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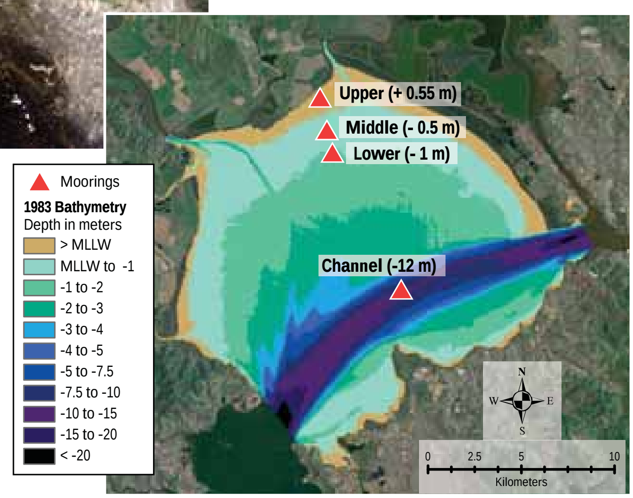
Fieldwork

Connecting Marshes to the Sea—Sediment in the Shallows of San Francisco Bay

By Stephen Wessells, Jessica Lacy, Lissa MacVean, and Helen Gibbons

On a bright day in early February, 2011, U.S. Geological Survey (USGS) research oceanographer **Jessica Lacy** and USGS Mendenhall Fellow **Lissa MacVean** supervised the placement of aluminum platforms bristling with instruments into San Francisco Bay, California, for 6 weeks of gathering data on how bay waters move sediment. The scientists' goal is to determine how sediment is transported among the shallow environments of the bay—one factor that controls whether the sediment will reach marshes at the bay's edge. Their findings may improve the ability to predict the outcome of marsh-restoration projects around the bay. A recently released USGS video (**http://gallery.usgs.gov/videos/369**) highlights some of their goals and activities.

*San Francisco Bay and surroundings in a photograph acquired April 21, 2002, by astronauts aboard the International Space Station. Note brown plumes of suspended sediment in bay waters. Yellow box outlines study area in the San Pablo Bay portion; triangles are sites where instruments were deployed. Image courtesy of NASA's Earth Observatory (**http://earthobservatory.nasa.gov/IOTD/view.php?id=2474**).*



The study area, with triangles marking sites where instruments were deployed. Labels indicate each site's water depth relative to MLLW (mean lower low water), the average of the lowest water levels for each day. Regions below MLLW are virtually always submerged (subtidal); regions above MLLW are regularly exposed to the air (intertidal). Background image courtesy of Esri's ArcGIS Online map service and Aerials Express.

San Francisco Bay is a dynamic and complicated estuary where seawater entering through the Golden Gate mixes with freshwater from the San Joaquin and Sacramento Rivers and numerous local streams. The water is commonly clouded by muddy sediment lifted from the bottom or delivered by streams and kept afloat by the near-constant motion of the water in response to winds, waves, and tides. At times, the turbid water in the shallows looks like chocolate milk.

Fringing the bay are wetlands and tidal marshes that play an important role in bay ecosystems. More than 80 percent of the wetland habitats that existed before the 1850s and the Gold Rush have been lost because of human activities, including diking, draining, and filling. The USGS provides science support to many of the local, state, and federal efforts to improve the health of the bay by restoring tens of thousands of acres of commercial salt ponds, diked agricultural lands, and other lands to functioning tidal marsh and shallow ponds.

"Some wetlands-restoration projects actually deposit sediment to bring the marsh plain elevation up to the appropriate level for plants," said **Lacy**, "but it's considered a much better option to rely on natural processes because that is a sustainable restoration. And [relying on natural processes] means assuming that the turbid waters of the bay will deposit enough sediment in the marsh to restore it."

How long this process may take varies for different part s of the bay and is typically not well known at the beginning of a restoration project. Where the newly delivered sediment will come from is also not well known, raising concerns

(Bay Sediment continued on page 2)

Sound Waves

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Contents

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(Bay Sediment continued from page 1)

*USGS Marine Technician **Jenny White** steadies an instrumented platform as it is winched into the water at the Middle station (see map of study area), where the depth of the bay floor is 0.5 m below MLLW. Photograph taken February 2, 2011, by **Lissa MacVean**.*

The platform, deployed at high tide, is now resting on the bay floor, and all that's visible is a warning flag to alert boaters. During low tide, all but 0.5 m of the platform (which is a little more than 2-m tall) will be exposed to the air.

that large-scale marsh restoration might impact other bay habitats. For example, adjacent mudflats, which are critical foraging grounds for shorebirds, could be altered if natural processes carry significant amounts of sediment from the mudflats to the restored marshes.

The USGS study now underway will begin to address the question of how sediment is supplied to marshes by looking in detail at how bay sediment moves from areas that are always inundated, or are subtidal, into intertidal mudflats that are alternately wet and dry. The forces that drive sediment from subtidal to intertidal regions also influence how—and whether—it gets transported into marshes. Tides, winds, and storms all function in different ways and over different timescales. USGS observations of how the bay's shallow regions respond to such forces will provide answers to such essential questions as:

- On average, do tides transport sediment into or out of the shallows?
- When storms occur, is sediment from the watersheds washed into the shallow habitats, or does it bypass them, heading instead for the Golden Gate?
- On windy days, do waves pick up more sediment from the intertidal regions or the subtidal regions, or equal amounts from each?

The answers to these questions will help scientists understand where the sediment deposited in marshes comes from and what that means for nearby habitats like mudflats, as well as the rate at which sediment deposition will build up the marsh plain.

The study was designed by **MacVean** as part her work in the USGS Mendenhall Research Fellowship Program, which provides postdoctoral scientists an opportunity to conduct original research with USGS scientists. **MacVean** recently completed her Ph.D. in civil and environmental engineering at the University of California, Berkeley, with a focus on environmental fluid mechanics. Her Mendenhall project is titled "Sediment Cycling Between Estuarine Habitats," and **Lacy** is one of her USGS advisors. (For additional information about **MacVean**, see "Mendenhall Research Fellow to Study Sediment Fluxes in San Francisco Bay," *Sound Waves*, December 2010, **http://soundwaves.usgs.gov/2010/12/staff2.html**.)

"We're making field measurements of water velocities, salinities, and suspended sediment in order to determine exactly what's controlling how sediment moves

(Bay Sediment continued on page 3)

(Bay Sediment continued from page 2)

in really shallow environments in an estuary," said **MacVean**.

The scientists placed instrumented platforms at four sites in San Pablo Bay, a northern embayment of San Francisco Bay. The four sites lie along a gradient from the 12-m deep channel in the southern part of San Pablo Bay to intertidal mudflats that are exposed to air at each low tide. The platforms hold instruments to measure such variables as currents, waves, salinity, and suspended sediment.

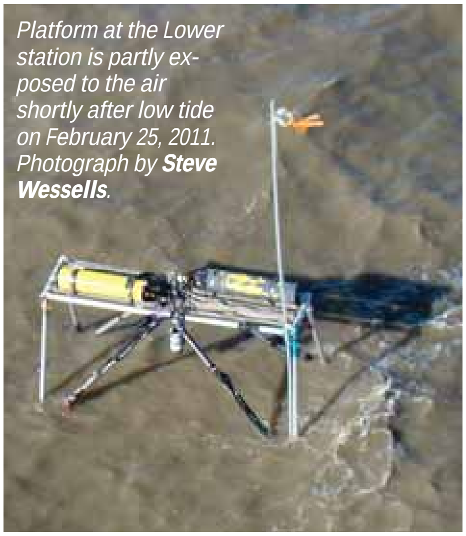
"We have more than one [of each type of instrument] on each platform," said **Lacy**, "because we're looking at different elevations above the seafloor, and that's because current speed and suspended-sediment concentration change a lot with height above the bed. If you can resolve those changes with depth, you can learn something about the mechanisms that are bringing sediment up into the water column and then moving it around."

During the 6-week deployment, the instruments gathered a massive amount of data, making measurements as fast as 10 times per second. Among other things, the data will show how sediment concentrations and water velocities change over a range of time scales—as the seasons change, when storms come and go, when it's windy or not windy, through each tidal cycle, and during the passage of a single wave.

(Left to right) ***Pete Dal Ferro***, ***Jenny White***, *and* ***Joanne Thede Ferreira*** *deploy a platform at the Lower station, where the depth of the bay floor is 1 m below MLLW. Photograph taken February 2, 2011, by* ***Jessie Lacy***.

"An even shorter time scale is the turbulence time scale," said **Lacy**. "Although waves pick the sediment up off the bed, it's the turbulence—the tiny, random motions caused by the interaction of currents with the bed and wind with the water surface—that actually mixes sediment up through the water column. In previous experiments, mostly in deeper water, we've been able to resolve that combination of processes. In this experiment, we'll be examining those processes right at this intertidal zone, where there are very few measurements."

This type of data is essential for verifying the accuracy of sediment-transport models, which can then be used to predict the impacts of long-term processes such as marsh restoration and sea-level rise.



Platform at the Lower station is partly exposed to the air shortly after low tide on February 25, 2011. Photograph by ***Steve Wessells***.

To supplement data collected by the instruments, ***MacVean*** *made periodic trips to each site to collect sediment samples. Here she extracts a small core of sediment collected from the bay floor on March 9, 2011. Cores from all sites will be analyzed to identify differences in sediment characteristics—such as grain size and porosity—that affect susceptibility to erosion. This knowledge will help the scientists understand whether sediment at the different sites will respond differently to the forces of tides and wind. Photograph by* ***Pete Dal Ferro***.

MacVean is excited about exploring unknown territory at their study sites: "The water is really turbid and murky, so you can't see to the bottom, even in a very shallow depth," she said. "It's sort of inhospitable for science, which is really why it's interesting. There's still a lot that isn't known about how these systems work."

The instruments were recovered in mid-March. After downloading the data,

(Bay Sediment continued on page 4)

(Bay Sediment continued from page 3)

MacVean began using a combination of data analysis and numerical modeling to provide a picture of how sediment is carried from shallow bay water to intertidal areas. When her work is complete, it will not only shed light on the mechanisms that transport sediment from the bay into recently restored marshes but will also provide information that can be used to address another important question: Will the bay-fringing marshes—both those that exist now and those that will be produced by restoration—survive in the face of accelerating sea-level rise? A 2007 report by the Intergovernmental Panel on Climate Change estimates that the global average sea level will rise between 0.18 and 0.59 m (0.6 and 2 ft) in the next century (**http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch10s10-6-5.html**). The results of **MacVean's** project will help resolve one piece of the puzzle of whether sediment deposition in marshes can keep up.

To learn more about salt-pond restoration in San Francisco Bay, visit **http://www.southbayrestoration.org/** and **http://www.napa-sonoma-marsh.org/**. Additional information is available in "South Bay Science Symposium," *Sound Waves*, March 2011 (**http://soundwaves.usgs.gov/2011/03/meetings.html**). To learn more about the USGS Mendenhall Research Fellowship Program, visit **http://geology.usgs.gov/postdoc/**. To watch **MacVean**, **Lacy**, and their field team in action, view the new USGS video, "Turbid Bay: Sediment in Motion," at **http://gallery.usgs.gov/videos/369**. ☸

*Platform on mudflat at the Upper station is completely exposed to the air shortly after low tide on February 25, 2011. Photograph by **Steve Wessells**.*

Birders Urged to Help Track the California Gull

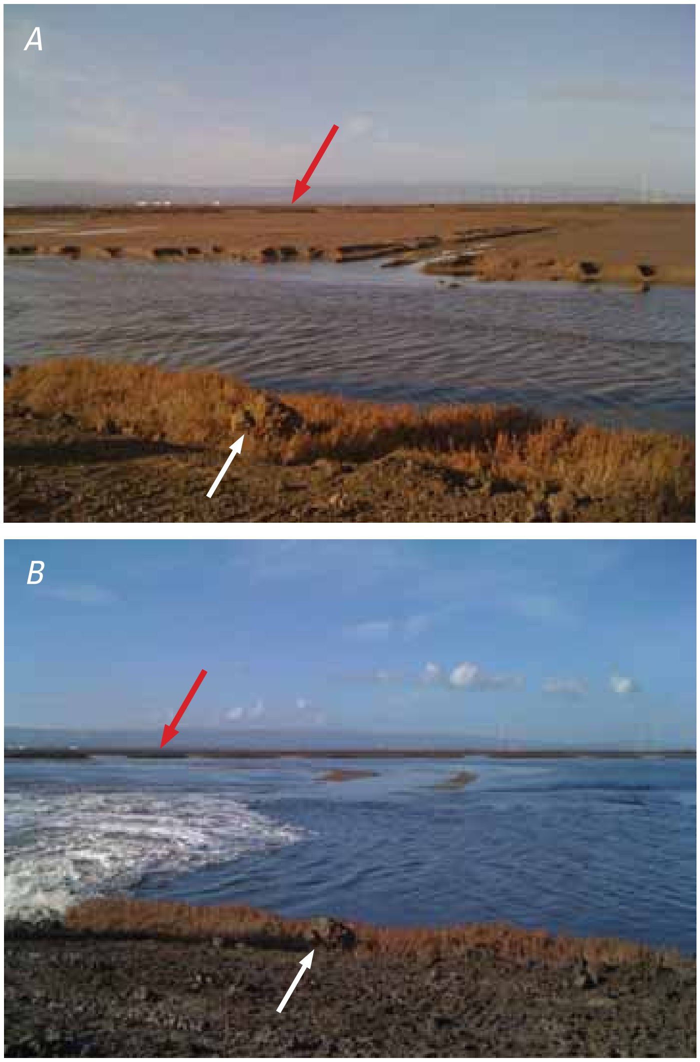
By Ben Young Landis

Attention researchers and seasoned birders: the Don Edwards National Wildlife Refuge, the San Francisco Bay Bird Observatory (SFBBO), and the U.S. Geological Survey (USGS) need your help this year in tracking the California gull (*Larus californicus*; referred to as "CAGU") as part of the South Bay Salt Pond Restoration Project (**http://www.southbayrestoration.org/**).

This gull species, which is native to California, has left an interesting history in its wake. Normally breeding in inland areas like Mono Lake, CAGUs suddenly began appearing in the San Francisco Bay area in dramatic numbers over recent decades, increasing from less than 200 before 1982 to more than 45,000 counted in 2008.

According to USGS Western Ecological Research Center scientist **Josh Ackerman**, these gulls may have been attracted to the region because of its nearby landfills. In addition to seeking out food scraps, however, CAGUs have been voracious predators of other nesting waterbirds in the area, raiding the eggs and chicks of

(California Gull continued on page 5)



*Views of Tract A6 before (A) and during (B) breaching of pond levee to allow bay waters to flow into the area. Arrows point to features common to each view: marsh islands constructed by the restoration project to serve as high ground during high tides (red arrows in background), and rock on levee that was breached to allow tidal water to ebb and flow into the pond (white arrows in foreground). Photographs by **Ben Young Landis**. For additional photographs and information, visit **http://www.werc.usgs.gov/outreach.aspx?RecordID=24**.*

(California Gull continued from page 4)

American avocets and black-necked stilts (see **http://www.werc.usgs.gov/Project.aspx?ProjectID=184**).

Some 20,000 CAGUs have been nesting each year in Tract A6 of the South Bay Salt Pond Restoration Project—a massive multiagency effort that's restoring acres of formerly private land back to natural wetlands (see map at **http://www.werc.usgs.gov/outreach.aspx?RecordID=22**). In December 2010, levees were breached to restore Tract A6 as a tidal marsh—no longer a static, drying field, but instead a dynamic marsh with the daily ebb and flow of the bay tides. (Visit **http://www.werc.usgs.gov/outreach.aspx?RecordID=24** to see photographs of the breaching process.)

So where will 20,000 voracious gulls go this year to establish new colonies? Researchers need your help to find out.

Caitlin Robinson-Nilsen of SFBBO is collecting the sighting data, which will contribute to research by **Ackerman** and managers at Don Edwards National Wildlife Refuge.

Here's how to participate:

- Detailed instructions and contact information are in PDF flyers that can be downloaded from **http://www.werc.usgs.gov/outreach.aspx?RecordID=54**.
- Since 2008, SFBBO and USGS have banded more than 1,000 CAGUs from Tract A6 with 3-digit alphanumeric bands on the left leg (see photo). Reporting the band number will greatly help the effort.
- Observers are encouraged to expand beyond the San Francisco Bay area to coastal and Central Valley sites, particularly noting where CAGUs have not nested before.

It's collaborative science at its best, and your observations can help researchers understand the distribution and movement of a key species—as well as the effects and implications of an ecosystem-restoration project. ❆

***Note:** The original version of this article, with additional links, appeared March 18, 2011, on the USGS WERC Outreach Web page at **http://www.werc.usgs.gov/outreach.aspx?RecordID=54**.*

*Many California gulls from Tract A6 have bands on their left legs. Photograph copyright **Lana Ellis**; used with permission.*

*Location of Tract A6 at south end of San Francisco Bay. Background image is part of a photograph acquired April 21, 2002, by astronauts aboard the International Space Station; image courtesy of NASA's Earth Observatory (**http://earthobservatory.nasa.gov/IOTD/view.php?id=2474**).*

*California gulls nesting in Tract A6 on May 13, 2009. Photograph copyright **Michael Kern** and the Gardens of Eden (**http://www.thegardensofeden.org/**); used with permission.*

Coral Reef Health and Environmental Changes in the Florida Keys and the Caribbean Sea—Video Podcasts Highlight USGS Research

By Matthew Cimitile


*Retired USGS geologist **Gene Shinn** photographs one of several coral reef sites he has chronicled for five decades.*

For five decades, coral reefs in the Florida Keys have experienced hurricanes, coral diseases, bleaching, die-off events, and boat groundings. And for five decades, U.S. Geological Survey (USGS) geologist **Gene Shinn** (retired) has been there to chronicle changing conditions at seven coral reef sites, creating an unprecedented 50-year photographic record of changes to coral reef ecosystems in what eventually became the Florida Keys National Marine Sanctuary. A new video podcast produced at the USGS office in St. Petersburg, Florida (**http://gallery.usgs.gov/videos/334**), highlights this one-of-a-kind photographic record of changes.

Shinn began work on reefs in the Florida Keys in 1960 as a support diver with scientists **Ed Hoffmeister** and **Gray Multer**, who were looking at growth rates of corals to better understand the origin of the emergent reef that forms the middle and upper Florida Keys. They measured coral growth rates by taking live corals out of the water, cementing them on tiles, and putting them back in the water—a method used since the early 1900s.

The photographic record also began in 1960, when **Shinn** started exploring new ways of measuring coral growth without removing corals from the water. One technique involved measuring branching coral growth by attaching a plastic ring to the branches as a reference point and using a millimeter scale to periodically measure the distance from the ring to the tip of the growing branch (see scientific report at **http://www.jstor.org/stable/1301658**). Another technique involved inserting stainless-steel rods into the coral as a reference point and measuring how fast the coral grew up around them.

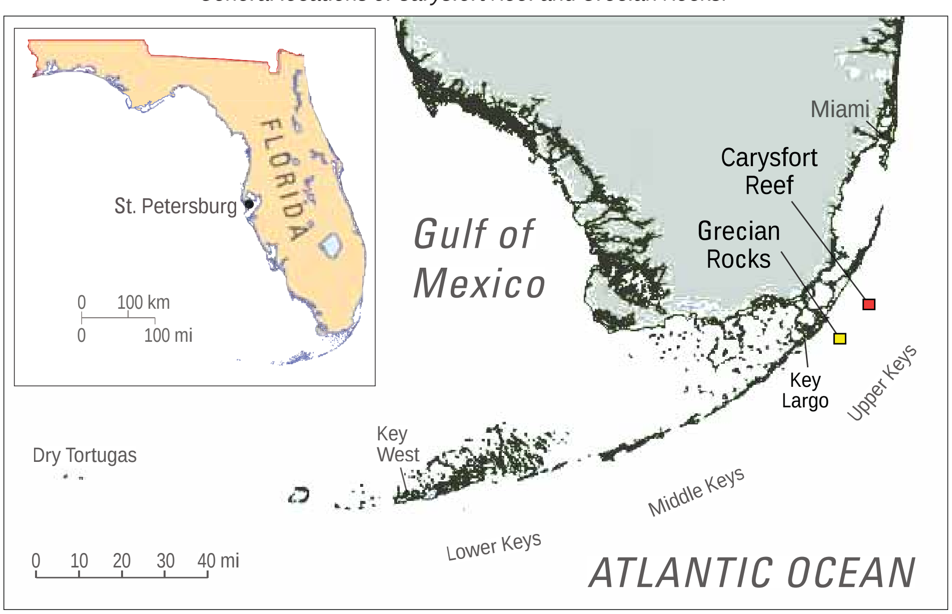
"I started this work, putting stainless rods in coral heads, in 1960, and I thought it might be a good idea to take photographs. I didn't realize what a good idea that was at the time," said **Shinn**.

What began as a coral experiment turned into 50 years of photographic documentation. Sequences of photos spanning the years 1960 to 2010 show alterations to the size, types, and structure of corals at Carysfort Reef and at another site called Grecian Rocks. **Shinn's** images of Carysfort Reef capture the appearance of coral disease that began in the late 1970s and the resulting deterioration of reef growth and structure that continues today. At Grecian Rocks, he documented the die-off of staghorn corals that were prolific until the early 1980s.

"Staghorn began to die in the late 1970s, but most died between 1980 and

(Coral Reef Health continued on page 7)

General locations of Carysfort Reef and Grecian Rocks.



(Coral Reef Health continued from page 6)

1988," said **Shinn**. "Historically throughout the Caribbean, coral deaths started in the mid-80s due primarily to coral disease, and from then on there is practically no more staghorn. Soft corals like gorgonians and sea fans have taken over."

Currently, there are approximately 30 types of coral diseases or disease-like states recognized worldwide. These include sea-fan disease (or gorgonian aspergillosis), black-band disease, white plague, white pox, and bacterial-induced bleaching.

"Diseases were first reported on coral reefs in the Caribbean in the late 1970s, and today disease is considered the primary factor causing mortality in corals," said **Ginger Garrison**, a USGS ecologist in St. Petersburg. "Caribbean coral reefs were the first ones that were hit and were hit hardest, but the problem today is global and is very serious."

One source of the deterioration of Caribbean reef health by diseases and other factors may be found halfway around the world (the subject of another USGS video podcast, **http://gallery.usgs.gov/videos/223**). Hundreds of millions of tons of dust are carried each year from the Sahara and Sahel regions of Africa to the Caribbean, the eastern United States, and beyond. At times, these dust air masses cover the tropical Atlantic and the entire Caribbean Sea. Although African dust has been carried out of the Saharan Desert and Sahel region and into the Caribbean and the Americas for hundreds of thousands of years, there have been significant changes in the past 40 years: the quantity of dust has increased and the composition has changed.

"Larger amounts of dust began to be carried out of the Sahara in the early 1970s due to a number of factors, including global climate, changes in regional meteorology, and local human activities," said **Garrison**. "During this same period, the composition of the dust changed. Toxic chemicals produced by the combustion of biomass, fossil fuels, and the burning of garbage and plastics in the source region have been carried along with the dust particles from Africa into the Caribbean. In addition, the source region is using more

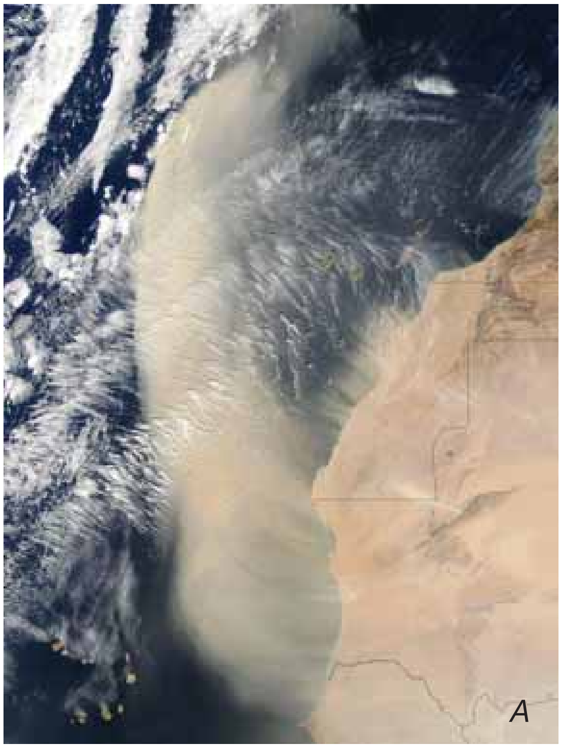
(Coral Reef Health continued on page 8)

An image of Grecian Rocks in 1971 shows a star coral surrounded by staghorn corals. The staghorn grew at a rapid rate in the decade preceding this photograph.

Staghorn began dying at the reef site in 1979, and by 1988 most staghorn at Grecian Rocks was severely eroded or dead.

By 2001, staghorn had been replaced by sea fans and sea whips, while the star coral (same star coral shown in 1971 and 1988 photographs) had become misshapen.

(Coral Reef Health continued from page 7)



*Two satellite images acquired in March 2004 by the Moderate Resolution Imaging Spectroradiometer (MODIS) aboard NASA's Terra satellite show large Saharan dust storms leaving Africa and moving over the Atlantic Ocean to cover downwind islands. A, Dust moving off the West African coast. Note Cape Verde Islands in lower left corner. Image courtesy **Jeff Schmaltz**, MODIS Rapid Response Team, NASA Goddard Space Flight Center (**http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=12813**). B, Saharan dust storm moving over the Cape Verde Islands. Image courtesy **Jacques Descloitres**, MODIS Rapid Response Team, NASA Goddard Space Flight Center (**http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=12836**).*

pesticides on crops as well as to fight mosquitoes (which transmit malaria and other diseases to humans) and crop-eating desert locusts. The pesticides appear to be coming across with the dust as well."

Changes in the quantity and composition of dust correlate with increased mortality from Caribbean coral diseases; however, causation has not been shown. To test the hypothesis that African dust is a factor in the deterioration of Caribbean coral reefs, scientists analyzed air samples from a dust-source area in Mali, West Africa; from a site off the west coast of Africa in Cape Verde; and at downwind sites in Trinidad and Tobago in the southeastern Caribbean and the U.S. Virgin Islands in the northeastern Caribbean.

It has been discovered that viable bacterial and fungal spores are transported long distances across the ocean in African dust events. Scientists have also found very fine particles that can be easily inhaled into the lungs of humans. According to USGS geologist and public-health specialist **Suzette Morman**, fine particulate matter has been correlated with increased rates of heart attack and stroke and exacerbations of asthma and other respiratory diseases. (For example, see "Cardiovascular mortality and long-term exposure to particulate air pollution…" in *Circulation*, 2004, v. 109, p. 71-77, **http://dx.doi.org/10.1161/01.CIR.0000108927.80044.7F**.)

*USGS ecologist **Ginger Garrison** trains **Mr. Henrique Monteiro** of the Instituto Nacional de Meteorologia e Geofísica (Cape Verde) in collecting dust samples on Ilha do Sal, Cape Verde.*

So far, carcinogens, neurotoxins, endocrine disruptors, and suppressors of immune systems have been identified in African dust air masses. (See article by **Garrison** and others in the *International Journal of Tropical Biology and Conservation*, 2006, v. 54, suppl. 3, p. 9-21, **http://www.ots.ac.cr/tropiweb/intpages/suppl/sup54-3.html**.) Some of these chemicals may have long-term effects on ecosystems because they persist in the environment for years, accumulate in organisms, are toxic and (or) carcinogenic, and interfere with physiological processes in low concentrations. Plumes of pollutants originate in industrialized as well as developing areas throughout the world and can have global impacts when transported long distances through the atmosphere.

(Coral Reef Health continued on page 9)

(Coral Reef Health continued from page 8)

Scientists are now beginning to test the toxicity of African dust and associated chemical contaminants on the life stages of many kinds of marine organisms, including corals, to see if they harm marine life and, if so, how they do so. And **Shinn** continues to monitor the health of coral ecosystems in the Keys, while moving into a sixth decade of documenting changing environmental conditions.

View the video podcasts "Corals: A 50-Year Photographic Record of Changes" and "African Dust, Coral Reefs and Human Health" at **http://gallery.usgs.gov/videos/334** and **http://gallery.usgs.gov/videos/223**, respectively. Both video podcasts are also posted at **http://coastal.er.usgs.gov/podcast/**. ☸

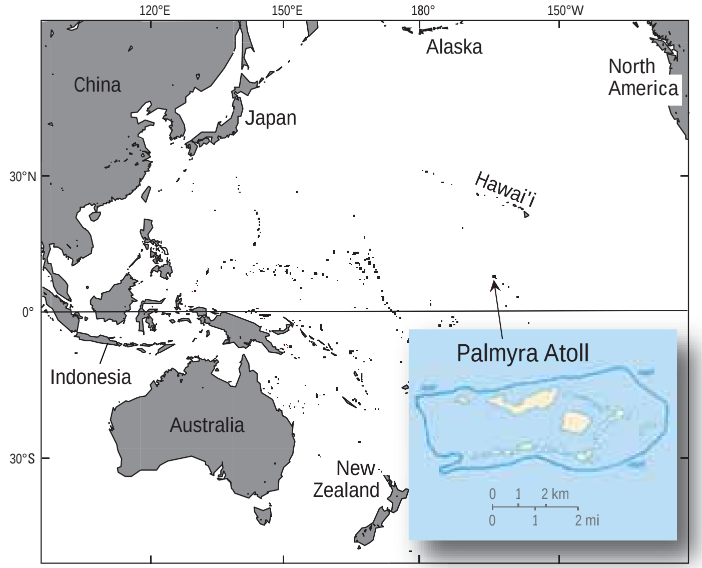
Black-band disease is one of the diseases causing coral mortality in the Florida Keys and the Caribbean. Live coral tissue is light brown, black line is disease lesion, and white area is dead coral skeleton. This disease occurs when corals are stressed by environmental factors such as pollution and high water temperatures and leads to the destruction of live tissue.

Palmyra Atoll: An Island Paradise In Recovery

By Ben Young Landis

It shares the name of a James Bond villain's gorgeous island lair, and it, too, is stocked with lush palm trees and marauding sharks. But at the Palmyra Atoll National Wildlife Refuge (**http://www.fws.gov/palmyraatoll/**)—a tropical island system in the remote reaches of the Pacific Ocean—it's the palm trees that are threatening and the sharks that are being protected.

U.S. Geological Survey (USGS) Western Ecological Research Center (WERC) biologists are part of the Palmyra Atoll Research Consortium (**http://www.palmyraresearch.org/**), a partnership of scientists and institutions studying the forests and waters of this U.S. territory. In the 1940s, Palmyra Atoll served as a U.S. military outpost, and now Palmyra faces challenges from past habitat impacts and present concerns about invasive species and sea-level rise.



Pacific Ocean, showing location of Palmyra Atoll.

A Not-So-Lovely Bunch of Coconuts

A USGS report released in January 2011 and authored by WERC scientists **Stacie Hathaway**, **Kathryn McEachern**, and **Robert Fisher** recommends habitat-management strategies for Palmyra. (See *Terrestrial Forest Management Plan for Palmyra Atoll*, USGS Open-File Report 2011-1007, **http://pubs.usgs.gov/of/2011/1007/**.) One finding casts the coconut palm in a villainous role.

Coconut palms, a species once farmed in local plantations, are taking over the island landscape and driving out a rare, native tree species, *Pisonia grandis*, whose distribution is limited to small remote islands in the Indian and Pacific oceans. *Pisonia* trees create immense forests that act as a key foundation of the Palmyra Atoll's terrestrial ecosystem.

A mature *Pisonia* forest has big trunks spaced far apart and a high, cathedral-like roof of leaves and branches knit together. This canopy cathedral provides valuable nesting habitat for vast numbers of seabirds, such as red-footed boobies, which can perch on and create stable nests in the maze-like branches of the *Pisonia* trees. In turn, feces from the nesting seabirds deliver important nutrients to the island ecosystem, fertilizing trees and sustaining the local food web.

In contrast, the long, slick fronds of the coconut palm provide no such nesting structure, and seabirds tend to avoid

(Palmyra Atoll continued on page 10)

(Palmyra Atoll continued from page 9)

them. Coconut fronds and nuts themselves also crush *Pisonia* saplings when they fall to the ground.

"As a result, coconut palms are quickly replacing the native forest; bird-nesting sites have shrunk; and ecosystem dynamics are changing," says **Hathaway**.

Coconuts may conjure up the image of paradise, but on Palmyra Atoll, coconut palms (lower image) are pushing out rare Pisonia *trees (upper image) and disrupting the nutrient and bird-nesting cycle of the island. Photographs by* ***Stacie Hathaway****.*

International Benefits

Research findings like this will inform the adaptive-management plans used by the U.S. Fish and Wildlife Service and The Nature Conservancy, who manage the Palmyra system. The research will also help other island territories and nations in the Pacific in sustaining their natural resources.

The USGS and others in the Palmyra Atoll Research Consortium continue to investigate the forests and shores of these islands. Underwater, Palmyra is now one of the world's few unfished coral reef ecosystems, with healthy populations of large predatory fish and sharks. It provides a perfect baseline for comparison with atolls that are suffering from overfishing and poor resource management. This haven, for example, allows USGS WERC biologist **Kevin Lafferty** and colleagues to explore ideas about the keystones and indicators of reef health—such as how the loss of sharks might cause negative, rippling effects down the food chain, and how a rich diversity of shark parasites might be a sign of a healthy reef.

"That's the key to adaptive management," says **Hathaway**. "As scientists learn more about the biological functions and processes of Palmyra, resource managers can continue to tweak and improve their strategies for conserving this unique ecosystem."

Note: *The original version of this article, with additional links, appeared February 24, 2011, on the USGS WERC Outreach Web page at* ***http://www.werc.usgs.gov/outreach.aspx?RecordID=47****.*

Many organisms depend on Palmyra's terrestrial ecosystem, including (clockwise from right) red-footed boobies, an undescribed gecko species, and the robber crab. Photographs by **Stacie Hathaway***.*

USGS Assists in Regional Competition in Florida for the National Ocean Sciences Bowl

By Heather Schreppel

On February 5, high-school academic teams from across the state of Florida assembled at the University of South Florida (USF) College of Marine Science and the adjoining Florida Fish and Wildlife Conservation Commission's Fish and Wildlife Research Institute in St. Petersburg for the Roseate Spoonbill Bowl. The Spoonbill Bowl is a regional-level competition by the Consortium for Ocean Leadership's National Ocean Sciences Bowl. The National Ocean Sciences Bowl strives to enrich science teaching and learning, increase knowledge of the oceans, and enhance public understanding and stewardship of the oceans.

Al Hine, Associate Dean and Professor of Geological Oceanography at the USF College of Marine Science, kicked off the event with a keynote address. He discussed the impacts of the Deepwater Horizon oil spill and the pivotal role that USF and the St. Petersburg science community played in that national disaster.

Following the keynote address, 16 high-school teams of four students each were tested on their scientific knowledge through quick-answer buzzer questions and team-challenge questions focusing on the scientific and technical disciplines used in studying the oceans. USGS participants included **Heather Schreppel** and **Theresa Burress**, who served as scorekeepers, and **Kara Doran**, who participated as a moderator. Eastside High School Team A from Gainesville won first place and advanced to the finals in Galveston, Texas, for a chance to win an exciting and informational trip providing hands-on field and laboratory experience in the marine sciences. This year's runners-up were Seminole High School (Seminole, Fla.) in second place and Barron Collier High School (Naples, Fla.) in third place.

The USGS, which participates in this event annually, supplied take-home bags filled with educational materials for the participating teams and their coaches. USGS participants agree that this event continues to be an exciting way to broaden students' and teachers' awareness of the latest scientific research on the oceans and the critical impact of the oceans on global climate, weather, and economies.

Publications

Impacts of Armoring on Sheltered Shorelines: Puget Sound, Washington

By Guy Gelfenbaum, Hugh Shipman, Rick Dinicola, and Helen Gibbons

Science experts from various agencies and universities have compiled a "state of the science" summary of information on the impacts of armoring on sheltered shorelines—such as those of Puget Sound, Washington—to help inform shoreline communities, planners, and agency decision makers. Their findings were recently released in a report published by the U.S. Geological Survey (USGS).

The report—*Puget Sound Shorelines and the Impacts of Armoring—Proceedings of a State of the Science Workshop, May 2009*, edited by **Hugh Shipman** (Washington State Department of Ecology), **Megan N. Dethier** (University of Washington), **Guy Gelfenbaum** (USGS), **Kurt L. Fresh** (National Oceanic and Atmospheric Administration), and **Richard S. Dinicola** (USGS)—addresses the geologic, oceanographic, and biologic responses to armoring and includes a section on management needs, a summary of science needs, and a literature review. The proceedings were published as USGS Scientific Investigations Report 2010-5254, available online at **http://pubs.usgs.gov/sir/2010/5254/**.

One of the largest estuaries in the United States, Puget Sound has roughly 2,500 miles of sheltered coastline, about one-third of which is armored. An increasing regional population and rising sea level will likely increase the pressure for additional shoreline armoring. Bulkheads, seawalls, and other armoring structures protect shoreline properties from damage and loss due to erosion, but armoring can also affect the nearshore habitat that is so important to restoring and preserving the health of Puget Sound.

The effects of armoring on shorelines are complex, and communities need to have the best available scientific information when facing difficult decisions about regulating shoreline activities and prioritizing restoration projects. To address this need, a scientific workshop was held near Hood Canal, Washington, on May 16-19, 2009, bringing together 38 local and national scientists to review the state of the science regarding the physical and biological impacts of armoring on shorelines—with a special emphasis on sheltered shorelines such as those of Puget

(Shoreline Armoring continued on page 12)

(Shoreline Armoring continued from page 11)

Sound. The workshop produced 22 scientific papers, which are compiled in the USGS report.

The summary of the report contains the following conclusions, based on breakout-group discussions during the workshop and findings reported in the scientific papers:

- Although armoring alters the shoreline in different ways in different ecosystems around the world, almost every study has demonstrated impacts to some beach feature or function that society regards as valuable. These impacts range from loss of space for recreation on the beach, to a decrease in the number of foraging shorebirds, to erosion of adjacent properties. The benefits accrued by erosion-control structures must be weighed against their negative impacts to public resources and shoreline ecosystems.
- Armoring constructed to prevent shoreline or bluff erosion also reduces sediment supply from the bluff onto the beach and into the drift cell (a segment of shoreline in which alongshore movement—or drift—of sediment is confined by natural barriers such as headlands, or manmade barriers such as jetties). Not all armoring, however, is likely to be equally harmful in terms of reducing sediment supply to the shoreline because natural sediment delivery to beaches varies so widely. Specific coastal assessments can suggest types of landforms or locations (for example, position within a drift cell) where armoring will have the least impact on sediment supply.
- The lower armoring is placed on the shore, the worse its impacts, particularly armoring built below the highest high-tide line. As sea level rises, even structures originally built high on the beach may encroach farther into the intertidal zone and produce increasingly negative impacts on the shoreline.
- Armoring of individual properties is often treated as a benign activity, but the cumulative result of armoring multiple properties may have significant long-term impacts on beaches and drift cells.
- As sea level rises, ongoing erosion in areas with armored shorelines will result in the progressive loss of beaches around Puget Sound. This will reduce both the recreational benefits and the ecological functions provided by the beaches. ☸

*Photograph from the cover of the new USGS report shows timber-pile bulkheads built to protect residential property from erosion at Ledgewood Beach, west side of Whidbey Island, Puget Sound. Photograph by **Hugh Shipman**, Washington Department of Ecology.*

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