Ecosystem Observations

for the Monterey Bay National Marine Sanctuary 2001

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Welcome

Ten years can be a very long time, or it can pass quite quickly. How long ten years feels is relative. To *Euphausid* shrimp, krill, living above Monterey Canyon, ten years is a length of time they will never know. At most, they might live a year and a half. For a blue whale or rockfish seeking a krill swarm for a meal, ten years is a small fraction of their normal life span. Both species' longevity matches that of humans.

The Monterey Bay National Marine Sanctuary reaches ten years of age in 2002. We are releasing this edition of *Ecosystem Observations*, which covers new discoveries and observations for 2001, in the Spring 2002. Therefore, we've tried to reflect back on how our knowledge of the Sanctuary and its resources has changed over a longer time period than just the past year.

We've learned a lot since 1992, as have our research and agency partners. Our techniques for uncovering answers and solving mysteries within our local marine ecosystem have grown as well. We've also learned how important it is to shift one's temporal horizon beyond the past year, and further than the next fiscal year.

Because *Ecosystem Observations* reports on science and natural history events, it is worth providing a biological example of why long time horizons can be important. Before three hundred years ago, intertidal and nearshore populations of black abalone (*Haliotis cracherodii*) were heavily preyed upon by sea otters and indigenous human populations. When sea otters were aggressively hunted for pelts and Native Americans forced off the coast, these abalone populations soared—large enough to support a wildly lucrative fishery for several hundred years. Then the otters came back, and drove abalone abundance back down to "natural" levels. While pockets of reasonably dense populations of black abalone can still be found, for the past fifteen years, a "withering foot" disease has slowly marched north, now threatening black abalone populations in the Sanctuary (*see story on page 9*). A single snapshot in any one year would have, perhaps, mis-described the health of abalone populations. A longer term horizon, even longer than ten years, is the only way to properly tell the story about black abalone.

It is also the best way to tell the story of the ecosystems and resources protected by the Monterey Bay National Marine Sanctuary.

– William J. Douros, Superintendent
NOAA's Monterey Bay National Marine Sanctuary

2001 Program Activities for the Monterey Bay National Marine Sanctuary

Dedicated in 1992, the Monterey Bay National Marine Sanctuary is the largest of thirteen sanctuaries nationwide managed by the National Oceanic and Atmospheric Administration (NOAA). Encompassing more than 5,300 square miles of water, its boundaries stretch along the central California coast from the Marin County headlands south to Cambria. The Sanctuary features many diverse biological communities, including wave-swept beaches, lush kelp forests, and one of the deepest underwater canyons in North America. An abundance of life, from tiny plankton to huge blue whales, thrives in these waters.

Our mission—to understand and protect the coastal ecosystem and cultural resources of central California—is carried out through the work of four program divisions: resource protection, education and outreach, research, and program support. A summary of each program's major accomplishments and activities for 2001 follows.

Resource Protection

The goal of the Resource Protection Program is to initiate and implement strategies to reduce or prevent detrimental human impacts on the Sanctuary. We address this goal through permits and enforcement, emergency response, and collaborations with other organizations and stakeholder groups.

Several efforts were initiated this year to develop regional guidelines on resource protection issues. By collaborating with the California Coastal Commission, we began work on evaluating and developing a comprehensive approach to both desalination projects and coastal armoring projects such as seawalls and revetments. Similarly, with the U.S. Fish and Wildlife Service and National Marine Fisheries Service (NMFS) we began developing a regional approach to fireworks displays that allows for the continuation of these festivities but limits their expansion, to ensure that significant noise impacts on marine mammals are avoided.

We worked with the Alliance of Communities for Sustainable Fisheries, a coalition of the region's fishing organizations, and other partners to evaluate the potential advantages and drawbacks of marine reserves that could limit fishing at some sites on the central coast. We continued our participation with the California Department of Transportation to develop a Coast Highway Management Plan for the Big Sur region that will maintain highway access while minimizing impacts of highway landslide disposal activities on marine life.

The resource protection team also reviewed sixty permit requests this year, issuing permits or authorizations for activities such as seabed alterations, discharges to the Sanctuary, and overflights below 1,000 feet in restricted zones. Various conditions were imposed on these activities to reduce or eliminate threats to Sanctuary resources. We also reviewed and commented on a variety of other projects, including ensuring that noise pollution in the Sanctuary would be minimized from proposed military operations such as a bombing range at Fort Hunter Liggett and a towed low-frequency array that would introduce additional noise sources offshore.

The first year of our pilot enforcement program was completed with the assistance of a dedicated special agent from NOAA's Office of Law Enforcement. California Department of Fish and Game (CDFG) and California State Parks rangers who are cross-deputized to enforce Sanctuary regulations also contributed more than 2,500 patrol hours. Enforcement cases leading to NOAA investigations during the year were primarily instances involving harassment of marine mammals or seabirds, unauthorized discharges into the Sanctuary, and seabed alteration.

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Volunteer Bonnie Van Hise and Sanctuary staff member Karen Grimmer collect water samples for the "First Flush" event in October.

We handled twelve emergency response events this year, ranging from tarballs on local beaches to sewage spills and small vessel groundings. We coordinated the salvage and de-fueling of three small vessel groundings, assessed damage to marine resources in collaboration with our research team, and initiated multi-agency discussions on ways to prevent and respond to these events better.

The Water Quality Protection Program and its partners continued to carry out plans for reducing contaminated runoff to Sanctuary waters. Funding obtained by Congressman Sam Farr to assist our partners in implementing the Sanctuary's agricultural plan has allowed the Natural Resources Conservation Service, the University of California Cooperative Extension, and the Monterey Bay Sanctuary Foundation to recruit a variety of new staff. The region's farm bureaus have established five pilot projects with their members in various Sanctuary watersheds to control sediment and nitrate runoff, and we worked with them to establish tracking and monitoring protocols to map the success of these efforts.

The Sanctuary Citizen Watershed Monitoring Network continued to coordinate twenty volunteer water quality monitoring groups. It organized several training sessions and led two region-wide monitoring events. Snapshot Day in April turned out 148 volunteers throughout the Sanctuary watersheds to assess coliform, nitrate, and sediment levels in more than 110 creeks, while "First Flush" sampling involved thirty-nine volunteers testing for these contaminants during the first heavy rain of the season, in October. The data were provided to local resource managers to help identify and reduce levels of contamination and to the public to enhance education.

We also began to focus additional effort on coliform bacterial levels and local beach closures, cosponsoring two public forums on the topic in January and beginning work with local cities to identify resources for replacing aging sewage pipelines.

Education and Outreach

The goal of the Education and Outreach Program is to promote understanding and stewardship of the Sanctuary. Our main focus in 2001 was to continue expansion of education and outreach efforts Sanctuary-wide by collaborating with an array of partners.

Long-time sponsor the Association of Monterey Bay Area Governments (AMBAG), along with NMFS and other partners, helped us organize the March *Sanctuary Currents* Symposium. The two-day event, entitled *Fishing for Our Future*, provided a venue for researchers to share their findings and for commercial and sport fishers to share their perspectives on local fisheries. Individuals and organizations were honored for their dedication to the Sanctuary (*see box on page 3*).

Collaborations in Santa Cruz reached new highs, as the Monterey Bay National Marine Sanctuary Interagency Task Force, comprised of local, state, and federal government representatives, dedicated the first interpre-

Sanctuary Reflections Awards

Presented at the 2001 Sanctuary Currents Symposium:

Public Official: *Mr. Oscar Rios, former mayor, City of Watsonville*

Conservation: *Ms. Donna Meyers, founder/former executive director, Coastal Watershed Council*

Science/Research: *Dr. Michael Foster, Moss Landing Marine Laboratories*

Citizen: *Mr. Scott Benson, graduate student, Moss Landing Marine Laboratories*

Education: *Ms. Arlene Breise, former youth programs manager, Monterey Bay Aquarium*

Business: *Pacific Merchant Shipping Association*

Organization: *United States Geological Survey*

Special Recognition: *Monterey Bay Aquarium and the Friends of Moss Landing Marine Laboratories, for the "Saving Our Seas" series of public forums*

tive panel of its largest project—the Sanctuary Scenic Trail—at the Santa Cruz Harbor. We were delighted to support this community effort with new funding to produce many more of the interpretive elements outlined by the task force's plan.

The efforts in Santa Cruz County have inspired a new local committee to extend the scenic trail along the entire Monterey Bay crescent. AMBAG is working closely with agency representatives to map existing and proposed trail locations. An interpretive committee is working to integrate the Santa Cruz design with Monterey's messages. Sanctuary education staff are members of both Santa Cruz and Monterey efforts.

Our partnership with California State Parks now includes all districts contiguous with the Sanctuary's boundaries. Housed with the San Simeon District headquarters, our educator in the south has been participating in campfire presentations, beach walks, and Coastal Cleanup efforts. Monterey District's regional interpretive specialist, Pat Clark-Gray, chairs the Sanctuary's Education Panel and holds the education seat on the Sanctuary Advisory Council (SAC). Santa Cruz District superintendent Dave Vincent is working with local officials to incorporate the idea of a Sanctuary Visitor Center into current county planning. In addition, our Santa Cruz educator worked with park interpretive staff to develop a new field trip program for grades K-2 at Seacliff State Beach. Finally, our new Half Moon Bay office will afford opportunities to work with the Bay Area District.

The Sanctuary Education Panel (SEP), comprised of members from local marine science education institutions and schools, began working to help create the Sanctuary's Regional Education Plan for the next ten years. The plan's completion awaits public input from scoping sessions held during the Sanctuary's Management Plan Review.

Our annual Student Summit, designed to inspire high school student teams to undertake field projects, again featured the theme of ecosystem monitoring. This year Monterey Peninsula College joined the program to offer the Summit and its related activities as a course with college credit. In April sixty students from ten high schools formally presented their project results to an audience of peers and local scientists.

A new plan for reaching multicultural audiences called Multicultural Education for Resource Issues Threatening Oceans (M.E.R.I.T.O.) is complete. Funding sources are being identified for three main program elements: community-based programs to work with youth and family-serving institutions; site-based programs hosted at state parks and Elkhorn Slough; and teacher programs to work with minority-serving institutions of higher learning to assist teachers in training and students in the sciences.

© Karen Grimmer for MBNMS

Sanctuary Education Coordinator Dawn Hayes leads students on a field trip to the Pacific Grove tidepools.

On a smaller scale, several other projects were accomplished. Education staff worked with Elkhorn Slough National Estuarine Research Reserve staff to host the NOAA workshop *Training Needs Assessment*. New brochures for the general public and for divers were produced, while our *50 Ways to Get Your Feet Wet in Santa Cruz County* and *Summary of Regulations* brochures were reprinted. Team OCEAN kayak staff and volunteers made 3,850 contacts with people on the water and land to provide information and prevent possible marine mammal and bird disturbances. Finally, the "Dirty Words" radio campaign, focusing on water quality, won gold Addy

Research

The Research Program focuses on science for resource management, identifying information gaps, developing collaborative studies to improve understanding of issues, and interpreting research for decision makers. The Sanctuary Research Program works closely with the many top-notch research institutions around central California, largely through our Research Activity Panel (RAP). Dr. Gregor Cailliet, who has led this group since the Sanctuary's inception, this year turned over his successful tenure as chair to Dr. Chris Harrold. A history of the RAP is now available on the Sanctuary web site.

We know that the natural and cultural resources of the Sanctuary are nationally significant, but it is an ongoing effort to determine where all the habitats are located and what lives in them. Completing a five-year, multi-institutional effort (that we supported through funding and ship and staff time) the U.S. Geological Survey (USGS) produced fine maps that detail the geology of much of the Sanctuary seafloor. A related project will provide us with information on the distribution and abundance of invertebrates that were collected in the USGS sediment samples. This information gives managers great insight into, for example, where it is safe to lay cables or why organisms congregate where they do.

Higher on the food chain, we discovered with NMFS and Hubbs Sea World Research Institute that one of the Sanctuary's endangered species, the leatherback turtle, migrates here after laying eggs in Indonesia. The oceanographic conditions in the Sanctuary provide excellent habitat for jellyfish, upon which the turtles feed. We continue to observe the links between our unique Sanctuary environment and a biodiversity that supports growing ecotourism and significant fisheries, conducting field measurements of physical conditions and animal counts while developing new predictive oceanographic models. Finally, expanding our breadth of resource inventories, we completed a list of known shipwrecks, including an oil tanker sunk by the Japanese during World War II, a 785-foot dirigible—the *Macon*, and transportation ships dating from the Gold Rush era.

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Our research team has initiated new studies on the impacts of boat groundings, like this vessel that sank off Big Sur last fall, to the rocky intertidal.

To assess the health of the Sanctuary, it is necessary to know how its natural resources are changing through time. This year, we expanded our beached marine mammal and bird surveys to the Cambria region and continued monitoring birds and mammals in Monterey Bay. These data have been used to investigate impacts of harmful algal blooms and seabird by-catch in fishing gillnets. This year a higher number of young, dead California Brown Pelicans seems to be a positive sign that the population is growing rather than suggesting a new threat to this endangered species. A monumental success this year was starting to implement the Sanctuary Integrated Monitoring Program (SIMoN), including an award of $2 million from the David and Lucile Packard Foundation to initiate critical new monitoring. We will now be able to understand ecosystem changes and their causes much more comprehensively for many years to come.

Our research staff are continually interacting with other agencies, educational institutions, researchers, and the public through meetings, developing documents, and responding to requests for information. This year the CDFG accepted essentially all the kelp management recommendations that the Sanctuary staff developed with scientists, the SAC, and the public over the last year. We've also provided scientific information to assist deliberations by community groups like the Alliance of Communities for Sustainable Fisheries and have updated a report on the status of fisheries in the Sanctuary. We plan to continue influencing conservation science with recent work by one of our team members on how removing oxygen from ballast water in ships can prevent species introductions (like a new kelp from Japan found in Monterey Harbor this year, see page 21) while reducing ship corrosion. There is also already great interest in our newly initiated studies on the human impacts of groundings and visitors

Program Support

The Program Support team continued to provide necessary administrative and operational support to allow us to stay focused on our mission and goals. Expanding our horizons beyond Monterey and Santa Cruz, we opened a new satellite office in San Simeon, which is co-located with the California Department of Parks and Recreation at Hearst Castle, and helped establish a national program office in Half Moon Bay. We also continued to operate the patrol vessel *Sharkcat* to monitor permitted activities and support research and education efforts.

Staff began to implement the joint management plan review process (along with Cordell Bank and Gulf of the Farallones Sanctuaries) in 2001 with an initial internal assessment and preparation of the *State of the Sanctuary Report*. The report provided background information on the Sanctuary's resources, history, accomplishments, and potential future resource issues and served as a base from which the public could offer comments and suggestions during the scoping process for the Sanctuary's management plan review. The scoping process, which occurred this winter in locations throughout central California as well as in Sacramento and Washington D.C., will help the Sanctuary define those priority issues to be addressed in the management plan update. The management plan review process will continue through 2002.

The Sanctuary Advisory Council continued to work with staff to establish priorities for the Sanctuary, provide a forum for presenting public issues and concerns, and provide information and advice to the superintendent. Many new members joined the Council this year, filling the primary and alternate seats for agriculture, at-large (3), business/industry, fishing, recreation, research, and tourism. Issues of interest and concern in 2001 included the management plan review process, California's Marine Life Protection Act, fiberoptic cable policy, SAC charter amendment, and the Sanctuary's new multicultural education plan.

As in the past, the Council worked closely with the Conservation Working Group, RAP, SEP, and Business and Tourism Activity Panel (BTAP) to obtain information on these issues. The BTAP was formally established as a working group of the Advisory Council and will continue to be a key tool for developing partnerships with the region's marine-related businesses.

The Monterey Bay Sanctuary Foundation was busy marketing and distributing numerous educational products and managing grants in support of the Sanctuary mission. Projects included Point Pinos tidepool issue facilitation, salmon/steelhead education projects, and Citizen Watershed Monitoring Network coordination. In an exciting development, the Foundation will be helping the Sanctuary with SIMoN coordination efforts and will manage a sizeable SIMoN grant from Duke Energy and the Packard Foundation.

Finally, our web site received a major overhaul and can be viewed at www.mbnms.nos.noaa.gov.

Monterey Bay National Marine Sanctuary Milestones 1992-2002

SEPTEMBER 20, 1992
A ceremony is held to celebrate the designation of the Monterey Bay National Marine Sanctuary, with Terry Jackson as the first Sanctuary manager

SEPTEMBER 30, 1992
The Marbled Murrelet is added to the federal threatened species list


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1993
A population explosion begins at a new elephant seal colony at Point Piedras Blancas

MARCH 5, 1993
The Western Snowy Plover is added to the federal threatened species list

SEPTEMBER 1993
The Scientific Research Plan—the first for any marine sanctuary—is completed

SEPTEMBER 1993
The first annual birthday celebration is held

1994
Brandts Cormorants establish a new breeding colony at Año Nuevo Island

1994
The non-native green crab invades Elkhorn Slough

JANUARY 1994
Water Quality Protection Program committees are established and workshops begin

FEBRUARY 1994
The Santa Cruz County Sanctuary Inter-Agency Task Force convenes to work on projects that enhance the economic and educational benefits of Sanctuary designation

MARCH 1994
The Sanctuary opens its current office on Foam Street in Monterey

MARCH 1994
The Sanctuary Advisory Council—the nation's second—is established and begins meeting

JUNE 16, 1994
The Eastern North Pacific population of the California gray whale is removed from the federal endangered species list

JULY 1994
The Great American Fish Count is held in the Sanctuary for the first time

SEPTEMBER 1994
Fort Ord closes; its prohibited and restricted marine zones off the coast—totaling 18 square nautical miles—open for unrestricted public use

MARCH 1995
Winter storms cause severe flooding around the Sanctuary

SPRING 1995
The Sanctuary conducts research cruises aboard the NOAA ship *McArthur*. Projects include geological coring, acoustical surveys, ecological surveys, meteorological analysis, and pollution studies


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MAY 1995
The Sanctuary web site—the National Marine Sanctuary Program's first—is unveiled to the public

AUGUST 1995
The Monterey Bay Sanctuary Foundation, a non-profit organization to support the Sanctuary, is established

DECEMBER 1995
Rodale's SCUBA Diving magazine names the Sanctuary as one of the "World's Best Marine Parks"

DECEMBER 1995
CMC (now The Ocean Conservancy) graduates its first group of BAY NET volunteers, who interpret at the shoreline as Sanctuary docents

1996
The first record of Heerman's Gull breeding in Northern California occurs at Año Nuevo Island

1996
The first Common Murre chicks fledge from Devil's Slide rocks since an oil spill wiped out the population in 1986

FEBRUARY 1996
Save Our Shores begins its first Sanctuary Stewards volunteer program to enhance public and school-based education about the Sanctuary


© MBNMS

SPRING 1996
The Water Quality Protection Program's Urban Runoff, Marinas, and Monitoring Plans are completed

MAY 1996
The Site Characterization, an in-depth description of the environment, ecology, history, and social settings of the Sanctuary, is available to the public on the Sanctuary web site

MAY 1996
Hundreds of juvenile male California sea lions invade Monterey Harbor and surrounding areas

SUMMER 1996
The Sanctuary conducts research cruises aboard the NOAA ship *McArthur*. Scientists conduct side scan sonar surveys, launch weather balloons, carry out plankton tows, and lower CTDs

AUGUST 1996
The Sanctuary web site wins the "Best NOS web site" award at the first annual "NOS WebShop"

FALL 1996
New regulations prohibiting white shark attraction go into effect

NOVEMBER 29, 1996
The 440-foot long oil tanker *Montebello*, sunk by Japanese submarine torpedoes in 1941, is discovered six miles off Cambria, just beyond the Sanctuary's boundary

SPRING 1997
The Monterey Bay Aquarium publishes *A Natural History of the Monterey Bay National Marine Sanctuary*

MAY 1997
A vessel traffic working group meets for the first time to evaluate ways to reduce the risk to the Sanctuary from large, ocean-borne oil spills

MAY 1997
Urban Watch, an urban runoff monitoring program, begins

MAY 1997
An El Niño event begins that lasts through June 1998, bringing warmer water and decreased productivity

MAY 1997
Beach COMBERS volunteers survey their beaches for the first time


©Greg Smith

OCTOBER 26, 1997
More than 300 birds covered with a sticky, oily substance die in Monterey Bay from an unidentified oil spill

1998
International Year of the Ocean. The Sanctuary is featured in *National Geographic*, *Sunset*, *Time*, and *Outside* magazines

1998
A Sanctuary GIS for mapping resource management information is made available for the first time

JANUARY 1998
The Citizen's Watershed Monitoring Network gets underway

JANUARY/FEBRUARY 1998
More than fifty live and dead oiled birds are found on Sanctuary beaches from a tar ball incident off Point Reyes that killed or debilitated at least 600 marine birds

FEBRUARY 1998
A major El Niño storm causes flooding of Pajaro River; Moss Landing Harbor fills with sediment, trapping vessels; and Highway 1 in Big Sur closes at sixteen locations

FEBRUARY 27, 1998
New Sanctuary Superintendent William Douros spots a rare northern right whale off the Big Sur coast

MARCH 1998
Robert Ballard's JASON Project broadcasts from the Sanctuary for two weeks

MAY 1998
California sea lions give birth to pups on the Monterey breakwater for the first time


© Stan Wilson for NOAA

JUNE 1998
A harmful algal bloom event in Monterey Bay kills more than 400 California sea lions along the central coast

JUNE 1998
Goodbye El Niño, hello La Niña

JUNE 11-12, 1998
The National Oceans Conference and Oceans Fair are held in Monterey. President Clinton and Vice President Gore visit the Sanctuary

JULY 1998
New regulations allowing limited collection of marine jade go into effect

SUMMER 1998
The Model Urban Runoff Program is up and running in Monterey and Santa Cruz

JANUARY 1999
The State of California's Marine Life Management Act is enacted

MARCH 1999
The first annual *Ecosystem Observations* report is released

MAY 1999
The Sustainable Seas Expeditions, a multi-year deep-water exploration project using the *DeepWorker* submersible and led by Dr. Sylvia Earle, visits the Sanctuary for the first time


© Kip Evans for National Geographic Society

MAY 1999
The first annual Student Summit is held, providing a forum for high school students to present marine science research projects to scientists and peers

AUGUST 5, 1999
The American Peregrine Falcon is removed from the federal threatened species list

SEPTEMBER 1999
A new Sanctuary office opens in Santa Cruz

OCTOBER 1999
The Sanctuary is named one of the top ten conservation accomplishments—"paradises preserved"—of the past 100 years by *Audubon* magazine

OCTOBER 1999
The Agricultural and Rural Lands Action Plan is released

NOVEMBER 1999
A new bathymetric and topographic map of the Sanctuary is released

2000
A special agent from NOAA's Office of Law Enforcement is assigned to the Sanctuary

APRIL 22, 2000
The first annual Snapshot Day is held, using volunteers to monitor water quality in watersheds throughout the Sanctuary

MAY 26, 2000
A vessel traffic agreement receives final international approval in London, moving large commercial vessels, oil barges, hazardous materials carriers, and tankers further offshore


Courtesy of Mario Tamburri

SUMMER 2000
The pilot program for S.E.A. Lab Monterey Bay is held

SUMMER 2000
The Sustainable Seas Expeditions return to the Sanctuary

AUGUST 2000
A harmful algal bloom event in Monterey Bay affects marine mammals, sardines, anchovies, and krill populations

SEPTEMBER 2000
A satellite tag is used for the first time on a leatherback turtle in Monterey Bay

OCTOBER 2000
Sanctuary staff complete the plan for an ecosystem monitoring program—SIMoN (Sanctuary Integrated Monitoring Network)

OCTOBER 2000
A new southern office in San Simeon is established

OCTOBER 2000
Team OCEAN, a new kayaker outreach and education program, begins

OCTOBER 3, 2000
The final Kelp Management Report is released

OCTOBER 10, 2000
The first annual "First Flush" storm drain monitoring event occurs during the first major storm of the season

NOVEMBER 2000
Reauthorization of the National Marine Sanctuaries (NMS) Act occurs; the NMS budget grows significantly (to $32.5 million); the number of Monterey Bay Sanctuary staff expands to twenty

JANUARY 2001
The Sanctuary releases its multicultural education plan, M.E.R.I.T.O.

APRIL 2001
The joint management plan review process begins with internal program review

MAY 30, 2001
A rare northern right whale is sighted in Monterey Bay by Sanctuary Cruises, a local whale watching company

SEPTEMBER 2001
A comprehensive continental shelf map for the Sanctuary is released by the USGS

SEPTEMBER 2001
The first interpretive exhibit of the Sanctuary Scenic Trail is installed in Santa Cruz

NOVEMBER 2001
The *State of the Sanctuary Report* is released, as the first of twenty public scoping meetings for the joint management plan review is held

DECEMBER 2001
Monterey Bay and Gulf of the Farallones sanctuaries open a joint office in Half Moon Bay

Ten Years of Technological Advances Result in Improved Sampling Techniques

As anyone who has bought a new phone, stereo, or computer recently will testify, everyday personal technologies are developing at an extraordinary pace. The same holds true for advances in the tools available for studying the sea. It was not long ago that the only way scientists could examine the organisms living 100 feet or more below the ocean surface was to drag a net through the water column or along the bottom. Now we are used to seeing tools like remotely operated vehicles (ROVs) exploring the great depths of the ocean and discovering new species and processes on an almost daily basis.

During the ten years since the Monterey Bay National Marine Sanctuary was designated, several new technologies have been developed and are now being used to survey, monitor, and understand our regional marine environment better. For example, thanks to high-resolution side-scan sonar and multibeam survey techniques, simple seafloor maps have now evolved into detailed bathymetric profiles and habitat characterizations. Similarly, our understanding of when, where, and how coastal erosion occurs has been extended greatly: rather than standard visual beach profile surveys, scanning airborne laser altimetry (LIDAR) is now used to measure and monitor changes to cliffs, bluffs, dunes, and beaches precisely.

Todd Walsh © 2001 MBARI

The integration of new sensors into autonomous underwater vehicles (AUVs) like this one represents an exciting advance in oceanographic sampling.

Several new advances in oceanographic sampling have also provided invaluable information on the Sanctuary. Precise and durable field sensors that measure a variety of physical, chemical, and biological parameters are constantly being developed and deployed on traditional platforms such as ships and moorings. However, what is truly exciting is the integration of these new sensors on innovative sampling systems such as autonomous underwater vehicles (AUVs). It will not be long before a fleet of torpedo-like AUVs is programmed to sample various aspects of the water column continuously and provide a more spatially and temporally comprehensive understanding of oceanographic processes throughout Monterey Bay.

Other technologies that are now part of our everyday sampling packages provide critical oceanographic information without ever getting wet. Remote sensing systems such as Coastal Radar (CODAR) and the Sea-Viewing Wide Field-of-View Sensor (SeaWiFS) satellite give us a much more complete understanding of ocean conditions—such as wind driven circulation patterns and primary productivity—and how they are changing through time. A system currently under development can even identify and map different biological communities and seafloor types as much as ten meters below the ocean's surface using hyperspectral images taken from a low-flying aircraft.

Scientific advances over the past ten years have also enabled us to understand marine life in ways only dreamed about previously. For example, standard tagging studies, where several animals are marked and then a few recovered (the researchers hope) to provide insight to migration patterns, have now been replaced by satellite tags that can continuously track individuals as they move around the world. Similarly, video cameras and various small sensor packages are now commonly placed on (and in some cases in) fishes, marine mammals, and sea turtles to study both their behavior patterns and physiology. These tools can now also be linked with satellite technology to send real-time data back to the lab.

Recent developments in the area of molecular biology have also led to an amazing new understanding of marine life. Scientists can now determine how closely related different individuals of a species are to answer important ecological questions of dispersal and recruitment. Molecular tools can also be used to address critical management concerns such as providing an early warning of potential hazards to marine life and human health.

Naturally occurring harmful algal blooms (HABs) provide another example. These phenomena can cause sickness and death in a variety of marine organisms like seabirds and marine mammals as well as humans who eat contaminated seafood. Previously, HABs were identified by either the presence of sick and dead animals, by analyzing shellfish tissues, or by periodically sampling the water directly and identifying harmful algae under a microscope in the lab. These approaches were often imprecise and typically only identified a problem after it was too late. A new automated system that uses molecular probes designed to identify specific species of toxic algae has been developed and will solve these problems. This system can be placed directly in the field and will send data back to the lab in real time, detecting whether harmful algae are present and in what concentrations, thus allowing early warning preparations.

These are just a few examples of recent technological advances that allow us to sample and study the Sanctuary better. Like advances in everyday personal technologies, there are almost too many to list. Looking back over how things have changed over the past ten years, it is exciting to imagine what is still to come.

– Mario Tamburri
Monterey Bay National Marine Sanctuary and Monterey Bay Aquarium Research Institute

Contributed Ecosystem Observations

© MBNMS

Beach Systems

El Nino Storms Erode Monterey Bay Beaches

Intense storms often produce especially high waves and elevated sea level, causing extensive beach erosion and dramatic shoreline retreat. The worst erosion usually occurs when multiple storms strike the coast during the highest tides. Several years can pass between stormy seasons intense enough to cause enough shoreline erosion to produce widespread damage to coastal land and structures. Although waves rebuild beaches after such storms, this seaward accretion may not return a beach to its pre-storm position, requiring coastal zone managers to consider whether to take long-term remedial measures.

During the winters of 1982-83 and 1997-98, two of the most severe El Niños of the twentieth century produced intense storms along the central California coast. These storms followed more southerly storm tracks than do non-El Niño storms. The southerly storms, combined with periods of high tides, intensify the normal winter erosional cycle. Coastal cliffs, dunes, and man-made structures along Monterey Bay suffered serious damage, much of it along the northern, most populated, part of the bay. To understand the effects of such storms better, United States Geological Survey (USGS) scientists, in cooperation with the California Department of Parks and Recreation, began a monitoring program at nine Monterey Bay beaches in the midst of the 1982-83 El Niño and four other beaches in 1985.

Landward or seaward shifts in the position of the shoreline at mean sea level (MSL) are a measure of the extent of beach erosion (loss) or accretion (growth), respectively. During the 1982-83 El Niño, storm waves stripped large volumes of sand from Monterey Bay beaches, leaving beachfront homes and coastal cliffs and dunes exposed to direct wave attack. By the end of the 1982-83 El Niño, Monterey Bay beaches had dramatically eroded. For example, Figure 1 shows beach conditions at Seacliff State Beach, on the northeast coast of the bay, at the end of the 1982-83 El Niño. During the ensuing two years, normal wave activity returned sand to the beaches, resulting in net accretion (*see insert to Figure 1*). However, there is no way of knowing whether the beaches returned to near their pre-El Niño positions, because no profile data had been collected just preceding the El Niño. Between 1985 and September 1997, the beaches went through typical seasonal fluctuations (erosional and accretionary cycles).

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Figure 1: February 1983 photograph of the remains of a wooden seawall at Seacliff State Beach. Waves generated by the 1982-83 El Niño destroyed the seawall and scattered the large stones that had been emplaced seaward of the wall. Insert: April 1985 photograph of the replacement seawall and rebuilt beach. That seawall remained intact through the 1997-98 El Niño.

During the 1997-98 El Niño, several intense winter storms from the south struck the Monterey Bay coastline. However, no Monterey Bay beach eroded as severely as during the 1982-83 El Niño. For example, at Seacliff State Beach, which is most susceptible to waves from the south, erosion during the 1997-98 El Niño was no more severe than during some non-El Niño years.

Only two beaches appear to have undergone net retreat since 1983. One, Moss Landing State Beach, is adjacent to the head of Monterey Canyon. This complicates interpretations of long-term shoreline retreat because sand eroded from the beach can wash into the canyon and be lost to the deep sea rather than being shifted onshore and offshore. Thus, the condition of Moss Landing State Beach also depends on the rate of longshore sand movement from the north. The other, Fort Ord Beach, is narrow and backed by a high cliff that is easily eroded. Even in most non-El Niño years, storm waves erode the beach enough to attack the cliff, which then fails. Consequently, the shoreline has retreated an average of one to two meters per year since monitoring began in 1983. However, the summer beach continues to return to the same shape and width as MSL moves landward.

The cooperative efforts of USGS scientists and the California Department of Parks and Recreation at Monterey Bay's beaches have led to a better understanding of how these beaches change during both El Niño and non-El Niño years. The State of California Department of Parks and Recreation is using the results of this study to aid its development of long-term plans for managing its public beaches along Monterey Bay. This research will also provide new insights into how beach erosion occurs in other coastal areas in an ongoing effort to protect people's lives and property from geologic and environmental hazards in the coastal zones of the United States. This study is part of the USGS research in the Monterey Bay National Marine Sanctuary, which will be published soon in a special volume of the journal *Marine Geology*.

–John Dingler
United States Geological Survey

PISCO Update: Withering Syndrome in Black Abalone

Once the largest and arguably most important herbivore in intertidal systems along much of the U.S. West Coast, the intertidal black abalone, *Haliotis cracherodii*, has experienced mass mortalities along California's coast since the mid-1980s. Mortality is due to infection by a pathogen that leads to a fatal wasting disease called "withering syndrome," where the foot of the abalone shrinks until it can no longer adhere to the substratum (*Figure 1*). Scientists first noted massive die-offs due to withering syndrome on the Channel Islands in 1986, and by 1992 the disease was observed near Point Conception, on the mainland. The general pattern of mortality, once die-offs start, is that within a few months to a year the population will decrease by more than 90 percent, but a few remnant individuals will remain healthy and persist. Since the early 1990s the disease has migrated sequentially northwards along the California coast; this migration poses a potential threat to healthy populations of *H. cracherodii* currently residing within the Monterey Bay National Marine Sanctuary.

Researchers with the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) project at the University of California Santa Cruz and their collaborators* are surveying black abalone populations at several sites. Six sites are within the Sanctuary and are currently the only sites in the study with healthy populations (*Figure 2*).

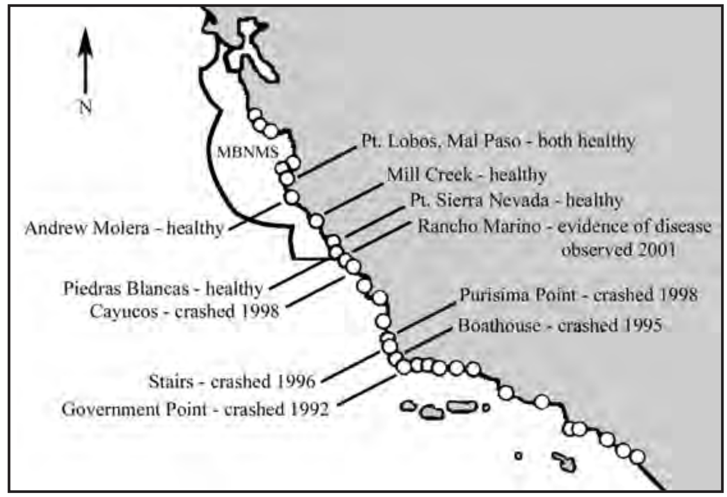

Figure 2: Location of monitoring sites along the south-central coast of California in relation to the Monterey Bay National Marine Sanctuary. Labels indicate the health of black abalone at each site.

THE PISCO PROJECT

Founded in 1999 by the David and Lucile Packard Foundation, PISCO is a consortium of four west coast universities that focuses on regional-scale, multidisciplinary research related to coastal rocky reefs. A significant amount of PISCO resources are devoted to monitoring nearshore oceanographic conditions and relating them to the community structure of subtidal and intertidal ecosystems over a long-time horizon. The black abalone monitoring described here is one of many PISCO research projects. *For more information, please visit: www.piscoweb.org.*

There are two main objectives of the surveys that started in southern California in 1992: to determine whether withering syndrome and associated mass mortalities of black abalone are progressing northward; and to assess whether the pattern of black abalone declines relates to elevated seawater temperatures. As movement of the disease northward became more evident over time, the study expanded to include more northerly sites. The study started in 1992-93 with four sites (Government Point, Boathouse, Stairs, and Purisima Point) and added three new sites in 1996-97 (Cayucos, Piedras Blancas, and Point Sierra Nevada). In 1999 five more sites were set up inside the Sanctuary: Mill Creek, Andrew Molera, Mal Paso, Rancho Marino, and Point Lobos.

Sampling occurs in the early spring and late autumn. Methods consist of thorough searching for abalone in defined areas and subsequent observation for clinical evidence of the withering disease while noting recent accumulations of abalone shells. Sea surface temperatures come from NOAA's online database *CoastWatch*.

The surveys reveal that mass mortalities of *H. chracherodii* due to withering syndrome are indeed progressing northward (*Figure 3*). The disease had decimated black abalone populations at the three southern-most sites by 1995. By 1998 massive die-offs struck the Purisima Point and Cayucos Point populations. Preliminary sampling in 2001 at Rancho Marino near the Sanctuary's southern border (data not included here) shows signs of the syndrome. This

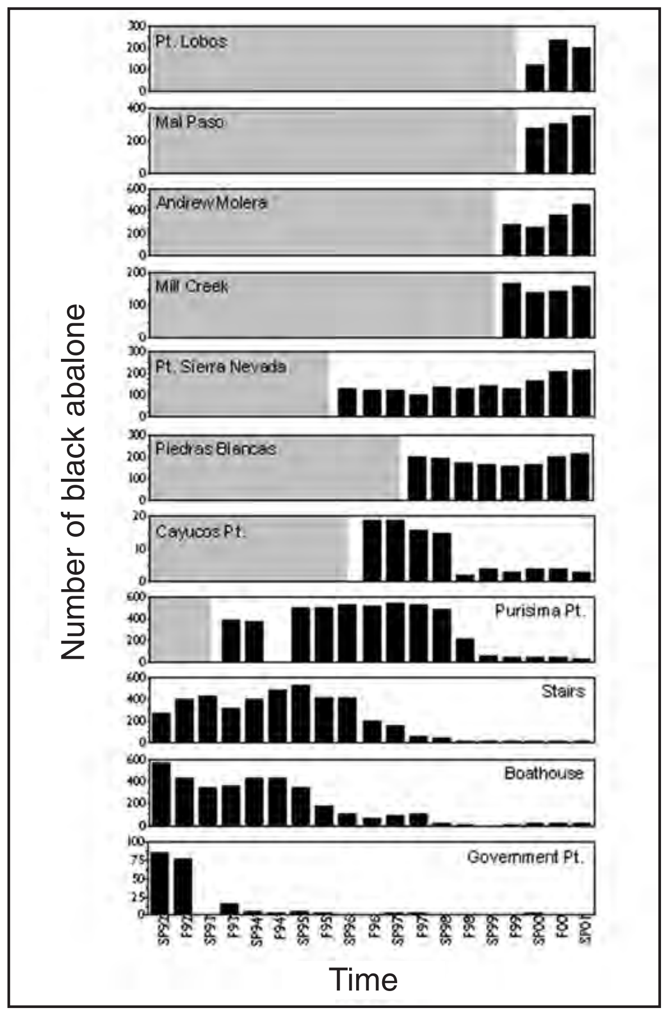

Figure 3: Changes in the number of black abalone at eleven sites arranged from north to south from 1992 to 2001. Note differences in the scale of y-axis. Gray shading indicates that no sampling was done.

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Figure 1: A diseased (left) and a healthy (right) abalone. Length is approximately 12 cm.

pattern suggests that the disease is gradually moving northward but the spreading rate of die-offs is variable. This variable rate of decline and an apparent lag between the incidence of withering syndrome in a local population of abalone and its subsequent mass mortality due to the disease suggest that the mass mortalities may not simply be due to the gradual northward progression of the causative agent of withering syndrome. Researchers predict that elevated sea surface temperatures due to El Niño (and other causes) may act as a trigger mechanism for mass mortalities at sites where the causative agent is already present. The field evidence generally supports this prediction, but massive die-offs have occurred during El Niño and non-El Niño years. Therefore elevated seawater temperatures are seemingly not necessary for occurrence of withering syndrome and the onset of mass mortality, but they are likely to promote these conditions.

The prognosis for rapid natural recovery of black abalone populations along the southern and central coasts of California is not good. Black abalone along the central and extending into the northern coast of California already show signs of withering syndrome, therefore mass mortalities throughout the Sanctuary are likely. In 1999 the National Marine Fisheries Service (NMFS) listed *H. cracherodii* as a candidate species for protection under the Endangered Species Act. If NMFS lists black abalone as endangered in the future, a management conflict may arise between protecting the remnant abalone at affected locations and the endangered sea otter population that feeds on them.

– Lydia Bergen[1] and Peter Raimondi[2]
[1]PISCO, University of California Santa Cruz
[2]Department of Ecology and Evolutionary Biology, University of California Santa Cruz

*Much of this work started prior to the founding of PISCO. Other funding sources for this research include the Natural Sciences and Engineering Research Council of Canada, the Mineral Management Service, the UC Toxics Substances Research and Teaching Program, and the National Science Foundation.

Open Ocean and Deep Water Systems

Observing Life Processes in the Sanctuary

Nowhere is the complexity of ocean processes or the need for advanced observation methods greater than in the coastal ocean. This complexity demands investigation of physical, chemical, geological, and biological realms across disciplinary boundaries. Within the rapidly changing fluid environment of the coastal ocean, capturing snapshots of environmental structure can be a powerful tool in the effort to understand processes that shape the environment of marine life. How can we take a snapshot that has conceptual breadth and depth? We need to move an interdisciplinary spectrum of sensors rapidly through large regions of the fluid environment. Ideally, the platform carrying these sensors would be smart enough to respond to the environment it is sampling. Wouldn't that be nice? …With help of AUVs, it sure is!

An autonomous underwater vehicle (AUV) is an unmanned, untethered, robotic submarine about the size of a large porpoise (or two aligned end-to-end). Programmed with a mission, the onboard computer directs the AUV to fly a course, sense the environment, and record what it senses. AUVs are becoming important research platforms in the Sanctuary. They were used extensively during a major field experiment last summer that brought together researchers from twelve institutions in a multidisciplinary study of processes in the Sanctuary (MUSE; see *Ecosystem Observations 2000*, page 7 and http://www.mbari.org/MUSE). Observations from the AUV provided remarkably clear definition of complex processes that influence life in the Sanctuary.

A Bloom and a Plume

During the MUSE 2000 field study, researchers were studying details of a harmful algal bloom (HAB) in Monterey Bay, including species identification with visual and molecular methods and toxin measurement within and around the microbes. In a concerted effort, researchers on another ship deployed an AUV to map the distribution of the bloom. In two hours the AUV surveyed at high-resolution an eight-kilometer section over the continental shelf in the bloom region, oscillating between the surface and bottom and using its ability to detect the bottom to follow the bottom topography. The resulting map (*Figure 1*) showed that the bloom was concentrated in a subsurface layer approximately five to ten meters thick that closely followed the seawater density distribution. (In Figure 1 the bloom is shaded, and the black contour is a constant density surface that the lower boundary of the bloom followed.)

Physical and biological layers exist across a wide range of scales in marine and estuarine ecosystems. Physical layers structure the fluid environment of ocean life through control of physical and chemical properties, and ocean life processes are concentrated in these layers. There is thus strong motivation to understand the physical-biological coupling underlying these relationships as well as the effects of layers on ecosystem structure and function (e.g., biogeography of marine organisms, survival of larval fish, and bioaccumulation of harmful algal bloom toxins).

We expected to map the structure of the harmful algal bloom, but we were surprised by another dimension of the marine environment sensed

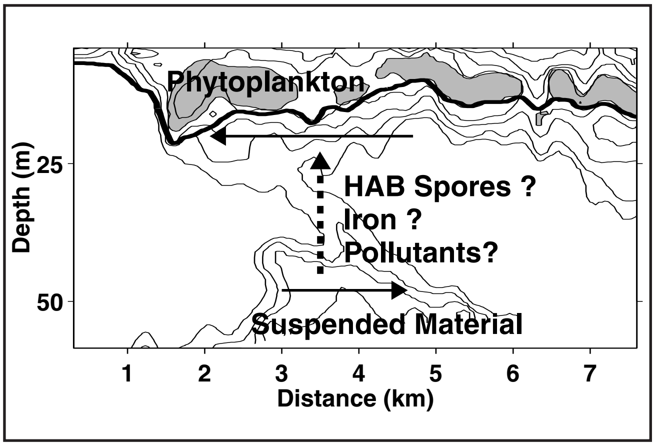


Figure 1: High-resolution vertical section of properties measured via autonomous underwater vehicle (AUV) adjacent to Monterey Canyon on August 30, 2000. Particle concentrations are contoured; the highest levels were in the phytoplankton bloom and in a plume of nonliving suspended material.

by the AUV. Beneath the bloom was a plume of suspended particulate material emanating from Monterey Canyon. The gray contours in Figure 1 delineate regions of high particle concentrations. The particles in the upper water column were largely living particles (phytoplankton), but those in the lower water column were non-living. The shallow phytoplankton layer was flowing opposite the deep plume of suspended material. Between these two flow regimes, particles were being transported from the bottom to the top. Particulate material from the bottom can contain iron-bearing sediments that fertilize productivity of the pelagic ecosystem as well as resting spores of harmful algal bloom species. Did the plume start the bloom by seeding the upper water column with resting spores? Did the plume fertilize the bloom with iron? Is transport from canyon to shelf a persistent influence on the ecology of Monterey Bay? What physical processes forced the transport? These and other questions are being pursued to further our understanding of ecology in the Sanctuary.

Beneath a Surface Slick

Have you ever been out on the bay and observed a surface slick, where the small wind-forced ripples are damped? If so, you have observed environmental structure that extends well beneath the surface. During MUSE, we set out to map an oceanic front on the northern Monterey Bay shelf. Fronts are regions where physical, chemical, and biological variability are concentrated and enhanced, and they are very important to marine ecosystem dynamics. We identified the location and orientation of a front from the ship's underway mapping system, then deployed the AUV to see what was happening beneath the surface. As we passed through a surface slick, which extended as far as the eye could see, we knew that a new window on complexity was opening because our AUV was flying a high-resolution, three-dimensional sampling pattern. Taking nearly 60,000 measurements from each of six instruments, we thoroughly surveyed a volume of ocean, 7 kilometers x 3 kilometers x 70 meters.

Similar to observations south of the canyon (*Figure 1*), north of the canyon there was a subsurface layer abundant in phytoplankton (*Figure 2*). The outer boundary of the layer is defined by the black mesh surface. Within the volume inside this boundary, phytoplankton abundance was equal to or greater than that along the outer boundary. The gray surface

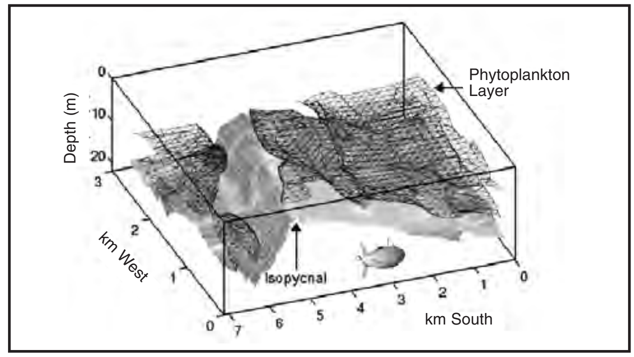


Figure 2: View from above Moss Landing, looking NW down into the ocean. Volume visualization of a subsurface phytoplankton bloom layer (mesh isosurface) on the northern Monterey Bay shelf relative to a constant density surface (gray). The bloom closely followed the density surface and was interrupted at a ridge in the density field. Chl_{max} identifies the highest chlorophyll fluorescence observed. Only the upper twenty-two meters of the seventy meters surveyed are shown.

in Figure 2 is a constant density surface, or isopycnal. We can view the density field as a kind of topography of the ocean interior that illustrates environmental structure and processes. Throughout the domain, the phytoplankton layer closely followed the density field, and a break in the biological layer was aligned with a ridge in the density field. The greatest concentrations of phytoplankton within the layer (Chl_{max}) were in a trough in the density field, south of the ridge. Internal waves deform the density field, create surface slicks, and concentrate plankton in their troughs. Thus the environmental structure observed beneath a surface slick suggests internal wave processes shaping life in the Sanctuary.

The complex and rapidly changing coastal ocean challenges our investigations of ecology. We seek to enter that complexity and to extract knowledge that can not only guide environmental decision making but also advance methods of study across disciplinary realms. The processes we study in the Sanctuary are important in marine systems around the world.

– John Ryan
Monterey Bay Aquarium Research Institute

The Physical Environment

Numerical Modeling of Monterey Bay Circulation and Ecosystem Dynamics

The physical characteristics of the marine environment (e.g., ocean currents, temperatures, and salinities) play a major role in the distribution and evolution of all material within the Sanctuary. This includes both beneficial material, such as the phytoplankton that form the base of the food web, and hazardous material, such as spilled oil. Observing the physical state of the area that makes up the Sanctuary is a daunting task, particularly since the relevant ocean currents span a wide range of scales from breaking waves and small eddies near coastal rocks and promontories out to kilometers-wide deep flows along the continental slope.

The complexity and vast extent of motions in the ocean dictate that some type of model must be coupled to the necessarily limited direct observations. The model itself may take on many different forms. One example is the physical notion that, due to the earth's rotation, wind blowing along the coast from the northwest will produce a net offshore current near the surface. For decades, this conceptual model has enabled predictions of coastal upwelling—which is needed to replace the surface waters—based simply on estimates of alongshore winds. It is now understood that much of the productivity within the Sanctuary depends on the nutrients that are upwelled into the lighted surface waters by this type of circulation. It is also understood, however, that this upwelling model is an oversimplification. Upwelling is observed to occur in isolated locations along the coast and nutrient-rich waters are spread horizontally by upwelling-related currents.

For several years, research institutions around Monterey Bay have deployed observing systems that go beyond the simple coastal wind measurements. Monterey Bay Aquarium Research Institute (MBARI), for example, has maintained two or three deep-ocean moorings that report subsurface temperature, salinity, and current information along with surface meteorological data in real time via radio links to shore. MBARI and the Naval Postgraduate School (NPS) have conducted regular ship-based transects across the Sanctuary. NPS and others have deployed high-frequency (HF) radars along the shoreline that produce maps of surface currents over much of the Sanctuary.

A new federal program called the National Ocean Partnership Program (NOPP) has made it possible to coordinate and expand many of these observing systems. In addition, numerical modeling experts from as far away as the University of Southern Mississippi and UCLA have begun to develop sophisticated computer models for the region. Once perfected, these models have the potential to act as "dynamic interpolators" that can fill in among the sparse observations. The physical circulation models also have the capability of hosting embedded ecosystem models, which take the environmental information as input for equations predicting trophic-level interactions within the food web.

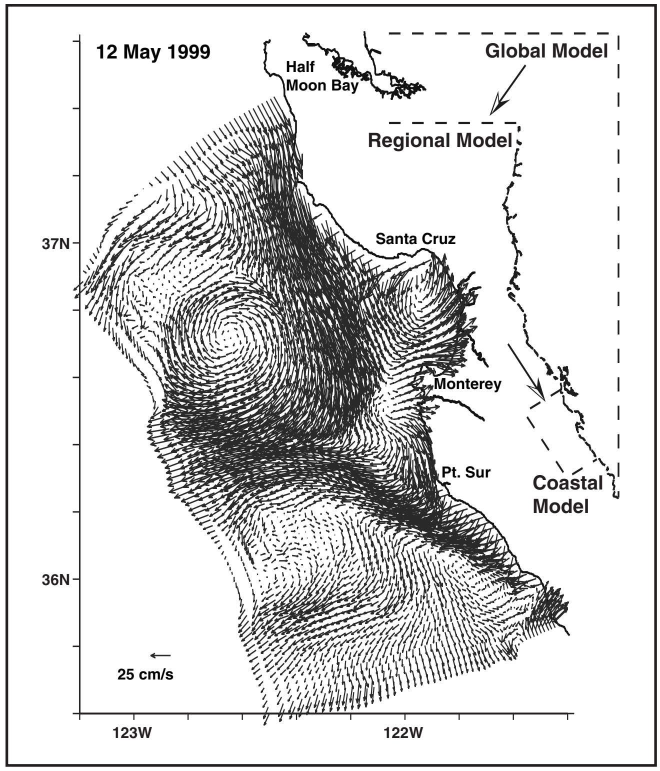
The first NOPP project, called the Innovative Coastal-Ocean Observing Network (ICON; see www.oc.nps.navy.mil/~icon), was begun in 1998 and is focused on circulation modeling and the coupling to physical data. The second NOPP project, called Simulations of Coastal Ocean Physics and Ecosystems (SCOPE; see www.mbari.org/bog/NOPP), was initiated in 2000. It is building on the modeling results from ICON and moving beyond them to incorporate ecosystem models. In this case, Monterey Bay is almost unique in the wealth of historical bio-chemical observations that have been taken alongside the physical observations. These data will be needed to validate the developing ecosystem algorithms. The many ICON and SCOPE partner institutions are listed in the table below.

NOPP Participating Institutions

ICON	***SCOPE***
Naval Postgraduate School*	Naval Postgraduate School
Monterey Bay Aquarium Research Institute	Monterey Bay Aquarium Research Institute*
University of California Santa Cruz	University of California Santa Cruz
Naval Research Laboratory	Naval Research Laboratory
HOBI Labs	HOBI Labs
University of Southern Mississippi	University of California Los Angeles
California State University Monterey Bay	Calif. Institute of Technology/ Jet Propulsion Laboratory
Codar Ocean Sensors	Monterey Bay National Marine Sanctuary
	University of Maine
	Duke University

*Lead institution

Finally, it is important in this short note to outline the extreme challenge that modeling Monterey Bay circulation represents. Because computers continue to become more and more capable, and because the fundamental physical equations describing ocean currents are known, it may appear straightforward to build and use such a numerical model. This appearance is far from accurate. Briefly, modeling coastal ocean currents is made difficult by a number of factors, some of which are internal to the numerical code while others are external. Internal limitations include the need to have sufficient grid resolution to allow for the interaction among scales and the breakdown of scales through turbulence. Despite today's computers, it is not possible to run models that cover hundreds of square kilometers with grid resolutions of just a few meters, which would be needed to resolve all of the interacting scales. Beyond that, grid resolutions of less than one centimeter would be needed to resolve the turbulent scales. Hence, it is always necessary to include some overly simplified parameterization of the small-scale currents and turbulence as part of any ocean model.



ICON model surface velocities during an upwelling event (courtesy I. Shulman). The coastal model receives boundary information from a navy regional model, which itself is embedded within a global navy model.

External limitations include the need to have accurate wind forcing, which can itself require high-resolution atmospheric models to produce the variability observed near the coastline. It is also necessary to provide inflow information along all of the open boundaries in a coastal ocean model. This requirement may be the most limiting effect of all. For example, a single snapshot of surface velocities from the ICON model is shown in the accompanying figure. The currents reflect the influence of strong upwelling centers located just north of Santa Cruz and offshore of Point Sur. This complex circulation is realistic and is largely driven by the wind forcing applied to the ICON model. However, the information supplied to the model along the offshore open boundaries will influence and overwhelm this circulation pattern within hours to days, which means that the source of boundary information becomes as important as the internal workings of the ICON model and the model's wind forcing.

In the case of the ICON model and the next-generation model under development within SCOPE, open boundary information is derived from a second, regional model that covers the entire West Coast with less resolution. The regional model itself is embedded within a lower-resolution global model (*see figure*). Information passed through this hierarchical scheme includes such effects as thermocline deepening due to coastally trapped waves initiated by El Niño events in the tropical Pacific. In this way, accurate circulation modeling within the Sanctuary really represents the need to model the entire north Pacific Ocean.

Despite the difficulties, the combined modeling and observing components of ICON and SCOPE represent an exciting beginning toward the goal of tracking and predicting ocean movements and productivity throughout the Sanctuary.

– Jeffrey D. Paduan[1] and Francisco P. Chavez[2]
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[2]Monterey Bay Aquarium Research Institute

Tidal Erosion at Elkhorn Slough

Virtually all of California's coastal wetlands have been dramatically altered by hydrological manipulations. Either flow has been decreased by diking and draining lands for agricultural uses, or it has been increased by dredging of deep channels for boat traffic. Both of these hydrological alterations have shaped wetlands at Elkhorn Slough. The most extensive diking occurred in the 1870s when an embankment was constructed to carry the railroad line right through the Slough. Tidal flow to marshes south and east of the main channel was restricted, and most of these wetlands were subsequently drained and converted to agricultural use. While dikes decreased tidal flow to some parts of the Slough, another project radically increased tidal flow to the undiked main channel and marshes: the 1947 opening of a large artificial mouth to the Slough.

Prior to 1947 the Slough mouth was a few miles to the north of the main channel. The opening was small and sometimes obscured by a sandbar, so tidal flow to the Slough was very muted. In 1947 an artificial mouth was dredged through shoreline dunes directly west of the Slough's main channel (*Figure 1*) to accommodate the newly constructed Moss Landing Harbor. Plans for tide gates under the Highway 1 bridge, which would have maintained the sluggish tidal character of the Slough, were never implemented. Since 1947, therefore, Elkhorn Slough's shallow, meandering channels have been exposed to unprecedented tidal flows.

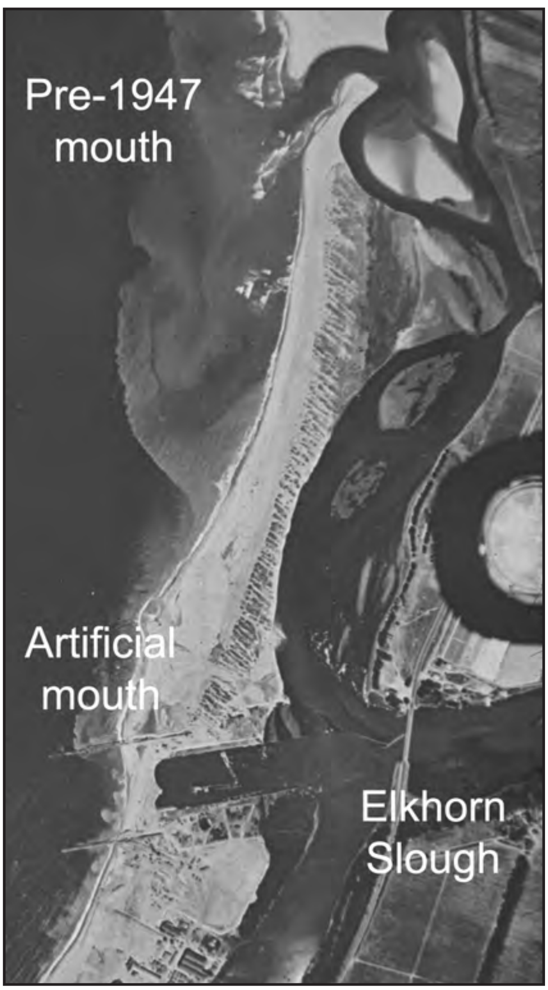


Figure 1: August 1946 aerial photo showing construction of the new artificial Slough mouth and a smaller natural mouth to the north [ESNERR collection]

Studying Tidal Erosion

What have been the consequences for Slough wetlands of the opening of the artificial mouth to Monterey Bay? This question was first addressed in the 1980s by the seminal work of John Oliver and colleagues at Moss Landing Marine Laboratories (MLML) and subsequently in the 1990s by various graduate students. Currently habitat changes continue to be studied by Rikk Kvitek and his students at California State University Monterey Bay and by researchers at Elkhorn Slough National Estuarine Research Reserve (ESNERR). The goal of the research is not only to document past changes but moreover to predict their future trajectory. After 1947 there was a gross mismatch between the size of the new mouth and the shallow Slough channels. Tidal scour will carve out the channels until a new equilibrium is reached. But when will this happen? If such an equilibrium were reached soon, Slough habitats might persist indefinitely with the current diverse mix of habitat types. However, if an equilibrium is only reached many decades from now, the Slough may resemble a muddy fiord, due to loss of most marsh and intertidal mudflat habitats. Since most of California's tidal marshes have already been lost to human uses, and since Elkhorn Slough boasts the second largest remaining area of salt marsh in the state, a better understanding of these habitat changes is critical for making wise conservation decisions.

Main Channel Bathymetry

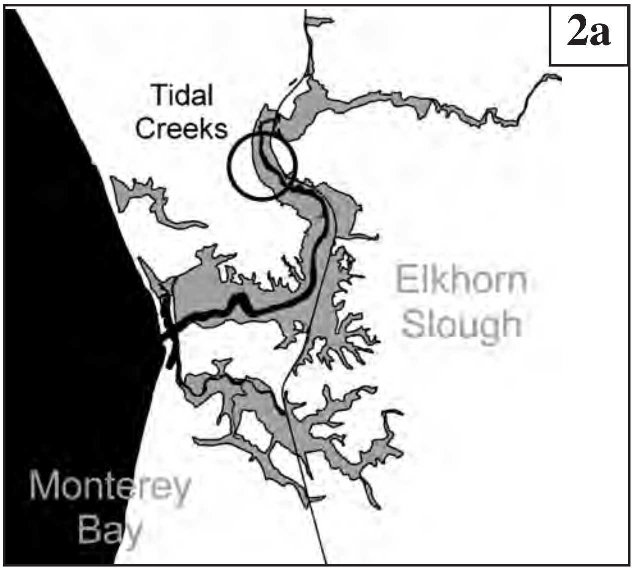
Depth of the main channel was measured manually using poles at several cross sections by National Oceanic and Atmospheric Administration researchers in the 1940s, Oliver and colleagues in the 1980s, and University of California Santa Cruz student Todd Crampton in the 1990s. Also in the 1990s Kvitek and MLML student Chris Malzone assessed depth contours at these cross-sections using a single-beam echosounder. Comparison of data from these studies revealed a dramatic increase in main channel subtidal area between the 1940s and the 1990s. Depth at the mouth increased from about 1.5 meters to greater than seven meters. Crampton estimated that 1.6 million cubic meters of sediments had eroded since 1947.

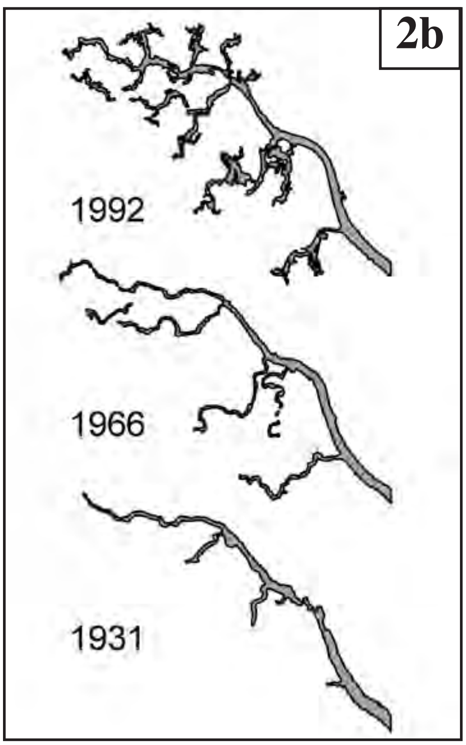
In 2001 Jeremiah Brantner and Kvitek initiated a new phase of bathymetric studies by using the research vessel *MacGinitie*, equipped with a multi-beam echosounder and global positioning system. In one day of surveying they obtained soundings at roughly 0.25-meter intervals throughout the whole subtidal portion of the main channel, yielding by far the highest resolution bathymetric map to date. Comparison of their data with those of Malzone demonstrates that erosion rates remain high, with channel depth increasing on average 0.5 meters in less than a decade. Erosion rates were greatest at the mouth (24 percent increase in depth), and at Seal Bend (30 percent) where the channel turns northward. Brantner estimates that the main channel increased in volume by about 15 percent in just seven years, translating into a loss of 58,000 cubic meters of sediment per year.

Changes in subtidal bathymetry are a key piece of evidence that will help answer whether erosion rates are tending towards equilibrium. Therefore Kvitek plans to resurvey main channel bathymetry on a regular basis and to expand the surveys to include shallower intertidal mudflats. Such detailed long-term monitoring would not have been feasible before the advent of sophisticated mapping technology.

Bank Erosion

In the early 1990s Crampton and Malzone set up markers along the main channel and tidal creeks of the Slough, returning after months or





Figures 2a and 2b: Diagrammatic representation of change in tidal creeks over time in the northwestern Slough [E. Van Dyke]

years to measure how the distance from the markers to the bank edge had changed. These simple techniques revealed astoundingly high rates of erosion. The markers were abandoned in the late 1990s but were reinstated in the summer of 2000 by San Jose State University student Shannon Bane in cooperation with the Monterey Bay National Marine Sanctuary and ESNERR. The first year of data suggests that bank erosion rates remain high, averaging forty centimeters per year and approaching two meters per year at some locations. Erosion at these markers will continue to be monitored annually.

Tidal Creek Structure

Analysis of aerial photographs complements field measurements of tidal erosion. Oliver and colleagues used visual interpretation to estimate a 70 percent average increase in tidal creek width in the first four decades following harbor opening. Eric Van Dyke at ESNERR is expanding these studies, using dozens of photographs taken at five- to ten-year intervals between the 1930s and the present and employing computer-based image analysis techniques to delineate vegetated marsh boundaries. This work is confirming trends reported by Oliver and has also revealed that tidal creek systems have become more extensive and reticulated at their margins, bringing tidal flow deeper into the marshes (*Figures 2a and 2b*).

Loss of Vegetated Marsh

Although bank erosion and tidal creek widening have caused marsh vegetation to be lost from the edges of the Slough, a more serious trend appears to be thinning from the interior. Historic aerial photographs clearly reveal that many areas that were covered with dense pickleweed prior to 1947 now have only sparse, patchy vegetation. This pattern was first described by Oliver and his co-workers. More recent work by MLML student Patricia Lowe demonstrated that percent cover of marsh vegetation declined sharply in the decade following the harbor opening and then declined again in the 1980s with more stable periods in between. While the initial decline is likely the direct result of increased tidal flow, the subsequent decline may be due to marsh subsidence.

Crampton documented a decrease in marsh plain elevation averaging twelve-centimeters since 1947. In transplant experiments, Lowe found that a twelve centimeter decrease in elevation significantly affected the growth of pickleweed: nearly all of the lower plants died, while the higher ones grew vigorously. Tidal scour of surface sediments, groundwater overdraft, and earthquakes may all contribute to subsidence. In any case, erosion now clearly outweighs deposition in the Slough's marshes, so subsidence can no longer be countered by sediment trapping by pickleweed. As long as this trend of subsidence persists, vegetated marshes will continue to be lost.

Restoring and Managing Slough Wetlands

The research described above indicates that Elkhorn Slough's channels have deepened and widened, banks have eroded, and salt marsh has been lost—all as a result of tidal erosion. Our new monitoring programs, carried out at higher resolution in both time and space, should soon reveal whether rates of tidal erosion are decreasing over time, but so far there is no evidence to support that this is occurring or that an equilibrium will soon be approached. Prediction of the trajectory of habitat change also requires that hydrology and sediment transport processes in the Slough be modeled; such studies will soon be undertaken as part of the Sanctuary Integrated Monitoring Program (SIMoN).

It appears likely that erosion at Elkhorn Slough will continue at high rates for decades to come, with substantial loss of 5,000-year-old salt marsh and intertidal mudflat habitats. These habitats play a critical role at the base of estuarine food webs; provide shelter for birds, crabs, and other animals; and serve as a filter between the land and the sea. Furthermore, if tidal creeks continue to widen and become more similar to the main channel, their characteristic fish and invertebrate assemblages may disappear. Continued erosion of marshes, mudflats, and tidal creeks threaten these rare natural communities and may also contribute to salt water intrusion in the area and pose a danger to the rail line that bisects the Slough. Coastal decision makers in the region may need to consider intervention to mitigate for the effects of the creation and maintenance of the large artificial mouth to the Slough. In this unusual system, wetland restoration may best be accomplished by maintaining dikes, rather than removing them. Muting tidal flow to some of the Slough's wetlands may be the best way of preserving salt marshes and intertidal wetlands and the diverse invertebrates, fishes, and shorebirds they sustain.

– Kerstin Wasson[1], Eric Van Dyke[1], Rikk Kvitek[2], Jeremiah Brantner[2], and Shannon Bane[3]
[1] Elkhorn Slough National Estuarine Research Reserve
[2] Earth Systems Science and Policy, California State University Monterey Bay

Population Biology of the California Sea Otter

Vast sea otter populations once ranged across the Pacific Rim from northern Japan to Baja California. Some 15,000 to 20,000 animals occurred in California alone. But like so many species, sea otters were overexploited. A mere fifty or so individuals remained near the mouth of Bixby Creek in 1911 when federal law prohibited further hunting.

This surviving colony gradually increased in abundance and range, albeit at a perplexingly slow rate. Then, in the mid-1970s, perplexity turned to alarm as the California sea otter population took a downturn. The likely cause of the decline was determined to be incidental mortality in fishing nets. Once this problem was identified and redressed, the California sea otter population began to increase – a trend that continued until the mid-1990s, when numbers again began to decline. Annual population surveys indicate that sea otter numbers in California currently are either stable or declining.

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A five-year study is underway that will help to identify threats to California sea otter populations.

The sluggish population growth during the best of times and declining numbers in recent years still mystify marine biologists and natural resource managers. To make matters worse, little research has been done on California sea otters since the late 1980s. At the most fundamental level, the depressed population growth is thought to be a consequence of elevated mortality, not diminished reproduction or immigration.

Why are so many otters dying? At least three explanations have been proposed, including elevated levels of infectious disease, nutritional limitation, and incidental mortality in fishing gear. Information from necropsies of beach-cast carcasses is insufficient to explain the high levels of mortality because only about half of the deaths are recovered as beach casts, and the cause of death cannot be determined for many of these.

The obstacle to understanding mortality in California sea otters has been a lack of funds rather than a lack of ideas, but that situation has now changed. New federal funding for research on California sea otters was provided in 2001, owing to the hard work of numerous local people, a research grant from the Minerals Management Service, efforts by Representative Sam Farr to obtain Congressional support, and a renewed commitment to learning by the responsible state and federal agencies.

The planned study, which began earlier this year and involves scientists from the U.S. Geological Survey, California Department of Fish and Game, University of California (Santa Cruz and Davis campuses), and the Monterey Bay Aquarium, will take five years. Its centerpiece is the comprehensive study of marked animals at three main sites: the Monterey Bay area, near Cambria, and south of Point Conception. About fifteen animals will be captured at each of these sites during both of the first two years of the study. These animals will be equipped with flipper tags, surgically implanted radio transmitters, body temperature sensors, and—in some animals—surgically implanted time-depth recorders. The instruments will give scientists a window into how sea otters live and die, and health profiles will be taken from each animal at the time of capture. The study will contrast these various measures with equivalent measures taken in a similar study conducted in the mid-1980s—a time when the population was increasing. Our study design will provide intriguing contrasts between the center of the current range (where food presumably has been depleted) and ends of the range (where food is more abundant).

Besides mortality, which is the metric of direct concern, diverse data gathered from the tagged otters will permit a more in-depth assessment of population status. For instance, if food is limiting, we would expect to see changes in diet, foraging behavior, and body condition between the ends and center of the range and between the mid-1980s and present. The importance of infectious disease should become much clearer as health profiles from the living animals become available. Similarly, the significance of incidental mortality should become evident from the fate of tagged animals. The physiological studies will provide a more basic understanding of how these small marine mammals cope with the rigors of life in a cold ocean (e.g., how and when they are most susceptible to cold; whether or not deep diving poses a thermal challenge to them; the costs and benefits of feeding on different prey species; and the energetic costs of diving).

Modeling provides a final dimension to the project. Various models are being developed to understand better how the observed patterns of behavior, physiology, and demography play out as long-term trends in abundance and distribution.

Long-term survival of the California sea otter depends in part on identifying and redressing significant threats to the population. The results of this study will provide an important step toward that end.

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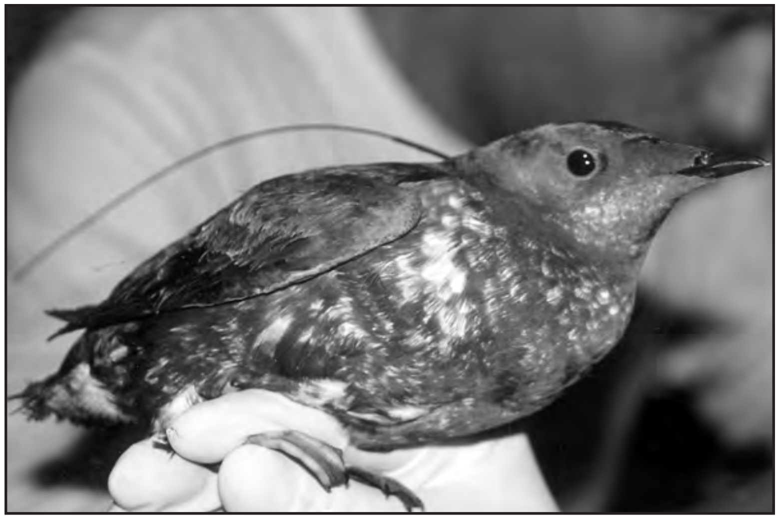
Marbled Murrelet Research in the Sanctuary

The Marbled Murrelet (*Brachyramphus marmoratus*) is a small seabird in the puffin family that breeds along the west coast of North America from the Aleutian Islands south to the Santa Cruz Mountains. Unlike other seabirds, Marbled Murrelets breed inland in old-growth redwood and Douglas fir forests. The Santa Cruz Mountains population is geographically separated from the next major population, in Humboldt County, by more than 300 kilometers. Population numbers are difficult to estimate for this enigmatic bird, but there are probably about 1,000 birds in the local population. Marbled Murrelet populations have been declining throughout the species' range, due primarily to loss of nesting habitat. This decline led to the listing of the species by the State of California as endangered, and by the U.S. Fish and Wildlife Service as threatened.

The Marbled Murrelet has been notoriously difficult to study. The first nest was not found until 1974, here in the Santa Cruz Mountains. Marbled Murrelets don't make much of a nest; they usually lay a single egg directly on a large horizontal limb of an old-growth tree. The tree limb must be large and flat enough to prevent the egg from rolling off, and the tree canopy must provide some cover from nest predators like Steller's Jays (*Cyanocitta stelleri*). This choice of nesting habitat, usually in the top third of very tall trees, makes studying the bird difficult.

Recent research in and around the Monterey Bay National Marine Sanctuary is helping to elucidate some of the mysteries of the Marbled Murrelet. Research on the local population falls into three categories: dawn forest surveys, at-sea surveys from boats, and radio-telemetry.

For more than a decade, local researchers have been conducting dawn surveys in forests of the Santa Cruz Mountains. During the nesting season, from May to August, adults take turns incubating for twenty-four hours at a time, switching duties at dawn. After the egg hatches, adults deliver a daily meal of fish for the nestling, usually at dawn. By monitoring activity levels in different forest habitats, researchers can determine which areas are most likely to harbor nesting Marbled Murrelets and track long-term changes in activity levels.



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Marbled Murrelet populations have been declining, due primarily to loss of nesting habitat.

At-sea surveys during the nesting season have been conducted locally for several years by Ben Becker and others at the University of California Berkeley (UCB). Because of the difficulty of effectively counting the birds at their nesting sites, at-sea surveys are the best tool to estimate population size. During the summer months, adult Marbled Murrelets are mottled brown (*see photo*), but the juvenile birds are black and white, resembling tiny Common Murres (*Uria aalge*). By carefully estimating the ratio of juvenile birds to adult birds on the water, researchers at UCB have been able to model the structure of the local population. At-sea surveys conducted during the non-breeding season by Moss Landing Marine Laboratories have helped determine the year-round distribution of the species. The local population generally moves south out of Año Nuevo Bay after they molt in September, and birds in their black and white winter plumage can usually be seen offshore from Santa Cruz in October. From November to April Marbled Murrelets occur primarily off Aptos in northern Monterey Bay, and then in April the birds return north to Año Nuevo and molt into their brown breeding plumage.

In 1997 a radio-telemetry study was initiated by Esther Burkett (California Department of Fish and Game) and was subsequently taken on by researchers at UCB. These studies have been instrumental in locating several nest sites in the forest and have increased our understanding of the species' nesting ecology tremendously. Interestingly, in the El Niño year of 1998 no radio-marked birds flew inland to nesting habitat, indicating that they may have been too physically stressed to breed.

One of the most interesting results of the radio-telemetry studies was the discovery that although the foraging range of breeding Marbled Murrelets was less than twenty-five kilometers, several birds dispersed from Año Nuevo to the south end of the Sanctuary, near Pt. Piedras Blancas—a journey of 200 kilometers. The birds were presumably traveling a considerable distance for some predictable food source.

Little is known of the at-sea distribution or seasonal occurrence of Marbled Murrelets in this area. The uncertain future of several offshore oil leases south of the Sanctuary off Morro Bay creates a pressing need for knowledge of Marbled Murrelet habitat use at the southern end of their at-sea range. Research on this unique species is continuing on several fronts in the Sanctuary, and through our increasing knowledge, we may be able to stem the rapid decline of the species.

– Laird Henkel
Moss Landing Marine Laboratories

Marine Mammals

Harbor Seals: The Diminutive Pinniped Living Large

Harbor seals are one of the most ubiquitous marine mammals, occurring in coastal areas around the world. Although often seen resting on shore (e.g., on mudflats, isolated sandy beaches, and offshore rocks), these creatures are not easily approached and spend most of their time underwater, so much of their life has remained a mystery. Below some of the results of harbor seal studies conducted by researchers from Moss Landing Marine Laboratories (MLML) are described.

In the eastern North Pacific, harbor seals occur from Baja through Alaska, with about 30,000 off California. At birth they are about eighty centimeters in length and ten kilograms in mass, and they are weaned within three to six weeks. The largest individual we have captured in Elkhorn Slough was a 145-kilogram male. Harbor seals have their pups and mate at different times, depending on latitude: they pup earliest in Baja and progressively later northward. Harbor seals in Puget Sound, however, pup one month later than individuals at the same latitude on the Washington coast. Meg Lamont (MLML 1995) determined that the individuals in Puget Sound were genetically different than those on the coast and probably more closely related to harbor seals to the north. This probably was caused by past glacial periods when harbor seals were forced southward, and a small group became reproductively isolated in southern Puget Sound.

After the pups are weaned they disperse widely, probably trying to find suitable habitat. Michelle Lander (MLML 1998) examined the survival and dispersal of wild and rehabilitated harbor seals pups. She found that,

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Generally, harbor seals forage at night and return to the shore during the day to rest.

University of California Santa Cruz student). This indicated that mature male harbor seals may establish underwater territories, use vocalizations as a way of advertising their presence, and presumably enhance their ability to mate with females.

Because harbor seals are coastal, they are susceptible to human influences (e.g., pollutants, disturbance, hunting). Rob Suryan (MLML 1995) found that, in Puget Sound, they were disturbed on 71 percent of days, often by powerboats that approached within 130 to 150 meters of seals resting on shore.

Disturbance often leads to short-term effects of animals vacating an area, but pollutants can have a long-term effect. Although Doreen Moser (MLML 1996) did not find that harbor seals in Elkhorn Slough had elevated levels of DDE, PCB, or heavy metals, she did find that seals with red pelage had hair shafts with irregular cuticles, possibly allowing deposition of iron. We suspect that the degradation of the hair may be from ingestion of selenium, which can alter the composition of hair. Dianne Kopec and I have found that some harbor seals in San Francisco Bay had levels of PCBs, mercury, cadmium, and selenium that exceeded levels of toxicity.

Although harbor seals are fairly small pinnipeds, they live an amazing life—becoming independent from their mothers within a month of birth, diving deep into Monterey Bay for food, roaring underwater to attract mates or establish territories, traveling thirty miles each night to feeding areas—all the while coping with increased levels of human disturbance and pollutants. Maybe they are not as small as we thought.

– Jim Harvey
Moss Landing Marine Laboratories

although there were some blood values that differed between wild and rehabilitated pups, once released, dispersal, diving behavior, and survival were relatively similar between the groups. Stori Oates (MLML current) also has found juveniles dispersing great distances. One of the factors that probably determines choice of location is presence of food resources.

In their early years, harbor seals eat small fishes and crustaceans, but as they mature they begin eating larger fishes and cephalopods (e.g., squids). Mike Torok (MLML 1994) determined that in San Francisco Bay, harbor seals were eating mostly staghorn sculpin, plainfin midshipman, and white croaker, but the most common prey was yellowfin goby—an introduced species from Asia. It is possible that harbor seals are helping contain the numbers of this introduced species. In Monterey Bay, Dion Oxman (MLML 1995) and Steve Trumble (MLML 1995) found that harbor seals ate primarily octopus, market squid, spotted cusk-eel, flatfishes, white croaker, and juvenile rockfishes, generally five to twenty centimeters in length.

In Elkhorn Slough we have radio-tagged individuals and monitored their movements and dive behaviors. Generally, harbor seals exit the Slough at dusk and forage in specific locations in the north bay until daylight, when they return to the Slough to rest. Harbor seals tagged off Monterey also foraged in the northern portion of the bay at night, indicating this part of the bay may have more food resources for harbor seals. Tomo Eguchi (MLML 1998) attached time-depth recorders to harbor seals and found that they could dive deeper than 500 meters and remain submerged in excess of twenty minutes, although generally dives averaged less than 100 meters deep and eight minutes long. Some harbor seals fed in Monterey Canyon.

The reproductive behaviors of harbor seals are poorly known because mating occurs underwater. Teri Nicholson (MLML 2001) identified more than 300 individual harbor seals off Monterey and used this to examine social structure. Older, larger males made long-duration, low-frequency calls (like a roar) underwater that attracted younger males. During frequent interactions underwater these males apparently established a hierarchy, and possibly the calls helped with recognizing higher ranking males in the society. Playback of calls from young males will elicit a response from older males apparently holding underwater territories (Sean Hayes,

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Harbor seals are susceptible to human influences.

Fishery Resources

About 200 species are typically caught in commercial and recreational fisheries in the Monterey Bay National Marine Sanctuary. From 1981 to 2000 reported commercial catches increased for about 10 percent of the approximately 90 species most frequently harvested in this region. Catches declined for about 30 percent of the frequently harvested species. Catch rates and thus population status of other species were either stable, highly variable, or unknown.

Invertebrate species most frequently harvested commercially include spot prawn, pink shrimp, Dungeness crab, rock crab, and market squid. These species have short life spans, their populations are greatly affected by environmental change, and higher harvests usually reflect higher population levels. Harvests of spot prawn and Dungeness crab increased from 1981 to 2001. Catches of rock crab increased from 1981 to 1993 but then decreased. Pink shrimp populations declined throughout much of the late 1980s, increased from 1994 to 1995, then decreased again in the late 1990s. The market squid population was low during the El Niño years of 1983–84, reached record levels in 1994 to 1996, then declined dramatically with the onset of the 1997-98 El Niño. In 2001 the market squid population in Monterey Bay showed strong signs of recovery.

Chinook salmon is the most common anadromous species caught in the Sanctuary. Reported catches of chinook salmon have been high in the last few years. Scientific stock assessments indicate that the fall run chinook salmon of the Sacramento River is in good shape, but that populations of coho salmon and winter and spring run chinook salmon are depressed. Steelhead populations are also extremely depressed in this area, due primarily to degraded stream habitats. There are escalating efforts to improve salmon and steelhead habitats in central California. The increased number of spawning winter-run salmon in the past few years indicates that improving river flows and habitats may play a large role in successfully rebuilding salmon and steelhead populations.

Abundances of most pelagic species are greatly determined by large-scale environmental phenomena. Northern anchovy and Pacific sardine are the predominant nearshore pelagic fishes caught in the Sanctuary. Anchovy spawning biomass in central California declined after 1985 but experienced a substantial increase in the late 1990s. Pacific sardine populations are also increasing rapidly throughout their range after nearly disappearing from the region in the 1950s. The population of Pacific albacore, another common pelagic species, is currently thought to be stable or increasing.

Migratory sablefish and Pacific hake are heavily fished in California waters. Sablefish catches in the Sanctuary have been decreasing since 1980, due to increased regulations and low recruitment. Seasonally abundant Pacific hake catches were high off central California throughout most of the 1980s.

Rockfishes are the most diverse group of fishes living in Sanctuary waters. Rockfish species comprise 98 percent of the total commercial catch from deep-water rocky habitats in the Sanctuary. In the recreational fishery, eight of the ten most abundant species in the recreational commercial passenger fishing vessel (CPFV) fishery are deep-water rockfishes.

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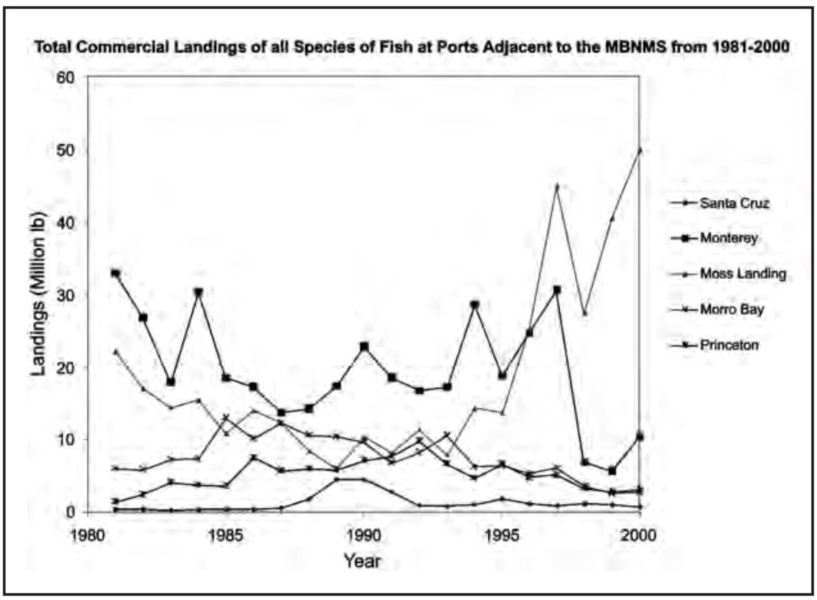
Rockfishes are the most diverse group of fishes living in the Sanctuary.

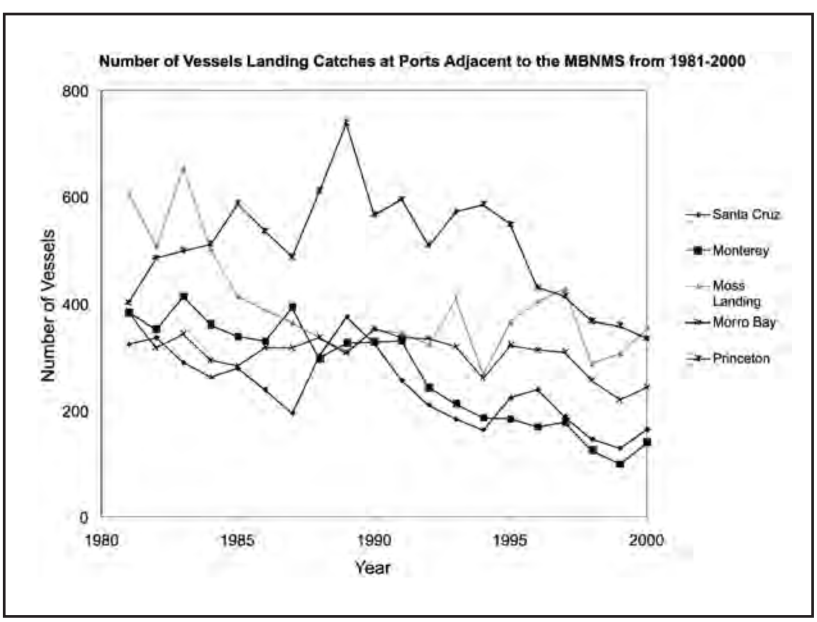
Average total landings (pounds), average dockside ex-vessel value (dollars), and principal species commercially landed at ports adjacent to the Monterey Bay National Marine Sanctuary. (Economic value equals dockside price times pounds sold, not adjusted for inflation.) Data provided by Pacific States Marine Fisheries Commission.

Fishing Port	Average Total Landings (lb) 1981-2000	Average Ex-vessel Value ($) 1981-2000	Principal Species Landed
Princeton–Half Moon Bay	5.1 million	4.1 million	Rockfishes Chinook Salmon Market Squid Dungeness Crab Dover Sole
Santa Cruz	1.1 million	1.3 million	Chinook Salmon Market Squid Rockfishes Northern Anchovy Dungeness Crab
Moss Landing	18.7 million	4.7 million	Pacific Sardine Market Squid Rockfishes Albacore Dover Sole
Monterey	19.5 million	3.6 million	Market Squid Pacific Sardine Northern Anchovy Rockfishes Chub Mackerel
Morro Bay	7.5 million	4.6 million	Dover Sole Rockfishes Thornyheads Albacore Sablefish

Monterey Harbor is home to many fishing vessels.



Note the large increase in landings at Moss Landing that is due to increased abundances of sardines.



The gradual decline in the number of vessels fishing matches the trend in reduced catches of many species due to declining stocks of fish and increased regulations.

Catches of deep-water rockfishes have declined dramatically in the last twenty years, due to stock depletions and stricter fishery regulations. In 1996 the U.S. Congress enacted the Sustainable Fisheries Act, which reauthorized and amended the Fishery Conservation and Management Act of 1976. The new legislation strengthened the requirement of federal fishery managers to prevent overfishing, rebuild depleted stocks, reduce bycatch, and protect fish habitat. The result of this new legislation has been a dramatic decrease in catch quotas for many species and an increase in the number of scientific stock assessments for commercially harvested fish species.

Stock assessments for chilipepper and shortbelly rockfishes indicate stable or increasing trends in abundance, while stock assessments published for bank, bocaccio, yellowtail, canary, and widow rockfishes show decreasing trends in abundance on the U.S. West Coast. Most of these deep-water rockfishes are slow growing, long-lived, and have experienced excessively high exploitation rates. Managers are concerned about the capability of some of these species to recover from high harvest rates, especially because some are prone to long periods of failed recruitment. There is some evidence from the commercial and recreational fisheries, however, that oceanographic conditions in the past few years resulted in improved recruitment of some species, such as bocaccio. More information is needed for all species in order to estimate stock size adequately for management purposes. This is especially important because stock assessments are usually conducted over large geographic scales.

One particularly notable example of high bycatch within the Sanctuary is the commercial set gillnet fishery. Set gillnets have been an effective way to catch California halibut, but they have also contributed to mortality of sea birds, harbor porpoise, and sea otters. From 1991 to 2000 an estimated 16,000 common murres and 450 harbor porpoise accidentally died in the set gillnet fishery. Evidence of continued high bycatch of birds prompted the California Department of Fish and Game in late 2000 to enact a series of emergency closures to move the set gillnet fishery to waters deeper than sixty fathoms in central California. There is a new regulation being proposed for permanent adoption that will restrict gill or trammel nets to ocean waters that are sixty fathoms or greater in depth at mean lower low water from Point Reyes to Point Arguello, essentially closing down the California halibut set gillnet fishery in this area.

Surfperches represent a diverse group of nearshore fishes in Sanctuary waters. Historical catch data show that surfperch populations have declined, due to a number of factors including environmental variation, lower production caused by smaller fish, habitat degradation, and increased fishing pressure. In contrast, landing data and stock assessments suggest that populations of many species of flatfishes are robust and could withstand increased levels of harvest.

The most rapidly developing fishery to emerge in recent years is the nearshore live fish fishery. In this fishery, small boats, skiffs, kayaks, and even surfboards are used to set baited hooks or traps in water less than 100 feet deep. Captured fish are held in aerated containers and transported live directly to seafood markets and restaurants locally and globally. The high demand for live fish has created a market with prices well above that of traditional commercial fisheries, thus increasing the value of catches and attracting more people to enter the fishery. The fishery began in southern California. In the early 1990s it expanded to central California, and in 1995 this region recorded the highest catches in California. The fishery has also moved from a limited target fishery to one that currently includes almost 100 species. Sheephead, cabezon, lingcod, greenlings, and nearshore rockfishes remain the most targeted species in the fishery.

Unfortunately, the life histories of many of the species caught in the live fish fishery are poorly understood. For the few species with dependable life history information available, their sedentary nature, slow growth, and late age of maturity increase their vulnerability to high fishing pressure. Preliminary studies have shown an overall decline in the average size, weight, and catch rate of cabezon and some rockfishes in the sport fishery since the late 1980s, suggesting stressed populations.

Depleted fish populations result in strict fishery regulations. For example, lingcod and some rockfish species have been overfished to the point that quotas are too small to allow a year-round fishery. In the past few years commercial and recreational fisheries for these species have been closed for several months at a time.

Declines in species abundance, closed fisheries, and resulting reduced income to coastal communities led to changes in fishery management in California. In 1999 the Marine Life Management Act (MLMA) was signed into California law, redefining the state's marine living resource policy. The MLMA represents a notable change in state resource management responsibilities by delegating the authority for managing commercial fisheries from the State Legislature to the California Fish and Game Commission and the California Department of Fish and Game. The primary goal of the Act is to establish sustainable fisheries through the restoration and conservation of fisheries and ecosystems—including non-target species and habitats—while also maintaining healthy, growing commercial and recreational fisheries.

– Richard Starr[1], Jason Cope[2], and Lisa Kerr[2]
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[2]Moss Landing Marine Laboratories

Exotic Species

Ballast Water Deoxygenation: A New Technique for Preventing Species Introductions that Should Make Everyone Happy

Invasions by non-native aquatic species are increasingly common worldwide in coastal habitats. Estuaries, in particular, harbor large numbers of introduced species. For example, there are about 250 known invasive species in San Francisco Bay and Delta. Although the effects of many introduced aquatic species on habitats they colonize remain largely unknown, some clearly have had serious negative influences. Impacts often include decreases in abundance and even local extinction of native species, alteration of habitat structure, and massive economic costs due to biofouling.

Probably the most important mechanism for the introduction of aquatic species is transport in ship ballast tanks. Vessels commonly pump water into ballast tanks or into empty cargo holds in one port (to increase the draft, regulate the stability, or maintain the stress loads) and discharge it at another. Examinations of ballast water when ships arrive into port after long ocean crossings have revealed living and viable bacteria, protists, dinoflagellates, diatoms, zooplankton (including numerous larval forms), and in some cases small benthic invertebrates and fishes.

A lot of effort has therefore been put into developing ways to kill or remove organisms from ballast waters. Dozens of strategies have been suggested, including approaches like intensive filtration, thermal treatment, and biocides. Although several of these approaches appear promising, they all have one major limitation: to date, all proposed ballast water treatments will result in significant costs to the vessel owners.

Until a ballast water treatment is mandated by international law, it is extremely unlikely that the shipping industry will voluntarily employ anything that will cost them money. Therefore, the key to reducing the potential of aquatic introductions is to find a technique that is effective at killing or removing organisms and that will be accepted by the ship owners. We believe we have found such a technique.

Ballast tank corrosion is a huge problem for the shipping industry. Rusting reduces ship life and currently can only be managed by costly and time-consuming painting and maintenance. Recently, however, scientists from Sumitomo Heavy Industries of Japan have found that purging or removing the oxygen from ballast tanks with nitrogen gas is a cost-effective technique for reducing corrosion.

Recognizing the potential for this technique to kill organisms in ballast waters also, we studied the effectiveness of deoxygenation in preventing species introductions. In particular, the oxygen tolerance of larvae from diverse invasive invertebrate species was tested (two of which nuisance

Water carried in ship ballast tanks is an important mechanism for the introduction of exotic species.

species occur in the Sanctuary) and focused literature reviews were conducted. Larvae of the Australian reef-building tubeworm (*Ficopomatus enigmaticus*), the European green shore crab (*Carcinus maenas*), and the European zebra mussel (*Dreissena polymorpha*) were found to survive only a couple of days under the low oxygen conditions produced in ballast tanks treated with nitrogen to prevent corrosion.

The results from our laboratory study were similar to what we found in the literature for the oxygen tolerance of various other aquatic species: most organisms will only survive hours to days under low oxygen conditions, while cargo ships are typically at sea for weeks. However, it is also important to point out that there are some organisms—like facultative anaerobic bacteria—that may survive the deoxygenation of ballast water.

In a 1996 report the National Research Council proposed that successful ballast water treatments should be 1) effective at killing potential invaders, 2) safe for shipboard crew, 3) environmentally benign, and 4) affordable for ship owners. First, our results show that deoxygenation is highly effective at killing animal invaders but may be less effective for other taxa, particularly those adapted to low oxygen environments or with resistant stages such as cysts. Second, with proper equipment and training, nitrogen (which makes up 78 percent of the air we breathe) poses no major threats to crew safety. Third, hypoxic ballast water would appear to be relatively benign when discharged. Hypoxic water will mix rapidly with shallow oxygenated water in harbors and therefore create little danger for native estuarine organisms. However, if temporary exposure to reduced oxygen levels does prove harmful to some native organisms, it would be simple to re-oxygenate water before release. Finally, ballast water admirably meets the fourth criterion: rather than an added expense for ship owners, it actually represents a net savings due to the significant decrease in corrosion. To our knowledge, this is the only example of a ballast water treatment technique with economic incentives for the shipping industry.

The National Research Council evaluated ten candidate technologies for shipboard treatment of ballast water and concluded that intensive filtration, use of biocides, and thermal treatments held the most promise. Deoxygenation did not receive high priority because of its failure to kill organisms with stages resistant to hypoxia. Although other ballast water treatment options may be more comprehensively effective, they come at greater environmental and financial cost. For instance, biocides may be hazardous for the crew as well as for native organisms in the vicinity of the ballast discharge. Moreover, these techniques come at a significant price for ship owners.

In contrast, we propose that widespread voluntary adoption of nitrogen treatment may result if the economic benefits for controlling corrosion become well known. Ballast water deoxygenation certainly deserves further exploration as a potential high priority treatment option, at least until international legislation mandates total mortality of ballast water organisms. While ballast water treatment has been controversial, raising conflicts between environmentalists and industry, nitrogen treatment represents a working solution that should appeal to both parties.

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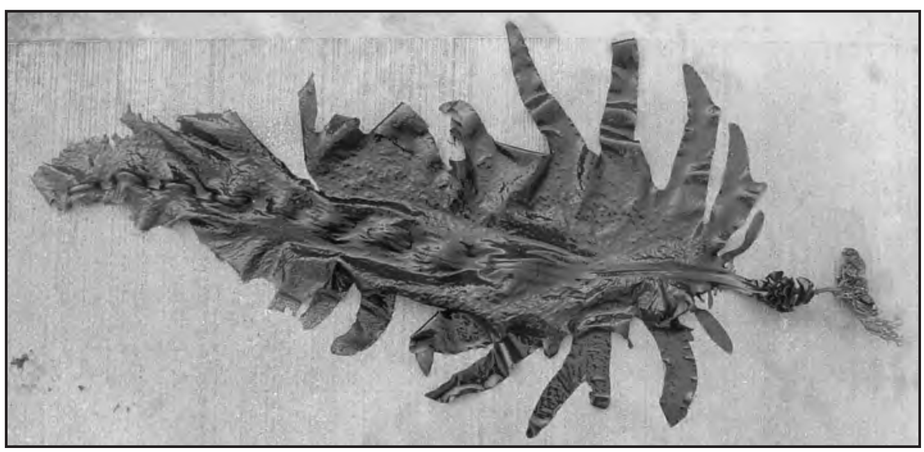
A New Invasive Species: *Undaria pinnatifida*

In May 2001 Monterey Bay National Marine Sanctuary staff alerted divers and other coastal users to be on the lookout for the golden brown kelp *Undaria pinnatifida*. This notorious seaweed is native to the west coast of Japan but has been introduced into Australian, New Zealand, and European waters. Unfortunately, *Undaria* has now also shown up on the California coastline. Although it isn't known how this invasive kelp got to the west coast of the United States, the species does appear to be spreading from southern California northward. Only two months after the Sanctuary issued the alert, John Hunt, a graduate student from Hopkins Marine Station, found several mature individuals of this new invader in Monterey Harbor.



© John Hunt

Undaria pinnatifida, *a seaweed native to Japan, has the potential of becoming a major pest in the Sanctuary.*

Commonly known as Wakame in Japan, *Undaria* is extensively cultivated as a fresh and dried food plant. However, in our coastal waters it has the potential of becoming a major pest: a single plant can release up to 100 million spores a day that can colonize both hard bottom surfaces as well as floating objects such as sea grass blades, ropes, ship and boat hulls, and pier pylons. An annual kelp, it can grow quickly—up to one centimeter a day—and at only fifty days old is mature enough to reproduce. Like other weeds, it thrives in disturbed habitats, often outcompeting and overgrowing native species. Long-term effects on the marine environment are not completely known, but elsewhere in areas of mass infestation by this kelp, marine ecosystems have completely changed.

A mature *Undaria* grows up to two meters in length and has a distinctive, spiraled (frilly), spore-producing structure at its base. It also has an obvious central stem or midrib to ten centimeters wide that extends for the length of the plant. The blade may be up to one meter wide and extends from the tip of the plant for half to three-quarters the length of the plant. *Undaria* is commonly found in sheltered harbor waters on rocks, breakwaters, and marine debris from the low-tide mark to fifteen meters.

Please report possible sightings of *Undaria* to the Monterey Bay National Marine Sanctuary at (831) 647-4206.

– Liz Love[1] and Mario Tamburri[1, 2]
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[2]Monterey Bay Aquarium Research Institute

Aquaculture in the Sanctuary

Aquaculture has a long and rich history along the central California coast within what are now the boundaries of the Monterey Bay National Marine Sanctuary. Beginning in the mid-nineteenth century, Chinese immigrants working around the Monterey Peninsula and southwards to Cambria burned intertidal areas to expose rocks on which they could cultivate a variety of red algal species. The algae were then harvested, dried, and used as food. This practice carried on into the mid-twentieth century.

The latter part of the twentieth century saw a number of different species cultivated with varying degrees of success. Species as diverse as abalone, algae, lobsters, oysters, sea hares, steelhead trout, salmon, and shrimp have been grown in and around the Sanctuary. Oysters were cultivated in Elkhorn Slough and at Pigeon Point during the 1960s and 1970s, but poor water quality eventually curtailed both operations. SilverKing Oceanic Farms in Davenport attempted salmon ranching from the late 1960s up until the mid-1980s. The idea of releasing salmon and waiting two to three years for their return seemed to work, as many fish did return. However, as the salmon were returning most were either caught by fishermen or devoured by hungry sea lions prior to reaching their final destination. The 1960s and 1970s also saw attempts to culture lobster on Cannery Row and abalone at Pigeon Point and on Cannery Row.

Currently at least six aquaculture companies operate within the Sanctuary, culturing such diverse species as abalone, algae, steelhead, salmon, and shrimp. A brief review of these operations follows.

There are three abalone farms operating within the Sanctuary. Abalone are a unique animal for cultivating, because every part of the animal can be sold at market. In addition to the meat, the shells can be sold for jewelry, ornaments, and souvenirs. The viscera can be processed for fish food for the aquarium trade or sold as bait. Finally, pearls can be cultured from the abalone. This product holds the most exciting potential, as a single gem-quality pearl may bring fifty times the price that the same animal would garner if sold without a pearl.

US Abalone, located in Davenport, cultures abalone in land-based tanks referred to as raceways. It has been in operation for more than twelve years and is one of the largest producers of cultured abalone pearls in the

© David Ebert

Market abalone being fed kelp.

The following chart highlights some of the ways in which the Monterey Bay National Marine Sanctuary plays an important role in our lives. It is, of course, not comprehensive. (Footnotes describe the limitations to, and sources for, these statistics.)

Examples of human interaction with the Sanctuary are found throughout the *Ecosystem Observations* report. For example, pages 5-6 list important dates in the Sanctuary's history—many of which highlight efforts to effectuate ecosystem protections. Other relevant articles include those about technological advances that improve our research capabilities (p. 7), tidal erosion at Elkhorn Slough (pp. 12-14), California sea otters (p. 15), Marbled Murrelets (pp. 15-16), ballast water (pp. 20-21), fishery resources (pp. 18-20), and aquaculture (pp. 22-25).

ACTIVITY	DETAILS
Visitors to State Parks and Beaches Contiguous to the Sanctuary (Estimates)[1]	San Mateo County coast – 1.89 million paid and free day users Santa Cruz County coast – 4.17 million paid and free day users Monterey County coast – 2.29 million paid and free day users San Luis Obispo County coast, north of the Sanctuary boundary – 437,378 paid and free day users
Whale Watchers and Pleasure Boaters[2]	Whale watch and sea life cruises – 20,300 people Sail and yacht charters – 12,980 people *Please note: these numbers represent a few, but not all, whale watch and pleasure boat charters in Monterey, Santa Cruz, and San Mateo Counties*
Kayakers[3]	Estimated number of kayak trips via rentals or tours – 29,500 *Please note: these numbers represent a few, but not all, kayak shops in Monterey, Moss Landing, Santa Cruz, Cambria, and San Simeon*
Surfers[4]	Estimated number of regular surfers on the Monterey Peninsula – 300 annually Estimated number of regular surfers from Pleasure Point, Santa Cruz to Capitola – 300 daily Lessons or rentals provided in Santa Cruz—3,000 Lessons or rentals provided in Monterey—1,600
Divers[5]	Estimated number of diver days using equipment rentals, air fills, tours – 25,000 *Please note: these numbers represent a few, but not all, dive shops in Monterey, Santa Cruz, San Simeon, and Cambria*
8th Annual Great American Fish Count[6]	Total divers – 20 Total locations – 19 Total bottom time – 42 hours and 29 minutes

(Continued)

world. Two other farms currently produce abalone in the Sanctuary: Monterey Abalone Company and Pacific Abalone Farms are located in Monterey and grow abalone in habitats suspended in the ocean. Their principal product is live red abalone, most of which is sold locally.

Reed Mariculture, founded in 1995, is the leading marine microalgae producer in the world. The company's original concept was to produce bivalve shellfish, from seed to adult, fed only on algae raised at the site. In 1998 its product focus shifted from shellfish to the production of commercial microalgae feed for aquaculture. Marine microalgae is used in fin-fish, shrimp, and shellfish hatcheries as either a direct or indirect larviculture feed. The "Instant Algae" brand of algae concentrates is used to replace or supplement live algae grown in hatcheries, resulting in lower costs, increased production, and reduced risk. Reed produces a wide variety of algae species, including *Nannochloropsis*, *Tetraselmis*, *Isochrysis*, *Chaetoceros*, *Thalassiosira weissflogii*, *Thalassiosira pseudonana*, and *Pavlova*. Reed's primary customer base is in the Mediterranean, Europe, and Asia, with smaller markets in North and South America.

©David Ebert

Checking abalone in the nursery.

Monterey Bay Salmon and Trout Project is an organization whose efforts are focused on three programs. The main focus is to enhance salmon populations and to reduce pressure on wild fish populations by allowing fishermen to target hatchery fish. Fall run chinook or king salmon smolts are obtained from state hatcheries and acclimated in net pens in Monterey and Santa Cruz harbors. Up to 300,000 fish may be released per year. There are no wild runs of fall chinook in this area because the streams are dry at the time of year they are genetically programmed to return. The fish do not survive beyond the fall and therefore do not interfere with any other

ACTIVITY	DETAILS
8th Annual Great American Fish Count[6]	Total surveys completed – 58 Total species counted – 67 Most frequently sighted species: painted greenling (seen on 90% of dives), blackeye goby, and kelp rockfish
Fishing Licenses by County[7]	Commercial fishing licenses: / Charter boat licenses (recreational fishers):* **Marin** 152 / 17 **San Mateo** 198 / 9 **Santa Clara** 148 / 0 **Santa Cruz** 148 / 5 **Monterey** 473 / 6 **San Luis Obispo** 336 / 3
2001 Coastal Cleanup[8]	Coastal Cleanup beach debris collected, by county: **Marin** – 7,104 lbs. trash; 2,731 lbs. recyclables; 1,076 volunteers **San Mateo** – 91,417 lbs. trash; 26,940 lbs. recyclables; 1,462 volunteers **Santa Cruz** – 6,000 lbs. trash; unknown lbs. recyclables; 1,500 volunteers *(note: these are estimated numbers only, exact figures not available)* **Monterey** – 3,527 lbs. trash; 1,543 lbs. recyclables; 1,191 volunteers **San Luis Obispo** – 5,567 lbs. trash; 3,331 lbs. recyclables; 1,058 volunteers *Of special note, approximately 100 recreational divers collected more than 605 lbs. of trash and 40 lbs. of recyclables at Monterey Harbor.*
Volunteer Docents	Estimated contacts with the public: Save Our Shores Sanctuary Stewards (Santa Cruz and San Mateo) – 75,000 BAY NET (Santa Cruz and Monterey Peninsula) – 35,000 Friends of the Elephant Seal (San Luis Obispo County) – 100,000
Sanitary Exceedances and Unauthorized Discharges[9] **(Jan. 1, 2001 – Oct. 9, 2001)**	Reported sanitary exceedances and unauthorized discharges, by county: **Marin** Effluent exceedances in watershed – 0 Effluent exceedances w/direct discharges to Sanctuary – 0 Unauthorized discharges in watershed – 0 Unauthorized direct discharges to Sanctuary – 0 **San Mateo** Effluent exceedances in watershed – 0 Effluent exceedances w/direct discharges to Sanctuary – 0 Unauthorized discharges in watershed – 0 Unauthorized direct discharges to Sanctuary – 0 **Santa Cruz** Effluent exceedances in watershed – 8 Effluent exceedances w/direct discharges to Sanctuary – 1 Unauthorized discharges in watershed – 3 Unauthorized direct discharges to Sanctuary – 12

ACTIVITY	DETAILS
	Monterey Effluent exceedances in watershed – 25 Effluent exceedances w/direct discharges to Sanctuary – 1 Unauthorized discharges in watershed – 4 Unauthorized direct discharges to Sanctuary – 18 **San Luis Obispo** Effluent exceedances in watershed – 0 Effluent exceedances w/direct discharges to Sanctuary – 0 Unauthorized discharges in watershed – 0 Unauthorized direct discharges to Sanctuary - 0
Beach Postings and Closures[10] *monitoring as required by State Law AB411 (not all beaches are monitored)*	By county: **Marin** – no beach closures or postings from Rocky Point to Point Bonita. *(Note: Marin does not have a monitoring program, except for oil spills.)* **San Mateo** – information not available from the county. **Santa Cruz** – (Jan. 1, 2001- Sept. 30, 2001) – 4 beaches posted due to sewage spills for 8 days; 5 beaches posted for unknown reasons for 47 days; 4 beaches permanently posted due to high levels of fecal contamination; 1 beach posted seasonally. **Monterey** – (Jan. 1, 2001 – Oct. 25, 2001) – 1 beach closed for sewage spill; 6 beaches had advisories for high bacteria for a total of 16 days. **San Luis Obispo** – (Apr. 2001 – Oct. 2001) – no beach closures, 1 advisory at a Cambria beach for 4 days.

Vessel Incidents with with Sanctuary Response[11]

Date	Vessel	Grounding	Sinking	Discharge	Seabed Disturbance
1-29	Fishing			✓	
2-02	Fishing		✓	✓	✓
2-04	Motor	✓	✓		✓
4-18	Motor			✓	✓
5-11	Fishing		✓	✓	
7-05	Motor		✓	✓	
7-05	Motor		✓	✓	
7-14	Motor		✓	✓	✓
8-21	Sail	✓			✓
9-09	Fishing	✓		✓	✓
9-13	Motor		✓	✓	✓
10-03	Fishing	✓		✓	✓
12-19	Fishing		✓	✓	✓

runs of anadromous fish. In good years, 6 to 10 percent of the fish will return to the area as adults.

Another program involves the capture, spawning, and release of steelhead and coho salmon (both endangered species) from their Davenport hatchery. Each winter steelhead are caught at a station on the San Lorenzo River, with fifteen to thirty adult fish taken to

Courtesy of Pacific Northwest National Laboratory.

Steelhead swimming upstream.

the hatchery, spawned, and then returned to the river. Coho, or silver salmon, are very scarce, and the only viable run of these fish into the Sanctuary waters is from Scott Creek. Unfortunately, project members report no mating pairs of coho for the last two winters. They fear that unless coho are able to return and spawn this winter, the run may be lost.

The third program involves setting up chilled aquaria in about 140 classrooms in central coast communities. Project members put steelhead eggs in the aquaria, and students are able to observe the hatching and development of the fry and then release them into local creeks. The hope is to foster a sense of stewardship and an awareness of the environment in the students.

As we have seen, the products of aquaculture may be used to enhance wild populations, as food, or for other products such as jewelry. Despite the long and varied history of the aquaculture industry in the Sanctuary, its current production is relatively small when compared to the size of the area and the population living along the Sanctuary's shores. The U.S. seafood trade deficit was a record $7.1 billion in 2000, up 19 percent over 1999. With wild fisheries under pressure, further growth in seafood consumption will depend on the success of aquaculture, both locally and globally.

– David A. Ebert[1] and Arthur Seavey[2]
[1]US Abalone
[2]Monterey Abalone Company


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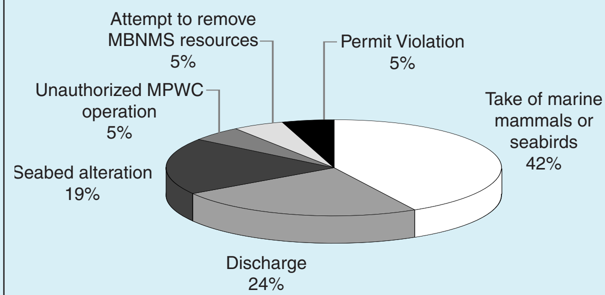
ACTIVITY	DETAILS
Enforcement Actions under the Marine Sanctuaries Act[12]	**Profile of Documented Enforcement Cases (June 2000 – May 2001)**  ** The above data represent only 21 reported National Marine Sanctuaries Act, Marine Mammal Protection Act, and Endangered Species Act violations (within the Sanctuary) that were assigned case numbers by the NOAA Enforcement Management Information System. The data do not reflect total reported incidents or number of convictions. They suggest a relative comparison of the type of violations occurring within the Sanctuary. (MPWC= motorized personal watercraft)*

Sources:

1 - California State Parks Districts: Bay Area, Santa Cruz, Monterey, San Simeon; Cambria Chamber of Commerce
2 - Bay Watch Cruises Monterey, Queen of Hearts, Houdini Sport Fishing, Randy's Fishing Trips, O'Neill Sea Odyssey, O'Neill Yacht Center, Pacific Yachting and Sailing
3 - Adventures by the Sea, Adventure Sports Unlimited, Coastal Kayaking, Kayak Connection, Kayak Horizons
4 - On the Beach Surf Shop, Paradise Surf Shop, Santa Cruz Surf Shop
5 - Adventure Sports Unlimited, Aquarius Dive Shops, Aqua Safaris Scuba Center, Manta Ray
6 - Reef Environmental Education Foundation
7 - California Department of Fish and Game
8 - California Coastal Commission
9 - Regional Water Quality Control Boards
10 - County Environmental Health Departments
11 - Monterey Bay National Marine Sanctuary
12 - NOAA Enforcement

Site Profile

Pigeon Point

Since the time Spanish mariners began charting America's western seaboard in the early 1600s, the hidden shoals of "Punta de las Ballenas," or Whale Point, provided refuge for explorers, traders, and whalers alike. Located fifty miles south of San Francisco, Whale Point is now called Pigeon Point and offers safe harbor to the gray whales that were once actively hunted in the area. It is also the site of one of the tallest lighthouses on California's coast.

In the early 1800s trading companies made commercial inroads in California, and Atlantic whalers discovered a rich harvest along the Pacific shore. After gold was discovered in the Sierra foothills in 1848, the ocean off Whale Point became a veritable marine highway. Predictably, the rockbound coast, with its heavy surf, strong currents, and thick fog banks, snagged its share of unsuspecting ships. One of those ships was a clipper called the *Carrier Pigeon*, making its maiden voyage from Boston in 1853. Lost in a blanket of fog, the vessel ran aground at Whale Point, breaking apart and sinking on a ledge of rocks just 500 feet from


Courtesy of Bud and Gert Woodhams

The site of the Pigeon Point lighthouse was declared a State Historic Landmark and the surrounding cottages became a hostel in 1980. (Photo is from 1952.)

shore. Nearby settlers found the incident unforgettable and the site was soon known as Pigeon Point.

Public outcry grew over the need for a lighthouse in the area. Unfortunately, it took the wreck of three more ships—the *Sir John Franklin* in 1865, the *Coya* in 1866, and the *Hellespont* in 1868—along with the loss of many lives, to exert pressure on the Lighthouse Board for money to build the structure. In 1872 the 115-foot tower, constructed of 500,000 locally-made bricks and built to contain a giant first-order Fresnel lens, was completed. A two-story Victorian-style home was added as keepers' quarters.


© Kelly Newton for MBNMS

The Pigeon Point lighthouse was completed in 1872. It is one of the tallest along California's coast.

In the late 1800s Pigeon Point was not only the site of a lighthouse but also the location of a small shipping center, trading village, and whaling station. Originally established by Portuguese shore whalers from the Azores, the cove south of the lighthouse sheltered twelve cottages and two warehouses. On the beach below were trypots with men busy extracting oil from heaps of blubber. Whalers considered the gray whale the most dangerous to hunt because it is more aggressive in protecting its young.

At the same time, it was also easier prey since it is frequently found in shallow waters close to shore. Under the lee side of Pigeon Point was an anchorage where ships could be warped into a space not much bigger than a dry dock. The region exported whale oil, tallow, potatoes, butter, cheese, grain, lumber, and hides—mostly to San Francisco.

The lighthouse nearly put an end to major shipwrecks, but not entirely. In 1896 the *Columbia*, a steamer making its first run from Panama to San Francisco, ran aground just south of the tower. In 1913 the steam schooner *Point Arena* was dashed upon the rocks in rough seas and broke in half as it attempted to moor at the landing. The last and worst maritime disaster of the area occurred in 1929. The passenger steamer *San Juan* was sailing through fog-obscured waters off the coast of Pigeon Point when it collided with the oil tanker *S.C.T. Dodd*. The *San Juan* sank within five minutes, taking seventy-five passengers and crew to a watery grave.

In recent years the lighthouse has faced many changes yet stands nearly the same as when it was built. The keepers' quarters survived a fire in 1933 but faced demolition in 1960 to make way for four bungalow structures. In 1972 the light station was automated with an aero-beacon but still retains its original first-order Fresnel lens. In 1980 the site was declared a State Historic Landmark and the cottages became a hostel, open to the public for overnight stays. Tours began in 1984.

Today Pigeon Point is one of the best landfalls from which to see gray whales on their annual migration between Baja, Mexico and Alaska. They travel thousands of miles each way on one of the longest migratory journeys on earth. It is not uncommon to see these magnificent mammals nurturing their young very close to shore in the cove once called Whale Point. It is a visit they have been making for centuries.

– JoAnn Semones

Gray Whales—A Success Story

Population

Intensive commercial whaling in the nineteenth century reduced the eastern north Pacific gray whale population almost to the brink of extinction.

Protected by international treaty in 1946 and by the Marine Mammal Protection Act of 1972, this population swiftly rebounded and was finally removed from the federal endangered species list on June 16, 1994.

Based on the counts of southbound gray whales during the 1997-1998 winter migration (by scientists from the National Marine Mammal Laboratory), the population numbers about 26,600 whales.

Migration

Gray whales travel farther than any other species of migratory mammal—nearly the full length of the Pacific coast of North America (up to 12,000 miles round trip)—from their icy feeding grounds in cold Arctic seas to the warm waters of the Mexican breeding lagoons.

The animals move south along the Pacific Coast, often just a few miles from shore, during the fall and winter (October to early February), returning north during the late winter and spring (mid-February to early June).

Appearance

A 45-foot, 35-ton adult gray is roughly the same size and weight as ten large elephants. The lack of a dorsal fin distinguishes it from other whale species.

Grays carry the heaviest parasite load of all cetaceans, including a barnacle species that attaches exclusively to grays and three different species of whale lice (amphipods).

These giants can be recognized by a characteristic heart-shaped spout, or "blow," up to fifteen feet high.

Threats

Gray whales have few natural enemies. Killer whales pose the greatest threat, often seeking out and attacking young calves or yearlings.

Other potential threats include pollution, vessel or boat traffic, industrial noise, offshore oil and gas exploration, fishing activities (gillnet entanglement), and general degradation of habitat or food sources.

Feeding

During the seven months of migration, gray whales survive almost entirely on fat reserves they have acquired during the previous summer at their feeding grounds.

They then gain back an estimated 16 to 30 percent of their total body weight during the five months on the feeding grounds.

This species is the only baleen whale that regularly feeds on bottom-dwelling animals by sucking up mud containing amphipods—their primary source of food.

– Liz Love
Monterey Bay National Marine Sanctuary

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