Ecosystem Observations

for the Monterey Bay National Marine Sanctuary
2002

National Marine Sanctuaries™
Monterey Bay

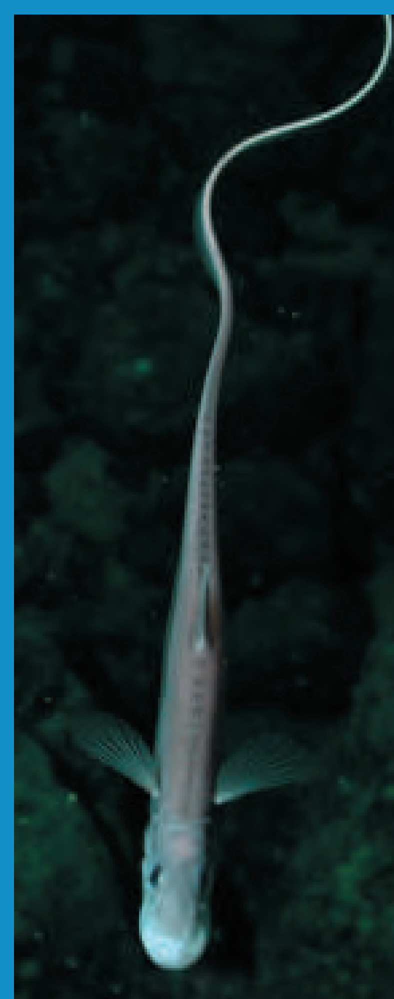

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Table of Contents

Welcome

Whew. It was quite a year for us here at the Monterey Bay National Marine Sanctuary. We dedicated a lot of time to our ten-year anniversary and to hosting a number of events that would allow the public to connect, or in some cases re-connect, to the sanctuary. We wanted people to remember why it is a special place, and why so many went to the trouble ten years ago to designate it.

Nearly 15,000 people participated in a number of events, with the largest turnout – more than 10,000 – at the Oceans Fair in Monterey. So many people, so many partners helped make all the events a success, and we can't thank them enough. You may have heard me say it many times: we succeed in protecting this beautiful stretch of coast only because of the partnerships we have.

The other huge successes of the past year – launching the Threatened and Thriving conservation series, the first biological exploration of the Davidson Seamount, expansion and accolades for the Agricultural and Rural Lands water quality plan – come amidst a vortex of planning for the future with the management plan review process. If you haven't been participating with the review process to date, there is still time to help shape the future of the sanctuary.

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Monterey Bay National Marine Sanctuary Staff

In early 2003 we began a monumental task of stakeholder participation with fifteen working groups focusing on our key priority issues for the future. Our Sanctuary Advisory Council will deliberate on the efforts of those working groups this summer, and we hope to have a draft plan released in the winter.

Not much time to catch our breath, but the mission of the sanctuary, and the energy of the local communities, motivate us.

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

2002 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 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 2002 follows.

Resource Protection

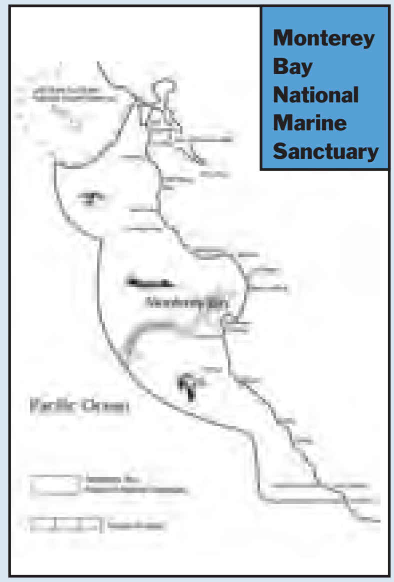
A variety of resource protection issues exist within the sanctuary region, due to the sensitivity of habitats and species in the region, the long stretch of adjacent populated coastline, and the multiple uses of the marine environment. The goal of the Resource Protection team is to initiate and carry out strategies to reduce or prevent detrimental human impacts.

Effective protection of the sanctuary requires partnerships with many other agencies and organizations. The team led or participated in a number of ongoing, collaborative, multi-stakeholder efforts to identify and reduce impacts to the sanctuary, including development of regional approaches to desalination, coastal armoring, marine reserves, fireworks, and landslides associated with the Coast Highway. Many of these efforts will be continued under the Joint Management Plan Review (JMPR) (*see p. 4 under Program Support)*, and the team has been heavily involved in that effort as well.

The team increased its involvement in evaluating opportunities for ecosystem protection via marine reserves that would reduce or eliminate fishing activity in critical habitats – an important issue to be addressed further in the JMPR. Membership on the regional working groups established by the California Department of Fish and Game (CDFG) under the Marine Life Protection Act is providing sanctuary input into reserve development in state waters. Ongoing meetings with the Alliance of Communities for Sustainable Fisheries have continued to provide valuable input from the fishing community on the potential benefits and drawbacks of reserves.

A new project this year focused on the arrival of three large cruise ships to Monterey Bay. As these ships carry thousands of passengers, the volume of their potential discharges was of concern to the sanctuary, the City of Monterey, and many environmental organizations. All three cruise lines ultimately offered to adhere to a no-discharge policy while within the sanctuary, including no discharge of sewage, gray water, ballast, or bilge water (*see page 24*).

The Water Quality Protection Program and its partners continued efforts in the watersheds to reduce contaminated runoff to the sanctuary. Carrying out the sanctuary's Agriculture and Rural Lands Plan, staff at County Farm Bureaus, the Natural Resources Conservation Service, Resource Conservation Districts, the Sanctuary Foundation, and other groups have made great strides in working with local farmers and ranchers to improve sediment, nitrate, and pesticide management. Ten watershed working groups, which include 200 farmers, have been formed and ten more are under development (*see page 25*). Efforts to use trained volunteers to monitor water quality continued under the Sanctuary Citizen Watershed Monitoring Network, including multiple trainings, database development, and two successful regional events – Snapshot Day and First Flush (*see page 13*).



The Resource Protection team reviewed fifty permit requests this year, issuing permits or authorizations for activities such as seabed disturbance, discharges to the sanctuary, and overflights below 1,000 feet in restricted zones. Various permit conditions were imposed on these activities to reduce or eliminate threats to the sanctuary. We also conducted outreach to numerous pilot organizations to explain the overflight regulations and the effects low flights have on seabirds.

The team also reviewed and commented on a variety of projects, plans, or policies under development by other agencies to ensure that they incorporated adequate protection of sanctuary resources. Issues included local programs such as county general plans and local coastal programs; state plans for the nearshore fishery, squid, cabezon, and gillnets; and national issues such as the development of policy on aquaculture and military acoustic impacts.

Enforcement efforts continued with a special agent from NOAA's Office for Law Enforcement and with CDFG and California State Park rangers who are cross-deputized to enforce sanctuary regulations. Cases were primarily instances of marine mammal harassment, unauthorized discharges into the sanctuary, or seabed alteration. We conducted an assessment of the enforcement program this year, resulting in a shift of our resources from an investigative special agent to a more field-based enforcement officer. We also responded to ten emergencies, primarily vessel groundings, to ensure adequate removal of fuel and oil from the vessels. Staff also worked with the U.S. Coast Guard, CDFG, and others on assessment of damages and mitigation measures associated with the large-scale oiling of seabirds attributed to periodic leakage from the sunken World War II ship *Luckenbach* (*see page 23*).

Education and Outreach

The goal of the Education and Outreach Program is to promote understanding and stewardship of the sanctuary. Themes for 2002 revolved around celebrating the tenth anniversary of the sanctuary's designation while looking forward to the future.

The first look at the future came with the annual *Sanctuary Currents* symposium, "New Technologies: Revealing the Secrets of the Sea." This event, co-hosted by the Association of Monterey Bay Area Governments (AMBAG), was one of the best attended to date. More than 300 people gathered to hear about new explorations, techniques, education, research, and resource decision-making assisted by cutting-edge technology.

This same theme spilled over into the student summit, which evolved into a Student Ocean Conference. In partnership with the Marine Advanced Technology Education (MATE) Center and the

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As part of the sanctuary's new MERITO program, students from Pajaro Middle School gather seeds for a wetlands restoration project.

Sanctuary Reflections Awards

Presented at the 2002 Sanctuary Currents Symposium:

Public Official: *Ms. Sandra Koffman, former mayor, City of Pacific Grove*

Citizen: *Leon and Joanne Garden, divers and underwater photographers*

Conservation: *Ms. Vicki Nichols, Save Our Shores*

Education: *Ms. Liz Love, Monterey Bay National Marine Sanctuary*

Science/Research: *Dr. Steve Eittreim, United States Geological Survey*

Business: *West Marine*

Organization: *Friends of the Elephant Seal*

Monterey Bay Aquarium, several student opportunities were combined and offered as a two-day conference. One hundred and twenty students participated; some took part in a remotely operated vehicle (ROV) competition and others reported on monitoring projects they had developed. Dr. Sylvia Earle and marine engineer Alan Scott were featured speakers, and a career panel discussion took place. The event featured classes in GIS mapping, ROV building, SCUBA, and kayaking along with a trip to Monterey Bay Aquarium Research Institute (MBARI) and an overnight stay at the aquarium. We are grateful to Coastal America and National Geographic for providing a $10,000 grant for this conference.

The technology theme extended all the way to Mystic, Connecticut with the debut of Dr. Robert Ballard's Immersion Institute. The Mystic Aquarium and Institute for Exploration, along with the National Marine Sanctuary Program, piloted a live televised program between the sanctuary and Mystic. Underwater cameras, located offshore from Monterey, televised footage across the nation to the Mystic Aquarium's visitors. The remotely operated camera was controlled from more than three thousand miles away, bringing the wonders of Monterey's kelp forest to the eastern seaboard. Sanctuary and Institute staff worked together to develop themes and messages for the programming.

Amidst all of the technological advances of the present, we also stepped back to look at the past. So much of our educational programming, research, and resource protection has been accomplished over the past ten years by a large group of very dedicated volunteers. As the first big step in celebrating the ten-year anniversary, the sanctuary hosted a volunteer appreciation event. The sanctuary has many volunteers, some working behind the scenes, others interpreting along the shores or on the water – monitoring beaches or monitoring storm drains and watersheds. Each person is a valuable part of learning about and protecting the sanctuary's resources.

Tenth anniversary events came to a crescendo in September, as the sanctuary and its partners staged four successful day-long celebrations up and down the coast, attended in all by more than 15,000 people. Kick-off festivities in San Simeon began with kayaking, an environmental fair, and a beach barbecue followed by the dedication of a new sanctuary exhibit and special film showing at the Hearst Castle Visitor Center and National Geographic Theater. In Half Moon Bay we celebrated with the grand opening of a new State Parks visitor center, an environmental fair, a volunteer recognition ceremony, and the grand opening of our new sanctuary office in the downtown area. The festivities continued in Monterey with a huge Oceans Fair. The crowd enjoyed fantastic hands-on exhibits, entertainment, boat rides, tours, birthday cake, speeches by dignitaries, and a special "blessing of the sanctuary" ceremony. As part of Coastal Cleanup Day, Whole Foods donated lunch to the 150 volunteers who cleaned up beaches that morning. Our final event, the Santa Cruz Shark Festival and Sanctuary Celebration, featured a treasure hunt, shark tank, shark release, environmental fair, birthday cake, and entertainment.

Two evening events also marked the sanctuary's anniversary. We collaborated with the National Marine Sanctuary Foundation and Monterey Bay Sanctuary Foundation to host a reception and "Oceans Forum." Special guests included Dr. Sylvia Earle and artist Robert Lyn Nelson, who unveiled his commemorative painting, "Leatherbacks of the Pacific." The Honorable Leon Panetta moderated the forum with guest speakers Jean-Michel Cousteau and Julie Packard, who discussed threats to the ocean's health and the challenges ahead. The next evening AMBAG held an anniversary dinner at the Monterey Beach Hotel. We are thankful for all the support from our partners who helped us stage these special and memorable occasions for the sanctuary's tenth birthday.

Children enjoy many of the activities at the Oceans Fair.

Toward the year's end we launched a well-received multicultural education program, MERITO, whose projects include an after-school program in partnership with Elkhorn Slough Reserve and Pajaro Middle School, college internships for Latino students through California State University Monterey Bay, and a survey of families in Watsonville to learn what ocean issues concern them. Finally, the team began researching a potential visitor center location and developing a new suite of interpretive displays, signage, interactive kiosks, and exhibits with a focus on interpreting resource issue topics.

Research

The Research Program develops and interprets scientific information to enhance our understanding of the sanctuary and to support effective resource management. This year was exciting in terms of program growth, variety of research efforts, and a growing leadership role.

The research staff has doubled in size to eight people. Through innovative partnerships with the Monterey Bay Aquarium, Monterey Bay Sanctuary Foundation, and MBARI we are able to support employees who focus on sanctuary issues while enhancing the capabilities of other institutions. Our Research Activities Panel, which continues to be a vibrant group, met eight times this year to advise and assist the sanctuary with expertise from twenty-two regional research institutions. We have created a new science committee to provide advice specifically on the Sanctuary Integrated Monitoring Network (SIMoN).

Though not yet fully underway, SIMoN has made significant advances this year in developing a program that will be able to document changes to the sanctuary and determine if their causes are natural or human-induced. Four staff are focusing on monitoring: gathering historical information, integrating data from existing monitoring programs, funding new studies, and developing new ways to make data more available to resource managers and the public. This year we funded three new projects associated with Elkhorn Slough; supported bird and mammal surveys as well as offshore studies of oceanographic trends; maintained our beachcast organism surveys (*see page 17*) and kelp canopy assessments; and sponsored a workshop to integrate bird and mammal surveys across the West Coast sanctuaries. SIMoN has two new strong partners. The first, CI-CORE, is a Cal State University program to integrate coastal observations. The second, CIMT, is a regional effort led by the University of California Santa Cruz and the Naval Postgraduate School to integrate marine technology and develop methods to present data from coastal ecosystems in the greater Monterey Bay area. We put a lot of effort into developing a solid administrative foundation for the growing SIMoN program and setting up a new office for the staff.

Sanctuary research enhances understanding of the ecosystem by funding various projects, actively collecting data, and developing interdisciplinary collaborations with numerous institutions. In May we led a multi-institution expedition to characterize the biology of the Davidson Seamount, using a remotely operated vehicle from MBARI, with funding from the new NOAA Office of Exploration (*see page 9*). Our other research efforts ranged from supporting ship and plane time for leatherback turtle tagging, testing new methods of aerial surveys of kelp canopies, and mapping the seafloor at the legendary Mavericks surf spot. We are testing removal methods for a non-native kelp, *Undaria*, which has invaded the Monterey Harbor, following up on a discovery discussed in our last *Ecosystem Observations*.

Cultural resources, such as shipwrecks and historical coastal communities, are an important component of sanctuary management and protection. This year we completed an inventory of the hundreds of shipwrecks within the sanctuary. These include the 785-foot *Macon* air ship, which served in part as an aircraft carrier and sank off the Big Sur coast in 1935, and the *Montebello*, an oil tanker sunk off Cambria by a Japanese submarine during World War II. Wrecks are of historical interest and can also affect the environment if they contain hazardous materials that eventually escape (*see page 23*).

The sanctuary uses the Internet to make scientific information easily accessible to the public. Our Davidson Seamount expedition was interpreted to the public with daily video clips and written updates on a web site (viewed by as many as 140,000 people per day), while the public communicated with our at-sea explorers through e-mail with questions and comments. We also continued to produce publications such as a review of marine reserve effectiveness within the sanctuary, a review of the status of fisheries within the sanctuary, and a forthcoming environmental review document to support the management plan.

Underwater image of the cockpit of one of three sparrowhawk planes that were found with the wreck of the dirigible Macon in about 1,450 feet of water

Organizations beyond the sanctuary are taking notice of our research efforts. Information on our programs was presented at several national conferences, and we organized the first cultural resources session in the history of the *California and the World Ocean* conference. SIMoN, as a model for regional monitoring, has been an important part of developing a system-wide monitoring program for all the sanctuaries and received an award for "science in action" from our headquarters. Moreover, we were invited to discuss our entire research program as a potential model to the Ministry of Maritime Affairs and Fisheries in South Korea. The new Office of Exploration chose our sanctuary to host a workshop on prioritizing ocean exploration for the West Coast. Finally, indicating a trend of increasing links between academic and applied research, Dr. Andrew DeVogelaere, the sanctuary's research coordinator, was elected president of the Western Society of Naturalists. This is the first time a government employee has served the West Coast marine science society in this role.

Program Support

The Program Support team provided administrative and operational support, continuing to help us stay focused on our mission and goals. Staff dedicated a significant amount of time (in conjunction with Cordell Bank and Gulf of the Farallones Sanctuaries) to keeping the Joint Management Plan Review (JMPR) moving forward.

We also worked with the Sanctuary Advisory Council to finalize a priority list of issues to be addressed in the plan. Council members and Conservation Working Group, Research Activities Panel, Sanctuary Education Panel, and Business and Tourism Activity Panel members participated in work groups formed to develop action plans to address the identified management plan issues. The sanctuary and the council made a special effort to involve the public and receive comments on the management plan review, holding a special public comment meeting in Cambria to address public interest in sanctuary protection for waters off San Luis Obispo County. Specific resource priorities to be addressed in the management plan include: coastal development; coastal armoring; dredge disposal; benthic habitats; krill harvesting; marine reserves; beach closures and coliform contamination; desalination facilities; tidepool protection; marine mammal, seabird, and turtle disturbance; and motorized personal watercraft. For a complete update, visit www.sanctuaries.nos.noaa.gov/jointplan.

Other issues addressed by the Sanctuary Advisory Council included fiberoptic cables, the Water Quality Protection Program's Agricultural and Rural Lands Plan, the sanctuary's ten-year anniversary, and cruise ships. The council also received a special presentation about the state of our oceans from Pew Commission Chair and former Congressman Leon Panetta.

Several new members joined the council. A new government seat was appointed for the CDFG, and new representatives filled the diving, tourism, and California State Parks seats.

This year we started an active public relations and community outreach effort, with special emphasis placed on raising public awareness of the sanctuary during its ten-year anniversary celebrations in September. The sanctuary's accomplishments over the past ten years received significant media coverage, including feature articles in local and regional media.

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Contributed Ecosystem Observations

Beach Systems

A Visit from *Velella Velella*

During April and May of 2002 sanctuary beaches were bombarded with millions of by-the-wind sailors (*Velella velella*). The sanctuary office as well as the California Department of Fish and Game received several calls reporting oil slicks off the coast of Big Sur. These reported slicks turned out to be thousands of these iridescent *Velella* floating at the surface.

Velella are bright blue pelagic colonial hydrozoans (a type of cnidarian) distributed worldwide in temperate and tropical seas. They float at the surface, mouth down due to their gas-filled bodies, and travel using a transparent sail that is formed by a chitinous exoskeleton. The sail is angled at 45 degrees to the right or left of the main body axis, allowing the animal to drift at a 45-degree angle to the wind direction, hence the name ‘by-the-wind sailor.’

Velella are normally found in the central water masses of the Pacific Ocean, where the prevailing northwesterly winds hold the population offshore of California. Last spring persistent southwesterly winds pushed the *Velella* onto sanctuary beaches from Cambria to north of San Francisco. All sizes of *Velella*, ranging from one to eight centimeters in length, were found. Several weeks after the initial strandings, all that remained of the *Velella* were clear chitinous exoskeletons.

While at sea, these animals feed upon fish eggs, crustacean larvae, and other zooplankton. *Velella* also contain single-celled symbiotic algae (zooxanthellae) in their tissues. It is thought that they may gain some nourishment from the photosynthetic activity of these algae. Pelagic gastropods, along with the ocean sunfish (*Mola mola*), feed on *Velella*.

The life cycle of *Velella* includes both asexual and sexual stages. This type of reproduction is known as alternation of generations. The asexual stage, or polyp, is the bright blue animal that washed ashore in 2002. The asexual polyp is made up of two different types of polyp: the central feeding polyp, or mouth, and smaller polyps surrounding the mouth that are both reproductive and used for feeding. From these smaller polyps small medusae bud off. Each medusa is either male or female, representing the sexual stage of *Velella*. These medusae sink to depths of 600 to 1,000 meters, where eggs and sperm are then released. A planula larva is formed that develops into the next larval stage, or conaria. This very small asexual polyp secretes an oil droplet, causing it to float back up to the surface where it will develop into the larger animal with sail.

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Last spring persistent southwesterly winds pushed Velella velella onto Sanctuary beach-

In general, the *Velella* population spends three to four months on the surface in the spring, two to three months at depth, and then three to four months in the late summer on the surface before sinking to depth for two to three months in the fall. The *Velella* on the surface are larger in the spring than in the late summer. The late summer *Velella* rarely wash ashore, due to the prevailing northwesterly winds.

Velella wash ashore every few years. It has been several years since the last time they were cast upon sanctuary beaches, and it is likely that it will be several more before they return again.

–Kelly Newton
Monterey Bay National Marine Sanctuary

Status of the Western Snowy Plover in the Monterey Bay Region

The next time you go for a walk on a sandy beach, keep your eyes open for what appears, at first glance, to be a drift of small snowballs. These diminutive fluffballs are actually roosting flocks of Western Snowy Plovers (*Charadrius alexandrinus*), small shorebirds that nest and winter on the sandy beaches of Monterey Bay. In the Monterey Bay region during spring and summer, Western Snowy Plovers nest and raise their chicks along the shoreline from Sunset State Beach south to Marina, at saline flats within the Moss Landing Wildlife Area, and at several small pocket beaches in northern Santa Cruz County. In winter large roosting flocks congregate at these locations, often near river mouths.

In 2002 Western Snowy Plovers nesting locally fledged more than 210 chicks – the second greatest number ever documented in the Monterey Bay region. The number of chicks fledged per breeding male was 1.4, well over the estimated 1.0 chicks per male necessary to stabilize the population. In 1997 and 1998 La Niña conditions over winter resulted in high adult mortality, but the high level of fledging success of the past three years has nonetheless resulted in a measurable increase in the size of the local breeding population (*see Figure 1, opposite*).

Despite these increases, the range of the plover in Monterey Bay has contracted, and nesting success at historic sites on the fringes

© Greg Smith

Western Snowy Plover male and chick

has declined. As recently as five years ago, Western Snowy Plovers occupied nesting sites as far south as Monterey State Beach in southern Monterey Bay. In 2002, however, the southernmost nesting attempt documented was north of Reservation Road in Marina. Prospecting pairs were observed at Marina State Beach and at Sand City, but nesting was not confirmed at these locations. Similarly, although 2002 was a banner year for plovers nesting at Sunset State Beach, it was the first time this site had been occupied in three years.

The success of plovers attempting to nest at pocket beaches in northern Santa Cruz County gradually has decreased. (Pocket beaches are small and bound at each end by a physical barrier that chicks cannot cross, so adults are unable to move their chicks large distances away from disturbances such as humans or predators.) At these beaches only 60 percent of fifteen nests hatched successfully, and only two fledglings were produced, in 2002. In response to their lack of success at their traditional nesting beaches, some pocket beach nesters have defected to the beaches of central Monterey Bay for their second nesting attempt.

What are the factors that influence Western Snowy Plovers' reproductive success? These shorebirds require relatively undisturbed areas to nest and rear chicks. They lay a clutch of three sand-colored eggs directly on the bare sand on the middle to upper beach area, above the wrack line but below the heavily vegetated dune. Because plovers must incubate the clutch around the clock for twenty-eight days, any disturbance that prevents the bird on duty from returning to the nest jeopardizes the survival of the eggs. Nests are also susceptible to trampling from humans, dogs, horses, and vehicles.

Plover chicks are precocial (active from birth), leaving the nest within hours of hatching, but they remain flightless for about one month. The male plover usually rears the brood alone. He protects them from danger, broods them until they can thermoregulate, and leads them to foraging areas. The birds feed primarily on small invertebrates associated with beach wrack, and chicks often make treacherous daily trips down to the wet wrack line, where they are susceptible to predators, trampling, and separation from the male parent. Because young chicks must be brooded regularly by the male to stay warm during the chilly Monterey Bay summers, prolonged separation can mean death for the chicks.

Urbanization, degradation and loss of coastal habitat, and the effects of introduced predators and invasive vegetation led to the listing of the Pacific Coast population of the Western Snowy Plover as threatened by the U.S. Fish and Wildlife Service in 1993. Currently, an estimated 1,200 to 1,500 Western Snowy Plovers compose the Pacific Coast population, which ranges from southern Washington south to Baja. Ten years after the plover's listing, the same factors continue to affect the breeding success of these birds locally and throughout their range. Around Monterey Bay, recreational use of beaches continues to grow, causing an increase in human-related disturbance to nesting plovers. Habitat fragmentation and urbanization have enhanced the accessibility of beach habitat to non-native predators such as the red fox (*Vulpes vulpes regalis*) and invasive predators such as the Common Raven (*Corvus corax*) and American Crow (*Corvus brachyrhynchos*). Red foxes have been actively controlled since 1993 but are still present on beaches at the start of each nesting year. In 2002 ravens depredated twelve nests at the Pajaro River mouth – the first documented nest losses in the central Monterey Bay region attributed to this increasingly abundant predator.

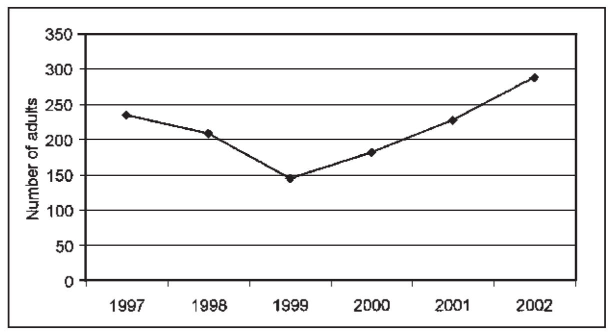


Figure 1. Number of Western Snowy Plovers nesting in Monterey Bay and northern Santa Cruz County

The future of the Western Snowy Plover depends on several factors. As plovers are increasingly concentrated into smaller habitat areas, we have an obligation to protect them in their remaining habitat from the effects of our activities. This will mean active management of non-native and invasive predators, restoration of habitat, and a basic willingness on our part to share beaches and coastal areas with species that depend on these areas for basic life functions.

–Kriss Neuman
Point Reyes Bird Observatory

Rocky Intertidal and Subtidal Systems

Long-Term Monitoring Program and Experiential Training for Students (LiMPETS): Monitoring the Sanctuary's Rocky Intertidal with High School Students and Other Volunteers

The intertidal zone is the coastal strip that is covered and uncovered by the sea during the rise and fall of the tides. An incredible variety of life inhabits this zone, and the rocky intertidal of central California is especially rich. There are the familiar fishes, snails, mussels, crabs, and sea stars as well as beautiful nudibranchs and sea anemones, delicate hydroids and bryozoans, and colorful sponges and ascidians that abound in crevices and pools. Bright green surfgrasses mark the lower parts of the low tide zone, while bizarre forms of red and brown algae cover much of the middle and high zones. There are few places in the world where so many kinds of organism live in such a small area. Abundant oxygen, nutrients, and wave motion make this area one of the richest and most productive on earth.

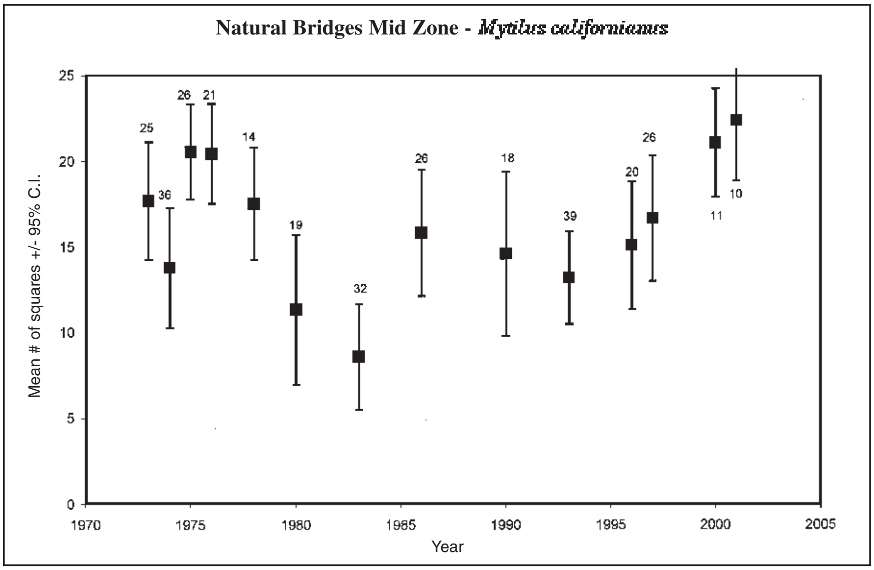


Figure 1. Abundance of California sea mussels (Mytilus californianus) within a 9 x 30 m permanent plot in the mid zone at the Natural Bridges site. Values for 1973 to 1997 taken by UCSC undergraduate students; those of 2000 and 2001 taken by Aptos High School students. Numbers indicate number of quadrats counted.

Indeed, the intertidal zone is a wonderful place to learn about life on our planet. For many years biologists have recognized the opportunities for understanding nature by studying the intertidal, and many of our ideas about how communities of plants and animals function come from observations and experiments done there. The organisms are arranged in bands, with fewer species higher up in the intertidal and the most species crowded in the low zone. This gradient is similar to what one would see by traveling over great distances from mountain tops to lowlands, deserts to wetlands, or the polar regions to the tropics, and for the same reasons – but in the intertidal there are only a few meters to traverse and it is easily accessible. In more physically stressed regions, such as the high zone of the intertidal, species diversity is restricted to those few that can tolerate stresses such as temperature extremes and long periods without water. In contrast, in the more favorable regions, like the low zone of the intertidal, many species crowd together, vying for space and competing intensely to survive. Though the intertidal appears benign on an early morning low tide, the low zone is a place of high conflict, full of predators and competitors using nearly unimaginable means for offense and defense.

The accessibility of the rich and varied biota in the intertidal and the information accumulated from years of study there provide a wonderful opportunity for the public in general, and curious youngsters in particular, to learn about biology and the natural world. Programs developed by the national marine sanctuaries and public aquariums, such as the Monterey Bay Aquarium, have been leading the way in introducing the intertidal to people from all walks of life. Interpretative materials in the form of written articles and books, videos, and web sites are proliferating to meet the increased interest, and these are leading to increased conservation efforts.

On the other hand, the very accessibility of the intertidal has led to more and more people visiting it. And while reckless collecting might be decreasing in response to better understanding and enforcement, simply clambering around on the rocks may disturb some species, leading to unpredictable changes. Moreover, by its very nature, the intertidal zone is a place exposed to many of the pollutants produced by human society. Contaminants released into the air fall on the surface of the sea, and those dumped on the land are washed into the sea. In addition, many contaminants that are discharged directly into the sea pass through the intertidal, and some of the material from all these sources is washed back onto the shore, ending up in the intertidal. Indeed, the animals and plants of the intertidal may be affected more severely by human activities than those in most other parts of the sea. Fortunately, because of their accessibility, they may also be the easiest to monitor and so can serve as our marine canaries.

For example, the tightly organized zonation pattern of the intertidal, with species sorted into bands with respect to tidal height, may be particularly sensitive to global warming because a rise in sea temperature leads to a rise in sea level. Such a rise in sea level should not only shift the entire zone higher on the shore but also change the zonation pattern. Moreover, we should expect the distribution of species along our coast to shift in response to a rise in both air and sea temperatures. At any given site, southern species would be expected to become more common and northern species less common. Indeed, that was exactly the result seen when species abundance was compared between the early 1930s and the mid 1990s at a site at Stanford University's Hopkins Marine Station in Monterey Bay: several common southern Californian species that were rare or absent in the 1930s are now abundant there. But will all these predictions hold in general?

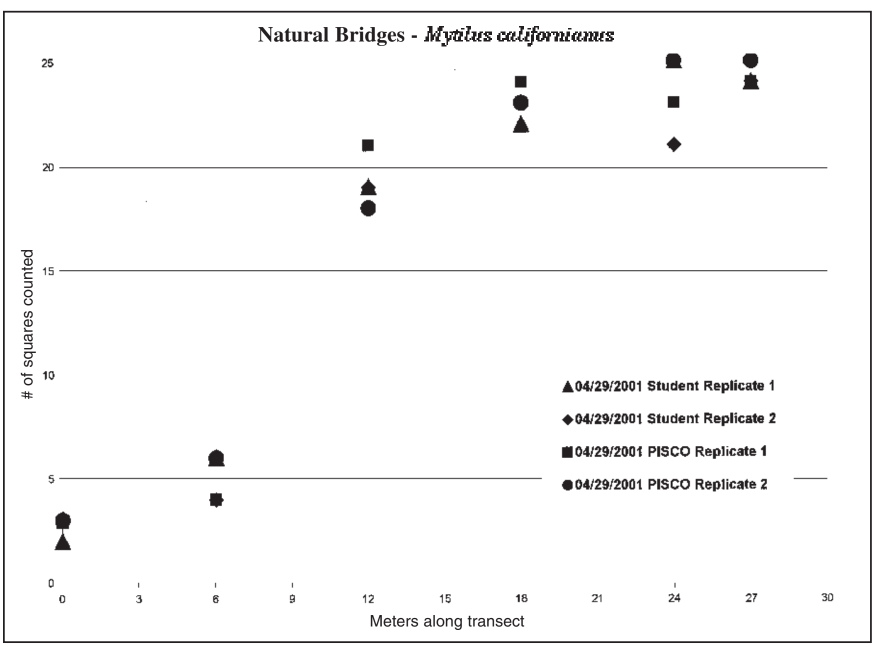


Figure 2. Abundance of California sea mussels (Mytilus californianus) along the vertical transect (across the intertidal from high to low) at the Natural Bridges site, as counted by professional researchers in the PISCO program and Aptos High School students. Each quadrat along the transect was counted by two professional teams and two student teams.

© Christy Roe/Dawn Osborn

Watsonville High School students with their teacher, Burnne Yew, at the Point Pinos site

The biotic diversity combined with abundance, organization, and sensitivity to environmental change therefore present an enormous opportunity both for informing the public about life in the sea and for monitoring biotic changes over time. In particular, the education of high school students and other curious people can be enhanced while they collect important data to be archived and used to detect change. This is the goal of Long-term Monitoring Program and Experiential Training for Students (LiMPETS), which is being developed by the West Coast marine sanctuaries.

The rocky intertidal portion of LiMPETS* was developed at the Long Marine Laboratory of the University of California Santa Cruz (UCSC), with support from the California Sea Grant College program. Eight sites were developed in the Monterey Bay National

Location	Groups Monitoring
Davenport Landing Santa Cruz County	San Lorenzo Valley High School
Wilder Ranch Santa Cruz County	Available
Natural Bridges Santa Cruz County	Aptos High School
Almar Street Santa Cruz County	Alternative Family Education Homeschool Association, Save Our Shores
Soquel Point Santa Cruz County	Harbor High School
Point Pinos Monterey County	Watsonville High School, Monterey Academy of Ocean Sciences
Carmel Point Monterey County	Available
San Simeon San Luis Obispo County	Available

Sites and groups for monitoring by LiMPETS of the rocky intertidal in the Monterey Bay National Marine Sanctuary

Marine Sanctuary; five of these have already been used by six school groups and one volunteer group (*see table, above*). Three other sites have been developed and are open for "adoption." At all the sites, half meter by half meter square quadrats are placed along a vertical transect – crossing the intertidal from the top of the high zone into the low zone, and marked with stainless steel eyebolts – and the abundance of selected algae and invertebrates are counted within them. Large animals that are infrequently found in the quadrats, such as owl limpets and sea stars, are counted and measured in larger, delineated areas that can be carefully searched. In addition, at four sites in Santa Cruz County where the intertidal is relatively uniform and covered predominately by a single species

Are We Loving Our Tidepools to Death?

New Study Examines Relationship of Visitor Use and Marine Life Biodiversity at Point Pinos

Rocky intertidal zones with pinnacle outcroppings and tidepools support some of the most diverse marine plant and animal communities along the coast. These habitats have become increasingly popular for their educational, recreational, and scenic values and have become more frequently visited by school groups, tourists, and the general public. However, studies have shown that heavy visitor use can negatively affect the communities in these habitats through trampling, collecting, handling organisms, and simply turning rocks.

Point Pinos, a prominent rocky headland of the Monterey Peninsula, is one of the most biologically diverse and picturesque habitats in the Monterey Bay National Marine Sanctuary. It is of particular interest because it is easily accessible. Concerns have arisen that the marine life at Point Pinos is being negatively affected by visitor overuse.

A study initiated in 2001 is obtaining data to determine the extent and magnitude of the biological impacts associated with visitor use at Point Pinos. Sampling is also being done in adjacent areas with less visitor use, for comparison purposes. The biological surveys consist of inventories of key species selected for their ecological or numerical importance and susceptibility to visitor impacts. Sampling transects are established in the upper and lower intertidal zones in each study area. Tidepools close to public access points are also being sampled to determine whether there are any indications that tidepools at Point Pinos are less diverse than those in areas with less visitor use. In addition, species at higher risk of being illegally collected for food, such as owl limpets and abalone, are being studied to determine the status of their local populations.

TENERA Environmental of San Luis Obispo, California is conducting the studies. The Point Pinos Tidepool Task Force Research Committee, a panel comprised of local scientists and citizens, commissioned the study. The David and Lucile Packard Foundation, City of Pacific Grove, and Monterey Bay National Marine Sanctuary are financing the study, with the funding being administered through the Monterey Bay Sanctuary Foundation. BAY NET, a volunteer group specializing in marine science education outreach, is conducting the visitor census surveys and tallying the types of visitor activity observed. The final report, due to be completed in the spring of 2003, will provide a scientific basis for guiding resource management at Point Pinos.

Courtesy of Scott Kimura

Visitors frequently explore the Point Pinos shore.

–Scott Kimura
Tenera Environmental

(mussels or surfgrass), large permanent plots have been established, and selected species are counted in randomly placed quadrats that permit statistical comparisons. Data collected by UCSC college classes are already available for those sites, going back to the early 1970s, for comparison (*see Figure 1, p. 7*).

Although getting high school students into the intertidal may be a great educational experience, it has been questioned whether they are able to collect reliable data. To make sure that they can, common species of ecological importance were selected for monitoring and their suitability tested by students in the field. Those that are difficult to distinguish (even by professionals) were either eliminated or combined into general groups. Moreover, protocols used in professional monitoring programs were followed, and data collected by students were found to be indistinguishable from those collected in the same quadrats by teams of professional researchers (*see Figure 2, p. 7*). The sites, species, and protocols are all on the LiMPETS project web site (*www.limpets.org*).

–John Pearse, Dawn Osborn, and Christy Roe
Joseph M. Long Marine Laboratory, University of California Santa Cruz

*The sandy beach portion of LiMPETS is being developed by the Gulf of the Farallones National Marine Sanctuary (*www.sandcrabs.org*), and a pelagic, offshore sampling program is planned by the Cordell Bank National Marine Sanctuary.

Open Ocean and Deep Water Systems

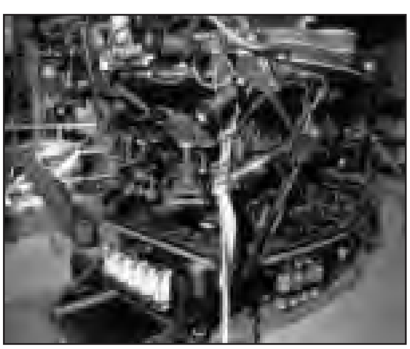
Exploring the Davidson Seamount

The Davidson Seamount is an impressive geologic feature that has intrigued people since it was first mapped as a "sea mountain" in 1933. It is located 120 kilometers southwest of Monterey, just outside the sanctuary boundary, due west of Point Piedras Blancas. The seamount is an inactive volcano that last erupted about 10 million years ago; its summit is far below the ocean surface at a depth of 1,300 meters. Rising above the relatively flat abyssal plane, the seamount dominates the ocean floor like Mount Shasta dominates northern California and is as tall as much of the Sierra Nevada Mountains (2,300 meters). It's as long and as wide as Monterey Bay.

Following decades of curiosity about the seamount, the new NOAA Office of Exploration funded a sanctuary-led, multi-institution expedition to characterize the distribution and abundance of creatures living there.

Though Davidson Seamount is not far away geographically, it is only recently that technology has been available to navigate, gather high quality images, and collect delicate organisms from these ocean depths. The sanctuary contracted with Monterey Bay Aquarium Research Institute (MBARI), one of the few organizations worldwide that has a ship and robot able to access these areas effectively on a regular basis. Imagine sending a robot down on 3,600 meters of cable into the pitch black, following specific routes up the side of the seamount and along particular ridges, and documenting areas never or rarely seen before.

After months of planning, we set off in May on a one-week cruise, with the main objective being to characterize invertebrates and fishes of the seamount. We also wanted to involve the public in the exploration through the Internet, evaluate the seamount's relevance to the sanctuary, gather geologic samples, make opportunistic bird and mammal observations, and collect organisms for study and display at the Monterey Bay Aquarium.



The ROV Tiburon is able to travel far below the ocean's surface and gather images and organism samples from around the Davidson Seamount.

After the cruise, we learned that creatures living on the Davidson Seamount could be grouped in depth zones – from the base to the summit – not unlike terrestrial plant life on mountains. Like tourists driving up a mountain at night and noting all the wildlife in their headlights, we

The blob sculpin (Psychrolutes phrictus) and sponges on the Davidson Seamount at 1,317 meters (4,321 feet). Blob sculpins are opportunistic feeders, most commonly eating sea pens, snails, and crabs.

cruised up the sides of the seamount and noted what was found in the lights of MBARI's deep-sea robot, the *Tiburon*. However, what we saw was much more colorful and abundant than tourists are likely to have seen from their cars. At the base of the seamount are common bottom fishes, like the rattails exhibited at the Monterey Bay Aquarium. Near the base, we found large, crab-like creatures called sea spiders. These can also be found on rocky shores, but never as big as the Davidson Seamount's foot-long "spiders"; in fact, many of the organisms we encountered were much larger than their relatives in the much warmer and shallower areas of the California coast.

Mid-way up, we saw species of fishes never seen live before, with names such as toadfish and witch eel. Some of the most impressive lava flows and geologic features were evident in the mid-range, as sediments down low and animals above covered the seamount's rock surface.

Invariably, it was the ridges at the top of Davidson Seamount that had the most spectacular life forms: twelve-foot-tall corals, large vase- and horn-shaped sponges, and a variety of sea stars. In a habitat where sunlight never reaches, we were surprised by bright yellow, pink, red, and purple organisms. As noted above, the size of most organisms surprised us all. We found sponges as large as a phone booth and others as wide as a soccer goal. We carefully photographed giant red corals that reached fifteen feet tall along several ridge lines. One "cone" of the volcano was completely blanketed with one sponge or a colony of sponges – a density of cover that surprised us all. Currently, we are carefully quantifying the distribution and abundance of species, but our initial observations have already influenced the public and resource managers alike.

Above the seamount, we made observations of birds and mammals during the daylight hours. We encountered a total of nine different species of mammal, including killer whales, as well as fifteen species of bird, of which the Black-Footed Albatross was the most common. We followed a pod of sperm whales with a small boat launched from the ship but were not able to obtain skin samples requested by NOAA Fisheries for genetic analysis.

A key component of our expedition team was the educators, who were team members along with the scientists and resource managers. Our expedition was shared with students and the public on a web page that consisted of daily updates and video clips along with an "ask the explorer" e-mail option to link us with the rest of the world. Whether it was the unique creatures, the geology, or the technology, we piqued the interest of the public – with up to 140,000 visitors per day to our web site and a story on the CBS Evening News.

Resource managers came to the conclusion that the Davidson Seamount is a unique habitat, based on the number of new and rare species, large and long-lived species, and the potential fragility of this habitat. Currently, there are no seamount habitats under protection in any of the thirteen national marine sanctuaries around the United States. As part of the current sanctuary management plan revision process, a diverse working group of interested parties is assessing the necessity of including the Davidson Seamount within the sanctuary boundary.

Our cruise was exciting in terms of scientific discovery as well as educating the public and influencing resource management processes. Bringing educators and resource managers on what could have been a more standard science cruise was a successful experiment for us. Today, ocean exploration is clearly a wide-open field with many opportunities for public involvement and resource management. We're looking forward to finalizing our analyses of the collected video images and listing all the new patterns and questions that arise from our quantitative descriptions. Perhaps most importantly, we are eager to contribute to conservation efforts, if the public and formal decision makers decide that the Davidson Seamount deserves special protection.

Pink gorgonian coral growing on hard substrate at 1,573 meters (5,161 feet). Shrimp, brittle stars, and crabs were often found associated with this gorgonian.

The Davison Seamount expedition was a multidisciplinary effort with members from the following institutions: the sanctuary, Moss Landing Marine Laboratories, the Monterey Bay Aquarium, MBARI, the National Marine Fisheries Service, the Alliance for Coastal Technologies, and the Office of Exploration.

–ANDREW DEVOGELAERE
MONTEREY BAY NATIONAL MARINE SANCTUARY

One Year on Pioneer Seamount

Fifty miles off the California coast, just over the edge of the continental shelf, an underwater mountain rises from the Pacific Ocean floor, cresting 900 meters below the ocean surface. This underwater aerie, twice as high as Mount Tamalpais, surveys the open ocean to the west, the Juan de Fuca Plate to the north, and, to the south, the teeming wildlife of the Monterey Bay National Marine Sanctuary. Pioneer Seamount is an ideal vantage point for observing everything happening in this part of the ocean.

Underwater observation is not done with light. In even the clearest of seawater, light is strongly absorbed: two-thirds of blue light is absorbed over a distance of fifty meters, and red light fares even worse. In the murkier water of the Pacific, a whale can barely see its own tail, much less its mate or a straying baby. In this situation, sound replaces light and ears become eyes.

In contrast to light, sound travels almost forever underwater. Frequencies of 50 hertz (Hz) and below, favored by some whales, travel long distances with little attenuation. In 1995 this led the scientists of the Acoustic Thermometry of Ocean Climate (ATOC) project to choose Pioneer Seamount as a site for transmission and reception of low-frequency signals.

At the end of the project, an initiative was undertaken to preserve the underwater cable to shore for use in non-invasive environmental monitoring, spearheaded by our group at San Francisco State University, with the support of David Evans, Director of NOAA's division of Oceanic and Atmospheric Research. Concerned environmental groups acceded to the logic of this proposal. A team of scientists led by Chris Fox of NOAA's Pacific Marine Environmental Lab (PMEL) and Jim Mercer of the University of Washington's Applied Physics Lab then installed a small vertical linear array (VLA) of four hydrophones, covering the frequency range of 10 to 450 Hz. On September 1, 2001, the Pioneer Seamount Observatory came on line.

During the following year, the observatory suffered a variety of minor equipment problems and one failure that required bringing the "wet electronics" to the surface for repairs. This entailed a wait of four months for ship availability and suitable weather conditions. Even so, the observatory's live time averaged nearly 60 percent during a period of more than a year, and a large body of data is now available for analysis.

The accompanying figure (*see p. 11*) is a composite spectrogram of acoustic signals commonly observed at Pioneer Seamount. The spectrograms show frequency versus time, and most of the interesting phenomena can be located by scanning the spectrograms. Four signals of interest are shown.

Ship Propeller Sounds

The most obvious and loudest feature is the pattern of nested parabolic lines covering most of the spectrogram. This is the signal of a ship passing over Pioneer Seamount. Sounds like this are the loudest noises observed at Pioneer Seamount. Because of the long distances these sounds travel, the sounds from distant ships also make a major contribution to the ambient noise level.

The complex pattern of this spectrogram is due to the interference among the four hydrophones of the VLA, whose signals are added coherently. Where the bright lines dip down to their lowest frequencies, the ship is at its point of closest approach, and the frequency at that point gives its distance. From the rate at which the interference lines diverge, the speed of the ship can be determined. The pattern shown corresponds to a ship passing

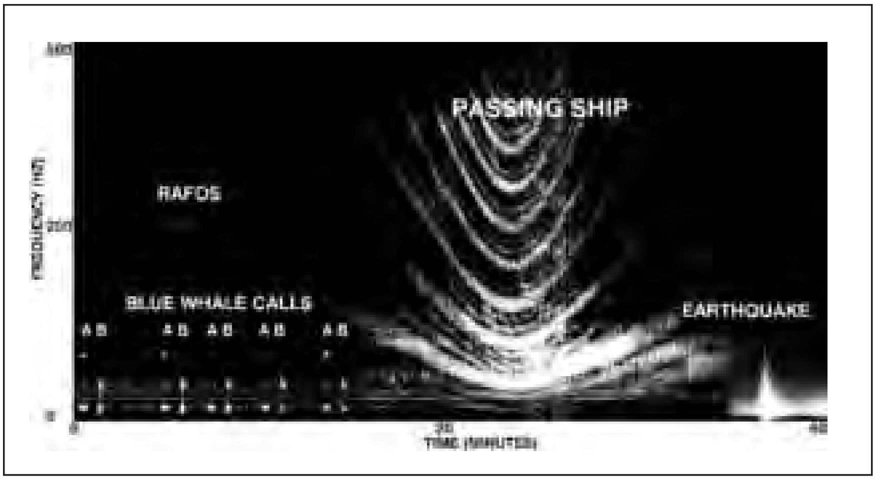


Figure 1. Composite spectrogram showing four commonly observed acoustic signals

about 350 meters from the array's location, and traveling roughly in a straight line, at a constant speed of twelve knots.

Blue Whale Calls

On the lower left-hand side of the figure appears a series of five blue whale (*Balaenoptera musculus*) "A-B" calls. Each pair starts with an "A" call about twenty seconds long, with substantial power at 16 Hz (below the limit of human hearing) and at 90 Hz, near the fifth harmonic of the low-frequency fundamental. The "B" call follows about fifty seconds later and has its frequencies concentrated at 16 and 48 Hz, the first and third harmonics of the same fundamental. These sounds are generally played back at between four and ten times their true speed, moving their frequencies into the center of the range of human hearing. The "A" call sounds like a series of "gurgles," and the "B" call that follows is a sad "moan," dropping steadily in frequency during its fifteen-second duration.

The "B" call, the less complex of the two, is fairly easy to recognize with automated pattern recognition. An effective method described in the literature uses a "matched filter" consisting of a perfect sine wave at about 16 Hz, dropping slightly in frequency during the "moan." This procedure identified about 5,000 "B" calls during the last year, most of them coming in the fall months of September through November. While data from a full year are not available, the difference between the busy fall and a silent spring is striking.

The large number of individual whale calls recorded may eventually provide a means of approaching the "holy grail" of marine mammal acoustics – the identification of individuals from their calls. The most striking feature of the blue whale calls is their lack of variability, as if the whale were repeating the same "word" over and over. However, there is some variation in harmonic structure, length of calls, and spacing of calls. In the future, these and other details of the calls may provide a way to tag individuals, age groups, or sex groups.

RAFOS Timing Sources

The fine, nearly horizontal line on the spectrogram labeled "RAFOS" is the signature of a swept-frequency signal (a "chirp") from one of the acoustic beacons that make up a sort of underwater GPS navigation array for the eastern Pacific Ocean. The signal shown is from a source moored 400 kilometers west of Portland, Oregon. The delay between the known broadcast time and the detection time can be translated into a distance from the source. The signals from multiple active sources permit the determination of the position of a drifting receiver. Plotting daily positions of each drifting instrument allows determination of the eastern Pacific subsurface ocean currents, something otherwise very difficult to measure. The Pioneer Seamount Observatory is used to monitor the timing accuracy of the sources.

Earthquakes and LFA

The signal from a small earthquake is indicated on the spectrogram. Such quakes are detected about once per day. These arrivals will eventually be integrated with seismometer data to study earthquakes in the Pacific floor, although at present there are no ocean-floor seismometers in this general area of the Pacific. At present, study of plate-tectonic motion along the California coast is hampered by the fact that most observations are made east of the plate boundary. The addition of a seismometer would be very valuable for earthquake geologists.

The recent announcement by the U.S. Navy of its intention to test the SURTASS LFA (surveillance towed array sensor system, low-frequency active) sonar system for submarine detection in the Pacific lends additional interest to underwater acoustic monitoring. The proposed source level of the LFA array is 240 dB re 1 µPa ("water decibels," not "air decibels"; to convert from dB in water to dB in air, subtract 60 dB) at 1 meter. Operation 200 miles off the California coast would result in sound levels of 180 dB re 1 µPa (again "water decibels," not "air decibels") in the sanctuary, a sound level considered by some to be dangerous to marine mammals. Independent monitoring of these sounds at Pioneer Seamount during these tests would enable the sanctuary to quantify the noise levels produced and to look for the response of marine mammals to the noise.

The Future of the Pioneer Seamount Observatory

Pioneer Seamount is the first, and only, publicly accessible underwater observatory. Its first year of operation revealed the variety and quality of information to be obtained from a cabled offshore acoustic observatory. Its data support basic research in physical oceanography, geophysics, ocean engineering, and marine mammal research as well as the sanctuary missions of tracking populations of marine animals and monitoring their acoustic environment. With the use of air guns for geophysical investigations (potentially including oil exploration) and the prospect of SURTASS operation nearby, an acoustic monitoring station takes on added importance.

Pioneer Seamount went off the air on September 24, 2002 at 12:07 universal time. The center conductor of the coaxial cable is apparently shorted out to sea water. This is only the second cable failure over the seven years that the cable has been in place. The first failure (and possibly the current damage) was caused when a bottom trawler snagged the cable, an unavoidable hazard of the marine environment. Once repaired, this unique window into the ocean will continue to help scientists and regulators protect the sanctuary environment.

Interested readers can listen to the sounds of the Pioneer Seamount at www.physics.sfsu.edu/~seamount/gallery.html.

–Roger Bland[1,2] and Newell Garfield[2,3]
[1]Physics and Astronomy Department, San Francisco State University
[2]Romberg Tiburon Center for Environmental Studies, San Francisco State University
[3]Geosciences Department, San Francisco State University

Green Waters of the Sanctuary: the Role of Iron

The phytoplankton-rich green waters of the Monterey Bay National Marine Sanctuary support a remarkably rich ecosystem. Although the coastal waters off central California are highly productive, there is a great deal of variability, and some of the waters are not nearly as productive as one would expect them to be. One of the keys to understanding the variability in phytoplankton biomass and productivity lies in understanding the supply of the micronutrient iron.

Northwesterly winds along the coast of central California result in wind-driven coastal upwelling that brings colder, nutrient-rich water to the surface. This process is most intense during the spring and summer. The large flux of the essential plant macronutrients nitrate, phosphate, and silicic acid can allow extensive phytoplankton blooms to occur that may extend tens to hundreds of kilometers offshore. Phytoplankton blooms occur when nutrient-replete conditions promote rapid algal growth rates temporarily uncoupled from grazing pressure. Large diatoms tend to dominate the biomass in phytoplankton blooms that develop in these coastal upwelling regimes, and it has been argued that diatom-driven new production efficiently fuels the food chains that support coastal fisheries, seabirds, and marine mammals.

The potential productivity associated with upwelling centers, however, is not always realized. Recent studies have demonstrated that the supply of iron, a key micronutrient, plays a critical role in controlling phytoplankton blooms in these coastal upwelling regimes. Iron-rich upwelling regions experience extensive blooms of diatoms that deplete available macronutrients; while in iron-poor areas, the biomass of phytoplankton is greatly reduced and high concentrations of unutilized macronutrients persist. Thus, understanding the supply of iron is a key for understanding the variability in productivity along the California coast.

Diatoms are composed of soft organic tissue plus hard parts of biogenic opal. The ratio of elemental building blocks of coastal diatoms normalized to one iron atom is given by:

Carbon :	Nitrogen :	Phosphorus :	Silicon :	Iron
20,000:	3,000:	190:	3,400:	1

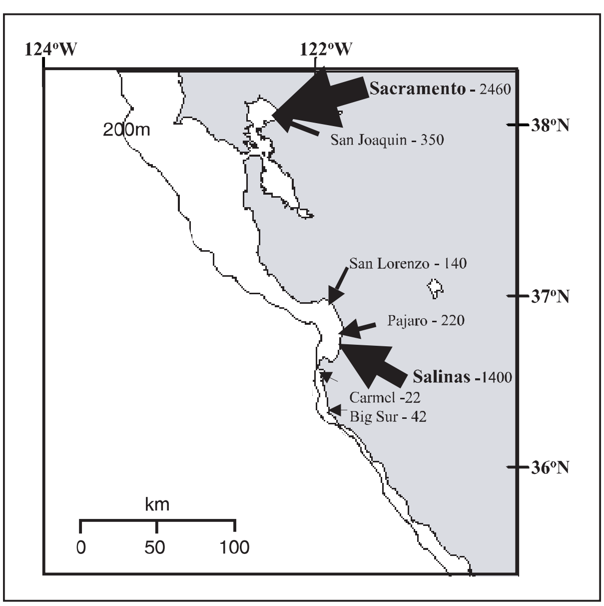


Figure 1. Continental shelf 200-meter depth contour and annual average suspended sediment discharge (in thousand metric tons per year) by the various rivers along central California

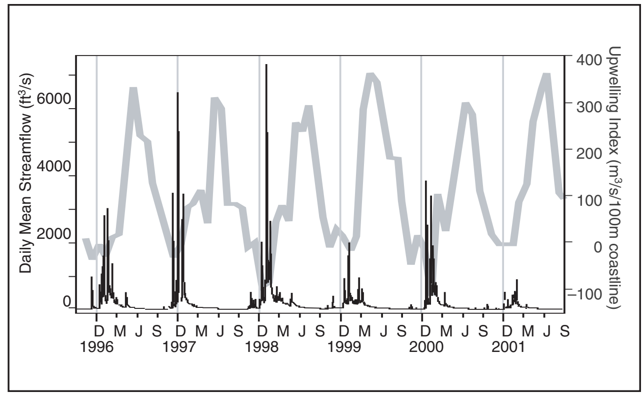


Figure 2. Upwelling index off central California (light; NOAA/PFEL data) and the daily mean stream flow of the San Lorenzo River (dark; USGS data) from October 1995 to September 2001

This means that for every 20,000 atoms of carbon in the soft organic tissue of a coastal diatom, there is a requirement for 3,000 atoms of nitrogen and one atom of iron. The amount of these elements required to produce an extensive bloom of diatoms compared to the concentrations available in the upwelled water correspond to only 10 percent of the available inorganic carbon, versus 100 percent of the available nitrate, 85 percent of the phosphate, 95 percent of the silicic acid, and anywhere from 50 to 1,000 percent of the available iron. If adequate iron is available, then nitrate becomes the key nutrient that limits bloom development. If, however, only a small amount of iron is available, then iron can be the key nutrient that limits the bloom and can result in water low in phytoplankton biomass, but still rich in unutilized macronutrients such as nitrate.

The major source of iron to the central California upwelling regime originates from river discharge of suspended sediments, which is unevenly distributed spatially and temporally (*Figures 1 and 2*). It can be seen that the larger rivers are in the north where the shelf is also broader and that flows are dominated by episodic flood events during the winter. (Often greater than 90 percent of the water discharge can occur during a one-week period.) The suspended sediment discharge is even more episodic, with the rare, high-energy, and high-discharge events able to carry a tremendous amount of mud. In marked contrast, during the summer there is no significant discharge from coastal streams and rivers of central California.

The width of the continental shelf plays a role because when a sufficiently broad continental shelf is present, much of the winter fluvial (from rivers) discharge of suspended sediment is rapidly deposited on the shelf at depths of 40 to 100 meters; thus a relatively broad continental shelf can act as an "iron trap" for these fluvial inputs. This is important since in the winter, when fluvial input is the greatest, upwelling is at a minimum (*Figure 2*). When coastal upwelling of macronutrient-rich water takes place over these broad shelf regions, elevated iron concentrations can be entrained, resulting in water enriched with both macronutrients and iron (*Figure 3, p. 13*). This is the case in the regions to the north of Monterey Bay where extensive blooms of large diatoms are commonly observed. This extra source of iron is not provided along the Big Sur coast, with its narrow shelf and lack of rivers (*Figure 3*). This region along the Big Sur coast has been observed to be a low phytoplankton biomass, iron-limited regime.

The Monterey Bay area is a world center for iron research. Study on the role of iron in the oceans started with pioneering efforts by the late John Martin of Moss Landing Marine Laboratories (MLML) and our research group at the University of California Santa Cruz (UCSC). It has been continued by Kenneth Coale's research group at MLML and Ken Johnson's group at Monterey Bay Aquarium

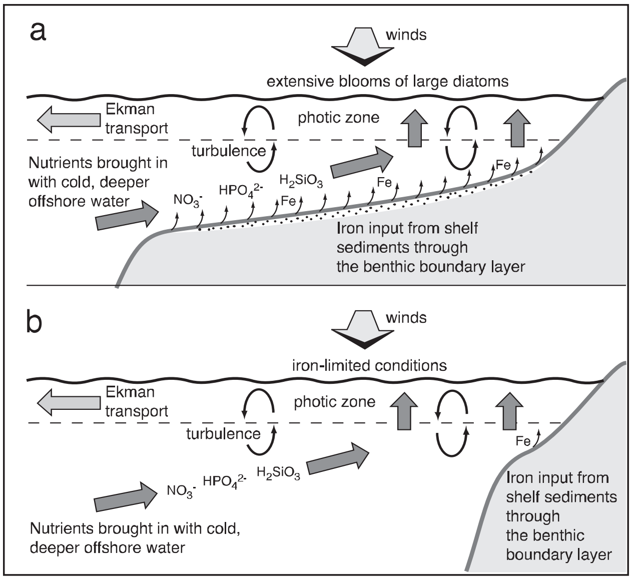


Figure 3. Conceptual model depicting iron supply to surface waters during upwelling under different conditions: a) wide shelf with winter flood deposits; b) narrow shelf without winter flood deposits

Research Institute (MBARI) along with our research group at UCSC, particularly Eden Rue. This expertise is also due in large part to the contributions of research technicians such as Mike Gordon of MLML and Geoffrey Smith at UCSC.

Questions that members of our research group at UCSC are still addressing in the sanctuary region include 1) gaining a better understanding of the mechanisms of delivery and entrainment of the benthic supply of iron during upwelling events; 2) determining the importance of particulate versus dissolved iron as a source of iron to the phytoplankton; 3) determining if there is an enhanced supply of iron to the system in the upwelling seasons following years with major flood events (*see 1997 and 1998 in Figure 2*) versus years without major flood events (*2001 and 2002*); 4) working with Raphe Kudela's research group (UCSC) to examine the potential for optical data (e.g., backscattered light and fluorescence) as tools to map particulate iron distributions in coastal upwelling regions; and 5) examining the role of luxury uptake of iron by diatoms during a time of high availability and their ability to pass this stored iron on to their progeny for them to continue high rates of productivity even under low external iron availability.

A new research program that will allow us to continue to address some of these questions in the sanctuary is the recently funded interdisciplinary program entitled "From Wind to Whales: Understanding California's Upwelling Ecosystems." This is a collaborative research initiative that includes a variety of scientists from the Naval Postgraduate School, MBARI, and UCSC under the auspices of The Center for Integrated Marine Technologies with funding from NOAA.

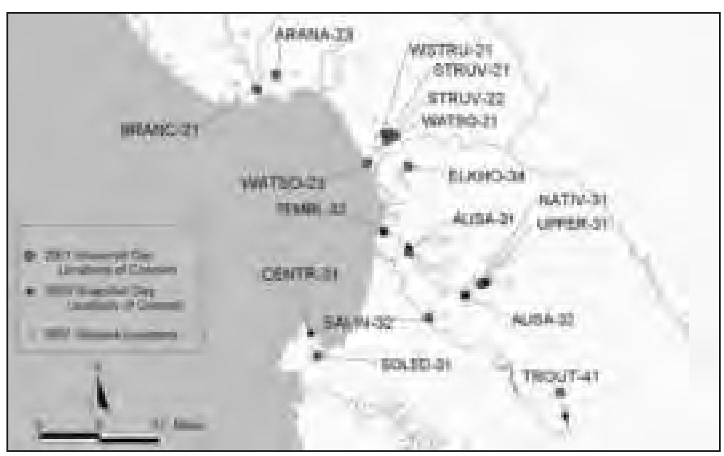
–Kenneth W. Bruland and Ana M. Aguilar-Islas
Institute of Marine Sciences and Department of Ocean Sciences,

Wetlands and Watersheds

Monterey Bay Sanctuary Citizen Watershed Monitoring Network

The Monterey Bay Sanctuary Citizen Watershed Monitoring Network supports approximately 200 citizen water quality monitors throughout the Monterey Bay National Marine Sanctuary. It arose from the need for more information on the health of the sanctuary and its eleven major watersheds and to communicate that information effectively to agencies and the public. Key partners in the network include the sanctuary, the Central Coast Regional Water Quality Control Board (CCRWQCB), the Coastal Watershed Council (CWC), the California Coastal Commission, and The Ocean Conservancy. These groups recognize that individual monitoring groups are more effective when they are integrated, use standardized monitoring protocols and equipment, and have a common database for their data.

The network has provided support and resources to citizen monitoring programs for the past four years. The network coordinator provides annual training events, loans water quality monitoring equipment, maintains a listserv, and has a state-approved quality assurance project plan. A network brochure and web site (www.montereybay.noaa.gov/monitoringnetwork/welcome.html) provide information for citizens to get involved and make a difference in their watersheds. Among other things, the web site contains a directory of active monitoring programs, downloadable reports, and a link to the volunteer Central Coast Ambient Monitoring Program (CCAMP) database developed by the CCRWQCB.



Snapshot Day 2000 revealed five locations of concern. In 2001 four of the five remained on the list, and twelve new sites were added.

With assistance from the CCRWQCB and the State Water Resource Control Board's Clean Water Team, the network coordinator has been working to establish a certification process to "qualify" the data collected by citizen groups, thereby making them more useful to resource managers. Volunteer data uploaded into the CCAMP database will contain qualifiers based on six programmatic elements including: planning and design, training, protocols, quality assurance planning, quality assurance procedures, and record keeping. To date, the Upper Salinas Las Tablas Resource Conservation District (with volunteers from the Upper Salinas Watershed Coalition), San Pedro Creek Watershed Coalition, and the Pacific Grove and Monterey Urban Watch programs are contributing their monitoring results to CCAMP. Soon, the CWC will be uploading their Clean Streams data into CCAMP. Eventually, all of this valuable information will be online on the network web site.

The network coordinator is also responsible for organizing two annual water quality monitoring events each year. First Flush, in which volunteers collect urban storm water runoff from the first major rain of the season, takes place each fall. Samples are collected from storm drain outfalls around Monterey Bay. The samples are analyzed for bacteria, nutrients, oil and grease, total dissolved solids, total suspended solids, zinc, copper, and lead. Interesting trends have been identified with just two years of data. Overall, bacteria, copper, and orthophosphate levels exceeded CCAMP action levels (benchmarks established by the CCRWQCB) at the majority of monitoring sites both years. These contaminants may contribute to fish and wildlife diseases, shellfish contamination, and human health threats.

On November 7 the first rains of 2002 brought the first flush in a storm that drenched the entire West Coast. More than an inch of rain pelted the central coast with walls of water and winds that brought down trees. Capitola and Santa Cruz volunteers mobilized at 2:30 a.m., while Monterey and Pacific Grove volunteers eagerly waited until 5:30 p.m. for the storm to arrive. Added to the list of

WATER QUALITY MONITORING IN ELKHORN SLOUGH

The Elkhorn Slough National Estuarine Research Reserve (ESNERR) has two programs in place to monitor water quality. The volunteer monitoring program began in 1988 and is a cooperative effort among ESNERR, the Elkhorn Slough Foundation, and the Monterey County Water Resources Agency. Twenty-four stations are sampled monthly for temperature, salinity, dissolved oxygen, pH, turbidity, nitrate, ammonium, and dissolved inorganic phosphate. The data are collected in the field by coordinating volunteer Sue Shaw and others.

Courtesy of John Haskins

Volunteer Sue Shaw collecting water quality data in Elkhorn Slough

A second (national) program began in 1995 and also monitors for temperature, salinity, dissolved oxygen, pH, and turbidity (and since March 2002 monitors nitrate, nitrite, phosphate,

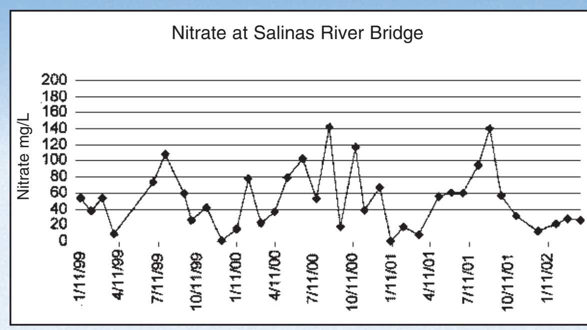


Figure 2. Nitrate in milligrams per liter at the Salinas River Bridge, revealing frequent high levels

ammonia, and chlorophyll). These data are collected continuously at the cooperating twenty-five NERR sites nationwide, allowing for rigorous analyses of time series data across a sample of the nation's estuaries. Data are available from all NERR sites at http://cdmo.baruch.sc.edu/. Originally starting with two sites, this program has grown to four sites at Elkhorn Slough, all of which are sampled for water quality parameters every half hour and for nutrients once a month.

Combining both these programs enables us to conduct spatial and temporal analyses in the Slough. As expected, temporal trends indicate that tides and sunlight have a strong influence on the water quality parameters investigated in the slough. For instance, Azevedo Pond, which is in the upper slough off the main channel and receives a muted tidal signal, has a large fluctuation in dissolved oxygen (DO) saturation (*Figure 1*). This pattern of high saturation in the midday hours and low saturation in the early morning hours is most likely because of shallow waters and muted tidal signals increasing residence time of pond waters, allowing algae to supersaturate the water with oxygen during the day and almost completely remove it during the dark hours through respiration.

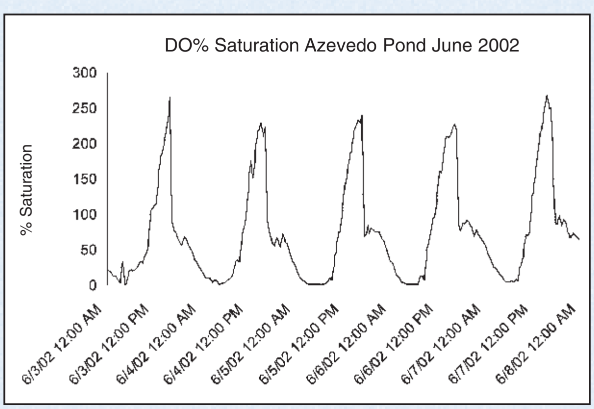


Figure 1. Percent saturation of dissolved oxygen in Azevedo Pond in June 2002. Note the distinctive pattern of high saturation in the middle of the day, when photosynthesis is most active, and lowest saturation – anoxic at times – during the middle of the night when respiration is high.

Spatial analyses have revealed significant differences among sites. For instance, monthly nutrient sampling has revealed exceptionally high nitrate concentrations at stations in waters that feed the lower slough area (*Figure 2*), reaching above 100 milligrams per liter on numerous occasions at multiple sites. These parameters also indicate possible seasonal trends. With long-term data sets such as these we are able to identify human and naturally induced impacts. They also enable us to track changes as a result of mitigations and new management strategies.

–JOHN HASKINS
ELKHORN SLOUGH NATIONAL ESTUARINE RESEARCH RESERVE

laboratory analysis this year was toxicity. Samples were collected at fifteen of the sites for toxicity analysis at the Department of Fish and Game's Marine Pollution Laboratory.

Snapshot Day, in which volunteers collect and analyze water samples from local creeks and rivers, takes place each spring. More than 150 volunteers monitor the health of streams from Pacifica to Morro Bay. This event has been extremely popular and continues to provide a "snapshot" of coastal streams as well as an opportunity for all the groups to work together on a single day. In order to evaluate the results from snapshot days and compare them from year to year, six parameters were chosen to determine "locations of concern." These include dissolved oxygen, water temperature, pH, nitrate, orthophosphate, and E. coli/fecal coliform. If the CCAMP action level was exceeded for three or more of the parameters listed, it was deemed a location of concern. For Snapshot Day 2000, there were five locations of concern. In 2001 four of the five sites remained a location of concern, and twelve additional sites were added to the list (*see Figure 1, p. 13*). For more Snapshot Day information, reports can be downloaded from the network web site. Snapshot Day will expand to become a coast-wide monitoring event in the spring of 2003, thanks to the painstaking efforts of the California Coastal Commission and funding from the State Water Resources Control Board and the Environmental Protection Agency (EPA). The Monterey Bay Sanctuary Foundation will administer the funding.

Citizen water quality monitoring data are becoming a valuable resource for management decisions. Local and state agencies are increasingly searching for answers through data collected by citizen groups. Local jurisdictions use the data to help identify problem areas and improve management decisions. As an example, within the sanctuary, several cities have been supporting a dry weather urban watch program for the past five years. Samples of urban runoff are collected at fifteen different locations bi-weekly, from June through October. The samples are processed using an EPA Pollution Detection kit. The data from this program are used to justify programs such as public education and targeted business outreach. Citizens will continue to provide valuable data as long as a support structure is in place for them and they know the information they are collecting is useful.

–Bridget Hoover
Monterey Bay Sanctuary Citizen Watershed Monitoring Network Coordinator

Endangered and Threatened Species

Foraging Ecology of the Leatherback Turtle

The leatherback turtle is a powerful ocean traveler that ranges from the Arctic Circle to the edges of the Antarctic convergence zone. This unique pelagic reptile spends most of its life at sea, but females haul out onto tropical beaches every two to four years to lay their eggs. Much has been learned about the animal's reproductive biology from studies conducted on nesting beaches, where the females, eggs, and hatchlings are easily accessible, yet little is known about leatherbacks in the marine environment, where they remain elusive and difficult to study. The need to achieve a better understanding of this part of the animal's life history has become increasingly urgent as Pacific populations continue to decline to the brink of extinction, despite intense conservation efforts on the nesting beaches. The Pacific Leatherback Recovery Plan (http://swfsc.nmfs.noaa.gov/PRD/Seaturtle/) has identified the need to identify forage areas, to determine marine habitat needs, and to describe migratory patterns among the highest priorities for action. Monterey Bay is one of the first index areas to have been established for in-water studies of this species.

Leatherbacks have been known to occur in Monterey Bay for some time, but it was not until 2000 that we achieved an exciting breakthrough with our first attempts to capture foraging animals (*see Ecosystem Observations 2000*). Prior telemetry studies had been limited to post-nesting movements of females tagged on nesting beaches.

We attached satellite transmitters to two adult females in September 2000 and tracked the animals as they migrated west; we continued to receive data from one of the turtles for eighteen months as she crossed the Pacific to the Mariana Trench, just north of the main nesting beach in North Papua, when she turned and began swimming east toward the central Pacific. Despite making this long migration back to the nesting areas in Papua, this turtle appears not to have nested, raising questions about factors that might influence timing of nesting and migratory behavior.

This pilot study was expanded in 2001 and is now a permanent component of the National Marine Fisheries Service (NMFS) Southwest Fisheries Science Center's Sea Turtle Research Program, which partners with the Monterey Bay National Marine Sanctuary, Moss Landing Marine Laboratories, University of California Santa Cruz, and Hubbs-Sea World Research Institute. Having established the capacity to capture animals at sea, we increased field effort in 2002 and have now deployed transmitters on a total of thirteen animals, including three males. All were adults, with the largest one weighing 580 kilograms. Genetic results from six samples analyzed so far indicate that the animals are from western Pacific nesting stocks, most likely North Papua, Papua New Guinea, or the Solomon Islands.

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Leatherback turtles aggregate in Monterey Bay in late summer.

We are currently tracking eight turtles (six females and two males), which were tagged in September 2002. As in previous years, the turtles moved rapidly westward after release. One of the turtles has turned around approximately 800 kilometers offshore and recently returned inshore and is currently just south of Monterey Bay. One of the females tagged in 2001 traveled north and foraged around the Gulf of the Farallones for two months before she began a westward migration.

Satellite telemetry is one aspect of a multi-faceted approach to studying the foraging ecology of leatherbacks that involves genetic, biochemical, behavioral, ecological, and oceanographic studies. In addition to looking at long-range movement and pelagic migrations, we are beginning to gain new insights into how leatherbacks interact with the marine environment by focusing on the Monterey Bay ecosystem.

Monterey Bay is one of several areas along the central California coast where leatherbacks aggregate during late summer. Other areas where we have observed the highest densities using aerial surveys include waters off Point Reyes, south of Point Arena, and in the Gulf of the Farallones. These areas represent upwelling shadows or regions where larval fish, crabs, and gelatinous organisms are retained during upwelling relaxation.

We hypothesize that leatherback turtle abundance is linked to the hydrographic retention of zooplankton and subsequent concentration of scyphomedusan prey (jellies and similar animals) in these coastal areas during relaxation of upwelling-favorable winds. When upwelling diminishes at the end of summer, sea surface temperatures along the coast tend to rise markedly. Observations suggest that leatherbacks move into Monterey Bay along with the 14-15^{o} C water. The frequency, duration, and relaxation of upwelling-favorable winds can influence food web development in this region, including the occurrence and concentration of leatherback prey, such as scyphomedusae. Observations suggest that leatherbacks seek out the sea nettle (*Chrysora spp*.) to feed on in Monterey Bay, even though they have several different types of jellyfish to choose from. A better understanding of the factors that influence distribution and abundance of this jellyfish may help shed light on the local movement and dive behavior of the leatherbacks in the bay.

In 2001 locations where turtles were seen during fine-scale aerial surveys corresponded to the 50- to 100-meter depth contours throughout the bay (*Figure 1*). Local hydrographic features may have influenced prey distributions, and future work will attempt to map turtle's behavior against a three dimensional matrix of physical and biotic factors that describe its forage habitat. In 2002 pop-up archival tags (PATs) were attached to four of the turtles in addition to the satellite-linked dive recorders previously used. These PATs were programmed to collect fine-scale dive and temperature data that are archived and transmitted to orbiting satellites once the PAT releases and pops to the surface. Once these data are analyzed we will be able to look at foraging behavior on a finer scale than has previously been possible.

The sanctuary will continue to play a key role in the recovery effort for Pacific leatherbacks by providing a unique venue to study foraging animals. Monterey Bay is perhaps one of the best-studied marine ecosystems in the world, with a wealth of data now available from various projects monitoring the physical characteristics of the marine environment using remote observing systems, such as the deep-ocean moorings deployed by Monterey Bay Aquarium Research Institute that report subsurface temperature, salinity, and current information, or ship-based transect studies across the sanctuary. We will be able to integrate physical and biological oceanographic data from these studies with results from our telemetry and aerial survey work to understand better how the leatherbacks interact with their ocean environment. We will also be able to develop new models to predict their oceanic distribution in order to help formulate appropriate at-sea conservation measures to complement the ongoing efforts on the nesting beaches.

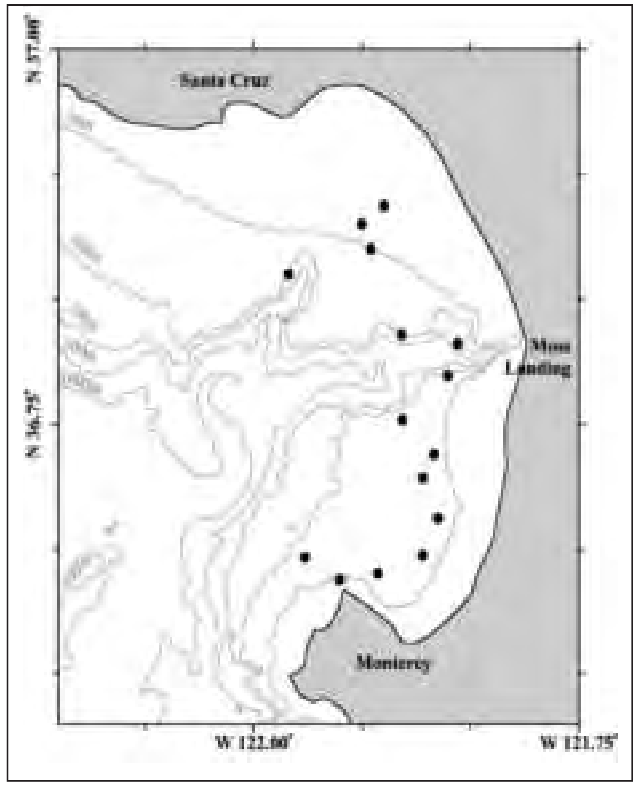

Figure 1. Leatherback sea turtle sightings in Monterey Bay

–PETER H. DUTTON[1], SCOTT BENSON[1], AND SCOTT A. ECKERT[2]
[1]NOAA-NATIONAL MARINE FISHERIES SERVICE, SOUTHWEST FISHERIES SCIENCE CENTER
[2]HUBBS-SEA WORLD RESEARCH INSTITUTE

MARINE MAMMALS

Whale Falls: Islands of Abundance and Diversity in the Deep Sea

Although bottom-dwelling animals are surprisingly abundant in Monterey Bay's deep waters, they are often food-limited – most deep benthic food webs are supported by the slow drizzle of organic particles and detritus ("marine snow") from sunlit waters far above. But every now and then, this slow, nutrient-limited world receives a really big food "particle," such as a dead whale. One whale fall can deliver as much organic material as several thousand years worth of marine snow.

In February 2002 Robert Vrijenhoek and Shana Goffredi of Monterey Bay Aquarium Research Institute (MBARI) discovered a recent whale fall while exploring the outer portion of the Monterey Canyon with MBARI's remotely operated vehicle, *Tiburon*. They returned to the site in October 2002 with Craig Smith, a University of Hawaii professor who has studied whale falls for nearly twenty years. Based on repeated observations of several whale falls off southern California, Smith believes that many whale falls develop similarly over time.

When a large whale dies, its body often sinks directly to the sea bottom, especially if the animal is undernourished. Within days, active scavengers, such as sleeper sharks, rattails, hagfish, and amphipods, converge on the new food source and voraciously remove the flesh from the bones. (Smith has estimated consumption rates of forty to sixty kilograms of flesh per day.) In many cases the whale is stripped to the bone in a matter of months.

Within a year after the whale fall, the whalebones and nearby organically enriched sediment typically become infested with huge populations of polychaete worms and unusual crustaceans, as well as mollusks and other invertebrates. Worms often carpet the seabed at densities of up to 45,000 animals per square meter – higher densities than in any other deep-sea environment. Animals in this

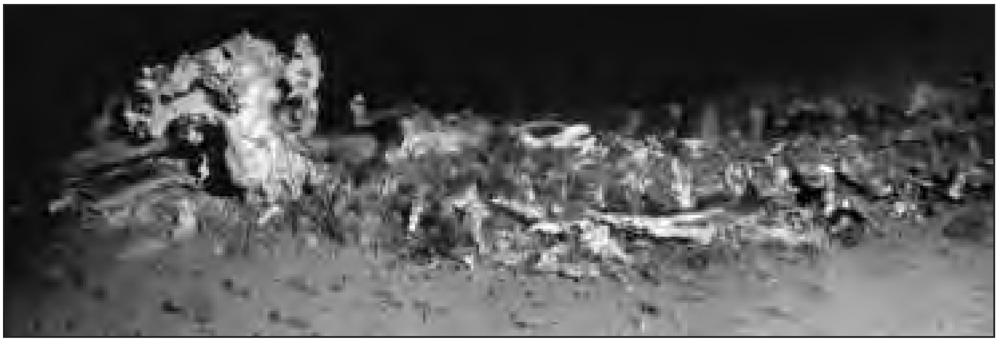

Photo montage of whale fall in Monterey Bay taken during the discovery dive in February 2002

“enrichment-opportunist” community feed directly on organic material in the whalebones and surrounding sediment. Many of the species are as yet undescribed and may be unique to deep-sea whale falls. Despite the high biomass, species diversity is relatively low at this stage, as it is near other concentrated sources of organic material in the marine environment, such as sewer outfalls and salmon pens.

About a year or two after the whale fall, most of the easily digestible organic material has been consumed. However, sulfur-reducing bacteria continue to feed on lipids deep within the whale bones, gradually releasing hydrogen sulfide. This hydrogen sulfide provides the basis for a third-stage, “sulfophilic” community. This community is remarkable for a number of reasons. First, it consists of a self-contained food web with up to five levels (e.g., bacterial producers, bacterial grazers, animals that obtain nutrients from sulfur-oxidizing bacteria within their bodies, scavengers, and primary and secondary predators). Second, this food web is based almost entirely on energy from chemosynthesis instead of photosynthesis. Third, it includes an extremely diverse group of animals (up to 190 different macrofaunal species have been found on a single whale skeleton), many of which are specifically adapted to utilize whale-falls as a food source and substrate. Fourth, the community can be amazingly persistent – at least one large whale-fall community has apparently lasted more than fifty years.

Late-stage whale-fall communities resemble communities at deep-sea hydrothermal vents and cold seeps, where chemosynthetic bacteria also form the basis for unusual, self-contained food webs. About 10 to 20 percent of the roughly 200 sulfophilic species found at whale falls are also found at underwater hydrothermal vents and cold seeps, respectively. However, the majority of species found in each type of environment are unique. Since many of these organisms are difficult to identify based on appearance, researchers at MBARI are using genetic and molecular tools to understand the evolutionary patterns among whale-fall communities and to determine relationships among animals at whale falls, seeps, and hydrothermal vents.

Thirty-million-year-old assemblages of fossil clams and whale bones suggest that whale-fall communities have been around at least as long as whales themselves. This persistence is particularly impressive because each whale-fall community is based on a transitory food source. Sooner or later, planktonic larvae of invertebrates at one whale fall must somehow find and colonize a new whale in order to survive. But whale falls might be relatively common. Smith estimates that, based on current whale populations and whale-fall community persistence, dead whales may occur roughly every five to sixteen kilometers along the seafloor off the Pacific coast of North America. Distances such as these are easily traversed by planktonic larvae.

Octopus living in the remains of the whale’s skull

The recent whale fall in Monterey Canyon is particularly interesting because it lies in deep water (2,891 meters). At this depth mobile scavengers are probably less active, but sulfophilic organisms may appear sooner. Smith and the MBARI scientists are currently analyzing the results of their latest visit to learn more about the persistence and distribution of these unique benthic communities.

–Kim Fulton-Bennett
Monterey Bay Aquarium Research Institute

Bird Populations

Monitoring Mortality Events and Oiling of Seabirds and Marine Mammals Using Beach COMBERS Data

Since May 1997 the Monterey Bay National Marine Sanctuary’s beach monitoring program, the Coastal Ocean Mammal and Bird Education and Research Survey (Beach COMBERS) has obtained important baseline data on deposition rates of beached marine birds and mammals from sanctuary beaches. Local citizen volunteers are trained to conduct systematic monthly beach surveys in order to enumerate and identify all beach cast marine birds and mammals within a three- to four-kilometer stretch of coastline. In May 2001 five additional beaches in the southern portion of the sanctuary were added to the program.

During the past six years, the Beach COMBERS project has revealed episodic mortality events related to natural (e.g., 1998 El Niño) and anthropogenic (e.g., oil spills, fishery interactions) factors and provided data to resource managers and scientists. In 1997 Beach COMBERS data were used to assess fishery-related mortality in southern Monterey Bay. In 1998 the program provided information regarding harmful algal blooms and domoic acid toxicity that affected seabirds and marine mammals in the sanctuary. In the summer of 2001 we provided data on hook-and-line entanglements of the endangered California Brown Pelican to the California Department of Fish and Game and size and age class data to University of California Davis researchers. In 2002 Beach COMBERS provided genetic samples to Cheryl Baduini of Claremont College and her colleagues to examine population genetics and colony affiliation of Shearwaters (*Puffinus spp.*) that travel from colonies in Chile, Australia, and New Zealand. Leg bands recovered from beached birds were useful in documenting movements and survival, contributing to an international effort to understand seabird populations.

During unusual mortality events, Beach COMBERS volunteers collect carcasses for necropsy to determine cause of death. Veterinarians Melissa Miller and David Jessup at the Marine Wildlife Veterinary Care and Research Center in Santa Cruz conduct necropsies and examine birds for disease. The major cause of death for most beached birds was emaciation, but bacterial and fungal infections also may be factors. Collaborations like these will contribute to a greater understanding of the diseases affecting the seabird community in the sanctuary.

To examine trends in seabird mortality in the sanctuary, we have compared data from the current Beach COMBERS program (1997 to 2002) with past beach survey data collected during 1968 to 1969 and 1974 to 1975 by Victor Morejohn at Moss Landing Marine Laboratories and during 1971 to 1985 by researchers at Point Reyes Bird Observatory (PRBO).

The assemblage of species collected during the past and present beach surveys is similar, with changes in composition mainly relating to seasonal influxes in migratory species and episodic booms or die-offs in other species. One apparent difference in species composition is the past abundance of White-Winged Scoter (*Melanitta fusca*). In previous studies, this sea duck was often found on beaches during the winter and spring. Today it is rarely found on Beach COMBERS surveys, which probably reflects changes in its population throughout the North American breeding areas. Since 1977 U.S. Fish and Wildlife Service surveys indicate a 2 to 3 percent annual decline in the number of Scoters (both surf and white-winged) breeding in interior Alaska. Surveys of Canadian breeding areas indicate a reduction in the breeding range and significant declines in numbers of breeding birds. Although the reasons for these declines are not certain, habitat degradation, disturbance, and climate change are suspected as contributing factors. With long-term data sets and a historic perspective, we can gain insight regarding problems facing sea ducks and other wintering waterbirds that visit the sanctuary.

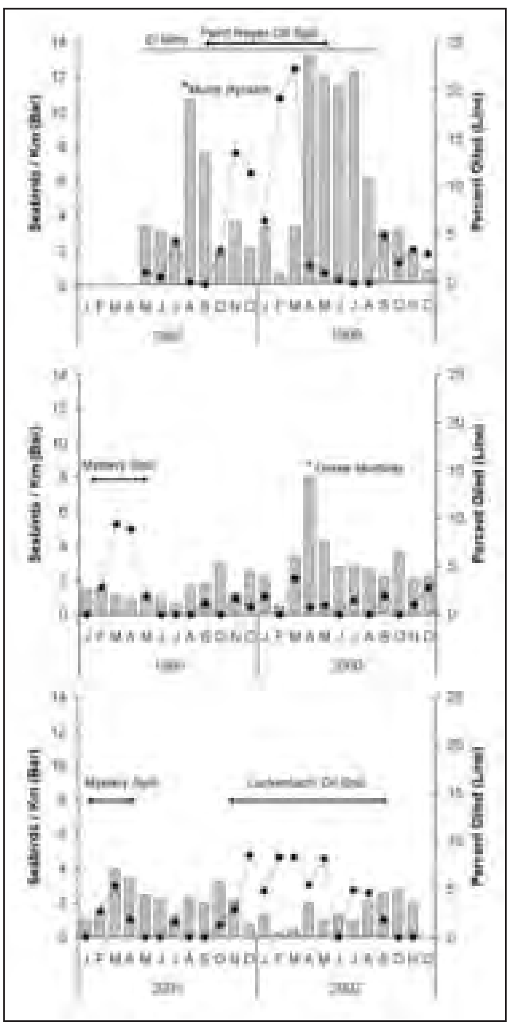

Figure 1. Long-term average deposition rate (Bar) and oiling rate (Line) for ten Sanctuary beaches. Deposition is greatest during El Niño ocean conditions and lowest during major oil events when oiled carcasses are collected from beaches.

Brandt's Cormorants are among the species affected by oil spills.

We have examined trends in oiling rates over our six-year data set (*Figure 1*) and compared these with past surveys to determine whether there has been a change in the incidence of chronic oiling in Monterey Bay. Chronic oiling (non-source) affects seabirds throughout the year, and deposition increases particularly during months with strong onshore winds. During 1971 to 1985, PRBO reported oiling rates averaging 8 percent in Monterey Bay, with the greatest incidence of oiling for diving birds (Loons 9 percent, small Grebes 7 percent, and Alcids 17 to 20 percent). The present oiling rate (2 percent) of seabirds recorded by Beach COMBERS is relatively low by comparison, possibly indicating that oil pollution prevention measures in the past twenty years have been successful. Common Murres (48 percent) and other divers continue to comprise a significant proportion of the total recorded oiled birds. Smaller species, including small Alcids (14 percent) and small Grebes (16 percent) are proportionally more affected relative to their deposition.

From November 2001 to July 2002 Beach COMBERS detected an increase in oiled seabirds. This event was attributed to an ongoing leaking shipwreck, the *Jacob Luckenbach*, off the San Mateo County coast. This source of oil contributed to the death of 236 seabirds collected within the Beach COMBER survey area. The species affected by this spill were mainly diving seabirds, primarily Common Murres (91 percent of total), Rhinoceros Auklet (3 percent), Ancient Murrelet (2 percent), Loons (1 percent), and Western and Clark's Grebes (1 percent). Other species recorded within the survey area were affected to a lesser extent, including California Brown Pelicans, Shearwaters, Fulmars, Gulls, Cormorants, and others (less than 1 percent each). (*The immediate threat from the Luckenbach has been removed; see article on page 23.*)

Results from the recent *Luckenbach* spill are consistent with our five-year trend in species-specific oil rates; namely diving seabirds, Alcids, Loons, and Grebes, which spend their time at sea sitting on the water, are the most susceptible to oiling. One caveat to these data is that small-bodied birds (like shorebirds, smaller Alcids, and Storm-Petrels) probably are not represented in the beach bird data simply because they do not persist long on the beach. Mobile birds that are apt to fly when disturbed (e.g., Gulls, Shearwaters) may move out of the area and die before being detected. Within these limitations, we are confident that the Beach COMBER program is making great progress in understanding trends in sources of mortality for seabirds in the sanctuary.

–Hannah Nevins and Jim Harvey
Moss Landing Marine Laboratories

The Groundfish Crisis: What Went Wrong?

The groundfish fishery off the U.S. West Coast is facing unprecedented restrictions as 2003 approaches. The Pacific Fishery Management Council (PFMC; www.pcouncil.org/) has adopted a new management framework for controlling the harvest of overfished rockfish stocks within the Exclusive Economic Zone (EEZ). Under this new regulatory framework, large areas will be closed to groundfish fishing year-round. For example, south of Cape Mendocino a “Rockfish Conservation Area” has been established that strictly regulates fishing in ocean waters 120 to 900 feet deep, which essentially encompasses the entire continental shelf ecosystem off the coast of California. Within that depth zone, no fishing for rockfish or lingcod will be allowed. This new regulatory framework was implemented to reduce the bycatch of several overfished rockfish species, especially bocaccio (*Sebastes paucispinis*).

So how did we get into this dire situation? Have we been the victims of avaricious fishermen and laissez-faire managers? That seems to be the most frequent explanation, and it is they who have been most severely criticized in the media. However, there is much more to this story. In fact, for years there were serious flaws in the scientific advice that was presented to the council as the foundation of its decision making. The deficiencies were not easy to foresee and were due to a combination of inadequate data and fishery productivity that was far lower than anyone imagined. To understand how we got to this point, one must follow the history of groundfish management since the passing of the original Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) in 1976 to the present.

At the time the MSFCMA was passed, we knew little about the groundfish resources off the U.S. West Coast, particularly with respect to the potential sustainability of these fisheries. Even so, by 1982 the PFMC had developed a groundfish Fishery Management Plan (FMP) that required the determination of allowable biological catches (ABCs) for each actively managed stock. The ABC is a purely scientific determination that attempts to identify the annual catch of a stock if the fishery were managed to achieve the long-term maximum sustainable yield (MSY). However, facing a dearth of scientific information during the early 1980s, the PFMC adopted ABCs for many stocks that were based simply on the amount of historical catch, which capped groundfish harvests at their existing levels. At the time, this was viewed as a “first, do no harm” approach to management.

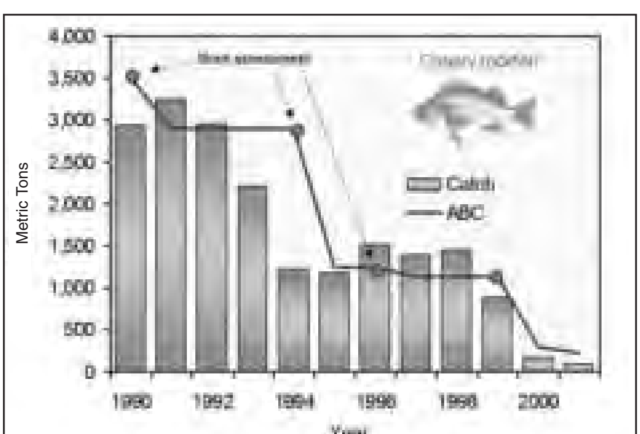

Figure 1. Relationship between the allowable biological catch (ABC) and the total catch of canary rockfish from 1990 through 2001. Points mark the completion of stock assessments, which resulted in a scientific change in the ABC.

As the information base increased markedly during the 1980s, individual “stock-assessments” began to be completed on the most important species in the fishery. A stock assessment is a scientific analysis that assembles all known sources of information about a species (e.g., landings, age- and length-frequency data, catch-per-unit-effort statistics, life history parameters) and funnels the information into a population model that statistically fits the data. The model is then used to answer questions concerning the status of the stock. Several things result from a stock assessment, including (1) an estimate of current stock size and (2) the historical time series of spawning stock size and recruitment, that is the new additions to the population. In theory, the latter information can be used to establish the innate productivity of a stock and MSY and the optimal rate of fishing (FMSY) can be determined. However, because of tremendous year-to-year variation in reproductive success, estimates of recruitment are inherently imprecise. This variability makes it nearly impossible to determine stock productivity parameters accurately.

Instead of relying on ‘noisy’ spawner-recruit information to set ABCs, the council adopted a harvest policy that still enjoys widespread use throughout the world today. That policy consists of

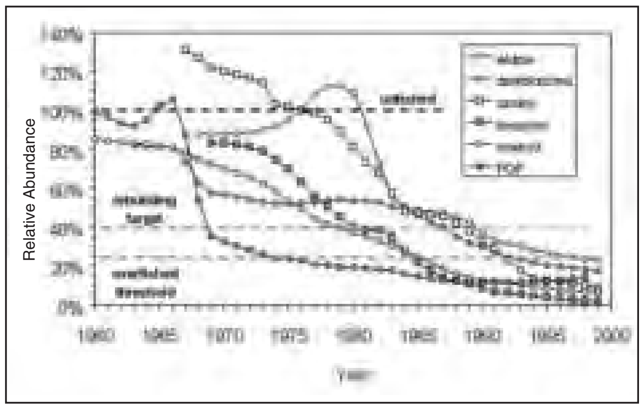

Figure 2. Relative population status of six overfished rockfish species. Populations that decline to below 25 percent of their unfished population level are declared overfished. Overfished stocks are considered rebuilt when they reach 40 percent of their unfished level.

applying a constant rate of fishing pressure to a stock, irrespective of population size; that is, a constant rate policy takes a fixed fraction (e.g., 10 percent) of the stock every year as harvest. Theoretical results show that such a policy has many desirable qualities, although F_{MSY} must first be determined, which unfortunately requires analysis of highly variable spawner-recruit data. However, theoretical results developed in the early 1990s by William Clark seemed to solve that problem. He showed that, over a broad range of productivity conditions, harvesting at the so-called $F_{35\%}$ rate would be expected to produce no worse than 75 percent of MSY. ($F_{35\%}$ is the rate of fishing that reduces the reproductive contribution of a new female recruit entering the exploited stock to 35 percent of what it would be if there were no fishing.) Best of all, that rate could be calculated from basic life history and fishery information; no spawner-recruit analysis was needed. Based on this scientific information, the council then adopted a groundfish harvest policy that applied the $F_{35\%}$ rate to estimated stock size to yield the ABC. As a case in point, Figure 1 shows that the annual catch of canary rockfish was usually well within the ABC during the entire 1990s. The important conclusion here is that the PFMC adopted a scientifically based harvest policy to set ABCs, and that harvest levels actually conformed to the policy for many years. In that regard, canary rockfish is by no means exceptional.

It wasn't until the MSFCMA was re-authorized in 1996 that the real difficulty was revealed. Language in the new Sustainable Fisheries Act required that all fishery management councils establish biomass-based targets and thresholds when setting ABCs. Whereas up until that point catches were determined solely by current stock size and the harvest rate proxy, now the councils had to consider the overall amount of stock depletion. To satisfy this new law, the PFMC adopted an amendment to the groundfish FMP that set a biomass target of 40 percent of the unfished level (B_0) and an overfished threshold of 25 percent of B_0. The new law also required that if stock size were to fall below the overfished threshold, then a rebuilding plan had to be developed to return the stock to target level. However, as the council began applying its new biomass-based policies, it quickly became apparent that many rockfish stocks were overfished, some severely so (*Figure 2, p. 19*). Bocaccio, for example, is currently estimated to be 4 percent of B_0.

So what went wrong? Results from a recent harvest policy workshop on West Coast groundfishes show clearly that over the past two decades these species have been amazingly unproductive stocks. The fallacy of applying Clark's $F_{35\%}$ rate as a surrogate estimate for F_{MSY} is that under current conditions many of our stocks, especially the rockfishes, are barely able to replace themselves, even in the absence of a fishery. In essence, the PFMC used an established "rule of thumb" to set ABCs when they were dealing with stocks that were statistical outliers. Because the proxy harvest rate greatly overestimated F_{MSY}, the stocks continued to decline. Now, due to the need to rebuild and continued low productivity, it will take many years to rebuild overfished species to their target levels.

–Steve Ralston
National Marine Fisheries Service

Behind the Groundfish Closure

In the summer of 2002 the Pacific Fisheries Management Council (PFMC) closed waters outside of twenty fathoms to groundfishing, due to the depleted status of bocaccio, whose numbers have plunged by 96.4 percent since 1969. The council asserts that this action should save the fish commonly sold as Pacific red snapper from extinction and promote its eventual recovery. However, even under the new restrictions the slow-growing, slow-to-reproduce rockfish is not expected to recover for 170 years, according to the National Marine Fisheries Service (NMFS).

The Magnuson-Stevens Fishery Conservation and Management Act, passed in 1976, created a network of regional councils to manage the nation's fisheries in federal waters. The councils are required to manage these resources pursuant to management plans that are approved by NMFS. The Pacific Coast Groundfish Fishery Management Plan (FMP) was implemented in 1982. Previously management had been under the jurisdiction of the states of California, Oregon, and Washington. When the groundfish FMP was adopted, it established the authority and limitations on council actions, but was essentially a framework plan that did not contain specific regulations or management measures. It has been amended thirteen times in the last twenty years to respond to new statutory requirements and changing conditions in the fishery. Many argue that until now, the commercial fishery has been overexploited, despite a maze of regulation. In 1983 catch limits were first imposed, and over the past twenty years certain species have been the targets of specifically tailored efforts such as trip limits and regional management schemes. In 1994 the groundfish fishery was divided into open access and limited entry, with separate quotas and trip limits for each. The recreational fishery has traditionally been restricted with bag limits, but in 2000 recreational fishing was closed from March to June for all non-nearshore rockfishes.

The accompanying graph (*Figure 1*) depicts the catch of rocky deep shelf and slope rockfishes in the sanctuary over the past twenty years. The downward trend is likely due to a combination of decreasing abundance and increasingly restrictive regulations. Each "Q" on the graph represents the imposition of a quota for a species within the rocky deep shelf and slope groundfish complex. Common species within the sanctuary that have simultaneously exhibited the most significant declines in mean length over the past twenty years include chilipepper rockfish, bocaccio, yellowtail rockfish, and widow rockfish.

Bycatch is a particularly serious issue with which the council has had to contend. Mortality of deep-dwelling rockfishes is virtually guaranteed when they are brought to the surface. The council has used estimates of rockfish bycatch of 15 to 30 percent of total catches for harvest modeling and management purposes. However, this range is a rough approximation and may represent a conservative estimate, particularly in bottom trawls. This has greatly complicated the effective establishment of harvest levels, which aim to restore what may be severely depleted stocks. Bycatch problems may also impact or even close other fisheries with high incidental catch rates such as the spot prawn fishery.

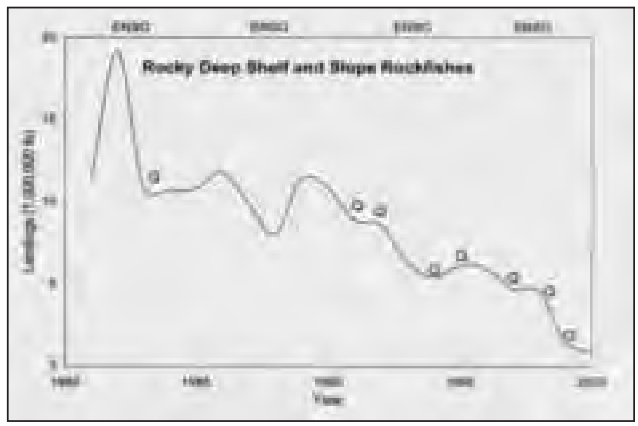

Figure 1: Reported commercial landings from 1981 through 2000 of rockfishes within the rocky deep shelf and slope habitats at the five major ports associated with the sanctuary. ENSO: El Niño Southern Oscillation (Source: Richard Starr, Jason Cope, and Lisa Kerr, Trends in Fisheries and Fishery Resources, a Sea Grant Publication, 2002.)

Local environmentalists believe that the groundfish collapse could have been avoided if the PFMC had heeded repeated warnings from marine scientists. They feel that the council has a pro-fishing bias and required absolute proof of a collapse before it was willing to restrict fishing, which has resulted in massive closures that will last decades with no guarantee that these fisheries will ever rebuild. Lawsuits filed by environmentalists such as the Natural Resources Defense Council may have been an additional catalyst for the closure. These alleged failures on the part of the council to adhere to statutorily required rebuilding plans designed to restore overfished stocks.

On the other hand, many central coast trawlers feel that the council is caving to pressure from environmental groups. The fishermen argue that the PFMC is required to base its decisions on data, and that the paucity of information available is an insufficient basis for such draconian measures. Many assert that there are more bocaccio in local waters now than at any time in the past ten years, and that the closure is a response to old, unreliable data.

Conservationists and fishermen are both concerned about the increased fishing pressure that will now be shifted to the nearshore and deep slope environments. Particularly susceptible are species such as lingcod and greenlings, which are already subject to heavy fishing pressure. With an increased amount of commercial and recreational fishing effort nearshore, there will also likely be more vessel groundings, exposing fishermen and the coastal environment to greater risks. Fishermen and environmentalists both hope that the social and economic sacrifices caused by the groundfish closure will ultimately lead to solutions that protect the ecosystem and its resources and sustain the fishing industry as a vital part of the local culture and economy.

–Huff McGonigal
Monterey Bay National Marine Sanctuary

The Marine Life Protection Act

In February 1999 the Marine Life Protection Act (MLPA) was added to the California Fish and Game Code to deal explicitly with the use of marine protected areas (MPAs) to conserve marine resources in California. This idea of setting aside specific areas of marine habitat for restricted purposes is long-standing, but the explicit use of MPAs as an alternative management scheme for worldwide marine ecosystems has only been seriously considered since the late 1950s. The MLPA recognizes the educational, recreational, scientific, socioeconomic, and environmental importance of California's living marine resources and the need to protect them from potentially destructive entities such as pollution, coastal development, and other destructive human activities. Along with the modification of California's existing MPAs, a process of abolishing or establishing new MPAs is also required by the MLPA. The following is a list of six primary goals of the MLPA, to be used as guidelines to formulate MPAs:

1. To protect the natural diversity and abundance of marine life and the structure, function, and integrity of marine ecosystems
2. To help sustain, conserve, and protect marine life populations, including those of economic value, and rebuild those that are depleted
3. To improve recreational, educational, and study opportunities provided by marine ecosystems that are subject to minimal human disturbance and to manage these uses in a manner consistent with protecting biodiversity
4. To protect marine natural heritage, including protection of representative and unique marine life habitats in California waters for their intrinsic value
5. To ensure that California's MPAs have clearly defined objectives, effective management measures, and adequate enforcement and are based on sound scientific guidelines
6. To ensure that the state's MPAs are designed and managed, to the extent possible, as a network

The California Department of Fish and Game (CDFG) has begun a process to designate MPAs that fulfill the requirements of the MLPA. Constituent involvement and input is important in the plan preparation, with all final decisions and recommendations based on the best available scientific knowledge. The following components are to be included in the plan:

- Recommendations for the extent and type of habitat that should be included in MPAs
- A list of species and groups of organisms that may benefit from MPAs – including their habitat and ecological requirements and dependent oceanographic conditions
- An analysis of current MPAs, with recommendations on the adequate size, number, and siting of each MPA, and proposed alternatives to current networking of MPAs
- Recommendations for monitoring and research within the proposed MPA network to assist in the adaptive management of the system
- Recommendations for management and enforcement to ensure appropriate and effective protection of each area under designation

Seven regional working groups representing various constituencies have been convened by CDFG to provide input into the process of designating MPAs. Three of these groups (from the San Francisco, Monterey, and Morro Bay regions) are focusing on the area encompassed by the Monterey Bay National Marine Sanctuary. Further information can be found by visiting the California Department of Fish and Game web site (www.dfg.ca.gov/mrd/mlpa).

(Edited from *Trends in Fisheries and Fishery Resources Associated with the Monterey Bay National Marine Sanctuary from 1981-2000*, by Richard Starr[1], Jason M. Cope[2], and Lisa Kerr[2], with GIS analysis and maps provided by Jamie Kum[3].)

[1]University of California Sea Grant Extension Program
[2]Moss Landing Marine Laboratories
[3]California Department of Fish and Game

Squid Management Plan

Market squid, *Loligo opalescens*, are the focus of the largest commercial fishery in California and are harvested commercially by targeting spawning aggregations primarily off southern California and Monterey Bay. In addition to supporting an important commercial fishery, the market squid resource is important to the recreational fishery and is vital forage for numerous seabirds, marine mammals, and fish species.

A growing international market for squid and declining squid production in other parts of the world have resulted in an increased demand for California market squid. As a result, commercial landings of market squid in California more than quadrupled from 1980 to 1997. Concern over the rapid increase in squid harvest and new, more efficient vessels entering the fishery led to industry-sponsored legislation in 1997 that asked for management improvements and placed a moratorium on the number of vessels in the fishery. In 2001 the legislature approved a bill that provides for the management of the market squid fishery by the Fish and Game Commission (FGC) and requires the adoption of a squid fishery management plan.

Several interim regulations have been enacted by the FGC to manage the squid fishery. These include: 1) Commercial squid fishing is prohibited from noon Friday through noon Sunday. Because spawning aggregations are targeted by fishermen, this closure provides a consecutive two-day respite for squid from fishing pressure. 2) Squid fishing vessels and light boats are required to maintain logbooks, which provide the California Department of Fish and Game with information on fishing activities. 3) The squid fishery uses high-powered lights to attract and aggregate spawning squid to surface waters for harvest. Each vessel fishing or lighting for squid is limited to a maximum of 30,000 watts of attracting lights; these lights must be shielded. Lighting regulations are intended to reduce the total amount of light each vessel may use and keep light from shining on land where it may impact seabirds or coastal communities. 4) Finally, a seasonal harvest guideline of 125,000 short tons was enacted for the commercial squid fishery to prevent expansion of the harvest beyond current levels. In addition to the interim management regulations, the squid fishery management plan considers options for limited entry including a capacity goal and permit transferability, daily trip limits, and monitoring the fishery through egg escapement.

The original adoption date (December 31, 2002) for the market squid fishery management plan has been delayed; the expected adoption date is now the summer of 2003. A preliminary draft of the management plan can be viewed at www.dfg.ca.gov/mrd/marketsquid/index.html. Public comment is still being accepted.

–Annette E. Henry and Kevin T. Hill
California Department of Fish and Game

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Market squid (Loligo opalescens)

Exotic Species

Keeping Watch for "Least Wanted" Invaders

Biological invasions of marine habitats, particularly estuaries, are occurring at an accelerating rate. The ecological threats posed by some alien species rival those of pollution or anthropogenic habitat destruction and are among the greatest resource management challenges for marine and estuarine ecosystems. Once widespread and abundant, aquatic invaders are extremely difficult, if not impossible, to eradicate. However, if they are detected soon after initial establishment, removal efforts can be successful. Such management depends on early detection of new invasions within this window of opportunity.

The Elkhorn Slough National Estuarine Research Reserve, in partnership with the Elkhorn Slough Foundation and the Monterey Bay National Marine Sanctuary and with funding from California Sea Grant, has recently launched an "Early Detection Program for Aquatic Alien Invaders." The goal of this new program is to detect new invasions of problematic non-native aquatic organisms early enough to allow for successful eradication.

"Alien," "non-indigenous," "non-native," "exotic," or "introduced" species are those moved far beyond their natural ranges by human activities. Aquatic species are transported among bioregions by activities such as commercial shipping and oyster culturing and can spread within a region due to local boat traffic and dispersal of larvae on currents. Aquatic invasions have been extremely common in recent decades and are continuing at a rapid pace. Estuaries are particularly highly invaded; those with big ports often have hundreds of non-native species established in them. Many non-native species may have relatively minor influences on the communities they


Northern Pacific Seastar
(*Asterias amurensis*)

Description: This is a large, hardy seastar that can grow to 40-50 cm in total diameter but has a relatively small central disk. The tips of the arms are distinctively turned upwards. The body is yellow and is sculptured with red and purple pigmentation on its top surface, while the underside is uniformly yellow. The native ocher star (*Pisaster ochraceus*) is superficially similar, but generally doesn't have such strongly upturned arm-tips. The native pink seastar (*P. brevispinus*) can be distinguished by its pink color, and the giant spined seastar (*P. giganteus*) by the distinctive blue rings surrounding spines on its top surface.

Habitat: This species is typically found in shallow water of protected coasts. It can tolerate a wide range of temperatures, and, unusual for an echinoderm, a wide range of salinities. Unlike the native *Pisaster* species, *Asterias* is often found in estuaries.

Origin: Northern China, Korea, Russia, Japan and far northern Pacific waters.

Invaded Areas: South Eastern Australia and the Tasmanian coast.

Concerns: Invasive *Asterias* number in the millions on parts of the Australian coastline. A voracious predator particularly on bivalves, this seastar has been shown to impact oyster culturing and shellfish production in these regions. Since estuaries on our coast do not have any native seastar predators, our native bivalves might be particularly vulnerable to an invasion by *Asterias*. Other native consumers of bivalves might also suffer from competition with rapidly burgeoning seastar populations.

Northern Pacific Seastar Image © NOAA Photo Library

Sample page from Elkhorn Slough National Estuarine Research Reserve's new booklet on exotic species

invade. Some, however, have dramatic negative impacts. Our early detection program focuses on such species, whose negative effects have been demonstrated elsewhere. These non-native species may have impacts at a variety of scales. Invaders have been shown to cause local extinction of native competitors or prey organisms, alteration of community composition or food webs, change in physical habitat structure, and even alteration of energy or material flux through whole ecosystems.

What can be done about aquatic invasions? On one hand, prevention of further invasions is critical. Public support for regulatory measures decreasing human transport of invasive propagules will help prevent invasions. On the other hand, control of existing invasions is sometimes possible. Once a non-native aquatic species has become abundant and widespread, it is difficult or impossible to control it. However, there is a window of opportunity soon after invasion when eradication efforts may be successful. In order to intervene during this early establishment phase, early detection of new invasions is essential.

In order to accomplish such early detection during the window of opportunity for eradication, we have developed this new program. We began by assessing existing non-native species composition in the region to establish a baseline and then chose "least wanted" invaders for the area. From a potential pool of hundreds of known aquatic invaders, we chose a subset of two dozen species that: 1) are not yet present in the Monterey Bay area, 2) have a high potential to be transported there (especially from nearby sources such as San Francisco Bay), 3) are relatively large and easy to identify, and 4) are likely to have a significant ecological impact if they invade.

For example, one invader included is the Northern Pacific sea star (*Asterias amurensis; see box at left*), which has invaded Australia and become very abundant, affecting oyster culturing and other native shellfish, which it consumes voraciously. Another species highlighted is the Atlantic ribbed mussel (*Ischadium demissum*), blamed with killing and maiming endangered California Clapper Rails in San Francisco Bay. The channeled whelk (*Busycotypus canaliculatus*) was included because it is much larger than our native mudflat snails and has been shown to consume a variety of bivalves in San Francisco Bay.

Each of the two dozen "least wanted" species is described in booklets we have published. We provide information on diagnostic features for identification; information on habitat, native origin, invaded areas, and ecological concerns; and instructions on what to do if a putative invader is sighted. We will help to coordinate interagency efforts to plan the most appropriate response strategy and will support rapid response efforts to contain or eradicate the new invasion, if appropriate. The target areas for this early detection program are Elkhorn Slough and Monterey Bay, because the coordinators of this program are based there, because we have good baseline information for these areas, and because there are many citizens active in aquatic habitats there. However, we welcome reports from as far south as Morro Bay to as far north as Moss Beach.

The success of this program depends on having as many pairs of eyes as possible on the lookout for new aliens. Towards this end, we are attempting to provide booklets to all citizens in the Monterey Bay area who frequent aquatic habitats and are likely to notice alien species. By holding a training workshop and providing free materials, we have involved about fifty regional coastal organizations (kayaking, fishing, diving, conservation groups; harbormasters; government agencies; aquaria; universities and research organizations) in this effort, resulting in broad dissemination of nearly 4,000 booklets. Free booklets, flyers, and a CD providing background on aquatic invasions are available by sending an e-mail to research@elkhornslough.org. The booklet is also available in PDF format from www.elkhornslough.org/invader.

By involving the community in this effort to look for and report new invasions of "least wanted" species, we are increasing the likelihood of detecting new invasions in time to take action. The more individuals who are familiar with these unwanted aliens, the better chance we have to protect the rich native coastal biodiversity of central California.

–Kerstin Wasson
Elkhorn Slough National Estuarine Research Reserve

The two dozen least wanted alien species for the Monterey Bay region

GROUP	LEAST WANTED SPECIES	COMMON NAME
Algae	*Caulerpa taxifolia*	Caulerpa
	Undaria pinnatifida	Wakame
Plants	*Spartina alterniflora*	Smooth cordgrass
Invertebrates	*Phyllorhiza punctata*	Spotted jellyfish
	Maeotias inexspectata	Black Sea jellyfish
	Sabella spallanzanii	Mediterranean fan worm
	Balanus amphitrite	Striped barnacle
	Procambarus clarkii	Red swamp crayfish
	Homarus americanus	American lobster
	Eriocheir sinensis	Chinese mitten crab
	Rhithropanopeus harrisii	Harris mud crab
	Ilyanassa obsoleta	Eastern mud snail
	Busycotypus canaliculatus	Channeled whelk
	Rapana venosa	Veined rapa whelk
	Ischadium demissum	Atlantic ribbed mussel
	Perna spp.	Green mussel
	Mercenaria mercenaria	Northern quahog
	Petricolaria pholadiformis	False angelwing
	Pteria sterna	Winged oyster
	Potamocorbula amurensis	Asian clam
	Asterias amurensis	Northern Pacific sea star
	Zoobotryon verticillatum	Spaghetti bryozoan
Vertebrates	*Tridentiger trigonocephalus*	Chameleon goby

Human Interactions

The SS *Jacob Luckenbach*: Solving the Mystery of the Winter Serial Killer

December 8, 2001 – A U.S. Coast Guard helicopter skims over ocean waters of the Monterey Bay National Marine Sanctuary, searching for a mystery oil spill that is forcing hundreds of oiled seabirds ashore from Point Reyes to Moss Landing. This day the helicopter crew expands its search farther offshore and discovers an isolated patch of oil seventeen miles southwest of the Golden Gate Bridge.

July 14, 1953, 4:38 a.m. – The 468-foot freighter *Jacob Luckenbach*, laden with war supplies, steams westward out of San Francisco Bay into a black and foggy sea en route to Korea, just days before the end of the war. Suddenly, the *Luckenbach* shudders from the impact of a violent collision with an identical freighter, the SS *Hawaiian Pilot*. The crippled *Hawaiian Pilot* limps into San Francisco Bay, as the *Luckenbach* suffers massive flooding and slips beneath the waves just thirty minutes later. For decades, the *Luckenbach* lies silent in 180 feet of water, but time, currents, and aging metal conspire to release up to 450,000 gallons of fuel oil trapped in the ship's lower holds.

Throughout the 1990s natural resource agencies were baffled by the mysterious oiling of large numbers of seabirds during fall/winter storm seasons. The oil-soaked birds suddenly appeared on central coast beaches, but no oil slicks could be found. Oiled feathers and sticky tar balls were put into cold storage, in hopes that the oil could someday be matched to a source. On Thanksgiving Day 2001 the oiling started all over again, but this time an aggressive investigation by a special task force of twenty agencies identified the culprit, using oil chemistry analysis and other advanced technological tools.

By early January lab tests concluded that the oil sampled from seabird feathers collected from November through December was from the same source. Further investigation matched the recent samples to oil samples from years past, signifying a single source for a decade of spills. Oil spill computer modeling, hindcasting, satellite imagery, and aerial survey data provided clues to the approximate location of the source, by then suspected to be a submerged shipwreck or a natural petroleum seep. Further chemical analysis eliminated natural seeps as a likely cause.

A search of four federal and state archaeological databases identified eight suspect shipwrecks from decades past, and a side-scan sonar search pinpointed the final resting place of the *Jacob Luckenbach*. When investigators arrived to inspect the site, they found oil floating on the water above the wreck. Fuel oil taken from the ship's hold by underwater submersibles and divers matched the historical samples, proving conclusively that the *Luckenbach* was the source of the mystery spills.

Federal and state natural resource agencies decided that the future threat of oil releases from the shipwreck had to be eliminated. The Coast Guard funded and led development of a plan to pump the fifty-year-old oil from the *Luckenbach* into a barge, but the project would prove to be a monumental challenge, growing in cost from an initial estimate of $3 million to $19 million.

A massive 400-foot work barge was anchored over the *Luckenbach*, and divers lived in a continuously pressurized environment for days on end. The ship lay broken into three major sections, still loaded with thousands of tons of unstable cargo – presenting a constant physical threat to divers in an already hostile environment. The oil had migrated into compartments throughout the hull and was often the consistency of molasses, requiring specially designed pumps, heating rods, and steam injection equipment to liquefy the oil for slow transport to the surface.

The projected two-week removal process stretched to four months as the team encountered one obstacle after another. By project end, 85,000 gallons of heavy oil had been removed. But throughout the project, the *Luckenbach* continued to leak oil, fouling more than 2,000 additional seabirds.

Ongoing research and advanced technology contributed greatly in solving this mystery. The response effort reconfirmed the value of archaeological assessment and data collection to sanctuary resource protection. Years of beach survey programs and sample collection/storage proved key to pinpointing the oil source, and interagency coordination and basic investigative techniques were essential to the success of the response effort.

The immediate threat from the *Luckenbach* has been removed, but an unknown amount of oil still remains trapped in the inner reaches of its hull. Even more ominous is the knowledge that many more *Luckenbach*s lie quietly on the seafloor within the sanctuary, such as the 440-foot oil tanker *Montebello*, sunk by a Japanese submarine in 900 feet of water off Point Piedras Blancas in 1941, with 4.1 million gallons of heavy Santa Maria crude oil on board. The challenge to the sanctuary and its partners is finding solutions and funding to remove these deadly cargoes before the sea does.

–Scott Kathey
Monterey Bay National Marine Sanctuary

Cruise Ship Visits

This year Monterey Bay hosted three visits from cruise ships – in May, September, and October. This unusual activity was preceded by a small cruise ship visit in 1996. Not surprisingly, local citizens and organizations, including the Monterey Bay National Marine Sanctuary, expressed concern about this activity. During the spring the sanctuary led collaborative efforts with local, state, and federal agencies; non-profit advocacy organizations; the local business and tourism industry; and the cruise line industry to try to identify potential environmental impacts as well as economic and educational opportunities associated with scheduled cruise ship stopovers and to recommend solutions to minimize impacts and maximize opportunities.


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Three cruise ships visited the Sanctuary in 2002.

Sanctuary Regulations Relevant to Cruise Ships

Regulations prohibit discharges into the sanctuary but provide an exception for biodegradable effluent generated by a properly functioning marine sanitation device (MSD) approved in accordance with section 312 of the Federal Water Pollution Control Act. However, the standards set for MSD-generated sewage are significantly lower than those required by municipal treatment plants. Discharge of oily bilge water is not allowed.

No new municipal or private sewage outfalls may be constructed in the sanctuary. While this does not include regulation of cruise ship discharges, it does point to the intent of the regulations to restrict the location of large-scale sewage discharges.

Cruise ship visits attract attention because there are many related concerns as well as opportunities. Major concerns include discharges in the form of treated and untreated sewage; “gray water” from sinks, showers, galleys, and laundries; detergents from washing down decks; hazardous wastes from photography labs, dry cleaning, medical and dental wastes, and used paints; and solid waste. Other concerns include exotic species transfer via ballast water or hull transport, seafloor and habitat damage from anchoring, and marine mammal and bird harassment. Cruise ships offer many opportunities as well, including economic benefits to local communities and the potential to educate large numbers of visitors, as well as the cruise ship industry and crew, about the sanctuary program, our sanctuary, and protection of our natural resources.

As a result of the sanctuary’s dialog with the cruise ship industry and local community concerns, all three cruise lines agreed in writing to a no-discharge policy, while operating within the sanctuary, in relation to their one-day port calls to Monterey Bay in 2002. They also agreed to provide records to support their commitments. These no-discharge agreements excluded cooling water but applied to all wastewater, ballast water, water discharged through oily water separators, and all forms of solid waste. The cruise lines also agreed to adhere to the International Maritime Organization’s vessel traffic lanes while in transit, to anchor in a designated location to minimize seafloor impacts, and to work with sanctuary staff in providing education to their passengers.

As a result of the cruise ship industry’s record of violations, independent monitoring would be desirable to verify compliance with regulations and voluntary agreements. Unfortunately, no model exists for continual tracking of cruise ship discharges, although the industry has agreed to turn over its discharge records for evaluation by government agencies. With thirteen cruise ship visits scheduled for next year (as of January 2003), the sanctuary will continue to work with all relevant parties to minimize environmental impacts associated with these visits.

–Lisa de Marignac
Monterey Bay National Marine Sanctuary

The Agriculture and Rural Lands Plan

The rich agricultural lands of the central coast produce more than 200 types of crop that sustain a $3.5 billion industry, employing more than 60,000 people. Much of this abundant productivity happens within a stone's throw of the Monterey Bay National Marine Sanctuary. The direct link between land and sea means that water flowing down the watershed through agricultural lands can carry potential pollutants to the region's rivers, wetlands, and nearshore waters.

The Agriculture and Rural Lands Plan was developed in 1999 to address agricultural runoff in the form of sediment, nutrients, and persistent pesticides. At the heart of the plan are twenty-four strategies intended to protect and enhance the quality of water that drains into the sanctuary while sustaining the economic viability of agriculture. Some of the key partners, with regional representation, include the sanctuary, Coalition of Central Coast County Farm Bureaus (CCCCFB), Natural Resources Conservation Service (USDA), Resource Conservation Districts, University of California (UC) Cooperative Extension, and the Regional Water Quality Control Boards.

The CCCCFB, formed in 2000, is taking a leadership role in establishing watershed groups of farmers and ranchers to establish improved management practices, building on the many positive practices already underway in the industry. Other industry groups, agencies, and researchers are working to increase available technical assistance and education, expand funding and economic incentives for conservation measures, coordinate and streamline the existing regulatory system in order to reduce barriers to implementing water quality protection practices, and improve management practices for rural roadways and public lands.

The agriculture plan has helped to direct considerable activity over the past two years. Ten farm bureau watershed groups have formed throughout the region, comprising 180 farmers and ranchers. Five of these groups have completed a Farm Water Quality course developed by UC Cooperative Extension. To assist these groups and other interested agricultural landowners and managers, many of the agricultural plan partners have hired technical staff, including an agronomist, water quality specialist, rural roads engineer, irrigated agriculture specialist, agricultural economics research assistant, and a hydrologist. These staff provide technical assistance for site-specific concerns and lead technical workshops. More than 900 farmers and ranchers have attended thirty-six workshops on specific conservation practices that protect water quality.

These collaborative strategies to protect water quality are showing concrete signs of success. For example, due to conservation practices that have been installed in the past two years, an estimated 258,875 tons of soil (equivalent to the area of a football field piled eleven stories high with eroded soil) per year have been prevented from eroding into the sanctuary.

Progress is being tracked by the sanctuary and through a monitoring and tracking program with the Regional Water Quality Control Boards. This industry-led regional effort can serve as a model for other areas working to protect water quality.

–Katie Siegler
Agriculture Water Quality Coordinator

Site Profile

Landels-Hill Big Creek Reserve and Big Creek State Marine Reserve

Protected by the Santa Lucia Mountains and rocky cliffs, and included within the Monterey Bay National Marine Sanctuary, the Big Sur coast includes some of the most pristine coastal habitats in central California. In the center of this area, the University of California Natural Reserve System and the University of California Santa Cruz (UCSC) operate two adjacent natural reserves. The Landels-Hill Big Creek Reserve extends from the rocky shoreline up through redwood forest, coastal scrub, coastal grassland, mixed conifer-hardwood forest, oak woodland, pine woodland, and chemise chaparral, topping at more than 3,000 feet (910 meters) above sea level. The Big Creek State Marine Reserve is co-administered with the California Department of Fish and Game (CDFG). It begins at the shoreline and extends offshore to a depth of 300 feet (ninety-two meters), including rocky shoreline, sand beaches, rocky reefs and pinnacles, sand canyons, boulder fields, sandy bottom, and other soft bottom habitats. Formerly known as the Big Creek Ecological Reserve, this no-take marine reserve is dedicated to "scientific research related to the management and enhancement of marine resources." With a combined area of more than 5,600 acres (22.6 square kilometers), these reserves comprise a unique mountain/shoreline/ocean shelf ecosystem, protected against future development and available for scientific and educational purposes.

© Geoff Phillips

View of Big Creek Canyon and flanking ridges showing forest and grassland habitats. Big Creek joins Devil's Creek (center left) and runs down the canyon to the ocean.

At these sites the university's primary mission is to contribute to the understanding of ecological processes as they occur in intact, protected natural systems through on-site research and education and to provide a benchmark for interpreting long-term environmental change. To this end the university supports facilities and programs at the site that are carefully designed to balance long-term protection with teaching, research, and public service. These currently include two in-residence staff, overnight accommodations

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View of Big Creek Cove. This is the principal access point for researchers entering the marine reserve.

for visitors (both indoor and camping), library and specimen collections, a carefully managed road and trail system, automated weather stations, and a database and Internet web site designed to support teaching and research.

The centerpiece of the reserves is Big Creek, a perennial stream with four major forks, fed by hundreds of free-flowing springs. Originating in the Ventana Wilderness Area to the northeast, Big Creek and tributaries maintain a flow of more than three cubic feet per second even in the driest years. This provides permanent habitat for anadromous steelhead (*Oncorhychus mykiss*) and Pacific lamprey (*Lampetra tridentata*) coming up from the ocean, as well as for freshwater stream residents such as Water Ouzels (*Cinclus mexicanus*), Belted Kingfishers (*Ceryle alcyon*), and resident rainbow trout (*Oncorhychus mykiss*). The mouth of Big Creek is spanned by a 500-foot concrete arch bridge, which carries traffic 100 feet overhead, abating noise and creating a safe access point for wildlife and reserve visitors to travel down to the shoreline. Big Creek enters the ocean in Big Creek cove, a rocky inlet protected to the north and west by a promontory rock and reef. Although not a harbor, the cove does provide a relatively safe landing for skiffs and inflatable craft and is the principal access point for entering the marine reserve. Several studies and surveys focus on the creek, including monthly water quality measurements, steelhead monitoring by classes and volunteers, steelhead research by the National Marine Fisheries Service (NMFS), a volunteer stream insect survey, and a stream gravel and geomorphology survey by UC Berkeley. Stream flow data are available. Square Black Rock, a massive cube rising forty feet above sea level and surrounded by rock shelf, reefs, and pinnacles, lies 1,000 feet offshore. Between the rock and the shoreline is the Big Creek kelp forest, dominated by giant kelp (*Macrocystis pyrifera*) and bull kelp (*Nereocystis luetkeana*). The kelp forest sustains dense populations of kelp forest fishes and other organisms; each spring and summer it also serves as a nursery for up to 150 harbor seal pups (*Phoca vitulina*) born on beaches within the reserve. Offshore from the rock and to the south of the mouth of Big Creek lies a soft-bottom plain that extends from the beaches to the outer edge of the reserve. A steep coastal slope begins at about the edge of the reserve and drops sharply to a system of submarine canyons and ridges.

CDFG and NMFS have conducted surveys of subtidal habitats and fish assemblages and have jointly produced a map of the marine reserve bottom habitats as well as baseline data on the numbers, species, and sizes of fish inside and outside of the marine reserve. More recently NMFS tested a new laser scanning technology in the marine reserve in an effort to improve techniques for counting, measuring, and identifying fishes. Its findings have highlighted the value of no-take marine reserves in sustaining larger and more numerous fish. The deep-water surveys have also revealed a need to capture additional deep-water habitats within the reserve so as to protect a representative sample of habitats, particularly hard-bottom habitats in waters deeper than 100 feet. One proposal would extend the boundary to three miles from shore, which would extend the depth to about 2,500 feet (760 meters).

UCSC faculty and the Partnership for Interdisciplinary Study of Coastal Oceans (PISCO) have recently set up a long-term study of biological community assemblages inside and outside the reserve. Their goal is to understand ecosystem processes and environmental change, both human-induced and natural, and to communicate their findings in a constructive way to policy makers, resource managers, and the general public. They chose to work at Big Creek because of the protection offered by the marine reserve as well as for the opportunity to work at the mouth of a pristine wild stream. The reserve also sponsors the Big Sur Skiff Fishing Survey, a cooperative agreement among a group of commercial fishermen who launch skiffs across the beaches in Big Sur and catch nearshore fishes for market. The survey generates fishery-dependent data on fish sizes and assemblages and has an eleven-year record for about ten species caught in waters outside the marine reserve. The data show fluctuations in the average length of some species, but overall, the mean length has not declined, suggesting that healthy fish populations may remain in many of those areas. In addition to long-term projects, the reserve also supports graduate and undergraduate thesis projects. Current graduate student projects range from studying rockfish recruitment and genetics to intertidal community responses to disturbance from highway construction and maintenance. Undergraduate projects include measurements of kelp forest fish sizes inside and outside of the marine reserve boundaries.

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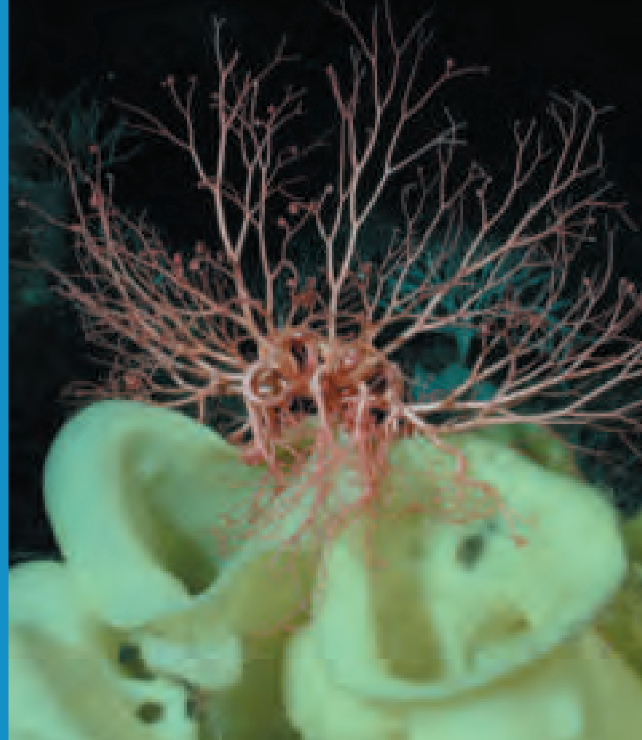
The reserve is an important site for counting and measuring fish populations not subject to fishing pressure. This is a diver's eye view of the reserve.

The combined Landels-Hill Big Creek Reserve/Big Creek State Marine Reserve offers an ideal situation for studies of water quality, coastal processes, and other areas of investigation into natural ecosystems. Realizing this potential requires implementation of program and facilities improvements, carried out in a way that carefully protects natural values yet facilitates access and study. The long-term goal for these reserves is for them to contribute significantly to our knowledge of coastal ecosystems, now and into the foreseeable future.

–John Smiley
Landels-Hill Big Creek Reserve



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All cover photography is from the Davidson Seamount (*see article, p. 9*).

Front cover:
Top left: gorgonian, "bubblegum coral" (*Paragorgia spp.*) and purple polychaete worms (species unidentified); top right: sea cucumber (*Benthodytes spp.*); bottom left: big red jelly (*Tiburonia granrojo*); bottom center: fly-trap anemone (*Hormathiidae*); bottom right: halosaur (*Aldrovandia spp.*).

Back cover:
Left: crab (*Neolithodes spp.*); center: basket star (*Gorgonocephalus eucnemis*) atop yellow sponges (species unidentified); right: tomopterid worm (species unidentified).

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