ECOSYSTEM OBSERVATIONS

for the Monterey Bay National Marine Sanctuary

2004

NATIONAL MARINE SANCTUARIES ™
MONTEREY BAY


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Welcome

For about half of 2004, I had a great opportunity to live in Italy and study how it manages its national marine sanctuaries, called "marine protected areas." It was a fantastic opportunity for me and for our National Marine Sanctuary Program, as I have returned with many ideas about what to do to improve our management of this nation's system of marine protected areas.

I also returned with ideas about what not to do. Some of those come from observations about programs or tactics that did not seem effective, while many others were things that are different because the United States and Italy are different nations culturally.

It was reassuring to see that the cultural core of the National Marine Sanctuary Program and the Monterey Bay National Marine Sanctuary – to involve stakeholders in making resource management decisions – is also a large part of how Italian protected area managers operate. While nothing may match how national marine sanctuaries involve the public in management plan reviews, the Italians also look to fishermen, dive shops, charter boat operators, local governments, and the general public in their decision making.

Our written tools to manage national marine sanctuaries surpass those in Italy. Our detailed five- to ten-year management plans, our research plans, our water quality plans, and our education plans have no parallel. Certainly, some Italian marine protected areas have annual newsletters like our *Ecosystem Observations*. Most sites in Italy have effective brochures, and they generally do a good job of communicating to marine users about the rules of marine zones. So again, while there are differences, there are things in common.

Perhaps one of the most reassuring traits Italian and U.S. marine protected areas share is the challenge to balance the needs of locals within the context of a nationally significant protected status. Whether "use" means extracting resources, just looking at them, or just knowing they are there, I found much in common with fellow site managers in Italy who struggled each day with providing as much as possible to locals while reminding all that this is a resource protected for an entire nation.

In fact, protected for international benefit. So, it is your sanctuary, enjoy it. And share it, because it is the sanctuary for many others, too.

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

2004 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 operations. A summary of each program's major accomplishments and activities for 2004 follows. This year's report also includes a review of activities surrounding the Joint Management Plan Review (JMPR).

Resource Protection

Resource protection issues involve a wide range of habitats, species, and human impacts – reflecting the sanctuary's multiple uses and its connection to a long coastline and to nearby watersheds. The resource protection team works closely with a variety of partners to initiate and carry out strategies to reduce or prevent detrimental human impacts on sanctuary resources.

Work continued on the evaluation of the potential for marine protected areas (MPAs) to conserve habitats and ecological functions. The sanctuary is coordinating the ongoing efforts of a multi-stakeholder work group composed of agencies, scientists, environmental organizations, fishermen, and other ocean users. The group's initial work has focused on compilation of literature and maps on habitats and ecological functions, refinement of conservation goals for MPAs, and socioeconomic analyses of fisheries by gear types, ports, and target species.

Following through on a recommendation in the JMPR, staff developed and presented a detailed analysis and recommendation to the Pacific Fishery Management Council (PFMC) to ban krill harvesting in the three central coast sanctuaries. Krill – small, shrimp-like organisms – are one of the central prey items in the sanctuary's ecosystem and are fed upon by a wide range of whales, seabirds, and fishes. (*See p. 9.*) The recommendation to ban the harvest of these organisms was very favorably received, and PFMC is investigating the most effective means to enact such a ban throughout West Coast federal waters.

The Water Quality Protection Program and its many 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 the Sanctuary Foundation, the Natural Resources Conservation Service, County Farm Bureaus, and others have collaborated with local farmers and ranchers in twenty-three watershed working groups. These joint efforts have included water quality training courses in four counties and targeted efforts to improve sediment, nitrate, and pesticide management. Detailed watershed assessments identifying pollutant sources were completed for the Pescadero-Butano and Pajaro watersheds and can be used to help target future efforts. (*See p. 12.*) In our local cities, we conducted six technical training workshops with public works and planning staff on management practices to reduce contaminants in urban runoff as well as a training on best management practices for private construction companies operating on the coast.


© Alan Bilinsky

Erica Burton participates in the First Flush event at Steinbeck Plaza in Monterey.

The resource protection team worked closely with the research team to host a workshop on water quality monitoring in the sanctuary that identified existing programs and opportunities for enhanced coordination. They also made the data summaries of most known programs available on the Internet via the Sanctuary Integrated Monitoring Network (SIMoN) web site. Efforts to use trained volunteers to monitor water quality continued under the Sanctuary Citizen Watershed Monitoring Network. The network initiated a new monitoring effort in Salinas, sampling three creeks for both urban and agricultural contaminants. Our annual Snapshot Day monitoring event has continued to grow, this year with more than 200 volunteers monitoring water quality contaminants such as nutrients and bacteria from Pacifica to Morro Bay. The fifth annual First Flush, a volunteer event to monitor contaminants flushed off streets by the first heavy rains, took place in the fall. It involved more than seventy trained volunteers in Pacific Grove, Monterey, Capitola, Santa Cruz, Half Moon Bay, and – for the first time – Seaside. Staff worked with local cities and counties to use the data gathered to identify sources, reduce contamination levels, improve permit programs, and target public education.

The team initiated a variety of additional workshops on critical sanctuary issues. These included a workshop (co-hosted with the Association of Monterey Bay Area Governments) on desalination that attracted more than 200 participants who gathered to discuss existing and proposed facilities, the need for regional planning, and ways to reduce impacts to sanctuary resources. (*For more information on desalination, see p. 22.*)

Enforcement staff received several hundred notifications of potential sanctuary violations and investigated a wide variety of incidents (*see p. 24*). Wildlife disturbance, ranging from lethal injury to physical displacement, continues to top the list of cases investigated. There were eleven reported vessel groundings/sinkings (*see p. 24*), which often involved the potential for debris and fuel spills, in the sanctuary. Raw sewage spills from land were the most prevalent type of larger discharge into the sanctuary, ranging in individual volume from fifty to 121,000 gallons in 2004.


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Volunteers are trained for First Flush by sampling the storm drain before the first rains at San Carlos Beach.

We received several reports of large commercial vessels operating outside of shipping lanes established within the sanctuary by the International Maritime Organization to reduce the risk of oil spills. Also, a container ship lost fifteen large cargo containers overboard within the sanctuary during 2004. The sanctuary enforcement officer and resource protection staff investigated these violations, followed up with responsible parties to address the violations, and identified ways to prevent them in the future – in coordination with a variety of state, federal, and local agencies.

The resource protection team also 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 conditions are imposed on these types of activities in order to reduce or eliminate threats to the sanctuary. Staff also reviewed and commented on a variety of projects and plans under development by others to ensure that they adequately protected sanctuary resources, with a particular focus this year on the growing number of seawalls along our coast.

As we head into 2005, the team looks forward to continuing our partnership efforts with federal, state, and local agencies; industries such as agriculture and fishing; environmental groups; scientists; and citizens throughout the region to protect sanctuary resources.

Education and Outreach

The education and outreach team, along with the rest of the sanctuary's staff, has spent the majority of the past year planning new programs, activities, and facilities to address the issues and action plans developed for the JMPR.

For our team, this planning encompassed an evaluation of everything from our education mission to the expansion of our multicultural program and exploring innovative ways to address new and sometimes sensitive issues. The education team is proud to share our updated mission, which we feel better reflects what we try to accomplish each day: *To promote understanding, support, and participation in the protection and conservation of the Monterey Bay National Marine Sanctuary*. This mission, like our new action plans, takes a more participatory approach to getting people involved in ocean conservation. The sanctuary's management plan is undergoing historic change and has already provided the public with a wonderful opportunity to participate. As we move into the new year, we will continue to encourage strong participation in the sanctuary and its endeavors, as now reflected by our new mission.

The thrust of this new mission reflects the purpose of the multicultural program, MERITO (Multicultural Education for Resource Issues Threatening Oceans), which currently serves our large Spanish-speaking community. Because of MERITO's success here in Watsonville, Pajaro, and Salinas, our national program supported its expansion to the Channel Islands National Marine Sanctuary. We conducted a needs assessment to identify what kinds of MERITO programs we could export as well as what new programs we need to develop. This assessment, so critical to effective program development here, will ensure equally successful programming in Santa Barbara.

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Spanish-speaking families learn about rocky shore life and how to protect it during a MERITO tidepool field experience.

Expansion also occurred in the sanctuary's TeamOCEAN kayak/naturalist program, which swelled to more than fifty volunteers this year, allowing the possibility to add this interpretive enforcement effort in Santa Cruz next year.

We organized two major events: the annual *Sanctuary Currents* Symposium, "Clean Waters, Healthy Oceans" focused on water quality issues, while the "Fishermen's Fiesta" celebrated the fishing community and its contribution to the history and economy of Monterey Bay.

Both water quality and maritime heritage are themes that will be showcased in exhibits planned for the new Santa Cruz and San Simeon visitor centers. The San Simeon center is well underway, after an overhaul of the existing building and office space. The exhibit designs have been finalized, and fabrication has commenced. Planning for the Santa Cruz center is off to a solid start, also, after an extensive search to identify the architectural and

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MERITO bilingual volunteer Ivan Uriostegui interprets watershed protection to students at the Santa Cruz County Fair in Watsonville.

Eleventh Annual Sanctuary Reflections Awards

Presented at the 2004 Sanctuary Currents Symposium:

Ruth Vreeland Public Official Award: *Ruth Vreeland (posthumously)*

Citizen: *Phil and Carole Adams, Cambria*

Conservation: *Monterey Bay National Marine Sanctuary Management Plan Review Process*

Education: *Pat Clark-Gray, California Department of Parks and Recreation*

Science/Research: *Dr. Pete Raimondi, University of California Santa Cruz*

Business: *Cannery Row Company, Monterey*

Organization: *Monterey Bay Sanctuary Foundation*

Special Recognition: *Dr. Steve Webster, Monterey Bay Aquarium* interpretive design firms. The City of Santa Cruz is a critical partner and has participated in the planning process since its inception, bringing prime ocean front property and critical urban planning expertise to the table.

In order to maximize the impact of all the new program ideas generated by the extensive JMPR planning, our team has begun to develop a series of planning and assessment tools for several of the more complex issues in the management plan. We will use these newly developed tools to determine how best to go about creating several new outreach campaigns related to the issues the sanctuary is now preparing to address.

The past year of planning has set us up for success in 2005, and we look forward to implementing the many new programs, projects, and facilities so carefully crafted this year.

Research

Each day our research staff interprets scientific information on a variety of topics. A tremendous amount of information about the sanctuary is available, but it can be difficult to find and is often in a format that's not easily understood. Requests for information on sanctuary resources come from sanctuary staff to guide them in developing policy on management issues as well as from the media, politicians, educators, students, scientists around the world, and the general public. We make information available through our web sites (sanctuary: www.montereybay.noaa.gov; SIMoN: www.mbnms-simon.org;), publications, and through direct communication. We also speak to community groups and give talks at national and international conferences. For example, we spoke at the International Cable Protection Committee in Cannes, France about our collaborative study on the impacts of an undersea cable between Half Moon Bay and Pioneer Seamount. We serve on numerous committees, like the National Invasive Species Council, to help in the development of science-based policy. Clearly there is a growing interest and need to apply science to resource management, and our research team has taken a leadership role in this important activity.

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A Pacific Giant Octopus (Enteroctopus dofleini) was seen off Point Pinos in August at a depth of 65 meters during sanctuary seafloor monitoring surveys using the Delta submersible.

Often, we report on research done by our colleagues at other research institutions, but we conduct our own field research as well. The SIMoN web site lists a growing number of research projects, providing summary information as well as basic habitat descriptions and related educational links for students and educators. This year we added a water quality theme to our interactive maps. Now users can view the locations of water monitoring projects, generate maps in a printable format, and view recent and historical data through dynamic links to the agencies collecting the information. Regular visitors to the site simply click on "What's New" to view the latest information on a variety of topics, ranging from plankton blooms to NOAA aerial images of elevation contours in Elkhorn Slough. Also posted is information on our latest research projects, such as our studies on removal of the invasive kelp, *Undaria*, in Monterey Harbor and kelp forest surveys of the Big Sur coast in relation to Highway 1 maintenance.

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Researchers conduct surveys along the Big Sur coast to learn about the effects of landslides on nearshore habitats.

Three research areas that received significant attention this year were habitat mapping (*see p. 8*), Elkhorn Slough (*see pp. 13 and 21*), and ocean observing systems (*see p. 11*). While California State University Monterey Bay (funded by SIMoN) mapped nearshore sanctuary areas using sonar techniques, our staff characterized the seafloor with a video camera sled towed from NOAA ships. As a result of these efforts, we have been able to develop a clearer picture of the tapestry that makes up the sanctuary's seafloor: large fields of a variety of organisms blanket mud, sand, and rocks. Having access to this information is critical in guiding important management decisions, such as the location and impacts of marine reserves, desalination outfall pipes, and submerged cables.

Eight cross-disciplinary teams met at a SIMoN-sponsored workshop to discuss recent findings in Elkhorn Slough on water flow models, habitat changes, water quality, and biological surveys. This information is critical to informing a tidal wetland plan process to develop a vision of habitat needs for the long-term stewardship of slough wildlife.

Finally, we are involved in a national priority to develop ocean observatories, where measurements are taken "around the clock" to protect human lives, property, and natural resources. Interestingly, eight marine regions around the nation are going to develop independent observatories based on regional abilities and needs. Therefore, our understanding of the types of product required to address specific ocean issues is critical to this effort.

Our Research Program has a dedicated and hard working team; however, we are effective only because of the tremendous science capabilities of our region. The greater Monterey Bay area has a very high density of research institutions, with many capabilities unrivaled throughout the world. Our efforts are supported by information sharing and generous research collaboration with some of the best scientists in the world and the bright young students and colleagues they mentor. We all benefit from this unique component of our regional community.

Joint Management Plan Review

This sanctuary, along with Cordell Bank and the Gulf of the Farallones National Marine Sanctuaries, continues to update a joint management plan, known as the Joint Management Plan Review (JMPR). For each sanctuary, this includes a review of current and future priorities for resource protection, education, and research programs; the program's resource and staffing needs; regulatory goals; and sanctuary boundaries. After nearly three years of public input, issue prioritization, and recommendations from the Sanctuary Advisory Council (SAC), the sanctuary is close to releasing a draft management plan and draft environmental impact statement.

In 2004 staff incorporated recommendations from the SAC, prepared budgets, identified performance measures, and worked to complete an environmental impact statement. During the summer, staff worked closely with the council to prioritize the significant increase in work load associated with the implementation of twenty-five action plans identified in the new management plan. These plans address the following issues:

- Coastal armoring
- Desalination
- Harbors and dredge disposal
- Submerged cables
- Bottom trawling effects on benthic habitats
- Big Sur coastal ecosystem plan
- Davidson Seamount
- Emerging issues
- Introduced species
- Special marine protected areas
- Operations and administration
- Fishing-related education and research
- Performance evaluation
- Interpretive facilities
- Multicultural education
- Beach closures and microbial contamination
- Cruise ship discharges
- Water Quality Protection Program implementation
- Marine mammal, seabird, and turtle disturbance
- Motorized personal watercraft
- Tidepool protection
- Ecosystem monitoring
- Maritime heritage and submerged cultural resources
- Community outreach

The National Marine Sanctuaries Act requires each sanctuary to review its management plan periodically, ensuring that it will continue to conserve, protect, and enhance nationally significant living and cultural resources. Draft management plans, proposed regulations, and a draft environmental impact statement are scheduled for release to the public in late spring of 2005. Following their release, the sanctuaries will hold public hearings in several locations throughout the region to gather public comment. For more information about the JMPR, please visit www.sanctuaries.nos.noaa.gov/jointplan/.

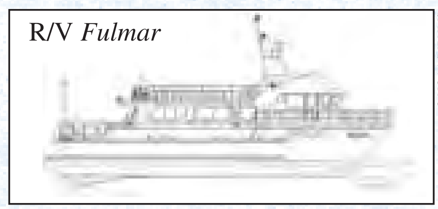
Program Operations

Our program operations team continued to provide daily support for the education, research, and resource protection teams to help keep programs running smoothly and effectively. Program Operations involves a myriad of responsibilities, including facilities management, computer network and web site development, media and public relations, diving and boat operations, SAC liaison, and overall financial administration. Here are a few highlights from 2004:

A project to expand outreach to the southern region with partner agency California State Parks was finalized, resulting in an agreement to establish a new sanctuary office and visitor center at the William R. Hearst Memorial State Park in San Simeon. While the office is now operational, we look forward to the interpretive facility opening by late 2005.

Working closely with national headquarters and Channel Islands National Marine Sanctuary staff, we began designing a new 65-foot West Coast research vessel. Based on the Channel Islands catamaran *Shearwater*, the vessel will be an important asset to the sanctuary program and larger community, enabling our staff and collaborating institutions to conduct ecosystem-based research, monitoring, and education addressing critical resource management issues. Delivery of the vessel to Monterey is set for March 2006.

As part of a new Memorandum of Agreement with California State University Monterey Bay, we developed an internship program and hosted five college interns during the summer. Three students worked with staff on topics such as water quality monitoring, web site development, and marine debris (focused on abandoned fishing gear). In addition, two other students – from the Monterey Institute of International Studies and University of California San Diego – investigated newly emerging resource protection issues. We hope to continue providing support for college students through this new partnership.



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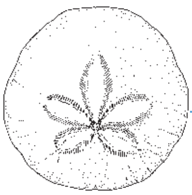
Delivery of the new research vessel Fulmar is set for March 2006.

Working side by side with the SAC, we prioritized twenty-five action plans under the new management plan, slated for finalization in 2005. Other topics addressed by the council included a National Marine Fisheries Service presentation regarding Department of Defense actions, the Northern Management Area, and discussion of the partnership with the Association of Monterey Bay Area Governments. Several changes in council membership occurred. New members sworn in were: Margaret Webb and Robert Frischmuth (At-large), Howard Egan (Fishing alternate), Steve Shimek (Conservation alternate), Nancy Black and Anjanette Adams (Business/Industry), Tim Frahm (Agriculture alternate), Gary Pezzi (Recreation alternate), and Steve Clark (Education alternate). The Harbors seat rotated this year to include Brian Foss and Steve Scheiblauer, and Deborah Streeter was elected council chair and Tom Canale as vice chair.

The Monterey Bay Sanctuary Foundation continued to play an integral role with SIMoN administration and management. In addition, the foundation expanded its scope of operation to help manage our multicultural education, management plan review, and agricultural programs. We are truly lucky to have such a great partner.

With Superintendent William Douros on detail in Italy for part of the year, we kept in close communication through a new web page logging his travels and activities. Many other new pages, containing a plethora of information on resource protection issues, were added to our very popular web site, also. Check them out at www.montereybay.noaa.gov.

Contributed Ecosystem Observations



Beach Systems

Coastal Sand Transport in the Sanctuary

The stunning shoreline of the Monterey Bay National Marine Sanctuary consists of long stretches of sandy beaches, tall dune fields, rocky cliffs with sediment-bearing coves, and sandy river and creek mouths. Understanding beach processes and the dynamic nature of sand transport provides insight into these different coastal features and a context for effective resource management. Knowledge of sand sources, sinks, and transport mechanisms is necessary to understand and respond to coastal erosion as well as to evaluate the impact of human activities on coastal systems.

Littoral cells represent segments of coastline within which sand input, transport, and output are essentially self-contained. Littoral sand is defined as particles that are sufficiently small to be moved by waves yet are large enough to remain in the beach system and not be carried offshore. In theory, the littoral sand budget in each cell is unaffected by changes in other cells. Hence, human activities such as construction of seawalls and other coastal protection structures (collectively known as coastal armoring), dredging, or beach nourishment that occur in one cell should not affect sand dynamics in an adjacent cell. Understanding the location of littoral cell boundaries is important for evaluating the potential impact of various coastal management options.

Figure 1. Littoral cells within the sanctuary

At least four major littoral cells, some with sub-cells, exist in the sanctuary. (*See Figure 1.*) The Santa Cruz cell is the longest; it is thought to extend from San Francisco Bay to the head of Monterey Canyon near Moss Landing. The Southern Monterey Bay littoral cell begins at the Monterey Canyon and probably extends to the Monterey Peninsula. Little is known about littoral cells along the Big Sur coast. Submarine canyons that reach the shoreline (such as Monterey Canyon) intercept longshore transport, funneling sand out of the littoral system and into the deep ocean. Therefore, Partington Canyon (south of the Big Sur River) is likely a boundary subdividing the Big Sur coast into at least two littoral cells.

The main sources of sand for sanctuary littoral cells are coastal streams and erosion of dunes and cliffs. Studies of the Santa Cruz cell indicate that coastal streams contribute about 75 percent and bluff retreat, about 20 percent of sand entering this cell. Dams frequently trap sediment carried by streams. Hence, installation of new dams could have a cumulatively important effect on sand supply to this cell. Of the contribution from bluffs, nearly all the sand comes from dunes and the marine terraces that cap many coastal cliffs. Thus, seawalls that armor marine terrace deposits are likely to have a greater impact on local sand supply than seawalls armoring other rock types.

Once sand enters the littoral system, it is carried along the coast by longshore currents and waves (typically southward in the sanctuary) toward its termination in a submarine canyon, offshore shelf, or dune field. The transport system is like a constantly moving conveyor belt that carries sand grains. For example, Santa Cruz littoral sand transport rates range from 200,000 to 400,000 cubic meters per year. This is roughly equivalent to between fifty and 100 dump trucks full of sand gradually moving down the coast every day.

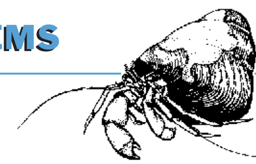
Compared with the Santa Cruz cell, analyses of the Southern Monterey Bay littoral cell indicate that longshore transport rates are relatively low and suggest that only small amounts of sand are mobilized to nourish down-coast beaches. The primary source of sand to the Southern Monterey Bay cell is the erosion of the Fort Ord area dunes, with a small contribution by the Salinas River. Lack of information on the volume of historic sand loss due to mining provides uncertainty to sand budgets. A small sub-cell is thought to deliver sand predominantly from the Salinas River into Monterey Canyon. This sub-cell shares a sand source (the Salinas River) with the sub-region that extends from the Salinas River to Del Monte Beach but is otherwise independent. Monterey Peninsula beach sand is sourced from the breakdown of local granite and differs compositionally from sand found north of Del Monte Beach. The lack of sand exchange between sub-regions and low overall littoral transport rate imply that southern Monterey Bay beaches are likely to be very sensitive to changes in local sand supply.

Big Sur coast littoral system(s) have not been well studied. Coastal streams and frequent landslides transport large volumes of sediment into the littoral zone of the Big Sur coast. Littoral sand budgets, however, have not been compiled.

Understanding littoral cell extent and the relative importance of factors affecting sand supply are first steps to understanding beach systems. The Coastal Armoring Action Plan, part of the sanctuary Joint Management Plan Review, aims to develop a regional, scientifically informed approach to these issues. Efforts are underway to further compile available information, build partnerships, and encourage additional research.

– Irina Kogan
Gulf of the Farallones National Marine Sanctuary

Rocky Intertidal and Subtidal Systems



Acoustic Fish Tracking in Monterey Bay

Many marine resource management tools, such as reserves or multiple-use zones, control user activities in order to benefit an area's organisms. From a management point of view, this approach is relatively simple to apply and enforce, but its effectiveness in managing motile organisms such as reef fishes may depend on whether the organism can move from one zone to another. For example, kelp forests are spatially patchy and may have different levels of 'connectedness' for different fish species. Some fishes might not cross large sand patches to move from one rock to another but might frequently move among rock pinnacles separated by rocky habitat 'corridors.' If the boundary between an area that is closed to fishing and one that is open to fishing is highly connected (from a fish's point of view), then the level of protection anticipated by the no-fishing zone may not be as high as assumed.

Over the past two years the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) has been conducting a study – funded jointly by the National Undersea Research Program (NURP) and PISCO – to examine how fishes move in kelp forest landscapes. We are using the commercially available VEMCO Radio Acoustic Positioning system (VRAP) of acoustic tags and moored receivers to track movement patterns of blue rockfish, kelp rockfish, and kelp greenlings on the Monterey Peninsula. Sonic tags have been surgically implanted in thirty individuals each of the three species in kelp forests with different

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Figure 2. After tagging a fish, divers return it to its capture location to reduce predation.

levels of patchiness and connectivity. The receivers triangulate the positions of each tag every three minutes and radio this information to a computer base station at the Monterey Bay Aquarium. Computer software then calculates the position of each individual and overlays it in real time over bathymetric maps.

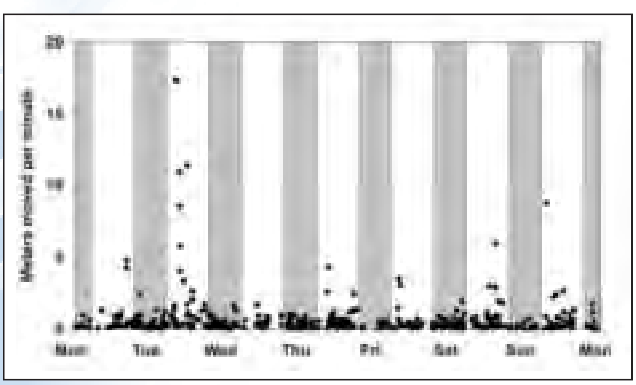

Figure 1. A week in the life of a blue rockfish. A plot of movement rates (the distance moved among triangulations as a function of time) reveals variability in activity. Each dot represents a position fix, and the shaded regions are night-time periods. This blue rockfish was more active during daytime, but the amount of activity varied day to day.

This study was initiated in the summer of 2003 and is now in its second year. Data analysis is in a preliminary stage, but some interesting patterns are beginning to emerge. Initial results suggest that kelp rockfish typically occupy a range approximately 20x20 meters in area, while kelp greenlings occupy a home range from 20x20 to 40x40 meters, depending on habitat quality. In contrast, blue rockfish move over larger areas (hundreds of meters), with occasional movements in excess of 400 meters. However, all species have been observed to make long forays away from their 'typical' home range. For example, one kelp rockfish crossed 150 meters of sand to move to an isolated rock patch, then 'leap-frogged' across a series of rock patches for a distance of 350 meters, and returned by the same route four days later.

An unforeseen result from this project has been information on the animals' daily activity patterns. Blue rockfish, for example, are typically motile during the day, with a lot of day-to-day variability in their movement rates. (*See Figure 1, previous page.*) The final analysis of these data will enable information on movement rates and the position of fishes to be overlaid on habitat topography and connectedness as well as biological characteristics such as kelp density.

In addition to contributing to ecological understanding about fish movements in kelp forest landscapes, this project has important societal implications. Marine protected areas (MPAs) have received increased attention as a tool to manage and conserve marine resources – by protecting habitat and ecological function and supplementing traditional fisheries management by protecting a subset of a fishery stock from exploitation. However, predicting how effective a reserve will be requires an understanding of the relationship among the size and shape of a reserve, fish home ranges, and habitat complexity. This study represents one of a handful of studies that can explicitly link habitat use and movement of individuals to remotely sensed habitat maps within and adjacent to existing marine reserves. The development of such an approach and the information gleaned from this study are fundamental to the sound development and evaluation of MPAs for reef fish conservation throughout coastal, temperate oceans.

– Craig Syms
Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) and School of Marine Biology & Aquaculture, James Cook University of North Queensland

Habitat Mapping: Characterizing Sanctuary Seafloors

Terrestrial landscapes have been well mapped and documented. Maps are available that provide a wealth of spatial information on landscape features (e.g., elevation, slope) and composition (e.g., rivers, mountains, farms, cities). We also have maps and information on the distribution of the flora and fauna that inhabit these different landscapes. Consequently, one might expect similar maps and information to be available for our marine environment. Alas, we know relatively little about the habitats and organisms that exist on our seafloors.

A key mission of the national marine sanctuaries is to understand and manage the marine environment within sanctuary boundaries. This requires a sound knowledge of the composition and complexity of the marine environment, its habitats, and the organisms that occur there.

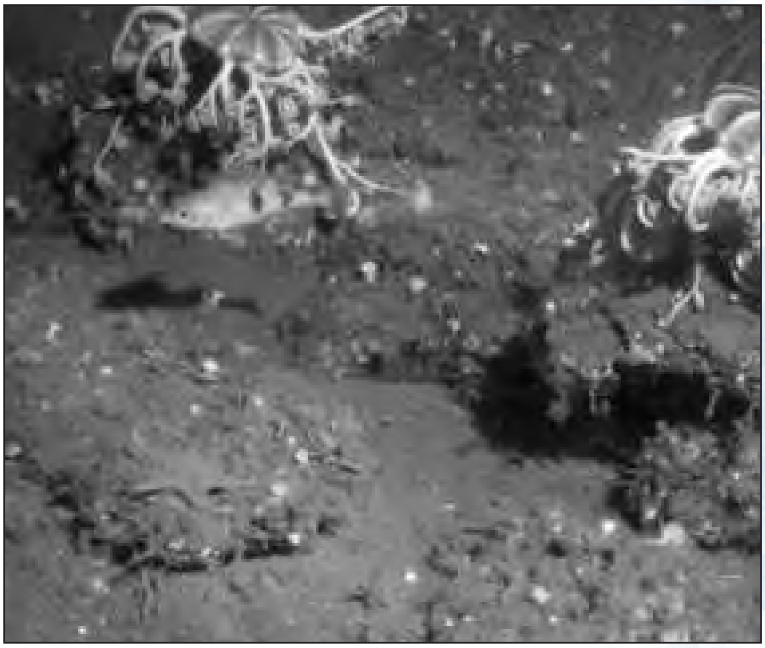

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Figure 1. Low-lying cobble habitats inhabited here, 110 meters off Point Pinos, by basket stars (Gorgonocephalus eucnemis), vermilion star (Mediaster aequalis), and half-banded rockfish (Sebastes semicinctus)

In April 2004 a team of scientists from the U.S. Geological Survey (USGS), the National Oceanic and Atmospheric Administration (NOAA) Sanctuaries, and NOAA Fisheries collaborated on a twenty-day research cruise to map and describe the seafloor across the continental shelf from the northern reaches of the Cordell Bank National Marine Sanctuary (CBNMS) to the southern reaches of Monterey Bay. The survey's goals were to map the geology, habitat, and biodiversity within regions of the three adjacent national marine sanctuaries: Monterey Bay (MBNMS), Gulf of the Farallones (GFNMS), and Cordell Bank. This project aimed to build on existing data but in many places provided our very first glimpses of the seafloor.

Research surveys were conducted from April 1 to April 21 aboard the 225-foot NOAA ship *McArthur II*. Our research team, including Roberto Anima, John Chin, and Fred Payne (USGS); Dale Roberts and Dan Howard (CBNMS); and Jean de Marignac and Erica Burton (MBNMS), worked day and night to collect information on the seafloor in the three sanctuaries. During the day, side scan sonar was used to map seafloor geology over large areas. At night, a towed camera-sled was used to film these habitats and document the organisms living there. USGS scientists used a Klein 3000 side scan sonar system to acoustically image several previously unmapped sections of the seafloor within each sanctuary (e.g., Pescadero Reef in the MBNMS) and to extend coverage from earlier missions (e.g., Fanny Shoals in the GFNMS). Hundreds of hours of video footage were then collected from multiple transects with the towed camera, providing a wealth of information about the types of habitat and life found on the seafloor and about the distributions of geological features, habitats, and organisms across and along the shelf.

A variety of seafloor habitats and marine creatures were identified within the sanctuaries. For example, sand-wave habitats were verified in areas around Point Pinos and were occupied by sand dabs and schools of juvenile rockfish. Sediment-ripple habitats were common across regions of the shelf and were often densely populated with white brittle stars with their bodies buried in sediment. Low-lying cobble habitats were verified along the mid-shelf region south of Monterey Canyon and were occupied by encrusting organisms such as basket stars, sponges, and gorgonian corals and by fishes such as the half-banded rockfish, *Sebastes semicinctus*. (*See Figure 1.*) High-relief bedrock habitats, although less common on the mid- to outer shelf, were also surveyed and characterized. These habitats were occupied by encrusting invertebrates, vase sponges, large anemones, gorgonians, and many rockfish species.

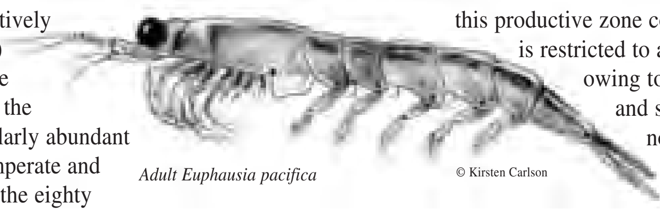
An integral aspect of this project involved the development of a rapid-data-entry protocol whereby seafloor categorizations and descriptions were recorded in real time. Although requiring effort, the protocol enables seafloor data to be processed while at sea, including the production of maps within hours of data collection. This, in turn, dramatically reduces the time before seafloor information can be made available to managers, stakeholders, and the public. Importantly, this approach also enables web users to view actual footage from locations of interest within weeks of survey completion (*see www.mbnms-simon.org/other/moreLinks/whats_new_mac.php*).

The ability to map seafloor habitats within our sanctuaries and the creatures that inhabit them will help managers better protect these habitats, plants, and animals. Further, the knowledge of what is present today will provide the foundation to monitor future changes in these important resources.

– Tara Anderson
U.S. Geological Survey (USGS-CMG) and NOAA Fisheries (NMFS, SWFSC), Santa Cruz Laboratory

Open Ocean and Deep Water Systems

Krill: It's What's for Dinner



Adult Euphausia pacifica

© Kirsten Carlson

Euphausiids, or krill, are relatively small (two to four centimeters) shrimp-like crustaceans that are broadly distributed throughout the world's oceans and are particularly abundant in the productive waters of temperate and polar regions. The majority of the eighty or so krill species feed predominantly on phytoplankton – small unicellular organisms capable of photosynthesis. In addition, most krill migrate diurnally, spending daylight hours clustered in aggregations at depth (up to several hundred meters) and rising to the surface at night to feed.

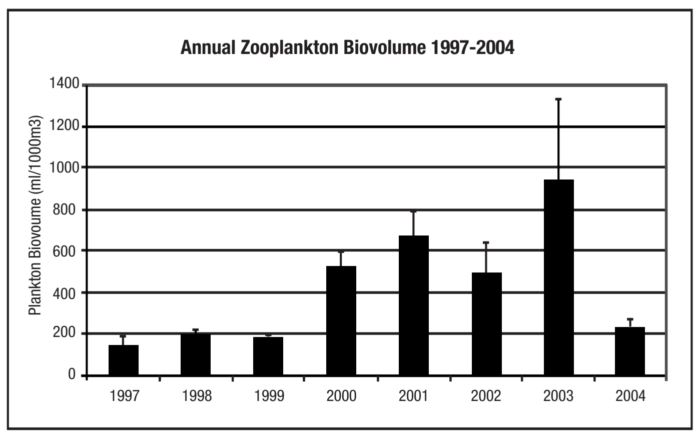
Within the coastal upwelling systems of the Northeast Pacific, krill are key players in pelagic food webs. In particular, they are important forage for a number of commercially valuable species (market squid, salmon, rockfishes, hake, and sardine) as well as several species of seabirds (Cassin's Auklet, Sooty Shearwater, and Common Murre) and marine mammals (humpback, fin, and blue whales). Krill are relatively large compared to other grazing zooplankton, which makes them directly accessible to these predators. Indeed, the blue whale – the largest animal to have ever lived – feeds almost exclusively on krill.

Several species of krill may be found within the waters of the Monterey Bay National Marine Sanctuary, but two species – *Euphausia pacifica* and *Thysanoessa spinifera* – are typically the most abundant. *E. pacifica* is found in deeper waters associated with the continental slope and open ocean regions, while *T. spinifera* is more common in waters associated with the outer continental shelf and continental slope. Both undergo strongly seasonal patterns of reproduction and growth within sanctuary waters. Peak larval production occurs in the spring and early summer, when phytoplankton abundance is typically highest.

The newly hatched larvae occupy the surface waters (<100 meters) and drift with the prevailing currents as they rapidly grow. Individuals typically develop to the juvenile stage within two months of hatching, and adult status can be attained in as little as four to five months. In years when upwelling persists into late summer, this new generation may reproduce in the early fall, but usually, the surviving adults overwinter and complete the cycle the following spring.

Krill distributions within the sanctuary also appear to have a seasonal pattern. During the spring and early summer, strong coastal upwelling results in the offshore advection (movement) of nutrient-rich water. This results in a broad zone of high phytoplankton abundance and krill, particularly larvae and juveniles. As upwelling-favorable winds subside in the late summer and fall, this productive zone collapses coastward, until by winter it is restricted to a relatively narrow band. Adults, owing to their deeper day time distributions and superior swimming capability, may not be subject to the same forcing mechanisms, and their abundance is consistently higher in the nearshore (<40 kilometers) region.

Krill populations within the sanctuary also appear to fluctuate on interannual – and even longer – time scales. We have been monitoring total zooplankton and krill abundance within the Monterey Bay region since 1997. This period has included both the large 1997-98



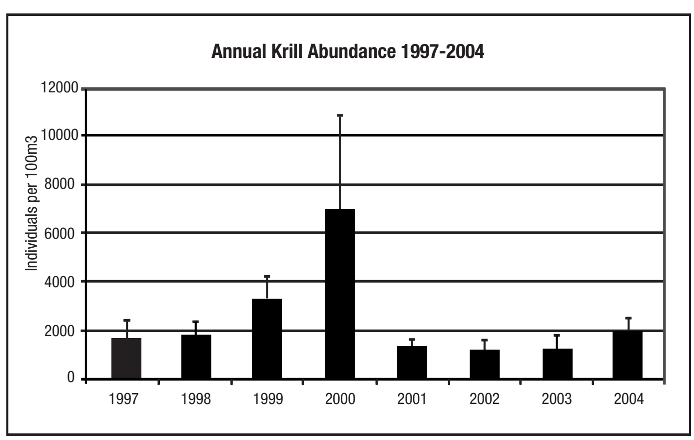


Figure 1. Mean (+ se) annual zooplankton biovolume (top panel) and krill abundance (bottom panel) collected in net samples taken within the Monterey Bay region between 1997 and 2004

El Niño as well as the 1998-99 La Niña, both of which disrupted the normal seasonal cycle of productivity within the sanctuary. Specifically, during the summer of 1998, krill were essentially restricted to a narrow (approximately twenty kilometers) coastal band, which greatly restricted the forage habitat for krill predators. This resulted in a disproportionately high number of baleen whale sightings during our research cruises, including the usual blues and humpbacks as well as fin whales, which typically forage in waters further offshore.

Many oceanographers believe that the recent La Niña event corresponded in time with a shift in the Pacific Decadal Oscillation (PDO) from a warm to a cool phase, though this is by no means accepted as certain. The PDO is a low-frequency climatic phenomenon, in contrast to the more dramatic, higher-frequency phenomena such as El Niños/La Niñas. It may nevertheless have profound impacts on the structure of the pelagic ecosystem. Indeed, a shift in the PDO from a warm to cool phase in the 1940s was implicated in the decline of the California sardine fishery. Unfortunately, while the impacts of acute interannual events such as El Niños/La Niñas may be assessed through research and monitoring in a relatively timely manner, the ramifications of longer-term phenomena such as the PDO require more extensive datasets and the benefit of increased hindsight.

Nevertheless, our data have suggested some interesting trends. Zooplankton biovolume dramatically and significantly increased following the 1999 La Niña event. (*See Figure 1, previous page.*) Preliminary analysis suggests that this was due to an increase in gelatinous plankton such as hydromedusa (small jellyfish), ctenophores (comb jellies), and pelagic tunicates (salps and doliolids). In contrast, no such pattern was evident in krill abundance, which remained statistically unchanged over the study period.

While the data are far from conclusive, these results stress the importance of krill as a key forage species for both commercially valuable and endangered species within the sanctuary's waters. Further, they highlight the uncertainty of how shifts in marine climate may impact krill population dynamics and regional distribution within the California coastal environment.

– Baldo Marinovic
Insitute of Marine Sciences, University of California Santa Cruz

Efforts to Prohibit Krill Harvesting

Due to the critical role krill play in the sanctuary's ecosystem, the Monterey Bay National Marine Sanctuary convened a working group in January 2003, as part of its management plan review, to address the threat of krill harvesting. The State of California and commercial fishermen have also recognized the threat krill harvesting poses to the ecosystem and the state's fisheries.

California was the first state to prohibit a targeted krill fishery in 2000, and Oregon and Washington have since followed suit. However, the threat of a fishery remains, as the most dense aggregations of krill often occur beyond the states' three-mile jurisdictions. The working group therefore identified strategies to pursue a complementary ban in federal waters.

In June 2004 the three central coast sanctuaries submitted a request to the Pacific Fishery Management Council to prohibit krill fishing within their waters. They requested that the council take this action pursuant to its own authority under the Magnuson-Stevens Fishery Conservation and Management Act. The proposal was met with broad support from fishermen, environmentalists, and fishery managers, who all saw this as an opportunity to act preemptively to protect the marine ecosystem. As a result, after presenting this request to the council and its advisory bodies in June 2004, there was broad-based consensus that such a prohibition should not just be limited to sanctuary waters but rather should apply to all federal waters along the West Coast.

The council agreed to move forward and is currently pursuing a prohibition by including krill in the Coastal Pelagic Fishery Management Plan and then setting the total allowable catch to zero. Amending this fishery management plan can be expected to take some time, and a prohibition may not be fully implemented until late 2005.

– Huff McGonigal
Monterey Bay National Marine Sanctuary

Tagging of Pacific Pelagic (TOPP) Project

While the open ocean forms the largest component of the Monterey Bay National Marine Sanctuary, it is also one of its least understood. The surface area is vast and hides the inhabitants as they move through a water column that is also ever-changing. These qualities have made following large, open-sea predators such as whales, tunas, sea turtles, and sharks in their ecosystem a daunting task throughout history. Today, advances in microelectronics and satellite technology offer scientists unprecedented access to the world of these oceanic travelers and their journeys.

Launched in late 2000, the Tagging of Pacific Pelagics (TOPP) program is a pilot project of the Census of Marine Life – a global network of researchers engaged in a ten-year initiative to assess and explain the diversity, distribution, and abundance of life in the ocean. A collaboration among Stanford University, University of California Santa Cruz, the National Oceanic and Atmospheric Administration's (NOAA) Pacific Fisheries Environmental Lab, and the Monterey Bay Aquarium, TOPP seeks to discover and describe the highways and "hot spots" (areas of high activity) of ocean life by using a variety of pelagic animal species as sensors. Twenty-two species of marine predator – including pinnipeds, whales, tunas, turtles, seabirds, and large squid – will offer TOPP scientists an "organism's view" of their environment as they migrate, feed, and breed.

During the first three years of the TOPP program, more than fifty scientists from eight countries worked together to tag nineteen different species of open-ocean animals in the North Pacific with more than 1,500 data-collecting electronic tags. TOPP scientists tested the effectiveness of existing electronic tags, and their experience has driven design improvements and innovations to these small but powerful devices. Some of the animals carry archival tags, which record data to be retrieved later in the journey, while frequently-surfacing animals like sharks or whales carry devices that regularly uplink to satellites, providing a near-real-time record of the animals' movements across the Pacific.

While TOPP scientists continue to improve the tags and build software tools that integrate and visualize tracking and environmental information, the data returning from the tagged animals are building a complex picture of activity in the eastern Pacific. Scientists have observed tunas that undertake trans-oceanic journeys to and from the coast of Mexico to the Sea of Japan, and they have followed salmon sharks for more than two years on migrations from the Gulf of Alaska to Hawaii and back. In the course of their journeys, the animals collect valuable environmental information, recording ocean temperature, salinity, light level, and depth preferences en route.

Photo courtesy of Dan Costa, UCSC and TOPP

Elephant seals are among the many species that will offer TOPP scientists an "organism's view" of their environment.

Working with oceanographers, the biologists hope to model how TOPP predators use the North Pacific ecosystem. A Live Access Server (a near-real-time data repository) will allow scientists to access and analyze tag data in the context of simultaneously gathered oceanographic information from weather satellites, buoys, and research vessels. This cross-disciplinary approach helps TOPP scientists understand what factors influence migratory behavior.

Equally valuable to scientists and resource management officials are the larger patterns revealed through multi-species tagging. Finding areas where whole communities of open ocean animals converge, "ocean hot spots" that are analogous to the watering holes and fertile valleys on land, is an important goal of the TOPP project. Locating areas where animals at the top of the oceanic food web congregate helps scientists reconstruct the larger ecosystem in which these "apex predators" move in conjunction with their prey.

TOPP information will not only advance our understanding of the open ocean and its inhabitants but will help policy makers develop ecosystem-based management strategies to ensure a future in which these magnificent animals maintain healthy populations.

To learn more about the TOPP project, visit www.toppcensus.org. For a real-time look at TOPP data, visit http://las.pfeg.noaa.gov/TOPP_recent/index.html.

– Diane Richards
Monterey Bay Aquarium

The Physical Environment

Ocean Observing Systems in Central and Northern California

In recent years national and international efforts to develop standardized earth observing systems have increased. The Integrated Ocean Observing System (IOOS) is the U.S. contribution to the Global Ocean Observing System (a multinational effort sponsored by the International Council for Science and several United Nations groups) and the U.S. Environmental Protection Agency's Global Earth Observing System of Systems.

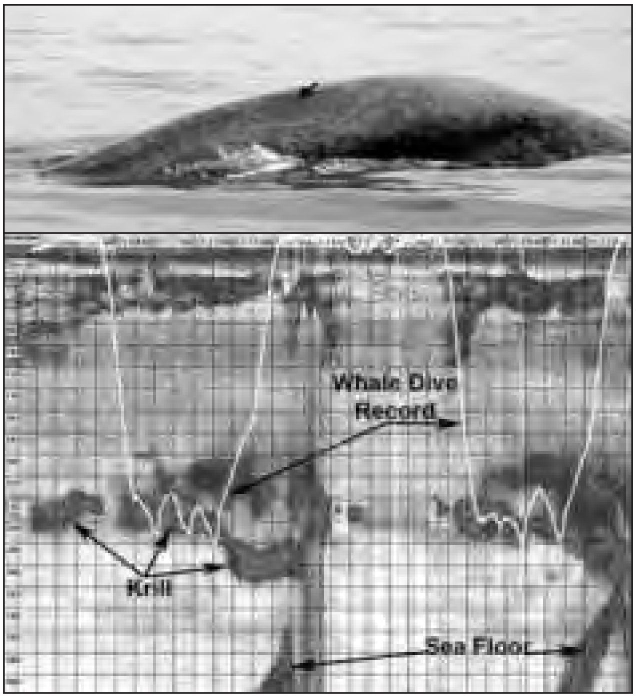
IOOS involves a spectrum of activities that efficiently link ocean observations, data management, modeling, and product development, providing information to significantly improve the nation's ability to achieve seven societal goals:

- Improve predictions of climate change and weather and their effects on coastal communities and the nation
- Improve the safety and efficiency of marine operations
- Mitigate the effects of natural hazards more effectively
- Improve national and homeland security
- Reduce public health risks
- Protect and restore healthy coastal marine ecosystems more effectively
- Enable the sustained use of marine resources

It is envisioned as a coordinated national and international observation network that systematically and efficiently acquires, analyzes, manages, and disseminates data and information on the oceans and coasts, including the U.S. Exclusive Economic Zone (from mean low water of the coastline outward 200 nautical miles), Great Lakes, and estuaries.

IOOS consists of three highly inter-related subsystems: an observational subsystem includes observing platforms (e.g., ships, moorings, satellites, planes), sensors, and sampling devices; a data management and communications subsystem provides protocols and standards for quality assurance and control, data dissemination and exchange, data archiving, and user access; and a modeling and analysis subsystem provides predictive models, data assimilation, and the development of data products. IOOS consists of a national "backbone" complemented by eleven regional ocean observing systems.

Monterey Bay is in the center of one of the eleven regional associations of ocean observing systems: the Central and Northern California Ocean Observing System (CeNCOOS). Formed in 2003 and currently funded by the National Oceanic and Atmospheric Administration's (NOAA) Coastal Services Center, CeNCOOS has a mission to coordinate and support the development and implementation of a regional ocean observing system from the northern California border to Point Conception, providing data and products to a diversity of end users at appropriate spatial and temporal scales. CeNCOOS collects data on a standard suite of variables (e.g., sea surface temperature, wind speed and direction, currents, salinity). Currently the national backbone provides a common set of goals and data collection methods across all of the regional associations,



© John Calambokidis

Courtesy of Kelly Newton

Blue whale equipped with a dive recorder as part of the Center for Integrated Marine Technologies program (upper image). Dive profile of a tagged whale in relation to krill swarms near the Monterey Bay Submarine Canyon (lower image)

but each region (e.g., CeNCOOS) augments these national efforts with data collection platforms and sensors that address region-specific variables over smaller spatial and temporal scales.

CeNCOOS is a collaboration of approximately fifty-five public agencies, academic/research institutions, and private non-profit and for-profit corporations. The CeNCOOS geographic database of existing observing systems in the region includes information on more than seventy-five different observing activities involving more than 175 different partner institutions and 1,000+ sites. The majority of these sites are within the Monterey Bay, Cordell Bank, and Gulf of the Farallones National Marine Sanctuaries. Multiple institutions within the Monterey Bay National Marine Sanctuary partner with CeNCOOS, including the Monterey Bay Aquarium Research Institute (MBARI), the Naval Postgraduate School, University of California Santa Cruz, Moss Landing Marine Laboratories, California State University Monterey Bay, and NOAA Fisheries at Santa Cruz.

Readers can visit the CeNCOOS web site (www.cencoos.org) for more information about the organization, including information about observing activities in the region and partner institutions. With the help of the Sanctuary Integrated Monitoring Network (SIMoN), the CeNCOOS web site also includes a portal to real-time and near-real-time data from moored buoys, satellites, high-frequency radar, shore-based stations, and biological platforms (e.g., elephant seals tagged with environmental sensors).

In a complementary effort and with funding from NOAA since 2002, many of the Monterey Bay area partners currently involved in CeNCOOS formed the Center for Integrated Marine Technologies (CIMT). Viewed as an IOOS pilot project, CIMT uses and develops new technological approaches to study the processes driving the highly productive coastal upwelling ecosystems along the California coast. CIMT scientists measure key components in the system and integrate diverse data sets across disciplines and programs. By studying ecosystem components from wind to whales, CIMT will establish a scientific basis for effective monitoring and management of fisheries and other resources associated with them.

Visitors to the CIMT web site (http://cimt.ucsc.edu/) can view several products centered on Monterey Bay. For example, users can access real-time physical oceanographic and meteorological data collected by MBARI moorings, view surface currents in real time, and see near-real-time satellite images of sea surface temperature, chlorophyll, winds, and the output of a wave model. In addition, CIMT ship surveys collect acoustic backscatter data that are displayed on top of Monterey Bay bathymetric data to yield a 3-D view.

In the coming years, as societal needs increase, ocean observing and the development and delivery of useful data products will become more prominent. The Monterey Bay National Marine Sanctuary, along with both the Gulf of the Farallones and Cordell Bank National Marine Sanctuaries, will continue to be a major partner in these activities along the central and northern California coast.

– Steve Lonhart[1] and Stephanie Watson[2]
[1]Monterey Bay National Marine Sanctuary and Sanctuary Integrated Monitoring Network (SIMoN)
[2]Central and Northern California Ocean Observing System

Wetlands and Watersheds

Pescadero and Pajaro Watershed Assessments

With eleven major watersheds draining to the Monterey Bay National Marine Sanctuary, a dynamic interaction exists between the land and the sea. As water flows through our rivers and creeks, it moves through different types of land uses, picking up pollutants and carrying them downstream. Excessive sedimentation and erosion in these coastal watersheds can affect riparian, wetland, and nearshore ecosystems.

A good example of the potential impacts is what happens to anadramous fishes such as coho salmon (endangered) and steelhead trout (threatened), which require both freshwater and marine environments for their unique life cycle. Each year salmonids leave the ocean and enter freshwater systems to spawn. They lay their eggs in gravelly river beds, and if excessive sedimentation has occurred, spawning areas may become buried in fine sediments.

The Monterey Bay Sanctuary Foundation managed two watershed assessments, funded by the State Water Resources Control Board, that were completed this year. Both the Pescadero-Butano and the Upper Pajaro watersheds are identified on California's List of Impaired Water Bodies. As part of the sanctuary's voluntary Agriculture and Rural Lands Plan, the assessments were carried out with the assistance of the local Farm Bureaus and farmers. These completed studies provide local communities and resource agencies with important data for future watershed planning and restoration activities. The reports are available online at www.mbnms.nos.noaa.gov/resourcepro/reportssedrep/ welcome.html.

Pescadero-Butano Watershed Assessment

The Pescadero-Butano watershed is the largest coastal watershed between the Golden Gate and the San Lorenzo River. Its two principal streams, Pescadero Creek and Butano Creek, join at Pescadero Marsh and drain about 210 square kilometers (eighty-one square miles) of watershed. The Pescadero-Butano watershed assessment, undertaken via a contract to Environmental Science Associates, characterized sediment sources and dynamics, assessed current habitat conditions for coho salmon and steelhead trout, and identified factors limiting the quality and extent of salmonid habitat.

To identify relative sediment yields within this large and diverse watershed, the area was divided into distinct units defined by geology, slope, and vegetation cover. Of these units, forty field plots of forty acres each were systematically surveyed for erosional features that delivered sediment to a stream channel. In addition, twenty-three stream reaches were surveyed to determine priority stream basins for salmonid habitat. These surveys ranked physical habitat quality, biotic conditions, pool habitat conditions, and water quality conditions pertaining to salmonids. Areas recommended for protection and/or restoration were identified and ranked as high- or medium-quality salmonid habitat. The main impediments to salmonids were identified as excessive fine sediments, lack of cover, and shallow pools.

A historical study revealed that much of the damage in the watershed was done in the mid-twentieth century by clear cutting and tractor logging, abandoned agricultural fields that began forming gullies, and road construction practices and road placement. Major flooding events recorded from the 1930s to the present have flushed large quantities of sediment downstream, where it has accumulated in the lower watershed areas.

Current contributions to the sediment load include – in order of magnitude – roads (active unpaved, forest, and ranch land), timber harvesting, and agriculture. The assessment was done in conjunction with agricultural demonstration projects to minimize sediment erosion that were developed by the San Mateo County Farm Bureau. These projects included cover cropping, using different seed mixes to prevent erosion, and installation of three different types of livestock exclusionary fencing to protect riparian areas. In addition to highlighting the value of these projects, useful cost data comparisons were compiled for growers to use in the future.

The Coastal Watershed Council also conducted water quality monitoring at five sites with a team of volunteers. During the short sampling season, water quality was found to be relatively good.

The assessment recommends conducting more detailed stream assessments, implementing sediment control practices in the basins identified as high priority for salmonids, and continued water quality monitoring.

Upper Pajaro River Sediment Assessment

The Pajaro River watershed is one of the largest riverine systems entering Monterey Bay and drains an area of approximately 3,370 square kilometers (1,300 square miles) of watershed. The upper Pajaro River sediment assessment was developed for 523 square kilometers (202 square miles) in southern Santa Clara County. The assessment characterizes erosion and sedimentation dynamics in Llagas and Uvas Creeks, including an evaluation of sediment conditions, erosion risk, and potential impacts to the watershed.


© NOAA/MBNMS

Steelhead require both freshwater and marine environments for their unique life cycle.

The assessment, performed via a contract to Fall Creek Engineering, was conducted in preparation for a sediment total maximum daily load (TMDL) study. The TMDL process attempts to identify the maximum acceptable load of a pollutant for a given body of water. This pre-TMDL assessment documents current land uses in the area and identifies sediment sources for hillside development, road ditches, agriculture, and equestrian lots; it determined which of these sources could be controlled using management practices.

The watershed was divided into four geographic sections based on landscape position, sub-watersheds, and current land uses. Within these sections, land-use types were categorized as rangeland, urban and residential, agricultural, and equestrian. The major reasons for impairment varied by section but collectively included vegetation removal, channel hydromodifications, concentrated hillside development, road ditches, agriculture, equestrian activities, and land use encroachment to riparian areas. The assessment was done in conjunction with landowner outreach by the Santa Clara County Farm Bureau.

The assessment recommends integrating ecological restoration activities, such as re-establishing native vegetation and buffers into the sediment TMDL. Additional water quality monitoring by local community organizations and agencies will also be necessary.

Both of these assessments show the critical need for continued work by landowners and managers to prevent erosion and sedimentation of local waters. The sanctuary's partners in the Agriculture and Rural Lands Plan will continue to work in these watersheds to protect water quality.

–Katie Siegler
Monterey Bay National Marine Sanctuary

Physical and Biological Exchange between Elkhorn Slough and Monterey Bay

The physical and biological exchange between Elkhorn Slough and the Monterey Bay National Marine Sanctuary is largely unknown, yet important. The slough serves as a significant year-round link between land use activities and the coastal waters of Monterey Bay. Agricultural runoff, concentrated in the slough during periods of precipitation, can be carried by tidal exchange into the sanctuary. Tidal scouring of the slough's banks and bed can resuspend pollutants that have accumulated in sediments over the past several decades. Increased fluxes of nutrients and pollutants into the bay can influence water quality, increase the prevalence of harmful algal blooms and marine diseases, and have consequences for nearshore ecology.

This exchange is of particular concern because the slough's physical configuration has been drastically altered by human intervention. In 1946 the Army Corps of Engineers changed the morphology of Elkhorn Slough by cutting through the dune barrier separating the slough from Monterey Bay. Since then the slough has been transformed from a sluggish backwater to a shallow, tidally forced embayment. Maximum tidal currents in the main channel have increased from approximately 1.5 knots in 1971 to 3.0 knots today, and the tidal prism – the volume of water exchanged between the slough and the bay over a tidal cycle – has increased significantly during the past decade. While the incoming tide introduces relatively clear water from Monterey Bay into the slough, waters discharged into Monterey Bay during the ebb tide are laden with sediments. As the tidal currents and prism continue to increase, and the surrounding watershed is subject to growing population pressures and land use change, there is an urgent need to understand the physical extent and the biological impacts of the discharge plume that enters the bay from the slough.

Recent observations from high-resolution aircraft remote sensing and ship-based measurements are helping characterize the plume's physical and biological characteristics. Recent overflights by the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) have provided imagery at far greater resolution than that provided by instruments currently being flown at satellite altitudes. This imagery reveals a sediment-laden discharge plume exiting the slough at ebb tide. (*See Figure 1.*) The plume extends south along the coast and eventually becomes entrained in the longshore currents. The extent of the plume varies in accordance with the tides, and previous observations have shown patches of plume water entrained in the bay's circulation extending far offshore.

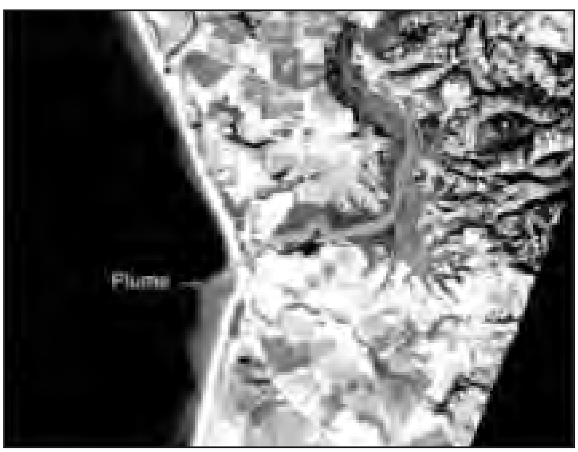


Figure 1. An enhanced hyperspectral image, acquired by the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS), reveals a discharge plume exiting the mouth of Elkhorn Slough.

The plume's physical characteristics, obtained through ship-based measurements, reveal a wedge of warmer, less saline water exiting the slough at maximum ebb tide, producing a sharp salinity gradient (halocline) where slough waters meet oceanic waters. This results in separation of water masses along density gradients, isolating plume waters from oceanic waters below and suppressing vertical mixing. Consequently, conditions favorable for phytoplankton growth and harmful algal blooms develop.

Water samples, collected at successive locations with increasing distance seaward of the slough, reveal distinct assemblages of phytoplankton between plume and bay waters. Analyses of these samples for chlorophyll and carotenoids, naturally occurring plant pigments, show high concentrations of alloxanthin, a carotenoid found in cryptophytes, dominating the inland waters of Elkhorn Slough (*Figure 2a*). Cryptophytes are a group of phytoplankton quantitatively dominant in turbid waters. Further offshore, alloxanthin concentrations diminish and concentrations of peridinin, a pigment indicative of the phytoplankton group dinoflagellates,

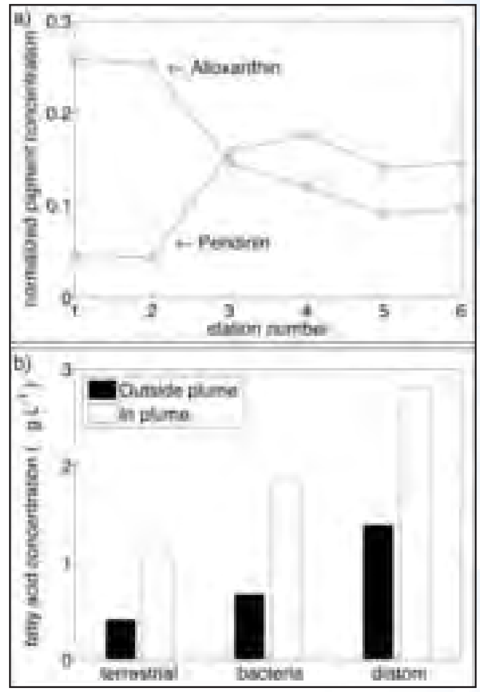


Figure 2. a) Alloxanthin and peridinin pigment concentrations retrieved from stations in Monterey Bay along the plume track. Increasing station numbers represent progressively greater distances from the entrance of Elkhorn Slough. Carotenoid pigments were referenced against chlorophyll a, a pigment common to all algae.
b) Fatty acid concentrations of terrestrial matter, bacteria, and diatoms averaged among six stations within the slough plume (white bars) and compared with a control sample of oceanic water (dark bars)

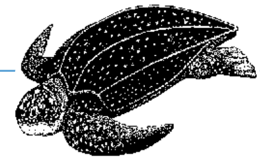
increase. It is possible that a plume of inland slough water, on spring tides, can introduce rich concentrations of cryptophytes into the bay, significantly impacting food web cycling and biogeochemical transformation rates.

The water samples were examined further using fatty acid biomarker analysis. Examination of specific fatty acids and different lipid classes will provide a better understanding of sources of input to plume waters. The results show that plume water carries indicators of terrestrial material, bacteria, and diatoms. Fatty acid concentrations of each of these markers are more abundant than those sampled from a control sample taken from nearby oceanic waters (*Figure 2b*). The presence of terrestrial biomarkers indicates the transport of "foreign," or land-based, materials into Monterey Bay.

Recent measurements, although preliminary, have revealed components of the physical and biological exchange between Elkhorn Slough and the sanctuary. These measurements show a stratified plume of slough water with significantly different phytoplankton diversity and abundance entering the sanctuary. Plume waters are dominated by terrestrial biomarkers, indicating the flux of land-based materials.

Further research is needed to combine on-location measurements with airborne imagery to understand the fate and consequences of these fluxes better. Due to the dynamic nature of the plume, innovative sampling techniques are needed to capture the process during the evolution of the tide. Repeat coverage of airborne imagery coupled with concurrent on-location measurements will help further examine the ultimate fate of plume waters and what role the plume constituents play in influencing the ecology and water quality of the sanctuary.

– Andrew Fischer[1], Erich Reinecker[1], John Ryan[1], Nick Welchmeyer[2], and Larry Breaker[2]
[1]Monterey Bay Aquarium Research Institute
[2]Moss Landing Marine Laboratories



A Review of the Status of "At-Risk" Species in the Sanctuary

The boundaries of the Monterey Bay National Marine Sanctuary encompass a high diversity of marine habitats and nutrient-rich waters. These conditions combine to create an area with an incredible level of biodiversity. The populations of some species – such as krill and jellies – are thriving in sanctuary waters. However, other species are considered to be "at risk" because their population sizes are reduced or declining.

Reduced or declining populations may be caused by human exploitation, habitat degradation, disease, environmental change, or a combination of these factors. The sanctuary, through its research, education, and resource management programs, has the ability to help improve the status of many at-risk species. However, to make these efforts most effective, it must determine which species are at risk and which actions will be the most beneficial for each species.

The goal of a new one-year research project of the Sanctuary Integrated Monitoring Network (SIMoN) is to compile this type of information. The project has three phases. In the first, a list was compiled of all the species occurring in sanctuary waters that are designated at risk by a variety of resource management agencies and conservation groups. For the second phase, status reports for a number of species are being generated that cover a variety of topics, including geographic range, abundance, migration patterns, threats, current research projects, and conservation efforts. In the third phase, we will determine what actions the sanctuary can take to help improve the status of at-risk species. Recommended actions may include research projects to collect data needed to improve species management or outreach programs to help increase public awareness of at-risk populations. All the material compiled for this project will be available after the project ends in July 2005 in a published technical report and in digital form on the SIMoN web site.

Below are examples of at-risk species in the sanctuary, with brief updates on their current status.

The leatherback turtle, *Dermochelys coriacea* is a common summer/fall visitor to sanctuary waters, where it feeds on seasonally abundant jellies. Drastic population declines have led to this species being listed as "endangered" under the federal Endangered Species Act (ESA) and "critically endangered" by the World Conservation Union (IUCN). Human impacts, such as entanglement in fishing gear, ingestion of marine debris, and harvesting of nesting females and eggs, are the main cause of decline. Improving management and conservation of the leatherbacks that visit the sanctuary requires an understanding of when and why they visit these waters as well as where they go and what threats they may encounter after leaving the sanctuary.

The leatherback population in Monterey Bay has been the focus of a research project led by the National Marine Fisheries Service Sea Turtle Research Program. Some of the project's goals are to determine foraging areas, habitat needs, and migratory patterns of this population. Aerial surveys in September found that the distribution of leatherbacks had shifted this year: fewer turtles were seen in Monterey Bay, and more were seen in areas to the north. Preliminary results suggest that this northward shift may have been tied to unusual oceanographic conditions in the bay. Satellite transmitters were attached to three leatherbacks in Monterey Bay in September. Tracking the turtles' movements will help researchers identify important foraging areas in the sanctuary as well as determine where the turtles go after they leave sanctuary waters.

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The leatherback turtle is a common summer/fall visitor to sanctuary waters.

The Marbled Murrelet, *Brachyramphys marmoratus* is a small seabird found along the coast between central California and the Aleutian Islands. It has the unusual habit – for seabirds – of nesting in old-growth forests. Loss of nesting habitat has caused Marbled Murrelet populations to decline in many areas, with the most dramatic declines in Washington, Oregon, and California (the "three-state area"). For example, in California, murrelets have declined from an estimated 60,000 individuals prior to the start of timber harvesting to a current estimate of 4,600. The southernmost population, which nests in the mountains of Santa Cruz and San Mateo Counties and forages in sanctuary waters, is estimated to contain only 600 individuals.

Given these drastic declines and the three-state area's geographic isolation from the species' population center in Alaska, murrelets in this area were listed in 1992 as "threatened" under the ESA. Listing has increased protections for this species and restrictions on timber harvest near nesting colonies. In May 2004 the U.S. Fish and Wildlife Service (FWS) completed a review of the "threatened" status of the Marbled Murrelet in the three-state area and concluded that this population (which constitutes less than 2.5 percent of the entire species) does not qualify for listing under the ESA as a distinct population segment. However, before the Marbled Murrelet can be reclassified or delisted in the three-state area, the FWS will need to complete a review of the range-wide status of the species. Some researchers and conservationists are concerned that delisting would diminish protection of old-growth nesting habitat and lead to further population declines.

The blue whale, *Balaenoptera musculus* and humpback whale, *Megaptera novaeangliae* can been seen year-round in the sanctuary but are most abundant in the summer and fall. Though both species are locally abundant at times, their numbers are still recovering from severe overexploitation by commercial whaling in the early- to mid-1900s. Both are listed as "endangered" under the ESA and as "depleted" under the Marine Mammal Protection Act. In addition, they are protected from commercial take by the International Whaling Commission. Even with these protections, humpback and blue whales still face threats in their environment, including collisions with ships and noise pollution. To help reduce threats in sanctuary waters, whale behavior, abundance, and movement patterns in and around the sanctuary must be better understood.

A collaborative research program, which includes scientists from a number of Monterey Bay research institutions, is collecting this type of data on humpback and blue whales in and around the sanctuary. The researchers use ship-board surveys to determine the distribution and abundance of whales in Monterey Bay. This year's surveys revealed a few unusual patterns for humpback whales, including the early arrival (in May) of many individuals and their spending a higher proportion of time in shallow water (where they were seen feeding on schools of fish). To monitor the whales' feeding behavior and movement patterns, a total of thirty-three long-term and ten short-term tags were attached to blue and humpback whales off southern and central California in August and September. These tags will allow researchers to determine what the whales are doing while in sanctuary waters and where they go once they leave. Another notable event during this year's research was the deployment in May of a passive acoustic array in Monterey Bay. By recording visiting whales' vocalizations, this array allows researchers to determine when different whale species appear in the bay.

– Jennifer Brown
Sanctuary Integrated Monitoring Network (SIMoN)

Marine Mammals

Spring 2004: Unprecedented Predation by Killer Whales on Gray Whales

Killer whales occur worldwide from the polar regions to the tropics; they are the ocean's top predator and the most intelligent of all cetaceans. They are social, charismatic animals that live in family groups based on a matriarchal system, with adult females and their offspring enjoying the closest associations. Males may stay with their mothers for life. Their vocal repertoire is complex, comprising echolocation pulses and communication calls with distinct dialects among different groups or populations. As a predator at the top of the marine food chain, killer whales consume a range of prey – from small fishes to the enormous blue whale. Three known eco-types occur along the West Coast: residents, offshores (both of which eat fishes), and transients (which prey on marine mammals).

With such a high diversity of marine mammals inhabiting Monterey Bay, it's not surprising that transient killer whales frequent this area year-round. Over the past seventeen years, we have identified more than 150 different transient whales, based on distinct markings, and have documented association patterns, calving rates, behavior, and long-range movements. Some of this information was gained through opportunistic photographs from our whale-watching vessels. Our team (which also includes Richard Ternullo, Alisa Schulman, Peggy Stap, and Sarah Graham) has also collected small biopsy samples (skin and blubber) from our dedicated research inflatable under permits in conjunction with the National Marine Mammal Laboratory/National Marine Fisheries Service (NMFS). These samples have provided valuable data on genetics and organic pollutants.

Although killer whale occurrence is unpredictable, and the whales are seen between two and eight times per month, they are frequently seen in Monterey Bay during the spring, corresponding to the migration of mother gray whales and their calves. Gray whales undergo their yearly migration from feeding grounds in. the Bering Sea to breeding areas along the west coast of Baja California. The migration is segregated by age and reproductive status. Gray whales with recently born calves spend the most time in the lagoons and are the last whales to head back up to Alaska; these individuals pass through Monterey Bay during April and May. The mothers and calves hug the coast closely as they travel north.

When the whales reach Monterey Bay, they generally cross the bay and the deep submarine canyon, where their migration path crosses the deep-water habitat of the killer whales. The killer whales patrol the canyon edges in search of the gray whale calves. When a gray whale calf is located, one of the most dramatic predation events on earth occurs: several five-ton killer whales battling a forty-five-ton gray whale mother and her ten-ton calf for up to six hours. If successful, the killer whales gain a rich source of food for more than twenty whales.

Although this is a yearly event, the spring of 2004 was unprecedented as far as the frequency of killer whale sightings and the number of attacks and feeding events on gray whales. After several years with relatively low

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Killer whale holding down a gray whale numbers of gray whale calves and a significant decrease in the gray whale population, the number of calves born in 2004 was the highest since counts began ten years ago by the NMFS. Wayne Perryman, who heads these counts, believes that more calves survive through full term and are successfully nursed during years when whales have an abundant and predictable food source in the Bering Sea – a situation that occurred during the summer of 2003. Last spring many calves passed through the bay each day, with a peak of around forty mother-calf pairs per day – compared to less than ten in previous years.

From April through mid-May, we documented sixty-five different killer whales involved in at least sixteen attacks on gray whale calves (including four escapes), compared to just a few attacks over the past six years. The usual group size for transient killer whales averages three to eight whales, but during the spring season, several of these core or family groups gathered together in a coordinated effort to hunt the gray whales and share the food.

Reproductively active females were most involved in the attacks. At least thirteen different core groups were found over this period, and four groups were present nearly 50 percent of the days, while some groups occurred just once or twice. It was surprising that some groups were involved so frequently, and we wondered if they were binge-feeding by taking advantage of this huge food source over a short period of time.

Another function of pursuing gray whales is for adult female killer whales to teach their young how to hunt. A great deal of learning, cooperation, and communication is required to take down such a large animal.

We hope to continue monitoring the killer whales over many more years. As a keystone species, these whales act as health indicators for the marine environment.

– Nancy Black
Monterey Bay Cetacean Project

Marine Mammal Viewing Guidelines

This yearly phenomenon of killer whales pursuing gray whales corresponds to the salmon-fishing season, often when there are hundreds of boaters out in the bay. While this is an exciting and once-in-a-lifetime event to witness, boaters must observe from a reasonable distance and not interfere with the whales. (While such an event may be difficult for many to watch, it is not our place to intervene – and, in fact, it is illegal to cause a change in behavior of whales by our presence.)

All marine mammals are protected by the federal Marine Mammal Protection Act, and most large whales in the area are further protected under the federal Endangered Species Act. Under these acts, it is illegal to "harass, hunt, capture, or kill" any marine mammal. Prohibited conduct includes any "negligent or intentional act that results in the disturbing or molesting of marine mammals." Here are some basic guidelines for observing marine mammals:

- Do not approach a marine mammal closely enough to cause a change in behavior, such as causing resting sea otters to dive; seals or sea lions to enter the water from their haul-out area; or whales or dolphins to exhibit evasive actions, quick dives, or abruptly stop the behavior they are currently engaged in.
- Always approach whales slowly ("see a blow, take it slow"), without blocking their path of travel or boxing them in.
- Parallel their course and speed without drastic changes in engine speed, and do not approach head-on.
- If whales approach your boat, put engines in neutral and wait until they leave.
- Exit slowly from any areas where whales are present.

An Ecosystem-Based Approach to Protecting a Highly Migratory Species

Humpback whales inhabit all of the world's oceans. Like most of the great whales, they undertake seasonal migrations between "high-latitude" summer feeding grounds and "low-latitude" winter mating and calving grounds. In the warm-water but unproductive wintering areas, they forego feeding and concentrate on finding mates, conceiving, and then giving birth the following winter. This ability to store enough food reserves to allow the animals to fast for months, while traveling thousands of miles, is a remarkable adaptation that has apparently served them well through the inevitable natural variation in food and climate over tens of thousands of years. However, for scientists trying to understand, manage, and protect humpbacks, the animals' ability to use an entire ocean basin as their home seems an insurmountable obstacle. How does one apply an ecosystem approach to protecting such a species?


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The SPLASH Project is an unprecedented effort to coordinate research on humpback whales throughout the North Pacific Ocean.

To address this challenge, the SPLASH (Structure of Populations, Levels of Abundance, and Status of Humpbacks) Project was conceived. In order to gather systematic data from humpback whales in all of their known summer and wintering areas, within one of their largest ocean habitats, the SPLASH Project has formed a collaboration among virtually all of the humpback whale research teams working in the North Pacific Ocean. As a result, approximately 130 researchers are gathering data from the winter of 2004 through the winter of 2006, making the project the largest (in geography and participation) whale study ever attempted. The Hawaiian Islands Humpback Whale National Marine Sanctuary is at the center of much of the work in the winter, while most sampling along the U.S. West Coast is focusing on the national marine sanctuaries there, including the Monterey Bay National Marine Sanctuary.

But even with this unprecedented geographic scope, one might wonder how a project that focuses on just one species will gain insight into that animal's role in the ecosystem. Because most of the SPLASH teams will be working directly with individual whales from small vessels, the environmental data that can be collected is limited. However, through images and tissue samples, some of the data collected from individual whales will tell us about the environments they inhabit.

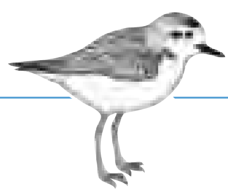
The project's basic methodology is to collect images and tissue samples from individual whales throughout the North Pacific Ocean. The black and white pattern on the underside of an animal's tail flukes is, like a fingerprint, unique to each individual and allows it to be identified – which can help researchers understand population structure, abundance, and movements. Moreover, images of each animal's flanks and "tailstocks" allow for an examination (through scarring) of obvious physical impacts, like entanglements, vessel collisions, and predators. This analysis will give us an indirect look at some of the dangers the whales face in their different environments.

Finally, the tissue samples collected, using biopsy darts shot from a crossbow, will allow a suite of analyses that will give tremendous insight into how this species uses its ocean basin habitat. The molecular determination of sex and genetic relatedness will allow a more complete understanding of population structure within the North Pacific and give insights into the species' responses to global changes over thousands of years. But on a more timely scale, new analyses of the small bits of skin and blubber collected will allow a look at prey preferences (through fatty acids and stable isotopes), toxins, and – as these analyses are perfected – hormone assays, stress, and age. All of this, when combined with what we do know of its physical environment, will allow a tremendous advance in our understanding of the humpback whale's place in the ocean-basin ecosystem.

This project is supported in part by National Oceanic and Atmospheric Administration (NOAA) Fisheries, NOAA's National Marine Sanctuary Program, the National Park Service, the Marine Mammal Commission, the North American Commission for Environmental Cooperation, the Department of Fisheries and Oceans (Canada), the National Fish and Wildlife Foundation, and the World Wildlife Fund.

For more information, start at:
http://hawaiihumpbackwhale. noaa.gov/special_offerings/sp_off/splash/splash.html.

– David Mattila
Hawaiian Islands Humpback Whale National Marine Sanctuary



Bird Populations

Mortality of Northern Fulmars in Monterey Bay

During October and November 2003 hundreds of dead and live Northern Fulmars (*Fulmarus glacialis*) began washing in to beaches in the Monterey Bay National Marine Sanctuary. Fulmars are "tube-nose" seabirds (Family Procellariidae, which includes fulmars, petrels, and shearwaters) that nest on islands from British Columbia to Alaska. Fulmars migrate south from nesting areas during winter and are common off the West Coast of North America during October through March. Periodic die-offs of this species have been reported in past years, and these are often associated with unusual weather patterns.

We investigated this seabird mortality in cooperation with California Department of Fish and Game (CDFG) biologist Jack Ames and veterinary staff at CDFG – Marine Wildlife Veterinarian Care and Research Center, Santa Cruz (CDFG-MWVCRC). To establish the cause of death, we collected and dissected 186 dead fulmars that had stranded in Monterey Bay. In order to determine if the abundance of dead fulmars on beaches was unusual, we reviewed BeachCOMBERS (Coastal Ocean Mammal and Bird Education and Research Surveys) data collected since 1997 for comparison to the current data. To make surveys comparable, we standardized deposition rate by the number of kilometers walked. We found that the deposition recorded during the die-off was an order of magnitude greater than our long-term deposition rate for this species.

By examining feather wear, we concluded that most (96 percent) of the birds were young-of-the-year and few (4 percent) were older than one year. We examined the ratio of color morphs (light and dark plumage phases) to ascertain the potential colony of origin for these birds. Geographic differences in the ratio of light to dark morphs vary throughout the breeding range: Bering Sea colonies have few dark morphs (0 – 0.2 percent), whereas birds from the Aleutian Islands are mostly (99 percent) dark morphs, and those from the Gulf of Alaska and British Columbia are 75 to 85 percent dark morph. We found 92 percent dark and 8 percent light morphs of fulmars stranding in the sanctuary, indicating that these birds originated from colonies in the Gulf of Alaska. Data from Scott Hatch at the U.S. Geological Survey-Alaska Science Center corroborated our findings. Hatch tracked three adult fulmars with satellite tags from breeding sites in the Semidi Islands in the Gulf of Alaska to central California during the time of the die-off.

© Hannah Nevins

Veterinary assistant Eva Berberich examines the wing of a dead fulmar at the necropsy lab at CDFG-MWVCRC in Santa Cruz.

We found that all fulmars examined were below normal body mass and had essentially no body fat, indicating severe starvation. Pectoralis muscles were atrophied, suggesting protein catabolism during the starvation event. Stomachs were empty or contained plastic and few other remains. No evidence of disease was found, and starvation was considered to be the most probable and consistent cause of death in this event.

Because the North Pacific population of Northern Fulmars is estimated at 1.4 million breeding individuals, a periodic die-off such as the one we described during the winter of 2003 is not expected to significantly alter the population. However, events such as these offer great insight into how mortality factors can regulate seabird populations. Persistent storms during September and October along their migration path may have contributed to this starvation event, either by preventing foraging or reducing prey availability. Knowledge of the source of migratory species that inhabit the sanctuary is a first step in understanding how factors outside the sanctuary (such as ocean conditions in the Gulf of Alaska) can influence the abundance and distribution of seabirds in this area.

Beach COMBERS surveys are conducted by volunteers, with support from the Sanctuary Integrated Monitoring Network (SIMoN) through a research grant to Moss Landing Marine Laboratories.

– Hannah Nevins and Jim Harvey
Beach Combers, Moss Landing Marine Laboratories

Tracking the Movements and Trans-Pacific Migration of Sooty Shearwaters Captured off California

The arrival of hundreds upon thousands of Sooty Shearwaters (*Puffinus griseus*) to the Monterey Bay National Marine Sanctuary is an extraordinary annual phenomenon that attests to the global importance of Monterey Bay's abundant prey resources. Beginning in about April, we begin seeing scattered individuals and small flocks of hundreds to thousands of Sooty Shearwaters that have made their way to the coastal waters of California from breeding colonies in New Zealand, southern Australia, and Chile. (*See Figure 1.*) Situated along the inside of one of only four eastern boundary currents, the sanctuary hosts some of the world's most productive ocean waters; the abundant shoals of anchovy, sardine, rockfishes, krill, and squid in Monterey Bay draw the shearwaters here.

The Sooty Shearwater is the most abundant seabird off the coast of California from May to September. Surveys at sea, however, reveal a 90 percent decline in numbers since the late 1970s. Reasons for this dramatic decline likely include a combination of factors, such as breeding habitat loss, introduced non-native predators on breeding islands, marine climate change, incidental fisheries take, traditional Maori harvest of chicks, and oil pollution. Sooty Shearwaters also may have become more confined to highly productive "refuge" marine areas such as Monterey Bay and San Luis Bay, California and the Cape Blanco-Heceta Bank region off Oregon. And it has been suggested that large numbers of birds shifted to relatively cooler waters in the central North Pacific following the recent warm regime of the Pacific Decadal Oscillation that has affected the California Current ecosystem.

Figure 1. Sooty Shearwater flock off Moss Landing Marine Laboratories 26 May 2004. Large numbers of shearwaters aggregate, often in dense flocks that can exceed half a million individuals, to feed on shoaling fishes, squid, and euphausiids concentrated in productive marine areas influenced by coastal upwelling.

The Sooty Shearwater is one of five shearwater species frequently observed in the sanctuary. Shearwaters are members of the Family Procellariidae, often collectively referred to as "tube-noses" for their pronounced nostrils. The function of their unique bill morphology is unknown but may relate to the group's keen sense of smell – a trait required for locating patchy prey while navigating over thousands of square miles of open ocean. Alternatively, this structure – combined with greatly developed olfactory anatomy – may help these remarkable birds to sense subtle changes in sea-level atmospheric pressure gradients that shape global ocean wind patterns. (Strong winds are required for energy-efficient flight in order to traverse large expanses of open ocean in search of food or during migration.)

Shearwaters were named for their characteristic flight behavior, or "jizz." During flight, a Sooty Shearwater arcs and tips to gather speed as wind velocity increases several meters off the ocean's surface. At the apex, the bird again tips and dips, accelerating down with wind and gravity to slip in front of a wind wave or ocean swell. Skimming the ocean with its wingtips, the bird "shears" the surface, tips, and accelerates up to repeat this pattern, termed "dynamic soaring."

In 2003 we sought funding to follow up on shearwater research conducted in the mid- to late 1970s. We received the first of two small grants from the California Department of Fish and Game Oil Spill Response Trust Fund, administered through the Oiled Wildlife Care Network (OWCN) at the Wildlife Health Center, School of Veterinary Medicine, University of California Davis to examine the body condition, blood chemistry, diet, and molt pattern of shearwaters in Monterey Bay. This information is necessary to establish reference ranges and target release criteria for rehabilitated birds. With the support of the OWCN, we have established methods to capture wild shearwaters and measure seasonal variability in body condition and blood parameters in relation to feeding habits off California.

This past year, we teamed up with K. David Hyrenbach (Duke Marine Laboratory, Beaufort, North Carolina) and Cheryl Baduini (Claremont Colleges Consortium, Claremont, California) to examine the movements and migration of birds captured and outfitted with small satellite radio transmitters off central California. To date we have captured ninety-seven Sooty Shearwaters off Santa Cruz and San Luis Obispo Counties and outfitted twenty sub-adult to adult birds with satellite transmitters.

Six birds captured during the molting period in June and July off Capitola resided within the sanctuary and adjacent waters off California for one to two months. One individual ranged as far as Vancouver Island, BC, Canada before its transmitter's battery failed (after seventy-six days; twice its expected duration). By September 2004 oceanographic conditions in Monterey Bay contributed to an impressive, lingering red tide, which we hypothesize might have caused large numbers of shearwaters to leave the area. Our satellite data revealed that San Luis Bay and Pismo Beach were important destinations for birds marked in Monterey Bay.

In early September we traveled to Port San Luis to capture and attach transmitters to fourteen additional shearwaters, in an effort to examine the timing, duration, and route of the annual pre-breeding trans-Pacific migration to Southern Hemisphere breeding colonies. (*See Figure 2.*) Twelve of fourteen birds departed the California Current System, crossed the equator, and appeared destined for breeding colonies off New Zealand. The first individual to leave California, named Moana-Nui after the Maori words for the Pacific, made it within 1,000 kilometers of New Zealand before heading back east across the ocean toward South America. Was this individual perhaps a Chilean breeder?

This study marks the first time researchers have tracked, in detail, the incredible trans-Pacific migration of individual Sooty Shearwaters. Continuing investigations of the ecology of the Sooty Shearwater – the dominant member in the sanctuary's rich avifauna and a shared global natural resource – will provide important information related to the health of Monterey Bay and surrounding waters. In the future we hope to work more closely with the sanctuary, together with our colleagues in the Southern Hemisphere, to examine post-breeding migration routes from Chile and New Zealand.

– Josh Adams[1] and Jim Harvey[2]
[1]U.S. Geological Survey, Western Ecological Research Center
[2]Moss Landing Marine Laboratories

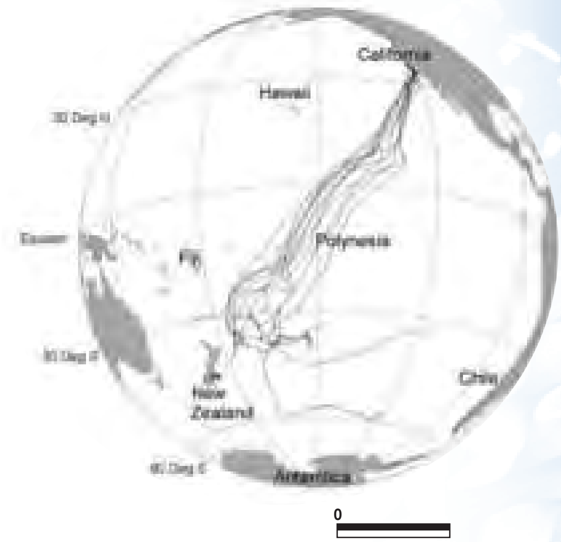
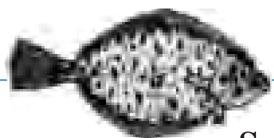


Figure 2. The trans-Pacific pre-breeding migration of twelve Sooty Shearwaters captured and outfitted with satellite radio transmitters near Pismo Beach, California. Track lines show direct movements from California toward New Zealand and as far south as 60 degrees, near the Antarctic convergence. Tracks shown are from approximately 1 September 2004 to 3 December 2004. (Data are ongoing, please visit www.seaturtle.org/tracking or www.signalsofspring.net for maps updated daily.)



Harvested Species

Squid Spawning Behavior and Advanced Monitoring Methods for a Heavily Harvested Fishery

The California market squid, *Loligo opalescens*, bridges the subtidal and pelagic (open water) nearshore habitats of the central and southern California coastline. This species is the target of California's largest and most valuable marine fishery, and because the fishery is conducted on and around the spawning ground, consideration must be given to spawning habitat. Our goal is to inform management by providing agencies with methods and critical data on the reproduction biology of mobile, aggregating squids.

Squids play a central role in nearshore marine ecosystems worldwide, not only as the prey of many marine mammals, birds, and fishes but as predators on a wide variety of crustaceans and fishes. Juveniles and adult *Loligo opalescens* are a key food component of nineteen fish, nine bird, and two marine mammal species in the nearshore pelagic ecosystem.

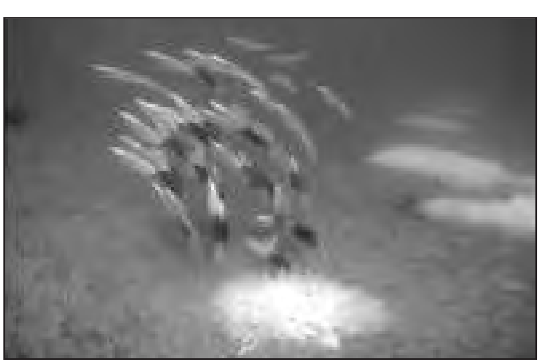


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Figure 1. Typical spawning pod of squids off Cannery Row at thirty-five-meter depth, just beyond the kelp beds.

The life cycle of squid is very short – less than one year – and therefore squid stocks are dependent upon successful reproduction every year. The fishery in Monterey Bay has, for 140 years, centered on the spawning grounds off Pacific Grove and Monterey. Sustainable fishing has been achieved for most of that period, despite the fact that fishing pressure has increased substantially over the past decade. Fishing is now being conducted both during the day, when the squid are spawning, and at night. There is limited protection of spawning grounds through weekend closures. While stocks seem to be healthy, fishery managers continue to ask how best to balance protection of spawning beds with a viable fishery.

It has long been thought that the main mode of reproduction for *Loligo opalescens* is large-scale spawning events at night followed by mass death. However, recent research has shown that this is not the case in Monterey Bay. Squids spawn most commonly during the day and in small groups (*Figure 1*) in which egg deposition is slow and immediate die-offs do not occur. Thus, it seems prudent to determine the exact locations of the spawning grounds, and to develop methods to quantify mating and egg laying, to ensure that sufficient eggs are deposited before the squids are harvested.

Using Acoustic Technology to Quantify and Monitor Egg Beds

In 2003 we began testing the notion that acoustic technology could be used to image bundles of gelatinous squid egg capsules called egg mops. Squids are one of the few marine species that deposits its eggs in masses on the seafloor. It was our hope that these egg mops would be amenable to quantification and monitoring.

After testing an array of equipment during recent sea trials in Monterey and the Channel Islands, we found that high-frequency side scan sonar towed about five to ten meters above the bottom was capable of distinguishing egg mops 0.5 meters or greater in diameter. (*See Figure 2.*) We know from recent ROV trials in Monterey Bay that most eggs are found on open, sandy substrate in depths of twenty-five to fifty meters.

By means of side scan sonar samples acquired from a fifty-meter-wide swath extending twenty-five meters on either side of the towfish, sufficient overlap in adjacent swaths, and GIS positioning, we have assembled mosaics of side scan sonar images for quantification. Through video photography we have verified distinctive sonar features as being due to egg mops. Given success with the verification in 2004, we will perform larger-scale surveys in Monterey Bay in 2005. We anticipate that a systematic survey comprising ten square kilometers could be completed within five days and that the post-survey analysis could be completed in two weeks. These time scales would make the method practicable as a monitoring tool, so that data accumulated seasonally and yearly could be used to measure potential recruitment.

Figure 2. Side scan sonar mosaic of a sandy bottom area, 105 by 162 meters, off Pacific Grove, showing squid egg mops in the central region.

Using Video and Acoustic Technology to Quantify and Monitor Mating and Egg Laying

Fishermen generally attempt to harvest the squids as soon as they arrive near or at the spawning grounds. Our recent ROV work suggests that the squids require several days (if not longer) of spawning to produce any significant numbers of egg beds. We learned that only small "spawning pods" of squid descend from the large schools in the water column to engage in sexual selection behaviors. (*See Figure 1.*) It would be beneficial to develop a method that allows monitoring of spawning activity so a judgment could be made about when to allow targeted fishing – for example, focusing fishing efforts after egg mops are made or when spawning is complete. So the question arises: could we quantify how many squids are actively engaged in benthic spawning?

Standard fathometers used by fishermen can locate squid in the water column, especially when in large aggregations. The video display of such fathometers is not suitable for quantitative work. Scientific echo sounders such as the Simrad EK60/200-kHz system can image both large aggregations and individual organisms. Groups of organisms observed near the bottom at the time of squid spawning appear to be in the size range of squids and are likely to be squids, yet we have to validate these images visually in a fashion similar to our research on squid eggs. This will be the subject of our research beginning in 2005.

Summary

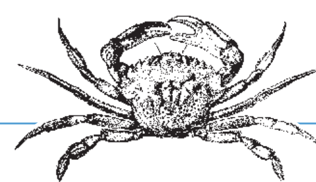
By concentrating first on benthic egg mops, we have shown that acoustic technology can measure reproductive output on the main spawning grounds. We will now apply acoustics to measure the dynamic process of mating and egg-laying, which is possible because this takes place at the bottom, in discrete social groups in the vicinity of existing communal egg beds.

The eventual goal is to accomplish an ecologically-based (specifically, a behaviorally-based) monitoring and management plan for squids in Monterey Bay. Current fishing pressure mandates such a goal if the squid stock(s) is to be effectively managed. Since the Monterey squid fishery is geographically concentrated, and the fleet relatively small, one can envision real-time, ecology-based management of squids. This may take five to ten years of technology refinement, accumulation of biological information, and close cooperation with fishermen, but the rewards would be substantial for all parties concerned as well as the overall ecological health of Monterey Bay.

Only space limitations prevent proper acknowledgement of the historical work that is built upon here and the valuable assistance rendered by many colleagues, most recently by R. Kvitek and P. Iampietro at California State University Monterey Bay. Support for the work has been provided by the National Undersea Research Center (NURC) West Coast and Polar Regions, National Sea Grant, the Sholley Foundation, and the Packard Foundation.

– Roger T. Hanlon[1] and Kenneth G. Foote[2]
[1]Marine Biological Laboratory, Woods Hole
[2]Woods Hole Oceanographic Institution

Exotic Species



Invasion Rates Differ across Marine Habitats

The spread of species beyond their native range can have severe impacts to the invaded ecosystems. No habitat is immune from biological invasions; non-native species have been found virtually every place that has been thoroughly searched for them. Nevertheless, all habitats are not equally susceptible to invasions. Non-natives often show up in human-disturbed habitats, while some other habitats appear to resist invasions. We recently carried out an investigation on the incidence of non-native species found in different marine habitats, at two spatial scales.

First, we quantified number and abundance of species in samples of hard (rock and oyster shell) and soft (mudflat) substrates from the same sites in Elkhorn Slough, the major estuary in the Monterey Bay area. We found that 52 percent of the species on hard substrates were non-native, while only 21 percent of those on or within soft substrates were non-native. This difference was particularly pronounced for sessile (non-mobile) species: 77 percent versus 7 percent were non-native in hard versus soft substrates. Similar patterns were obtained for abundance: non-natives dominated hard, but not soft, substrates.

The simplest explanation for this difference is that boat traffic and oyster culturing, the main vectors introducing exotic species to Elkhorn Slough, disproportionately transported non-native species

Elkhorn Slough National Estuarine Research Reserve researcher Susie Fork monitors mudflat communities at the slough.

associated with hard substrate in the slough. Soft sediment invaders also face rigorous competition from the diverse native species inhabiting estuarine mudflats. In contrast, there are very few native hard substrate specialists in our estuaries, which historically had very little in the way of natural hard substrates. So non-native hard substrate specialists that encounter the extensive artificial hard substrates (gravel bars, jetties, docks, etc.) in estuaries today may face little competition from natives and thus readily establish there.

The second component of our study compared the incidence of non-natives in estuarine versus open coast habitats. We compiled a database for Elkhorn Slough, building on observations of scientists at Moss Landing Marine Laboratories and other regional institutions over many decades. Overall, we documented 527 invertebrate species for the slough. For the open coast, surveys by University of California Santa Cruz students in the 1970s and 1990s of rocky intertidal habitats of the Monterey Bay National Marine Sanctuary compiled a list of 588 invertebrate species.

The difference between these lists was striking. The absolute number of exotic species in the estuary was an order of magnitude higher than along the open coast (fifty-eight versus eight species), as was the percentage of the invertebrate fauna that was exotic (11 percent versus 1 percent). The eight non-natives found on the open coast made up a subset of the Elkhorn Slough invaders, and all were rare. In contrast, many of the fifty-eight non-natives in Elkhorn Slough were highly abundant. The finding that the more species-rich habitat – the open coast – is less invaded contrasts with many terrestrial examples, where native and exotic species richness appear to be positively correlated at a broad geographic scale.

Again, a variety of causes can be invoked to explain the bias of invasions in sheltered estuaries. Boat traffic and culture of non-native oysters in estuaries certainly enhanced introductions there. In addition, limited dispersal of larvae in the somewhat closed circulation of estuaries may enhance the establishment of breeding populations. Moreover, estuaries on this coast are geologically young and have less diverse invertebrate communities than their more ancient counterparts on the open coast. Consequently, invaders to estuaries may face less competition from natives than invaders on the open coast. For instance, the European green crab (*Carcinus maenas*) occurs in both habitat types along the geologically young North American Atlantic coast but is only found in estuaries along the Pacific coast, perhaps because the richer crab fauna of the rocky intertidal prevents it from becoming established there. Finally, open coast communities may be better able to resist invasions because their members evolved under conditions similar to the present ones, while those of estuaries have been subject to substantial human alterations in recent centuries. In California, estuaries have certainly been subject to more pollution and changes in habitat structure than have rocky intertidal habitats of the open coast.

Our investigation revealed that marine invertebrate invasions vary dramatically across habitats. In our region, the rocky intertidal of the open coast is barely invaded, while estuarine habitats are highly invaded. Estuaries thus require particular focus for prevention and early detection of invasive species. Within the estuary, hard substrates are more heavily invaded than soft sediments. However, since hard substrates are mostly artificial, they may merit less conservation focus than the rich and spatially limited mudflat communities that face many threats, including invasions.

– Kerstin Wasson[1], John Pearse[2], and Katherine Fenn[3]
[1]Elkhorn Slough National Estuarine Research Reserve
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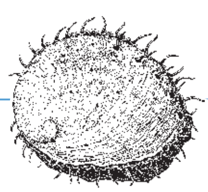
For information on exotic species in sanctuary harbors, please see Ecosystem Observations 2003, p. 21.



Human Interactions

Desalination and the Sanctuary

Central coast residents are likely to have heard a lot about desalination lately; it has received increasing attention over the past several years. Much of this is due to many more desalination plants being proposed in California, including a number along the shoreline of the Monterey Bay National Marine Sanctuary.

Desalination refers to the process by which salts and other chemicals are removed from salt or brackish water and other impaired water resources. It is also referred to as desalinization, desalting, or simply “desal.”

The topic is clearly of increasing interest and concern – in addition to a diverse range of viewpoints – in the community. Some view desalination as an unlimited and drought-free source of water and a solution to California’s long-standing

Perhaps the most contentious environmental issue surrounding desalination is the potential for it to induce additional coastal development.

water shortages, while others perceive it as an infeasible and unproven technology incapable of providing an economically viable source of drinking water for California's population. Moreover, a growing number of people are concerned that an increase in the use of seawater represents a threat to our fragile environment and has the potential to fuel the growth of coastal communities where development has been traditionally restricted by limited water resources. Regardless of one's outlook, one thing is certain: we are seeing a growing trend in local jurisdictions considering these facilities.

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In some cases desalination facilities can provide ecological benefits – by decreasing overdraft of groundwater or offsetting water that can be used to restore streams and rivers.

Historically, desalination has not been used extensively in California because the cost has always been significantly higher than traditional sources, making it prohibitively expensive. However, recently several factors have led decision makers to turn their attention to desalination as a new source of freshwater. The central California coast is faced with recurring droughts and an existing shortage of water that will become more severe as populations continue to expand in the region. Current water sources are being overdrafted, causing significant environmental impacts, such as saltwater intrusion and damage to plant and animal habitat. As traditional sources of fresh water continue to be depleted and degraded, water agencies and local

HUMAN INTERACTIONS

Visitors to State Parks and Beaches Contiguous to the Sanctuary[1]

San Mateo County coast – 2,293,154 visitors
Fitzgerald Marine Reserve – 110,000 visitors
Santa Cruz County coast – 11,890,018 visitors
Monterey County coast – Not available
San Luis Obispo County coast, north of the Sanctuary boundary – 470,000 visitors

2004 Coastal Cleanup[2]

County	Volunteers	Trash (lbs.)	Recyclables (lbs.)
Marin	1,026	10,579	1,644
San Mateo	1,190	27,265	3,159
Santa Clara	1,246	33,171	6,586
Santa Cruz	3,196	8,736	3,142
Monterey	1,610	18,619	2,180
San Luis Obispo	1,290	14,857	2,784

Volunteers[3]

Año Nuevo State Reserve: 208 volunteers; 15,762 hours
BAY NET Monterey Bay National Marine Sanctuary Volunteer Network: 32 volunteers; 1,650 hours
California State Parks, Monterey District: 431 volunteers; 44,413 hours
California State Parks, San Mateo Coast Sector: 2,665 volunteers; 15,682 hours
California State Parks, Santa Cruz District: Not available
Coastal Watershed Council: 122 volunteers; 3,200 hours
Elkhorn Slough National Estuarine Research Reserve: 112 volunteers; 8,200 hours
Fitzgerald Marine Reserve: 65 volunteers; 6,041 hours
Friends of the Elephant Seal: 80 volunteers; 11,300 hours
Friends of the Sea Otter: 14 volunteers; 1,700 hours
Gulf of the Farallones National Marine Sanctuary Beach Watch (south of Golden Gate only): 47 volunteers; 3,900 hours
Maritime Museum of Monterey: 57 volunteers; 4,150 hours
Monterey Bay Aquarium; 1,132 volunteers; 137,450 hours
Monterey Bay National Marine Sanctuary Beach COMBERS: 72 volunteers; 1,752 hours
Monterey Bay National Marine Sanctuary TeamOCEAN: 35 volunteers; 519 hours
Monterey Bay Sanctuary Citizen Watershed Monitoring Network: 288 volunteers; 4,140 hours
Pigeon Point Lighthouse: 20 volunteers; 2,160 hours
Return of the Natives Restoration Education Project of the Watershed Institute, CSUMB: 4,631 volunteers; 5,018 hours
San Gregorio Environmental Resource Center: 17 volunteers; 650 hours
Save Our Shores: 1,600 volunteers; 14,200 hours
Seymour Center at Long Marine Lab, UCSC: 215 volunteers; 18,331 hours
Surfrider, San Mateo County Chapter: 226 volunteers; 1,620 hours
The Marine Mammal Center: 202 volunteers; 22,263 hours (excluding San Mateo volunteer hours, which are not available)

Total number of volunteers: 12,159

Total hours donated: 324,101

Total value of volunteer services (calculated at $15.00/hour): $4,861,515

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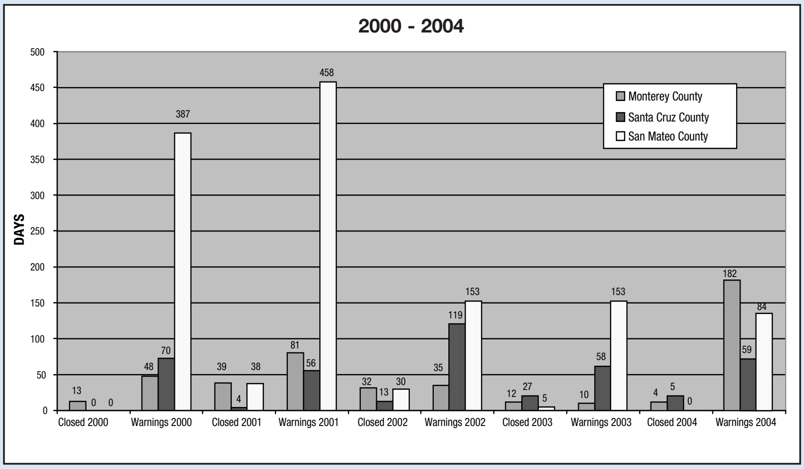
Volunteers everywhere play a critical role in protecting – and cleaning up – the marine environment.

Annual Beach Warnings and Closures by County[4]



Data obtained from State Water Resources Control Board:
http://water24.waterboards.ca.gov/BeachWatch/cla_pub/index.jsp

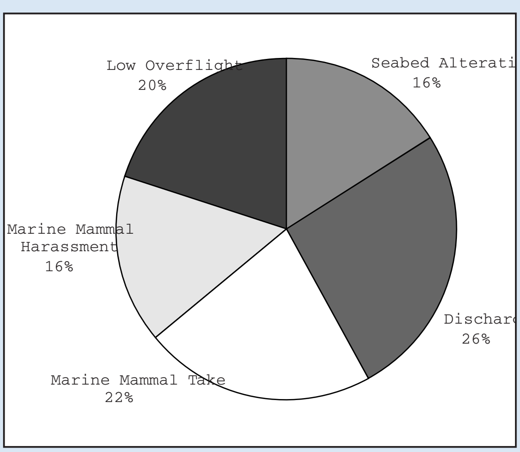
Note: San Mateo County issues beach warnings when single sample values exceed the more stringent 30-day geometric mean standards.

Vessel Incidents with Sanctuary Response[5]

Incident Type	Date Reported	Location	Cost to NOAA
Grounding (R/V)	4/10/2004	Within .5 mile of Moss Landing Harbor entrance	$450.00
Sinking (C/V)	5/6/2004	Approx. 16 nm WNW of Pescadero Point, San Mateo County	$1,200.00
Sinking (R/V)	6/5/2004	50 yards SE of Wharf II , Monterey, approx. 200 yards from the shoreline	$750.00
Grounding (C/V)	6/8/2004	Naval Postgraduate School Beach, Monterey	$725.00
Grounding (C/V)	6/10/2004	Bradley Beach, San Mateo County, just south of Año Nuevo State Reserve	$4,000.00
Sinking (R/V)	6/12/2004	12.5 nm NW of Cape San Martin, Monterey County	$550.00
Grounding (R/V)	6/20/2004	50 yards offshore from mouth of the Pajaro River	$300.00
Sinking (R/V)	6/26/2004	Approximately 2 miles SE of the Santa Cruz Pier	$300.00
Sinking (R/V)	6/26/2004	Approximately 2 miles SE of the Santa Cruz Pier	$300.00
Sinking (R/V)	11/23/2004	4 miles off Martin's Beach, Half Moon Bay	$225.00
Grounding (R/V)	11/30/2004	Shallows between Point Año Nuevo and Año Nuevo Island	$8,000.00
			$16,800.00

R/V-Recreational vessel C/V-Commercial vessel

Profile of Documented Enforcement Cases January - December 2004[6]



These data represent only sixty-four formally documented cases by the NOAA Office for Law Enforcement and do not reflect all investigative actions or patrol contacts by NOAA enforcement personnel or enforcement actions by partner agencies. The data do not reflect total reported incidents or number of convictions within the sanctuary. They simply provide a relative comparison of the types of violations occurring within the sanctuary.

- *Marine mammal take cases were processed as actions under the Marine Mammal Protection Act instead of the National Marine Sanctuaries Act.*
- *Vessel groundings and sinkings are counted as seabed alteration cases, though most also involved discharges.*

Sources:
1 – California State Parks, San Mateo Coast Sector; Pigeon Point Lighthouse; Año Nuevo State Reserve; Fitzgerald Marine Reserve; California State Parks-Santa Cruz, Monterey, and San Luis Obispo Coast Districts
2 – California Coastal Commission
3 – Organizations listed
4 – State Water Resources Control Board
5 – Monterey Bay National Marine Sanctuary
6 – NOAA Office for Law Enforcement

jurisdictions are clearly looking more toward desalination as a drought-resistant water supply that can augment existing sources. This increased interest in desalination can also be traced in part to significant advances in desalination technology over the past decade, which have increased the efficiency and decreased the costs of desalinating seawater. With more efficient desalting technologies capable of producing water at cheaper prices, in conjunction with the escalating costs of obtaining fresh water from traditional sources and declining freshwater sources, desalination has become an attractive option to many water purveyors.

This trend is clear along the shoreline of the sanctuary, where there are around ten proposed or potential desalination facilities in some stage of planning, including several proposals that are an order of magnitude larger than any existing facilities currently operating within the state. Most of these facilities are proposed to be located in Monterey Bay. In most cases these proposals have been developed independently of one another. The sanctuary is concerned that a proliferation of desalination plants, without consideration for regional planning, proper siting, or cumulative impacts, could lead to significant environmental impacts.

Without careful planning and mitigation measures, desalination plants have the potential to harm the marine environment. One of the major concerns surrounding these facilities is the impacts that result from the introduction to the ocean of concentrated saline brine that may kill or harm sensitive marine organisms. In addition, the intake of ocean water directly through plant pipelines can result in the death of marine life through impingement (where marine organisms collide with screens at the intake pipe) or entrainment (where animals and plants are taken into the facility through the pipe and are killed during plant processes). Perhaps the most contentious environmental issue surrounding desalination is the potential for it to induce additional coastal development, which could lead to significant indirect impacts, such as degradation of water quality from increased urban runoff and other pressures to the sensitive coastal environment resulting from increased population. Finally, new pipeline construction associated with desalination plants can disturb the seafloor, surf zone, and dunes. Permits for desalination related to discharges into the sanctuary and certain construction activities must be authorized by the sanctuary.

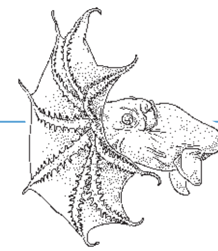
© NOAA/MBNMS

New pipeline construction associated with desalination plants can disturb the seafloor, surf zone, and dunes.

The good news is that, through proper design and siting, desalination plants can significantly reduce impacts to the marine environment. In some cases these facilities can provide ecological benefits – by decreasing overdraft of groundwater or offsetting water that can be used to restore streams and rivers. As part of the Joint Management Plan Review process, the sanctuary convened a multi-stakeholder working group that collaboratively developed an action plan to address the issue in a comprehensive and coordinated fashion. This plan lays out a framework for a regional approach to address desalination, aimed at reducing impacts to marine resources in the sanctuary through consideration of regional planning, facility siting, on-site mitigation measures, modeling and monitoring, and outreach and information exchange. The sanctuary will continue to promote a collaborative and precautionary approach to desalination, in order to protect the phenomenal resources of the central California coast.

– Brad Damitz
Monterey Bay National Marine Sanctuary

Site Profile



Davidson Seamount

© C. King

Figure 1. Davidson Seamount and the southern portion of the sanctuary

It is estimated that there are more than 30,000 seamounts in the world's oceans, including numerous volcanic seamounts offshore of California. Davidson Seamount is located 120 kilometers (75 miles) to the southwest of Monterey, 150 kilometers (93 miles) west of Cambria, and is one of the largest known seamounts along the western United States. (*See Figure 1.*) It is 42 kilometers long and 13.5 kilometers wide. From base to crest, Davidson Seamount is 2,400 meters tall; yet it is still 1,250 meters below the sea surface. It has an atypical seamount shape, created by a type of volcanism only recently described by geologists; it last erupted about 9.5 million years ago.

Exploration history of the Davidson Seamount is simple, yet notable. The seamount was first mapped in 1933. This large geographic feature was the first to be characterized as a "seamount" in 1938 and was named in honor of George Davidson (1825-1911), a leader in charting West Coast waters. During the 1970s rock samples were collected to study the seamount's geology. Sonar mapping techniques improved geologic images during the 1990s, and recently, remotely operated vehicles (ROVs) have provided more precise collection devices and photo images of the seafloor, associated biology, and surrounding water column.

During May 2002 a multi-institution expedition, led by the Monterey Bay National Marine Sanctuary, characterized the distribution and abundance of organisms at the Davidson Seamount. (*See Ecosystem Observations 2002, p. 9.*) The sanctuary partnered with the Monterey Bay Aquarium Research Institute (MBARI), Monterey Bay Aquarium, Moss Landing Marine Laboratories (MLML), and the National Oceanic and Atmospheric Administration (NOAA) Fisheries to explore the seamount using MBARI's Research Vessel *Western Flyer* (*Figure 3*) and ROV *Tiburon*. The ROV traversed a bottom distance of 43,537 linear meters and recorded ninety hours of digital video imagery. In addition, a bird and mammal survey was conducted at the sea surface, and approximately 255 species were identified. With these and other data from MBARI, Davidson Seamount is one of the best mapped and biologically characterized seamounts in the world.


© NOAA/MBARI

Figure 2. Bamboo coral (Keratoisis sp.), like this one at 1,452 meters below the surface, have been aged to greater than 200 years.

Several spectacular habitats can be found on the seamount. The surface waters above it host a variety of seabirds, marine mammals, and surface fishes, including albatrosses, shearwaters, jaegers, sperm whales, killer whales, and ocean sunfish. From the sunlit surface waters to the top of the seamount lies a vast, three-dimensional habitat known as the midwater. Organisms here include the big red jelly, an undescribed mollusk, and tomopterid worms. The greatest diversity can be found at the seamount crest (~1,250-1,500 meters below the surface), including forests of large bubblegum coral (*Paragorgia* sp.), vast sponge fields, crabs, deep-sea fishes, and basket stars. The slope habitat (~1,500-2,500 meters below the surface) is composed of cobble and rocky areas interspersed with shallow areas of ash and sediment. This area hosts a diverse assemblage of sessile invertebrates and seldom-seen deep-sea fishes. The interface between rocky outcrops and the deep soft bottom is a distinct base habitat (~2,500-3,250 meters below the surface) for mobile animals. These organisms consist of familiar-looking species with relatives living in the nearshore, including cucumbers, urchins, anemones,and sea stars.

The Davidson Seamount exhibits high coral abundance and diversity and is a relatively pristine area. Twenty coral species were observed and located almost exclusively on seamount ridges (1,248-2,846 meters below the surface). Many of the corals are large and fragile to physical disturbance. Researchers at MLML determined age estimates for two coral species ranging from 115 years (precious coral, *Corallium* sp.) to greater than 200 years (bamboo coral, *Keratoisis* sp.; *see Figure 2*). Habitat and species analyses will be used to characterize the area, provide information for resource managers, educate the public, and further the advancement of seamount research.

This research on Davidson Seamount has received more public attention than any other sanctuary research effort. National television news, in-flight airline news, newspapers, radio programs, newsletters, an interactive educational compact disc, and several web sites highlighted results and activities from the cruise. The compact disc, "Exploring Davidson Seamount," is available for purchase through the Monterey Bay Sanctuary Foundation. Readers can share the excitement by visiting the Sanctuary Integrated Monitoring Network (SIMoN) web site (www.mbnms-simon.org/sections/seamounts/overview.php?sec=s).

The sanctuary is formally assessing the option of providing national marine sanctuary status to the Davidson Seamount. The Sanctuary Advisory Council unanimously supported its designation so long as current fishing activities in the area were not impacted. While no bottom trawling currently takes place at depth, sanctuary designation will help preserve the fragile resources on the seamount by protecting them from any future expansion of trawling effort. It will also ensure that impacts from bioprospecting and scientific collection are minimized, through the use of the sanctuary's permitting system. Currently, there are no government education programs broadly focusing on seamount biology, and the designation of a seamount would therefore represent a unique opportunity for education and outreach. A draft environmental impact statement for the sanctuary's revised management plan will be available in the early summer of 2005 and will analyze alternatives for seamount designation and protection. A final decision is expected in 2006.

– Erica Burton and Andrew DeVogelaere
Monterey Bay National Marine Sanctuary


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Figure 3. During May 2002 a multi-institution expedition explored the seamount using MBARI's Western Flyer.


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Figure 4. Several undescribed sponges were observed, including this mushroom-like sponge (Caulophecus sp.) at 1,949 meters.

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