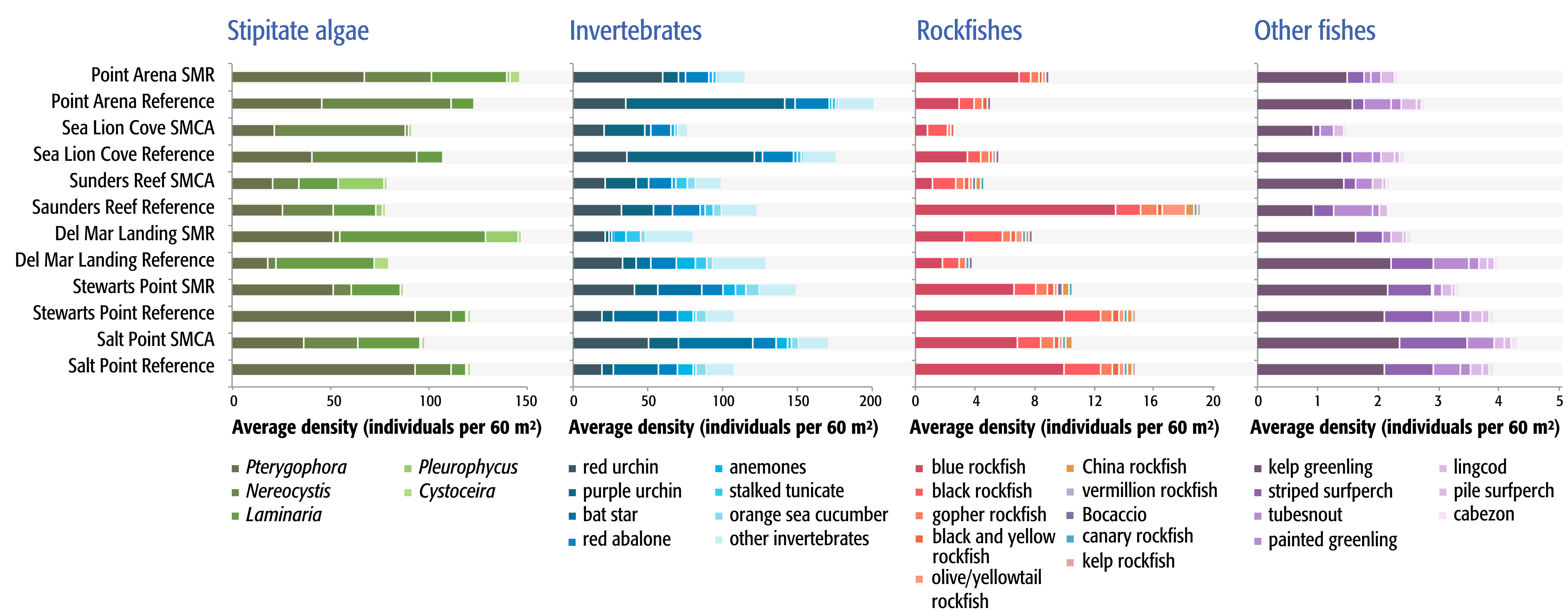
—Mark Carr

Kelp forests grow on shallow rocky reefs that are up to 17 meters (56 feet) deep, and these giant algae extend all the way to the water surface, providing a complex habitat that is teeming with many species of fish, sea urchins and other invertebrates. This habitat also supports a wide variety of human activities, from fishing to diving to watching marine life. For baseline monitoring in the region, PISCO (Partnership for Interdisciplinary Studies of Coastal Oceans) divers applied their long-held and rigorous survey methods to provide the first snapshot of kelp forest and rocky reef habitat and community structure in the region. Scuba divers surveyed 35 sites inside and outside six MPAs, while carefully avoiding the shark abundant waters in the southern part of the region.

PISCO conducts long-term monitoring along the West Coast, and includes researchers from four universities in California and Oregon. Led by Dr. Mark Carr (University of California, Santa Cruz), PISCO divers identified and estimated the cover or abundance of 129 major kelp forest species, including algae, invertebrates and fishes. These data provide a baseline for future monitoring and give insight into how kelp forest communities vary across the region.

To characterize kelp forest communities along the region's coast, surveys assessed the most common species of algae, large invertebrates, and fishes. At about half of the sites surveyed, the dominant stipitate algae (those with a stipe, or 'stem') is *Pterygophora californica* (see graph, bottom far left). At the remaining sites, *Nereocystis luetkeana* (bull kelp) and *Laminaria setchellii* were dominant. Red sea urchins (*Strongylocentrotus franciscanus*) were the primary large invertebrate at most sites, with a few sites dominated by purple sea urchins (*Strongylocentrotus purpuratus*). Red abalone (*Haliotis rufescens*) were also common (with the exception of Del Mar SMR), and bat stars (*Patiria miniata*) are one of the most common invertebrates at Stewarts Point and Salt Point, both inside and outside of MPAs (see graph, bottom left). By far the most common fish was blue rockfish (*Sebastes mystinus*) followed closely by black rockfish (*S. melanops*) and kelp greenling (*Hexagrammos decagrammus*) (see graph below right and far right).

Similar to rocky intertidal sites, diversity and composition of species between paired kelp forest sites inside and outside MPAs did not show statistically significant differences, although they did vary geographically within the region. The scientifically rigorous protocols employed by PISCO produced data that are optimal for tracking changes in species diversity and abundance over time. Thus, their data provide an important foundation for long-term monitoring of this important ecosystem that supports a wide range of human activities.



Graphs at right: Average density of stipitate algae (far left), invertebrates (left), rockfishes (right), and other fishes (far right) observed across 12 sites in the North Central Coast region in 2010–2011. Sites are arranged from north to south. Stipitate algae are those with stipes or 'stems'. Source: PISCO, UCSC

Kelp Forests & Shallow Rocky Reefs (Citizen Science)

Reef Check California

We now have teams of citizen scientists in the region who can continue monitoring; building capacity is an essential element of creating a sustainable monitoring program.
—Jan Freiwald

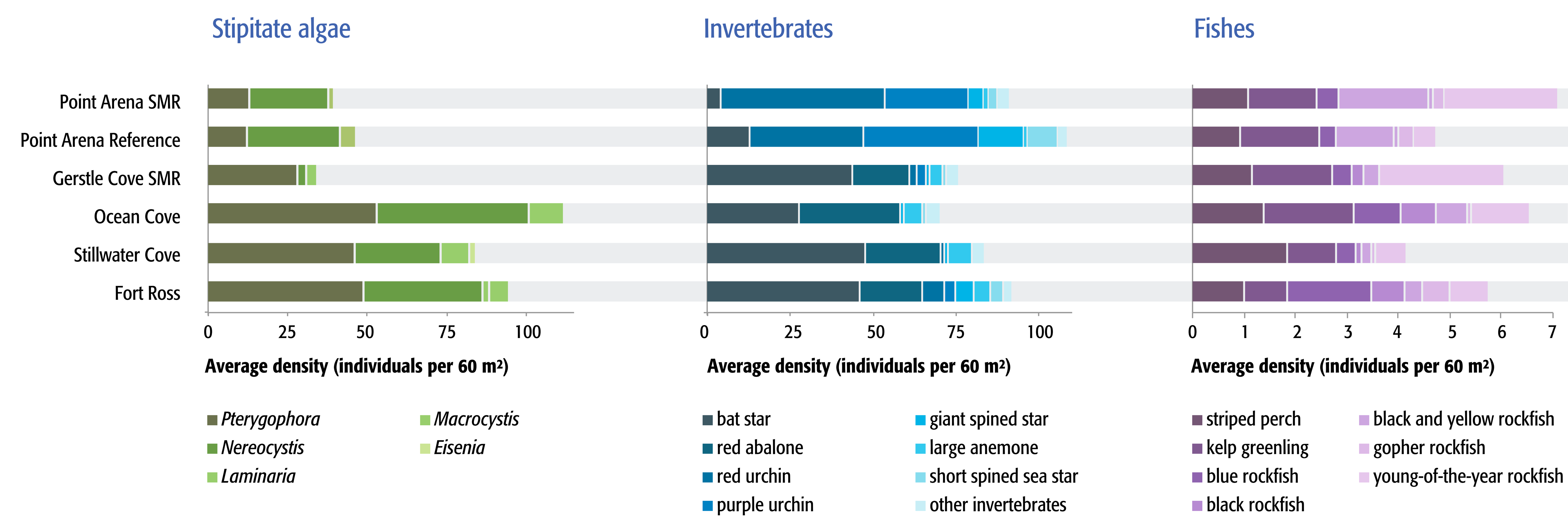
Rocky reefs and the kelp forests above them are full of marine life, but surveying this diverse subtidal habitat can be challenging. This makes rigorous citizen science a valuable addition to monitoring efforts. Using a protocol similar to those of academic SCUBA divers such as PISCO, Reef Check California trains and certifies volunteer SCUBA divers to survey the abundance and diversity of fish, invertebrates, and algae in rocky reefs.

As part of their baseline monitoring project in the North Central Coast, Reef Check trained or recertified more than 100 citizen scientist divers, building capacity in the region to support long-term monitoring. Before participating in surveys, volunteer divers complete an intensive 32-hour training and are only certified to do transect surveys after passing classroom and field-testing for each transect type. They are required to be recertified and tested by Reef Check staff before collecting data each year.

Led by Dr. Jan Freiwald (Reef Check California), volunteers conducted surveys at seven sites in the region, monitoring the abundance of 73 rocky reef species. Consistent with the results from PISCO surveys, Reef Check surveys showed that kelp forest communities in the region are dominated by blue rockfish (*S. mystinus*) and kelp greenling (*H. decagrammus*) (see graph, below right). At the sites Reef Check surveyed, the most common invertebrates are bat stars (*P. miniata*) and red abalone (*H. rufescens*) (see graph, below center), compared to the sites PISCO surveyed where red and purple sea urchins are dominant.

Monitoring, both before and during this baseline period, also showed that that the red urchin population declined along the Sonoma coast between 2007 and 2012. In addition, their average size dropped 1.5 centimeters (0.6 inches) between 2010 and 2011, but sizes were the same inside and outside MPAs. The densest red urchin populations were at Point Arena SMR with 145 per 60 square meters, followed by the Point Arena reference site with 53 per 60 square meters, and Fort Ross with nearly 10 per 60 square meters.

Reef Check's recreational SCUBA divers complement those on academic teams, which come to the region to survey just once a year. In contrast, Reef Check volunteers are local and dive recreationally year-round, positioning them to serve as an early warning system for events such as the 2011 die-off of abalone and other invertebrates along the Sonoma coast due to a harmful algae bloom (see page 14). Moreover, participation in the North Central Coast baseline program gave Reef Check the opportunity to expand their program to include new sites in the region, expanding its citizen science monitoring capacity.



Abundance of stipitate algae (left), invertebrates (center), and fishes (right) across six sites in the North Central Coast region in 2011–2012. Sites are arranged from north to south. Stipitate algae are those with stipes or 'stems'. Source: RCCA

Mid-depth & Deep Ecosystems

CSU Monterey Bay MARE

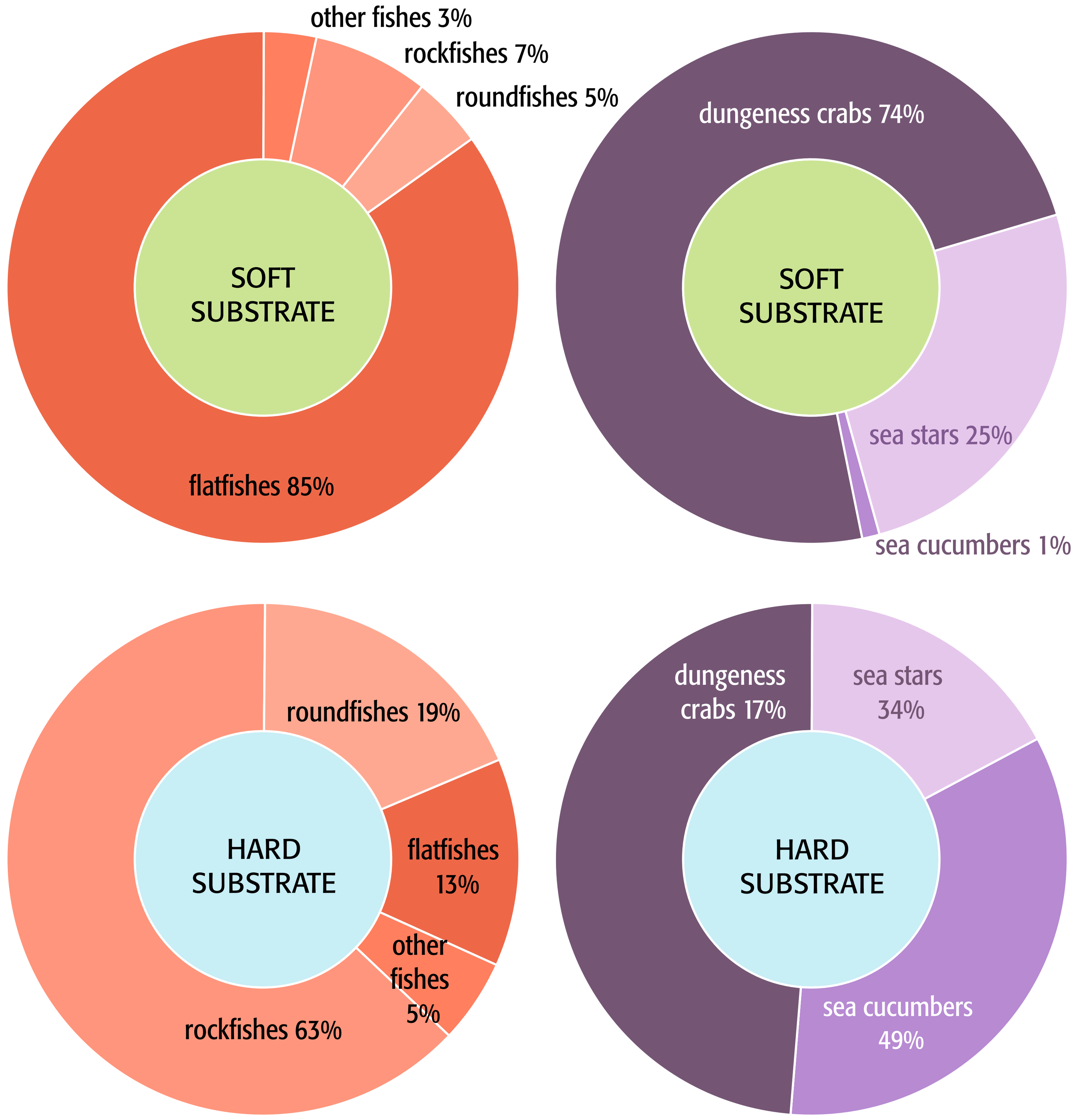
The deep waters off California's coast provide a range of habitats, from sand and mud to rocky reefs and pinnacles, which sustain the state's commercial and recreational fisheries. These habitats are difficult to access and little is known about them. However, waters deeper than 20 meters (65 feet) are mostly free of kelp, making them ideal for monitoring by remotely operated vehicles (ROVs). Researchers surveyed deep water habitats in the North Central Coast region with an ROV, guided by a pilot at the surface, outfitted with cameras and "flown" about three inches above the seafloor between depths of 20 and 116 meters (65–380 feet). Video and still images captured the diversity of invertebrates and fishes inside and outside of ten MPAs that represented the region's deep water habitats.

Through a partnership among Dr. James Lindholm (California State University Monterey Bay), Dirk Rosen (Marine Applied Research and Exploration), and local fishermen, 82 ROV transects were completed that yielded more than 21,000 photographs and nearly 155 hours of video. Teams of primarily graduate students analyzed the survey data, and each student was trained to identify a few species accurately from the images. Collectively, these students documented thousands of invertebrates and about 8,400 fish. A third of these fish were observed near the South Farallon Islands, where rosy rockfish (*S. rosaceus*) was the most common species. Throughout the region, the dominant species observed over rocky substrates were rockfishes, sea cucumbers, and sea stars (see charts for example). Over soft substrates, the dominant fishes observed throughout the region were flatfishes. However, the most common invertebrate over soft substrates varied across the region. At Point Reyes, Dungeness crab (*Metacarcinus magister*) was the most common, whereas other soft-bottom sites were dominated by sea stars (Point Arena, Southeast Farallon Islands, Pillar Point), or shrimps (Bodega Head).

Based on these initial surveys, the researchers proposed 13 species as potential indicators for long-term monitoring of deep water habitats, all of which can be easily identified from image-based research platforms. Criteria for indicator species included that they were abundant enough to evaluate statistically, were associated with particular habitats, and represented a range of functional groups including herbivores, piscivores and omnivores. Proposed indicators include seven species of fish: kelp greenling (*H. decagrammus*), lingcod (*Ophiodon elongatus*) and five species of rockfish; and six invertebrates: Dungeness crab, red rock crab (*Cancer productus*), plumose anemones (*Metridium farcimen*), red gorgonians (Gorgoniidae), sea whips and pens (Octocorallia).

To further inform long-term monitoring, researchers are now exploring the relationships between these indicators and habitat characteristics such as substrate type (e.g., rocky, soft), substrate complexity (e.g., height, patch size, presence of structure-forming invertebrates). Understanding these relationships will provide the foundation for developing predictive models of population size and distribution of these indicator species, which will, for example, support the selection of long-term monitoring sites.

Point Reyes (2011)



Source: CSUMB, MARE

Mobilizing a Rapid Response Network

Monitoring Network Tracks Sea Star Epidemic

From San Diego to Alaska, sea stars are dying at an alarming rate and the cause remains unknown. Through investment in MPA monitoring, California has built a network of people who are in place to witness environmental changes and to quickly respond to emerging threats. Initial accounts of sea star wasting in California came from long-term monitoring programs including MARINe, PISCO, Reef Check California, and LiMPETS, and this network gave California an early start on tracking and responding to the outbreak. Baseline program funding has allowed PISCO to continue monitoring sea star wasting syndrome in North Central Coast MPAs.

Sea star wasting syndrome begins with an initial infection—as yet of unknown origin—that is followed by a bacterial infection. The initial infection appears as lesions on the upper surface of the sea star. Once afflicted, flesh begins to disintegrate and some sea star species lose entire arms. Most die within just a few days.

The current West Coast epidemic is unprecedented—wasting has never been so widespread—and could dramatically alter coastal ecosystems for years. It afflicts 16 species, including a keystone species in the rocky intertidal: ochre stars (*Pisaster ochraceus*); and the largest sea star, which is a voracious subtidal predator: sunflower stars (*Pycnopodia helianthoides*).

Since this outbreak began in 2013, researchers, led by Dr. Pete Raimondi, have found evidence of wasting syndrome at 60 of 84 long-term, rocky intertidal monitoring sites along the coast of California, and at a total of 66 of 107 sites along the entire Pacific Coast. Researchers observed symptoms in anywhere from 1% to 45% of the sea stars at each site. At some sites, the syndrome has killed up to 95% of the ochre stars. As pathologists continue investigating the cause, researchers across the West Coast are working together with citizen scientists to monitor the outbreak and assess the impacts on nearshore ecosystems. This information will form an important component of the baseline characterization of these habitats, inside and outside the region's MPA network.

Academic and Citizen Scientists Team Up to Monitor Abalone

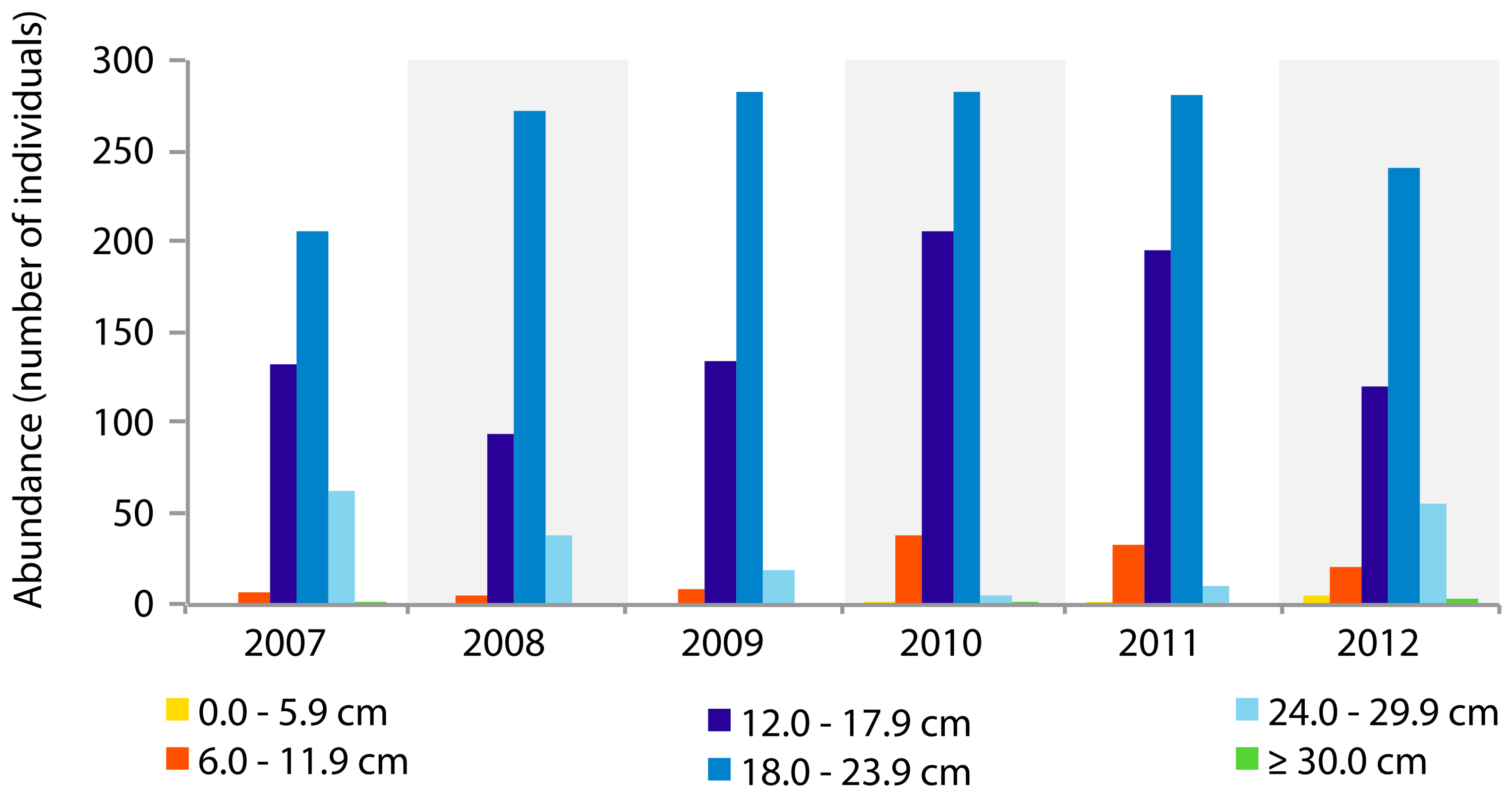
State resource managers observed a decline in red abalone (*H. rufescens*) populations along California's Sonoma coast following an intense harmful algal bloom (HAB) event in late summer 2011. To curb the decline, state resource managers approved an emergency closure of the fishery.

To investigate how red abalone were affected by the HAB event, Reef Check citizen scientists teamed with PISCO academic scientists to document abalone abundance, size structure, and distribution at 35 sites. Reef Check volunteers surveyed shallow coves up to depths of about 10 meters (30 feet), while PISCO divers surveyed open coast up to depths of 20 meters (65 feet). Reef Check and PISCO protocols are comparable, so data from the two programs can be integrated seamlessly.

Findings include that red abalone density dropped by 40% at some sites along the Sonoma coast between 2010 and 2011 both inside and outside MPAs, and that nearly a third of shells surveyed in 2011 were dead. Despite the die-off, however, the size distribution of red abalone did not differ before and after the HAB event (see figure).

In addition, the depth range of these abalone surveys encompassed both the harvest zone (0–15 meters) and deeper waters known as "depth refuges". Surprisingly, these depth refuges were quite narrow in the sites that were monitored, 15–20 meters (50–65 feet), beyond which abalone densities drop off steeply.

Abalone Size & Abundance Over Time



Size distribution of surveyed red abalone in the North Central Coast region from 2007–2012. Counts are summed across 4 sites: Fort Ross, Gerstle Cove, Ocean Cove, and Stillwater Cove. Each site survey consisted of 6 transects (30 meters long by 2 meters wide). The minimum harvest size is 17.8 centimeters. The harmful algal bloom event occurred in late summer 2011. Source: RCCA

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Collaborators

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Additional Resources

Technical reports and raw data for each baseline program project are available on OceanSpaces.org. Technical and annual reports are also available on the California Sea Grant website at http://www.csgc.ucsd.edu/RESEARCH/NCCMPA_Summaries_and_Reports.html.

More information about the North Central Coast MPAs, including boundaries, regulations, planning documents and management updates, is available at www.dfg.ca.gov/mlpa.

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